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**ANL FOUR-METER CALORIMETER
DESIGN AND OPERATION MANUAL**

by

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I. INTRODUCTION

The Four-Meter Fuel-Rod Calorimetric System (Fig. 1) is designed to measure the thermal power produced by radioactive decay of plutonium-containing fuel rods. The plutonium mass in a sample is related to the measured power through the weighted average of the product of the isotopic decay energies and the decay constants of the plutonium isotopes present. The uranium content of the fuel will not affect the measurement, since the thermal power produced by the uranium nuclides is insignificant when compared to plutonium. This is the result of the longer half-life of uranium relative to the Pu isotopes. The principal radiations from plutonium are alpha particles and low-energy photons. As a consequence of the low penetration power of this radiation, greater than 99.9% of the decay energy will be degraded to thermal energy measurable by the calorimeter. (A more detailed discussion of the physical principles involved in calorimetry is included in *A Portable Calorimeter System for Nondestructive Assay of Mixed-Oxide Fuels*, ISPO-16.)

The four-meter calorimeter is capable of measuring samples producing power up to 1.5 watts at a rate of one sample every 120 minutes. The measurement precision for the baseline power $[\sigma(P_0)/P_0]$ is better than 0.1%.

The instrument consists of three units: a data-acquisition module made up of a microprocessor with an 8K-byte nonvolatile memory, a control cabinet, and the calorimeter chamber. The calorimeter chamber is constructed in two halves so that it can be disassembled for shipping.

Fig. 1. The Four-Meter Calorimeter.

II. IAEA FOUR-METER CALORIMETRIC SYSTEM

The Four-Meter Calorimetric System is designed for in-field operation. Care has been taken to minimize the effects of nonideal environments encountered during the course of a typical assay. Field conditions have been simulated in the laboratory, and a set of operating conditions which ensure maintenance of a 0.1% measurement precision have been developed. Although these operating requirements are broad and should not restrict the inspector, reasonable care should be exercised in choosing a sampling location. Operation in any unfamiliar setting should be preceded by a calibration and a thorough check-out.

A. Environmental Operating Conditions

1. Temperature

The calorimeter unit is adjusted for a maximum sample power of 1.5 watts. The temperatures of the concentric chambers comprising this unit are: T_3 , 44.1°C; T_2 , 42.8°C; T_1 , 41.6°C; T_0 , 39.6°C. The system was tested for ambient temperatures between 10.5°C and 35.0°C. Over this temperature range, a drift in the measurement precision of less than 0.1%/°C was experienced.

2. Power Requirements

The calorimeter is designed to be operated with a voltage of 230 VAC (50 Hz). The device was tested for voltage fluctuation with a 230-VAC line. Operation was unaffected by fluctuations under 20%.

B. System Setup

1. System Interconnection

The calorimeter chamber halves must be coupled together, and the interconnecting cables must be in place. The calorimeter control and its data-acquisition system (DAS) MUST be connected prior to applying line volt-

age. The multipin connectors on the calorimetric unit, labeled P1, P2, should be connected to their respective receptacles on the DAS. Two identical AMP cables, which are stored in the DAS case, are provided for this purpose. The cables which connect the calorimeter chamber to the control unit must be in place.

2. Power Up

The power switch on the control cabinet applies power to the entire system. To avoid possible damage to the print head, the RESTART (RST) key on the DAS keyboard should be pressed immediately after the power is turned on. After the system has been set up, it must be allowed to reach equilibrium at operating temperature before assaying samples. This takes approximately four hours at 20°C. The temperature-error meters on the control unit will give an indication of the progress toward warm-up for each control circuit.

III. PHYSICAL DESCRIPTION

The calorimeter control unit is housed in an aluminum cabinet which is 50.8 cm wide, 33.0 cm high, and 45.7 cm deep. The cabinet contains a power supply and a NIM bin. The calibration module and the T_0 , T_1 , T_2 , T_3 control circuits are each single-width NIM modules. The calorimeter chamber is contained in two 13.3-cm-diameter tubes that couple together to form a 490.2-cm-long chamber with a 1.9-cm inside diameter. The measurement chamber will accommodate fuel rods up to 4267 mm long with fuel columns of up to 4000 mm in length. The calorimeter chamber is supported by four tripod stands that can be adjusted to a convenient height and that provide a means for leveling the calorimeter chamber. Detailed circuit schematics are provided in Appendix A.

IV. DATA ACQUISITION SYSTEM

A. Physical Description

The Data Acquisition System (DAS) is housed in a 47 cm × 35 cm × 16 cm attaché case and has a total weight of 5 kg. It is a totally dedicated

microprocessor-controlled device, designed around the INTEL 8085. The system memory consists of 8K bytes of erasable, programmable, read-only memory (EPROM) and 1K bytes of random-access memory (RAM). The program resides in the permanent memory, EPROM, and does not need to be reentered after the device is powered down. The EPROM is organized on four 2K-byte INTEL-2716 chips, the last 2K bytes being exchangeable. The RAM is organized on four 256-byte INTEL-8156 chips and serves as scratch-pad storage for the program. The microprocessor receives input either from the calorimeter through the 12-bit ADC or from the 25-key multifunctional keyboard. System output is through either the BOMAR TP3120-2 printer or the Liquid Crystal Display (LCD). A set of 6 LEDs are available to reflect system status. Detailed schematics and a copy of the μ P program are included in Appendix B.

B. Keyboard Action-Response

1. RST $\equiv$ Restart

Function: To place the system in an idle mode, where it will monitor the keyboard for a user command. All data processing is stopped. System default values are restored. The results of any uncompleted calculation will not be available to the user. The system will return to this mode after completing any noncyclical routine.

Use: This key should be used when first powering-up the system or when aborting a particular routine.

Status Light: READY

Printer: CALORIMETER READY

2. ENTR $\equiv$ Enter

Function: To signal the end of a numeric input.

Use: This key should be used when responding to a μ P prompt statement with a numerical value. It also acts as a "NO" in a situation

requiring a YES/NO response.

Printer: Carriage return - Line feed

3. BS $\equiv$ Backspace

Function: To permit the user to erase an undesired response to a μ P Prompt statement.

Use: This key repositions the input ASCII array by one character each time it is pressed.

Printer: Backspace

4. EXT $\equiv$ Execute external program

Function: To enable the user to expand the computational abilities of the DAS. The DAS is designed so that the last 2K of the 8K PROM memory is interchangeable by replacing the chip in the zero force socket with a different INTEL 2716 containing a new program.

Use: To be determined by user.

Status Light: EXT

Printer: Program dependent.

5. TP $\equiv$ Diagnostic Test Points

Function: To enable the user to examine the voltages of any of 32 selected locations within the calorimeter. (See Appendix A for TP locations within the calorimeter.)

Use: This routine may be used either to continuously monitor a particular point on the Liquid Crystal Display or to obtain a print-out of all 32 points. To change TP during continuous monitoring,

press "TP" and the number of the desired test point. Use RST to exit from continuous monitoring.

Status Light: A/D

Liquid Crystal Display: TP voltage

Printer: "TEST PNTS"

"ALL?" - μ P prompt statement

User Response - YES - all TP's printed (Option 1)
 - #, ENTR - individual TP displayed (Option 2)

6. PRINT $\equiv$ Print

Function: To allow user to obtain a printed record of a test point which is being continuously monitored or of a power which is being displayed on the Liquid Crystal Display.

Printer: Numeric output

7. INIT $\equiv$ Initial data input

Function: To permit the user to input parameters which will be used in the data analysis by the μ P.

Use: Input isotopic mass % + uncertainty, elapsed time since last isotopic analysis, default value of effective specific power, power normalization factor, system uncertainty.

Status Light: RSVP after μ P prompts

Printer: "DATA INPUT MASS %"

"AM241" - μ P prompt statement

A μ P prompting statement will be printed for ^{241}Am and for each

isotope $^{238-242}\text{Pu}$. After each prompt, enter the isotopic mass % and its uncertainty. [Note: 1) Include the leading zero in numbers less than 1.0, i.e., type 0.01, not .01. 2) Am % is defined as $[\text{Mass}(\text{Am})/\text{Mass}(\text{Pu})] \times 100.$]

"TIME-DAYS"

Enter the time elapsed since the last isotopic analysis was performed.

"POWER mW/g"

Enter a default value if it is decided not to calculate the Effective Specific Power from the isotopic mass fractions.

"P NORM"

This parameter relates the measured thermal power to the actual source-produced power (i.e., $P_{\text{measured}} = P_{\text{source}} \div \text{PNORM}$). A value of 1.0 is included as a default value. This value may be altered if necessary (see Sections V, VI).

"SIG(SY)"

This parameter contains the nonstatistical contributions to the measurement precision. (To be determined by user.) The default value is zero, meaning no systematic error is included. The components of this parameter are discussed in Section VI. (NOTE: The default values of PNORM and SIG(SY) are restored after an RST).

NOTE: The remaining keys (FRAC, SP, P_0 , RUN, and CAL) activate major subroutines used in data acquisition and analysis. Brief descriptions are given below. More detailed discussions are available in the sections on Recommended Procedures and on Data Analysis.

8. FRAC $\equiv$ Mass Fraction decay correction

Function: To calculate the changes in the mass percentages in a previously isotopically analyzed sample resulting from radioactive decay. A current set of mass % will be generated which may be used to calculate effective specific power.

Use: The program requires that the initial mass % and the elapsed time be entered through INIT prior to execution.

Printer: The decay-corrected isotopic mass % are printed.

9. SP $\equiv$ Effective Specific Power calculation

Function: To determine the power emitted per gram of the material to be assayed as well as the uncertainty associated with this calculation.

Use: The program requires that the mass % be available prior to execution.

Printer: The effective specific power and its uncertainty.

10. P_0 $\equiv$ Empty chamber baseline analysis

Function: To determine the power supplied by the calorimeter to maintain a constant temperature when no heat-producing source is present; to compare this with the power when the sample is in place and derive the sample power and mass.

11. RUN $\equiv$ Sample assay

Function: To determine the calorimeter-supplied power in the presence of a Pu-containing material.

12. CAL = Electrical calibration

Function: To supply a series of known electrical powers to the "electric fuel rod," and to determine the resulting measured powers, thus allowing the user to derive a relation between the measured and actual sample power.

NOTE: A simulated output tape showing the results of typical operations is given in Appendix C.

V. RECOMMENDED PROCEDURES

A. Assay Procedure1. Reset microprocessor-controlled DATA ACQUISITION SYSTEM.

Operator Action: Press RST

System Response: "CALORIMETER READY"

2. Rod Assay

After inserting fuel rod and centering fuel column in sample chamber

Operator Action: Press RUN

System Response: "MEAS"
"PRINT ALL?" (Print each PWR measurement)

Operator Action: YES = Yes
ENTR = No (Usual response)

System Response: "DELAY-MIN" (delay period to permit system to equilibrate)

Operator Action: 60 ENTR (Note: This value will differ with rod diameter.)

System Response: "SIGMA-%" (Limit of acceptable precision on $\bar{P}$)

Operator Action: 0.05 ENTR (2σ limit) If the operator wishes the instrument to repeatedly measure the same sample, enter 0.

System Response: "#DP/RUN" (~ 25 DP/m

Operator Action: 125 ENTR (5 min)

The system then enters the DATA ACQUISITION MODE, and the following sequence will occur:

- 1) The E·I products are monitored until $\bar{P} < 2$ W. This indicates that the heater circuits are no longer in saturation, and the system is approaching equilibrium.
- 2) The system enters an operator-determined wait period during which no data is accepted.
- 3) The μP accepts E, I digital data from the ADC. The E·I product is calculated. An operator-determined number of data points is collected. The value of the calorimeter applied power and the number of data points left to be acquired are alternately displayed on the liquid crystal display. $\bar{P}$ and the sample standard deviation of the mean are calculated. The results are compared with "SIGMA-%". If the precision is acceptable, the data is stored and printed; otherwise, a new set of data will be accumulated.
- 4) The system is reset if the experiment is not to be repeated.

3. Sample Baseline Measurement

After removal of fuel rod from the calorimeter,

Operator Action: Press P₀

System Response: "EMPTY MEAS"

At this point, the operator's options are identical to those just discussed in Section 2, above. An example of a set of typical responses and the results of an assay are shown in Appendix C.

B. Electrical Calibration Procedure

1. Place electric fuel rod into calorimeter and plug the cable into the calibration module front panel connector.
2. Determine sample chamber power with the electrical fuel rod off, after allowing the calorimeter to settle, by pressing the RUN key. (See Section 2 for Recommended Assay Procedure.)

NOTE: This assay is not used in the calibration calculation.

The purpose of this measurement is to ensure that the system is at equilibrium and to provide a check on the calibration-determined empty chamber intercept (P_0).

3. Reset DAS (if necessary).
4. Electrically calibrate system.

Turn the toggle switch on the calibration module to the ON position.

Operator Action: Press CAL

System Response: "CALIBRATE"

"CAL PNTS" (μ P prompt statement)

Operator Action: 5 ENTR This determines the number of points used to calculate the calibration parameters.

At this point, the same set of options discussed in Section 2 of the Recommended Procedures is available. The following responses are suggested.

<u>μP Prompt Statement</u>	<u>Operator Response</u>
CAL PNTS	5
DELAY MIN	20
SIGMA %	0.02
#DP/RUN	125

The μ P determines the incremental calibration voltage by dividing the chamber power, with the electric fuel rod turned off, by the number of calibration points. This value will be added to the applied calibration voltage through a digital analog converter. The microprocessor will then enter the operator-selected delay period to permit the system to reach equilibrium. Since the measurement chamber is not disturbed by changing the fuel rod between calibration voltage increases, the time necessary to reach equilibrium is significantly shorter than in an actual assay. The operator-determined #DP/RUNs are then collected and analyzed, and then the μ P measures the input calibration voltage. The data is printed, and the process is repeated for the next calibration point.

After the calibration has been completed, the operator may extract the zero-power intercept, and the power linearity factor (slope) with a linear least squares fitting technique. This calculation is discussed in the Data Analysis section of the manual. Typical values of slope and intercept are given in Appendix C.

VI. DATA ANALYSIS

A. Effective Specific Power

In order to obtain maximum utility from the calorimeter, the measured sample power must be combined with additional isotopic information to determine the plutonium content of the sample. If the unknown contains only one isotope of plutonium, the generated heat is related to the sample mass by the equation

$$W_U = 2.1193 \times M \times Q / T_{\frac{1}{2}} \times A$$

where

- W = power (mW)
- M = mass of Pu (g)
- Q = total disintegration energy (MeV)
- $T_{\frac{1}{2}}$ = half-life of the isotope of Pu (yrs)
- A = gram atomic weight (g)

Under normal assay conditions, nuclear fuel will contain a mixture of radionuclides, the principal power producers being $^{238-242}\text{Pu}$ and ^{241}Am . Consequently, the sample power may be obtained from

$$W_U = M \cdot \sum R_i \cdot P_i = M \cdot P_{\text{eff}}$$

where

- R_i = mass fraction of the radionuclide
- P_i = specific power of a Pu isotope mW/g
- P_{eff} = effective specific power of the sample

Two techniques are suggested for determining the effective specific power.¹ Representative samples may be subsequently analyzed chemically to determine the Pu content (mW/g). This method usually requires multiple measurements distributed in time to account for isotopic decay. The second

technique requires that the isotopic composition be determined by gamma-ray or mass spectrometry.² Determination of radionuclide abundances by gamma-ray spectrometry has the advantage of being nondestructive and may be conducted concurrently with a calorimetric analysis. While the method chosen may differ from assay to assay, the programs supplied will work with either technique.

1. Radioactive-Decay Correction

The isotopic mass ratios are continually changing owing to radioactive decay within the sample. In particular, the beta decay of ^{241}Pu to ^{241}Am , which is a short-lived alpha emitter, results in an increase in the effective specific power with time. If a detailed isotopic analysis of the sample material has been made at an earlier date, an on-site determination of the mass fractions may be unnecessary. The present composition may be calculated by means of the following decay equations:

$$F_i = F_i^0 \cdot \exp(-\lambda_i t) / \Sigma F_i^0 \cdot \exp(-\lambda_i t)$$

$$F_{AM} = [1 / \Sigma F_i^0 \cdot \exp(-\lambda_i t)] \cdot \{ F_{AM}^0 \cdot \exp(-\lambda_{AM} t) + [\lambda_{241} \cdot F_{241}^0 / (\lambda_{241} - \lambda_{AM})] \cdot [\exp(-\lambda_{AM} t) - \exp(-\lambda_{241} t)] \}$$

where

- F_i^0 = mass % of Pu isotope at last analysis
- F_{AM}^0 = mass % of ^{241}Am (relative to Pu) at last analysis
- λ_i = decay constant of Pu isotope (day^{-1})
- λ_{AM} = decay constant of ^{241}Am (day^{-1})
- t = time elapsed since last analysis (days)

<u>Isotope</u>	<u>Decay Constant (day⁻¹)</u>	3
²³⁸ Pu	2.1617 · 10 ⁻⁵	
²³⁹ Pu	7.880 · 10 ⁻⁸	
²⁴⁰ Pu	2.903 · 10 ⁻⁷	
²⁴¹ Pu	1.322 · 10 ⁻⁴	
²⁴² Pu	5.08 · 10 ⁻⁹	
²⁴¹ Am	4.372 · 10 ⁻⁶	

The 8080-μP code for these calculations is given in Appendix B.

2. Effective Specific Power Calculation

The effective specific power is defined as the weighted sum of the isotopic specific powers. The uncertainty in this value is dependent upon the measurement errors in both the isotopic mass fractions and the specific power.

$$P_{\text{eff}} = \frac{\sum_i F_i \cdot P_i}{\sum_i F_i}$$

$$\sigma^2(P_{\text{eff}}) = \sum_i \left(\frac{F_i P_i}{F_i} \right)^2 \left(\frac{\sigma^2(F_i)}{F_i^2} + \frac{\sigma^2(P_i)}{P_i^2} \right)$$

where

F_i	=	mass % of the radioisotope
$\sigma(F_i)$	=	uncertainty in F_i
P_i	=	isotopic specific power (mW/g)
$\sigma(P_i)$	=	uncertainty in P_i (mW/g)
P_{eff}	=	effective specific power (mW/g)
$\sigma(P_{\text{eff}})$	=	uncertainty in P_{eff} (mW/g)

<u>Isotope</u>	<u>Specific Power (mW/g)</u>	
^{238}Pu	567.16	± 0.57
^{239}Pu	1.9293	± 0.0053
^{240}Pu	7.098	± 0.015
^{241}Pu	3.390	± 0.002
^{242}Pu	0.1146	± 0.0003
^{241}Am	114.23	± 0.16

In general there is a negligible increase in the uncertainty reported in the isotopic mass % as a result of radioactive decay. This is not always the case for ^{241}Am . If ^{241}Am was absent at the time of the original analysis, or only present in minute amounts, then changes in $\sigma(^{241}\text{Am})$ must be considered.

$$\sigma^2(^{241}\text{Am}) = [1.034t(\lambda_{241} - \lambda_{\text{AM}}) \cdot \sigma(^{241}\text{Pu})]^2 + \sigma^2(^{241}\text{Am})$$

The 8080 μP code for these calculations is given in Appendix B.

B. Analysis of Sample Power

1. Data Acquisition

The calorimeter feedback circuitry adjusts the power supplied to the inner cylinder coils so that a constant temperature environment for the sample chamber is maintained. (See Fig. 2.) The inner coil (T_3) voltage and current are alternately monitored by a 12-bit analog-to-digital converter (ADC), which transmits data to the microprocessor at a rate of ten readings/sec. Software multiplication of each voltage-current pair produces an "instantaneous" T_3 power. Ten such measurements are averaged to produce a two-second reading which is displayed on the liquid crystal display. The system will then calculate the average power $[E(P_1)]$ supplied by the calorimeter, and the sample standard deviation $[s(P_1)]$ associated with the measurement. Since the microprocessor performs floating-point arithmetic with 5-digit software (NOVONICS FP 70B), it is necessary to use the following biased-average approach to maintain sufficient accuracy.

Fig. 2. Resistance thermometry and feedback control circuitry in ANL air-chamber calorimeters.

Given a set of power measurements

$$P_i \quad i = 1, N$$

Define a new set

$$\hat{P}_i = (P_i - P_1) \quad i = 1, N$$

then

$$E(\hat{P}_i) = \Sigma \hat{P}_i / N = E(P_i) - P_1$$

$$\therefore E(P_i) = E(\hat{P}_i) + P_1$$

and

$$\sigma^2(\hat{P}_i) = E(\hat{P}_i^2) - [E(\hat{P}_i)]^2 = \sigma^2(P_i)$$

$$s^2(P_i) = (N/N - 1) \cdot \sigma^2(\hat{P})$$

$$\equiv \Sigma [P_i - E(P_i)]^2 / (N - 1)(N)$$

A flowchart describing the data-acquisition process is given in Fig. 3.

2. Analysis of Data

The inner sample chamber is held at a constant temperature of 44.1°C. When no heat-producing source is present, the calorimeter supplies a constant power, P_0 , of 1.7 W to maintain this temperature. If a sample containing heat-producing plutonium is placed in the calorimeter, the power which the circuitry must supply to maintain 44.1°C drops to a lower value, P_c . Consequently, we may determine the power produced by the plutonium, as shown graphically in Fig. 4. Using the effective specific power, P_{eff} (see Section VI-A), we may determine the plutonium mass by:

DATA ACQUISITION ROUTINE

Fig. 3. Data acquisition flowchart.

Fig. 4. The measurement-chamber temperature and power relations in ANL air-chamber calorimeters.

$$M_{\text{Pu}} = \bar{P}_{\text{Pu}} / \bar{P}_{\text{eff}}$$

where

$$\bar{P}_{\text{Pu}} = F(\bar{P}_0 - \bar{P}_c)$$

F = Pu normalization factor = 1.0
(determined from an electrical calibration
and a Pu calibration)

The measurement precision is defined by

$$s^2(P) = s^2(\text{SYS}) + s^2(\text{STAT})$$

where

$s(\text{STAT})$ is the uncertainty of the mean which is defined as
(standard deviation)/ $\sqrt{N}$

$s(\text{SYS})$ is the uncertainty due to systematic imprecision

the components of which are

- a) system reproducibility error, $s(\text{REP})$
- b) sample heat distribution error, $s(\text{HDE})$
- c) calibration uncertainty, $s(\text{CALIB})$
- d) thermal interferences, $s(\text{TEMP})$

$$s^2(\bar{M}_{\text{Pu}}) = M_{\text{Pu}}^2 \left[\frac{s^2(\bar{P}_{\text{eff}})}{\bar{P}_{\text{eff}}^2} + \frac{s^2(\bar{P}_{\text{Pu}})}{\bar{P}_{\text{Pu}}^2} \right]$$

The code for the calculation of the sample mass and uncertainty is included in Appendix B.

A more rigorous analysis which may be performed off-line by the user is presented below.

1) Electrical Calibration

$$\bar{P}_M = A + B \cdot \bar{P}_A$$

where

$$\bar{P}_M = \text{measured power} = \frac{\sum P_{M_i} / s_i^2}{\sum 1/s_i^2}$$

$$\bar{P}_A = \text{applied power} = \frac{\sum P_{A_i} / s_i^2}{\sum 1/s_i^2}$$

$$s_i = \text{uncertainty in the mean of } P_{M_i} \text{ (statistical)}$$

The sample statistical uncertainty is defined as

$$s^2(\bar{P}) = \sum [P_i - E(P_i)] / n(n-1)$$

which is

$$s^2(\bar{P}) = s^2(P_i) / n$$

This is the uncertainty in the mean of the power distribution, rather than the uncertainty in a single measurement $[s(P_i)]$.

$$B = \frac{\sum (P_{A_i} / s_i - \bar{P}_A / s_i) (P_{M_i} / s_i - \bar{P}_M / s_i)}{\sum (P_{A_i} / s_i - \bar{P}_A / s_i)^2}$$

$$A = \bar{P}_M - B\bar{P}_A$$

2) Sample Power

$$\bar{P}_S = (\bar{P}_M - A)/B$$

relating the power (P_A) actually measured to the source-produced power (P_M).

$$s^2(P_A) = \left(\frac{\partial P_A}{\partial P_M}\right)^2 s^2(P_M) + \sum \left(\frac{\partial P_A}{\partial P_i}\right)^2 s^2(P_i)$$

where

$P_i \equiv$ measured calibration observations

$s^2(P_M) \equiv$ includes statistical and all other sources of error

$$\left(\frac{\partial P_A}{\partial P_i}\right) = \frac{\partial [(P_M - A) \cdot B^{-1}]}{\partial P_i} = - \left(\frac{P_S}{B} \times \frac{\partial B}{\partial P_i} + \frac{1}{B} \times \frac{\partial A}{\partial P_i}\right)$$

$$\therefore \sum \left(\frac{\partial P_A}{\partial P_i}\right)^2 s^2(P_i) = \sum \frac{s^2(P_i)}{B^2} \left[\frac{1}{n} + \frac{(P_S - \bar{\mu})^2}{q\mu^2}\right]$$

where $\bar{\mu} = (Yn) / (\sum P_i)$

$$q\mu^2 = \sum (P_i - \mu)^2$$

and $\left(\frac{\partial P_A}{\partial P_M}\right)^2 s^2(P_M) = \left(\frac{1}{B}\right)^2 s^2(P_M)$

3) Source Normalization

$$K_{Pu} = (W_{STD}/P_{STD}) \cdot P_A$$

where

W_{STD} represents the actual power output of a calibrated ^{238}Pu source

P_{STD} represents the calorimeter-determined output of the calibrated source

4) Sample Mass

Thus, by combining the above

$$\bar{M}_{Pu} = K_{Pu} (\bar{P}_M - A) / BP_{eff}$$

and the uncertainty is obtained from

$$s^2(M) = s^2(\bar{P}_{Pu}) + s^2(P_{eff})$$

where

$$\begin{aligned} \frac{s^2(\bar{P}_{Pu})}{\bar{P}_{Pu}^2} &= \frac{s^2(HDE)}{\bar{P}_0^2} + \frac{s^2(REP)}{\bar{P}_0^2} + \frac{s^2(CALIB)}{\bar{P}^2} \\ &+ \frac{s^2(\bar{P}_M)}{\bar{P}_M^2} + \frac{s^2(TEMP)}{\bar{P}_0^2} \end{aligned}$$

5) System Baseline Check

During multiple sample analysis, the system baseline should be checked periodically by using the relation

$$t = |\bar{P}_0 - A| / [s^2(P_0) + s^2(A)]^{\frac{1}{2}}$$

where

$\bar{P}_0$ is the current calorimeter-supplied power to an empty chamber.

If

$$t > 1.95$$

then a baseline shift must be assumed to have occurred, and a correction should be made to the zero-power intercept (A).

APPENDIX A

CALORIMETRIC UNIT CIRCUIT DIAGRAMS #1-9IAEA FOUR METER CALORIMETER:

1. Calorimeter section
2. Coil assembly block diagram
3. DC filter mode
4. T_0 control module
5. T_1 control module
6. T_2 control module
7. T_3 control module
8. T_3 preamplifier
9. Test point table

NOTES:

1- ALUMINUM TUBE, $\frac{7}{8}$ " O.D. x .065" WALL x 7'- $\frac{1}{4}$ " LONG

2- HTR. + SENSE WINDINGS WOUND AS SHOWN. HTR IS WOUND FIRST, THEN SENSE WINDING

3- STYROFOAM CORE, 2.00" O.D. x $\frac{1}{4}$ " I.D. x 4" LONG. APPROX 25 PCS REQ'D.

4- ALUMINUM TUBE, 2.130" O.D. x .065" WALL x 7'-3" LONG.

5- HTR + SENSE WINDINGS AS SHOWN. HTR WOUND FIRST, THEN SENSE WINDING

6- STYROFOAM CORE, 3.00 O.D. x 2.20 I.D. x 4" LONG APPROX. 25 PCS. REQ'D.

7- ALUMINUM TUBE, 3.166" x .083" WALL x 7'-6" LONG

8- HTR. WINDING + THERMISTORS AS SHOWN. HTR. WOUND FIRST THEN 16 FENWAL GB 31P2 THERMISTORS (100Ω EACH) EPOXIED ON 12" CENTERS.

9- STYROFOAM CORE, 4.0" O.D. x 3.25" I.D. x 4" LONG APPROX. 25 PCS. REQ'D.

10- ALUMINUM TUBE 4.25" O.D. x $\frac{1}{2}$ " WALL x 7'-9" LONG.

11- HTR. WINDING + THERMISTORS SIMILAR TO NOTE 8, EXCEPT HTR IS 246T TURNS #26 COPPER, $R_T = 100 \Omega$

12- STYROFOAM CORE, 5.0" O.D. x 4.25" I.D. 25 PCS. REQ'D.

13- ALUMINUM TUBE, 5- $\frac{1}{4}$ " O.D. x .125" WALL x 8' LONG

SENSE WINDINGS,

URNS #40 NICKEL WIRE, $R_T = 23.3 K\Omega$.466 lbs.

URNS #30 COPPER WIRE, $R_T = 158\Omega$.466 lbs.

WINDINGS
URNS OF #32
 $R_T = 3,436\Omega$.886 lbs.
URNS OF #24
 $R_T = 50\Omega$.236 lbs.

14- EPOXY LAYER .062" THICK TO PROTECT WINDINGS

15- A THERMO-LINEAR THERMISTOR, TYPE YSI 44018 IS MOUNTED MID WAY ON EACH TUBE FOR ABSOLUTE TEMPERATURE MEASUREMENT

TOLERANCES, UNLESS OTHERWISE NOTED		APPROVED FOR CONSTRUCTION	ARGONNE NATIONAL LABORATORY		DATE	BY
FRACTIONAL TOL. $\pm \frac{1}{50}$	DECIMAL TOL. $\pm .005$	DESIGNED BY R. PERRY	This drawing is the property of Argonne National Laboratory		PAGE 1	
ANGULAR TOL. $\pm \frac{1}{2}^\circ$		CHECKED BY			TITLE 4 METER CALORIMETER SECTION	
EXCEPT TO THE EXTENT SHOWN BY DIMENSIONS AND TOLERANCES, THIS DRAWING IS NOT TO BE USED FOR CONSTRUCTION		SCALE	MATL.	NO. DESIG.	QUANTITY	OTHER INFO.

REVISIONS	TITLE	DRAWING NO.
DATE: NATIONAL LABORATORY	Four Meter Calorimeter Coil Assembly Block Diagram	REV. OF
DESIGNED BY THE PROPERTY OF	DESIGNED BY G. Youngdahl	DATE 3-1-78
REVIEWED BY	CHK. BY	APPR. BY
BUILT FOR	SYN. NO.	SYN. NO.

NOTES:

- 1- ○ Refers To NIM Bin Connection Pins
- 2- All Capacitors Are 2000 MFD, 25 WVDC
- 3- Choke Is Signal Transformer Model CH-4
70 MHY. , 4 A. , .6 Ω DC
- 4- 48v. Supply Is Power-One Inc. Model HC48-1.0

TOLERANCES: UNLESS OTHERWISE NOTED		APPROV FOR CO
FRACTIONAL TOL.	$\pm \frac{1}{64}$	CHIEF ENG.
DECIMAL TOL.	$\pm .005$	CHIEF DRAFTS
ANGULAR TOL.	$\pm \frac{1}{4}^\circ$	CHECK
SURFACES TO BE WITHIN LIMITS OF COMMON PRODUCTION METH.		DRAW
ODS ASA B46.1 FIG. 19 (1959)		GROUP

UNLESS NOTED 1 1/4 2 1/2 2 1/4 IN LIMITS OF METH- ODS (1955)	APPROVED FOR CONST.			ARGONNE NATIONAL LABORATORY This drawing is the property of the Argonne National Laboratory	SYM.	CHANGE	DATE	BY	
	CHIEF ENG.				PART				
	CHIEF DRAFTSMAN				ASSEMBLY				
	CHECKED				DC Filter Module				
	DRAWN			SCALE	MATL.	NO. RECD.	SHEET	DRWG. NO.	
	GROUP	REPRESENTATIVE					OF	ITEM NO.

NOTES:

- 1) ○ INDICATES NIM CONNECTOR PIN NUMBER
- 2) >> INDICATES CIRCUIT BOARD CONNECTION PAD LETTER
- 3) NUMBERS AND LETTERS IN PARENTHESIS REFER TO CORRESPONDING POINT ON SECOND HALF.
- 4) OP-10 HAS OFFSET ADJUSTMENT POTS.
- 5) 8-GENVAL GB 3IP2 THERMISTERS ARE SPACED EQUALLY ALONG THE TUBE TOTAL RESISTANCE = 8000 Ω NOMINAL
- 6) CRYDOM D-2425 PHOTO-ISOLATED SOLID STATE RELAY, 240V. AT 25A MAX. ZERO VOLTAGE TURN-ON

TOLERANCES: UNLESS OTHERWISE NOTED	APPROVED FOR CONST.
FRACTIONAL TOL. $\pm \frac{1}{64}$	CHIEF ENG.
DECIMAL TOL. $\pm .005$	CHIEF DRAFTSMAN G.Y.
ANGULAR TOL. $\pm \frac{1}{4}^\circ$	CHECKED
SURFACES TO BE WITHIN LIMITS OF COMMON PRODUCTION METHOD: ASA B46.1 FIG. 10 (1955)	DRAWN
	GROUP

APPROVED FOR CONST.		ARGONNE NATIONAL LABORATORY			SYM.	CHANGE	DATE	BY
CHIEF ENG.		This drawing is the property of the Argonne National Laboratory			PART 1/2 T ₀ CONTROL MODULE			
CHIEF DRAFTSMAN	G.Y.				ASSEMBLY 4-METER CALORIMETER			
CHECKED		SCALE	MATL.	NO. REQD.	SK. SET	DRWG. NO.	ITEM NO.	
DRAWN								
GROUP	REPRESENTATIVE

NOTES :

- 1) ○ INDICATES NIM CONNECTOR
PIN NUMBER
- 2) >> INDICATES CIRCUIT BOARD
CONNECTION PAD LETTER
- 3) OP-10 HAS OFFSET ADJUSTMENT POTS
- 4) 8 FENWAL GB 31P2 THERMISTERS ARE
SPACED EQUALLY ALONG EACH HALF
AND CONNECTED IN SERIES. TOTAL
RESISTANCE = 16,000 Ω NOMINAL

TOLERANCES: UNLESS
OTHERWISE NOTED

FRACTIONAL TOL. $\pm \frac{1}{64}$
DECIMAL TOL. $\pm .005$
ANGULAR TOL. $\pm \frac{1}{4}^\circ$

SURFACES TO BE WITHIN LIMITS
OF COMMON PRODUCTION METH.
ODS ASA B46.1 FIG. 19 (1955)

APPROVED FOR CONSTRUCTION
CHIEF ENG.
CHIEF DRAFTSMAN
CHECKED
DRAWN
GROUP

UNLESS NOTED	APPROVED FOR CONST.	ARGONNE NATIONAL LABORATORY			SYM.	CHANGE	DATE	BY
	CHIEF ENG.				PART T ₁ CONTROL MODULE			
	CHIEF DRAFTSMAN	G.Y.	ASSEMBLY 4 - METER CALORIMETER					
	CHECKED		SCALE	MATL.	NO. REQD.	SHEET	DRWG. NO.	ITEM NO.
	DRAWN					OF		
GROUP	REPRESENTATIVE							

THIS DRAWING IS THE PROPERTY
OF
THE ARGONNE NATIONAL LABORATORY

SCALE: 1/64
1/32
1/16
1/8
1/4
1/2
1
2
4
8
16
32
64
128
256
512
1024
2048
4096
8192
16384
32768
65536
131072
262144
524288
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2097152
4194304
8388608
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62165404551223330265

GLENNON & KENN, INC., CHICAGO

NOTES :

- 1) INDICATES NIM CONNECTOR
PIN NUMBER.
- 2) INDICATES CIRCUIT BOARD
CONNECTION PAD LETTER.
- 3) OP-10 HAS OFFSET ADJUSTMENT
POTS.

APPROVED FOR CONST.		<h1 style="text-align: center;">ARGONNE NATIONAL LABORATORY</h1>			SYM.	CHANGE	DATE	BY
CHIEF ENG.					PART T2 CONTROL MODULE			
CHIEF DRAFTSMAN	G.Y.	<p style="text-align: center;">This drawing is the property of the Argonne National Laboratory</p>			ASSEMBLY			
CHECKED					<p style="text-align: center;">4 - METER CALORIMETER</p>			
DRAWN		SCALE	MATL.	NO. REQD.	SHEET	DRWG. NO.	ITEM NO.	
GROUP	REPRESENTATIVE				OF

- (15) +15v.
- (17) -15v.
- (27) GROUND (POWER)
- (42) GROUND (SIGNAL)

NOTES:

- 1) ○ INDICATES NIM CONNECTOR P
- 2) >> INDICATES CIRCUIT BOARD CO
- 3) ⬡ INDICATES J3 CONNECTOR P
- 4) NUMBERS & LETTERS IN PARENTH CORRESPONDING POINT ON SECON
- 5) OP-10 HAS OFFSET ADJUSTMEN

TOLERANCES: UNLESS OTHERWISE NOTED	APPROVE FOR CON
FRACTIONAL TOL. $\pm \frac{1}{64}$	CHIEF ENG.
DECIMAL TOL. $\pm .005$	CHIEF DRAFTSM
ANGULAR TOL. $\pm \frac{1}{4}^\circ$	CHECKER
SURFACES TO BE WITHIN LIMITS OF COMMON PRODUCTION METH-ODS ASA B46.1 FIG. 19 (1959)	DRAWN
	GROUP

UNLESS NOTED $\pm \frac{1}{64}$ $\pm .005$ $\pm \frac{1}{4}$ LIMITS IN METH. (1988)	APPROVED FOR CONST.		ARGONNE NATIONAL LABORATORY		SYM.	CHANGE	DATE	BY
	CHIEF ENG.		This drawing is the property of the Argonne National Laboratory		PART $\frac{1}{2}$ T3 CONTROL MODULE			
	CHIEF DRAFTSMAN	G.Y.			ASSEMBLY 4 - METER CALORIMETER			
	CHECKED		SCALE	MATL.	NO. REQD.	SHEET OF	CIRCUIT BOARD NUMBER	ITEM NO.
DRAWN					6PC 258			
GROUP	REPRESENTATIVE

TOLERANCES: UNLESS OTHERWISE NOTED		APPROVED FOR CONST.	
FRACTIONAL TOL.	$\pm \frac{1}{64}$	CHIEF ENG.	
DECIMAL TOL.	$\pm .005$	CHIEF DRAFTSMAN	
ANGULAR TOL.	$\pm \frac{1}{4}^\circ$	CHECKED	
SURFACES TO BE WITHIN LIMITS OF COMMON PRODUCTION METHODS ASA B46.1 FIG. 19 (1959)		DRAWN	
		GROUP	REP

NOTES-

1. All Amplifiers OP-10 CY.
2. All Resistors Vishay S102 Except "M.F." Indicates Metal Film.
3. All Pots Vishay 1240 W.
4. All Capacitances Are μ F.
5. $\diamond$ Refers To Test Points.
6. Printed Circuit 6PC257

APPROVED FOR CONST.		ARGONNE NATIONAL LABORATORY		SYM.	CHANGE	DATE	BY
CHIEF ENG.		This drawing is the property of the Argonne National Laboratory		PART 4-Meter Calorimeter			
CHIEF DRAFTSMAN				ASSEMBLY T ₃ Preamplifier			
CHECKED		SCALE	MATL.	NO. REVD.	SHEET OF	DRWG. NO.	ITEM NO.
DRAWN							
GROUP	REPRESENTATIVE						

TEST POINT TABLE

Test Point Number	Signal Description	DAS Connector Pin Number
1	T ₃ Right Heater Voltage	J ₁ - 8
2	T ₃ Right Heater Control	J ₁ - 7
3	Calibration Voltage	J ₁ - 6
4	Calibration Current	J ₁ - 5
5	T ₃ Left Heater Voltage	J ₁ - 4
6	T ₃ Left Heater Current	J ₁ - 3
7	T ₂ Heater Voltage	J ₁ - 2
8	T ₂ Heater Current	J ₁ - 1
9	T ₂ Right Coarse (Preamp)	J ₁ - 9
10	T ₃ Right Fine (Preamp)	J ₁ - 10
11	T ₃ Left Coarse (Preamp)	J ₁ - 11
12	T ₃ Left Fine (Preamp)	J ₁ - 21
13	T ₂ Coarse (Preamp)	J ₁ - 22
14	T ₂ TFine (Preamp)	J ₁ - 23
15	T ₂ Coarse	J ₁ - 24
16	T ₁ Fine	J ₁ - 25
17	T ₁ Right Summing Point	J ₁ - 3
18	T ₃ Left Summing Point	J ₂ - 4
19	T ₃ Summing Point	J ₂ - 5
20	T ₂ Summing Point	J ₂ - 6
21	Calibration Power Amp Drive	J ₂ - 7
22	Calibrator Power Amp Output	J ₂ - 8
23	T ₂ Power Amp Drive	J ₂ - 9
24	T ₂ Power Amp Output	J ₂ - 10
25	T ₂ Power Amp Drive	J ₂ - 2
26	T ₁ Power Amp Output	J ₂ - 20
27	No connection to calorimeter	J ₂ - 19
28		J ₂ - 18
29		J ₂ - 17
30		J ₂ - 16
31		J ₂ - 15
32		J ₂ - 14

APPENDIX B
DATA ACQUISITION SYSTEM

I. CIRCUIT DIAGRAMS #1-7

1. Keyboard layout and connections
2. Keyboard decode
3. Analog multiplexer
4. Display
5. Analog output
6. Printer output
7. 8085 microprocessor system

DRAWING NO. EL -		ISSUE
SHEET	OF	

$\frac{L}{K}$	$\frac{J}{M}$	$\frac{I}{O}$	$\frac{P}{N}$	$\frac{Q}{R}$
INIT	RUN	P.	SP	FRAC
$\frac{Z}{J}$	$\frac{V}{L}$	$\frac{W}{N}$	$\frac{T}{H}$	$\frac{U}{I}$
YES		PRNT	CAL	TP
$\frac{U}{E}$	$\frac{V}{F}$	$\frac{W}{G}$	$\frac{X}{H}$	$\frac{Y}{I}$
5	6	7	8	9
$\frac{P}{=}$	$\frac{Q}{A}$	$\frac{R}{B}$	$\frac{S}{C}$	$\frac{T}{D}$
L	1	2	3	4
		NUMB.	SHIFT	SPACE
RST	EXT	BS	.	ENTR

Y1-1, 9, 17, 25
Y2-2, 10, 18, 33
Y3-3, 4, 26, 34
Y4-11, 12, 19, 20
Y5-27, 28, 35, 36

X1-8, 14, 30, 31, 48
X2-7, 13, 16, 32, 47
X3-6, 15, 22, 24, 46
X4-5, 21, 23, 32, 37

A 38 RST
B 41 EXT
C 42 BS
D 45 DP
E 49 ENTR
F PAPER ADV

GND 39, 40, 43, 44, 50, PAPER ADV.

ELECTRONICS DIVISION ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	TITLE KEYBOARD LAYOUT AND CONNECTIONS			DRAWING NO. EL -	
	DESIGN BY			DRN. BY	DATE
BUILT FOR		DIV.	CHK. BY	APPD. BY	SYSTEM NO.

DRAWING NO. EL -		ISSUE
SHEET	OF

ELECTRONICS DIVISION ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	TITLE KEYBOARD DECODE		DRAWING NO. EL -	
	DESIGN BY		DRN. BY	DATE
	BUILT FOR		CHK. BY	APPD. BY
	DIV.		SYSTEM NO.	

EL-23 (12-75)

DIVISION	TITLE ANALOG MULTIPLEXER				DRAWING NO. EL -	
LABORATORY					SHEET 3 OF 3	
PROPERTY OF	DESIGN BY		DRN. BY		DATE	
LABORATORY	BUILT FOR		CHK. BY		APPD. BY	
					MODEL NO.	
					SYSTEM NO.	

OUT 3A
IC "H"

8170
8171
8172
8173

OUT 39
IC "H"

80
81
82
83
84
85
86

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DRAWING NO.		ISSUE
EL -		
SHEET	OF

S DIVISION
AL LABORATORY
THE PROPERTY OF
ONAL LABORATORY

TITLE

ANALOG OUTPUT

DRAWING NO.

EL -

SHEET 5 OF 2

MODEL NO.

SYSTEM NO.

DESIGN BY

DRN. BY

DATE

BUILT FOR

DIV.

CHK. BY

APPD. BY

ELECTRONICS DIVISION

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DRAWING NO. EL -		ISSUE
SHEET	OF	

DIP SOCKET

⑧ B2

⑦ B4

⑤ B5

④ B6

⑥ B7

③ B8

⑩ B9

+15

① (A6
A12
B1)

4.7K

⑫ A2

⑪ A4

⑬ B12

⑭ B11

② A9

+5

2.2K

⑨ A7
EOT SW

⑮ A8

BUSY

B1

IN 33
IC "I"

Bφ

⑩ A11

+15

+ 2000/25

PWR END

(A1
A10
B10)

VISION BRATORY PROPERTY OF LABORATORY	TITLE PRINTER OUTPUT			DRAWING NO. EL -	
				SHEET 6 OF 7	
	DESIGN BY	DRN. BY	DATE	MODEL NO.	
	BUILT FOR	DIV.	CHK. BY	APPD. BY	SYSTEM NO.

ELECTRONICS DIVISION
 ARMOHNE NATIONAL LABORATORY
 THIS DRAWING IS THE PROPERTY OF
 THE ARMOHNE NATIONAL LABORATORY

TITLE
 8085 μ P SYSTEM

DESIGN BY

BUILT FOR

REVISION NO.

REVISIONS

DATE BY

DRAWING NO.

DATE BY

DATE

DIV.

SHEET 2 OF 2

MODEL NO.

SYSTEM NO.

```

0000 3E46      BGIN:MVI A,46H
0002 D320      OUT 20H ;STOP COUNTER INIT 20-27
0004 3E4F      MVI A,4FH
0006 D328      OUT 28H ;STOP COUNTER INIT 28-2F
0008 3E40      MVI A,40H
000A D330      OUT 30H ;STOP COUNTER INIT 30-37
000C 3E4F      MVI A,4FH
000E D338      OUT 38H ;STOP COUNTER INIT 38-3F
0010 3E0F      MVI A,0FH
0012 D33A      OUT DISD ;DISPLAY DATA
0014 3E3F      MVI A,3FH
0016 D339      OUT DIS ;DISPLAY CONTROL 'OFF'
0018 AF        XRA A ;GET A ZERO
0019 D339      OUT DIS
001B D338      OUT LED ;LED'S OFF
001D D33A      OUT DISD
001F 3E40      MVI A,40H
0021 C34000    JMP 40H
0024          ORG 24H ;TRAP=RESET
0026 C30000    JMP BGIN
0028          ORG 2CH ;RST 5.5=TERMINAL COUNT
002A          JMP TC
002C          ORG 34H ;RST 6.5=PAPER ADVANCE
002E          CALL CRLF
0030          EI
0032          RET
0034          ORG 3CH ;RST 7.5=EXTERNAL FROM
0036          JMP 1800H
0038          ORG 40H
003A          OUT DIS ;DP OFF
003C          XRA A
003E          OUT DIS
0040          LXI SP,STACK
0042          CALL DTOA
0044          MVI A,85H
0046          STA MOTOR
0048          CALL CRLF
004A          MVI C,01
004C          LXI D,8000H
004E          LXI H,F
0050          CALL STOR
0052          MVI C,00H
0054          LXI D,00000H
0056          LXI H,SSQ
0058          CALL STOR
005A          LXI H,MSG1
005C          CALL SCRIN
005E          CALL RLK1
0060          LXI H,MSG2
0062          CALL SCRIN
0064          LXI SP,STACK
0066          CALL CRLF
0068          MVI A,01H ;BUSY NOT LED
006A          OUT LED
006C          MVI A,08H ;MASK FOR RST INTERRUPTS
006E          DB 30H ;"SIM" INSTRUCTION
0070          ;
0072          ;
0074          ;
0076          ;
0078          ;
007A          ;
007C          ;
007E          ;
0080          ;
0082          ;
0084          ;
0086          ;
0088          ;
008A          ;
008C          ;
008E          ;
0090          ;
0092          ;
0094          ;
0096          ;
0098          ;
009A          ;
009C          ;
009E          ;
00A0          ;
00A2          ;
00A4          ;
00A6          ;
00A8          ;
00AA          ;
00AC          ;
00AE          ;
00B0          ;
00B2          ;
00B4          ;
00B6          ;
00B8          ;
00BA          ;
00BC          ;
00BE          ;
00C0          ;
00C2          ;
00C4          ;
00C6          ;
00C8          ;
00CA          ;
00CC          ;
00CE          ;
00D0          ;
00D2          ;
00D4          ;
00D6          ;
00D8          ;
00DA          ;
00DC          ;
00DE          ;
00E0          ;
00E2          ;
00E4          ;
00E6          ;
00E8          ;
00EA          ;
00EC          ;
00EE          ;
00F0          ;
00F2          ;
00F4          ;
00F6          ;
00F8          ;
00FA          ;
00FC          ;
00FE          ;
0000          ;

```

```

0085 FB      EI
0086 CDA700  EOR1: CALL INB
0089 FE0A    CPI 0AH      ;NUMERIC?
008B DAB600  JC EOR1      ;NO COMMAND
           3E FE14    CPI 14H
0090 D2B600  JNC EOR1     ;NO COMMAND
0093 D60A    SUI 0AH
0095 47      MOV B,A
0096 87      ADD A        ;X2
0097 80      ADD B        ;X3
009B 214016  LXI H,COMM
009B 5F      MOV E,A
009C 1600    MVI D,0
009E 19      DAD D
009F 117B00  LXI D,EOR
00A2 D5      PUSH D       ;RETURN ADDRESS
00A3 AF      XRA A
00A4 D33B    OUT LED
00A6 E9      PCHL
00A7 DB23    INB: IN KST
00A9 E604    ANI 04H
00AB C2A700  JNZ INB
00AE DB21    INBC: IN KEY
00B0 47      MOV B,A
00B1 DB23    INBB: IN KST
00B3 E604    ANI 04H
00B5 DB21    IN KEY
00B7 CAB100  JZ INBB
00BA 78      MOV A,B
00BB E6B0    ANI ENTR
00BD C2CD00  JNZ INBA
00C0 78      MOV A,B
00C1 E640    ANI 40H      ;DP
00C3 C2CD00  JNZ INBA
00C6 78      MOV A,B
00C7 E620    ANI 20H      ;BS
00C9 78      MOV A,B
00CA C8      RZ
00CB 3E20    MVI A,20H
00CD 47      INBA: MOV B,A
00CE C9      RET
00CF 46      SCRN: MOV B,M  ;GET CHAR
00D0 3E0D    MVI A,0DH
00D2 B8      CMP B        ;CR? END
00D3 C8      RZ
00D4 CD6D01  CALL OUTB ;OUTPUT
00D7 23      INX H
00D8 C3CF00  JMP SCRN
00DB CDE200  CRLF: CALL HOME
00DE CD5501  CALL LJST
00E1 C9      RET
00E2 DB33    HOME: IN 33H  ;EOT SWITCH
00E4 E601    ANI 01H      ;MASK
00E6 C8      RZ
00E7 CD0F01  CALL GORT ;STEP RIGHT
           EA C3E200  JMP HOME

```

00ED E5	GOLF: PUSH H
00EE F5	PUSH PSW
00EF 218030	LXI H,MOTOR
00F2 7E	MOV A,M
03 CDFD00	CALL GLF1
00F6 77	MOV M,A
00F7 CD3A01	CALL PRNT
00FA F1	POP PSW
00FB E1	POP H
00FC C9	RET
00FD FE85	GLF1: CPI 85H
00FF CA3701	JZ SET6
0102 FE86	CPI 86H
0104 CA3401	JZ SETA
0107 FE8A	CPI 8AH
0109 CA3101	JZ SET9
010C 3E85	MVI A,85H
010E C9	RET
010F E5	GORT: PUSH H
0110 F5	PUSH PSW
0111 218030	LXI H,MOTOR
0114 7E	MOV A,M
0115 CD1F01	CALL GRT1
0118 77	MOV M,A
0119 CD3A01	CALL PRNT
011C F1	POP PSW
011D E1	POP H
011E C9	RET
011F FE85	GRT1: CPI 85H
0121 CA3101	JZ SET9
0124 FE89	CPI 89H
0126 CA3401	JZ SETA
0129 FE8A	CPI 8AH
012B CA3701	JZ SET6
012E 3E85	MVI A,85H
0130 C9	RET
0131 3E89	SET9: MVI A,89H
0133 C9	RET
0134 3E8A	SETA: MVI A,8AH
0136 C9	RET
0137 3E86	SET6: MVI A,86H
0139 C9	RET
013A D322	PRNT: OUT 22H
013C 3E08	MVI A,08H
013E D323	OUT 23H
0140 AF	XRA A
0141 D323	OUT 23H
0143 DB33	PNT1: IN 33H
0145 E602	ANI 02H
0147 CA4301	JZ PNT1
014A E5	PUSH H
014B 267D	MVI H,125 ;3 MS
014D E3	PNT2: XTHL
014E E3	XTHL
014F 25	DCR H
30 C24D01	JNZ PNT2

```

0153 E1      POP H
0154 C9      RET
0155 D5      LJST: PUSH D
0156 CDE200   CALL HOME
          39 1615      MVI D,21
015B CDE000   L1:  CALL GOLF
015E 15      DCR D
015F C25B01   JNZ L1
0162 AF      XRA A
0163 32B130   STA DIGT      ;DIGIT COUNT
0166 D1      POP D
0167 C9      RET
0168 CD6B01   BLK2: CALL BLK1
016B 0620     BLK1: MVI B,20H
016D 7B      OUTB: MOV A,B
016E FE0D     CPI 0DH      ;CR?
0170 CADB00   JZ CRLF
0173 FE0A     CPI 0AH      ;LF?
0175 CADB00   JZ CRLF
0178 FE0B     CPI 0BH      ;BS?
017A CAED00   JZ GOLF
017D F5      PUSH PSW
017E C5      PUSH B
017F 3AB130   LDA DIGT
0182 3C      INR A
0183 32B130   STA DIGT
0186 FE13     CPI 19      ;18 DIGITS ONLY
0188 CDB000   CZ CRLF     ;GET NEW LINE
018B C1      POP B
          8C F1      POP PSW
          3D E67F     ANI 7FH
018F CD3A01   CALL PRNT ;OUTPUT IT
0192 CD0F01   CALL GORT ;MOVE HEAD
0195 C9      RET
0196 3AB130   BS:  LDA DIGT
0199 FE00     CPI 0
019B C2ED00   JNZ GOLF
019E C9      RET
019F DB3B     IN5:  IN LED
01A1 F602     ORI 02H    ;RSVP
01A3 D33B     OUT LED
01A5 2100FF   LXI H, OFF00H
01A8 00      NOP
01A9 00      NOP
01AA 2E00     MVI L,0
01AC 0E00     MVI C,0
01AE 110000   LXI D,0
01B1 CDEB01   CALL LIN1
01B4 4F      MOV C,A
01B5 C2C101   JNZ IN5A
01B8 00      NOP
01B9 7C      MOV A,H
01BA FEFF     CPI 0FFH
01BC CA9F01   JZ IN5
01BF 00      NOP
          30 00      NOP

```



```

01C1 CDEB01      INSA: CALL LIN1
01C4 87          ADD A
01C5 87          ADD A
01C6 87          ADD A
01C7 87          ADD A
01C8 57          MOV D,A
01C9 00          NOP
01CA CDEB01      CALL LIN1
01CD 47          MOV B,A
01CE 7A          MOV A,D
01CF E6F0        ANI 0F0H
01D1 B0          ORA B
01D2 57          MOV D,A
01D3 CDEB01      CALL LIN1
01D6 87          ADD A
01D7 87          ADD A
01D8 87          ADD A
01D9 87          ADD A
01DA 5F          MOV E,A
01DB 00          NOP
01DC CDEB01      CALL LIN1
01DF 47          MOV B,A
01E0 78          MOV A,E
01E1 E6F0        ANI 0F0H
01E3 B0          ORA B
01E4 5F          MOV E,A
01E5 CDEB01      LIN2: CALL LIN1
01E8 C3E501      JMP LIN2
01EB CDA700      LIN1: CALL IN8
01EE FE80        CPI ENTR
01F0 CA2602      JZ LIN3
01F3 FE20        CPI BSP
01F5 CA1202      JZ BACK
01F8 FE40        CPI DP
01FA CA0902      JZ LIN4
01FD FEOA        CPI OAH
01FF D2EB01      JNC LIN1 ;NOT NUMERIC
0202 CD4402      CALL IN0
0205 2C          INR L
0206 E60F        ANI 0FH
0208 C9          RET
0209 65          LIN4: MOV H,L
020A 062E        MVI B,2EH ;ASCII DP
020C CD6D01      CALL OUT8
020F C3EB01      JMP LIN1
0212 0608        BACK: MVI B,0BH
0214 CD6D01      CALL OUT8
0217 E3          BCK1: XTHL
0218 7D          MOV A,L
0219 D60C        SUI 12
021B 6F          MOV L,A
021C 7C          MOV A,H
021D DE00        SBI 0
021F 67          MOV H,A
0220 E3          XTHL
0221 7C          MOV A,H

```

```

0222 BD      CMP L
0223 C8      RZ
0224 2D      DCR L
0225 C9      RET
    26 DB3B   LIN3: IN LED
0228 E6FD    ANI OFDH
022A D33B    OUT LED ;RSVP NOT
022C 7C      MOV A,H
022D FEFF    CPI OFFH
022F CA3F02  JZ LIN5
0232 B7      ORA A
0233 CA3B02  JZ LIN6
0236 7C      MOV A,H
0237 3D      DCR A
0238 47      MOV B,A
0239 E1      POP H
023A C9      RET
023B 0641    LIN6: MVI B,41H
023D E1      POP H
023E C9      RET
023F 7D      LIN5: MOV A,L
0240 3D      DCR A
0241 47      MOV B,A
0242 E1      POP H
0243 C9      RET
0244 FE40    IN0: CPI 40H
0246 C24E02  JNZ $+8
0249 062E    MVI B,2EH ;ASCII DP
024B C35102  JMP $+6
024E C630    ADI 30H
    50 47     MOV B,A
0251 CD6D01  CALL OUTB
0254 78      MOV A,B
0255 C9      RET
0256 D5      GETB: PUSH D
0257 46      MOV B,M
0258 23      INX H
0259 56      MOV D,M
025A 23      INX H
025B 5E      MOV E,M
025C 23      INX H
025D EB      XCHG
025E D1      POP D
025F C9      RET
0260 4E      GETC: MOV C,M
0261 23      INX H
0262 56      MOV D,M
0263 23      INX H
0264 5E      MOV E,M
0265 23      INX H
0266 C9      RET
0267 71      STOR: MOV M,C
0268 23      INX H
0269 72      MOV M,D
026A 23      INX H
    5B 73     MOV M,E

```

```

026C 23          INX H
026D C9          RET
026E 78          SWAP: MOV A,B
026F 41          MOV B,C
       70 4F      MOV C,A
0271 EB          XCHG
0272 C9          RET
0273 CD6002      OUTH: CALL GETC ;GET DATA
0276 CD000C      OUTB: CALL HEXB ;MAKE BCD
0279 2E05        OUTD: MVI L,5 ;# OF DIGITS
027B 79          MOV A,C
027C B7          ORA A
027D CAEC02      JZ ZERO
0280 78          MOV A,B
0281 E67F        ANI 7FH
0283 67          MOV H,A
0284 78          MOV A,B
0285 E680        ANI 80H
0287 062D        MVI B,'-'
0289 C46D01      CNZ OUTB
028C 7C          MOV A,H
028D E640        ANI 40H ;EXP SIGN
028F CAC002      JZ OUT3 ;POS EXP
0292 7C          MOV A,H
0293 FE44        CPI 44H
0295 D2F202      JNC OUTF-1 ;FLOAT PT OUT
0298 E603        ANI 03H
029A 67          MOV H,A
029B 0630        MVI B,'0'
029D CD6D01      CALL OUTB
       A0 062E    MVI B,'.'
02A2 CD6D01      CALL OUTB
02A5 0630        OUT1: MVI B,'0'
02A7 25          DCR H
02A8 CAB502      JZ OUT2
02AB FAEC02      JM ZERO
02AE 2D          DCR L
02AF CD6D01      CALL OUTB
02B2 C3A502      JMP OUT1
02B5 CD2C03      OUT2: CALL OUF2
02B8 CDDC02      CALL DIGIT
02BB 2D          DCR L
02BC C2B502      JNZ OUT2
02BF C9          RET
02C0 7C          OUT3: MOV A,H
02C1 FE05        CPI 5
02C3 D2F202      JNC OUTF-1 ;FLOAT PT OUT
02C6 24          INR H
02C7 CD2C03      OUT4: CALL OUF2
02CA CDDC02      CALL DIGIT
02CD 2D          DCR L
02CE C8          RZ
02CF 25          DCR H
02D0 CCD602      CZ OUT5
02D3 C3C702      JMP OUT4
       76 062E    OUT5: MVI B,'.'

```

```

02D8 CD6D01      CALL OUT8
02DB C9          RET
02DC 41          DIGIT: MOV B,C
02DD 7A          MOV A,D
       7E E6F0    ANI OF0H
02E0 0F          RRC
02E1 0F          RRC
02E2 0F          RRC
02E3 0F          RRC
02E4 4F          MOV C,A
02E5 EB          XCHG
02E6 29          DAD H
02E7 25          DAD H
02E8 29          DAD H
02E9 29          DAD H
02EA EB          XCHG
02EB C9          RET
02EC 0630        ZERO: MVI B,'0'
02EE CD6D01      CALL OUT8
02F1 C9          RET
;PRINT A DECIMAL FLOATING POINT NUMBER
;NO SIGN IS PRINTED
02F2 44          MOV B,H
02F3 C5          QUTF: PUSH B
02F4 78          MOV A,B
02F5 CD2C03      CALL DUF2
02F8 062E        MVI B,'.'
02FA CD6D01      CALL OUT8
02FD 2E04        MVI L,4
02FF CD0C02      CALL DIGIT
       02 CD2C03  DUF1: CALL DUF2
0305 CD0C02      CALL DIGIT
0308 41          MOV B,C
0309 2D          DCR L
030A C20203      JNZ DUF1
030D CD6B01      CALL BLK1
0310 0645        MVI B,'E'
0312 CD6D01      CALL OUT8
0315 C1          POP B
0316 48          MOV C,B
0317 78          MOV A,B
0318 E640        ANI 40H ;EXP SIGN
031A 062D        MVI B,'-'
031C C46D01      CNZ OUT8
031F 79          MOV A,C
0320 E630        ANI 30H
0322 CA2C03      JZ DUF2
0325 07          RLC
0326 07          RLC
0327 07          RLC
0328 07          RLC
0329 CD2D03      CALL DUF2+1
032C 79          DUF2: MOV A,C
032D E60F        ANI 0FH
032F C630        ADI 30H
       31 47      MOV B,A

```

```

0332 CD6D01      CALL OUT8
0335 C9          RET
;OUTPUT TO THE DISPLAY A NUMBER BETWEEN
;0.001 THRU 99.999 AND 0
DISH: CALL GETC
DISB: PUSH PSW
          PUSH B
          PUSH D
          PUSH H
          CALL HEXB
DISP: CALL PTCK ;PRINT CHECK
          PUSH B
          POP H
          SHLD OLDD
          PUSH D
          POP H
          SHLD OLDD+2
          MOV A,C
          ORA A
          JZ DIS6 ;ZERO
          MVI A,0FH ;BLANK
          OUT DISD ;DISPLAY DATA
          MOV A,B
          ANI 80H
          JZ S+7
          MVI A,0EH ;'-'
          OUT DISD
          MVI A,20H ;MSD
          CALL DISC
          MOV A,B
          ANI 3FH
          CPI 3
          JNC DIS6
          MOV A,B
          ANI 40H
          JZ DIS2 ;POS EXP
          MVI A,1 ;LEFT DP
          OUT DISD
          MVI A,40H
          CALL DISC
          MOV A,B
          ANI 0FH
          MOV L,A ;NEG EXP
          MVI H,5 ;NUMBER OF DIGITS
          XRA A
          OUT DISD
          MVI A,10H
          DCR L
          JZ DIS1+1
          CALL DISC
          DCR H
          RRC
          DCR L
          JZ DIS1+1
          CALL DISC
          DCR H
          77 25

```

```

0398 0F          DIS1: RRC
0399 F5          PUSH PSW
039A 79          MOV A,C
039B D33A        OUT DISD
          7D F1    POP PSW
          039E C0F04 CALL DISC
03A1 F5          PUSH PSW
03A2 CDDC02      CALL DIGIT      ;SHIFT DIGITS
03A5 F1          POP PSW
03A6 25          DCR H          ;# OF DIGITS
03A7 C29803      JNZ DIS1      ;NEXT OUTPUT
03AA C3D603      JMP DIS5
03AD 78          DIS2: MOV A,B
03AE E603        ANI 03H
03B0 47          MOV B,A
03B1 04          INR B
03B2 05          DCR B
03B3 3E02        MVI A,02H ;SECOND DP
03B5 CABA03      JZ DIS3
03B8 3E04        MVI A,04H
03BA D33A        DIS3: OUT DISD
03BC 3E40        MVI A,40H
03BE C0F04      CALL DISC
03C1 2605        MVI H,5
03C3 0610        MVI B,10H
03C5 79          DIS4: MOV A,C
03C6 D33A        OUT DISD
03C8 78          MOV A,B
03C9 C0F04      CALL DISC
03CC CDD002      CALL DIGIT+1
          3F 78    MOV A,B
03D0 0F          RRC
03D1 47          MOV B,A
03D2 25          DCR H
03D3 C2C503      JNZ DIS4
03D6 E1          DIS5: POP H
03D7 D1          POP D
03D8 C1          POP B
03D9 F1          POP PSW
03DA C9          RET
03DB AF          DIS6: XRA A
03DC D33A        OUT DISD
03DE 3E5F        MVI A,5FH
03E0 C0F04      CALL DISC
03E3 C3D603      JMP DIS5
03E6 3E0F        DISE: MVI A,0FH ;ERROR
03EB D33A        OUT DISD
03EA 3E3F        MVI A,3FH
03EC C0F04      CALL DISC
03EF AF          XRA A
03F0 D33A        OUT DISD
03F2 3E40        MVI A,40H
03F4 C0F04      CALL DISC
03F7 C3D603      JMP DIS5
          ;DISPLAY AN INTERGER NUMBER
          FA F5    DIS1: PUSH PSW

```

```

03FB C5          PUSH B
03FC D5          PUSH D
03FD E5          PUSH H
03FE CD1704      CALL PTCK          ;PRINT CHECK
    J1 3E0F      MVI A,0FH
0403 D33A        OUT DISD
0405 3E20        MVI A,20H
0407 CD0F04      CALL DISC
040A 3E00        MVI A,0
040C C3BA03      JMP DIS3
040F F5          DISC: PUSH PSW
0410 D339        OUT 39H          ;CONTROL PORT
0412 AF          XRA A
0413 D339        OUT 39H
0415 F1          POP PSW
0416 C9          RET
0417 DB23        PTCK: IN KST
0419 E604        ANI 04H
041B C0          RNZ
041C C5          PUSH B
041D CDA700      CALL INB
0420 FE0E        CPI 0EH          ;PRINT?
0422 C1          POP B
0423 C0          RNZ
0424 F5          PUSH PSW
0425 C5          PUSH B
0426 D5          PUSH D
0427 E5          PUSH H
0428 2ABD30      LHL D OLDD
    ^2B E5        PUSH H
    2C C1         POP B
042D 2ABF30      LHL D OLDD+2
0430 EB          XCHG
0431 CD7902      CALL OUTD          ;PRINT
0434 CDD800      CALL CRLF
0437 C3D603      JMP DIS5
;GET ANALOG VOLTAGE AND RETURN IN BI FP
;'A' CONTAINS MULTIPLEXER INPUT NUMBER
;OVERFLOW OF A/D RETURNS FP OF 1FFFH
043A E61F        ATOD: ANI 1FH
043C D329        OUT MUL
043E F5          PUSH PSW
043F DB3B        IN LED
0441 F608        ORI 08H
0443 D33B        OUT LED
0445 3E85        MVI A,133          ;1 MS DELAY
0447 3D          DCR A
0448 C24104      JNZ 5-7
044B DB29        IN MUL
044D F620        ORI 20H
044F D329        OUT MUL          ;START A/D
0451 E61F        ANI 1FH
0453 D329        OUT MUL
0455 DB32        AD1: IN AD+1
0457 E640        ANI 40H
    59 CA5504     JZ AD1          ;A/D BUSY

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045C DB32      IN AD+1
045E E620      ANI 20H
0460 CA6C04    JZ AD2
0463 11FF1F    LXI D,1FFFH      ;OVERFLOW
          56 010000    LXI B,0
          0469 C37D04    JMP AD3
046C DB32      AD2: IN AD+1
046E E610      ANI 10H      ;SIGN
0470 CAA104    JZ AD4      ;POSITIVE
0473 DB32      IN AD+1
0475 2F        CMA
0476 E60F      ANI 0FH      ;MS BITS
0478 57        MOV D,A
0479 DB31      IN AD
047B 2F        CMA
047C 5F        MOV E,A
047D CD390E    AD3: CALL FLOT ;FP OF A/D
0480 DB32      IN AD+1
0482 07        RLC
0483 07        RLC
0484 07        RLC
0485 E680      ANI 80H      ;SIGN
0487 B1        ORA C
0488 4F        MOV C,A
0489 0678      MVI B,78H
048B 2178EF    LXI H,0EF78H ;4096 FOR 15V FS
048E CD2C0F    CALL MULT
0491 0678      MVI B,78H
0493 21EFFF    LXI H,0FEFFH
0496 CD860E    CALL ADD1
          79 DB32      IN LED
049B E6F7      ANI 0F7H
049D D33B      OUT LED
049F F1        POP PSW
04A0 C9        RET
04A1 DB32      AD4: IN AD+1
04A3 E60F      ANI 0FH      ;MS BITS
04A5 57        MOV D,A
04A6 DB31      IN AD
04A8 C37C04    JMP AD3-1
;GET TWO A/D'S AND MULTIPLY TOGETHER
;ALSO MULTIPLY BY POWER CONSTANT
;MAKE 10 MEASUREMENTS AND AVERAGE AND DISPLAY THEM
;ASSUME "E" MULTIPLEX COMES IN "A"
;ASSUME "I" MULTIPLEX = "E"+1
PWR: STA PLEX
      CALL CLR ;ZERO REGISTERS
      LXI H,POWER
      CALL STOR
      MVI A,10
PWR1: PUSH PSW
      LDA PLEX ;MULTIPLEXER OUTPUT
      CALL PWR3
      LDA PLEX ;WHICH COIL?
      CPI 00H
      JNZ PWR4
04AB 328530
04AE CD970F
04B1 218230
04B4 CD6702
04B7 3E0A
04B9 F5
04BA 3A8530
04BD CD1905
04C0 3A8530
04C3 FE00
          25 C2DD04

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04C8 219530      LXI H,HFP      ;STORE RT-PWR
04CB CD6702      CALL STOR
04CE 00          NOP
04CF 3E04        MVI A,04H
                71 CD1905      CALL PWR3      ;MEAS LT-PWR
04D4 219530      LXI H,HFP
04D7 CD5602      CALL GETB
04DA CD860E      CALL ADD1      ;PWR=RT-PWR+LT-PWR
04DD 218230      PWR4: LXI H,POWER
04E0 CD5602      CALL GETB
04E3 CD860E      CALL ADD1
04E6 218230      LXI H,POWER
04E9 CD6702      CALL STOR
04EC F1          POP PSW      ;NUMBER OF ADDS
04ED 3D          DCR A
04EE C2B904      JNZ PWR1
04F1 0604        MVI B,04H
04F3 2100A0      LXI H,0A000H  ;TEN
04F6 CD6E02      CALL SWAP
04F9 CD7C0F      CALL DIV
04FC C5          PUSH B
04FD D5          PUSH D
04FE 3AAC30      LDA DCNT
0501 E601        ANI 01H
0503 CA1305      JZ PWR2
0506 2AAC30      LHLD DCNT
0509 EB          XCHG
050A CDA70D      CALL BIND
050D CDAF03      CALL DISI
0510 C31605      JMP PWR2+3
                13 CD3903      PWR2: CALL DISB      ;DISPLY ALT PWR & PT
0516 D1          POP D
0517 C1          POP B
0518 C9          RET
0519 CD3A04      PWR3: CALL ATOD      ;MEAS E
051C D5          PUSH D
051D C5          PUSH B      ;SAVE MEASUREMENT
051E 3C          INR A
051F CD3A04      CALL ATOD      ;MEAS I
0522 79          MOV A,C
0523 C1          POP B
0524 E1          POP H      ;GET 1ST MEASMT
0525 41          MOV B,C
0526 4F          MOV C,A
0527 CD2C0F      CALL MULT      ;PWR=EXI
052A 067B        MVI B,7BH
052C 21D7A3      LXI H,0A3D7H  ;PWR CONST.
052F CD2C0F      CALL MULT
0532 79          MOV A,C
0533 E67F        ANI 7FH      ;POSITIVE PWR ONLY
0535 4F          MOV C,A
0536 C9          RET
                ;OUTPUT /A/ TO THE D TO A CONVERTER
0537 D32A        DTOA: OUT DA
0539 F5          PUSH PSW
                3A DB23        IN 23H

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053C F610	ORI 10H
053E D323	OUT 23H ;LOAD D/A
0540 E6EF	ANI 0EFH
0542 D323	OUT 23H
14 F1	POP PSW
0545 C9	RET
1660	ORG 1660H
1660 C37800	JMP EOR
1663 C3A700	JMP IN8
1666 C39F01	JMP IN5
1669 C36D01	JMP OUTB
166C C3CF00	JMP SCRNB
166F C3DB00	JMP CRLF
1672 C36801	JMP BLK1
1675 C36801	JMP BLK2
1678 C37302	JMP OUTH
167B C37602	JMP OUTB
167E C37902	JMP OUTD
1681 C3F302	JMP OUTF
1684 C33603	JMP DISH
1687 C33903	JMP DISB
168A C3FA03	JMP DISI
168D C33A04	JMP ATOD
1690 C33705	JMP DTOA
1693 C3AB04	JMP PWR
1696 C38E05	JMP SDEV
1699 C35005	JMP AVE
169C C36002	JMP GETC
169F C35602	JMP GETB
1A2 C36702	JMP STOR
A5 C36E02	JMP SWAP
16AB C3C101	JMP IN5A
16AB C34402	JMP IN0
16AE C3AE00	JMP IN8C
1640	ORG 1640H
1640 C37800	COMM: JMP EOR
1643 C36D13	JMP INIT
1646 C37800	JMP EOR
1649 C38008	JMP RUN
164C C37800	JMP EOR
164F C38607	JMP PO
1652 C3F009	JMP CAL
1655 C32712	JMP SPOW
1658 C3300B	JMP TEST
165B C30010	JMP FRAC
38FF =	STACK EQU 38FFH
003A =	DISD EQU 3AH
0039 =	IIS EQU 39H
003B =	LED EQU 3BH
170D =	MSG2 EQU 170DH
7000 =	TC EQU 7000H
0023 =	KST EQU 23H
0021 =	KEY EQU 21H
0080 =	ENTR EQU 80H
0020 =	BSP EQU 20H
30 =	HEXR EQU 0C00H

0040 =	DP EQU 40H
136D =	INIT EQU 136DH
0880 =	RUN EQU 0880H
1227 =	SPOW EQU 1227H
36 =	PO EQU 0786H
07F0 =	CAL EQU 09F0H
0830 =	TEST EQU 0B30H
1000 =	FRAC EQU 1000H
0031 =	AD EQU 31H
0029 =	MUL EQU 29H
002A =	DA EQU 2AH
0E39 =	FLOT EQU 0E39H
0F2C =	MULT EQU 0F2CH
1700 =	MSG1 EQU 1700H
0E86 =	ADD1 EQU 0E86H
0F7C =	DIV EQU 0F7CH
0F97 =	CLR EQU 0F97H
3080 =	MOTOR EQU 3080H
3081 =	DIGT EQU 3081H
3082 =	POWER EQU 3082H
3085 =	PLEX EQU 3085H
30BD =	OLDD EQU 30BDH
0550 =	AVE EQU 0550H
058E =	SDEV EQU 058EH
30C4 =	F EQU 30C4H
30C1 =	SSQ EQU 30C1H
30AC =	DCNT EQU 30ACH
0DA7 =	BIND EQU 0DA7H
3095 =	HFP EQU 3095H
30BB =	EPORT EQU 30BBH

```

;THIS STORES SUM OF PO-PN & SUM (PO-PN)SQ
;N IS THE NUMBER OF SAMPLES
;ASSUME POWER IS IN CDE IN BINARY FP
30
VJ50 2A8730
0553 23
0554 228730
0557 218930
055A CD9F16
055D CD830E
0560 218C30
0563 CDA216
0566 218F30
0569 CD9F16
056C CD860E
056F 218F30
0572 CDA216
0575 218C30
0578 CD9C16
057B CD2B0E
057E 219230
0581 CD9F16
0584 CD860E
0587 219230
058A CDA216
058D C9
AVE: LHL D N
      INX H
      SHLD N
      LXI H,PO
      CALL GETB
      CALL SUB1
      LXI H,PI
      CALL STOR
      LXI H,SUM
      CALL GETB
      CALL ADD1
      LXI H,SUM
      CALL STOR
      LXI H,PI
      CALL GETC
      CALL SQ
      LXI H,SMSQ
      CALL GETB
      CALL ADD1
      LXI H,SMSQ
      CALL STOR
      RET
;THIS ROUTINE CALCULATES THE MEAN
;AND THE DEVIATION FROM THE MEAN
;PAVE=PO-SUM(PO-PN)/N
;SIGM=((SUM(PO-PN)SQ-N(PAVE)SQ)/(N(N-1))+SSQ)SQRT
SDEV: LHL D N
      XCHG
      CALL FLOT
      LXI H,TEMV
      CALL STOR
      LXI H,SUM
      CALL GETB
      CALL DIV
      LXI H,PI
      CALL STOR
      CALL SQ ;(AVE)SQ
      LXI H,TEMV
      CALL GETB
      CALL MULT ;N(AVE)SQ
      LXI H,TEMV
      CALL STOR
      LXI H,PI
      CALL GETC
      LXI H,PO
      CALL GETB
      CALL SUB1
      LXI H,PAVE
      CALL STOR ;STORE AVERAGE POWER
      LHL D N ;# OF SAMPLES
      DCX H ;N-1

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```

05D5 EB
05D6 CD390E
05D9 219B30
05DC CDA216
      7F 2A8730
V.E2 EB
05E3 CD390E
05E4 219B30
05E9 CD9F16
05EC CD2C0F
05EF 219B30
05F2 CDA216
05F3 219230
05F8 CD9C16
05FB 219530
05FE CD9F16
0601 CD830E
0604 219B30
0607 CD9F16
060A CDA516
060D CD7C0F
0610 21C130
0613 CD9F16
0616 CD830E
0619 CDE30D
061C 219B30
061F CDA216
0622 C9

      ^23 DB3B
      25 F620
0627 D338
0629 2A9E30
062C C34106
062F 0E3C
0631 11B888
0634 E3
0635 E3
0636 1R
0637 7A
0638 B3
0639 C23406
063C 0D
063D C23106
0640 28
0641 E5
0642 EB
0643 CDA70D
0646 0E0F
0648 3EF0
064A B2
064B 57
064C CDBA16
064F E1
0650 7C
      31 B5

XCHG
CALL FLOT
LXI H,SIGM
CALL STOR
LHLD N
XCHG
CALL FLOT
LXI H,SIGM
CALL GETB
CALL MULT
LXI H,SIGM
CALL STOR
LXI H,SMSQ
CALL GETC
LXI H,TEMP
CALL SUB1
CALL SUB1
CALL GETB
CALL SWAP
CALL DIV
LXI H,SSR
CALL GETB
CALL SUB1
CALL SRT
LXI H,SIGM
CALL STOR
STORE SIGMA
RET

;DELAY IN MINUTES DELAY STORED AT TIME
DELA: IN LED
ORI 20H
OUT LED
LHLD TIME
JMP DEL3
DELO: MVI C,60
DELI: LXI D,35000
DEL2: XTHL
XTHL
DCX D
MOV A,D
ORA E
JNZ DEL2
NOT 1 SEC
DCR C
JNZ DEL1
NOT 1 MIN
DCX H
DEL3: PUSH H
XCHG
CALL BCD
MVI C,OFH
MVI A,OF0H
ORA D
MOV B,A
CALL DISI
POP H
MOV A,H
ORA L

```

```

0652 C22F06      JNZ DELO ;NOT TIME
0655 DB3B        IN LED
0657 E6DF        ANI 0DFH
0659 D33B        OUT LED
      3B C9       RET
;GET AND STORE POWER PROMPTS
065C AF          PRMT: XRA A
065D 32A030      STA FLAG1
0660 210F00      LXI H,15 ;DEFAULT TIME
0663 229E30      SHLD TIME
0666 0E7D        MVI C,7DH
0668 11CCCC      LXI D,0CCCC ;DEFAULT SIGMA=0.1
066B 21A130      LXI H,SIGF
066E CDA216      CALL STOR
0671 21B400      LXI H,180 ;DEFAULT #IP/RUN
0674 22A430      SHLD DAPT
0677 213017      LXI H,MSG6 ;PRINT ALL?
067A CD6C16      CALL SCRNI
067D CD7516      CALL BLK2
0680 CD0F07      CALL RSVP
0683 32A030      STA FLAG1
0686 FE0A        CPI YES
0688 CA9406      JZ PRM0
068B 21E917      LXI H,MSGQ ;NO
068E CD6C16      CALL SCRNI
0691 C39A06      JMP PRM1
0694 21E517      PRM0: LXI H,MSGF ;YES
0697 CD6C16      CALL SCRNI
069A CD6F16      PRM1: CALL CRLF
      9D 212517    LXI H,MSG5 ;DELAY-MIN
      A0 CD6C16    CALL SCRNI
06A3 CD7516      CALL BLK2
06A6 CD0F07      CALL RSVP
06A9 DAB906      JC PRM2
06AC CDFF0C      CALL BCDH
06AF CD630E      CALL FIXX
06B2 EB          XCHG
06B3 229E30      SHLD TIME
06B6 C3BF06      JMP PRM3
06B9 2A9E30      PRM2: LHLD TIME
06BC CD4307      CALL OUTI
06BF CD6F16      PRM3: CALL CRLF
06C2 211B17      LXI H,MSG4 ;SIGMA-Z
06C5 CD6C16      CALL SCRNI
06C8 CD7516      CALL BLK2
06CB CD0F07      CALL RSVP
06CE DADD06      JC PRM4
06D1 CDFF0C      CALL BCDH
06D4 21A130      LXI H,SIGF
06D7 CDA216      CALL STOR
06DA C3E306      JMP PRM5
06DD 21A130      PRM4: LXI H,SIGF
06E0 CD7B16      CALL OUTH
06E3 CD6F16      PRM5: CALL CRLF
06E6 211317      LXI H,MSG3 ;#IP/RUN
      E9 CD6C16    CALL SCRNI

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06EC CD7516	CALL BLK2
06EF CD0F07	CALL RSVP
06F2 DA0207	JC PRM6
06F5 CDF00C	CALL BCDH
78 CD63CE	CALL FIXX
06FB EB	XCHG
06FC 22A430	SHLD DAPT
06FF C30807	JMP PRM7
0702 2AA430	PRM6: LHLD DAPT
0705 CD4307	CALL OUTI
0708 CD6F16	PRM7: CALL CRLF
070B CD6F16	CALL CRLF
070E C9	RET
070F DB3B	RSVP: IN LED
0711 F602	ORI 02H
0713 D33B	OUT LED
0715 110000	LXI D,0
0718 CD6316	CALL INB
071B FE0A	CPI YES
071D 37	STC
071E CA3A07	JZ RSV1
0721 FEB0	CPI ENTR
0723 37	STC
0724 CA3A07	JZ RSV1
0727 213807	LXI H,RSV2
072A E5	PUSH H ;RETURN ADDRESS
072B CDAB16	CALL INQ
072E 4F	MOV C,A
072F 2101FF	LXI H,0FF01H
732 110000	LXI D,0
35 C3AB16	JMP IN5A
0738 37	RSV2: STC
0739 3F	CMC
073A F5	RSV1: PUSH PSW
073B DB3B	IN LED
073D E6FD	ANI 0FDH
073F D33B	OUT LED
0741 F1	POP PSW
0742 C9	RET
0743 EB	OUTI: XCHG
0744 CDA70D	CALL BCDI
0747 EB	XCHG
0748 7C	MOV A,H
0749 B7	ORA A
074A C44E07	CNZ OUT1
074D 65	MOV H,L
074E 7C	OUT1: MOV A,H
074F 0F	RRC
0750 0F	RRC
0751 0F	RRC
0752 0F	RRC
0753 E60F	ANI 0FH
0755 F630	ORI 30H ;MAKE ASCII
0757 47	MOV B,A
0758 CD6916	CALL OUTB
38 7C	MOV A,H

```

075C E60F      ANI 0FH
075E F630      ORI 30H ;MAKE ASCII
0760 47        MOV B,A
0761 CD6916    CALL OUTB
              RET
              ;WAIT UNTIL POWER LEVEL IS BELOW 35 MW
0765 DB3B      WAIT: IN LED
0767 F5        PUSH PSW
0768 3E20      MVI A,20H
076A D33B      OUT LED
076C 3E00      WAI1: MVI A,00
076E 32BB30    STA EPORT
0771 CD9316    CALL PWR
0774 0602      MVI B,02H
0776 2100B0    LXI H,8000H ;2W
0779 CD830E    CALL SUB1
077C 79        MOV A,C
077D E6B0      ANI 80H ;SIGN BIT
077F C26C07    JNZ WAI1 ;P>2W
0782 F1        POP PSW
0783 D33B      OUT LED
0785 C9        RET
              ;MEASURE 4MC SAMPLE PWR
0786 21BB17    EMPT:LXI H,MSGJ ;MEAS
0789 CD6C16    CALL SCRNI
078C CD6F16    CALL CRLF
078F CD5C06    CALL PRMT
0792 CD6507    CALL WAIT
0795 CD2306    CALL DELA
0798 3E00      EMP1: MVI A,0
079A 32BB30    STA EPORT
079D CDFD07    CALL MEAS
07A0 CD8E05    CALL SDEV
07A3 217017    LXI H,MSGA ;POWER MW
07A6 CD6C16    CALL SCRNI
07A9 CD6F16    CALL CRLF
07AC 219830    LXI H,PAVE
07AF CD7816    CALL OUTH
07B2 217A17    LXI H,MSGB ;+/-
07B5 CD6C16    CALL SCRNI
07B8 219B30    LXI H,SIGM
07BB CD7816    CALL OUTH
07BE CD6F16    CALL CRLF
07C1 219830    LXI H,PAVE
07C4 CD9C16    CALL GETC
07C7 21A630    LXI H,PMT ;EMPTY POWER
07CA CDA216    CALL STOR
07CD 219B30    LXI H,SIGM
07D0 CD9C16    CALL GETC
07D3 21A930    LXI H,SGMT ;SIGMA EMPTY
07D6 CDA216    CALL STOR
07D9 CD4C08    CALL CHEK
07DC CAF407    JZ EMP2
07DF 21DE17    LXI H,MSGD ;AGAIN?
07E2 CD6C16    CALL SCRNI
07E5 CD7516    CALL BLK2

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07E8 21E517      LXI H,MSGP ;YES
07EB CD6C16      CALL SCRNI
07EE CD6F16      CALL CRLF
07F1 C39807      JMP EMP1
      F4 CDB709    EMP2: CALL AGAI ;AGAIN?
      07F7 CA9807    JZ EMP1
07FA C36016      JMP EOR
07FD 2AA430      MEAS: LHLD DAPT ;# DATA POINTS
0800 22AC30      SHLD DCNT ;DOWN COUNTER
0803 CD970F      BGIN: CALL ZERO
0806 22B730      SHLD N
0809 21BF30      LXI H,SUM
080C CDA216      CALL STOR
080F 219230      LXI H,MSGQ
0812 CDA216      CALL STOR
0815 3ABB30      LDA EPORT
0818 CD9316      CALL PWR
081B 218930      LXI H,PO
081E CDA216      CALL STOR
0821 C32A08      JMP BGNC
0824 3ABB30      BGN1: LDA EPORT
0827 CD9316      CALL PWR
082A 3AA030      BGNC: LDA FLAG1 ;PRINT?
082D FE0A        CPI YES
082F C23C08      JNZ BGN2 ;NO PRINT
0832 C5          PUSH B
0833 D5          PUSH D
0834 CD7B16      CALL OUTR
0837 CD6F16      CALL CRLF
      ^73A D1      POP D
      3B C1        POP B
083C CD5005      BGN2: CALL AVE
083F 2AAC30      LHLD DCNT
      0842 2B      DCX H
0843 22AC30      SHLD DCNT
0846 7C          MOV A,H
0847 B5          ORA L
0848 C22408      JNZ BGN1
084B C9          RET
      ;((SIGM/PAVE)/100-SIGF);BOH
084C 219B30      CHEK: LXI H,PAVE
084F CD9C16      CALL GETC
0852 219B30      LXI H,SIGM
0855 CD9F16      CALL GETB
0858 CD7C0F      CALL DIV
085B 0607        MVI B,07H
085D 2100C8      LXI H,0CB00H ;100
0860 CD2C0F      CALL MULT
0863 21A130      LXI H,SIGF
0866 CD9F16      CALL GETB
0869 CD830E      CALL SUB1
086C 79          MOV A,C
086D E680        ANI 80H ;IS SIGN MINUS
086F C9          RET
      ;MEASURE BASELINE
      70 21DB17    RUN: LXI H,MSGN

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0873 CD6C16      CALL SCRNI
0876 CD7216      CALL BLK1
0879 21BB17      LXI H,MSGJ
087C CD6C16      CALL SCRNI
      7F CD6F16      CALL CRLF
0882 CD5C06      CALL FRMT
0885 CD6507      CALL WAIT
0888 CD2306      CALL DELA
088B CD7408      RUNO: CALL RUN1
088E CADCOB      JZ RUN2
0891 C3C708      JMP RUN3
0894 3E00      RUN1: MVI A,0
0896 32BB30      STA EPORT
0899 CDFD07      CALL MEAS
089C CD8E05      CALL SDEV
089F 21DB17      LXI H,MSGN
08A2 CD6C16      CALL SCRNI
08A5 217017      LXI H,MSGA ;POWER MW
08A8 CD6C16      CALL SCRNI
08AB CD6F16      CALL CRLF
08AE 219B30      LXI H,FAVE
08B1 CD7B16      CALL OUTH
08B4 217A17      LXI H,MSGB ;+/-
08B7 CD6C16      CALL SCRNI
08BA 219B30      LXI H,SIGM
08BD CD7B16      CALL OUTH
08C0 CD6F16      CALL CRLF
08C3 CD4C0B      CALL CHEK
08C6 C9      RET
      ^C7 21DE17      RUN3: LXI H,MSGO ;AGAIN?
      CA CD6C16      CALL SCRNI
08CD CD7516      CALL BLK2
08D0 21E517      LXI H,MSGP ;YES
08D3 CD6C16      CALL SCRNI
08D6 CD6F16      CALL CRLF
08D9 C38D08      JMP RUNO
08DC 217017      RUN2: LXI H,MSGA ;POWER MW
08DF CD6C16      CALL SCRNI
08E2 CD6F16      CALL CRLF
08E5 21A630      LXI H,PMT
08E8 CD9C16      CALL GETC
08EB 219B30      LXI H,FAVE
08EE CD9F16      CALL GETB
08F1 CD830E      CALL SUB1
08F4 21C430      LXI H,F
08F7 CD9F16      CALL GETB
08FA CD2C0F      CALL MULT
08FD 21AE30      LXI H,PMEA ;P MEASURE
0900 CBA216      CALL STOR
0903 CD7B16      CALL OUTH
0906 CD6F16      CALL CRLF
0909 216D17      LXI H,MSG9 ;PU
090C CD6C16      CALL SCRNI
090F CD7216      CALL BLK1
0912 21B317      LXI H,MSGH+1 ;G
      15 CD6C16      CALL SCRNI

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0918 CD6F16	CALL CRLF
091B 212A30	LXI H,AVSP
091E CD9C16	CALL GETC
0921 21AE30	LXI H,PMEA
24 CD9F16	CALL GETB
27 CD7C0F	CALL DIV
092A 21B130	LXI H,MASS
092D CDA216	CALL STOR ;(P0-PH)/SF
0930 CD7B16	CALL OUTB
0933 217A17	LXI H,MSGB ;+/-
0936 CD6C16	CALL SCRNI
0939 21A930	LXI H,SGMT
093C CD9C16	CALL GETC
093F CD2B0E	CALL SQ
0942 219530	LXI H,TEMV
0945 CDA216	CALL STOR
0948 219B30	LXI H,SIGM
094B CD9C16	CALL GETC
094E CD2B0E	CALL SQ
0951 219530	LXI H,TEMV
0954 CD9F16	CALL GETB
0957 CD860E	CALL ADD1
095A 219530	LXI H,TEMV
095D CDA216	CALL STOR
0960 21AE30	LXI H,PMEA
0963 CD9F16	CALL GETB
0966 21C430	LXI H,F
0969 CD9C16	CALL GETC
096C CD7C0F	CALL DIV
6F CD2B0E	CALL SQ
72 219530	LXI H,TEMV
0975 CD9F16	CALL GETB
0978 CD7C0F	CALL DIV
097B 219530	LXI H,TEMV
097E CDA216	CALL STOR ;((SGMT)SQ+(SIGM)SQ)/(PMEA);;2
0981 212A30	LXI H,AVSP
0984 CD9C16	CALL GETC
0987 212D30	LXI H,SGSP
098A CD9F16	CALL GETB
098D CD7C0F	CALL DIV
0990 CD2B0E	CALL SQ
0993 219530	LXI H,TEMV
0996 CD9F16	CALL GETB
0999 CD860E	CALL ADD1
099C CDE30D	CALL SQRT
099F 21B130	LXI H,MASS
09A2 CD9F16	CALL GETB
09A5 CD2C0F	CALL MULT
09AB CD7B16	CALL OUTB
09AB CD6F16	CALL CRLF
09AE CDB709	CALL AGAI ;AGAIN?
09B1 CABB08	JZ RUNO
09B4 C36016	JMP EOR
09B7 21DE17	AGAI: LXI H,MSGD ;AGAIN
09BA CD6C16	CALL SCRNI
9D CD7516	CALL BLK2

09C0 3E02	MVI A,02H
09C2 D33B	OUT LED
09C4 CD6316	CALL INB
09C7 FE0A	CPI YES
29 F5	PUSH PSW
09CA AF	XRA A
09CB D33B	OUT LED
09CD F1	POP PSW
09CE F5	PUSH PSW
09CF 21E517	LXI H,MSGF ;YES
09D2 CAD809	JZ \$+6
09D5 21E917	LXI H,MSGQ ;NO
09D8 CD6C16	CALL SCRIN
09DB CD6F16	CALL CRLF
09DE F1	POP PSW
09DF C9	RET
	;CALIBRATE AND STORE AT CALS=2800H
	;MEASURE=6 BYTES CALIBRATE=6 BYTES
09E0 219E17	CAL: LXI H,MSGF
09E3 CD6C16	CALL SCRIN
09E6 CD6F16	CALL CRLF
09E9 3E05	MVI A,5
09EB 32B430	STA CLPT
09EE 21AB17	LXI H,MSGG ;CAL PNTS
09F1 CD6C16	CALL SCRIN
09F4 CD7516	CALL BLK2
09F7 CD6616	CALL IN5
09FA CDFF0C	CALL BCDH
09FD 7A	MOV A,D
09FE FE00	CPI 0
00 CA0B0A	JZ CAL0
0A03 CD630E	CALL FIXX
0A06 79	MOV A,E
0A07 32B430	STA CLPT
0A0A C3160A	JMP CAL1
0A0D 3AB430	CAL0: LDA CLPT
0A10 6F	MOV L,A
0A11 2600	MVI H,0
0A13 CD4307	CALL OUTI
0A16 CD6F16	CAL1: CALL CRLF
0A19 CD5C06	CALL PRMT
0A1C 3AB430	LDA CLPT
0A1F 5F	MOV E,A
0A20 1600	MVI D,0
0A22 CD390E	CALL FLOT
0A25 C5	PUSH B
0A26 D5	PUSH D
0A27 21A630	LXI H,PMT
0A2A CD9F16	CALL GETB
0A2D 0E7F	MVI C,7FH
0A2F 110080	LXI D,8000H ;0.25W
0A32 CD830E	CALL SUB1
0A35 EB	DCHG
0A36 79	MOV A,C
0A37 D1	POP D
38 C1	POP B

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0A39 47      MOV B,A
0A3A CD7C0F  CALL DIV ;(PMT-0.25W)/CLPT
0A3D 21B530  LXI H,PSTP
0A40 CDA216  CALL STOR
      13 21B830  LXI H,PSET
0A46 CDA216  CALL STOR
0A49 21002B  LXI H,CALS
0A4C 3E00    MVI A,00H ;OVERCOME DIODE DROP
0A4E 3C      CAL2: INR A
0A4F CD9016  CALL DTOA
0A52 F5      PUSH PSW
0A53 E5      PUSH H
0A54 3E02    MVI A,02H ;CALI VOLTAGE
0A56 CD9316  CALL PWR
0A59 21B830  LXI H,PSET
0A5C CD9F16  CALL GETB
0A5F CD830E  CALL SUB1 ;PSET-POUT
0A62 79      MOV A,C
0A63 E6B0    ANI 80H
0A65 C26D0A  JNZ CAL3
0A68 E1      POP H
0A69 F1      POP PSW
0A6A C34E0A  JMP CAL2
0A6D CD2306  CAL3: CALL DELA
0A70 3E02    CAL5: MVI A,02H ;CAL VOLTAGE
0A72 32B830  STA LPORT
0A75 3E04    MVI A,04H
0A77 D33B    OUT LED
0A79 CDFD07  CALL MEAS
^7C AF      XRA A
      7D D33B    OUT LED
0A7F CD8E05  CALL SDEV
0A82 219E17  LXI H,MSGF ;CALIBRATE
0A85 CD6C16  CALL SCRNI
0A88 217617  LXI H,MSGGA+6 ;MW
0A8B CD6C16  CALL SCRNI
0A8E CD6F16  CALL CRLF
0A91 219830  LXI H,PAVE
0A94 CD9C16  CALL GETC
0A97 E1      POP H
0A9B CDA216  CALL STOR
0A9B E5      PUSH H
0A9C CD7B16  CALL OUTB
0A9F 217A17  LXI H,MSGB ;+/-
0AA2 CD6C16  CALL SCRNI
0AA5 219B30  LXI H,SIGM
0AAB CD9C16  CALL GETC
0AAB E1      POP H
0AAC CDA216  CALL STOR
0AAF E5      PUSH H
0AB0 CD7B16  CALL OUTB
0AB3 CD6F16  CALL CRLF
0AB6 3E04    CAL4: MVI A,04H
0AB8 D33B    OUT LED
0ABA CD9408  CALL RUN1
      9D AF      XRA A

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OABE D33B      OUT LED
OACO 219830    LXI H,PAVE
OAC3 CD9C16    CALL GETC
OAC6 E1        POP H
      27 CDA216 CALL STOR
OACA E5        PUSH H
OACB 219B30    LXI H,SIGH
OACE CD9C16    CALL GETC
OAD1 E1        POP H
OAD2 CDA216    CALL STOR
OADS CAF40A    JZ CAL7 ;MEASURE OK
OADH 2B        DCX H
OADI 2B        DCX H
OADA 2B        DCX H
OADB 2B        DCX H
OADC 2B        DCX H
OADD 2B        DCX H
OADE E5        PUSH H
OADF 21DE17    LXI H,MSGD ;AGAIN?
OAE2 CD6C16    CALL SCRNI
OAE5 CD7516    CALL BLK2
OAE8 21E517    LXI H,MSGP ;YES
OAEB CD6C16    CALL SCRNI
OAEF CD6F16    CALL CRLF
OAF1 C3B60A    JMP CAL4
OAF4 E5        CAL7: PUSH H
OAF5 3AB430    LDA CLPT
OAF8 3D        DCR A
OAF9 32B430    STA CLPT
      FC CA190B JZ CAL6
      FF 21B830 LXI H,FSET
OB02 CD9C16    CALL GETC
OB05 21B530    LXI H,FSTP
OB08 CD9F16    CALL GETB
OB0B CDB60E    CALL ADD1
OB0E 21B830    LXI H,FSET
OB11 CDA216    CALL STOR
OB14 E1        POP H
OB15 F1        POP PSW
OB16 C34E0A    JMP CAL2 ;DO NEXT
OB19 AF        CAL6: XRA A
OB1A CD9016    CALL DTOA
OB1D C36016    JMP EOR
      ;GET TEST POINTS
OB20 21C017    TEST: LXI H,MSGK ;TEST PT
OB23 CD6C16    CALL SCRNI
OB26 0653      MVI B,'S'
OB28 CD6916    CALL OUTB
OB2B 3EFF      MVI A,OFFH
OB2D 32B830    STA POINT
OB30 32A030    STA FLAG1
OB33 CD6F16    TES0: CALL CRLF
OB36 219817    LXI H,MSGE ;ALL?
OB39 CD6C16    CALL SCRNI
OB3C CD7516    CALL BLK2
      3F CD0F07 TES7: CALL RSVP

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0B42 FE0A	CPI YES
0B44 CA610B	JZ TES1
0B47 FE80	CPI ENTR
0B49 CA610B	JZ TES1
1C CDFF0C	CALL BCDH
0B4F CD630E	CALL FIXX
0B52 7B	MOV A,E
0B53 FE33	CPI 33H
0B55 D2330B	JNC TESO
0B58 32BC30	STA POINT
0B5B CD6F16	CALL CRLF
0B5E C3750B	JMP TES4
0B61 21E517	TES1: LXI H,MSGP ;YES
0B64 CD6C16	CALL SCRNI
0B67 CD6F16	CALL CRLF
0B6A 3E0A	MVI A,YES
0B6C 32A030	STA FLAG1
0B6F CD6F16	CALL CRLF
0B72 C38C0B	JMP TES5
0B75 CD4E16	TES4: CALL IN8C
0B78 FE12	CPI 12H
0B7A CA3F0B	JZ TES7
0B7D 3ABC30	TES8: LDA POINT
0B80 3D	DCR A
0B81 F5	PUSH PSW
0B82 CDBA14	CALL TES9
0B85 CDB716	CALL DISB
0B88 F1	POP PSW
0B89 C3750B	JMP TES4
0B8C AF	TES5: XRA A
0B8E 3C	PUSH PSW
0B8F 32BC30	INR A
0B92 2600	STA POINT
0B94 6F	TES6: MVI H,0
0B95 3AA030	MOV L,A
0B98 FE0A	LDA FLAG1
0B9A F5	CPI YES
0B9B CC4307	PUSH PSW
0B9E F1	CZ OUTI
0B9F CC7516	POP PSW
0BA2 F1	CZ BLK2
0BA3 F5	POP PSW ;MULTIPLEXER #
0BA4 CDBA14	PUSH PSW
0BA7 CDB716	CALL TES9
0BAA 3AA030	CALL DISB
0BAD FE0A	LDA FLAG1
0BAF F5	CPI YES
0BB0 CC7B16	PUSH PSW
0BB3 F1	CZ OUTB
0BB4 CC6F16	POP PSW
0BB7 F1	CZ CRLF
0BB8 3C	POP PSW ;MULTIPLEXER #
0BB9 F5	INR A
0BBA 3ABC30	PUSH PSW
BD C601	LDA POINT
	ADI 1

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0BBF 32BC30      STA POINT
0BC2 FE21        CPI 33
0BC4 C2920B      JNZ TES6
0BC7 C36016      JMP EDR
30              ORG 3080H
3080      MOTOR DS 1 ;DRIVE OUTPUT
3081      DIGT DS 1 ;PRINT OUTPUTS
3082      POWER DS 3 ;SUM OF POWERS
3085      PLEX DS 2 ;MULTIPLEXER NUMBER
3087      N DS 2 ;NUMBER OF SAMPLES TAKEN
3089      PO DS 3 ;FIRST POWER MEASUREMENT
308C      PI DS 3 ;PO-PM
308F      SUM DS 3 ;SUM OF PI
3092      SMSQ DS 3 ;SUM OF SQ OF PI
3095      TEMV DS 3 ;TEMPERARY VARIABLE
3098      PAVE DS 3 ;AVERAGE OF POWER
309B      SIGM DS 3 ;SIGMA OF POWER
309E      TIME DS 2 ;DELAY TIME
30A0      FLAG1 DS 1 ;PRINT FLAG
30A1      SIGF DS 3 ;SIGMA DEFAULT
30A4      DAFT DS 2 ;NUMBER OF DATA POINTS
30A6      PMT DS 3 ;EMPTY POWER
30A9      SGMT DS 3 ;EMPTY SIGMA
30AC      DCNT DS 2 ;DOWN COUNTER
30AE      PMEA DS 3 ;PMT-PAVE
30B1      MASS DS 3 ;PU MASS
30B4      CLPT DS 1 ;CALIBRATE POINT
30B5      PSTP DS 3 ;POWER STEP
30B8      PSET DS 3 ;POWER SET
30BB      EPORT DS 1 ;VOLTAGE PORT
30BC      POINT DS 1 ;TEST POINT
30BD      OLDD DS 4
30C1      SSQ DS 3
30C4      F DS 3
1660 =      EDR EQU 1660H
1663 =      IN8 EQU 1663H
1666 =      IN5 EQU 1666H
16A8 =      IN5A EQU 16ABH
16AB =      IN0 EQU 16ABH
16AE =      INBC EQU 16AEH
1669 =      OUT8 EQU 1669H
166C =      SCRNI EQU 166CH
166F =      CKLF EQU 166FH
1672 =      BLK1 EQU 1672H
1675 =      BLK2 EQU 1675H
1678 =      OUTH EQU 1678H
167B =      OUTB EQU 167BH
167E =      OUTD EQU 167EH
1681 =      OUTF EQU 1681H
1684 =      DISH EQU 1684H
1687 =      DISB EQU 1687H
168A =      DISI EQU 168AH
168D =      ATOD EQU 168DH
1690 =      DTOA EQU 1690H
1693 =      PWR EQU 1693H
7C =      GETC EQU 169CH

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169F =      GETB EQU 169FH
16A2 =      STOR EQU 16A2H
16A5 =      SWAP EQU 16A5H
0E86 =      ADD1 EQU 0E86H
    33 =      SUB1 EQU 0E83H
0F7C =      DIV EQU 0F7CH
0F2C =      MULT EQU 0F2CH
0E2H =      SQ EQU 0E2BH
0DE3 =      SQR EQU 0DE3H
0F97 =      ZERO EQU 0F97H
0E63 =      FIXX EQU 0E63H
0E39 =      FLOT EQU 0E39H
0CFF =      BCDH EQU 0CFFH
0C00 =      HEXB EQU 0C00H
0DA7 =      BCD EQU 0DA7H
302A =      AVSP EQU 302AH
302D =      SGSP EQU 302DH
0023 =      KST EQU 23H
000A =      YES EQU 0AH
0080 =      ENTR EQU 80H
003B =      LED EQU 3BH
1700 =      MSG1 EQU 1700H
170D =      MSG2 EQU 170DH
1713 =      MSG3 EQU 1713H
171B =      MSG4 EQU 171BH
1725 =      MSG5 EQU 1725H
1730 =      MSG6 EQU 1730H
173B =      MSG7 EQU 173BH
1743 =      MSG8 EQU 1743H
176D =      MSG9 EQU 176DH
    70 =      MSGA EQU 1770H
177A =      MSGB EQU 177AH
1780 =      MSGC EQU 1780H
178D =      MSGD EQU 178DH
179B =      MSGE EQU 179BH
179E =      MSGF EQU 179EH
17AB =      MSGG EQU 17ABH
17B2 =      MSGH EQU 17B2H
17B5 =      MSGI EQU 17B5H
17BB =      MSGJ EQU 17BBH
17C0 =      MSGK EQU 17C0H
17CB =      MSGL EQU 17CBH
17D2 =      MSGM EQU 17D2H
17DB =      MSGN EQU 17DBH
17DE =      MSGO EQU 17DEH
17E5 =      MSGP EQU 17E5H
17E9 =      MSGQ EQU 17E9H
2800 =      CALS EQU 2800H ;CALIBRATE STORAGE
14BA      ORG 14BAH
14BA 0E00      TES9: MVI C,0
14BC 110000      LXI D,0
14BE 219530      LXI H,TEMP
14C2 CDA216      CALL STOR
14C5 3E0A      MVI A,10
14C7 32B430      TESA: STA CLPT
    2A 3ABC30      LDA POINT

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14CD 3D	DCR A
14CE CD8D16	CALL ATOD
14D1 219530	LXI H,TEMV
14D4 CD9F16	CALL GETB
77 CD960E	CALL ADD1
14DA 219530	LXI H,TEMV
14DD CDA216	CALL STOR
14E0 3AB430	LDA CLPT
14E3 3D	DCR A
14E4 C2C714	JNZ TESA
14E7 0604	MVI B,04H
14E9 2100A0	LXI H,0A000H
14EC CDA516	CALL SWAP
14EF CD7C0F	CALL DIV
14F2 C9	RET

TYPE DIR

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6735 *   ROUTINE TO CALCULATE UPDATED VALUS OF
6740 *   THE SAMPLE ISOTOPIC MAS FRACTION.
6745 MF   MVI A,4 ;SET LED 3
6750     OUT LED
6755     CALL NORM
6760     LXI H,MSF
6765     SHLD TS2 ;MSF PNTR
6770     LXI H,LAM
6775     SHLD TS1 ;LAMDA PNTR
6780     MVI A,5
6785 MF1  STA TSO ;STORE LOOP CONTER
6790     CALL GETC
6795     LXI H,TIME
6800     CALL GETB
6805     CALL MULT ;CDE=L*T
6810     CALL NEXP ;CDE=EXP(-L*)
6815     LHLD TS2
6820     CALL GETB
6825     CALL MULT ;CDE=F0*EXP(L*T)
6830     LHLD TS2
6835     CALL STOR
6840     LHLD TS2 ;INC PNTRS
6845     CALL INC3
6850     SHLD TS2
6855     LHLD TS1
6860     CALL INC3
6865     SHLD TS1
6870     LDA TSO
6875     DCR A
6880     JNZ MF1
6885     LXI H,LAM1 ;UPDATE FAM
6890     CALL GETC
6895     LXI H,MSF1
6900     CALL GETB
6905     CALL MULT ;CDE=L*F0
6910     LXI H,TS0
6915     CALL STOR ;TS0=L1*F1
6920     LXI H,LAMA
6925     CALL GETC
6930     LXI H,LAM1
6935     CALL GETB
6940     CALL SUB ;CDE=L1-LA
6945     LXI H,TS0
6950     CALL GETB
6955     CALL DIV
6960     LXI H,TS0
6965     CALL STOR ;TS0=L1*F1/(1-LA)
6970     LXI H,LAM1
6975     CALL GETC
6980     LXI H,TIME
6985     CALL GETB
6990     CALL MULT
6995     CALL NEXP ;CDE=EXP(-L1T)
7000     LXI H,TS0
7005     CALL GETB
7010     CALL MULT
7015     LXI H,TS2
7020     CALL STOR ;TS2=(EXP(-L*T)*L1*F1)(L1-LA)
7025     LXI H,LAMA
7030     CALL GETC
7035     LXI H,TIME

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7040      CALL GETB
7045      CALL MULT
7050      CALL NEXP
7055      LXI H,TS5
7060      CALL STOR ;TS5=EXP(-LAT)
7065      LXI H,TS0
7070      CALL GETB
7  5      CALL MULT ;CDE=EXP(-LAT)*L1*F1/(1-LA)
7080      LXI H,TS2
7085      CALL GETB
7090      CALL SWAP
7095      CALL SUB
7100      LXI H,TS0
7105      CALL STOR ;TS0=(EXP(-L*T)-EXP(-L*T))*L1
7110 *      *F1/(L1-LA)
7115      LXI H,MSFA
7120      CALL GETC
7125      LXI H,TS5
7130      CALL GETB
7135      CALL MULT ;CDE=FA*EXP(LA*T)
7140      LXI H,TS0
7145      CALL GETB
7150      CALL ADD
7155      LXI H,MSFA
7160      CALL STOR ;MSFA=FAM
7165      CALL NORM ;NORMALIZE MSS FRCT.
7170      LXI H,MFHD ;PRINT RESUTS
7175      CALL SCRN
7180      CALL CRLF
7185      CALL CRLF
7190      LXI H,MSFA
7195      SHLD TS2 ; MSF POINTER
7  0      LXI H, A1
7  5      SHLD TS1 ; LABLE POINTR
7210      MVI A,6
7215 MF2    STA TS0 ;LOOP CNTR.
7220      CALL SCRN
7225      CALL CRLF
7230      LHLD TS2
7235      CALL GETC
7240      LXI H,H100
7245      CALL GETB
7250      CALL MULT
7255      CALL OUTB
7260      CALL CRLF
7265      CALL CRLF
7270      LHLD TS2
7275      CALL INC3
7280      SHLD TS2
7285      LHLD TS1
7290      CALL INC3
7295      CALL INC3
7300      INX H
7305      SHLD TS1
7310      LDA TS0
7315      DCR A
7320      JNZ MF2
7325      RET
7  0 *      SUBROUTINE TO INCREMEN HL-POINTE 3 BYTES
7335 INC3    INX H
7340      INX H
7345      INX H
7350      RET
7355 LAMA    DB 6FH ;4.372*E-6
7360      DB 92H
7365      DB 63H

```

```

7370 LAM DB 71H ;2.1619E-5
7375 DB 0B5H
7380 DB 00H
7385 DB 69H ;7.88E-8
7390 DB 0A9H
7395 DB 39H
7400 DB 6BH ;2.903E-7
7 5 DB 96H
7410 DB 0DBH
7415 LAM1 DB 74H ;1.322E-4
7420 DB 8AH
7425 DB 9FH
7430 DB 65H ;4.907E-9
7435 DB 0ABH
7440 DB 7BH
7445 * SUBROUTINE TO CALCULAT THE EXPONENTIAL OF
7450 * SMALL NEGATIVE #
7455 NEXP LXI H,TMP3
7460 CALL STOR ;TMP3=X
7465 CALL ZERO
7470 LXI H,ATBL
7475 SHLD TMP2 ;TABLE PNTR.
7480 MVI A,6
7485 NE1 STA TMP1 ;LOOP COUNTER
7490 CALL GETB
7495 CALL ADD ;CDE=Y+ATBL
7500 LXI H,TMP3
7505 CALL GETB
7510 CALL MULT ;CDE=(Y+ATBL*X
7515 LHLD TMP2
7520 CALL INC3
7525 SHLD TMP2
7530 LDA TMP1
7 5 DCR A
7540 JNZ NE1
7545 LXI H,ATB1 ;ADD 1
7550 CALL GETB
7555 CALL ADD ;CDE=EXP(-X)
7560 RET
7565 ATBL DB 77H ;1/720
7570 DB 0B6H
7575 DB 00H
7580 DB 0FAH ;-1/120
7585 DB 8BH
7590 DB 8BH
7595 DB 7CH ;1/24
7600 DB 0AAH
7605 DB 0ABH
7610 DB 0FEH ;-1/6
7615 DB 0AAH
7620 DB 0ABH
7625 DB 00H ;1/2
7630 DB 80H
7635 DB 00H
7640 DB 81H ;-1
7645 DB 80H
7650 DB 00H
7655 ATB1 DB 01H ;1
7 3 DB 80H
7665 DB 00H
7670 * SUBROUTINE TO NORMALIZ THE SAMPL ISOTOPIC
7675 * MASS FRACTIONS TO UNIT
7680 NORM CALL ZERO
7685 LXI H,SUMF
7690 CALL STOR
7695 LXI H,MSF ;MSF PNTR

```

```

7700      SHLD TS1
7705      MVI A,5
7710 N1   STA TS0 ;LOOP CONUTER
7715      CALL GETB
7720      CALL ADD ;CDE=SUM OF F
7725      LHLD TS1
7730      CALL INC3
7735      SHLD TS1
7740      LDA TS0
7745      DCR A
7750      JNZ N1
7755      LXI H,SUMF
7760      CALL STOR ;SUMF=SUM OFMASS FRCT.
7765      LXI H,MSFA
7770      SHLD TS1
7775      MVI A,6
7780 N2   STA TS0 ; LOOP CNTR.
7785      LXI H,SUMF
7790      CALL GETC
7795      LHLD TS1
7800      CALL GETB
7805      CALL DIV
7810      LHLD TS1
7815      CALL STOR
7820      SHLD TS1
7825      LDA TS0
7830      DCR A
7835      JNZ N2
7840      LXI H,MSF+9 ;MSF1
7845      CALL GETC
7850      LXI H,MSF1
7855      CALL STOR
7860      RET
7865      RRC4 RRC ;ROTATE ACC 4 SPACS
7870      RRC
7875      RRC
7880      RRC
7885      RET
7890 H100 DB 07H
7895      DB 0CBH
7900      DB 00H
7905 *    ROUTINE TO CALCULATE SMPLE SPECIFIC POWER
7910 *    AND ITS ASSOCIATED UNCERTAINTY
7915 SP   MVI A,4 ;SET LED 3
7920      OUT LED
7925      CALL ZERO
7930      LXI H,AVSP
7935      CALL STOR
7940      LXI H,SGSP
7945      CALL STOR
7950      CALL NORM
7955      LXI H,ISPA
7960      SHLD TS1 ;ISP PNTR.
7965      LXI H,MSFA
7970      SHLD TS2 ;MFS POINTER
7975      MVI A,6 ;LOOP CNTR.
7980 SP1  STA TS0
7985      CALL GETC
7990      LHLD TS1
7995      CALL GETB
8000      CALL MULT ;CDE=P*F
8005      LXI H,AVSP
8010      CALL GETB
8015      CALL ADD
8020      LXI H,AVSP
8025      CALL STOR

```

```

8030      LHL D TS1
8035      CALL INC3
8040      SHLD TS1
8045      LHL D TS2
8050      CALL INC3
8055      SHLD TS2
8060      LDA TS0
E 5      DCR A
8070      JNZ SP1
8075      CALL UFAM ;SIGMA AM241
8080      LXI H,ISPA
8085      SHLD TS1 ;TS1=P
8090      LXI H,UMSF ;TS2=SIG F
8095      SHLD TS2
8100      LXI H,MSFA
8105      SHLD TS3 ;TS3=F
8110      LXI H,UISP
8115      SHLD TS4 ;TS4=SIG P
8120      MVI A, 6
8125 SP2 STA TS0
8130      CALL GETC
8135      LHL D TS3
8140      CALL GETB
8145      CALL MULT
8150      CALL SQ ;(F*SIG F)**2
8155      LXI H,SGSP
8160      CALL GETB
8165      CALL ADD
8170      LXI H,SGSP
8175      CALL STOR
8180      LHL D TS1
8185      LXI H,H100
8190      CALL GETC ;100
E 5      LHL D TS2
8200      CALL GETB ;SIG F
8205      CALL DIV ;CDE=SIG F/10
8210      LHL D TS1
8215      CALL GETB ;P
8220      CALL MULT
8225      CALL SQ ;(P*SIG F)**2
8230      LXI H,SGSP
8235      CALL GETB
8240      CALL ADD
8245      LXI H,SGSP
8250      CALL STOR
8255      LHL D TS1
8260      CALL INC3
8265      SHLD TS1
8270      LHL D TS2
8275      CALL INC3
8280      SHLD TS2
8285      LHL D TS3
8290      CALL INC3
8295      SHLD TS3
8300      LHL D TS4
8305      CALL INC3
8310      SHLD TS4
8315      LDA TS0
E 3      DCR A
8325      JNZ SP2
8330      CALL SQRT
8335      LXI H,SGSP
8340      CALL STOR
8345      CALL CRLF ;OUTPUT RESULTS
8350      LXI H,SPHD
8355      CALL SCRN

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8360      CALL CRLF
8365      LXI H,AVSP
8370      CALL GETC
8375      CALL DUTB
8380      LXI H,FOM
8385      CALL SCRNI
8390      LXI H,SGSF
E 5      CALL GETC
8400      CALL DUTH
8405      CALL CRLF
8410      RET
8415 ISPA DB 07H ;114.23
8420      DB 0E4H
8425      DB 76H
8430      DB 0AH ;567.16
8435      DB 8DH
8440      DB 0CAH
8445      DB 01H ;1.9293
8450      DB 0F6H
8455      DB 0F3H
8460      DB 03H ;7.098
8465      DB 0E3H
8470      DB 23H
8475      DB 02H ;3.390
8480      DB 0D8H
8485      DB 0F6H
8490      DB 7DH ;0.1146
8495      DB 0EAH
8500      DB 64H
8505 UISF DB 7EH ;0.16
8510      DB 0A3H
8515      DB 0D7H
8520      DB 80H ;0.57
8525      DB 91H
8530      DB 0E7H
8535      DB 79H ;0.0053
8540      DB 0ADH
8545      DB 0A7H
8550      DB 77H ;0.0015
8555      DB 0CAH
8560      DB 97H
8565      DB 78H ;0.002
8570      DB 83H
8575      DB 13H
8580      DB 74H ;0.0002
8585      DB 0D1H
8590      DB 0B7H
8595 *    ROUTINE TO INPUT SAMPL MASS FRACION DATA
8600 *    AND ASSOCIATED UNCERTANTIES
8605 PAR  CALL CRLF
8610      LXI H, PRHD ;LABEL
8615      CALL SCRNI
8620      LXI H,MFHD+1
8625      CALL SCRNI
8630      CALL CRLF
8635      CALL CRLF
8640      LXI H,MSFA
8645      SHLD TS2 ;MF PNTR.
E 2      LXI H,UMSF
8655      SHLD TS3 ;SIGMF PNTR.
8660      LXI H,A1
8665      SHLD TS1 ;LABEL PNTR
8670      MVI A,6
8675 PAR1 STA TSO
8680      CALL CRLF
8685      CALL SCRNI

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8690      CALL CRLF
8695      CALL INS ;INPUT MF
8700      CALL BCDH
8705      LHLD TS2
8710      CALL STOR
8715      LXI H,POI
8720      CALL SCRNI
E 5      CALL INS ;INPUT SIGMF
8730      CALL BCDH
8735      LHLD TS3
8740      CALL STOR
8745      CALL CRLF
8750      LHLD TS2
8755      CALL INC3
8760      SHLD TS2
8765      LHLD TS3
8770      CALL INC3
8775      SHLD TS3
8780      LHLD TS1
8785      CALL INC3
8790      CALL INC3
8795      INX H
8800      SHLD TS1
8805      LDA T30
8810      DCR A
8815      JNZ PAR1
8820      LXI H,TME
8825      CALL CRLF
8830      CALL SCRNI
8835      CALL CRLF
8840      CALL INS ;INPUT TIME
8845      CALL BCDH
8850      LXI H,TIME
E 5      CALL STOR
8860      CALL CRLF
8865      LXI H,MSF+9H
8870      CALL GETC
8875      LXI H,MSF1
8880      CALL STOR
8885      LXI H,SPHD
8890      CALL CRLF
8895      CALL SCRNI
8900      LXI H,MSGH
8905      CALL SCRNI
8910      CALL CRLF
8915      CALL INS ;INPUT SPC. PR.
8920      CALL BCDH
8925      LXI H,AVSF
8930      CALL STOR
8935      LXI H,POH
8940      CALL SCRNI
8945      CALL INS ;INPUT SGSP
8950      CALL BCDH
8955      LXI H,SGSF
8960      CALL STOR
8965      CALL CRLF
8975      LXI H,MSGR ;PWR NORM
8980      CALL CRLF
E 3      CALL SCRNI
8987      CALL CRLF
8990      CALL INS ;INPUT F
8995      CALL BCDH
9000      LXI H,F
9005      CALL STOR
9010      CALL CRLF
9020      LXI H,MSGT ;SIGMA(SYS)

```

```

9025      CALL CRLF
9030      CALL SCRNI
9035      CALL CRLF
9040      CALL INS ;INPUT SSQ
9045      CALL BCDH
9050      CALL SQ
9055      LXI H,SSQ
9060      CALL STOR
9065      CALL CRLF
9070      RET
9080 GETC EQU 169CH
9085 GETB EQU 169FH
9090 STOR EQU 16A2H
9095 SWAP EQU 16A5H
9100 HEXB EQU 0C00H
9105 BCDH EQU 0CFFH
9110 SQRTEQU 0DE3H
9115 SQ EQU 0E2BH
9120 SUB EQU 0E83H
9125 ADD EQU 0E86H
9130 MULT EQU 0F2CH
9135 DIV EQU 0F7CH
9140 ZERO EQU 0F97H
9145 CRLF EQU 166FH
9150 SCRNI EQU 166CH
9155 OUTB EQU 167BH
9160 INS EQU 1666H
9165 UFAM LXI H,LAM1
9170      CALL GETC
9175      LXI H,TIME
9180      CALL GETB
9185      CALL MULT ;CDE=L1*T
9190      LXI H,UMSF+0CH
9195      CALL GETB
9200      CALL MULT
9205      CALL SQ ;CDE=(L1*T*SIGFU1)**2
9210      LXI H,TS1
9215      CALL STOR
9220      LXI H,UMSF
9225      CALL GETC
9230      CALL SQ ;SIG AM**2
9235      LXI H,TS1
9240      CALL GETB
9245      CALL ADD ;(L1*T*S1)**2SA**2
9250      CALL SQRTEQU
9255      LXI H,UMSF
9260      CALL STOR
9265      RET
9270 MFHD EQU 173BH
9275 A1 EQU 1743H
9280 PRHD EQU 1780H
9285 PQM EQU 177AH
9290 TME EQU 178DH
9295 SPHD EQU 1770H
9300 MSGH EQU 1781H
9305 MSGR EQU 17ECH
9310 MSGT EQU 17F3H
9315 LED EQU 003BH
9320 FLOT EQU 0E39H
9321 F EQU 30C4H
9322 SSQ EQU 30C1H
9325      ORG 3000H
9330 MSF1 DS 3
9335 MSFA DS 3
9340 MSF DS 0FH
9345 TIME DS 3

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9350 SUMF DS 3
9355 TSO DS 1
9360 T81 DS 2
9365 T82 DS 2
9370 T83 DS 1
9375 T85 DS 1
9380 T84 DS 2
9385 TMP1 DS 1
9390 TMP2 DS 2
9395 TMP3 DS 3
9400 AVSP DS 5
9405 SGSP DS 3
9410 UMSF DS 12H
9415 NODP DS 3
9420 FNX DS 3
9425 FWRH DS 3
9430 FWR1 DS 3
9435 SMH DS 3
9440 SMH2 DS 3
9445 SMI DS 3
9450 SMH1 DS 3
9455 NX DS 1
9460 NODP DS 1

APPENDIX C

I. SIMPLIFIED OPERATING INSTRUCTIONS

A. Start Up

NOTE:

This synopsis is intended to be a check list for system operation DO NOT OPERATE this device without first reading the more detailed instructions.

1. Connect calorimeter chamber to control unit.
2. Connect calorimeter control unit to data-acquisition system.
3. Connect system power cord to building power and turn on power switch.
4. Reset microprocessor (μ). FAILURE TO RESET THE MICROPROCESSOR MAY RESULT IN DAMAGE TO THE PRINT HEAD.
5. Wait about 3-4 hours for the system to reach thermal equilibrium. The first fuel rod to be measured can be inserted at start up to reduce the time for the first measurement. (Temperature error meters should read approximately zero.)

B. Sample Measurement

1. Insert rod and center in calorimeter.
- 2.. Start sample measurements by pressing RUN.

Parameters	PRINT ALL?	-	ENTR (NO)
	DELAY-MIN	-	60
	Sigma %	-	0 (Statistical uncertainty only)
	#DP/RUN	-	125

The program will continue to measure and print out until stopped by pressing the RST key. When the power measurements become steady, indicating that thermal equilibrium has been reached, press RST.

3. Start final sample measurement.

Parameters	PRINT ALL?	-	ENTR (NO)
	DELAY-MIN	-	0
	Sigma %	-	0.02
	#DP/RUN	-	125

After print out, program will halt. Measured value will be retained by the microprocessor for future calculation. Additional measurements can be made by pressing YES.

4. Press INIT

Enter isotopic data. If the uncertainties in the entries are not known, skip by pressing ENTR. If the specific power is known, then the isotopic inputs may be skipped and the specific power can be entered at this point. The PNORM entry allows a bias correction to be entered.

SIG(SY) allows inclusion of a systematic error in the error propagation calculation. Skip entry if unknown. PNORM and SIG(SY) have default values of 1.0 and 0.0 and are reset to these values each time the RST key is used.

5. Remove the fuel rod being measured and press P_0 .

Parameters	PRINT ALL?	-	ENTR (NO)
	DELAY-MIN	-	10
	SIGMA %	-	0.02
	#DP/RUN	-	125

The baseline power will be measured and the sample power and sample plutonium content will be calculated. Repeat measurement several times by pressing YES key to ensure that the calorimeter has reached thermal equilibrium.

C. Electrical Calibration

1. Insert the electric fuel rod and connect the cable to the output connector on the front panel of the calibration module.
2. Wait for the calorimeter to reach thermal equilibrium.
3. Press the RUN key.

Parameters	PRINT ALL?	-	ENTR (NO)
	DELAY-MIN	-	0
	Sigma %	-	0
	#DP/RUN	-	125

Calorimeter will continue to measure the power until stopped. When the power repeats within the measurement precision, press reset. The last run will be stored and used by the calibration program.

4. Press the CAL key.

Parameters	CAL PNTS	-	5
	PRINT ALL?	-	ENTR (NO)
	DELAY-MIN	-	20
	Sigma %	-	0.02
	#DP/RUN	-	125

The calibration routine checks out the performance of the entire calorimeter system.

The output for each calibration point is a pair of power measurements. The first is the power to the electric fuel rod. The second is the power to the sample chamber heater. Test points have been provided on the calibration module for measuring the power to the electric fuel rod with an external digital voltmeter. At the end of the calibration sequence, a least squares fit of the pairs of points should give a slope of approximately one and an intercept of approximately zero. For x = calibrate power and y = measured power, example:

a_0	=	-0.00290
a_1	=	1.01486
r^2	=	0.99999598
s_{xy}	=	0.00102
s_0	=	0.00075
s_1	=	0.00077

The "calibrate" routine checks the accuracy of the A to D and the linearity of the calorimeter measurement system. The cable connected to the electric fuel rod may introduce a small bias so that absolute calibration of the measurement chamber power with the electric fuel rod is not recommended. A small bias is also associated with the fuel-column length.

For the most accurate calibration of the measurement-chamber power, a standard fuel rod with the same fuel-column length as the rods to be measured should be used.

II. EXPLANATION OF TYPICAL OUTPUT TAPE

USER ACTION/RESPONSE

SYSTEM OUTPUT

Press RST
Press RUN

CALORIMETER READY
MEAS

PRINT ALL? NO

Press ENTR (NO)

Input system equilibration time

DELAY-MIN 60

Limit of acceptable measurement uncertainty

SIGMA-% 0.02

Input system assay time 25 pnts/min

#DP/RUN 125

Power supplied by calorimeter to maintain constant T_3

POWER W
1.9405 +/- 6.9365
E - 5

Assay will automatically be repeated if

$\frac{(\bar{P})}{\bar{P}}$

SIGMA %. Otherwise,

repetition is a user option

AGAIN? YES
POWER W
1.9409 +/- 7.0728
E - 5
AGAIN? NO

Press CAL

CALIBRATE
CAL PNTS 5
PRINT ALL? NO
DELAY-MIN 20
SIGMA % 0.02

Input reequilibration time

Reference input power

Calorimeter-supplied power

Press RST

Press INIT

Enter numeric, followed by ENTR
(NOTE: 0.72112, not .72112)

If measurement error is not known,
press ENTR

NOTE: ²⁴¹Am content should be
entered relative to Pu value.

#DP/RUN 125

CALIBRATE W
0.34288 +/- 1.9639
E - 5

EMPTY POWER W
1.5943 +/- 1.2532
E - 4

CALIBRATE W
0.67216 +/- 2.4625
E - 5

EMPTY POWER W
1.2588 +/- 1.1581
E - 4

CALIBRATE W
1.0137 +/- 3.2839
E - 5

EMPTY POWER W
0.91113 +/- 1.3736
E - 4

CALIBRATE W
1.3446 +/- 3.6233
E - 5

EMPTY POWER W
0.57366 +/- 1.3263
E - 4

CALIBRATE W
1.6810 +/- 4.2598
E - 5

EMPTY POWER W
0.22760 +/- 1.4167
E - 4

CALORIMETER READY

DATA INPUT MASS %

AM241
0.72112 +/- (Measurement
uncertainty)

PU238
0.04312 +/-

PU 239
87.1389 +/-

Pu240
11.5464 +/-

	Pu241	
	1.0831 +/-	
	Pu242	
	0.18848 +/-	
	TIME-DAYS	
	20	
	POWER W/G	
	+/-	
	P NORM	
	1.0	
Systematic measurement uncertainty	SIG(SY)	
	0	
Press <u>FRAC</u>	MASS %	
Microprocessor calculated values for the sample isotopic composition	AM241	
	0.72396	
	Pu238	
	0.04310	
	Pu239	
	87.140	
	Pu240	
	11.546	
	Pu241	
	1.0802	
	Pu242	
	0.18847	
Press <u>SP</u>	POWER W	
Microprocessor-calculated sample specific power P_{eff} (mW/g) with fuel rod in measurement chamber	3.6090 +/- 0.00477	
Press <u>RUN</u>	MEAS	
	PRINT ALL?	ENTR (NO)
System reequilibration time following sample input (User must determine delay time for fuel rods being measured)	DELAY-MIN	60
	SIGMA-%	0.05
5-min assay	#DP/RUN	125
Calorimeter-supplied power ($\bar{P}_c$)	POWER W	
	0.77826 +/- 8.0381	
	E - 5	

After fuel rod is removed:

Press P₀

EMPTY MEAS
PRINT ALL? ENTR (NO)
DELAY-MIN 10
SIGMA-% 0.05
#DP/RUN 125

EMPTY POWER W
1.9376 +/- 1.1192
E - 4

Sample-supplied power $\bar{P}_S = \bar{P}_O - \bar{P}_c$

POWER W
1.1594

Sample mass, $\bar{M}_{Pu} = \bar{P}_S / P_{eff}$

PU KG
0.32126 +/- 4.2924
E - 4

AGAIN? YES

EMPTY POWER W
1.9372 +/- 1.4131
E - 4

POWER W
1.1589

PU KG
0.32113 +/- 4.3089
E - 4

AGAIN? NO