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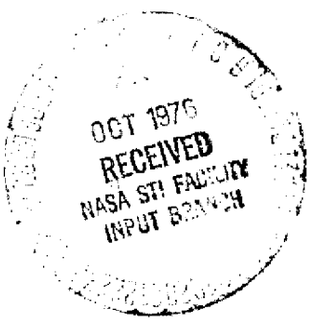
SPECIAL REPORT

An Automated System for Pulmonary Function Testing



November 21, 1974

CONTRACT NAS 9-13291

National Aeronautics and Space Administration
Johnson Spacecraft Center

TECHNOLOGY INCORPORATED

LIFE SCIENCES DIVISION

HOUSTON, TEXAS

SPECIAL REPORT

An Automated System for Pulmonary Function Testing

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INTRODUCTION

The integrity and proper function of the body are dependent upon adequate oxygen uptake and delivery to tissues by the cardiopulmonary system. The primary function of the lung is to arterialize the mixed venous blood through elimination of carbon dioxide and addition of oxygen. This is achieved by ventilation which is a function of volume and distribution of respired air in the ventilated alveoli. An additional important factor is the distribution of pulmonary blood flow. Postural position affects ventilation perfusion relationships. The space environment, which has been likened to bed rest, is expected to affect pulmonary function in a manner similar to assuming the supine position.

A demonstration of a potential experiment to quantitate pulmonary function was accepted for the Space Shuttle Concept Verification Test III. This report describes the system used in this experiment.

EXPERIMENTAL DESIGN

The design of an experiment for Space Shuttle flights requires that special attention be given to three areas: 1) time limitations for experimental activity, 2) ease of operation, 3) data reliability. To optimize these three areas without compromising experimental results, the hardware arrangement shown in Figures 1, 2, and 3 was constructed and implemented with the computer program listed in Appendix III.

To minimize subject interaction with the hardware and thus minimize both time expended and possible operator error, measurements were integrated so that only two subject activities are necessary. The first requires the subject to place a mouthpiece in his mouth and exhale completely to residual volume (RV) without inhaling. The subject

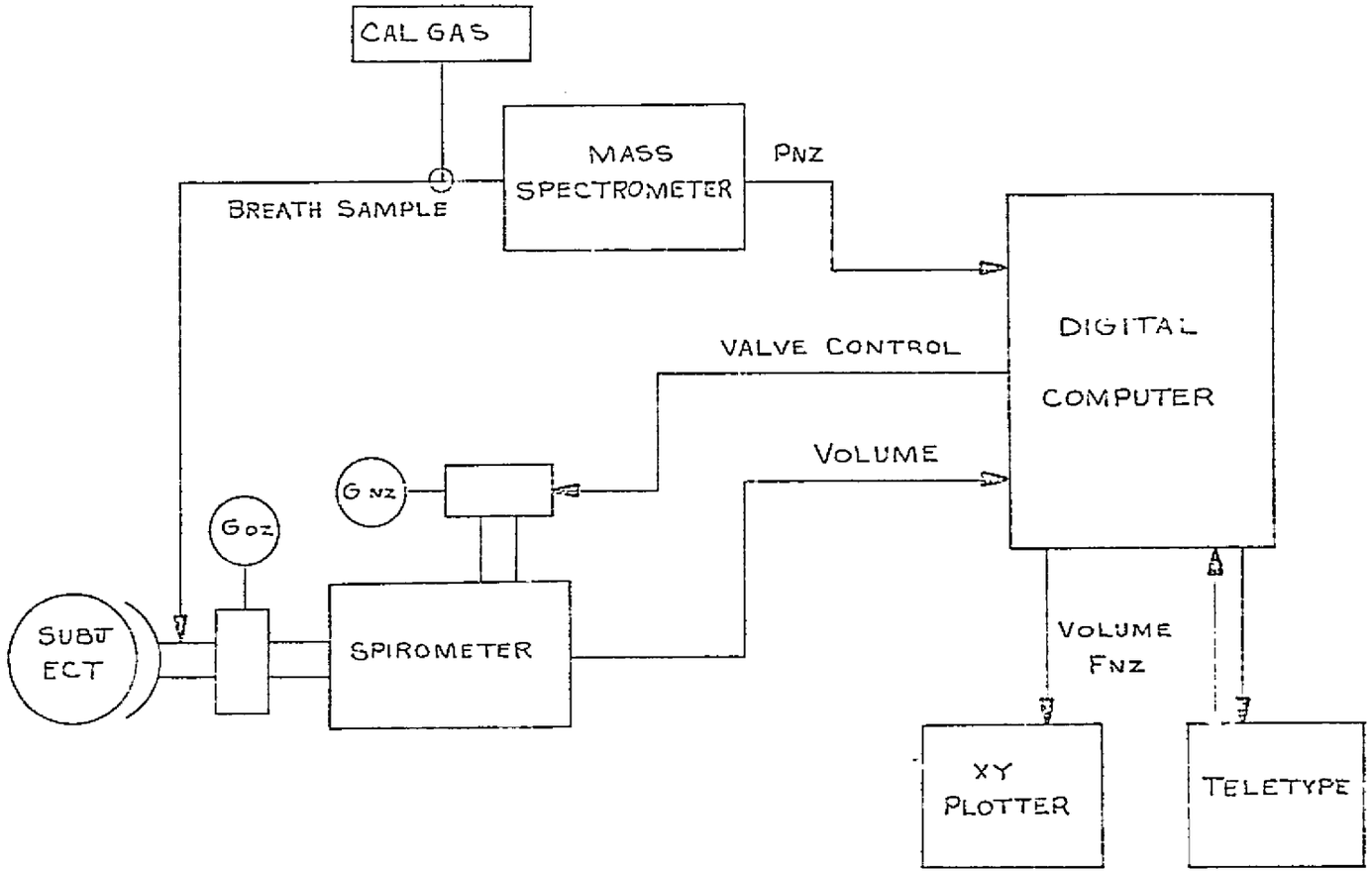

CAL GAS
MASS SPECTROMETER
PNZ
BREATH SAMPLE
DIGITAL COMPUTER
VALVE CONTROL
VOLUME
G NZ
G OZ
SUBJECT
SPIROMETER
VOLUME FNZ
XY PLOTTER
TELETYPE

FIGURE 1.

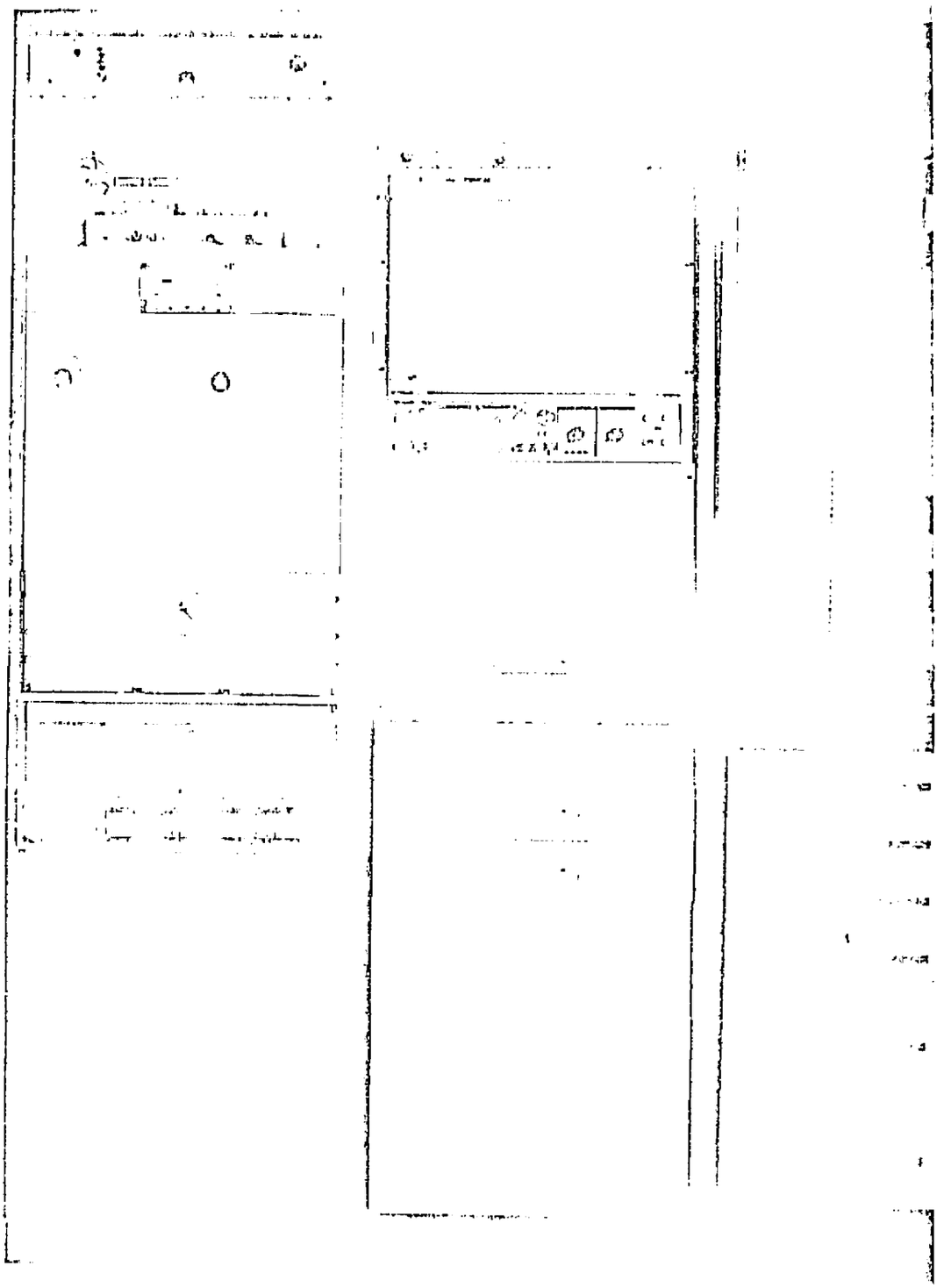


Figure 2

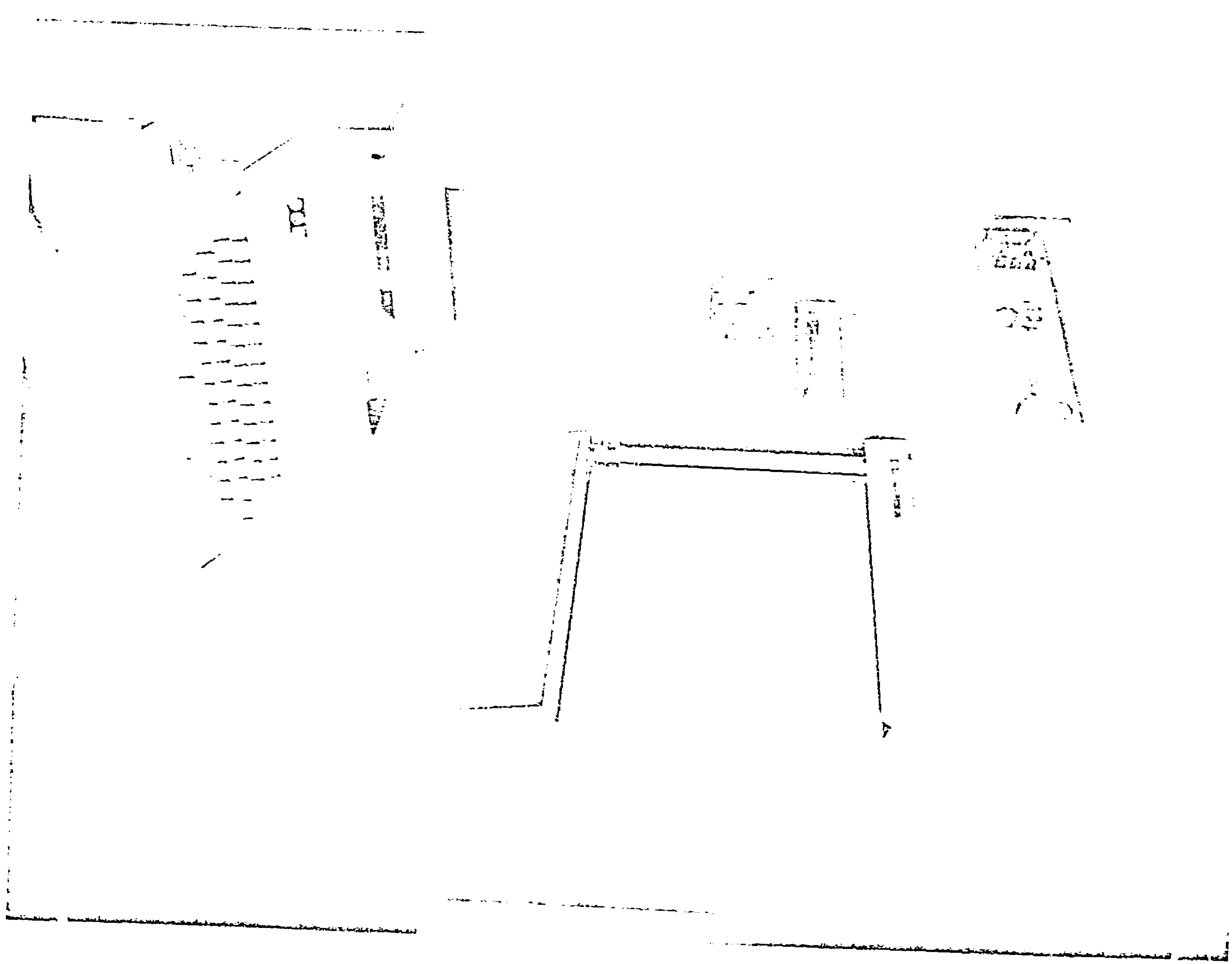


Figure 3

then takes a full inhalation of oxygen (inspiratory capacity) and again exhales completely to RV. After this initial maneuver, the subject continues to breathe normally through the mouthpiece for approximately 3 minutes. Data from this activity are used to quantitate the parameters defined in Table I. Traditionally, the single-breath maneuver and the nitrogen washout are conducted as two separate tests. By combining the two into a single procedure, the total test time is significantly reduced. The second subject activity requires the subject to take a complete inhalation and then exhale as completely and as rapidly as possible. The parameters defined in Table II are calculated from this forced vital capacity (FVC) maneuver. The parameters defined in Table III are derived from primary measurements.

TABLE I

Measurement	Definition
Residual Volume (RV)	The volume of air remaining in the lungs after a complete exhalation.
N_2 Delta	The change in nitrogen concentration (%) between 0.75 liters and 1.25 BTPS liters of the first exhalation after the first inhalation of 100% oxygen.
Closing Volume (CV)	The volume of air displaced from the apices following airway collapse at bases near the end of a full exhalation to RV.

TABLE I
(cont.)

Measurement	Definition
VA/RV	The amount of alveolar oxygen ventilation required to washout one liter of residual folume from the lungs.
Vital Capacity	The maximum volume of air that can be exhaled starting from full inspiration.

TABLE II

Measurement	Definition
Forced Vital Capacity (FVC)	The maximum volume of air that can be exhaled in the smallest possible time.
Forced Expired Volume - 1 Sec (FEV_1)	The maximum volume of air that can be exhaled in 1 second.
Maximum Expiratory Flow Rate (MEFR)	The mean flow rate between 0.2 liters and 1.2 liters of the forced vital capacity maneuver.
Maximum Midexpiratory Flow Rate (MMFR)	The mean flow rate for the middle half of the forced vital capacity maneuver.

TABLE III

Measurement	Definition
Total Lung Capacity (TLC) (TLC = RV + VC)	The total volume of the lungs at full inspiration.
FEV_1/FVC %	The percent of forced vital capacity that can be exhaled in 1 second.
FVC/VC %	The ratio of forced vital capacity to vital capacity expressed as a percentage.
CV/VC %	The ratio of closing volume to vital capacity expressed as a percentage.
CC/TLC %	The ratio of the sum of residual volume and closing volume to total lung capacity expressed as a percentage.

For ease of operation, the computer program structure has five independent modules, each called by a single key-in on the teletype. If some malfunction should occur during the use of a module, that module can be restarted by a key-in, increasing data reliability.

HARDWARE

The hardware configuration for this experiment is shown in Figure 1. The spirometer is used to measure the volume of each breath, and is the same type used in Skylab

Experiment M171. A fixed collector, magnetic sector mass spectrometer is used to provide continuous definition of gas composition (fractions of N_2, O_2, CO_2, and H_2O). The sample catheter for this mass spectrometer is inserted into the subject's valve assembly, so gas fractions represent concentrations at the mouth. The mass spectrometer was built by Perkin-Elmer as a breadboard unit for Skylab Experiment M171.

Mass spectrometer and spirometer analog data are received and analyzed by a PDP-8I computer with 4096 word memory, extended arithmetic element, teletype, and a special analog input-output interface. The analog interface contains four analog to digital (A/D) conversion channels, a clock that provides 40 millisecond sampling intervals, and six digital to analog channels. Since this interface is not standard hardware, program routines using these options would need modifications to allow their use on other computers.

For acquisition of analog data, a dual-slope integrating A/D converter is used. This A/D converter is very slow but is relatively immune to noise, and it provides excellent accuracy for low level signals while retaining a wide dynamic range. Two control words must be sent to the A/D converter to initiate a sample, and two words of data read back. First, a 12-bit number is loaded into the accumulator; then instruction 6537 (octal) executed. This instruction sends the 12-bit word to a DAC (not used in this program) and reads back a 12-bit word from the A/D converter. This word is the mantissa from the previous conversion, and must be saved. A second control word, described in Table IV, is then loaded into the accumulator and instruction 6537 (octal) executed. This initiates a sample, and transfers a 12-bit "mantissa descriptor" to the accumulator. Completion of A/D conversion sets a flag. Execution of instruction 6533 while this flag is set will clear the flag and cause the next instruction to be skipped.

Decoding of this mantissa requires that the mantissa be treated as a positive binary fraction, with the radix point at the left of the most significant bit. The "mantissa descriptor" must then be decoded to determine how many zeroes are to be inserted between the radix point and the most significant mantissa bit. A "mantissa descriptor" that is all zeroes indicates the mantissa expressed as a fraction is correct. For a non-zero descriptor, the descriptor should be shifted left, counting the number of shifts until a one is shifted out of the descriptor. This number of zeroes should be inserted between the radix point and the most significant mantissa bit. The resultant fraction can then be used as a fraction of full scale voltage. For example, a mantissa of 3213 (octal) and a descriptor of 0000 would yield a binary fraction of .011010001011 of full scale, while a mantissa of 3213 (octal) and a descriptor of 2000 (octal) would represent a binary fraction of .00011010001011 of full scale.

The interface contains two sets of DAC's, with each set containing three channels. Each channel has a 0- +5 volt output range, with a resolution of 5 mv. The output data word for these DAC's has a 10-bit mantissa in the most significant bits, with the two least significant bits selecting the output channel. To send an analog signal from the computer, the data word is put in the accumulator, then instruction 6065 for set 1 or 6075 for set 2 executed. The use of each DAC channel by this program is shown in Table V.

TABLE IV

MSB	CH1	W		L8	L4	CH2	CH3	CH4
BIT	0	1	2	3	4	5	6	7

Bit	Function
0-CH1	Enable Analog Input Channel 1
1-W	Do not start conversion until 40 msec clock pulse.
3-L8	Do not integrate more than 8 msec.
4-L4	Do not integrate more than 4 msec (requires Bit 3-L8 to be set).
5-CH2	Enable Analog Channel 2.
6-CH3	Enable Analog Channel 3
7-CH4	Enable Analog Channel 4

Restrictions

1. Only one of bits 0, 4, 5, 6 should be set.
2. To limit integration time to 4 msec, both bits 3 and 4 should be set.

TABLE V

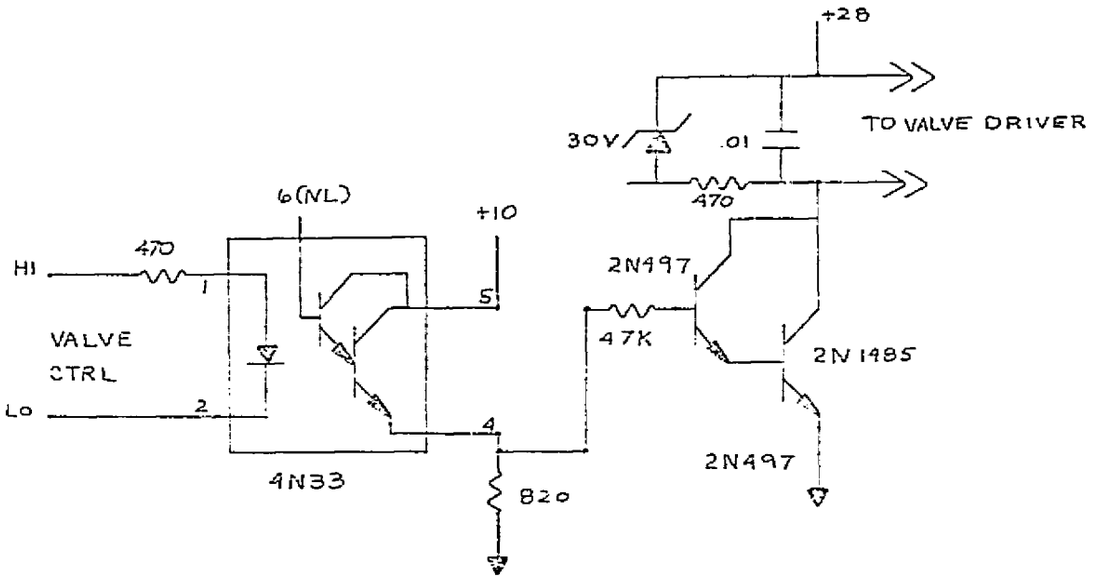
Channel (Bits 10, 11)	IOT	Function
00	6065	F_{N2}, Y Channel of X-Y Plotter
01	6065	Volume, X Channel of X-Y Plotter
10	6065	Sent to Amplifier with a Gain of 2, then to DVM.
00	6075	To Spriometer Valve Driver 0000 - Open Valve 7770 - Close Valve
01	6075	To X-Y Plotter Pen Control 0001 Pen Down 7771 - Pen Up

A special interface was constructed to allow control of external devices and to condition analog signals. It is represented schematically in Figures 4 and 5. This interface contains a solenoid driver to allow the computer to control the spirometer dump valve, a power source for the potentiometer on the spirometer, a buffer amplifier for the spirometer potentiometer, and an amplifier with a gain of 2 to boost 0 to +5 volt DAC output for display on a 0 to +10V meter.

PROGRAM

The computer program for system control, data acquisition, and data analysis consists of a group of six modules, four of which operate on a central data buffer, one for mass spectrometer calibration, and one idle loop, as shown in Appendix I-1. On initiation, the program resets various flags and I/O receivers, opens the spirometer valve, and enters an idle state waiting for another module to be called by an unsolicited control key-in. This loop is also entered at the completion of other modules. Modules called by recognized key-ins are summarized in Table VI.

The calibration routine samples the mass spectrometer nitrogen analog output every 40 msec. The sampled datum is then converted to percent, and stored. In addition, the concentration is scaled and output on the DAC for display on the digital volt meter (DVM), with 10V corresponding to 100% nitrogen. A P key-in will cause a type out of the most recently sampled nitrogen fraction. Rapid calibration of the mass spectrometer is possible by sampling gas of known nitrogen content. Either an S or CTRL S key-in will terminate this routine.



PDP-8 PFT INTERFACE

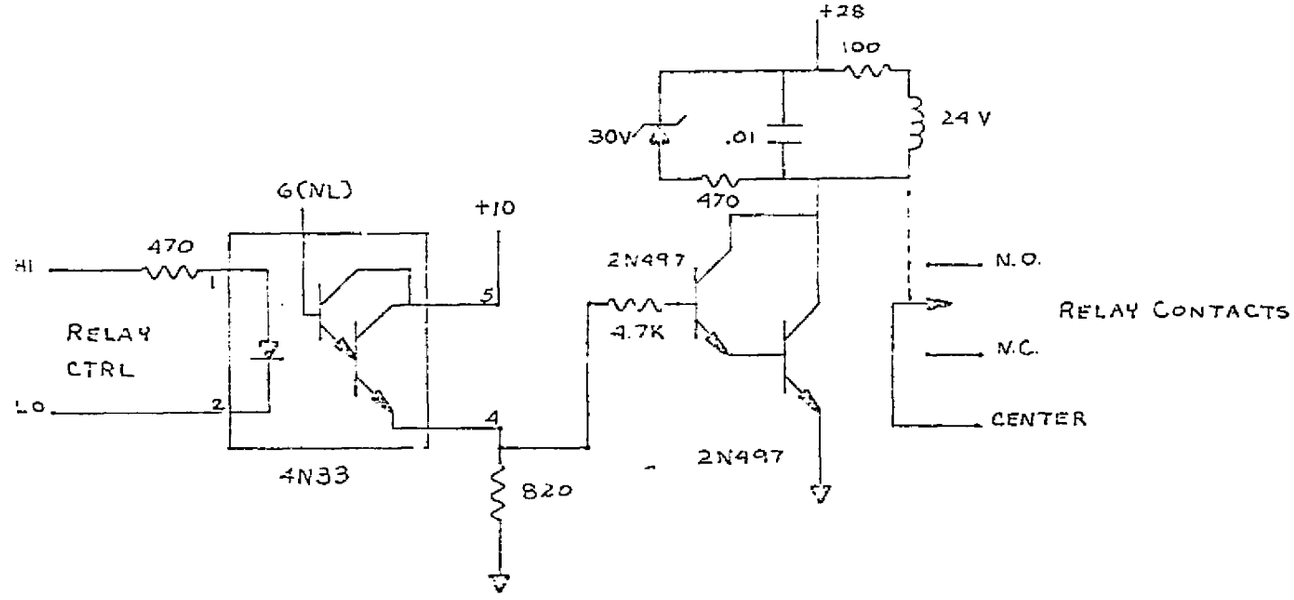
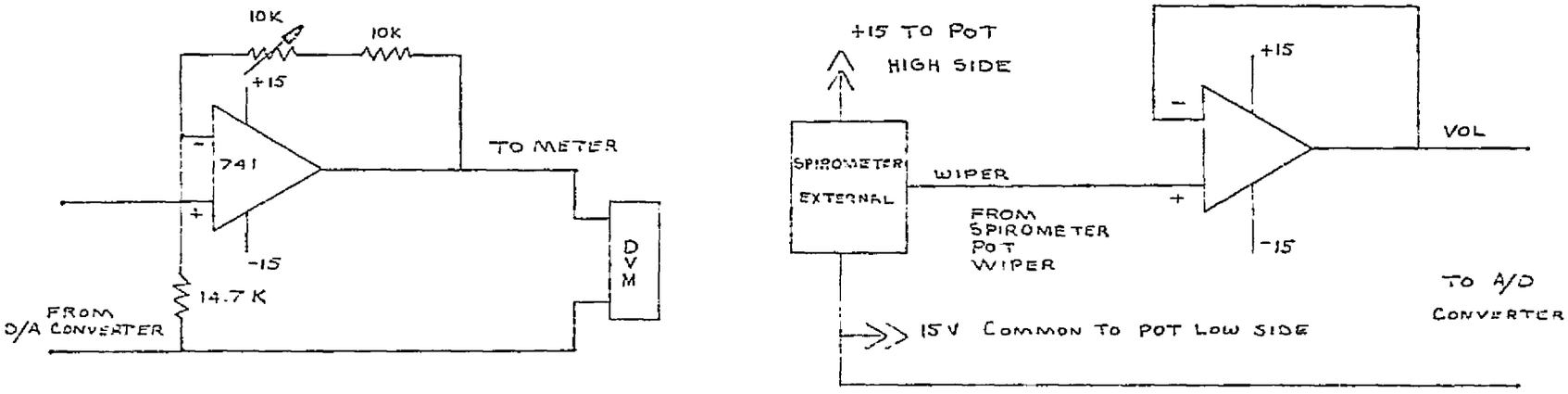


Figure 4



PFT INTERFACE

Figure 5

TABLE VI

Key-In	Module Called
CTRL C	Calibration
CTRL I	Initialize, Clear Data Buffer
CTRL F	Forced Vital Capacity
CTRL W	Nitrogen Washout
CTRL R	Report Data
CTRL S	Stop Whatever Module is in Progress. Begin Idle

The four other modules of this program all operate on a central data buffer. The initialization module sets the entire data buffer to zero.

The forced vital capacity module monitors a single breath, from the point of maximal inhalation to maximal exhalation. On initiation, this routine closes the spirometer valve and begins sampling spirometer displacement (volume) every 40 msec. Data are not saved until a sample above a threshold (120 millivolts) is detected, indicating the beginning of a breath. Each sample is then saved sequentially until there is no increase in volume for 0.5 second, signifying the end of the maneuver. At this time, the valve is opened and analysis begun. First, the sampled data are scanned and the maximum spirometer displacement found. This value is converted to liters BTPS and stored in the data buffer as FVC. Then, the sample occurring 1 second after the start of the maneuver is extracted, converted to liters BTPS, and stored in the buffer as FEV_1. Next, elapsed time values for one-quarter and three-quarters of FVC are found. The time between two points is determined by the number of samples between them and the fixed sampling rate of 40 msec/sample. MMFR is

calculated by dividing 0.5 FVC by the time between 0.25 FVC and 0.75 FVC. The above procedure is then repeated for 0.2 liters and 1.2 liters of the FVC to permit calculation of MEFR. The routine then exits to the idle state.

The nitrogen washout routine incorporates two separate procedures into one subject activity. As described earlier, the subject places the mouthpiece in his mouth, exhales completely to residual volume; inhales O_2 to full inspiratory capacity from an oxygen demand regulator, and again exhales completely. The subject then breathes normally until the procedure is completed, inhaling oxygen, and then exhaling into the spirometer.

The first analysis procedure requires waveform analysis of the instantaneous nitrogen concentration at the mouth versus volume exhaled for the first exhalation after 100% oxygen inhalation. The second procedure requires calculating the total volume of nitrogen exhaled during 100% oxygen breathing, and then calculating residual volume by nitrogen dilution.

Both procedures involve operations on data pairs of nitrogen concentration and volume. A potential problem exists when using instantaneous gas concentration and volume data pairs. Any gas analyzer has a delay time required for the gas sample to pass through the sample catheter to the analysis chamber and then be analyzed as evidenced by an analog output. Because of this delay, analog data at the mass spectrometer output represent gas concentrations which were sampled in the past. The time delay is relatively constant for a given mass spectrometer, but can vary from a few milliseconds to seconds, depending on such considerations as catheter length, sample flow rate, inlet rate and electrometer rise time. To avoid a problem in this program, volume and nitrogen are sampled every 40 msec. The volume sample is used by a spirometer control subroutine but is not used with

the corresponding nitrogen sample for calculations. Instead, it is placed at the end of a First In, Last Out Queue, and a volume sample taken from the other end of the queue. This effectively delays the volume signal by a time of N*SI, where N is the queue length and SI is the sampling interval, resulting in data pairs which are phased in time. The mass spectrometer used in this experiment had a total delay time of approximately 500 msec, so a queue of length 12 was used, resulting in a 480 msec delay.

Upon entry, the module begins monitoring volume/nitrogen data pairs as described above. No computations are done until after the first end of breath is sensed by monitoring spirometer position as in the FVC module. Because the subject breathes ambient air before the first test maneuver, nitrogen concentration concentration at the mouth following the end of his first exhalation can be used as the nitrogen concentration in his lungs. This nitrogen concentration is stored for later use in calculating residual volume. After this initial exhalation of ambient air, no calculations are performed until the next exhalation which is the first one following oxygen inspiration from RV to TLC. All volume/nitrogen concentration data pairs for this exhalation are stored for for later analysis.

After the subject begins inhaling 100% oxygen, it is necessary to compute the total amount of nitrogen exhaled. This accumulation is initiated by the same logic that initiates storing of all data samples for a breath waveform. The spirometer control subroutine returns a spirometer displacement of 0 liters unless an exhalation is occurring. Thus, for any 40 msec time period, volume exhaled during the period is simply the difference in a volume sample and the previous volume sample. A negative difference occurs at the end of a breath, when the spirometer begins returning volume values of 0 liters and is treated as zero volume difference. The volume of nitrogen exhaled during a 40 msec period is then computed by multiplying that volume difference by the properly phased

nitrogen concentration. These 40 msec nitrogen volumes are accumulated from initiation until the end of the washout. The criterion for ending the washout is the occurrence of two successive breaths with maximum nitrogen fractions less than 0.02. To preclude terminating the test prematurely, these two successive breaths must also occur at least 2.75 minutes after the washout begins.

After criteria for washout termination have been met, analysis of the collected data begins with analysis of the first exhalation after oxygen inhalation. The volume array is scanned and the maximum volume located, converted to BTPS liters and stored as Vital Capacity (VC). Then volume/nitrogen fraction pairs corresponding to 0.75 liters and 1.25 liters are found. The nitrogen fraction sampled at 0.75 liters is subtracted from the nitrogen fraction at 1.25 liters, and the difference stored as N_2 delta, or the slope of the alveolar plateau. Next, volumes 1.5 liters and 2.5 liters less than the vital capacity are found. A linear regression routine computes the best straight line expressing nitrogen concentration as a function of volume in this one liter volume. The line is extrapolated toward residual volume to locate the last volume/nitrogen fraction pair for which sampled nitrogen fraction is less than nitrogen fraction computed from the linear regression curve using the corresponding volume. The volume from this pair is subtracted from vital capacity and the difference stored as closing volume. The single-breath data pairs are plotted on an X-Y plotter as nitrogen concentration versus volume.

Residual volume is computed using a nitrogen dilution technique implemented with the following formula.

$$RV = \frac{V_{N_2} - .0312\,T}{F_{N_2}\,(\text{init}) - F_{N_2}\,(\text{final})} - 0.2$$

V_{N_2} = Total volume of nitrogen exhaled during the washout.

.0312 T = Amount of nitrogen washed out of blood and tissues. T is time in minutes.

F_{N_2} (init) = Initial alveolar nitrogen concentration.

F_{N_2} (final) = Alveolar nitrogen concentration after washout.

Because of the small amount of core memory available, it was necessary to use two approximations in deriving this formula from traditional equations. The factor, .0312 T, is traditionally a correction factor based on subject body surface area and time of washout. A mean body surface area for the expected subject group is used with actual time of washout to determine the volume of nitrogen washed out of the tissues. The constant, 0.2 liters, is an approximation of anatomical dead space.

The report module computes secondary data from data in the data buffer. Results of all measurements are then printed on the teletype. An example of this output superimposed on a single-breath plot is shown in Figure 6.

IMPROVEMENTS

Implementation of this system on a different computer would allow certain improvements to be realized. The PDP 8-I used in this system was designed in the mid-1960's, and is quite large by current standards. By using a current minicomputer, the size and power requirements for the computer could be reduced by 80%, with no loss in capability. By using a different A/D conversion system, analog signals could be sampled at a higher rate. This would allow better definition of flow rates and the single-breath washout curve. Extra memory for program storage and a higher sampling rate would also allow additional measurements such as dead space computation and plotting of flow-volume loops.

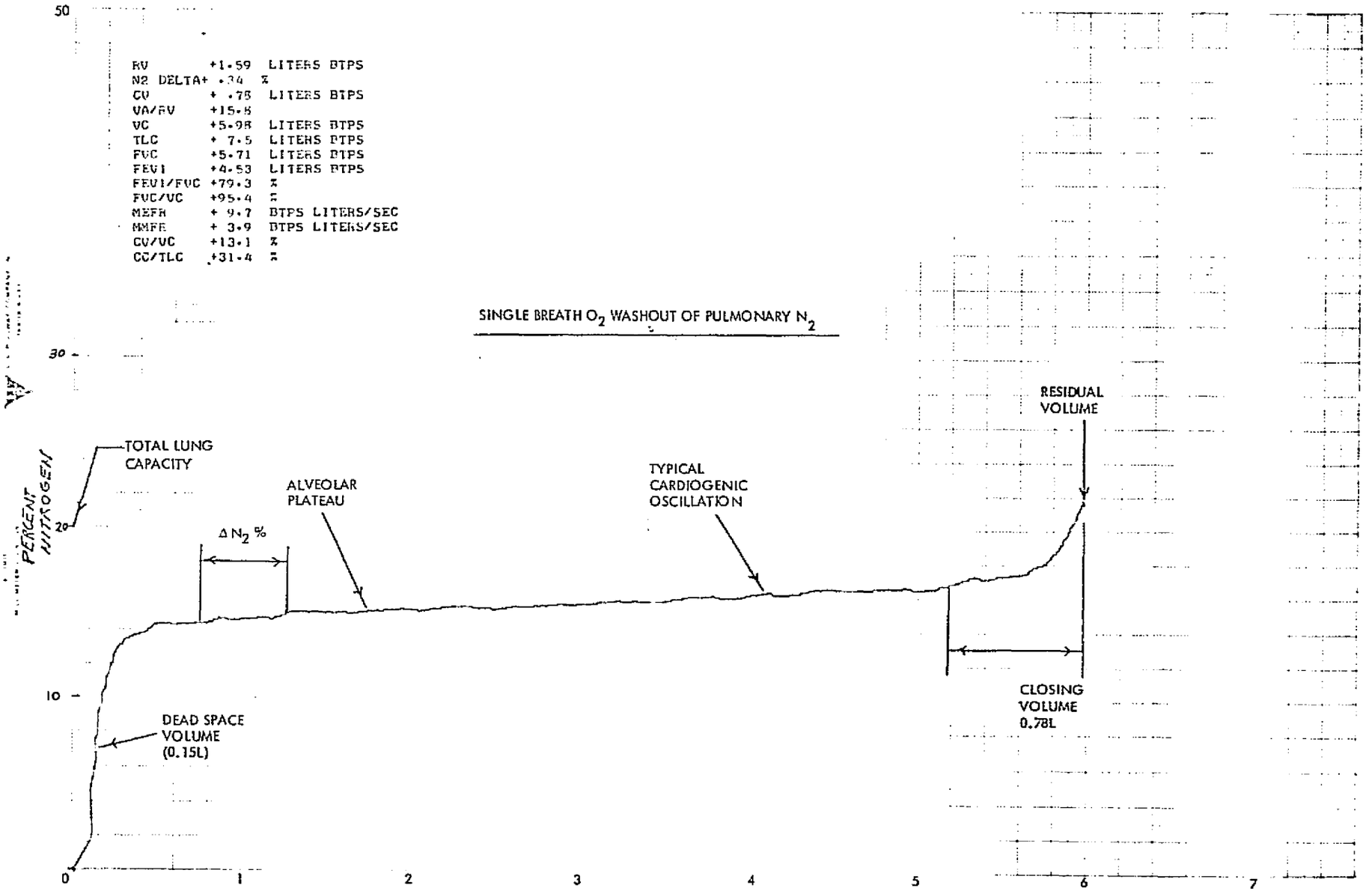
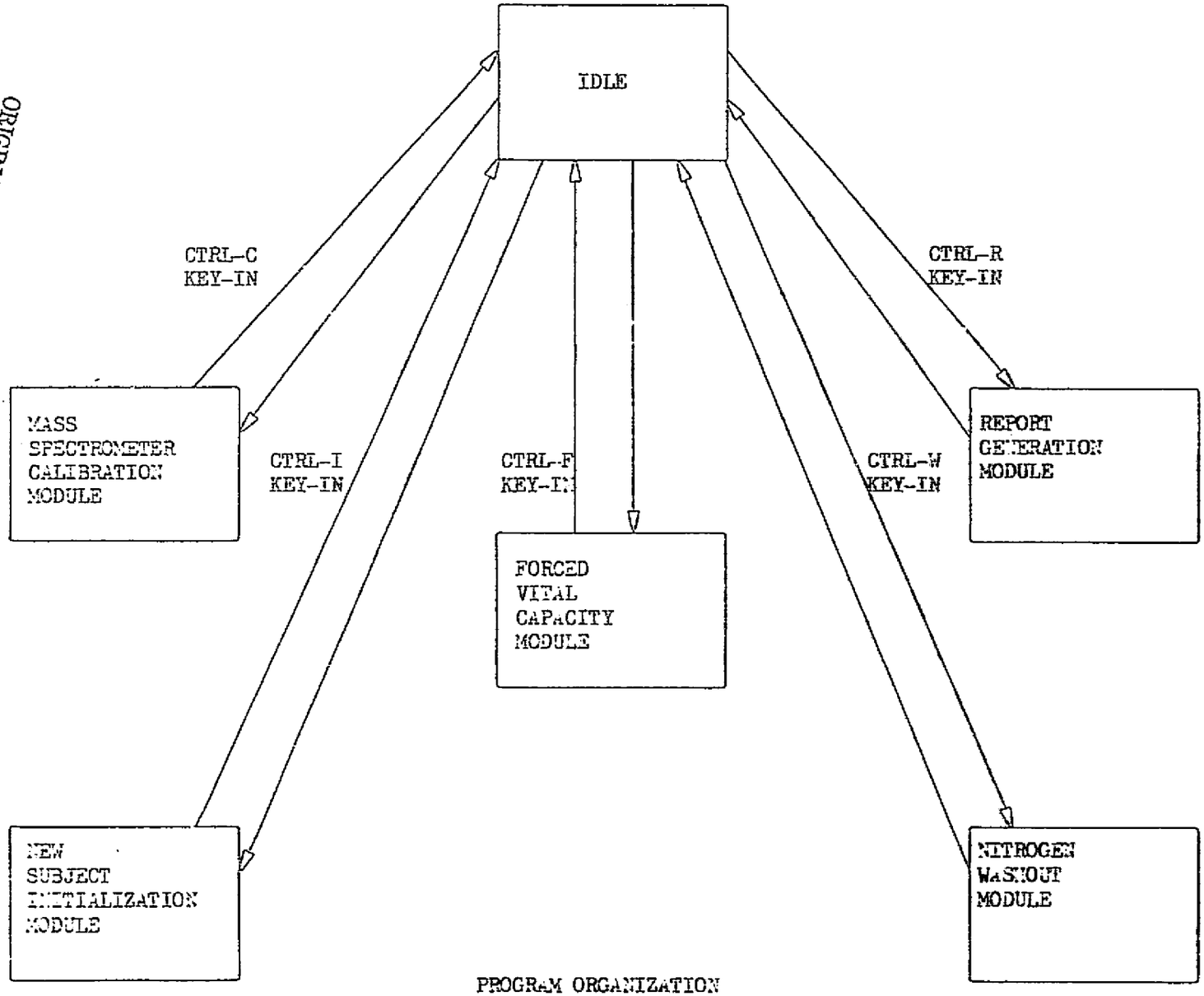


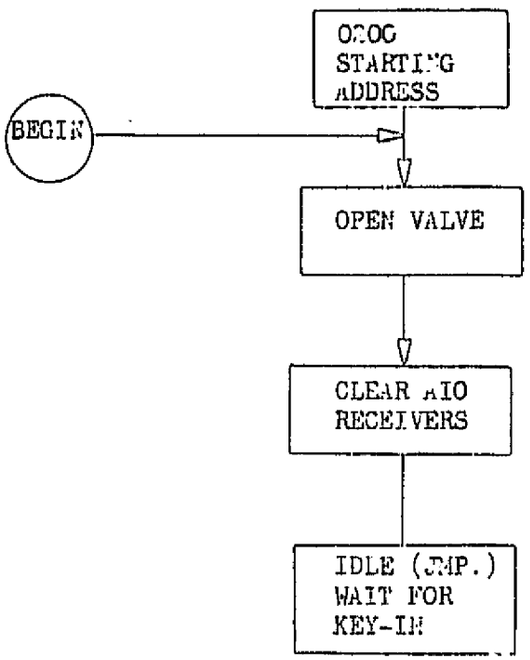
Figure 6 - Expired Volume - L, BTPS

APPENDIX I

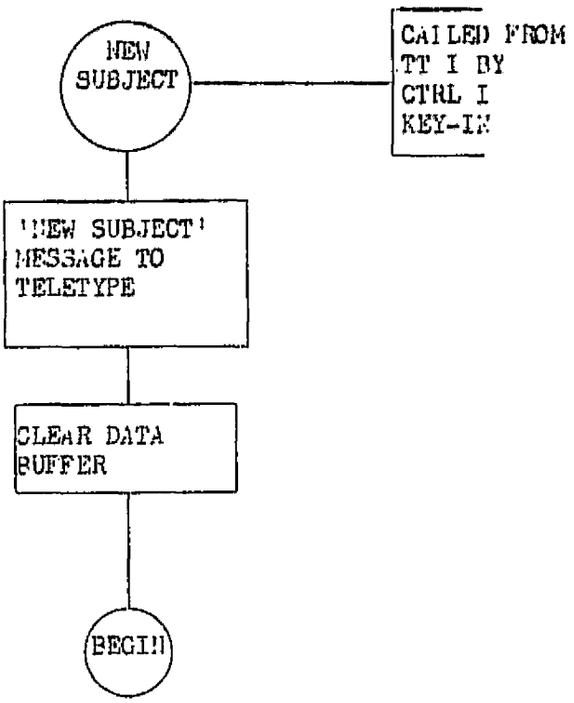
Program Flow Charts



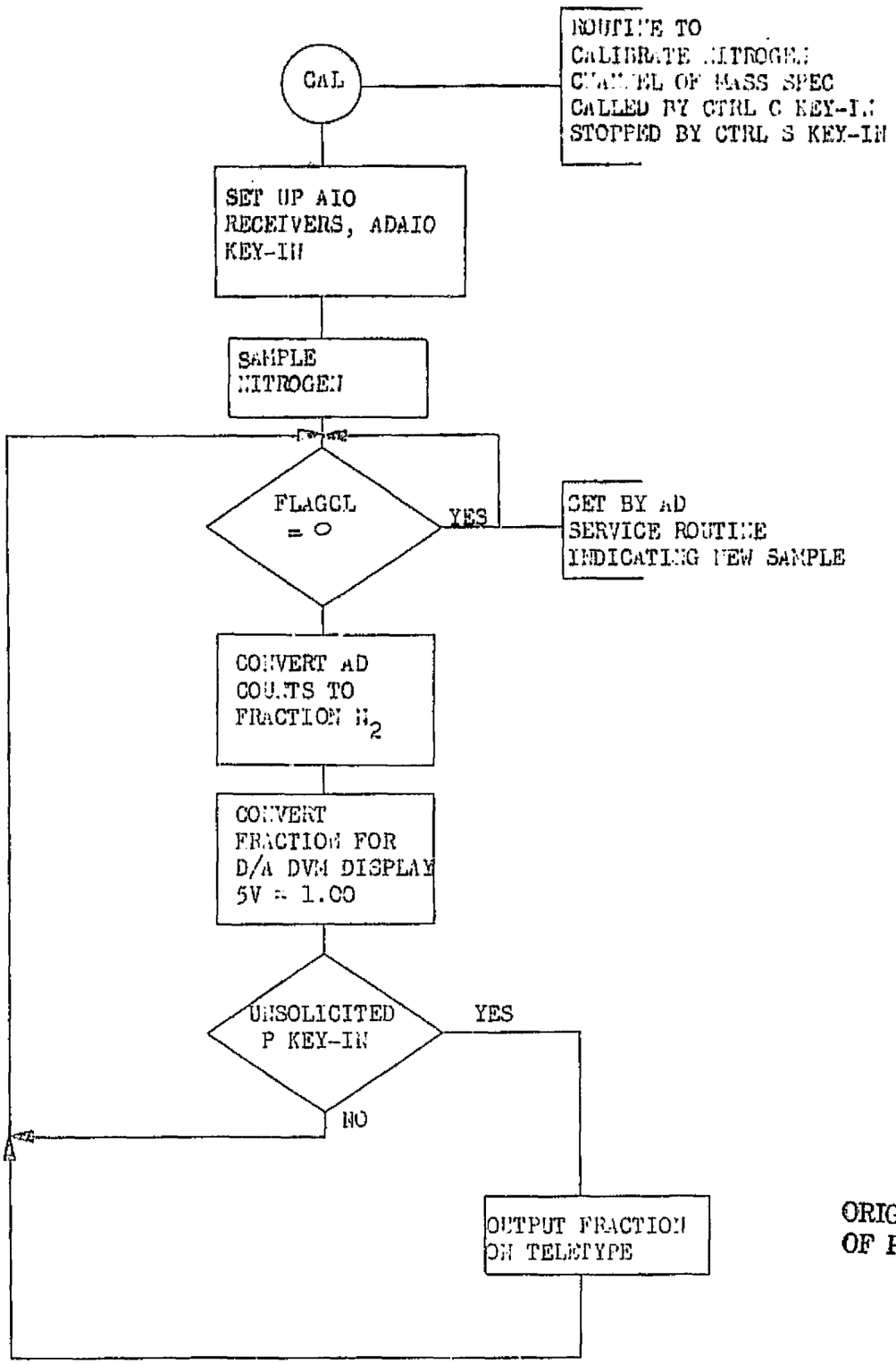
PROGRAM ORGANIZATION


BEGIN
STARTING
ADDRESS
OPEN VALVE
CLEAR AIO
RECEIVERS
IDLE (JMP.)
WAIT FOR
KEY-IN

IDLE MODULE



NEW SUBJECT INITIALIZATION MODULE



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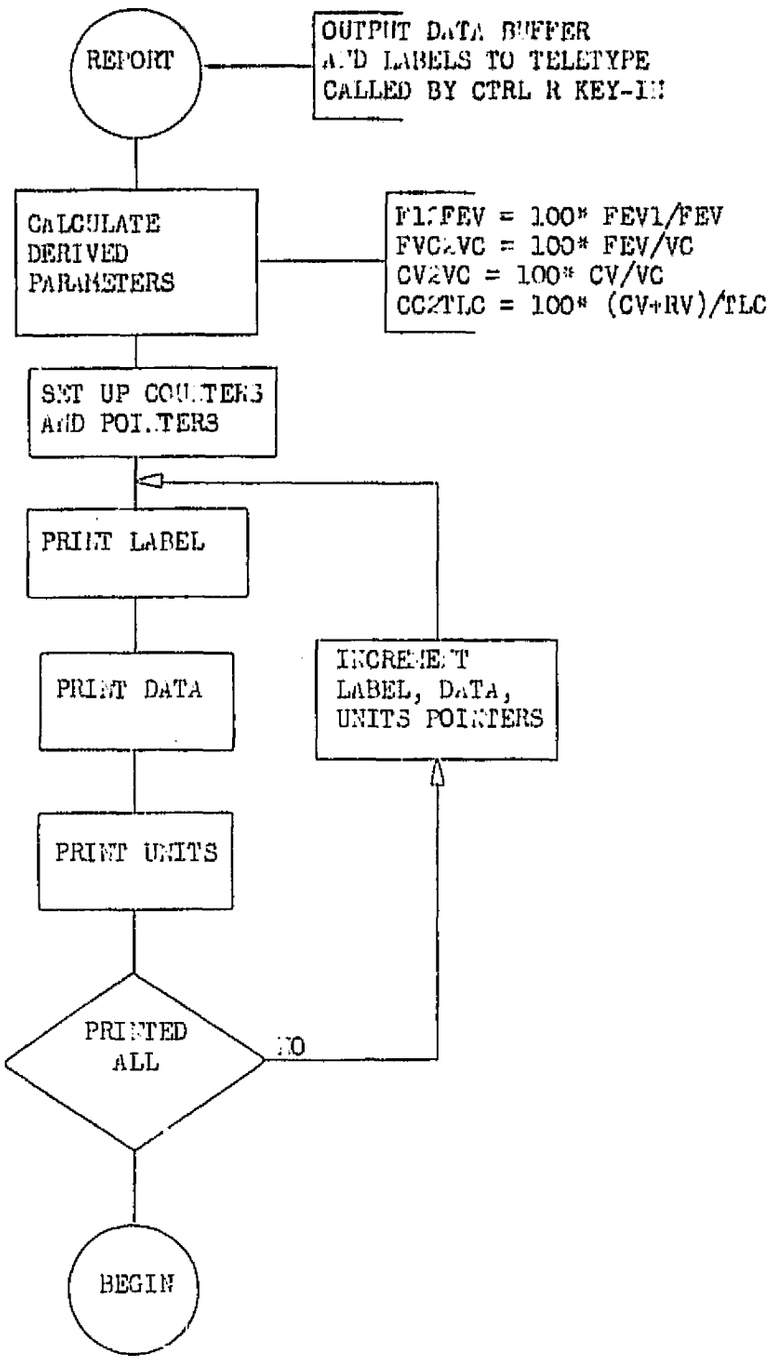
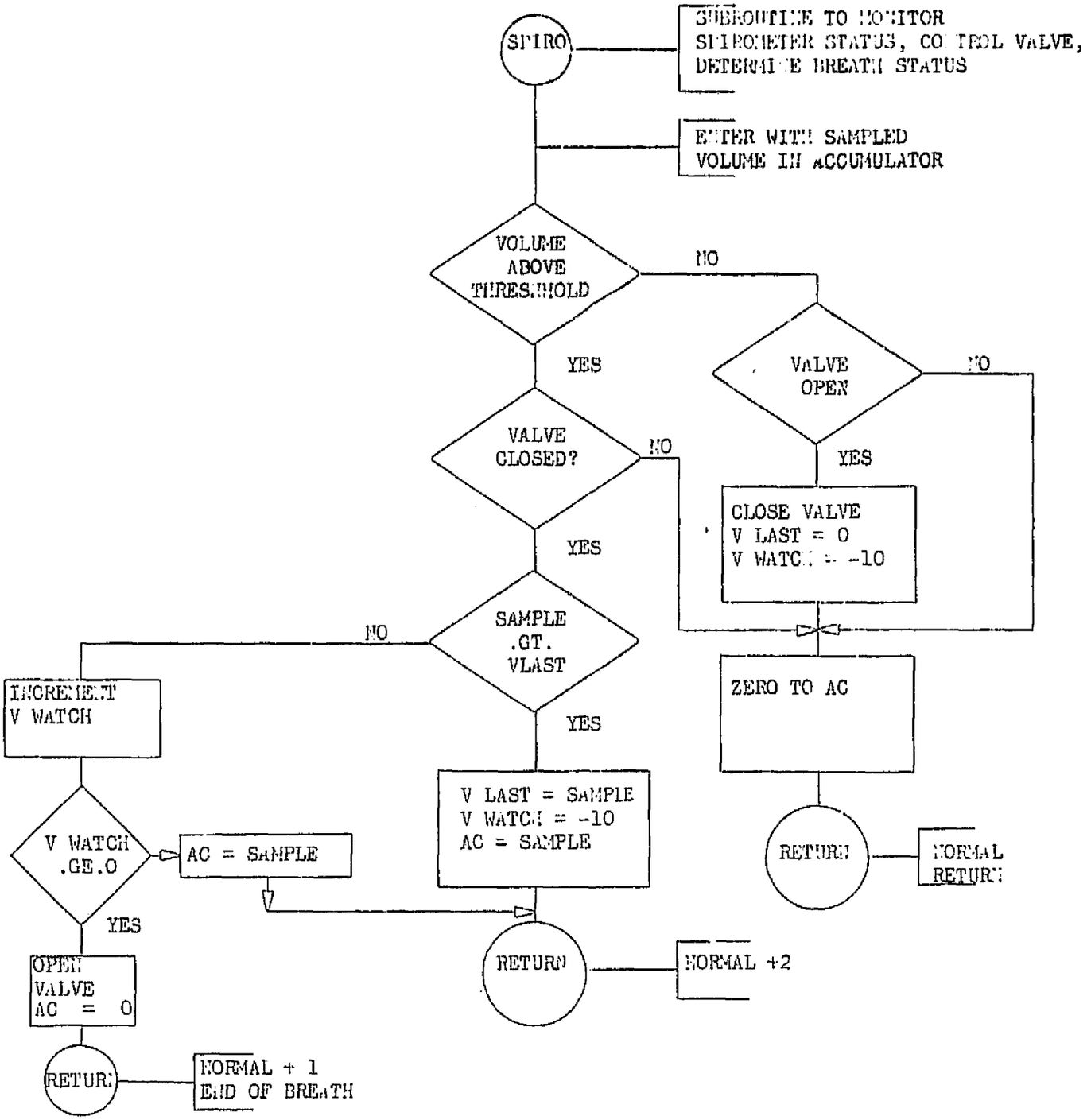
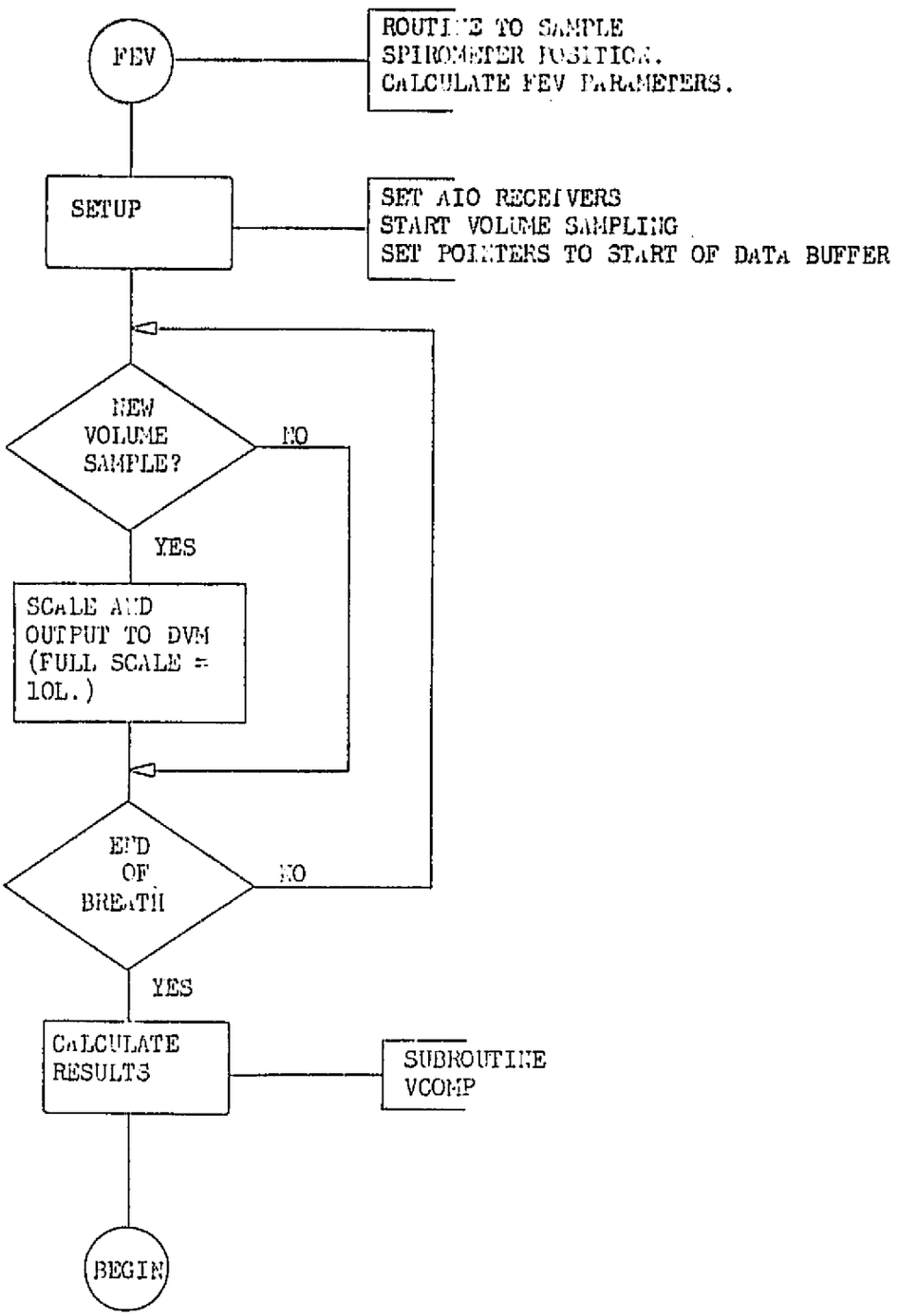
MASS SPECTROMETER CALIBRATION MODULE

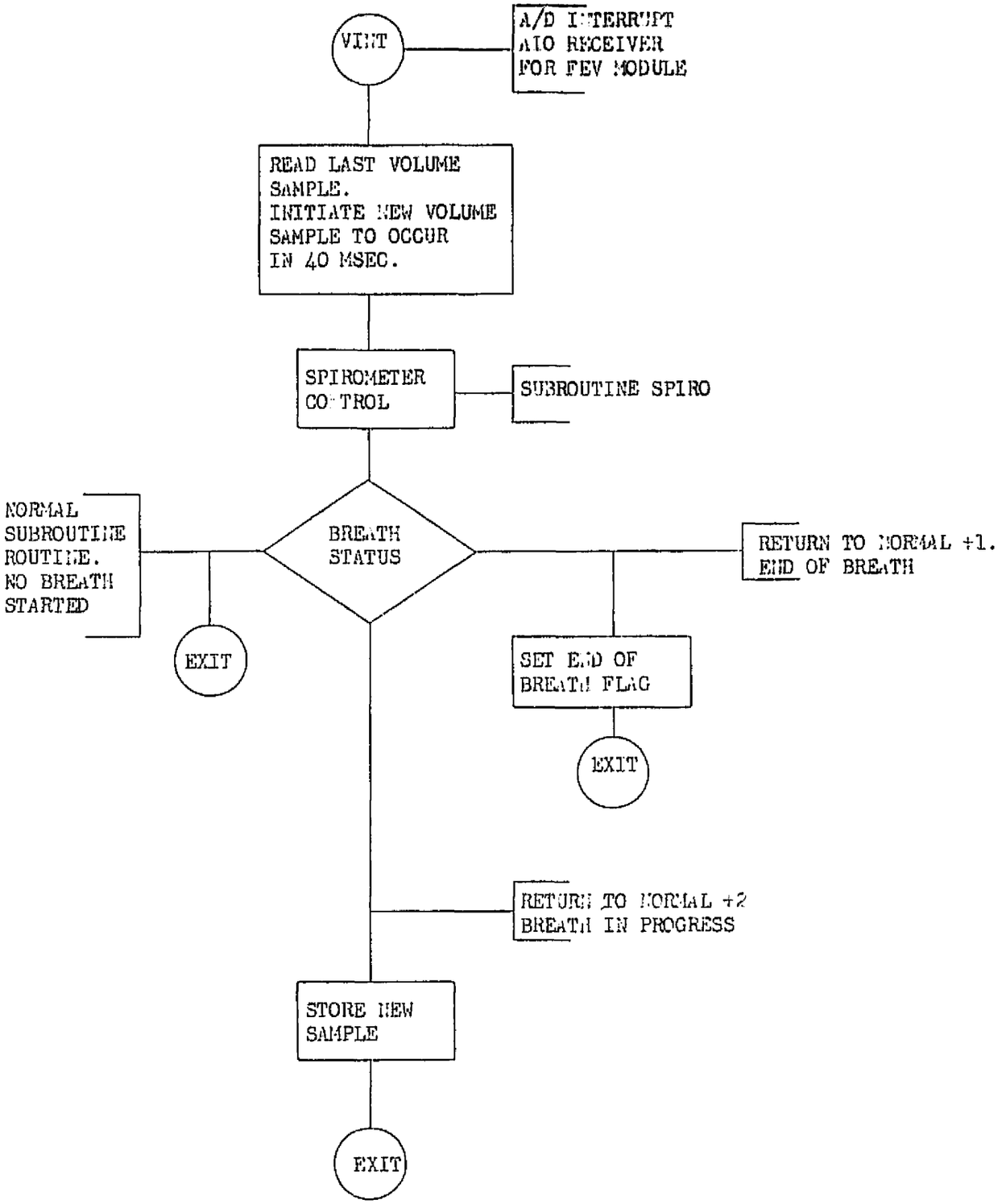


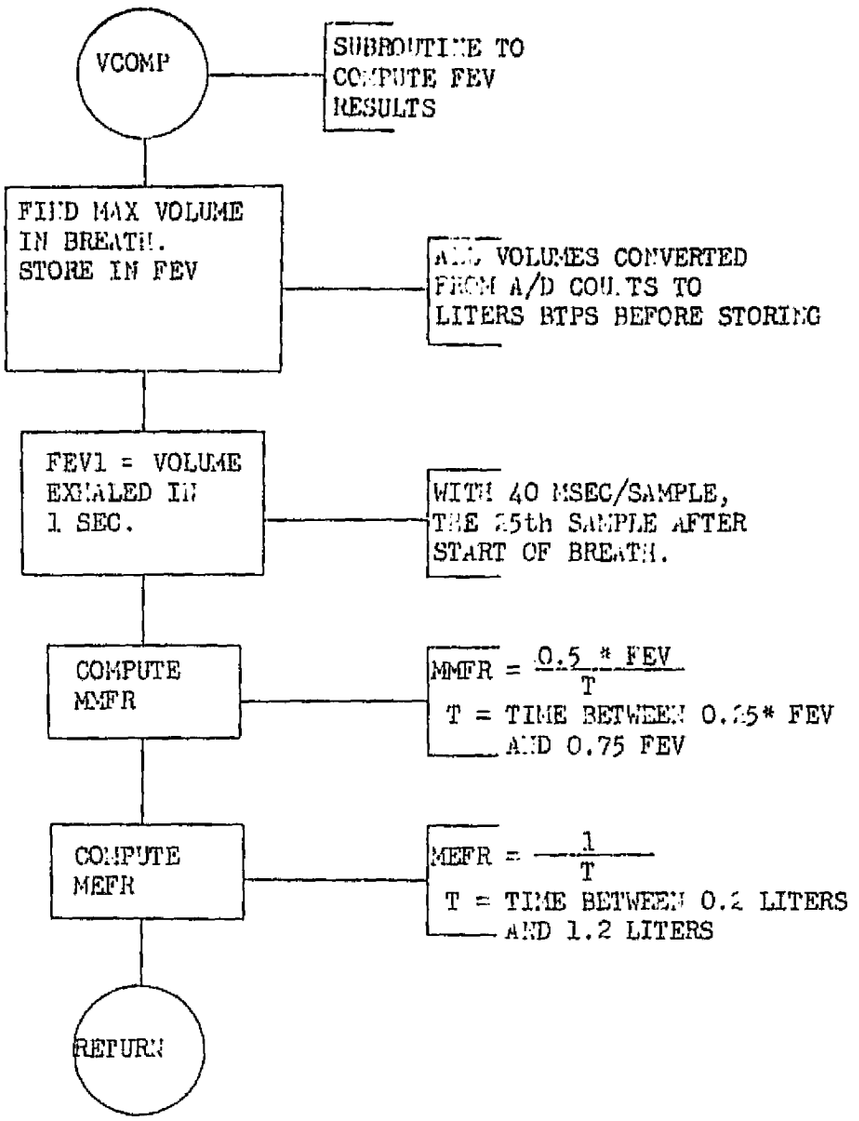
REPORT GENERATION MODULE

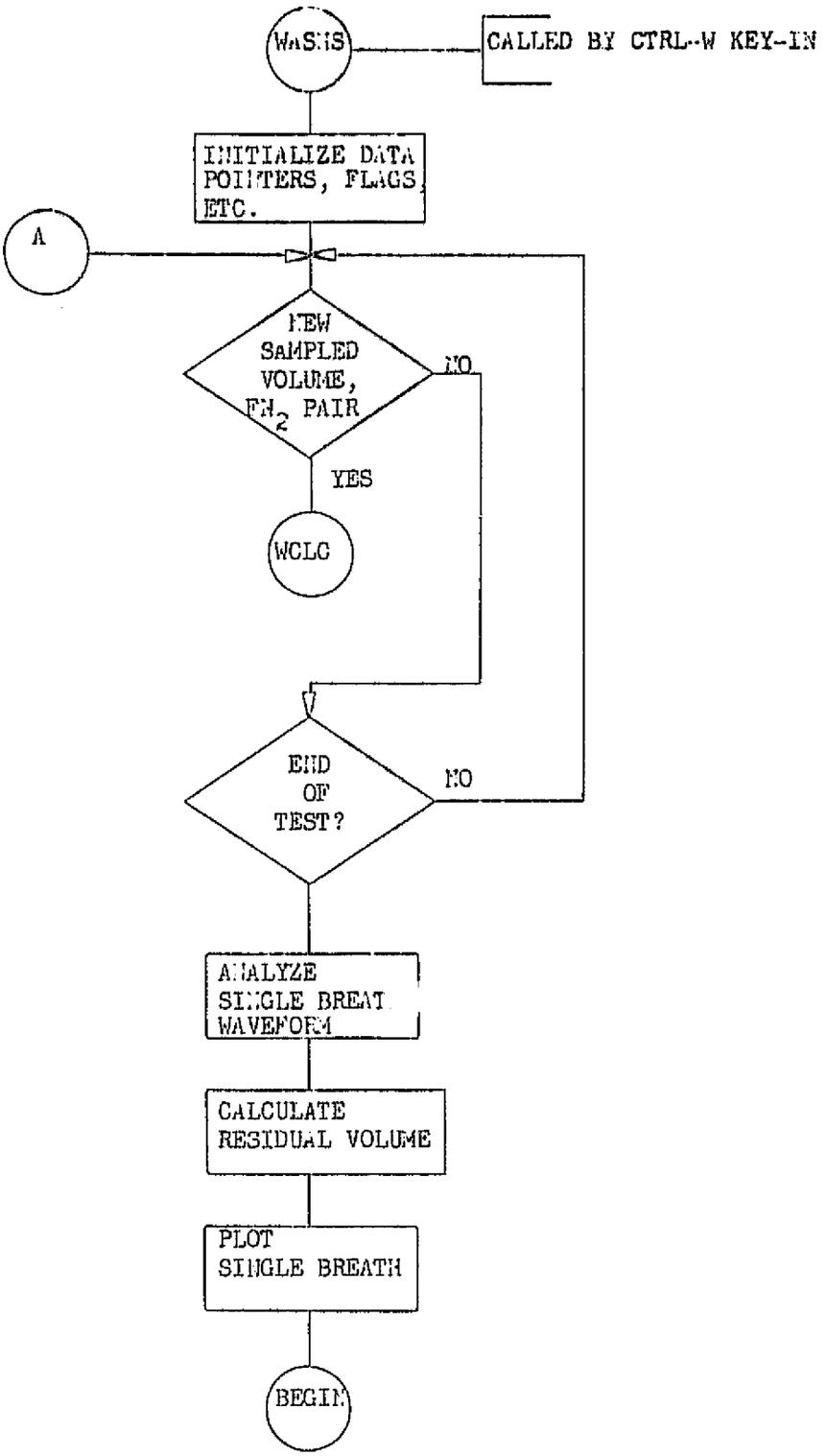

SPIRO
SUBROUTINE TO MONITOR SPIROMETER STATUS, CONTROL VALVE, DETERMINE BREATH STATUS
ENTER WITH SAMPLED VOLUME IN ACCUMULATOR
VOLUME ABOVE THRESHOLD
NO
YES
VALVE OPEN
NO
YES
VALVE CLOSED?
NO
YES
CLOSE VALVE
V LAST = 0
V WATCH = -10
SAMPLE .GT. VLAST
NO
YES
INCREMENT V WATCH
ZERO TO AC
V LAST = SAMPLE
V WATCH = -10
AC = SAMPLE
V WATCH .GE.0
AC = SAMPLE
RETURN
NORMAL RETURN
YES
OPEN VALVE AC = 0
RETURN
NORMAL +2
RETURN
NORMAL + 1
END OF BREATH



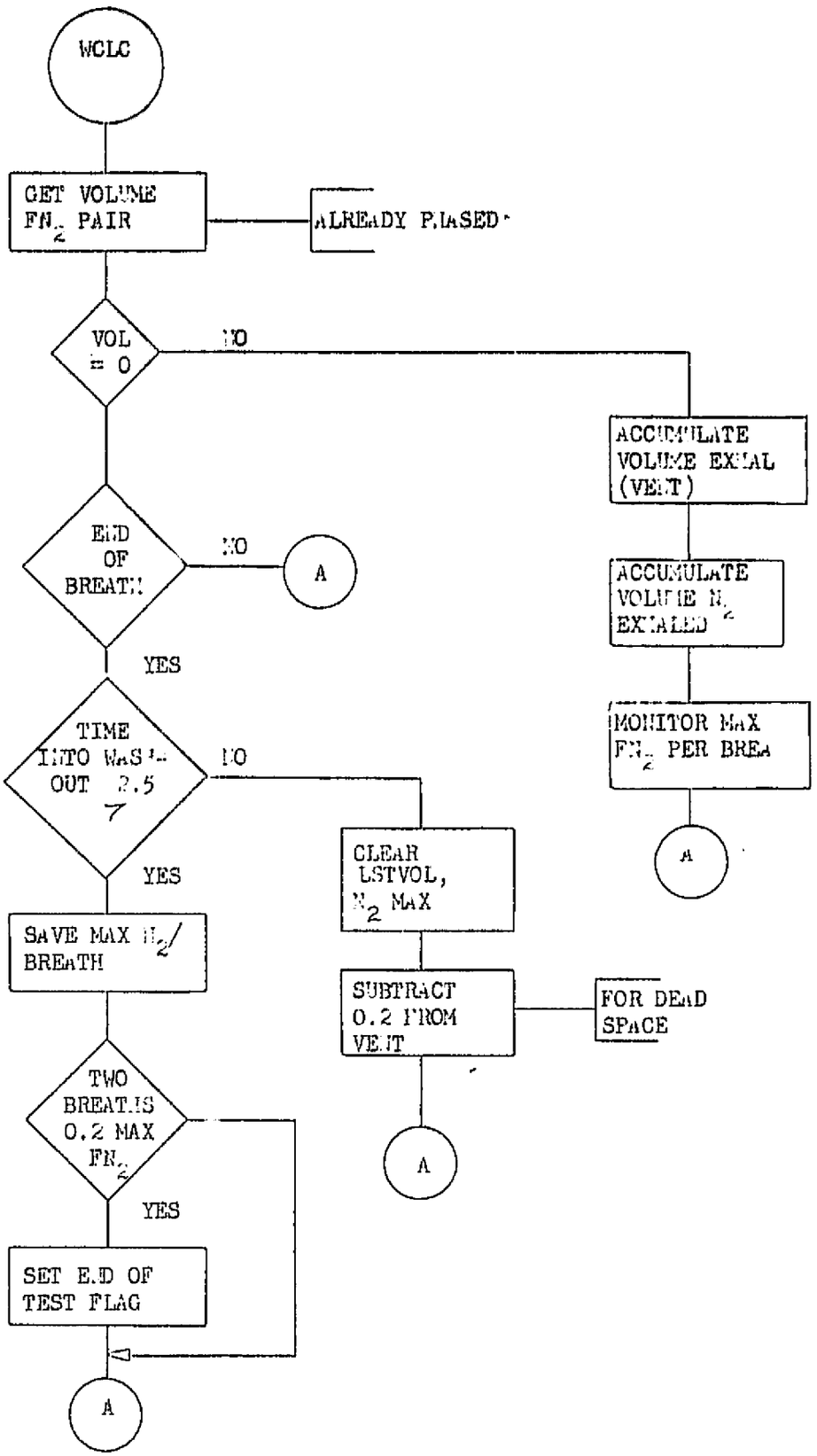
FORCED VITAL CAPACITY MODULE

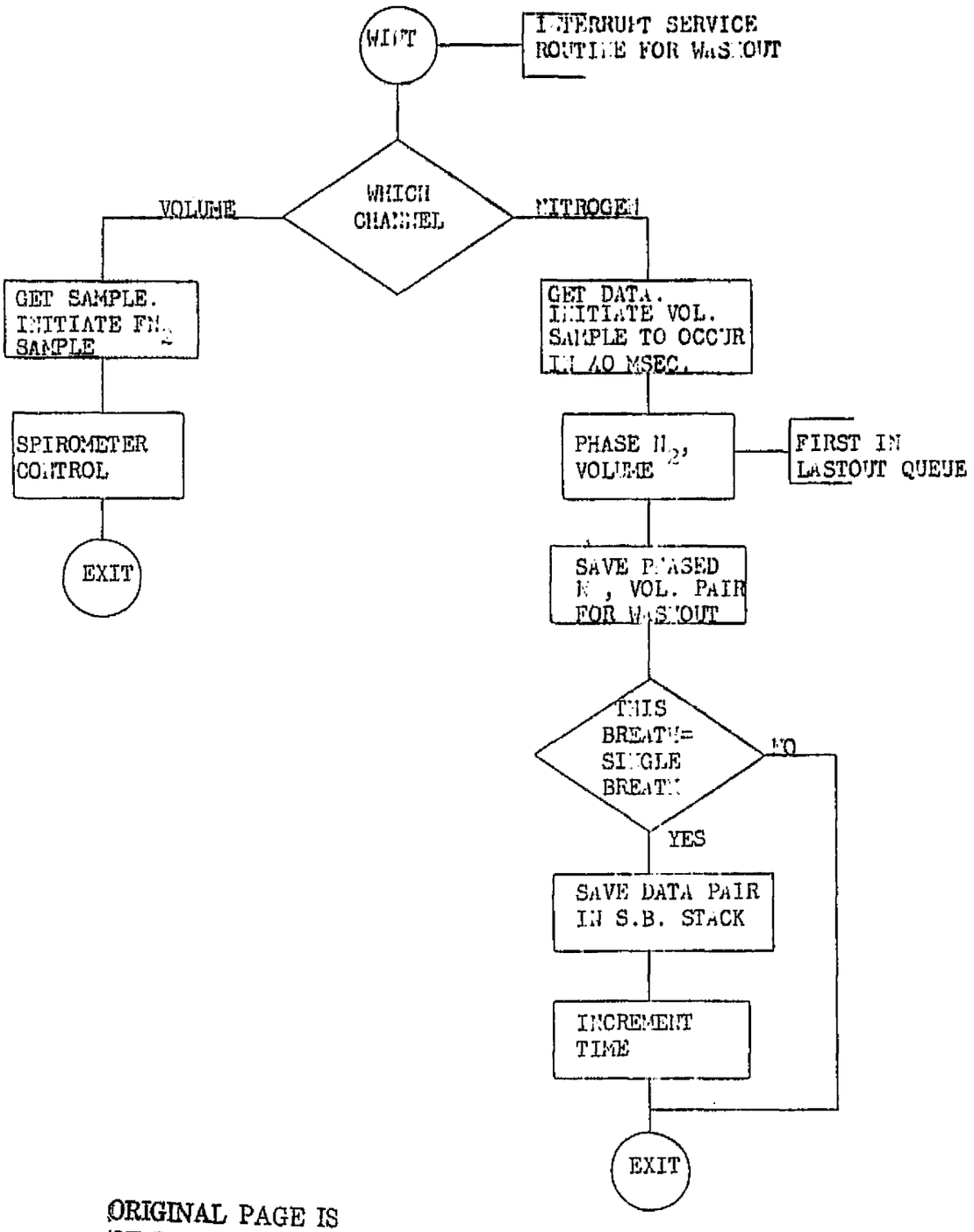

VIRT
A/D INTERRUPT
AIO RECEIVER
FOR FEV MODULE
READ LAST VOLUME
SAMPLE.
INITIATE NEW VOLUME
SAMPLE TO OCCUR
IN 40 MSEC.
SPIROMETER
CONTROL
SUBROUTINE SPIRO
NORMAL
SUBROUTINE
ROUTINE.
NO BREATH
STARTED
BREATH
STATUS
RETURN TO NORMAL +1.
END OF BREATH
EXIT
SET END OF
BREATH FLAG
EXIT
RETURN TO NORMAL +2
BREATH IN PROGRESS
STORE NEW
SAMPLE
EXIT

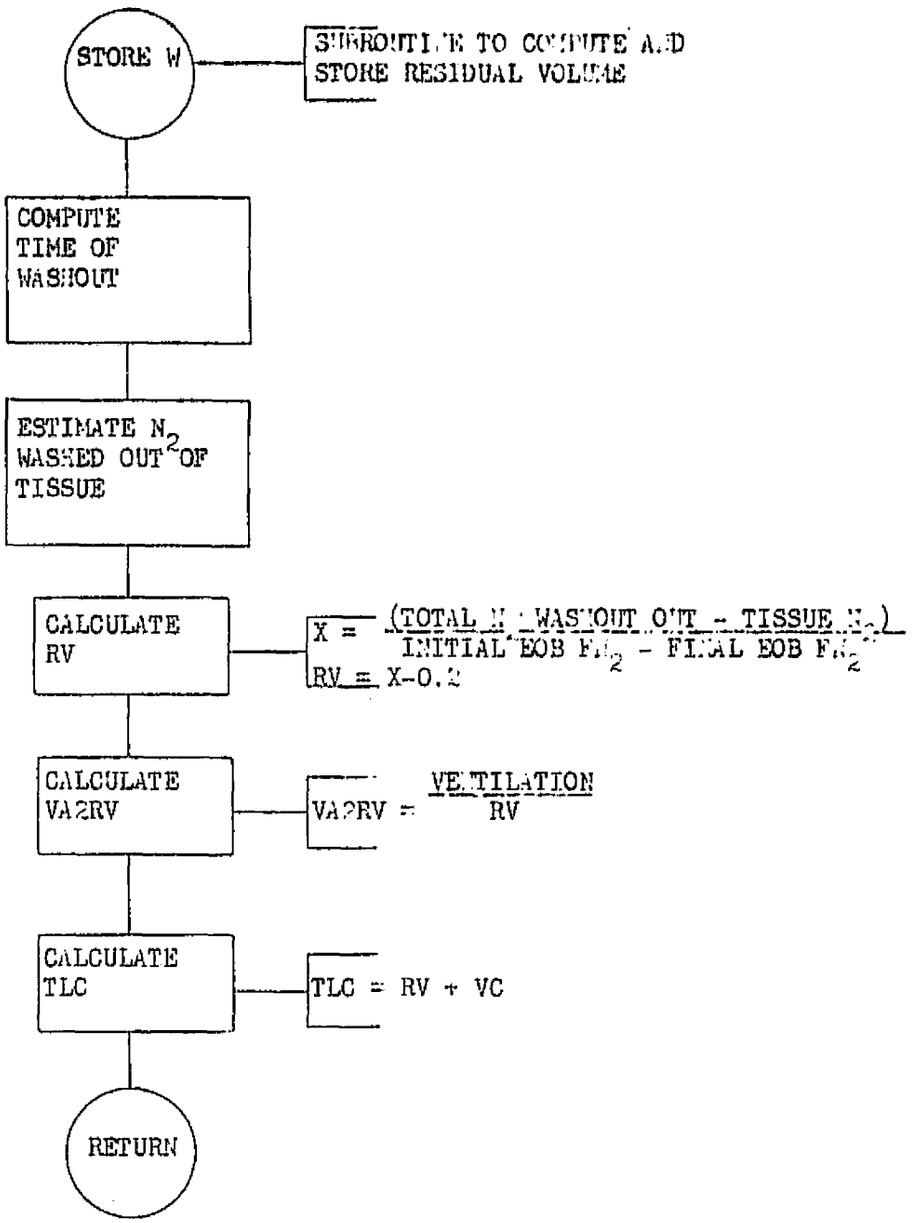

VCOMP
SUBROUTINE TO COMPUTE FEV RESULTS
FIND MAX VOLUME IN BREATH. STORE IN FEV
ALL VOLUMES CONVERTED FROM A/D COUNTS TO LITERS BTPS BEFORE STORING
FEV1 = VOLUME EXHALED IN 1 SEC.
WITH 40 MSEC/SAMPLE, THE 25th SAMPLE AFTER START OF BREATH.
COMPUTE MMFR
MMFR = 0.5 * FEV / T
T = TIME BETWEEN 0.25* FEV AND 0.75 FEV
COMPUTE MEFR
MEFR = 1 / T
T = TIME BETWEEN 0.2 LITERS AND 1.2 LITERS
RETURN

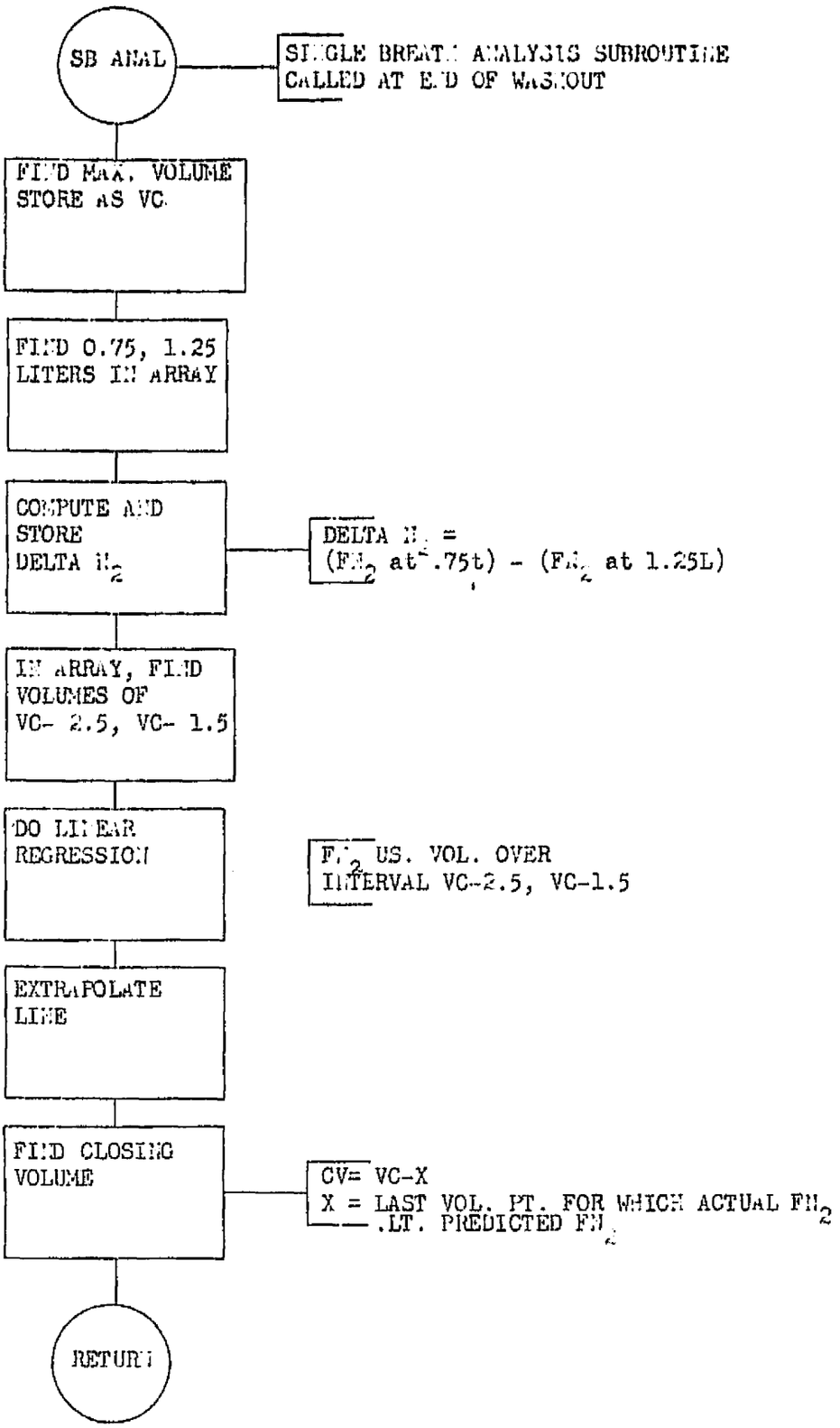


NITROGEN WASHOUT MODULE






STORE W
SUBROUTINE TO COMPUTE AND STORE RESIDUAL VOLUME
COMPUTE TIME OF WASHOUT
ESTIMATE N_2 WASHED OUT OF TISSUE
CALCULATE RV
$X = \frac{\text{(TOTAL N WASHOUT OUT - TISSUE } N_2)}{\text{INITIAL EOB } F_{N_2} - \text{FINAL EOB } F_{N_2}}$
RV = X-0.2
CALCULATE VA/RV
$VA/RV = \frac{\text{VENTILATION}}{RV}$
CALCULATE TLC
TLC = RV + VC
RETURN


SB ANAL
SINGLE BREATH ANALYSIS SUBROUTINE CALLED AT END OF WASHOUT
FIND MAX. VOLUME STORE AS VC
FIND 0.75, 1.25 LITERS IN ARRAY
COMPUTE AND STORE DELTA N_2
DELTA N_2 = (FN_2 at .75L) - (FN_2 at 1.25L)
IN ARRAY, FIND VOLUMES OF VC- 2.5, VC- 1.5
DO LINEAR REGRESSION
FN_2 VS. VOL. OVER INTERVAL VC-2.5, VC-1.5
EXTRAPOLATE LINE
FIND CLOSING VOLUME
CV= VC-X
X = LAST VOL. PT. FOR WHICH ACTUAL FN_2 .LT. PREDICTED FN_2
RETURN

APPENDIX II

Operating Instructions

(DISPLAY)(LSP$1-001

1-001_ DATE 9/25/74

PULMONARY FUNCTION

PREPARATION

OBS 1. Contact STDN to verify GN2, GO2, CAL GAS, & vacuum pump are on

2. INTERFACE PANEL:
   POWER SW - ON
   DVM - counter fluctuating

3. OXYGEN REGULATOR:
   SUPPLY SW - ON
   SUPPLY 100% OXYGEN SW - 100% OXYGEN (verify)
   FLOW SW - NORMAL (verify)
   OXYGEN SUPPLY PRESSURE ind - 200 ± 25 PSIG (verify)

CAUTION

Follow next steps in exact order or Mass Spectrometer may vent and preclude proper experiment operation

4. RESPIRATORY MONITORING ANALYZER:
   BYPASS LINE VLV (red handled vlv on left) - open (90 deg CCW)
   INLET CAPILLARY VLV (red handled vlv on right) - open (90 deg CCW)
   ANALYZER POWER SW - ON
   AMPLIFIER POWER SW - ON
   CATHETER SELECT SW - INLET B
   ANODE CURRENT ADJUST cont - CW till meter reads approximately 5-10 microamps anode current

5. After 30 min warmup period:
   Turn on Video
   ION PUMP CURRENT - 200±50 micro-amps (verify)

PROCESSING

6. XY PLOTTER:
   POWER SW - ON (red lt - on)
   Place chart paper to lower left of chart bed
   Remove cap from XY Plotter pen
   CHART SW - ON (amber lt - on)
   SERVO SW - ON (amber lt - on)

7. COMPUTER:
   POWER SW (key lock) - on

8. Go to PROGRAM LOADING INSTRUCTIONS on page 1-5

9. TTY:
   Depress CNTL key and then C key (maintaining CNTL key depressed)
   XY plotter drives to Y = 50% M2 and X = 7 Liters Volume

   RESPIRATORY MONITORING ANALYZER:
   Sample calibration gas with known FN2 using catheter 9 (red lt - on)

   Note: FN2 of present CAL GAS is 0.8010 ± 0.002

   ANODE CURRENT ADJUST cont - adjust until cal gas FN2 is observed on INTERFACE PANEL DVM and/or on TTY after depressing the P key
   CATHETER SELECT SW - INLET B (green lt - on)

10. Remove blue and gold respiratory hoses from stowage and attach blue hose to OXYGEN SUPPLY quick disconnect and gold hose to EXHALATION HOSE quick disconnect. Attach other ends of hoses to v1v assembly. Attach Mass spectrometer sampling to v1v assembly. Flush respiratory v1v with O2 using TEST MASK position on O2 regulator

SUBJ 11. Sit in front of RESPIRATORY VLV ASSEMBLY

12. Washout Test

OBS TTY:
Depress CNTL key and then I key (maintaining CNTL key depressed)
Depress CNTL key and then W key (maintaining CNTL key depressed)

SUBJ Place nose clamp on
Inspire room air, hold breath, then place mouthpiece in mouth and seal lips over mouthpiece
Exhale slowly to Residual Volume (RV), inspire Vital Capacity (VC) of oxygen and again exhale to RV (10-15 sec)
Following initial maneuver, relax and breathe normally until washout is complete. Washout is complete when XY Plotter automatically plots out single breath washout test. Carefully remove mass spectrometer capillary. Disconnect blue hoses & vlv assembly and stow

13. Forced Vital Capacity Test

OBS TTY:
Depress CNTL key and then F key (maintaining CNTL key depressed)
Place FVC hose and cardboard mouthpiece on spirometer

SUBJ Wet cardboard mouthpiece with tongue.
Hold mouthpiece hose assembly to side of mouth, inspire VC of oxygen air, momentarily hold breath, seal lips on mouthpiece, then forcibly exhale to RV. Both flow and volume should be at maximum effort

OBS 14. Print_Report

TTY:
Depress CNTL key and then R key
(maintaining CNTL key depressed)
Annotate printout with name of subject
and date
Turn off Video

POWERDOWN

OBS 1. TTY:
Slide TTY into storage position

2. XY PLOTTER:
SERVO SW - OFF
POWER SW - OFF
Put cap back on XY Plotter pen

3. RESPIRATORY MONITORING ANALYZER:
ANODE CURRENT ADJUST cont - 0
CATHETER SELECT SW - REMOTE
AMPLIFIER POWER SW - OFF
ANALYZER POWER SW - OFF
INLET CAPILLARY VLV (red handled
vlv on right) - close (90 deg CW)
BYPASS LINE VLV (red handled vlv on
left) - close (90 deg CW)

4. OXYGEN REGULATOR:
SUPPLY SW - OFF

5. INTERFACE PANEL:
POWER SW - OFF

6. Contact STOW to verify GO2, GN2, CAL
GAS, & vacuum pump are off

7. Clean washout valve and mouthpiece with
sterile wipe and stow

8. Stow FVC hose, discard cardboard mouth-
piece and debrief experiment

*** Command completed. ***

PROGRAM LOADING INSTRUCTIONS

Nominal Startup

NOTE: After nominal shutdown program will still be in memory

1. SING STEP sw - normal (top of sw depressed)
2. SING INST sw - normal (top of sw depressed)
3. Put 200 (000 010 000 000) in SWITCH REGISTER
4. Depress LOAD ADD
5. PROGRAM COUNTER (PC) should contain 200
6. Verify high speed paper tape reader is disengaged (sprocket cover up)
7. Depress START

Program should be functioning correctly (PC holding at 213 - 000 010 001 011)

* If program is not functioning correct-*
* ly proceed to Loading Binary Tapes *
* procedure below *

Loading Binary Tapes

NOTE: If BINARY LOADER is in memory, proceed to step 1 below. IF BINARY LOADER is not in memory proceed to Loading Binary Loader procedure on page 1-7

1. Put 7777 (111 111 111 111) in SWITCH REGISTER
2. Depress LOAD ADD

3. PROGRAM COUNTER should read 7777_8

4. Place paper tape floating point package (DIGITAL 8-25-F-BIN, FLOATING PACKAGE 2) in reader, with arrow up, pointing from right to left, sprocket holes over sprucket, and tape leader over read head (leader is the portion of tape with two rows of holes, one at the front side of the tape)

5. Depress START

   * If tape does not read to data portion *
   * of tape, depress STOP, LOAD ADD, *
   * then START *

6. Tape should read to end and reader stop

   * If tape does not read, perform Loading*
   * Binary Loader procedure on page 1-7 *

7. When tape stops, LINK should be illuminated, and all accumulator lights should be out

   * If not, a parity error occured. *
   * Start over on step 1 of Loading *
   * Binary Tapes procedure on page 1-5 *

8. Remove tape from reader

9. Place PFT Program paper tape in reader, with arrow up, pointing from right to left, sprocket holes over sprockets, and tape leader over read head

10. Verify 7777_8 (111 111 111 111) in SWITCH REGISTER

11. Depress LOAD ADD

12. PROGRAM COUNTER should read 7777$_8$

13. Depress START

14. Tape should read to end and reader stop

    * If tape does not read, perform Loading Binary Loader procedure below *

15. When tape stops, LINK should be illuminated, and all accumulator lights should be out.

    * If not, a parity error occured. Start over on step 1 of Loading Binary Tapes procedure on page 1-5 *

16. Remove tape from reader and rewind by hand

17. Proceed to NOMinal Startup procedure on page 1-5

Loading Binary Loader

NOTE: Loading BINARY LOADER requires depositing and examining data in memory using the panel switches

MEMORY CHECK TO SEE IF RIM LOADER IS IN CORE

1. Put 7756$_8$ (111 111 101 110) in SWITCH REGISTER

2. Depress LOAD ADD

3. Verify 7756$_8$ in PROGRAM COUNTER

4. Depress EXAM repeatedly and verify the following MEMORY BUFFER (MB) readout sequence. If verify fails, perform TO CHANGE A SINGLE LOCATION procedure on page 1-9

MEMORY BUFFER (MB)

7200_8	(111 010 000 000)
6011_8	(110 000 001 001)
5357_8	(101 011 101 111)
6012_8	(110 000 001 010)
7106_8	(111 001 000 110)
7006_8	(111 000 000 110)
7510_8	(111 101 001 000)
5374_8	(101 011 111 100)
7006_8	(111 000 000 110)
6011_8	(110 000 001 001)
5367_8	(101 011 110 111)
6012_8	(110 000 001 010)
7420_8	(111 100 010 000)
3776_8	(011 111 111 110)
3376_8	(011 011 111 110)
5357_8	(101 011 101 111)

5. Put 7755_8 (111 111 101 101) in SWITCH REGISTER

6. Depress LOAD ADD
7. Place BINARY LOADER paper tape in reader, with arrow up, pointing from right to left, sprocket holes over sprocket, and tape leader over read head (leader is the portion of tape with two rows of holes, on at the front side of the tape)
8. Depress START
9. Tape will read completely through
10. Depress STOP
11. Go to Loading Binary Tapes procedure on page 1-5

TO CHANGE A SINGLE LOCATION

1. Put address in SWITCH REGISTER
2. Depress LOAD ADD
3. Put data in SWITCH REGISTER
4. Depress DEP
5. Return to MEMORY CHECK TO SEE IF RIM LOADER IS IN CORE, page 1-7, step 1

TO LOAD ENTIRE RIM LOADER

1. Put 7750 (111 111 101 110) in SWITCH REGISTER
2. Depress LOAD ADD

3. In sequence for the following, verify PROGRAM COUNTER is correct, set SWITCH REGISTER to correct value, depress DEP

PROGRAM COUNTER	SWITCH REGISTER
7756 (111 111 101 110)	7200 (111 010 000 000)
7757 (111 111 101 111)	6011 (110 000 001 001)
7760 (111 111 110 000)	5357 (101 011 101 111)
7761 (111 111 110 001)	6012 (110 000 001 010)
7762 (111 111 110 010)	7106 (111 001 000 110)
7763 (111 111 110 011)	7006 (111 000 000 110)
7764 (111 111 110 100)	7510 (111 101 001 000)
7765 (111 111 110 101)	5374 (101 011 111 100)
7766 (111 111 110 110)	7006 (111 000 000 110)
7767 (111 111 110 111)	6011 (110 000 001 001)
7770 (111 111 111 000)	5367 (101 011 110 111)
7771 (111 111 111 001)	6012 (110 000 001 010)
7772 (111 111 111 010)	7420 (111 100 010 000)
7773 (111 111 111 011)	3776 (011 111 111 110)
7774 (111 111 111 100)	3774 (011 011 111 110)
7775 (111 111 111 101)	5357 (101 011 101 111)

4. Perform Loading Binary Loader on page 1-7

APPENDIX III

Program Listing

```
                /PULMONARY FUNCTION TEST
                /HARDWARE-PDP-8I,PERKIN ELMER MASS SPEC,SPIROMETER
                /       XY PLOTTER,DVM
1000            FIXMRI FADD=1000
2000            FIXMRI FSUB=2000
3000            FIXMRI FMPY=3000
3000            FIXMRI FMUL=3000
4000            FIXMRI FDIV=4000
5000            FIXMRI FGET=5000
6000            FIXMRI FPUT=6000
0000            FEXT=0000
7000            FNORM=7000
0000            FEXIT=0000
6537            SAMPLE=6537
6065            DAC=6065
4407            FENTER=4407
7501            MQA=7501
7421            MQL=7421
6075            CTRL=6075
                /DESCRIPTION OF SOME SUBROUTINES
                /CONVRT
                        /ENTER WITH MANTISSA IN MQ, EXP(FROM AD)
                        /IN AC.  RETURNS 12BIT UNSIGNED UMBER
                        /IN AC
                /UNPACK
                        /ENTER WITH 12 BIT UNSIGNED NUMBER IN AC
                        /RETURNS WITH FPAC CONTAINING NORMALIZED
                        /FRACTION CORRESPONDING TO AC/4096
```

```
                    EJECT
          0001      *1
00001     5402      JMP I .+1
00002     1000      SERVIC
00003
00004
          0005      *5
00005     7400      7400
00006     7200      7200
00007     5600      5600
00010
00011
00012
          7345      *7345
07345     3416      3416
07346     5744      5744    /PATCH TO FPP FOR OUTPUT
                            /VIA AUTO INDEX REG 16
00017                               /FOR USE WITH LEAST SQUARES ROUTINE
00020     0020      *20
00020     0000      N,      0;0;0
00021     0000
00022     0000
00023     0000      EXY,0;0;0
00024     0000
00025     0000
00026     0000      EX,0;0;0
00027     0000
00030     0000
00031     0000      EY,     0;0;0
00032     0000
00033     0000
00034     0000      EX2,    0;0;0
00035     0000
00036     0000
          0065      *65


                    /DEFINE SOME SUBROUTINE CALLS BY MNEMONICS


          4465      UNPACK=JMS I .:WD2FLT
00065     3144
          4466      FOUT=JMS I .:   FOUTS
00066     0213
          4467      SPIRO=JMS I .:SPIROS
00067     0400
          5470      BEGIN=JMP I .:INIT
00070     0200
          4471      BTPS=JMS I .:BTPSR
00071     1732
          4472      FIX=JMS I .:FIXX
00072     1536
          4473      READY=JMS I .:RPTCK
00073     0557
```

```
00102          4474  FLOAT=JMS I .:FLTR
00103  00074   2152
00104  00075   0000  MSG1,  .-0
00105  00076   0000  MSG2,   0
00106  00077   0000  MS1PK,  0
00107  00100   0000  MS2PK,  0
00108                                /MSG1,MSG2 POINT TO MESSAGES IN QUE,
00109                                /MS1PK,MS2PK SAY IF PACKED ASCII OR NOT
00110                                /0 PACKED,  1 NOT PACKED
00111  00101   1026  XITPT,  XIT     /POINTER TO EXIT FROM INTERRUPT SERVICE
00112  00102   1043  FRSMG,  TTO+1   /ENTRY POINT
00113  00103   0000  KEYIN,0         /AIO RECEIVER FOR UNSOLICITED KEY-IN, NON CTRL
00114  00104   0114  WAITPT,WAIT
00115  00105   3547  FRTBT,  FRTBFR-1  /FOR USE USING FPP TYPE OUTS, PUT THIS IN 10
00116  00106   0000  INPUT,0         /KEY IN BUFFER
00117  00107   0077  K77,77          /A CONSTANT
00118  00110   0000  LASTSM,0        /WHICH CHANNEL WAS SAMPLED LAST
00119  00111   1026  ADAIO,  XIT     /AIO RCVR FOR A-D
00120          4512  OUTPUT=JMS I .
00121  00112   0657  MGPT,MESSAG     /POINTER TO OUTPUT SCHEDULER
00122  00113   0620  N2SAM,620       /CONSTANT TO SELECT AD CHANNEL N2
00123                DELAY,
00124  00114   2000  WAIT,2000       /SAYS WAIT FOR 40 MSEC CLOCK TO SAMPLE
00125          4515  CONVRT=JMS I .:AD21WD
00126  00115   0474
00127
00128
00129
00130  00116   7774  K7774,7774      /MASK FOR DAC, CHANNEL SELECT IN OTHER BITS
00131  00117   0003  K3,3            /A CONSTANT, A TO CHANNEL FOR DVM OUTPUT
00132  00120   7455  MINUS3,-323     /NEGATIVE OF ASCII 3, USED TO STOP VARIOUS TESTS
00133
00134
00135
00136
00137
00138
00139  00121   0000  EXP,0
00140  00122   0000  MANTIS,0        /A BUFFER FOR AD DATA AND CONVRT
00141  00123   0000          0
00142  00124   0002  M2?210,0002:0000:0000
00143  00125   0000
00144  00126   0000
00145                                /5V GIVES 1.79545X100 =N2
00146  00127   0000  VALVE,0
00147  00130   0000  OPEN,0
00148  00131   7773  CLOSE,7773
00149  00132   4000  VOLUME,4000
00150  00133   0002  DVM,2
00151  00134   1572  ADLOOP,LOOPAD
00152  00135   4000  VSTART,DATA
00153          4536  FLTVOL=JMS I .:SD2VOL
00154  00136   1737
00155  00137   0013  F2047,0013
00156  00140   3777          3777
```

```
00141  7777          7777
00142  0000  VFHI,0
00143  0000  VFLO,0
00144  0000  FKAC,0:0:0
00145  0000
00146  0000
00147  7462  MINUSN,-316
00150  0003  VLPR10,3:3100:0000              /6.5L/10V
00151  3100
00152  0000
                     /CONSTANTS FROM HERE ON OUT USED BY WASHOUT ROUTINE
                     /NO STORAGE LEFT AT THAT ROUTINE
00153  0000  VSKEY,0
00154  0000  VNKEY,0
00155  0000  VPKEY,0
00156  0000  NTIMAL,0:0:0
00157  0000
00160  0000
00161  2640  DUMAD,2640
00162  5320  VSTORE,5320
00163  5350  NSTORE,5350
00164  5377  NLAST,5377
00165  5350  NSTART,5350
00166  5347  WVLAST,5347
00167  5320  VFIRST,5320
00170  5317  NWLST,5317
       5317  NWLST1=5317
00171  4550  WNSTOR,4550
00172  3777  W/STOR,DATA-1
00173  0007  F100,7:3100:0
00174  3100
00175  0000
       4575  DACIC=JMS I .:DACN
00176  1524
```

```
                0200  *200

                      /PROGRAM INITIATION
                      /ALSO, RETURN FROM DIFFERENT MODULES

00200  7200  INIT,CLA
00201  7200          CLA
00202  6002          IOF
00203  1130          TAD OPEN        /OPEN VALVE
00204  6075          CTRL
00205  3127          DCA VALVE
00206  1154          TAD ADLOOP      /CLEAR AIO RECEIVERS
00207  3111          DCA ADAIO
00210  3103          DCA KEYIN
00211  6001          ION             /TURN ON INTERRUPT
00212  5212          JMP .           /IDLE
```

```
                        EJECT
00213  00J0  FOUTS,0
00214  3062             DCA 62          /C(55)=0  NO CRLF
00215  7010             RAR             /NOT =0 CRLF
00216  3055             DCA 55          /C(62)=#DIGITS
00217  1235             TAD STORP       /WHERE TO PUT THE ASCII
00220  3016             DCA 16
00221  1076             TAD MSG2
00222  7640             SZA CLA
00223  5221             JMP .-2         /BUFFER READY
00224  4406             JMS I 6
00225  7300             CLA CLL
00226  3416             DCA I 16
00227  7201             CLA IAC
00230  7010             RAR             /SET LINK
00231  7201             CLA IAC
00232  1235             TAD STORP
00233  4512             OUTPUT
00234  5613             JMP I FOUTS
00235  3547  STORP, PRTBFR-1
```

```
                EJECT


                /ROUTINE TO PRINT OUTPUT ON TELETYPE

00236  7300  REPORTS, CLA CLL
00237  3103          DCA KEYIN
00240  1134          TAD ADLOOP
00241  3111          DCA ADAIO
00242  4777'         JMS AUX          /SUBROUTINE TO COMPUTE DERIVED VARIABLES
00243  1315          TAD NUMOUT
00244  7041          CIA
00245  3314          DCA OUTCT        /SET EXIT LOOP COUNTER
00246  1312          TAD NAMESP       /SET POINTERS TO FORMAT OUTPUT
00247  3010          DCA I0
00250  1311          TAD FRP
00251  3011          DCA I1
00252  1310          TAD DIGP
00253  3012          DCA I2
00254  1313          TAD UNITP
00255  3013          DCA I3
00256  1307          TAD DAPT
00257  3306          DCA DATUM
00260  7300  OVERY,  CLA CLL
00261  4473          READY
00262  1410          TAD I I0         /GET LABEL
00263  4512          OUTPUT           /PRINT IT
00264  4407          FENTER
00265  5706          FGET I DATUM     /GET DATUM
00266  0000          FEXIT
00267  2306           SZ DATUM; ISZ DATUM; ISZ DATUM
00270  2306
00271  2306
00272  7300          CLA CLL
00273  1411          TAD I I1         /GET Y OF FX.Y FORMAT
00274  7421          MQL
00275  1412          TAD I I2         /GET X
00276  4436          FOUT             /FLOATING POINT OUTPUT
00277  7300          CLA CLL
00300  4473          READY
00301  1413          TAD I I3         /GET UNITS
00302  4512          OUTPUT           /PRINT THEM
00303  2314          ISZ OUTCT        /THROUGH?
00304  5260          JMP OVERY        /NO
00305  5472          BEGIN            /YES. BEGIN IDLE
00306  0000  DATUM, 0
00307  1200  DAPT, RV
00310  0532  DIGP, DIG-1
00311  0540  FRP, FR-1
00312  0732  NAMESP, NAMES-1
00313  1153  UNITP, UNIT-1
00314  0000  OUTCT, 0
00315  0016  NUMOUT, 16
```

```
                EJECT
                /NEW SUBJECT ROUTINE
                /CALLED BY CTRL-I KEYIN
                /CLEARS DATA BUFFER
00316  7300  NEWS,   CLA CLL
00317  1335          TAD NEWPT       /PRINT "NEW SUBJECT"
00320  4512          OUTPUT
00321  7240          CLA CMA
00322  1307          TAD DAPT        /SET POINTERS
00323  3010          DCA 10
00324  1315          TAD NUMOUT
00325  7041          CIA             /AND COUNTER
00326  3314          DCA OUTCT
                                     /CLEAR A VARIABLE
00327  3410  NEWSS,DCA I 10;DCA I 10;DCA I 10
00330  3410
00331  3410
00332  2314          ISZ OUTCT       /THROUGH?
00333  5327          JMP NEWSS       /NO
00334  5470          BEGIN           /YES. BEGIN IDLE
00335  0762  NEWPT,NEWS
```

```
                EJECT


                /ROUTINE TO SCALE DATA AND COMPUTE SUMS FOR LINEAR
                /REGRESSION FOR USE IN CLOSING VOLUME CALCULATION
                /
                /X=VOLUME
                /Y=NITROGEN FRACTION
                /
                /ENTERED WITH SAMPLED N2 IN MQ,SAMPLED VOLUME IN AC

00336  0000  SUMS,   0
00337  3372          DCA XHOLD
00340  7501          MQA
00341  4465          UNPACK
00342  4407          FENTER
00343  3124          FMUL N2PR10      /CONVERT NITROGEN TO FRACTION
00344  6144          FPUT FKAC        /SAVE
00345  1031          FADD EY          /ADD TO SUM Y
00346  6031          FPUT EY
00347  0000          FEXIT
00350  1372          TAD XHOLD        /CONVERT VOLUME TO LITERS
00351  4536          FLTVOL
00352  4471          DTFS
00353  4407          FENTER
00354  6121          FPUT EXP         /SAVE
00355  1026          FADD EX          /SUM X
00356  6026          FPUT EX
00357  5121          FGET EXP
00360  3121          FMUL EXP
00361  1034          FADD EX2         /SUM X**2
00362  6034          FPUT EX2
00363  5121          FGET EXP
00364  3144          FMUL FKAC
00365  1023          FADD EXY         /SUM XY
00366  6023          FPUT EXY
00367  0000          FEXIT
00370  2021          ISZ N+1
00371  5736          JMP I SUMS
00372  0000  XHOLD,  0
```

```
00377  1341
       0400  *400
00400  0009  SPIROS,0              /ENTER THIS SUB AFTER
                                   /MONITORING POSITION, 0-10V CHANNEL
                                   /WITH MANTISSA IN MQ,EXPONENT IN AC
                                   /ENTER WITH INTERRUPT OFF
                                   /EXITS
                                   /1,NORMAL-SPIRO DUMPING
                                   /OR BELOW THRESH
                                   /2,NORMAL+1 EOB
                                   /JUST OPENE VALVE
                                   /3,GOOD DATA IN AC
                                   /THIS DATA RETURNDE IN AC
                                   /AS A 12 BIT POSITIVE NUMBER
                                   /WITH 7777 INDICATING 10 V
00401  4515          CONVRT        /MAKE ONE WORD
00402  3266          DCA VTEMP
00403  7100          CLL
00404  1266          TAD VTEMP     /SCALE RIGHT FOR MANIPULATIONS
00405  7010          RAR
00406  7421          MQL           /SAVE FOR LATER USE
00407  7200          CLA
00410  7501          MQA
00411  1270          TAD VTHRSH    /IS SPIROMETER FULLY DUMPED?(BELOW THRESHHOLD)
00412  7710          SPA CLA
00413  5250          JMP VBELOW    /YES
00414  1127          TAD VALVE     /IS VALVE OPEN?  (DUMPING)
00415  7041          CIA           /(SPIRO ABOVE THRESH TO BE HERE)
00416  1130          TAD OPEN
00417  7650          SNA CLA
00420  5600          JMP I SPIROS  /YES VALVE OPEN SO DUMPING, NORMAL EXIT, V=0
00421  7501          MQA           /NOT DUMPING SO EXHALATION IN PROGRESS
00422  7041          CIA
00423  1265  TAD VLAST
00424  1273          TAD K10
00425  7700          SMA CLA       /SAMPLES IN A ROW WITH NO
00426  5249          JMP NOCHG     /MORE THAN 10 COUNTS CHANGE
00427  1272          TAD KWAIT     /MORE THAN 14 CTS INCREASE SO
00430  3271          DCA VWATCH    /RESET COUNTERS
00431  7501          MQA
00432  3265          DCA VLAST     /AND COMPARISON VALUE
00433  7200  OK,     CLA
00434  1266          TAD VTEMP     /GET VALUE
00435  2300          ISZ SPIROS    /AND EXIT TO NORMAL +2
00436  2200          ISZ SPIROS
00437  5600          JMP I SPIROS
00440  7200  NOCHG,  CLA           /NOT MOVED MORE THAN 10 CTS
00441  2271          ISZ VWATCH    /IS IT 10 TIMES IN A ROW??
00442  5233          JMP OK        /NO, TAKE BREATH IN PROGRESS EXIT
00443  1130          TAD OPEN      /YES, END OF BREATH
00444  6075          CTRL          /OPEN VALVE, SAVE VALVE STATUS
00445  3127          DCA VALVE
00446  2300          ISZ SPIROS    /TAKE NORMAL + 1 EXIT
00447  5600          JMP I SPIROS
00450  1127  VBELOW, TAD VALVE     /COMES HERE IF WAS DUMPED
```

```
00451  7041          CIA
00452  1137          TAD OPEN        /IS VALVE OPEN ?? (DUMPING)
00453  7[illegible]  SZA CLA
00454  5600          JMP I SPIROS    /NO. VALVE CLOSED.  WAITING FOR BREATH. EXIT
00455  7200  VCLOSE, CLA             /YES,VALVE OPEN.
00456  1272          TAD KWAIT
00457  3271          DCA VWATCH      /RESET POINTERS
00460  3265          DCA VLAST
00461  1131          TAD CLOSE       /CLOSE VALVE
00462  6075          CTRL
00463  3127          DCA VALVE
00464  5600          JMP I SPIROS    /EXIT
00465  0000  VLAST,0
00466  0000  VTEMP,0
00467  0000  VSHIFT,0
00470  7754  VTHRSH,-24
00471  0000  VWATCH,0
00472  7770  KWAIT,7770
00473  0004  K10,4
```

```
                EJECT
                /ROUTINE TO PACK A/D DATA INTO ONE WORD
                                        /ENTER WITH EXPONENT IN AC
                                        /MANTISSA IN MQ
                                        /RETURNS .2 BIT NUMBER IN AC
                                        /POSITIVE
                                        /7777 IS FULL SCALE. NOT MINUS 1
00474  0000  AD21WD. 0
00475  3266          DCA I/TEMP        /SAVE EXPONENT
00476  3267          DCA I/SHIFT
00477  1266          TAD I/TEMP        /IS EXPONENT ZERO?
00500  7450          SNA
00501  5320          JMP NOSHFT
00502  2267          ISZ /SHIFT
00503  7004          RAL               /NON ZERO EXPONENT,SHIFT LEFT UNTIL
00504  7420          SNL               /SHIFT OUT A ONE, COUNTING SHIFTS
00505  5302          JMP .-3
00506  7300          CLA CLL
00507  1267          TAD I/SHIFT       /SHIFTED THIS MANY TIMES
00510  7041          CIA
00511  3267          DCA I/SHIFT       /MAKE IT A COUNTER AND SHIFT
00512  7501          MQA
00513  7100          CLL               /MANTISSA RIGHT THAT MANY TIMES
00514  7010          RAR
00515  2267          ISZ I/SHIFT
00516  5313          JMP .-3
00517  7421          MQL
00520  7300  NOSHFT, CLA CLL
00521  7501          MQA
00522  5674          JMP I AD21WD
```

```
                    EJECT


                    /FORMAT CONSTANTS.  IN F FORMAT. FDIG.FR
00523  0003  DIG.5;3;3;3;3;3;3;3;3;3;3;3;3;3;3;3
00524  0003
00525  0003
00526  0003
00527  0003
00550  0003
00531  0003
00532  0003
00533  0002
00534  0003
00535  0003
00536  0003
00537  0003
00540  0003
00541  0003  FR.2;2;2
00542  0002
00543  0002
00544  0001          1;2
00545  0002
00546  0001          1;2;2
00547  0002
00550  0002
00551  0001          1;1;1
00552  0001
00553  0001
00554  0001          1;1;1
00555  0001
00556  0001


00557  0000  RPTCK,0
00560  7200          CLA
00561  1076          TAD MSG2        /WAIT LOOP DURING REPORT FOR TTY
00562  7640          SZA CLA         /TO OUTPUT DATA
00563  5360          JMP .-3
00564  5757          JMP I RPTCK
00565  4040  L,TEXT '  LITERS BTPS<>'
00566  1411
00567  2405
00570  2423
00571  4003
00572  2420
00573  2374
00574  7690
```

```
524          0600  *600
525
526
527                /INTERRUPT SERVICE FOR TTY KEYBOARD
528
529
530    00600  6036  TTI,    KRB
531    00601  3186          DCA INPUT
532    00602  1186          TAD INPUT
533    00603  1256          TAD M232
534    00604  7710          SPA CLA          /CONTROL CHARACTER?
535    00605  5212          JMP CTRL1        /YES
536    00606  1103          TAD KEYIN
537    00607  7640          SZA CLA          /RIO SPECIFIED?
538    00610  5503          JMP I KEYIN      /YES
539    00611  5501          JMP I XITPT      /NO,FORGET IT
540
541    00612  1186  CTRL1,  TAD INPUT        /CTRL CHARACTER,JUMP INDIECT THROUGH
542    00613  0107          AND K77          /TABLE BELOW
543    00614  1222          TAD OFFSET
544    00615  3221          DCA .+4
545    00616  1621          TAD I .+3
546    00617  3221          DCA .+2
547    00620  5621          JMP I .+1
548    00621  0000          0
549    00622  0623  OFFSET,.+1
550    00623  1026          XIT
551    00624  1026          XIT      /CTRL A
552    00625  1026          XIT      /" B
553    00626  1400          CAIS     /CTRL C
554    00627  1026          XIT:XIT /D,E
555    00630  1026
556    00631  1600          FEVS     /CTRL F
557    00632  1026          XIT
558    00633  1026          XIT
559    00634  0316          NEWS
560    00635  1026          XIT:XIT:XIT:XIT:XIT
561    00636  1026
562    00637  1026
563    00640  1026
564    00641  1026
565    00642  1026          XIT
566    00643  1026          XIT
567    00644  1026          XIT
568    00645  0236          REPORTS /REPORT
569    00646  0200          INIT             /STOPS ALL IMMEDIATE
570    00647  1026          XIT:XIT:XIT
571    00650  1026
572    00651  1026
573    00652  2350          WASHS
574    00653  1026          XIT:XIT:XIT
575    00654  1026
576    00655  1026
577    00656  7546  M232,-232
```

```
                    EJECT


                    /ROUTINE TO PLACE AN ASCII MESSAGE ON PRINT QUEUE
                    /ENTER WITH ADDRESS OF MESSAGE IN AC
                    /ZERO LINK, DATA IS PACKED TWO CHAR PER WD
                    /NON-ZERO LINK   1 CHAR PER WD


00657  0000  MESSAG, 0
00660  3320          DCA HOLD
00661  6002          IOF
00662  7010          RAR
00663  3321          DCA LINKMG
00664  1075          TAD MSG1
00665  7640          SZA CLA          /PRINTING?
00666  5300          JMP QUE          /YES
00667  1320          TAD HOLD         /NO
00670  3075          DCA MSG1         /ADDRESS OF MESSAGE
00671  1321          TAD LINKMG       /PACKED?
00672  7440          SZA
00673  7201          CLA IAC          /NO
00674  3077          DCA MS1PK
00675  6046          TLS              /TO GET AN INTERRUPT GOING
00676  6001          ION
00677  5657          JMP I MESSAG
00700  1076  QUE,    TAD MSG2
00701  7640          SZA CLA
00702  5313          JMP LOSTMG       /QUE WAS ALREADY FULL
00703  1320          TAD HOLD         /QUEUE NOT FULL
00704  3076          DCA MSG2         /PUT ADDRESS IN MSG2 AND
00705  1321          TAD LINKMG
00706  7440          SZA
00707  7201          CLA IAC
00710  3100          DCA MS2PK        /AND PACKED FLAG IN MSG2PK
00711  6001          ION
00712  5657          JMP I MESSAG
00713  1322  LOSTMG, TAD LOSTPT       /NO ROOM TO STACK NEW MESSAGE
00714  3076          DCA MSG2
00715  3100          DCA MS2PK
00716  6001          ION
00717  5657          JMP I MESSAG
00720  0000  HOLD,   0
00721  0000  LINKMG, 0
00722  0723  LOSTPT, LOST
00723  1417  LOST,   TEXT <LOST MESSAGE><12>
00724  2324
00725  4015
00726  0523
00727  2301
00730  0705
00731  7674
```

```
00732  0000

               /DATA LABEL POINTERS


00733  3342  NAMES,L1;L2;L3
00734  0771
00735  1252
00736  1257          L4;L5
00737  1264
00740  1271          L7;L8;L9
00741  1276
00742  1303
00743  1310          L10;L11;L12
00744  1315
00745  1322
00746  1327          L13;L14;L15
00747  1354
00750  2707
00751  1662  CALMSG,TEXT 'N2 CALIBRATION<>'
00752  4003
00753  0114
00754  1102
00755  2201
00756  2411
00757  1716
00760  7476
00761  0000
       0760  B=.-2
00762  1605  NEWMG,TEXT 'NEW SUBJECT<>'
00763  2740
00764  2325
00765  0212
00766  0503
00767  2474
00770  7600
00771  1662  L2,TEXT 'N2 DELTA'
00772  4004
00773  0514
00774  2401
00775  0000
```

```
                    EJECT
          1000      *1000
01000     3241  SERVIC, DCA AC   /SAVE AC
01001     7010      RAR
01002     3240      DCA LINK      /SAVE LINK
01003     7501      MQA
01004     3237      DCA MQ
01005     1000      TAD 0         /SAVE PC
01006     3236      DCA PC
01007     6533      6533          /AD?
01010     7410      SKP           /NO
01011     5511      JMP I ADAIO   /SEE WHY THE RECEIVERS SHOULD BE RESET
01012     6135      6135          /CLOCK?
01013     7410      SKP           /NO
01014     5226      JMP XIT       /I DONT USE IT
01015     6143      6143          /PRINTER?
01016     7410      SKP
01017     5226      JMP XIT       /DONT USE IT EITHER
01020     6041      TSF           /TTO?
01021     7410      SKP           /NO
01022     5242      JMP TTO       /YES INDEED
01023     6031      KSF           /KEY-IN?
01024     7410      SKP           /LIES. NO INTERRUPT
01025     5777      JMP TTI       /KEYBOARD
01026     7300  XIT, CLA CLL
01027     1237      TAD MQ        /RESTORE
01030     7421      MQL           /PUT IT THERE
01031     1240      TAD LINK      /THIS TOO
01032     7004      RAL
01033     1241      TAD AC
01034     6001      ION
01035     5636      JMP I PC      /CONTINUE
01036     0000  PC, 0
01037     0000  MQ, 0
01040     0000  LINK, 0
01041     0000  AC, 0             /STORAGE

                    /NOTE ONLY ONE LEVEL.  ONLY SERVICE CAN TURN INTERRUPTS ON
                    /KEEP ALL ROUTINS VERY SHORT
```

```
                        EJECT
01042  6042  TTO.TCF
01043  7200          CLA
01044  1077          TAD MSIPK
01045  7640          SZA CLA          /PACKED DATA?
01046  5313          JMP NOTPCK       /NO
01047  1343          TAD FIRST        /PRINTING LEFT HALF?
01050  7740          SZA CLA CLL
01051  5260          JMP RIGHT        /NO
01052  1475          TAD I MSG1       /GET WORD
01053  7012          RTR;RTR;RTR      /PUT CHARACTER IN RIGHT HALF
01054  7012
01055  7012
01056  2343          ISZ FIRST        /NEXT ONE TO BE RIGHT HALF
01057  5263          JMP DECODE
01060  3343  RIGHT,DCA FIRST
01061  1475          TAD I MSG1
01062  2075          ISZ MSG1
01063  0177  DECODE,AND [77
01064  7450          SNA
01065  5320          JMP THRU         /ZERO CHARAC  ? SAYS END OF MESSAGE
01066  3355          DCA CHHOLD       /BUFF
01067  1355          TAD CHHOLD
01070  1351          TAD MT4          /<T
01071  7650          SNA CLA
01072  5311          JMP RETURN       /CODE FOR CR
01073  1355          TAD CHHOLD
01074  1352          TAD MT6          />?
01075  7650          SNA CLA
01076  5332          JMP LF           /LINE FEED
01077  1355          TAD CHHOLD
01100  1344          TAD M37
01101  7450          SNA      /RETURN IS CODE 37
01102  5311          JMP RETURN               /YES IT IS
01103  7510          SPA
01104  1346          TAD D100
01105  1347          TAD D137
01106  0040  TYPE,TLS
01107  7200          CLA
01110  5501          JMP I WITPT
01111  1347  RETURN, TAD D215
01112  5006          JMP TYPE
01113  1477  NOTPCK, TAD I MSG1        /UNPACKED
01114  7450          SNA
01115  5320          JMP THRU         /LAST CHARAC
01116  2077          ISZ MSG1
01117  5006          JMP TYPE
01120  7200  THRU, CLA          /RESET FLAGS.
01121  3343          DCA FIRST
01122  1076          TAD M32
01123  7640          SZA CLA          /ANOTHER MESSAGE IN QUE?
01124  5254          JMP PRINT1
01125  1077          TAD MSIPK
01126  3077          DCA MSIPK
```

```
769   01130  3100          DCA MS2PK
770   01131  5501          JMP I XITPT
771
772
773   01132  1353  LF,TAD K212
774   01133  5506          JMP TYPE
775   01134  1076  NEWMS1,TAD MSG2
776   01135  3075          DCA MSG1
777   01136  3076          DCA MSG2
778   01137  1100          TAD MS2PK
779   01140  3077          DCA MS1PK
780
781   01141  3100          DCA MS2PK
782   01142  5242          JMP TTO
783
734
735
786
787   01143  0000  FISST,0
788   01144  7741  M37,-37
789   01145  0237  K237,237
790   01146  0100  K100,100
791   01147  0215  K215,215
792   01150  0000  CHHOLD,0
793   01151  7704  M74,-74
794   01152  7702  M76,-76
795   01153  0212  K212,212
```

```
                        EJECT
01154  0565  UNIT/L;P;L
01155  1172
01156  0565
01157  0780          B;L
01160  0565
01161  0565          L;L;L
01162  0565
01163  0565
01164  1172          P;P;F
01165  1172
01166  1366
01167  1366          F;P;P
01170  1172
01171  1172
01172  4040  P,      ' TEXT'  %<>'
01173  4574
01174  7000
01177  0600
       1200  *1200
                     /DATA BUFFER
01200  0000  RV,0;7;0                /RESIDUAL VOL
01201  0000
01202  0000
01203  0000  N2DELT,3;0;0             /DELTA % N2 750-1250
01204  0000
01205  0000
01206  0000  CV,0;0;0                 /CLOSING VOLUME
01207  0000
01210  0000
01211  0000  VA2RV,0;0;0              /VA-RV
01212  0000
01213  0000
01214  0000  VC,0;0;0                 /VITAL CAPACITY
01215  0000
01216  0000
01217  0000  TLC,0;0;0                /TOTAL LUNG CAPACITY
01220  0000
01221  0000
01222  0000  FEVT,0;0;0               /FORCED VITAL CAPACITY
01223  0000
01224  0000
01225  0000  FEV1,0;0;0               /FEV AT 1SEC
01226  0000
01227  0000
01230  0000  F12FEV,0;0;0            /FEV1/FVC
```

```
851   01231  0000
852   01232  0000
853   01233  0000  FVC2VC,0;0;0          /FVC/VC
854   01234  0000
855   01235  0000
856   01236  0000  MEFR,0;0;0            /200-700  BTPS L/SEC
857   01237  0000
858   01240  0000
859   01241  0000  MMFR,0;0;0            /.25-.75 BTPS L/SEC
860   01242  0000
861   01243  0000
862   01244  0000  CV2VC,0;0;0           /%
863   01245  0000
864   01246  0000
865   01247  0000  CC2TLC,0;0;0          /%
866   01250  0000
867   01251  3000
868   01252  0326  L3,TEXT 'CV
869   01253  4540
870   01254  4040
871   01255  4040
872   01256  4000
873   01257  2601  L4,TEXT 'VA/BV
874   01260  5726
875   01261  2640
876   01262  4040
877   01263  4000
878   01264  2603  L6,TEXT 'VC
879   01265  4040
880   01266  4040
881   01267  4040
882   01270  4000
883   01271  2414  L7,TEXT 'TLC
884   01272  0340
885   01273  4040
886   01274  4040
887   01275  4020
888   01276  0326  L8,TEXT 'FVC
889   01277  0340
890   01300  4040
891   01301  4040
892   01302  4000
893   01303  0605  L9,TEXT 'FEV1
894   01304  2661
895   01305  4040
896   01306  4040
897   01307  4000
898   01310  0605  L10,TEXT 'FEV1/FVC '
899   01311  2661
900   01312  5726
901   01313  2603
902   01314  4020
903   01315  0626  L11,TEXT 'FVC/VC   '
904   01316  0357
905   01317  2603
```

```
 906   01320  4040
 907   01321  4000
 908   01322  1505  L12, TEXT 'MEFR
 909   01323  0622
 910   01324  4040
 911   01325  4040
 912   01326  4000
 913   01327  1515  L13, TEXT 'MMFR
 914   01330  0622
 915   01331  4040
 916   01332  4040
 917   01333  4000
 918   01334  0326  L14, TEXT 'CP/VC
 919   01335  5729
 920   01336  0340
 921   01337  4040
 922   01340  4000
```

```
                EJECT

                /COMPUTATION OF DERIVED VARIABLES
                /CALLED BY REPORT


01341  0000  AUX,0
01342  4407          FENTER
01343  5225          FGET FEV1       /F12FEV=FEV1*100/FEV
01344  4222          FDIV FEVT
01345  3173          FMUL F100
01346  6230          FPUT F12FEV
01347  5222          FGET FEVT
01350  4214          FDIV VC         /FVC2VC=100*FEV/VC
01351  3173          FMUL F100
01352  6235          FPUT FVC2VC
01353  5220          FGET CV
01354  4214          FDIV VC
01355  3173          FMUL F100       /CV2VC=100*CV/VC
01356  6244          FPUT CV2VC
01357  5220          FGET CV
01360  1200          FADD RV         /CC2TLC=100*(RV+CV)/TLC
01361  4217          FDIV TLC
01362  3173          FMUL F100
01363  6247          FPUT CC2TLC
01364  0000          FEXIT
01365  5741          JMP I AUX

01366  4040  F,TEXT '  BTPS LITERS/SEC<>'
01367  0224
01370  2023
01371  4014
01372  1124
01373  0522
01374  2357
01375  2305
01376  0274
01377  7400
```

```
 961           1400          *1400
 962
 963
 964                         /ROUTINE TO CALIBRATE MASS SPECTROMETER NITROGEN
 965                         /CHANNEL.  THE MASS SPEC USED WITH THIS PROGRAM
 966                         /HAS A VARIABLE ION CURRENT. SO IT WAS EASIER TO
 967                         /CHANGE IT THAN THE CONVERSION FACTOR.  FOR SOME MASS SPECTROMETERS,
 968                         /TIS ROUTINE SHOULD CHANGE THE CONVERSION FACTOR. N2PR10.
 969
 970
 971
 972
 973    01400  7300  CALS,CLA CLL
 974    01401  1371          TAD CALMPT
 975    01402  4512          OUTPUT
 976    01403  7240          CLA CMA
 977    01404  3116          AND K7774.
 978    01405  6065          DAC                 /SEND FULL SCALE VOLTAGES TO XY PLOTTER
 979    01406  7001          IAC                 /CHANNEL3
 980    01407  6065          DAC
 981    01410  7200          CLA
 982    01411  1323          TAD CALXT?
 983    01412  3133          DCA KEYIN           /SET TTI AIO RECEIVER
 984    01413  1321          TAD CALN2
 985    01414  3111          DCA ADAIO           /SET AD AIO RECEIVER
 986    01415  1113          TAD N2SAM           /INITIATE A SAMPLE
 987    01416  6537          SAMPLE
 988    01417  7200          CLA
 989    01420  1113          TAD N2SAM
 990    01421  6537          SAMPLE
 991    01422  7200          CLA
 992    01423  3313          DCA FLAGCL          /CLEAR SAMPLE FLAG
 993    01424  6001          ION
 994    01425  7200  RPT.    CLA                 /WAIT LOOP
 995    01426  1313          TAD FLAGCL          /NEW SAMPLE?  FLAG SET BY INTERRUPT SERVICE
 996    01427  7650          SNA CLA
 997    01430  5225          JMP .-3             /NO   WAIT
 998    01431  3313          DCA FLAGCL          /YES  PROCESS
 999    01432  1322          TAD HOLD            /GET SAMPLE
1000    01433  4465          UNPACK
1001    01434  4407          FENTER
1002    01435  3124          FMUL N2PR10         /CONVERT TO FRACTION
1003    01436  6015          FPUT FN2CL          /AND SAVE
1004    01437  0000          SWAIT
1005    01440  4576          BMON2               /SUBROUTINE TO SEND TO DVM
1006    01441  7200          CLA
1007    01442  1314          TAD TYPFLG
1008    01443  7650          SNA CLA             /ANY KEYINS?
1009    01444  5225          JMP RPT
1010    01445  3314          DCA TYPFLG          /YES  A P KEYIN
1011    01446  4407          FENTER
1012    01447  5315          FSET FN2CL
1013    01450  0000          FEXIT
1014    01451  7337          CLA CLL IAC CML RTL
1015    01452  7421          MQL                 /SEND FORMAT
```

```
1016   01453  7307          CLA CLL IAC RTL
1017   01454  7120          CLL CML
1018   01455  4466          FOUT            /PRINT FRACTION
1019   01456  5225          JMP RPT
1020
1021
1022
1023
1024   01457  7200  NEW%2,  CLA
1025   01460  6537          SAMPLE
1026   01461  7421          MQL             /INTERRUPT SERVICE FOR AD IN CAL
1027   01462  1113          TAD N2SAM
1028   01463  1114          TAD DELAY
1029   01464  6537          SAMPLE          /START NEW SAMPLE IN 40 MSEC
1030   01465  4515          CONVST          /GET LAST DATUM AND PACK INTO ONE WD
1031   01466  3322          DCA NHOLD       /SAVE IT
1032   01467  7001          IAC
1033   01470  3313          DCA FLGCL       /SET NEW SAMPLE FLAG
1034   01471  5501          JMP I %ITPT     /EXIT FROM INTERRUPT SERVICE
1035
1036
1037
1038   01472  7200  CALXIT, CLA             /TTI A%D RECEIVER
1039   01473  1106          TAD INPUT
1040   01474  1120          TAD MINUS8      /WAS IT AN 8
1041   01475  7640          SZA CLA
1042   01476  5303          JMP NOSTOP      /NO
1043   01477  3103          DCA KEYIN       /YES EXIT FROM CAL
1044   01500  1134          TAD ADLOOP
1045   01501  3111          DCA ADA%D
1046   01502  5470          JMP%I           BEGIN
1047
1048
1049
1050   01503  7200  NOSTOP, CLA
1051   01504  1106          TAD INPUT
1052   01505  1320          TAD MINUSP      /WAS IT A P?
1053   01506  7640          SZA CLA
1054   01507  5501          JMP I %ITPT     /NO
1055   01510  7001          IAC
1056   01511  3314          DCA TYPFLG      /YES  SET PRINT FLAG
1057   01512  5501          JMP I %ITPT
1058                 FLGCL,
1059   01513  0003  FLAGCL,3
1060   01514  0000  TYPFLG,0
1061   01515  0000  PN2CL,0;0;0
1062   01516  0000
1063   01517  0000
1064   01520  7450  MINUSP,-320
1065   01521  1457  CALN2,NEW%2
1066   01522  0000  NHOLD,0
1067   01523  1472  CALXTP,CALXIT
1068
1069
1070
```

```
1071
1072   01524  0000  DACN,0
1073   01525  4407          FENTER          /MULTIPLY N2 FRACTION BY 2047
1074   01526  3137          FMUL F2047
1075   01527  0A00          FEXIT
1076   01530  4472          FIX             /MAKE IT A SIGNED 12 BIT NUMBER
1077   01531  7004          RAL             /NOW AN UNSIGNED NUMBER
1078   01532  0116          AND K7774       /MASK
1079   01533  1133          TAD DVM         /ADD DVM CHANNEL
1080   01534  6005          DAC             /SEND TO DVM
1081   01535  5724          JMP I DACN
```

```
1082                    EJECT
1083
1084
1085                    /ROUTINE TO CONVERT FLOATING NUMBERS TO SIGNED 12 BIT INTEERS
1086
1087
1088    01536   0000    FIXX,0
1089    01537   7200            CLA
1090    01540   1044            TAD 44          /GET EXPONENT
1091    01541   7540            SZA SMA         /EXPONENT .GT. 0
1092    01542   5345            JMP .+3
1093    01543   7200            CLA             /NUMBER LESS THAN 1 (ABS VALUE)  EXIT
1094    01544   5364            JMP D+1         /WITH ZERO IN AC
1095    01545   1370            TAD M13         /EXPONENT .GT. 0  COMPARE TO 13
1096    01546   7450            SNA
1097    01547   5363            JMP D           /EQUAL TO 13  45 CONTAINS ANSWER
1098    01550   7500            SMA
1099    01551   5365            JMP ERR         /NUMBER TOO BIG FOR 12 BITS
1100    01552   3044            DCA 44          /HOW MANY TIMES TO SHIFT RIGHT
1101    01553   7100    GG,     CLL
1102    01554   1045            TAD 45          /GET MSB
1103    01555   7510            SPA
1104    01556   7020            CML             /PRESERVE SIGN
1105    01557   7010            RAR             /SHIFT
1106    01560   3045            DCA 45
1107    01561   2044            ISZ 44          /THROUGH?
1108    01562   5353            JMP GG          /NO
1109    01563   1045    D,      TAD 45          /YES  GET NUMBER
1110    01564   5736            JMP I FIXX      /EXIT
1111    01565   7340    ERR,    CLA CLL CMA     /NOT FIXABLE
1112    01566   5736            JMP I FIXX
1113    01567   5363            JMP D
1114    01570   7765    M13,-13
1115    01571   9751    CALMPT,CALMSG
1116
1117
1118
1119                     /SERVICE ROUTINE FOR AD WHILE NO ONE USES AD
1120                    /TO KEEP FROM LOSING SYNC
1121    01572   7200    LOOPAD,CLA
1122    01573   6537            SAMPLE
1123    01574   7200            CLA
1124    01575   1161            TAD DUMAD
1125    01576   6537            SAMPLE
1126    01577   5501            JMP I XITPT
```

```
1127            1600            *1600
1128
1129
1130
1131
1132                    /FEV ROUTINE, CONSISTING OF THREE PARTS
1133                    /       1. WAIT LOOP-MONITORS SAMPLED DATA BUFFER
1134                    /                       AND UPDATES DVM WITH LATEST VOLUME.
1135                    /                       AT END OF BREATH, INITIATES COMPUTATION ROUTINE.
1136                    /       2. A/D INTERRUPT SERVICE-RECEIVES AND STORES SAMPLED
1137                    /                       DATA, INITIATES SAMPLES, AND CONTROLS
1138                    /                       SPIROMETER VALVES.
1139                    /       3.CALCULATIONS-COMPUTES FEV PARAMETERS
1140
1141
1142
1143
1144
1145
1146    01600   7300    FEVS,CLA CLL
1147    01601   1253            TAD FEVNET
1148    01602   4512            OUTPUT
1149    01603   6537            SAMPLE          /INITIATE VOLUME SAMPLE
1150    01604   7200            CLA
1151    01605   1152            TAD VOLUME
1152    01606   6537            SAMPLE
1153    01607   7200            CLA
1154    01610   1252            TAD VADAIO
1155    01611   3111            DCA ADAIO       /SET AIO RECEIVERS
1156    01612   1251            TAD VKEYIN
1157    01613   3103            DCA KEYIN
1158    01614   3239            DCA VEOS
1159    01615   3153            DCA VSKEY       /CLEAR FLAGS
1160    01616   3154            DCA VNKEY
1161    01617   1170            TAD OPEN
1162    01620   6075            CTRL            /OPEN VALVE UNTIL FIRST SAMPLE COMPLETE
1163    01621   3127            DCA VALVE
1164    01622   7256    FLRST,  JMS VERDR
1165    01623   7200    FLWAIT, CLA
1166    01624   1152            TAD VSKEY
1167    01625   7640            SZA CLA
1168    01626   5254            JMP FLEXIT
1169    01627   1247            TAD VUSE        /NEW SAMPLE?  NOT IF VUSE=VIN
1170    01630   7041            CIA
1171    01631   1246            TAD VIN
1172    01632   7540            SMA SZA
1173    01633   5267            JMP VCLC        /YES.  GO DISPLAY IT
1174    01634   7200            CLA
1175    01635   1239            TAD VEOS        /END OF BREATH?
1176    01636   7650            SNA CLA
1177    01637   5223            JMP FLWAIT      /NO.  GO WAIT SOME MORE
1178    01640   3250            DCA VEOS
1179    01641   1134            TAD ADLOOP      /YES CLEAR AD AIO RECEIVER
1180    01642   3111            DCA ADAIO
1181    01643   6001            IOT
```

```
1182   01644  4777'          JMS /COMP        /GO COMPUTE DATA.
1183   01645  5254           JMP FLEXIT
1184   01646  0000  /IN,0                     /USED BY INT. SERVICE TO STORE DATA
1185   01647  0000  /USE,0                    /USED BY WAIT LOOP TO DISPLAY DATA
1186   01650  3809  /EOB,0
1187   01651  2244  /KEYIN,/KEY
1188   01652  1711  /ADAIO,/INT
1189   01653  1276  FE/INPT,L8
1190
1191
1192
1193   01654  6082  FLEXIT,IOF
1194   01655  5470  BEGIN
1195
1196
1197                 /SETUP ROUTINE
1198
1199
1200   01656  0000  NEWBR,0
1201   01657  7300          CLA CLL
1202   01660  6002          IOF
1203   01661  1135          TAD /START
1204   01662  3246          DCA /IN          /RESET DATA STORAGE POINTERS
1205   01663  1135          TAD /START
1206   01664  3247          DCA /USE
1207   01665  6001          ION
1208   01666  5656          JMP I NEWBR
1209
1210
1211
1212
1213   01667  7300  /CLC,CLA CLL
1214   01670  1647          TAD I /USE       /GET SAMPLED DATA
1215   01671  2247          ISZ /USE
1216   01672  4536          FLT40L           /SCALE IT TO LITERS
1217   01673  4471          BITS
1218   01674  4407          FENTER
1219   01675  4306          FDIV F10         /10 LITERS =FULL SCALE
1220   01676  3137          FMUL F2047       /FULL SCALE =2047 COUNTS
1221   01677  0000          FEXIT
1222   01700  4472          FIX
1223   01701  7004          BSL              /DAC WANTS 12 BIT POSITIVE NUMBER
1224   01702  6116          /IO/ 6774
1225   01703  1133          TAD DATI         /SEND TO DAC
1226   01704  6055          DAC
1227   01705  5226          JMP FLWAIT
1228   01706  0004  F10,4
1229   01707  2400  2400
1230   01710  0000  0000
```

```
1231                    EJECT
1232    01711   7200    VINT,   CLA                     /INTERRUPT SERVICE FOR AD DURING FEV
1233    01712   1132            TAD VOLUME
1234    01713   6537            SAMPLE                  /GET LAST VALUE AND INITIATE NEW SAMPLE
1235    01714   7421            MQL
1236    01715   1132            TAD VOLUME
1237    01716   1114            TAD DELAY
1238    01717   6537            SAMPLE
1239    01720   4467            SPIRO                   /CALL SPIROMETER SUBROUTINE
1240    01721   5501            JMP I XITPT             /FEV NOT STARTED
1241    01722   7410            SKP                     /END OF BREATH
1242    01723   5327            JMP STORE               /STORE NEW DATA POINT
1243    01724   7240            CLA CMA
1244    01725   3250            DCA VEOB                /SET END OF BREATH FLAG
1245    01726   5501            JMP I XITPT
1246
1247
1248
1249    01727   2246    STORE,  ISZ PTR                 /INCREMENT STORAGE POINTER AND
1250    01730   3646            DCA I PTR               /SAVE DATA
1251    01731   5301            JMP I XITPT
1252
1253
1254
1255
1256    01732   0000    BTPSR,  0
1257    01733   4407            FENTER
1258    01734   3353            FMUL BTPSFC             /CONVERT LITERS TO BTPS LITERS
1259    01735   0000            FEXIT
1260    01736   5732            JMP I BTPSR
1261
1262
1263
1264
1265
1266    01737   0000    SD2VOL, 0
1267    01740   7100            CLL
1268    01741   7010            RAR                     /CONVERT 12 BIT POSITIVE SAMPLE TO
1269    01742   3045            DCA 45                  /FLOATING POINT LITERS
1270    01743   7010            RAR
1271    01744   3046            DCA 46                  /MAKE FLOATING POINT FRACTION OF FULL SCALE
1272    01745   3044            DCA 44
1273    01746   4407            FENTER
1274    01747   7000            FNORM
1275    01750   3150            FMUL VLPR10             /MUL BY VOLUME AT FULL SCALE
1276    01751   0000            FEXIT
1277    01752   5737            JMP I SD2VOL
1278    01753   0001    BTPSFC, 0001
1279    01754   2130            2130
1280    01755   0406            0406                    /1.086
1281
1282
1283
1284
1285
```

```
1286
1287
1288   01756  0000  CLSUM,0                  /ROUTINE TO CLEAR LEAST SQUARES SUMS
1289   01757  1367        TAD NP             /PUT HERE BECAUSE NO ROOM AT ROUT
1290   01760  3010        DCA 10
1291   01761  1370        TAD NC
1292   01762  7371        DCA NCI
1293   01763  3410        DCA I 10
1294   01764  2371        ISZ NCI
1295   01765  5363        JMP .-2
1296   01766  5756        JMP I CLSUM
1297   01767  0017  NP,N-1
1298   01770  7761  NC,-17
1299   01771  0000  NCI,0
```

```
01777  2000
       2000             *2000

                  /COMPUTATION SUBROUTINE FOR FEV

02000  0000  VCOMP,0
02001  4777'          JMS MAXV          /FIND MAX VOLUME IN THIS BREATH
02002  326            DCA VPOINT              /LAST DATA POINT ADDRESS
[illegible]  1661     TAD I VPOINT
[illegible]  4536     FLTVOL
[illegible]  4471     BTPS
02006  4407           FENTER
02007  6776'          FPUT FEVT                    /MAX DATA POINT IN LITERS BTPS
02010  0000           FEXIT
02011  1175           TAD VSTART        /DATA BUFFER FIRST SAMPLE ADDRESS
02012  1260           TAD K31
02013  3261           DCA VPOINT        /31(OCTAL), 25 DECIMAL SAMPLES INTO BUFFER
02014  1661           TAD I VPOINT      /IS ONE SECOND.  GET THAT VOLUME
02015  4536           FLTVOL            /AND MAKE IT BTPS LITERS
02016  4471           BTPS
02017  4407           FENTER
02020  6775'          FPUT FEV1         /STORE IT AS FEV1
02021  5270           FGET FPT25
02022  3776'          FMPY FEVT
02023  6262           FPUT FOTR
02024  5776'          FGET FEVT
02025  1273           FMPY FPT75        /WANT VOLUMES =.25 FEVT, AND .75 FEVT
02026  6205           FPUT FSVTR
[illegible]  [illegible]  FEXIT
[illegible]  4504     JMS SEARCH        /FIND THEIR DISPLACEMENT IN ARRAY
02031  3142           DCA VFA1
[illegible]  4407     FENTER
[illegible]  5262     FGET FOTR
[illegible]  0000     FEXIT
02035  4504           JMS SEARCH
02036  3143           DCA VFLO
02037  4774'          JMS FLO           /COMPUT FLOW RATE BETWEEN AND
02040  4407           FENTER            /STORE AS MMFR
02041  6773'          FPUT MMFR
[illegible]  5270     FGET FMFR
[illegible]  0000     FEXIT
[illegible]  [illegible]  JMS SEARCH
02046  3143           DCA VFLO
[illegible]  4407     FENTER
[illegible]  [illegible]  FGET FIPTO    /SAME FOR 0.2 LITERS AND 1.2 LITERS
02051  0000           FEXIT
02051  4504           JMS SEARCH        /TO GET MEFR
02052  3142           DCA VFA1
02053  4774           JMS FLO
[illegible]  4407     FENTER
[illegible]  [illegible]  FPUT MEFR
```

```
1355   02056  0000          FEXIT
1356   02057  5600          JMP I VCOMP
1357                 K31,
1358   02060  0031  K25,31
1359   02061  0000  VPOINT,0
1360   02062  0000  FQTR,0;0;0
1361   02063  0000
1362   02064  0000
1363   02065  0000  F3QTR,0;0;0
1364   02066  0000
1365   02067  0000
1366   02070  7777  FPT25,7777;2000;0
1367   02071  2000
1368   02072  0000
1369   02073  0000  FPT75,0;3000;0
1370   02074  3000
1371   02075  0000
1372   02076  7776  FPT2,7776;3146;3147
1373   02077  3146
1374   02100  3147
1375   02101  0001  FIFT2,1;2314;6315
1376   02102  2314
1377   02103  6315
1378
1379
1380
1381   02104  0000  SEARCH,0              /ENTER WITH VOL DESIRED IN FLOATING AC
1382   02105  4407          FENTER
1383   02106  6347          FPUT VWANT
1384   02107  0000          FEXIT
1385   02110  7201          CLA IAC
1386   02111  1135          TAD VSTART
1387   02112  3261          DCA VPOINT
1388   02113  3346          DCA FIRST1
1389
1390
1391
1392                 /*************************************************
1393                 /
1394                 /DONT CHANGE THIS STUFF WITHOUT LOOKING AT SBANAL
1395                 /IT USES THIS ROUTINE ALSO
1396
1397
1398   02114  7200  RPTR,   CLA             /INDEX THROUGH POINTS UNTIL FIND
1399   02115  1661          TAD I VPOINT    /FIRST ONE GREATER THAN DESIRED VOLUME
1400   02116  4036          FLTVOL
1401   02117  4471          STPS
1402   02120  4407          FENTER
1403   02121  6347          FSUB VWANT
1404   02122  0000          FEXIT
1405   02123  7200          CLA
1406   02124  1045          TAD 45
1407   02125  7700          SMA CLA
1408   02126  5341          JMP BIGGER      /FOUND IT
1409   02127  7640          CMA
```

```
1410   02130  3346          DCA FIRST1
1411   02131  2261          ISZ VPOINT
1412   02132  1261          TAD VPOINT
1413   02133  7041          CIA
1414   02134  1771          TAD VSIZE        /ARE WE THROUGH ARRAY?
1415   02135  7540          SMA SZA
1416   02136  5314          JMP RPTR         /NO
1417   02137  7200  BAD,    CLA              /YES AND D.. ' FIND IT
1418   02140  5704          JMP I SEARCH
1419   02141  1346  BIGGER, TAD FIRST1       /FOUND IT
1420   02142  7650          SNA CLA
1421   02143  5337          JMP BAD
1422   02144  1261          TAD VPOINT       /GET ITS ADDRESS AND RETURN
1423   02145  5704          JMP I SEARCH
1424   02146  0002  FIRST1, 0
1425   02147  0000  VWANT,  0
1426   02150  0000
1427   02151  0000
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437   02152  0000  FLTR,   0                /FLOAT A SIGNED 12 BIT NUMBER
1438   02153  3045          DCA 45           /PUT IN LOATING AS MSB
1439   02154  3046          DCA 46           /CLEAR LSB
1440   02155  1363          TAD C13
1441   02156  3044          DCA 44           /EXPONENT TO PUT RADIX PT BETWEEN MSB.ISB
1442   02157  4407          FEINTER
1443   02160  7900          SWBYT            /NORMALIZE
1444   02161  0000          EXIT
1445   02162  5752          JMP I FLTR
1446   02163  0013  C13, 13
```

```
1447                    EJECT
1448   02171  1647
1449   02172  1236
1450   02173  1241
1451   02174  2206
1452   02175  1225
1453   02176  1222
1454   0217*  2277
1455          2200  *2200
1456                /CALCULATES FLOW BETWEEN VOLUMES POINTED AT BY VFHI,VFLO
1457
1458
1459
1460   02200  0000  FLO,0
1461   02201  7200          CLA
1462   02202  3044          DCA 44
1463   02203  3045          DCA 45;DCA 46
1464   02204  3046
1465   02205  1142          TAD VFHI
1466   02206  7650          SNA CLA
1467   02207  5600          JMP I FLO
1468   02210  1143          TAD VFLO
1469   02211  7450          SNA
1470   02212  5600          JMP I FLO
1471   02213  7041          CIA                 /GET NUMBER OF SAMPLES BETWEEN THE TWO
1472   02214  1142          TAD VFHI
1473   02215  4474          FLOAT
1474   02216  4407          FENTER
1475   02217  3274          FMUL FPT040         /*40 MSEC /SAMPLE
1476   02220  6144          FPUT FAC
1477   02221  0003          FEXIT
1478   02222  1543          TAD I VFLO
1479   02223  4536          FLTVOL
1480   02224  4471          BTPS                 GET VOLUME IN LITERS BTPS FOR VFLO
1481   02225  4407          FENTER
1482   02226  6241          FPUT FLTEMP
1483   02227  0009          FEXIT
1484   02230  7200          CLA
1485   02231  1542          TAD I VFHI
1486   02232  4536          FLTVOL              /AND VFHI
1487   02233  4471          BTPS
1488   02234  4407          FENTER
1489   02235  3241          FSUB FLTEMP         /TAKE DIFFERENCE AND
1490   02236  4144          FDIV FAC            /DIVIDE BY TIME FOR FLOW
1491   02237  0020          FEXIT
1492   02240  5640          JMP I FLO
1493   02241  0000  FLTEMP,0;0;0
1494   02242  0000
1495   02243  0000
```

```
1496                    EJECT
1497   02244  7200      /KEY, CLA
1498   02245  1106              TAD INPUT
1499   02246  7421              MQL
1500   02247  7501              MQA
1501   02250  1120              TAD MINUSS
1502   02251  7640              SZA CLA
1503   02252  5256              JMP .+4
1504   02253  7001              IAC
1505   02254  3153              DCA /SKEY
1506   02255  5501              JMP I /ITPT
1507   02256  7501              MQA
1508   02257  1147              TAD MINUSN
1509   02260  7640              SZA CLA
1510   02261  5265              JMP .+4
1511   02262  7001              IAC
1512   02263  3154              DCA /NKEY
1513   02264  5501              JMP I /ITPT
1514   02265  7501              MQA
1515   02266  1777'             TAD MINUSP
1516   02267  7640              SZA CLA
1517   02270  5501              JMP I /ITPT
1518   02271  7001              IAC
1519   02272  3155              DCA /PKEY
1520   02273  5501              JMP I /ITPT
1521   02274  7774   FPT040,7774
1522   02275  2436              2436
1523   02276  5606              5606
```

```
1524                    EJECT
1525
1526                    /ROUTINE TO SCAN VOLUME SAMPLED DATA AND FIND MAX
1527
1528
1529    02277   0000    MAXV, 0
1530    02300   7200            CLA
1531    02301   1135            TAD VSTART      /SET POINTERS AT START
1532    02302   3344            DCA VU
1533    02303   3345            DCA VM
1534    02304   1135            TAD VSTART
1535    02305   3346            DCA
1536    02306   1746            TAD I VMP
1537    02307   7100            CLL
1538    02310   7010            RAR
1539    02311   3345            DCA VM
1540
1541
1542
1543                    /XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
1544
1545
1546                    /DONT CHANGE THIS STUFF WITHOUT AT LEAST CHECKING
1547                    /VC COMPUTATION IN SBANAL
1548                    /SBANAL USES THIS STUFF
1549
1550
1551    02312   2344    NEWV,   ISZ VU          /GET NEXT
1552    02313   7200            CLA
1553    02314   1344            TAD VU
1554    02315   7041            CIA
1555    02316   1776'           TAD VUSE
1556    02317   7750            SPA SNA CLA     /HAVE WE LOOKED AT THEM ALL
1557    02320   3327            JMP LVMX        /YES
1558    02321   1744            TAD I VU        /NO GET NEXT
1559    02322   7100            CLL
1560    02323   7010            RAR             /SCALE RIGHT FOR SIGNED ARITHMETIC
1561    02324   3347            DCA VSV         /SAVE IT
1562    02325   1347            TAD VSV
1563    02326   7041            CIA
1564    02327   1345            TAD VM          /COMPARE IT TO OLD MAX
1565    02330   7770            SMA CLA
1566    02331   5312            JMP NEWV        /LESS THAN
1567    02332   1347            TAD VSV         /GREATER THAN
1568    02333   3345            DCA VM
1569    02334   1744            TAD VU          /STORE NUMBER AND POINTER AS NEW MAX
1570    02335   3346            DCA VMP
1571    02336   5312            JMP NEWV
1572    02337   7200    LVMX,   CLA
1573    02340   1346            TAD VMP
1574    02341   3776'           DCA VUSE
1575    02342   1346            TAD VMP
1576    02343   5677            JMP I MAXV
1577    02344   0000    VU, 0
1578    02345   0000    VM, 0
```

```
1579   02346  0000  VMP.0
1580   02347  0000  VSV.0
```

```
1581                    /START OF WASHOUT ROUTINE     CALLED BY CTRL-W
1582                    /SUBPROGRAMS
1583                    /1. INTERRUPT SERVICE-SAMPLES 02,N2 PAIRS, STICKS DATA AWAY
1584                    /       ALSO ON SECOND BREATH (FIRST AFTER INHALING O2,SE..ES ALL DATA PAIRS
1585                    /2.  IDLE LOOP-AS SAMPLES COME IN, KEEPS TRACK OF MAX N2 FRACTION FOR
1586                    /       CURRENT BREATH, DISPLAYS IT ON W/M, ACCUMULATES TOTAL NITROGEN EXHALED.
1587                    /3. SBANAL-ANALYZES SB WAVEFORM FOR NO..OPE,CLOSING VOLUME
1588                    /4. CVS-CALCULATES CLOSING VOLUME
1589                    /5  STOREW-COMPUTES RV
1590                    /6. FPLOT-XY PLOT OF SINGLE BREATH
1591
1592
1593
1594
1595
1596
1597
1598    02350   7200    WASHS,CLA                   /N2 WASHOUT
1599    02351   4775'           JMS INTSU           /SETUP FLAGS FRO INTRPT ROUT
1600    02352   1365            TAD WADAIO
1601    02353   3111            DCA ADAIO           /AIO RCVRS
1602    02354   1366            TAD WKEY
1603    02355   3103            DCA KEYIN
1604    02356   4774'           JMS LOOPSU          /SET UP MORE CONSTANTS
1605    02357   6537            SAMPLE
1606    02360   1132            TAD VOLUME
1607    02361   1114            TAD DELAY
1608    02362   6537            SAMPLE
1609    02363   6001            ION
1610    02364   5773'           JMP WLOOP
1611
1612
1613
1614
1615    02365   2600    WADAIO,WINT
1616    02366   0244    WKEY,1KEY
1617    02367   2400
1618    02370   3035
1619    02371   3000
1620    02372   1647
1621    02373   1520
1622            2406    $2403
1623    02374   7200    WLOOP,CLA
1624    02375   1155            TAD NSKEY
1625    02376   7040            SZA CLA  THROUGH
1626    02377     70            BEGIN
1627    02400    165            TAD NSTART
1628    02401   7041            CIA
1629    02402   1166            TAD NSTORE          /IS THERE A SAMPLE PAIR T  .E ANALYZED
1630    02403   7740            SZA CMA CLA
1631    02404   5221            JMP ..+15           /YES
1632    02405   1367            TAD NFIN            /NO. IS TEST COMPLETE
1633    02406   7450            SNA
1634    02407   5200            JMP WLOOP           /NO
1635    02410   6002            IOF                 /YES
```

```
1636  02415  4777'          JMS SBANAL      /ANALYZE SB WAVEFORM
1637  02416  4776'          JMS STOREW      /COMPUTE RV
1638  02417  4775'          JMS FPLOT       /PLOT SB WAVEFORM
1639  02420  5470           BEGIN
1640
1641
1642
1643
1644
1645  02421  7200  WCLC.    CLA
1646  02422  1165           TAD NSTART      /VOLUME,N2 PAIRS ARE STORED IN A QUEUE
1647  02423  3372           DCA NUSEP       /TO BE USED BY WCLC
1648  02424  1167           TAD VFIRST      /QUEUE STARTS AT NSTART,VFIRST
1649  02425  3373           DCA VUSEP.
1650  02426  6002           IOF
1651  02427  1772           TAD I NUSEP
1652  02430  3371           DCA NNUSE
1653  02431  1773           TAD I VUSEP
1654  02432  3370           DCA VNUSE
1655  02433  1165           TAD NSTART
1656  02434  7041           CIA
1657  02435  1163           TAD NSTORE
1658  02436  7041           CIA
1659  02437  3365           DCA NC
1660  02440  7240           CLA CMA
1661  02441  1165           TAD NSTART
1662  02442  3011           DCA 11
1663  02443  1165           TAD NSTART
1664  02444  3010           DCA 10
1665  02445  7240           CLA CMA
1666  02446  1167           TAD VFIRST
1667  02447  3013           DCA 13
1668  02450  1167           TAD VFIRST
1669  02451  3012           DCA 12
1670  02452  1410           TAD I 10
1671  02453  3411           DCA I 11
1672  02454  1412           TAD I 12
1673  02455  3413           DCA I 13
1674  02456  2365           ISZ NC
1675  02457  5252           JMP .-5
1676                                        /THE ABOVE WERE
1677                                        /TO MOVE THE DATA DOWN THE LIST
1678  02460  7240           CLA CMA
1679  02461  1163           TAD NSTORE      /DECREMENT NSTORE,VSTORE SO INTERRUPT SERVICE PUTS
1680  02462  3163           DCA NSTORE      /THEN IN RIGHT PLACE
1681  02463  7240           CLA CMA
1682  02464  1162           TAD VSTORE
1683  02465  3162           DCA VSTORE
1684  02466  6001           ION
1685  02467  1370           TAD WNUSE       /DID SPIRO SERVICE ROUTINE RETURN 0 VOL
1686  02470  7450           SNA
1687  02471  5774'          JMP WZERO       /YES, WAS DUMPING OR NO BREATH
1688  02472  4556           FLTVOL          /NO. GET VOLUME TO BTPS LITERS
1689  02473  4471           BTPS
1690  02474  4407           FILTER
```

```
1691   02475  6144          FPUT FKAC       /SAVE
1692   02476  2343          FSUB LSTVOL     /SUBTRACT LAST VOLUME
1693   02477  6346          FPUT VOLDIF     /HOW MUCH EXHALED LAST 40 MSEC
1694   02500  1354          FADD VENT       /SUMMED DEEP WASHOUT
1695   02501  6354          FPUT VENT
1696   02502  5144          FGET FKAC
1697   02503  6343          FPUT LSTVOL
1698   02504  0000          FEXIT
1699   02505  7240          CLA CMA
1700   02506  3364          DCA BREATH      /EXHALATION FLAG
1701   02507  1371          TAD WNUSE
1702   02510  4465          UNPACK
1703   02511  4407          FENTER
1704   02512  3124          FMUL N2FR10     /GET PHASED N2 SAMPLE
1705   02513  6144          FPUT FKAC
1706   02514  3346          FMUL VOLDIF     /N2 VOL THIS TIME FRAME =FN2*DELTA V
1707   02515  1351          FADD N2SUM      /SUM OVER WASHOUT
1708   02516  6351          FPUT N2SUM
1709   02517  5144          FGET FKAC
1710   02520  2361          FSUB N2MAX      /CHECK N2 CONCENTRATION
1711   02521  0000          FEXIT
1712   02522  1045          TAD 45          /NEED MAX FN2 FOR EACH BREATH
1713   02523  7510          SPA
1714   02524  5200          JMP WLOOP
1715   02525  4407          FENTER
1716   02526  5144          FGET FKAC
1717   02527  6361          FPUT N2MAX      /IF WAS HIGHER  SAVE IT
1718   02530  0000          FEXIT
1719   02531  4576          DACN2           /OUTPUT ON METER
1720   02532  7200          CLA
1721   02533  1154          TAD WNKEY       /FLAG SET NONZERO ON FIRST EOB
1722   02534  7440          SZA
1723   02535  5200          JMP WLOOP
1724   02536  4407          FENTER
1725   02537  5361          FGET N2MAX
1726   02540  6156          FPUT ATIDAL     /MAX N2, FIRST EXHALATION IS AMBIENT N2 FRACTION
1727   02541  0000          FEXIT           /USED IN WASHOUT EQUATION
1728   02542  5200          JMP WLOOP
1729   02543  0000  LSTVOL,0;0;0
1730   02544  0000
1731   02545  0000
1732   02546  0000  VOLDIF,0;0;0
1733   02547  0000
1734   02550  0000
1735   02551  0000  N2SUM,0;0;0
1736   02552  0000
1737   02553  0000
1738   02554  0000  VENT,0;0;0
1739   02555  0000
1740   02556  0000
1741   02557  0000  ET,0;0
1742   02560  0000
1743   02561  0000  N2MAX,0;0;0
1744   02562  0000
1745   02563  0000
```

```
1746   02564  0000  BREATH,0
1747   02565  0000  WC,0
1748   02566  0000  WSTOP,0
1749   02567  0000  WFIN,0
1750   02570  0000  WMUSE,0
1751   02571  0000  WNUSE,0
1752   02572  0000  NUSEP,0
1753   02573  0000  MUSEP,0
```

```
1754   02574  3062
1755   02575  3400
1756   02576  3200
1757   02577  3250
1758          2600          PAGE
1759   02600  7200  WINT,CLA
1760   02601  1344          TAD LSTCH       /WHICH VOL OR N2
1761   02602  7640          SZA CLA
1762   02603  5240          JMP MSINT       /LAST CHANNEL WAS NITROGEN
1763   02604  7040          CMA
1764   02605  3344          DCA LSTCH       /LAST CHANNEL WAS VOLUME
1765   02606  6537          SAMPLE          /SAMPLE N2. GET VOLUME DATA
1766   02607  7421          MQL
1767   02610  1115          TAD N2SAM
1768   02611  6537          SAMPLE
1769   02612  4467          SPIRO           /USE FOR SPIRO CONTROL
1770   02613  5217          JMP TOOLO       /NO DATA THERE
1771   02614  5231          JMP EOB         /END OF BREATH
1772   02615  3765  SLEAF,DCA I INSERT     /SAVE VOLUME SAMPLE AT END OF QUEUE
1773   02616  5581          JMP I XITPT     /RETURN FROM INTERRUPT
1774
1775
1776
1777   02617  7200  TOOLO,CLA
1778   02620  1154          TAD VNKEY       /VNKEY IS FLAG   0-NO BREATHS
1779                                        /1   WAITING FOR DUMP AFTER FIRST EXHALATION
1780                                        /-1    THROUGH FIRST BREATH  AND RESET POINTERS
1781   02621  7750          SPA SNA CLA
1782   02622  5215          JMP SLEAF
1783   02623  4777          JMS INTSU       /ONLY GETS HERE ONCE. THE FIRST ZERO VOL AFTER
1784                                        /THE FIRST EXHALATION
1785   02624  7240          CLA CMA         /RESETS SUMS AND POINTERS AFTER AMBIENT EXHALATION
1786   02625  3344          DCA LSTCH
1787   02626  7240          CLA CMA
1788   02627  3154          DCA VNKEY
1789   02630  5215          JMP SLEAF
1790
1791
1792
1793
1794   02631  7200  EOB,    CLA
1795   02632  1154          TAD VNKEY       /FIRST EOB?   THIS ONE WHERE AMBIENT GAS EXHALED
1796   02633  7640          SZA CLA
1797   02634  5215          JMP SLEAF       /NO
1798   02635  7201          CLA IAC         /YES  SET FLAG SAYING ONE EXHALATION
1799   02636  3154          DCA VNKEY
1800   02637  5215          JMP SLEAF
1801
1802
1803
1804
1805
1806                /COMES HERE WHEN SAMPLED DATA TO GET IS NITROGEN
1807   02640  3344  MSINT,DCA LSTCH
1808   02641  6537          SAMPLE
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```
1809   02642  7421          MQL
1810   02643  1132          TAD VOLUME
1811   02644  1114          TAD DELAY       /SAMPLE VOLUME AT NEXT 40 MSEC TICK
1812   02645  6537          SAMPLE          /ALSO GET NITROGEN DATA
1813   02646  4515          CONVRT          /PACK INTO ONE WORD
1814   02647  3345          DCA NB          /SAVE IT
1815   02650  1164          TAD NLAST
1816   02651  7041          CIA             /IS THERE ROOM IN THE QUEUE
1817   02652  1163          TAD NSTORE
1818   02653  7700          SMA CLA
1819   02654  5776          JMP ABORT       /NO
1820   02655  1345          TAD NB
1821   02656  3563          DCA I NSTORE    /PUT N2 AT END
1822   02657  1346          TAD VOLBFR      /GET VOLUME FROM FIRST IN, LAST OUT STACK
1823   02660  3562          DCA I VSTORE    /PUT IN QUEUE.  THIS VOLUME WAS DELAYED BY
1824                                        /THE FILO STACK TO PHASE IT WITH N2 SIGNAL
1825   02661  1366          TAD NLAG        /NLAG-THE LENGTH OF THE STACK
1826   02662  7041          CIA
1827   02663  1365          TAD INSERT      /WHERE THE BUFFER WAS STUCK
1828   02664  3010          DCA I0
1829   02665  7040          CMA             /SET AUTOINDEX TO MOVE BUFFER UP
1830   02666  1010          TAD I0
1831   02667  3011          DCA I1
1832   02670  1366          TAD NLAG        /HOW MANY TIMES THROUGH LOOP
1833   02671  7041          CIA
1834   02672  3345          DCA NB
1835   02673  1410          TAD I I0        /MOVE THEM
1836   02674  3411          DCA I I1
1837   02675  2345          ISZ NB
1838   02676  5273          JMP .-3
1839   02677  1343          TAD SB          /IS THIS THE FIRST BREATH AFTER O2 INHALATION
1840   02700  7540          SMA SZA
1841   02701  5334          JMP NOSB        /NO,  ALREADY DONE
1842   02702  7700          SMA CLA
1843   02703  5329          JMP NOSBST                      /0-NO START
1844   02704  1562  WST,    TAD I VSTORE    /VOLUME ERROR
1845   02705  7650          SNA CLA
1846   02706  5323          JMP NFINIS      /YES.  FINISHED SB ACQUISITION
1847   02707  1341          TAD NNETR       /GET N2 POINTER
1848   02710  7041          CIA
1849   02711  1170          TAD NWLST
1850   02712  7750          SPA SNA CLA     /ROOM FOR ONE MORE PAIR???
1851   02713  5323          JMP NFINIS      /NO.  END IT
1852   02714  2341          ISZ NNSTR       /INCREMENT POINTERS
1853   02715  2342          ISZ NWSTR
1854   02716  1562          TAD I VSTORE    /GET PHASED N2,VOL PAIRS AND STORE
1855   02717  3743          DCA I WWSTR
1856   02720  1563          TAD I NSTORE
1857   02721  3741          DCA I WNSTR
1858   02722  5334          JMP NOSB        /EXIT
1859   02723  7201  NFINIS, CLA IAC         /THROUGH SB, SET FLAG
1860   02724  3343          DCA SB
1861   02725  5334          JMP NOSB
1862   02726  1562  NOSBST, TAD I VSTORE    /THIS LOOP DOESNT LET SB START UNTIL BREATH DOES
1863   02727  7650          SNA CLA
```

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1864   02730  5334          JMP NOSB
1865   02731  7040          CMA
1866   02732  3343          DCA SB
1867   02733  5304          JMP WST
1868
1869
1870
1871   02734  7200  NOSB,   CLA              /EXIT
1872   02735  2162          ISZ VSTORE
1873   02736  2163          ISZ NSTORE       /INCREMENT POINTERS
1874   02737  4775'         JMS TIMINC       /INCREMENT TIME FOR END OF TEST CHECK
1875   02740  5501          JMP I XITPT
1876
1877
1878
1879
1880
1881
1882   02741  0000  WNSTR,0
1883   02742  0000  WVSTR,0
1884   02743  0020  SB,0
1885   02744  0000  LSTCH,0
1886   02745  0000  NB,0
1887   02746  0000  VOLBFR,0;0;0
1888   02747  0000
1889   02750  0000
1890   02751  0000  0;0;0
1891   02752  0000
1892   02753  0000
1893   02754  0000  0;0;0
1894   02755  0000
1895   02756  0000
1896   02757  0000  0;0;0
1897   02760  0000
1898   02761  0000
1899   02762  0000  0;0;0
1900   02763  0000
1901   02764  0000
1902   02765  2766  INSERT,VOLBFR+14              /THESE 2 CTRL DELAY
1903   02766  0014  NLAG,14
1904   02767  0504  L15,    TEXT 'CC,TLC   '
1905   02770  3704
1906   02771  1403
1907   02772  4042
1908   02773  4600
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```
1909    02775  3134
1910    02776  3527
1911    02777  3600
1912           3000  *3000
1913    03000  0000  INTSU,0
1914    03001  1171          TAD I WNSTRP
1915    03002  3777          DCA WNSTR       /SET UP SINGLE BREATH POINTERS
1916    03003  1172          TAD IWNSTRP
1917    03004  3776          DCA WWSTR
1918    03005  1167          TAD MFIRST      /SET UP WASHOUT POINTERS
1919    03006  3161          DCA MSTORE
1920    03007  1166          TAD NSTART
1921    03010  3163          DCA NSTORE
1922    03011  1231          TAD NUMZRO
1923    03012  3230          DCA NBI         /CLEAR DATA AREAS
1924    03013  1233          TAD STZRO
1925    03014  3010          DCA I 10
1926    03015  2412          ISZ I 10
1927    03016  5214          JMP .-2
1928    03017  7200          CLA
1929    03020  1635          TAD N25UMP
1930    03021  3012          DCA 12
1931    03022  1234          TAD N2SCT
1932    03023  3232          DCA NBI
1933    03024  2410          ISZ I 10
1934    03025  3230          DCA NBI
1935    03026  5224          JMP .-2
1936    03027  5600          JMP I INTSU
1937    03030  0002  NB1,0
1938    03031  7751  NUMZRO,-25
1939    03032  2742  STZRO,SB-1
1940    03033  0555  N25UMP,N25UM-1
1941    03034  7770  N2SCT,-10
1942
1943
1944
1945
1946    03035  3000  LOOPSU,0
1947    03036  7200          CLA
1948    03037  1777          TAD UP
1949    03040  4000          JMS                     /RAISE PEN
1950    03041  7200          CLA                     /PUT PEN AT ORIGIN
1951    03042  4000          JMS
1952    03043  7001          IAC
1953    03044  4000          JMS
1954    03045  1166          TAD TST
1955    03046  7041          CIA
1956    03047  1636          TAD SAM
1957    03050  7041          CIA
1958    03051  3011          DCA 11
1959    03052  2411          ISZ I 10
1960    03053  2211          ISZ 11
1961    03054  5253          JMP .-1
1962    03055  7200          CLA
1963    03056  7100          CLL RAR
```

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1964   03056  5635          JMP I LOOPSU
1965   03057  2542  ZST,LSTVOL-1
1966   03060  7753  INM,-25
1967   03061  0000  ZC,0
```

C.2

```
1968                    EJECT
1969
1970
1971                    /THIS ROUTINE ENTERED AFTER A ZERO VOLUME RETRIEVED
1972
1973
1974
1975
1976    03062   7200    WZERO,CLA
1977    03063   1774'           TAD BREATH
1978    03064   7650            SNA CLA             /FIRST ZERO RETURN AFTER A BREATH (EOB)?
1979    03065   5773'           JMP WLOOP           /YES   EXIT
1980    03066   3774'           DCA BREATH          /NO CONTINUE
1981    03067   1772'           TAD ET              /HAS ENOUGH TIME PASSED TO END WASHOUT
1982    03070   7650            SNA CLA             /(4096*40 MSEC)
1983    03071   5310            JMP ZLEAVE          /NO
1984    03072   4407            FENTER
1985    03073   5771'           FGET N2MAX          /YES TIME SAYS OK TO END
1986    03074   2331            FSUB PT02           /WAS MAX N2 IN THAT BREATH .LT.0.02
1987    03075   0000            FEXIT
1988    03076   7200            CLA
1989    03077   1045            TAD 45
1990    03100   7700            SMA CLA
1991    03101   5310            JMP ZLEAVE          /NO
1992    03102   1330            TAD ZFRS            /YES IT WAS.      IT THE FIRST ONE.
1993    03103   7640            SZA CLA
1994    03104   5325            JMP ZFIN    .       /NO IT WAS NOT.  ZFIN WAS SET BY THE PREVIOUS BREATH
1995    03105   7001            IAC
1996    03106   3330            DCA ZFRS            /IT WAS THE FIRST OF TWO IN A ROW SO SET ZFRS
1997    03107   5313            JMP ZLEAVE+3        /SKIP THE PART THAT RESETS ZFIN
1998    03110   7200    ZLEAVE,CLA
1999    03111   3330            DCA ZFRS            /RESET ZFIN TO ASSURE TWO BREATHS IN A ROW
2000    03112   3770'           DCA LSTVOL
2001    03113   3767'           DCA LSTVOL+1        /RESET LSTVOL TO 0. SO NEXT SUBTRACTION FOR
2002    03114   3766'           DCA LSTVOL+2        /DELTA V IN 40 MSEC DOES NOT GIVE A NEGATIVE
2003    03115   3771'           DCA N2MAX
2004    03116   3765'           DCA N2MAX+1         /RESET N2MAX FOR NEXT BREATH
2005    03117   3764'           DCA N2MAX+2
2006    03120   4407            FENTER
2007    03121   5763'           FGET VENT
2008    03122   2762'           FSUB PT2            /SUBTRACT .2 FROM VENTILATION AT END OF BREATH
2009    03123   0000            FEXIT               /TO GIVE ALVEOLAR VENTILATION (.2 FUDGE FOR DEAD SPACE
2010    03124   3773'           JMP WLOOP
2011
2012
2013
2014
2015    03125   7240    ZFIN,CLA CMA
2016    03126   3761'           DCA WFIN            /END OF WASHOUT FLAG
2017    03127   5773'           JMP WLOOP
2018    03130   0000    ZFRS,0
2019    03131   7773    PT02,7773;2436;5606         /0.02
2020    03132   2436
2021    03133   5606
```

```
2022                    EJECT
2023
2024                    /ROUTINE TO KEEP TRACK OF TIME OF WASHOUT
2025
2026
2027
2028    03134   0000    TIMINC, 0
2029    03135   1154            TAD WNKEY
2030    03136   7650            SNA CLA             /WASHOUT STARTED?
2031    03137   5734            JMP I TIMINC        /NO.  EXIT
2032    03140   2760'           ISZ ET+1            /YES  BUMP 40 MSEC COUNTER
2033    03141   7410            SKP
2034    03142   2772'           ISZ ET              /THIS ONLY HAPPENS WHEN ET+1 OVERFLOWS
2035    03143   5734            JMP I TIMINC
2036
2037
2038
2039                    /FLOAT A POSITIVE 12 BIT NUMBER
2040                    /TO A FRACTION OF 4096
2041
2042
2043
2044    03144   0000    WD2FLT, 0
2045    03145   7100            CLL
2046    03146   7010            RAR                 /SHIFT RIGHT
2047    03147   3045            DCA 45              /PUT IN MSB
2048    03150   7010            RAR
2049    03151   3046            DCA 46              /PUT THE SHIFTED OFF BIT INTO LSB
2050    03152   3044            DCA 44              /ZERO EXPONENT AND
2051    03153   4407            FENTER
2052    03154   7600            FNORM               /NORMALIZE
2053    03155   0000            FEXIT
2054    03156   5744            JMP I WD2FLT
```

```
2055                    EJECT
2056    03160   2560
2057    03161   2567
2058    03162   2076
2059    03163   2554
2060    03164   2563
2061    03165   2562
2062    03166   2545
2063    03167   2544
2064    03170   2543
2065    03171   2561
2066    03172   2557
2067    03173   2400
2068    03174   2564
2069    03175   3441
2070    03176   2742
2071    03177   2741
2072            3200    *3200
2073
2074
2075                    /ROUTINE TO COMPUTE WASHOUT RESULTS FTER TEST
2076    03200   0000    STOREW, 0
2077    03201   7200            CLA
2078    03202   1777'           TAD ET
2079    03203   3045            DCA 45          /((ET*4096)+(ET+1))*.040=TIME OF WASHOUT IN SEC
2080    03204   1776'           TAD ET+1
2081    03205   3046            DCA 46
2082    03206   1247            TAD CK27
2083    03207   3044            DCA 44
2084    03210   4407            FENTER
2085    03211   7020            FNORM
2086    03212   3244            FMUL CONST      /CONST=.0312*.040/60
2087    03213   6144            FPUT FKAC       /FUDGE FOR BODY N2 WASHED OUT BASED ON TIME OF WO
2088    03214   5775'           FGET N2SUM
2089    03215   2144            FSUB FKAC       /SUBTRACT THIS FROM ACCUMULATED EXHALED N2
2090    03216   6144            FPUT FKAC
2091    03217   5156            FGET NTIDAL     /GET FN2 OF FIRST EXHALATION (AMBIENT)
2092    03220   2774'           FSUB N2MAX      /SUBTRACT FN2 OF LAST EXHALATION
2093    03221   6121            FPUT EXP
2094    03222   5144            FGET FKAC       /DIVIDE CORRECTED TOTAL EXHALED N2
2095    03223   4121            FDIV EXP        /BY THIS DIFFERENCE IN CONCENTRATIONS
2096    03224   2773'           FSUB FPT2       /SUBTACT A FUDGE FOR DEAD SPACE
2097    03225   6772'           FPUT RV         /AND WE NOW HAVE FOUND RV
2098    03226   5771'           FGET VENT
2099    03227   4772'           FDIV RV
2100    03230   6770'           FPUT VA2RV      /VA2V=RV/VENTILATION DURING WASHOUT
2101    03231   5767'           FGET VC
2102    03232   0000            FEXIT
2103    03233   7200            CLA             /GOOD VC?
2104    03234   1045            TAD 45
2105    03235   7650            SNA CLA
2106    03236   5600            JMP I STOREW
2107    03237   4407            FENTER
2108    03240   1772'           FADD RV
2109    03241   6766'           FPUT TLC        /YES, TLC=RV+VC
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2110   03242  0000          FEXIT
2111   03243  5600          JMP I STOREW
2112
2113   03244  7761  CONST,7761:2563:6725    /0.0000208
2114   03245  2563
2115   03246  6725
2116   03247  0027  CK27,27
```

```
2117                    /
2118                    /ROUTINE TO ANALYZE FIRST EXHALATION AFTER BREATHING 100% O2
2119
2120
2121
2122    03250   0000    SBANAL,0
2123    03251   7200            CLA
2124    03252   1765'           TAD W%STR
2125    03253   3764'           DCA %USE        /USE FEV ROUTINES TO FIND MAX VOLUME
2126    03254   4763'           JMS MAXV        /OF THIS EXHALATION
2127    03255   3341            DCA INDRC
2128    03256   1741            TAD I INDRC
2129    03257   4536            FLTVOL          /GET IT. CONVERT TO LITERS BTPS
2130    03260   4471            BTPS
2131    03261   4407            FENTER
2132    03262   6767'           FPUT VC         /STORE AS VC
2133    03263   5762'           FGET FPT75      /USE FEV ROUTINES TO FIND VOLUME
2134    03264   0000            FEXIT           /SAMPLES CORRESPONDING TO 0.75,
2135    03265   4761'           JMS SEARCH      /1.25  FOR N2SLOPE
2136    03266   3337            DCA PT750
2137    03267   4407            FENTER
2138    03270   5762'           FGET FPT75
2139    03271   1760'           FADD FPT25
2140    03272   1760'           FADD FPT25
2141    03273   0000            FEXIT
2142    03274   4761'           JMS SEARCH
2143    03275   3340            DCA PT1250      /STORE THESE ADDRESSES IN PT750,PT1250
2144    03276   7201            CLA IAC
2145    03277   1172            TAD W%STRP      /FIND DISPLACEMENT FROM START OF ARRAY FOR EACH
2146    03300   7041            CIA
2147    03301   1337            TAD PT750
2148    03302   7510            SPA
2149    03303   7041            CIA
2150    03304   1171            TAD WNSTRP      /USE THESE DISPLACEMENTS FROM START OF N2
2151    03305   3337            DCA PT750       /ARRAY TO GET CORRESPONDING N2 SAMPLES ADDRESSES
2152    03306   7201            CLA IAC
2153    03307   1172            TAD W%STRP
2154    03310   7041            CIA
2155    03311   1340            TAD PT1250      /FOR BOTH VALUES
2156    03312   7510            SPA
2157    03313   7041            CIA
2158    03314   1171            TAD WNSTRP
2159    03315   3340            DCA PT1250      /STORE IN PT750,PT1250
2160    03316   1737            TAD I PT750     /GOING INDIRECTLY, GET THE TWO VALUES
2161    03317   4465            UNPACK
2162    03320   4407            FENTER
2163    03321   3124            FMUL N2PR10     /CONVERT TO FRACTIONS
2164    03322   6144            FPUT FKAC
2165    03323   0000            FEXIT
2166    03324   7200            CLA
2167    03325   1740            TAD I PT1250
2168    03326   4465            UNPACK
2169    03327   4407            FENTER
2170    03330   3124            FMUL N2PR10
2171    03331   2144            FSUB FKAC       /TAKE DIFFERENCE
```

```
/PULMONARY FUNCTION TEST                    PAL8-VSB  11/21/74  PAGE 11-1

2172   03332  3173          FMUL F100        /MUL BY 100 TO PUT IN PERCENT
2173   03333  6757'         FPUT N2DELT      /STORE AS N2DELT
2174   03334  0000          FEXIT
2175   03335  4756'         JMS CVS          /GO COMPUTE CLOSING VOLUME
2176   03336  5650          JMP I SBANAL
2177   03337  0000  PT750.0
2178   03340  0000  PT1250.0
2179   03341  0000  INDRC,0
2180   03342  7476  L1,TEXT '<>>>>>R/
2181   03343  7676
2182   03344  7676
2183   03345  2226
2184   03346  4040
2185   03347  4040
2186   03350  4040
2187   03351  4000
```

```
2188                        EJECT
2189    03356  3600
2190    03357  1203
2191    03360  2070
2192    03361  2104
2193    03362  2073
2194    03363  2277
2195    03364  1647
2196    03365  2742
2197    03366  1217
2198    03367  1214
2199    03370  1211
2200    03371  2554
2201    03372  1200
2202    03373  2076
2203    03374  2561
2204    03375  2551
2205    03376  2560
2206    03377  2557
2207            3400  *3400
2208
2209
2210                  /ROUTINE TO PLOT SINGLE BREATH ON XY PLOTTER
2211
2212
2213    03400  0000  FPLOT,0
2214    03401  7200          CLA
2215    03402  6065          DAC              /PEN TO ORIGIN
2216    03403  7001          IAC
2217    03404  6065          DAC
2218    03405  6002          IOF
2219    03406  1171          TAD #NSTRP
2220    03407  3010          DCA 10           /SET POINTERS TO START OF VOL,FN2 ARRAYS
2221    03410  1172          TAD I#STR2
2222    03411  3011          DCA 11
2223    03412  1010          TAD I0
2224    03413  7041          CIA
2225    03414  1777          TAD #NSTR        /GET NUMBER OF POINTS TO PLOT
2226    03415  7041          CIA
2227    03416  3121          DCA EXP
2228    03417  1410          TAD I 10         /GET FIRST PAIR
2229    03420  7421          MQL
2230    03421  1411          TAD I 11         /VOLUME IN AC, FN2 SAMPLE IN MQ
2231    03422  2121          ISZ EXP          /BUMP COUNTER
2232    03423  4263          JMS PLOT         /GO PLOT FIRST
2233    03424  4243  MSWT1,JMS I#SWAIT        /WAIT 30 MSEC
2234    03425  1242          TAD DOWN
2235    03426  6075          CTRL             /LOWER PEN
2236    03427  1410          TAD I 10
2237    03430  7421          MQL
2238    03431  1411          TAD I 11         /GET NEXT PAIR
2239    03432  4263          JMS PLOT         /GO PLOT
2240    03433  2121          ISZ EXP          /THROUGH?
2241    03434  5234          JUP #SWT1        /NO.  GO TO START OF LOOP AND WAIT
2242    03435  1241          TAD UP           /YES  RAISE PEN AND EXIT
```

```
2243   03430  6075          CTRL
2244   03437  6001          ION
2245   03440  5600          JMP I FPLOT
2246   03441  7771  UP,7771
2247   03442  0001  DOWN,0001
```

```
2248                    EJECT
2249    03443   0000    MSWAIT,0
2250    03444   7201            CLA IAC         /LOOP TO DELAY 80 MSEC
2251    03445   7040            CMA
2252    03446   3262            DCA MSWA        /COUNTER TO -2 >
2253
2254
2255                    MSWTR,
2256    03447   6533            6533
2257    03450   5247            JMP .-1         /WAIT FOR TWO AD CONVERSIONS AT 40 MSEC EA
2258    03451   6537            SAMPLE
2259    03452   7200            CLA
2260    03453   1132            TAD VOLUME
2261    03454   1114            TAD DELAY
2262    03455   6537            SAMPLE
2263    03456   7200            CLA
2264    03457   2262            ISZ MSWA
2265    03460   5247            JMP MSWTR
2266    03461   5643            JMP I MSWAIT
2267
2268    03462   0000    MSWA,0
2269
2270
2271
2272
2273
2274                    /ROUTINE TO SCALE VOL,N2 PAIRS AND SEND TO PLOTTER
2275
2276
2277    03463   0000    PLOT,0
2278    03464   3122            DCA MANTIS      /SAVE VOL SAMPLE
2279    03465   7501            MQA
2280    03466   4465            UNPACK          /GET N2 SAMPLE
2281    03467   4407            FENTER
2282    03470   3124            FMUL N2FR10     /CONVERT TO FRACTION  RANGE 0-1
2283    03471   3137            FMUL F2047      /MUL TO GET FRACTION OF FULL SCALE
2284    03472   0000            FEXIT
2285    03473   2044            ISZ 44          /INCREMENTING EXPONENT MUL BY 2, GIVING RANGE OF 0-.5
2286    03474   4472            FIX             /MAKE AN INTEGER>>>
2287    03475   7100            CLL
2288    03476   7004            RAL             /WILL BE POSITIVE. MAKE UNSIGNED 12 BIT #
2289    03477   0116            AND K7774       /SET CHANNEL 0
2290    03500   3323            DCA N2HOLD      /SAVE
2291    03501   1122            TAD MANTIS
2292    03502   4536            FLTVOL
2293    03503   4471            BTPS            /VOL TO BTPS LITERS
2294    03504   4407            FENTER
2295    03505   4524            FDIV F7         /DIVIDE VOL BY 7, GIVING FRAC OF FULL SCALE
2296    03506   3137            FMUL F2047      /FRAC OF FULL SCALE COUNTS
2297    03507   0000            FEXIT
2298    03510   4472            FIX
2299    03511   7100            CLL
2300    03512   7004            RAL             /POS 12 BIT INTEGER
2301    03513   0116            AND K7774
2302    03514   7001            IAC             /SET CHANNEL 1
```

```
2303   03515  6065          DAC             /SEND IT
2304   03516  7200          CLA
2305   03517  1323          TAD N2HOLD
2306   03520  6065          DAC             /SENT N2 VALUE
2307   03521  7200          CLA
2308   03522  5663          JMP I PLOT      /EXIT
2309   03523  0000  N2HOLD,0
2310   03524  0003  F7,3:3400:0000
2311   03525  3400
2312   03526  0000
2313
2314
2315
2316
2317
2318   03527  7200  ABORT,CLA
2319   03530  1333          TAD ABTMPT
2320   03531  4512          OUTPUT
2321   03532  5470          BEGIN
2322   03533  3534  ABTMPT,ABTMG
2323   03534  2324  ABTMG,TEXT 'STORAGE OVERRUN ABORT<>'
2324   03535  1722
2325   03536  0107
2326   03537  0540
2327   03540  1726
2328   03541  0522
2329   03542  2235
2330   03543  1640
2331   03544  0102
2332   03545  1722
2333   03546  2474
2334   03547  7600
2335   03550  0000  PRTBFR,0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0
2336   03551  0002
2337   03552  0000
2338   03553  0006
2339   03554  0000
2340   03555  0000
2341   03556  0000
2342   03557  0006
2343   03560  0000
2344   03561  0006
2345   03562  0000
2346   03563  0000
2347   03564  0300
2348   03565  0000
2349   03566  0000
2350   03567  0000
2351   03570  0000
2352   03571  0000
```

```
2353   03577  2741
2354          3600  *3600
2355
2356
2357                 /ROUTINE TO COMPUTE CLOSING VOLUMES FROM SINGLE BREATH
2358
2359
2360
2361   03600  0000  CVS,0
2362   03601  4407          FENTER
2363   03602  5777'         FGET VC
2364   03603  2363          FSUB F1PTS      /USING FEV ROUTINES FIND POINT IN VOLUME ARRAY
2365   03604  0000          FEXIT           /CORRESPONDING TO (VC-1.5) LITERS AND
2366   03605  4776'         JMS SEARCH      /(VC-2.5) LITERS
2367   03606  3351          DCA LSEND       /THESE VALUES WOULD NEED TO BE ADJUSTED
2368   03607  4407          FENTER          /DOWNWARD IF THE ROUTINE WERE TO BE USED WITH
2369   03610  5777'         FGET VC         /SUBJECTS WITH LARGE CV
2370   03611  2366          FSUB F2PTS
2371   03612  0000          FEXIT
2372   03613  4776'         JMS SEARCH
2373   03614  3352          DCA LSSTRT
2374   03615  1752          TAD LSSTRT      /GET LEAST SQUARES START AND FINISH ADDRESS
2375   03616  3353          DCA LSSTR1
2376   03617  4775'         JMS CLSUM       /CLEAR LEAST SQUARES SUMS
2377   03620  1352          TAD LSSTRT
2378   03621  1350          TAD LSDEL
2379   03622  3354          DCA FSSTRT
2380   03623  1754  CVLOOP, TAD I FSSTRT
2381   03624  7421          MQL             /INDEX THROUGH ARRAYS GETTING N2,VOL PAIRS
2382   03625  1752          TAD I LSSTRT
2383   03626  4774'         JMS SUMS        /ROUTINE TO DO SUMS FOR LINEAR REGRESSION
2384   03627  2354          ISZ FSSTRT
2385   03630  2352          ISZ LSSTRT
2386   03631  1352          TAD LSSTRT
2387   03632  7041          CIA             /THROUGH?
2388   03633  1351          TAD LSEND
2389   03634  7740          SMA SZA CLA
2390   03635  5223          JMP CVLOOP      /NO
2391   03636  1021          TAD N+1         /YES.  GET NUMBER OF POINTS
2392   03637  4474          FLOAT
2393   03640  4407          FENTER
2394   03641  6020          FPUT N
2395   03642  0000          FEXIT
2396   03643  4315          JMS LSQ         /COMPUTE SLOPE, INTERCEPT BASED ON SUMS
2397   03644  1353          TAD LSSTR1      /WE NOW HAVE FN2=(SLOPE*VOL)+INTERCEPT
2398   03645  3352          DCA LSSTRT      /ON INTERVAL (VC-2.5,VC-1.5)
2399   03646  1353          TAD LSSTR1      /RESET POINTERS TO START OF INTERVAL
2400   03647  1350          TAD LSDEL
2401   03650  3354          DCA FSSTRT
2402   03651  1754  CKLP,   TAD I FSSTRT    /START OF LOOP TO LOCATE LAST POINT FOR WHICH
2403   03652  4485          UNPACK          /ACTUAL SAMPLED N2 IS LESSTHAN PREDICTED BY
2404   03653  4407          FENTER          /REGRESSION. EXTRAPOLATE BEYOND INTERVAL
2405   03654  3124          FMUL N2PR10
2406   03655  6142          FPUT FRAC       /GET SAMPLED N2 IN FLOATING
2407   03656  0000          FEXIT
```

```
2408   03657  1753          TAD I LSSTR1
2409   03660  4536          FLTVOL          /GET VOL IN BTPS LITERS
2410   03661  4471          BTPS
2411   03662  4407          FENTER
2412   03663  3355          FMUL SLOPE      /MUL BY SLOPE
2413   03664  1360          FADD INT        /ADD INTERCEPT
2414   03665  2144          FSUB FKAC       /SUBTRACT SAMPLED M2
2415   03666  0000          FEXIT
2416   03667  1045          TAD 45
2417   03670  7710          SPA CLA /ABOVE LINE?
2418   03671  5274          JMP CKLP1       /YES
2419   03672  1353          TAD LSSTR1      /NO  SAVE THIS POINT AS LAST
2420   03673  3352          DCA LSSTRT
2421   03674  2353  CKLP1,  ISZ LSSTR1
2422   03675  2354          ISZ FSSTRT      /BUMP POINTERS
2423   03676  1353          TAD LSSTR1
2424   03677  7041          CIA             /THROUGH?
2425   03700  1773'         TAD WRSTR
2426   03701  7740          SMA SZA CLA
2427   03702  5251          JMP CKLP        /NO  GET NEXT POINT
2428   03703  1752          TAD I LSSTRT    /YES -CHECKED TO END OF BREATH
2429   03704  4536          FLTVOL
2430   03705  4471          BTPS            /GET LAST POINT BELOW TO BTPS LITERS
2431   03706  4407          FENTER
2432   03707  6144          FPUT FKAC
2433   03710  5777'         FGET VC
2434   03711  2144          FSUB FKAC       /SUBTRACT FROM VC
2435   03712  6772'         FPUT CV         /STORE AS CLOSING VOLUME
2436   03713  0000          FEXIT
2437   03714  5600          JMP I CVS
2438
2439
2440
2441
2442
2443                 /ROUTINE TO USE SUMS TO CALCULATE SLOPE, INTERCEPT
2444   03715  0000  LSQ,0
2445   03716  4407          FENTER
2446   03717  5026          FGET SX
2447   03720  3026          FMUL SX
2448   03721  6144          FPUT FKAC
2449   03722  5020          FGET N
2450   03723  3034          FMUL SX2
2451   03724  2144          FSUB FKAC
2452   03725  6121          FPUT EXP
2453   03726  5026          FGET SX
2454   03727  3031          FMUL SY
2455   03730  6144          FPUT FKAC
2456   03731  5020          FGET N
2457   03732  3023          FMUL SXY
2458   03733  2144          FSUB FKAC
2459   03734  4121          FDIV EXP
2460   03735  6355          FPUT SLOPE
2461   03736  5026          FGET SX
2462   03737  3023          FMUL SXY
```

```
2463   03740  6144          FPUT FKAC
2464   03741  5034          FGET EX2
2465   03742  3031          FMUL ZY
2466   03743  2144          FSUB SM.AC
2467   03744  4121          FDIV EXP
2468   03745  6160          FPUT INT
2469   03746  0003          FEXIT
2470   03747  5715          JMP I LSQ
2471   03750  0551  LSDEL,.551
2472   03751  0000  LSEND,.0
2473   03752  0000  LSSTRT,.0
2474   03753  0000  LSSTR1,.0
2475   03754  0000  FSSTRT,.0
2476   03755  0000  SLOPE,.0;0;0
2477   03756  0009
2478   03757  0000
2479   03760  0000  INT,.0;0;0
2480   03761  0000
2481   03762  0000
2482   03763  2001  F1PTS,.1;3200;0
2483   03764  3080
2484   03765  0000
2485   03766  0002  F2PTS,.2;2400;0
2486   03767  2400
2487   03770  0000
2488   03771  1235
2489   03772  2742
2490   03773  0336
2491   03774  1756
2492   03775  3104
2493   03776  1214
2494          4000  *4000
2495   04000  0000  DATH,.0
2496                $
```

```
ABORT  3527    EX     0026    F2PT5  3766    L9     1303
ABTMG  3534    EXP    0121    F2047  0137    MANTIS 0122
ABTMPT 3533    EXY    0023    F3QTR  2065    MAXV   2277
AC     1041    EX2    0034    F7     3524    MEFR   1236
ADAIO  0111    EY     0031    GG     1553    MESSAG 0657
ADLOOP 0134    F      1366    HOLD   0720    MGPT   0112
AD21WD 0474    FADD   1000    INDRC  3341    MINUSN 0147
AUX    1341    FDIV   4060    INIT   0200    MINUSP 1520
B      0760    FENTER 4467    INPUT  0106    MINUSS 0120
BAD    2137    FEMPT  1653    INSERT 2765    MMFR   1241
BEGIN  5470    FEMS   1600    INT    3760    M9     1037
BIGGER 2141    FEMT   1222    INTSU  3000    MSG1   0075
BREATH 2564    FEMI   1225    KEYIN  0103    MSG2   0076
BTPS   4471    FEXIT  0000    KWAIT  0472    MSINT  2640
BTPSFC 1753    FEXT   0000    K10    0473    MSWA   3462
BTPSR  1732    FGET   5000    K100   1146    MSWAIT 3443
CALMPT 1571    FIRST  1145    K212   1153    MSWTR  3447
CALMSG 0751    FIRSTI 2145    K215   1147    MSWT1  3424
CALN2  1531    FIX    3472    K237   1145    MS1PK  0077
CALS   1400    FIXX   1536    K25    2060    MS2PK  0100
CALXIT 1473    FKAC   0144    K3     0117    M13    1570
CALXTP 1523    FLAGCL 1513    K31    2060    M232   0656
CC2TLC 1247    FLEXIT 1654    K77    0107    M37    1144
CHHOLD 1150    FLGCL  1513    K7774  0116    M74    1151
CKLP   3651    FLO    2200    L      0565    M76    1152
CKLP1  3674    FLOAT  4474    LASTSM 0110    N      0020
CK27   3247    FLRST  1622    LF     1132    NAMES  0733
CLOSE  0131    FLTEMP 2241    LINK   1040    NAMESP 0312
CLSUM  1756    FLTR   2152    LINKMG 0721    NB     2745
CONST  3244    FLTVOL 4536    LOGPAD 1572    NB1    3030
CONVRT 4515    FLWAIT 1623    LOOPSU 3035    NC     1770
CTRL   6075    FMPY   7000    LOST   0723    NCI    1771
CTRL1  0613    FMUL   3000    LOSTMG 0713    NEWBR  1656
CV     1205    FNORM  7200    LOSTPT 0722    NEWMG  0762
CVLOOP 3623    FN2CL  1515    LSDEL  3750    NEWMS1 1134
CVS    3600    FOUT   4466    LSEND  3751    NEWN2  1457
CV2VC  1244    FOUTS  0213    LSQ    3715    NEWPT  0335
C13    2163    FPLOT  3400    LSSTRT 3752    NEWS   0316
D      1563    FPT040 2274    LSSTR1 3753    NEWSS  0327
DAC    6065    FPT2   3076    LSTCH  2744    NEWV   2312
DACN   1524    FPT25  3078    LSTVOL 2543    NHOLD  1522
DACN2  4576    FPTT5  3075    LVMM   2537    NLAG   2766
DAPT   0387    FPUT   3000    L1     3342    NLAST  0164
DATA   4000    FQTR   3062    L10    1310    NOCHG  0440
DATUM  0306    FR     0641    L11    1315    NOSB   2734
DECODE 1063    FRP    3711    L12    1322    NOSBST 2726
DELAY  0114    FRSMG  0102    L13    1327    NOSHFT 0520
DIG    0523    FSSTRT 3754    L14    1334    NOSTOP 1503
DIGP   0310    FSUB   3000    L15    2767    NOTPCK 1113
DOWN   3442    FVC2VC 1233    L2     0771    NP     1767
DUMAD  0161    F1PT2  2101    L3     1252    NSTART 0165
DVM    0133    F1PT5  3763    L4     1257    NSTORE 0163
EOB    2631    F10    1706    L6     1264    NTIDAL 0156
ERR    1565    F100   0173    L7     1271    NUMOUT 0315
ET     2557    F12FEV 1230    L8     1276    NUMZRO 3031
```

```
NUSEP  2572      TYPE   1106      WKEY   2366
NWLST  0179      TYPFLG 1514      WLOOP  2400
NWLST1 5317      UNIT   1154      WNSTR  2741
N2DELT 1203      UNITP  0313      WNSTRP 0171
N2HOLD 3523      UNPACK 4465      WNUSE  2571
N2MAX  2561      UP     3441      WST    2704
N2PR10 0124      VADAIO 1652      WSTOP  2566
N2SAM  0113      VALUE  0127      WWLAST 0166
N2SUM  2551      VA2RV  1211      WWSTR  2742
N2SUMP 3033      VBELOW 0450      WWSTRP 0172
N2ZCT  3034      VC     1214      WWUSE  2570
OFFSET 0622      VCLC   1667      WZERO  3062
OK     0433      VCLOSE 0455      XHOLD  0372
OPEN   0130      VCOMP  2000      XIT    1026
OUTCT  0314      VENT   2554      XITPT  0101
OUTPUT 4512      VEOB   1650      ZC     3061
OVERY  0266      VFHI   0142      ZF..   3125
P      1172      VFIRST 0167      ZFRS   3130
PC     1036      VFLO   0143      ZLEAVE 3110
PLOT   3463      VIN    1646      ZMM    3060
PRTBFR 3530      VINT   1711      ZST    3057
PRT2T  0105      VKEY   2244
PT02   3131      VKEYIN 1651
PT1250 3340      VLAST  0465
PT750  3337      VLPR10 0150
QUE    0700      VM     2345
READY  4473      VMP    2345
REPORT 0236      VNKEY  0154
RETURN 1111      VOLBFR 2746
RIGHT  1060      VOLDIF 2546
RPT    1425      VOLUME 3132
RPTCK  0557      VPKEY  0155
RPTR   2114      VPOINT 2061
RV     1200      VSHIFT 0467
SAMPLE 5537      VSKEY  0153
S3     2743      VSTART 0135
SBANAL 3250      VSTORE 0162
SD2VOL 1737      VSV    2347
SEARCH 3104      VTEMP  0466
SERVIC 1000      VTHRSH 0470
SLEAF  2615      VU     2344
SLOPE  3755      VUSE   1047
SPIRO  4437      VUSEP  2373
SPIROS 0400      VWANT  2147
STORE  1727      VWATCH 0471
STOREW 3200      WADAIO 2365
STOSP  0235      WAIT   0114
STSPO  3032      WAITPT 3104
SUMS   0330      WASHS  2350
THRU   1120      WC     2565
TIMINC 3134      WCLC   2421
TLC    1217      WD2FLT 3144
TOOLO  2617      WFIN   2567
TTI    0600      WFINIS 3723
TTO    1042      WINT   2600
```

ERRORS DETECTED: 0
LINKS GENERATED: 81

```
          2452  2459  2467
EXY         69#  364   365  2457  2462
EX2         78#  360   361  2450  2464
EV          75#  348   349  2454  2465
F          807   808   951#
FADD        10#  348   356   360   364   944  1694  1707  2108  2139
           2140  2413
FDIV        14#  932   936   940   945  1219  1490  2095  2099  2295
           2459  2467
FENTER      22#  274   345   354   930  1001  1011  1073  1218  1257
           1273  1315  1324  1335  1341  1347  1353  1382  1402  1442
           1474  1481  1488  1498  1705  1715  1724  1984  2006  2051
           2084  2107  2131  2137  2162  2169  2281  2294  2362  2368
           2393  2404  2411  2431  2445
FEMPT       1147  1189#
FEMS         556  1148#
FENT         244#  932   935  1316  1327  1329
FENT1        247#  931  1325
FEXIT        19#  276   350   356   948  1004  1013  1075  1221  1259
           1276  1317  1332  1357  1344  1349  1355  1384  1404  1444
           1477  1483  1491  1498  1711  1713  1727  1987  2009  2053
           2102  2110  2134  2141  2165  2174  2284  2297  2365  2371
           2395  2407  2415  2435  2469
FEXT        17#
FGET        15#  275   358   362   931   935   939   943  1012  1326
           1329  1336  1343  1348  1696  1709  1716  1725  1985  2007
           2088  2091  2094  2098  2101  2133  2138  2363  2369  2433
           2446  2449  2453  2456  2461  2464
FIRST        720   727   729   762   787#
FIRST1      1388  1418  1419  1424#
FIX           98#  1076  1222  2296  2298
FIXX          99  1088#  1110  1112
FMAC        160#  347   363  1478  1490  1691  1696  1705  1709  1716
           2087  2089  2090  2094  2164  2171  2406  2414  2432  2434
           2448  2     2455  2458  2463  2466
FLAGCL       992   995   998  1059#
FLEXIT      1168  1183  1193#
FLGCL       1033  1058#
FLO         1349  1352  1460#  1467  1478  1492
FLOAT        102#  1473  2292
FLPST       1164#
FLTEMP      1492  1489  1493#
FLTX         103  1437#  1445
FLTVOL       153#  352  1216  1313  1322  1400  1479  1486  1688  2129
           2292  2409  2429
FLWAIT      1165#  1177  1227
FMPY          12#
FMUL          13#  340   359   365   933   937   941   946  1002  1074
           1220  1258  1275  1337  1330  1475  1704  1709  2036  2163
           2170  2172  2282  2293  2296  2405  2412  2447  2458  2454
           2457  2462  2467
FNORM       18#  1274  1443  2052  2065
FN2CL       1003  1012  1061#
FOUT         90#   284  1018
FOUTS        91   215#   235
FPLOT       1638  2213#  2245
FPT040      1475  1521#
FPT2        1345  1372#  2008  2096
FPT25       1326  1396#  2139  2140
FPT75       1370  1369#  2133  2138
```

```
L1          638  2189*
L10         646   898*
L11         647   903*
L12         648   908*
L13         649   913*
L14         650   918*
L15         651  1904*
L2          639   669*
L3          640   868*
L4          641   873*
L6          642   878*
L7          643   883*
L8          644   888* 1139
L9          645   893*
MANTIS      140* 2278  2291
MAXV       1310  1529* 1576  2126
MEF2        856* 1354
MESSAG      121   590*  606   617   622
MGPT        121*
MINUSN      103* 1508
MINUSP     1052  1064* 1515
MINUSS      132* 1049  1501
MTFR        859* 1342
MU          680   699   707*
MSG1        104*  595   599   723   738   731   756   759   766   776
MSG2        105*  221   512   607   611   619   763   767   775   777
MSINT      1762  1807*
MSWA       2252  2264  2268*
MSWAIT     2233  2249* 2266
MSWTR      2255* 2265
MSWT1      2233* 2241
MS1PK       100*  605   717   768   779
MS2PK       107*  615   620   799   778   781
MTS        1095  1114*
M232        533   577*
M37         745   788*
M74         737   793*
M76         741   794*
N            66*  367  1297  2291  2394  2449  2456
NAMES       296   639*
NAMESP      200   296*
NB         1814  1929  1834  1837  1886*
NB1        1923  1927  1952  1954  1937*
NC         1291  1298*
NC1        1292  1294  1299*
NEWBR      1164  1200* 1208
NEWMG       328   662*
NEWMS1      765   775*
NEWN2      1024* 1065
NEWPT       313   328*
NEWS        312*  559
NEWSS       322*  326
NEWV       1551* 1566  1571
NHOLD       999  1051  1066*
NLAG       1833  1832  1903*
NLAST      1834* 1815
NOCHG       426   410*
NOSB       1641  1858  1861  1864  1871*
NOSBST     1843  1862*
NOSHFT      456   471*
```