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DATA PROCESSING SUPPORT FOR EXPERIMENTAL STUDIES OF THE UPPER ATMOSPHERE

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This report describes the data processing support provided to reduce a variety of rocket-, satellite-, falling sphere-, and balloon-borne sensor data for analysis by Air Force scientists engaged in atmospheric research projects.

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FOREWORD

The efforts described herein were performed under contract to the Analysis and Simulation Section (SUWA), Computation Branch of the Air Force Geophysics Laboratory (AFGL), Hanscom Air Force Base, Massachusetts. Mr. Edward Robinson was Contract Monitor.

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1. Introduction

This report describes the data processing support provided for the telemetry data of a variety of sensors and vehicles utilized by Air Force scientists for project studies of the upper atmosphere. The substantive results of these experiments are described in the reports of the investigators.

2. A Processing System for Accelerometer-Equipped Falling Sphere Data

This section describes the processing system used to analyze data obtained from rocket flights with accelerometer-equipped falling spheres. The purpose of these flights is to measure atmospheric density, typically from an altitude of 50 to 150 kilometers. Several such flights have been analyzed by the programs described here. One of the flights and the results obtained, is described in publication (1) on which part of this report is based, and from which the experiment description was extracted.

(1) Philbrick, C.R., Faire, A.C., and Fryklund, D.H. (1978) Measurements of Atmospheric Density at Kwajalein Atoll, 18 May 1977, AFGL Report: AFGL-TR-78-0058

2.1 Experiment Description

An accelerometer capable of accurately measuring atmospheric drag acceleration between 10^{-1} m/sec^2 and 10^{-7} m/sec^2 has been developed to provide measurements of atmospheric density from 50 to 150 km. The instrument with its associated electronics, PCM encoder, telemetry transmitter, radar beacon, and batteries has been packaged into a sphere of 25 centimeters diameter.

2.1.1 Piezoelectric Accelerometer

The accelerometer is a triaxial piezoelectric sensor with the center of gravity of the three proof masses located near the center of the sphere. The piezoelectric crystals used for each axis provide a highly linear output voltage as a function of the strain produced in the crystal under the force produced by the acceleration of the proof mass.

In Figure 1, an individual sensor element is represented schematically. The sensor is a cantilever beam made in a bimorph construction. The ceramic element used is multicrystalline lead zirconite-lead titanate. This element was selected because of its high sensitivity, good mechanical strength, high internal capacitance, good chemical stability, and good thermal stability. An applied force produces a corresponding deflection that strains the crystal resulting in a voltage proportional to the applied force. The sensor elements used result in typical outputs of about 70 volts/g. Because the high acceleration forces from handling and launching could fracture the ceramic, the proof masses are held clamped until after the sphere is released from the payload. In order to determine the total drag acceleration at any particular time on the sphere, three orthogonal axes of measurement are desired. The configuration of concentric masses allows the center of mass of each proof mass to be located near the center of gravity of the sphere. During assembly and balancing, the first and second moments of inertia of the instrument are adjusted so that the spinning sphere will be gyroscopically stable and the precession frequency will be well removed from the measurement, or or spin frequency. The sphere is flown with the sensitive direction of the z-axis along the rocket longitudinal axis. The final spin rate is typically in the range between 5 and 6 Hz. and the precession frequency is about 1 Hz. The sphere is released with a mechanism designed to impart a large separation velocity from the payload, and to produce minimum forces that would result in precessional motions.

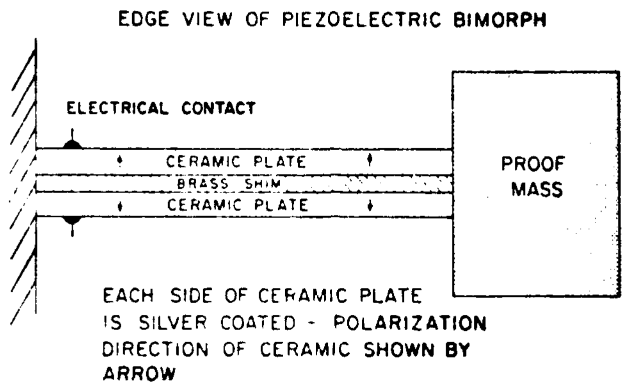

Figure 1. A Schematic Representation of the Sensor Construction Indicating the Orientation of the Polarization Field of the Piezoelectric Ceramic

2.1.2 Experiment Measurements

The atmospheric drag acceleration is collinear with and oppositely directed from the velocity. Figure 2 shows the angles defined for the sphere data analysis. After the sphere is released, its spin axis tends to stay fixed in inertial space. The precession motion typically results in a cone with a half-angle of about one degree sumperimposed on the mean spin axis direction. The spin stability should not allow the misalignment of center of mass and center of pressure to cause a change in the mean spin axis direction and accumulate an angle greater than one-half degree over the usable altitude range. The angle α between the vertical and the spin axis can be determined by two independent techniques and once known leads directly to independent measurements of drag acceleration from each of the sensor outputs. The relationships are

$$\alpha + \beta - \gamma = 180°$$

$$a_D = a_x/\sin\gamma = a_y/\sin\gamma = a_z/\sin\gamma$$

where

α is the angle between the spin axis and vertical,

β is the angle between the velocity vector and vertical,

γ is the angle between the drag acceleration vector and spin axis,

a_z is the acceleration component along the planned spin axis shich is smoothly and slowly changing during the flight,

a_x and a_y are the peak amplitudes of sine curves produced each spin period by the component accelerations in the spin plane.

One of the ways of determining the value of α is to use the a_x or a_y compnent together with a_z, calculating γ from

$$\gamma = \tan^{-1} a_x/a_z = \tan^{-1} a_y/a_z$$

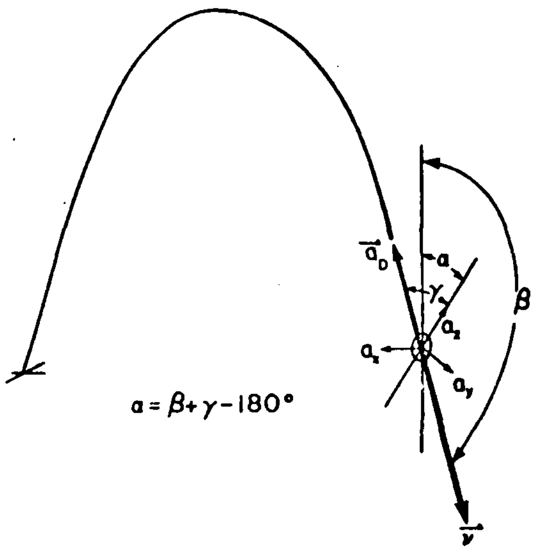

Figure 2. Representation of the Angles Used in the Analysis of the Sphere Data

with β known from the trajectory velocity components. Second, under the assumption that the spin vector stays fixed in space, the value of α can be determined as that value necessary to have reasonable agreement between a_D values on upleg, with those on downleg using a_x or a_y measurements. Note from Figure 2 that on upleg the angle between a_D and a_y is near 90°. This fact leads to a very sensitive dependence of upleg a_y values on the chosen α.

Each axis output voltage is sensed by a series of four amplifiers which have gain differences of about a factor of 20. The amplifiers have notch filters to strongly attenuate the precession frequency component of the signals. This minimizes the effects such as precessional motion of the sphere, particularly at the higher gain levels. Typically, the spin frequency is 5 to 6 Hz and the nutation frequency about 0.9 Hz with a nutation angle of 1° to 2°, which is measured by an accelerometer removed from the center of the sphere. The amplifiers are calibrated at about 20 different frequencies to determine the appropriate transfer function.

Once the drag acceleration a_D has been determined, the atmospheric density can be determined from the drag force

$$F = \frac{1}{2} \rho v^2 C_D A = m a_D$$

$$\rho = 2 a_D m / v^2 C_D A$$

The drag coefficient C_D can be determined from experimental results for Reynold numbers between 20 and 10 $^{(2)}$, and for Mach numbers between 0.1 and 6 (Bailey and Hiatt[2]) and from theoretical studies in the free molecular flow region (Schaaf and Chambre[3]). In the transitional flow region which corresponds to altitudes between 90 and 110 km, a model solution (Rose[4]) compatible to smooth transition between the continuum and free molecular cases is used. At lower altitudes the drag coefficient

2. Bailey,A.B.,and Hiatt,J. (1972) AIAA 10:1436
3. Schaaf,S.A.,and Chambre,P.L. (1958) Fundamentals of Gas Dynamics,687
4. Rose,M.H. (1964) Phys. Fluids I:1262

can be conveniently expressed in terms of Reynolds number and Mach number. At high altitudes the important parameters are the speed ratio and Knudsen number. But, in both cases, the atmospheric temperature is needed. A convenient table for determination of drag coefficient (Corbin[5]), based on the models mentioned, is used in this analysis. Thus, for the first solution a model atmosphere is used to provide the parameters to define the drag coefficient. The mass density is calculated and then used to calculate the temperature under the assumption of hydrostatic equilibrium. This calculated temperature is then used to recalculate the drag coefficient. When final density values are obtained, these results can be used to calculate molecular scale temperature which is converted to gas kinetic temperature using model values of mean molecular weight.

2.1.3 Atmospheric Model

The atmospheric models used for most of the comparisons have included the USSA 76 and the U.S. Standard Atmospheric Supplements 1966, 15°N Annual (USSAS[6]). The use of appropriate models is necessary to choose the temperature for a first calculation of Mach and Reynolds numbers to derive the drag coefficient to begin the iterative procedure. Also, models provide a convenient reference for plotting and comparing the density which changes by several orders of magnitude in the altitude range considered.

5. Corbin,V.L. (1975) Private communication of unpublished study, Drag Coefficients from Free Molecular Flow to Continuum Flow for Mach Numbers 1.5 to 6.0 .
6. USSAS (1966) U.S. Standard Atmospheric Supplements, 1966, U.S. Government Printing Office, Washington, D.C.

2.2 Analysis Procedure

The analysis of the data uses the following programs in sequential order:

- . HON316 - unpacks digital data tape
- . LISTR - lists unpacked digital tape
- . TA - separates the different data channels into individual files
- . SLIDE - fits data from x- and y-axis accelerometers to a sine curve at spin frequency and plots raw and fitted counts
- . ACCPLT - plots fitted x- and y-axis acceleration
- . OVERLAP - plots overlap region between sensitivity ranges for x- and y-axis acceleration
- . ZEE - filters the nutation frequency from z-axis and nutation data
- . MERGE - generates composite acceleration profile
- . PLOTOUT - drives subroutine for density profile
- . ACC - calculates density profile

A schematic diagram of the flow of the analysis is shown in Figure 3, and a diagram of the tapes and permanent files involved in the analysis is presented in Figure 4.

The analysis starts with the receipt of a tape containing the digitized output of the accelerometer amplifiers. This tape has been digitized from the analog telemetry experiment tape of PCM data by a Honeywell H-316 computer. The digital tape together with a stripchart of all data channels (x_1-x_4, y_1-y_4,z_1-z_4,nutation) comprises the input for the analysis of the data. Also available are trajectory data, the spin and nutation frequencies, and amplifier calibration data. The stripchart is used to determine useful data for each amplifier range, from minimal signal to saturation.

The digital tape is first copied to another tape and the original tape archived. This provides backup if the tape is damaged. As part of the copy

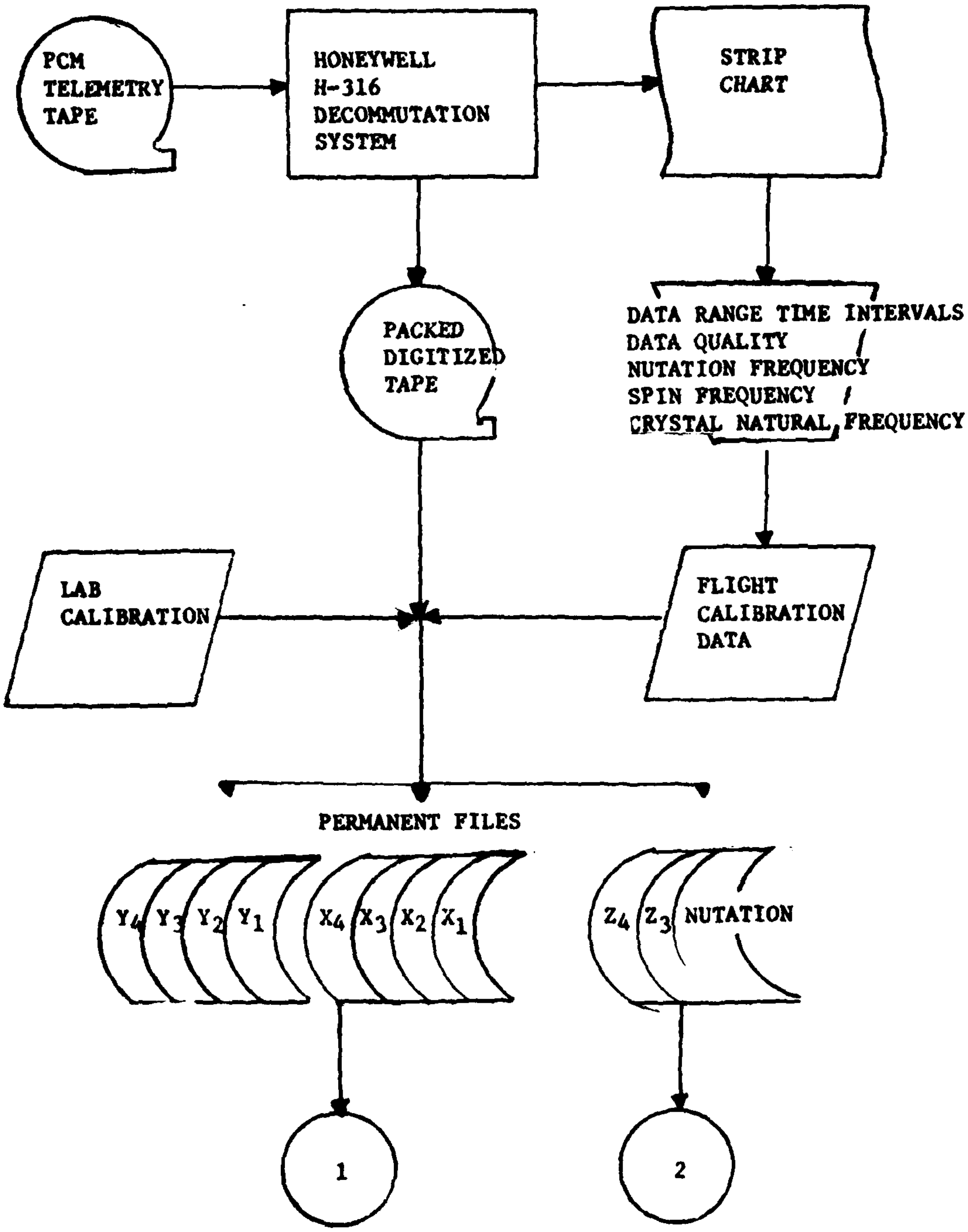

Figure 3a. Preliminary Data Reduction and Analysis

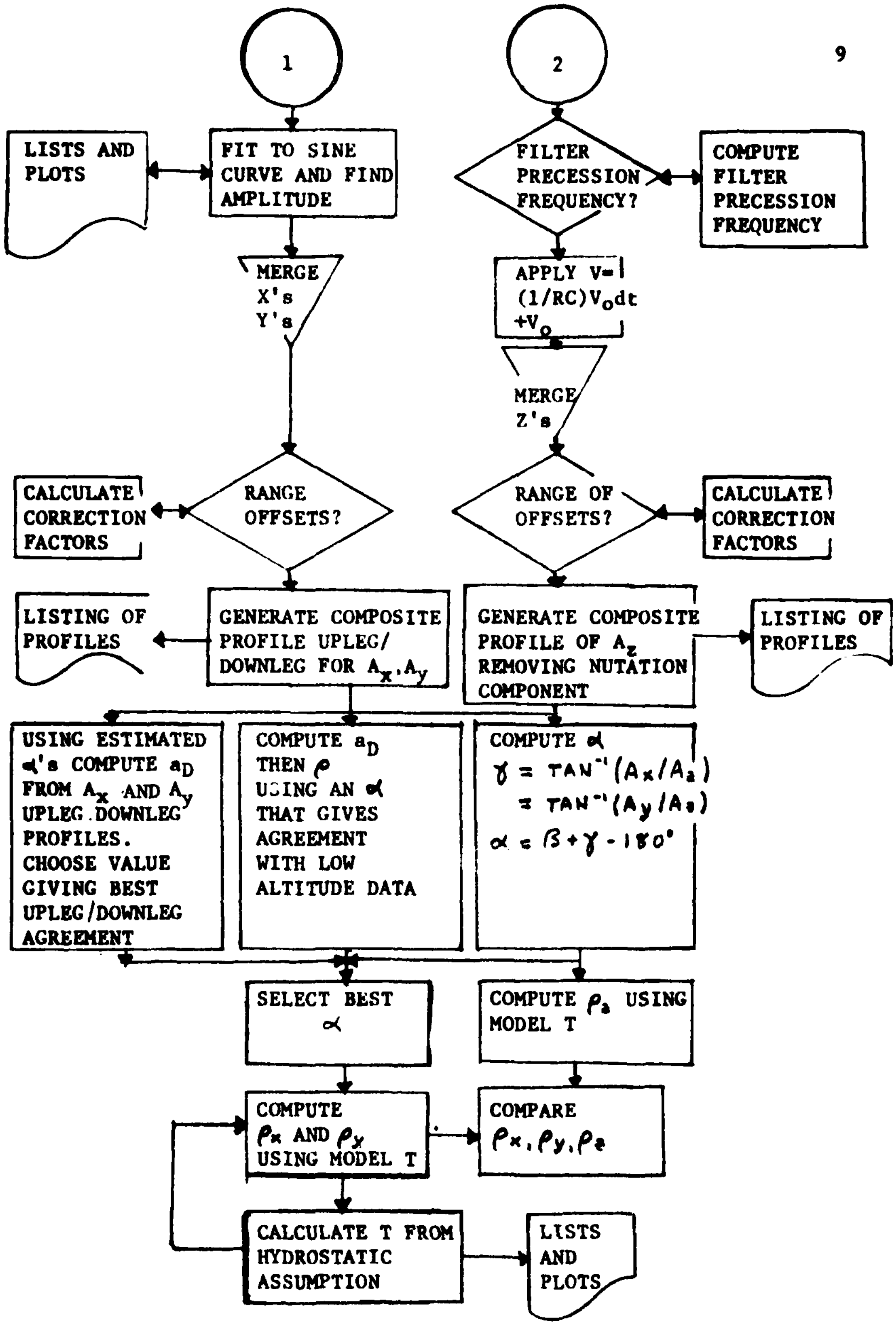

Figure 3b. Main Body of Analysis

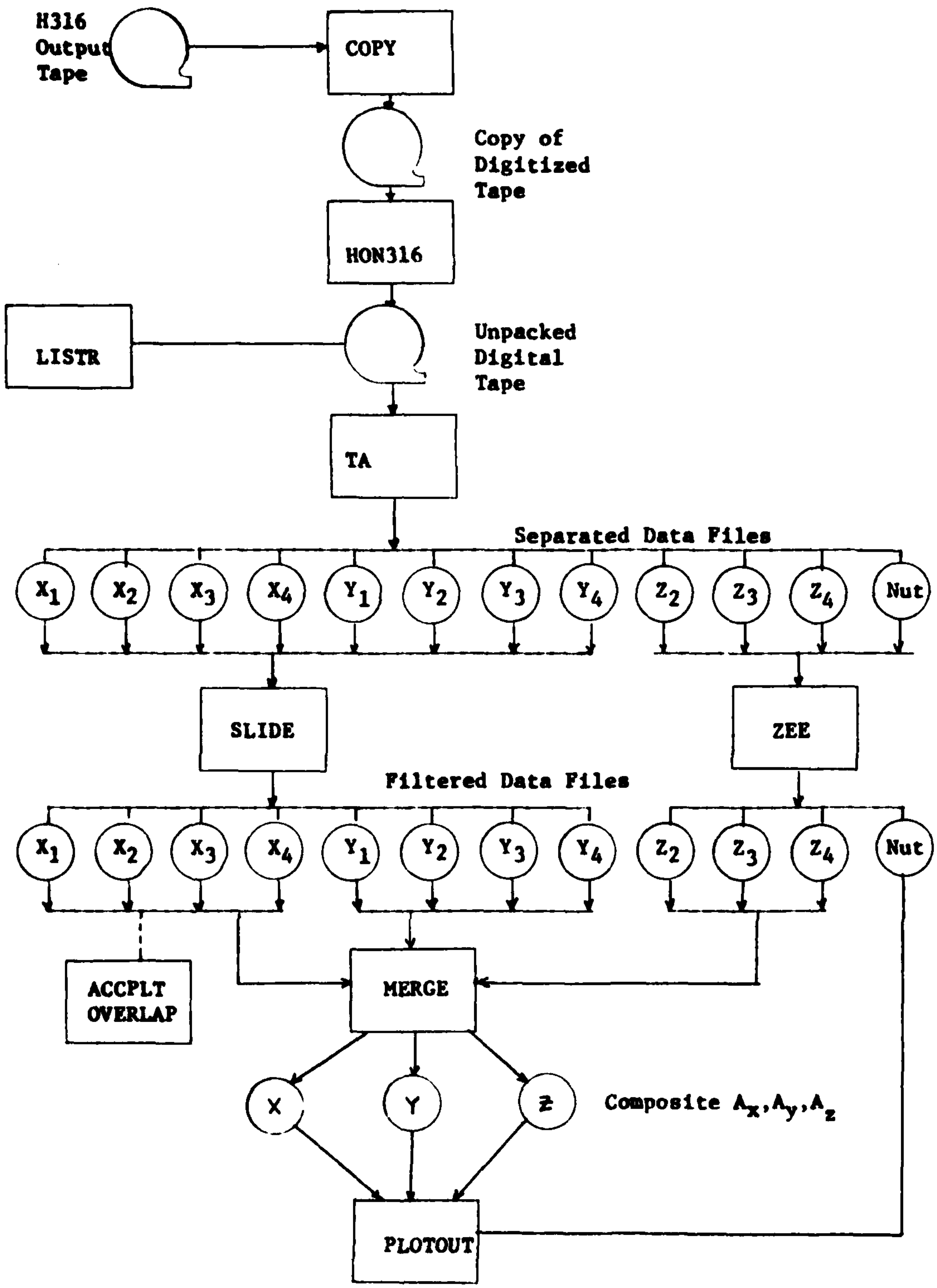

Figure 4. Programming System

operation, selected records of both the original and the copied tape are dumped to verify the copy and also to obtain a first look at the quality of the digital data. If there is an indication that the digitization was bad, a new digital tape can be requested at this stage.

Next, the digital tape is unpacked and converted from H-316 format to CDC format. The program used to unpack the data is HON316, a standard AFGL unpack routine. A complete listing of all data ranges versus time is then produced using routine LISTR.

For further processing it is convenient to separate the different data channels into distinct files. Program TA reads the unpacked digital tape and produces separate permanent files (or magnetic tape if so chosen) for the data channels x_1-x_4, y_1-y_4, z_1-z_4, and nutation. Although most of the data for each range will be either zero or saturated, the entire flight (or only upleg or downleg) data is separated into files. The selection of useful data (intervals of data within the range of a particular amplifier) is made at the next stage.

It should be noted that at this point the data consists of digital counts, from 0 to 256. Zero volts output nominally corresponds to 128 counts, so that 0 or 256 count values represent saturation.

A preliminary determination of the useful time interval for each data range can be made from the stripchart and the listing of program LISTR. The time interval is made sufficiently large to include all useful data. The time intervals for x_1-x_4,y_1-y_4,z_1-z_4, and nutation are noted and further analysis will be restricted to those ranges.

At this point the analysis diverges: the x- and y-axis data is analyzed by one procedure, and the z-axis and nutation data by another. The x- and y-axis sensor data is modulated by the spin frequency while the z-axis and nutation sensor data is continuous DC with a superimposed modulation.

2.2.1 Analysis of X- and Y-axis Data

In order to determine the drag acceleration, the data in the selected time interval is fitted to a sine curve of the form $A \sin(\omega t + \delta) + \theta$ over an interval of approximately one period. The fitted amplitude (A) is a measure of acceleration voltage for this fitting period, with modulation due to spin and any constant offset removed. The fitting program, SLIDE, converts the digital counts to sensor voltage and also to acceleration values, using calibration values provided by the investigator.

This fitting to a sine curve is done for all x- and y-axis data for time intervals with useful data. These time intervals overlap slightly for different sensitivity ranges, i.e., one range starts to give meaningful digital counts before the previous range saturates. Program ACCPLT and OVERLAP are used to determine the best time to switch from one sensitivity range to the next, and to calculate offset values to correct for a count shift between adjacent ranges.

The next program, MERGE, generates a composite x- or y-axis acceleration profile by merging the separate sensitivity ranges. Inputs to this program are the permanent files created by program SLIDE, together with the times of the range crossover points.

Normally, separate profiles are generated for upleg and downleg data.

A major uncertainty in the analysis is the value of α, the angle between spin axis and the vertical. As mentioned in the description of the experimental measurements, several options exist for estimating this angle. The density calculation routine, PLOTOUT, is used to generate a preliminary profile of the drag acceleration a_D (for both upleg and downleg) for various estimated values of α. Comparison between upleg and downleg acceleration, as well as comparison with known data at low altitudes, are used to estimate a final α to be used in the density calculations.

Finally, the merged acceleration profile for the x or y axis is input to PLOTOUT to calculate a final density profile. Program PLOTOUT acts as the driver to the subroutine ACC which does the actual density calculation for each data point. For the first iteration, the model temperature profile is used to calculate the drag coefficient, and the derived density profile is integrated using the hydrostatic equation to calculate temperature. This improved temperature profile can then be used to re-calculate the density profile. Generally only two iterations are required. PLOTOUT outputs a point by point profile of density versus time with associated values of altitude, temperature, acceleration, velocity, model density, and ratio of calculated density to model density. Plots of density ratio, density, acceleration, and temperature versus altitude are produced for each iteration.

2.2.2 Analysis of Z-axis and Nutation Data

Analysis is done by filtering the z-axis and nutation data with a digital filter which extracts the drag acceleration with the nutation frequency component removed. This is done by program ZEE. Also in this program the telemetry voltage is integrated to give the exact analog value of the measured acceleration.

The filtered data for the different ranges are then merged by program MERGE to give a composite z-acceleration profile. This acceleration profile is then used to calculate a density profile using program PLOTOUT. For the z-axis and nutation data, only one iteration of the density calculation is made using the model temperature profile.

2.3 Programming System

Functional descriptions of the individual programs are given below.

2.3.1 HON316

This program reads and unpacks a Honeywell H-316 digital data tape which is packed five twelve-bit words per 60-bit CDC computer word, checks for timing errors, deletes bad data frames and creates a new data tape in CDC format. Each tape record is 204 CDC words which is unpacked into 1020 data values (words of information). The first six of these twelve-bit words contain the request number, work request tape number, file number, record number, number of data channels (number of data words per frame), and the binary number 316 to identify the input tape data was recorded by the H-316 system. Words 7 thru 10 combine to give the major time in days, hours, minutes, and seconds. The remaining words hold a multiple number of data frames. Each frame has the same number of words. The first frame word contains a millisecond count. The last word of the frame is a synchronization code. Between the millisecond count and the synchronization code are the data words. If the synchronization code is incorrect, this frame and the succeeding ones are eliminated.

If an input frame has n data values, HON316 forms a time-data frame, time followed by n data values (n+1 CDC words). The time is in days-seconds formed from the major and minor times. The time-data frames are written as a sequential file on tape. Each output record has 1012 CDC words. The first two words contain the number of data words in a frame and the number of frames in the record.

2.3.2 LISTR

This program accesses the unpacked data tape created by HON316 and produces a listing of each data record, consisting of record number, time, and digital count values for the 17 data channels, viz. x_1 to x_4, y_1 to y_4, z_1 to z_4, and nutation. This listing provides a first look at the data and in conjunction with the stripchart allows identification of areas of interest for further processing.

2.3.3 TA

This program separates the data channels (x,y,z and nutation) and writes them as individual permanent files for further processing. The program also lists every 100th data point of the output.

This selective listing, together with the detailed listing given by LISTR, and the stripchart of the digital tape, is used to select the upper and lower bounds for each amplifier range. The upper bound of each range is limited by saturation. At saturation for one amplifier range, the next less sensitive range typically reads 5 to 7 counts. Further processing for each data channel (or range) will be done using this limited set of data only.

2.3.4 SLIDE

This program fits the raw count data of the x and y accelerometers to a sine curve of spin frequency. The spin frequency is typically 5 to 6 Hz, and at a data frequency of 100 values per second there are about 20 values for one spin cycle. The PCM output counts are fitted to a sine curve for 20 sequential points, approximately one spin, and then the first 10 points are dropped, 10 new sequential values added and a new fit determined. This procedure provides the amplitude of each fit as a fractional count of the PCM data, with values between 0 and 127 counts. Any bias in the spin axis is removed by the fit. The amplitude in counts is then converted to voltage determined from calibration signals. The laboratory determined sensor sensitivity and amplifier gains are then used to calculate the acceleration components.

The program fits one sensor sensitivity range at a time. The amplifier gain, and start and stop times are read in. The spin frequency is specified in the program. The appropriate permanent file created by program TA is attached and the time and PCM count for every point between the start and stop times are read into arrays. Initially, the first 20 points are transferred into a buffer array and the IMSL subroutine ZXMARQ is called to determine the best fit of the 20 points to a sine curve. The fitted amplitude together with the fitted frequency and phase angle are stored in arrays. The first 10 points are removed from the buffer, the remaining ten shifted down, and another 10 points added. The fitting routine is called again, and the procedure repeated until the data is exhausted. Then the fitted amplitudes in PCM counts are converted to voltage and also to acceleration units, using the amplifier gain. Finally, the fitted amplitudes and the corresponding times are written on a permanent file for further processing. At the same time, a listing of these quantities is produced, as well as a plot of initial and fitted counts versus time. See Figure 5.

2.3.5 ACCPLT

ACCPLT plots acceleration versus time, which was calculated in program SLIDE, and stored on permanent files.

2.3.6 OVERLAP

Acceleration measured at the same time by two overlapping amplifier sensitivity ranges should give the same values. In practice, however, because of experimental uncertainties in the amplifier calibrations, the two measured accelerations may differ. Later processing of both data must measure the same physical quantity. To determine these so-called range offsets it is useful to display overlapping measurements for two sensitivity ranges on the same plot. Program OVERLAP reads in the permanent files created by SLIDE for two adjacent ranges and plots the overlap region. This plot, together with listings of the fitted acceleration, is used to determine a reasonable correction to the amplifier calibration. The correction factor for the fitted acceleration is later applied in program ACC.

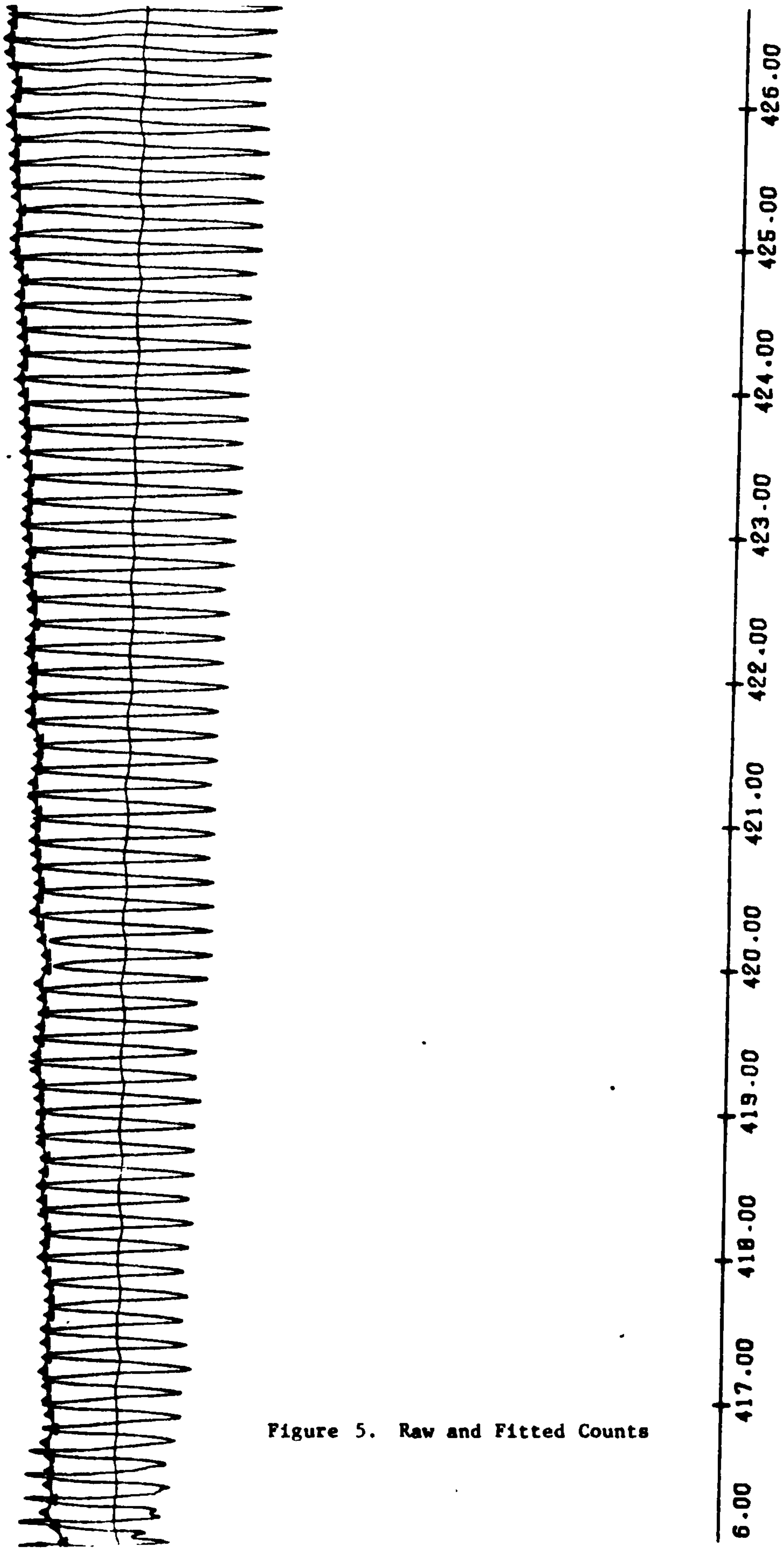

Figure 5. Raw and Fitted Counts

2.3.7 MERGE

Once the individual amplifier ranges have been separated and either fitted to a sine curve (x and y axes) or filtered (z axis), the individual segments are merged. This allows further processing to be done with a composite acceleration profile. Any adjustment to correct for range offsets will be done later. This program contains the times when the switching between amplifier ranges is to occur. The individual permanent files for the separate ranges are attached, and the data merged according to the specified crossover points. A listing of the merged data is also produced.

2.3.8 ZEE

This program filters the raw PCM counts for the z-axis accelerometer, and also the nutation sensor, in order to remove acceleration due to nutation. The PCM count data separated by program TA is read and passed through a digital filter cutting off frequencies above the nutation frequency. The measured telemetry voltage is integrated with the appropriate time constant to give the exact acceleration. Then the PCM counts are converted to voltage and subsequently to acceleration, and are stored on a permanent file. A listing of unfiltered and filtered data points is produced.

The permanent files created for the different ranges of the z-axis are later merged into a composite acceleration profile by program MERGE.

2.3.9 PLOTOUT

PLOTOUT, together with its subroutine ACC performs the major part of the analysis. Program PLOTOUT is the driving routine for subroutine ACC which calculates the density profile using the acceleration data output of program MERGE.

The density calculation can go through a variable number of iterations, each iteration resulting in an updated temperature profile which in turn is used for the next iteration of the density profile. The calculation of the density profile is done point by point by subroutine ACC. After an initial density profile has been calculated using the model temperature profile, this density profile can be used to calculate a new temperature profile by integrating the hydrostatic equation. This new temperature profile is in turn used to calculate the next iteration of the density profile, and so on. After the specified number of iterations have been performed the program produces the various listings and plots. A detailed description of the output is given in a later paragraph.

The program goes through the following major steps:

1) The program reads cards that assign values to various parameters such as begin and end times, altitude, plot titles.

2) All the points in the acceleration profile created by MERGE are read into arrays.

3) For each point in the profile, subroutine ACC is called. Given time and acceleration, ACC calculates model density, drag acceleration, molecular and kinetic temperature.

4) Upon return from ACC, the following quantities are calculated for each point: ratio of measured to model density, log of drag acceleration and log of the calculated density.

5) After all points in the density profile have been calculated and stored in an array, the density profile is integrated at one kilometer (or .5 kilometer) intervals to give a temperature profile. The integration is done in log density space.

6) The program is initialized for the next iteration. The temperature profile obtained by integration of the density profile replaces the previous profile. Plots of log acceleration, log density, temperature, and density ratio are generated (samples in Appendix). A test is made to see if the requested number of iterations has been performed; if not, another iteration is performed.

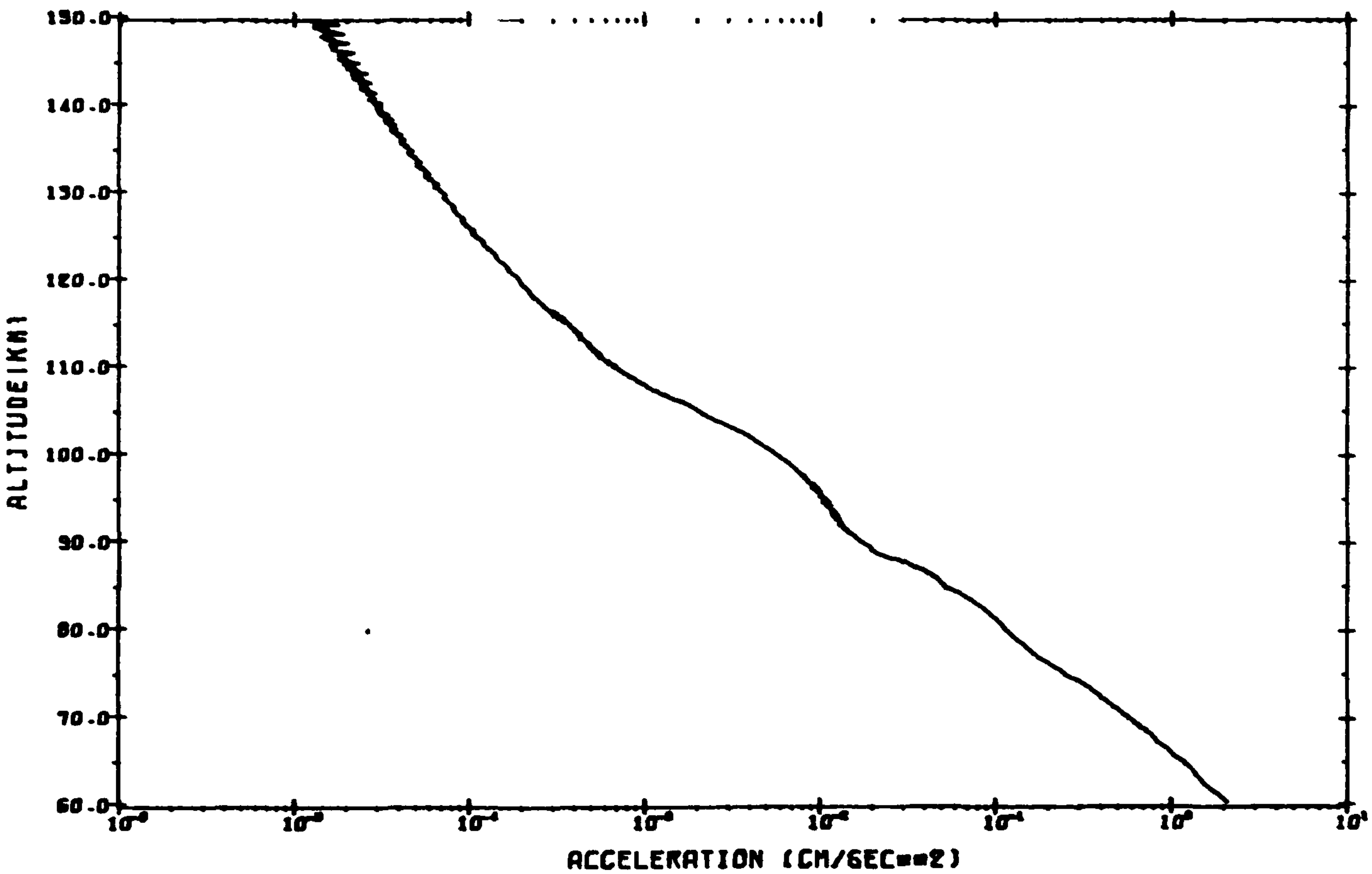

Figure 6. Acceleration - First Iteration

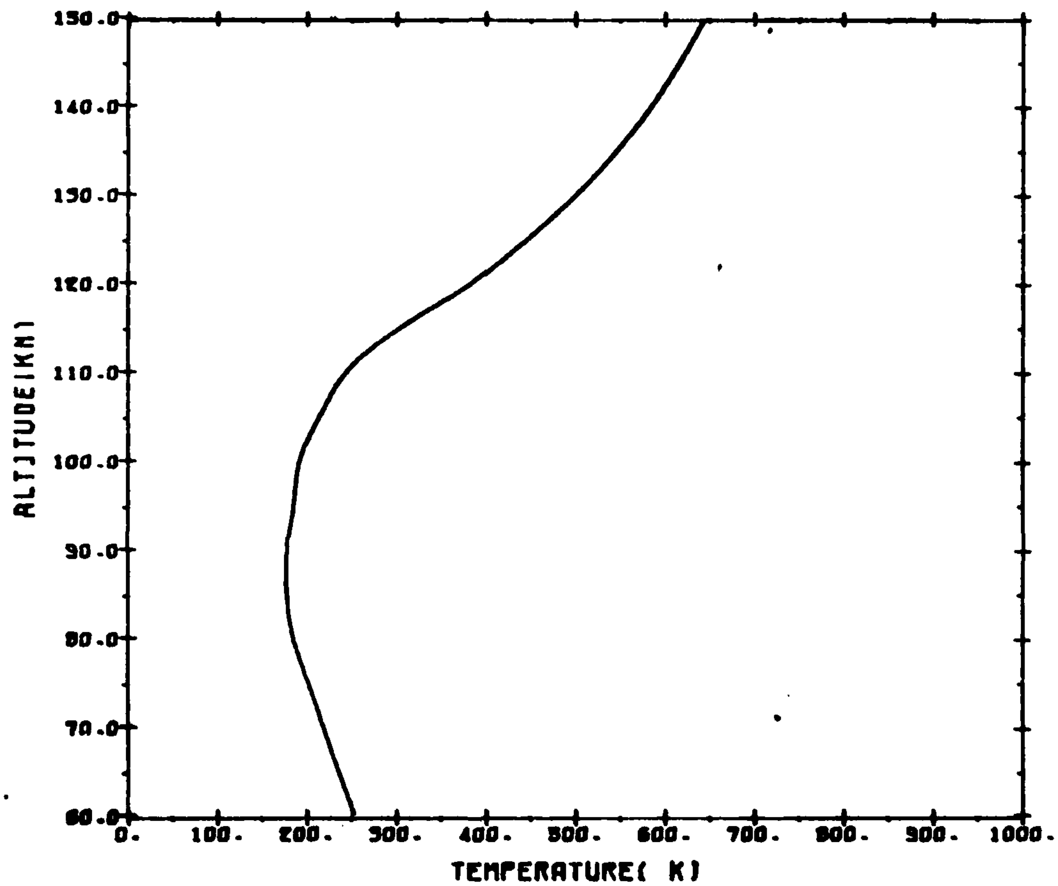

Figure 7. Model Temperature - First Iteration

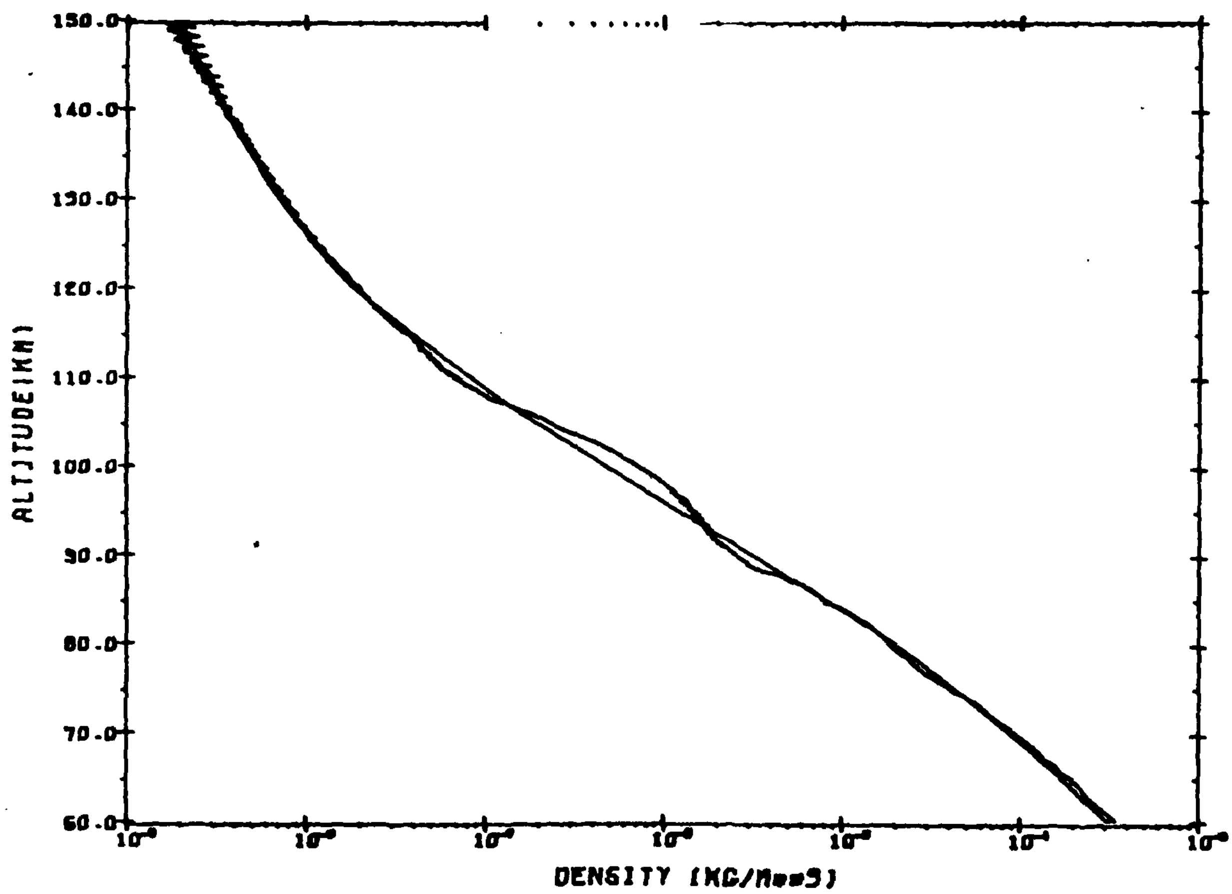

Figure 8. Density - First Iteration

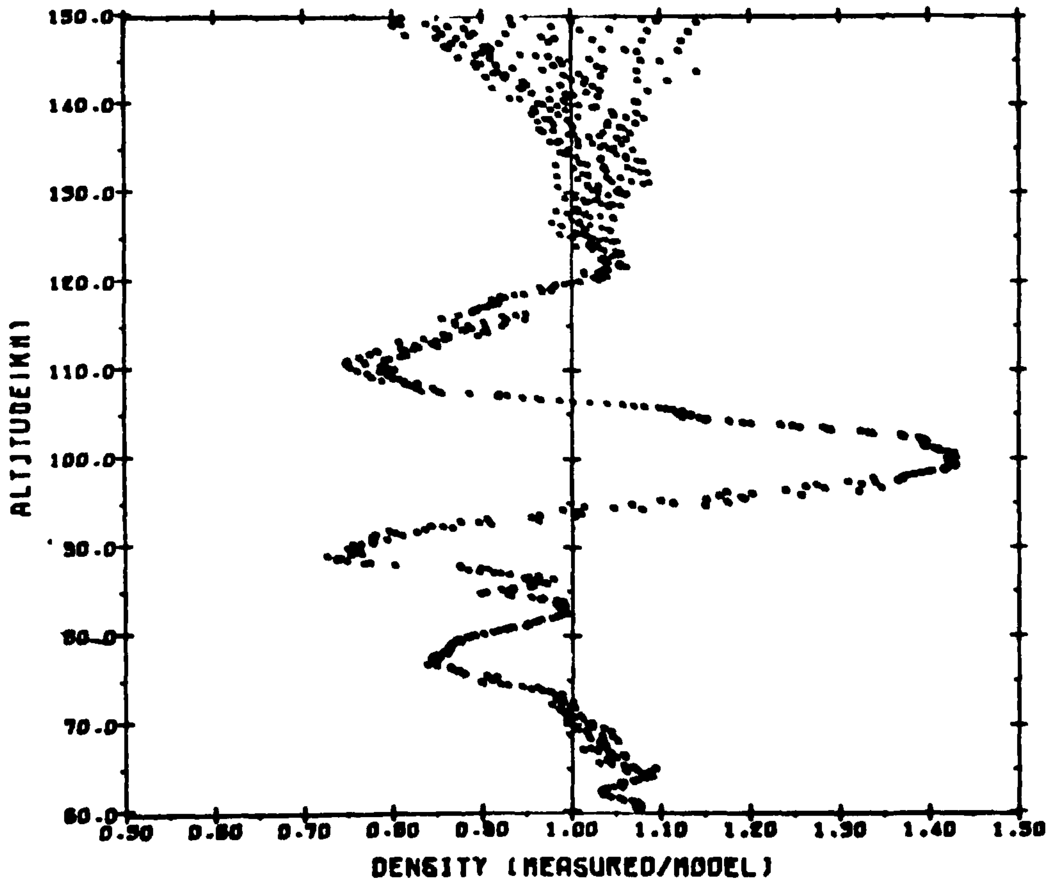

Figure 9. Density Ratio - First Iteration

7) If no more iterations are needed, final listings are generated. These listings include a point by point summary, both in metric and English units, and a summary at one kilometer and one kilo-foot intervals.

2.3.10 Temperature Determination

The initial temperature profile used in the first iteration is interpolated from the temperature of the model atmosphere.

After the first iteration, the temperature profile is determined from the density profile under the assumption of hydrostatic equilibrium.

$$dP = -g \rho \, dZ,$$

and the ideal gas law

$$P = \rho R T / M = R T_M / M_o$$

$$T_M = M_o T / M$$

where R is the universal gas constant, M_o is the sea level value of mean molecular weight, and T_M is the molecular scale temperature. These equations can be combined to the form,

$$dP = R [T_M \, d\rho + \rho \, dT_M] M_o$$

and yields

$$T_M = T_M \frac{\rho_1}{\rho_2} - \frac{M_o \, g(Z)}{\rho_2 R} \int_{Z_1}^{Z_2} \rho \, dZ$$

which is integrated along the density profile. The molecular scale temperature is converted to gas kinetic temperature using the model values of mean molecular weight.

The acceleration of gravity used for the calculation is obtained from the relation

$$g(Z) = g_\phi R_\phi^2 / (R_\phi + Z)^2$$

where g_ϕ is the sea level acceleration of gravity at latitude ϕ, and R_ϕ is the effective radius of the earth at that latitude.

2.3.11 ACC

This subroutine, called by PLOTOUT, performs the density calculation for each point. The angle α, determined earlier, is used in this routine. It also incorporates the trajectory data and the model atmosphere used in the analysis in the form of BLOCK DATA. The trajectory data contains entries for time, altitude, velocity, and x,y,z components of the velocity. The model atmosphere contains altitude, kinetic temperature, density and molecular mass. Typically, these tables contain about 80 entries. In addition there is a two-dimensional table giving the drag coefficient C_D as a function of both Reynolds number and Mach number.

Subroutine ACC is called by the driver PLOTOUT for each point in the acceleration profile, with arguments of time and acceleration. From these quantities ACC computes the density in the following major steps:

1) The altitude is calculated from the time by interpolating into the trajectory table. This interpolation, as well as all other interpolations done within ACC uses a spline fit algorithm (IMSL routine ICS1VU). Also interpolated from the trajectory table are the velocity components.

2) Using the quantities interpolated in the previous step, the angles β and γ are calculated as follows:

$$\cos\beta = V_z/V$$

$$\gamma = \alpha - \beta + 180^\circ$$

and the drag acceleration is obtained as

$$A_D = a_x/\sin\gamma \qquad \text{for x-axis acceleration } a_x$$

$$A_D = a_y/\sin\gamma \qquad \text{for y-axis acceleration } a_y$$

or

$$A_D = a_z/\sin\gamma \qquad \text{for z-axis or nutation axis acceleration } a_z$$

The acceleration may be corrected here for any remaining calbiration correction of the individual accelerometer ranges.

3) Interpolating the model atmosphere, the following quantities are obtained

model density ρ_M

molecular mass M

temperature T_M

4) From the above quantities, the Mach number (Ma) and the Reynolds number (Re) are calculated

$$Re = v \, l \, \rho_M / \mu$$

where v = velocity of sphere, l = sphere diameter, ρ_M = model density, and μ = coefficient of viscosity of the atmosphere.

$$Ma = v / C_s$$

where v = velocity of sphere, C_s = velocity of sound.

5) Using the Mach and Reynolds numbers as input, the C_D table is interpolated to obtain the drag coefficient C_D. Outside the boundaries of the table, C_D is obtained by an algorithm.

6) The density is finally calculated as

$$\rho = 2 \, a_D \, M / C_D \, A \, v^2$$

where a_D = drag acceleration, M = mass of sphere, C_D = drag coefficient, v = velocity of sphere, A = area of sphere cross-section

7) Before returning the calculated density to the calling program PLOTOUT, all relevant quantities for this data point are printed out.

3. Preprocessing System for Satellite-Borne Scanning Radiometer Data

This section describes the programming that preprocesses DMSP data to provide a data base for analysis of auroral spatial structure using a CDC 6600 computer.

The data is telemetered from a scanning radiometer or photometer mounted on an orbiting satellite. As the satellite orbits, a mirror oscillating sinusoidally provides a raster scan of a target surface below. The scan is in a plane perpendicular to the track of the satellite which simplifies the geometric view. The maximum angle of a scan is roughly $\pm 57°$. The data obtained is a picture transmission with 1464 picture elements with intensity scale 0 thru 99 (0 lightmost, 99 darkmost) for each scanline.

Data preprocessing has two separate program steps: 1) program PIXEL converts the data packed in 36-bit words to data packed in 60-bit words for processing by a CDC 6600 computer. This repacked pixel data is combined with ephemeris data necessary to compute the geographic coordinates of the pixels; 2) program PIXEL2 unpacks the CDC-formatted output tape of program PIXEL, computes geographic coordinates for each pixel, and prints a choice of data listings.

3.1 Preprocessing Procedure

Program PIXEL provides the first preprocessing steps:

1) Ephemeris data that gives the motion of the satellite over the time interval of interest is read from a permanent file into a table array. This table will be used to interpolate for the longitude, latitude, and the altitude of the satellite subpoint at each scanline time.

2) The first input record (68 CDC words) is skipped.

3) Fifteen successive records (672 CDC words each) are read into an input buffer array ID and processed at a time.

4) Successive word triplets of ID are unpacked into successive word quintuplets of array JD: three 60-bit CDC words hold five 36-bit words - the 36-bit information is right-adjusted in a word of JD. The first word of JD contains a word count of valid 36-bit data words. Therefore, the actual data begins at word 2 of JD. The data of a scanline delimits a logical record. A logical record of data is 249 words of JD, each containing 36 bits of information. JD contains 64 logical records (64 scanlines of data).

5) Scanlines are sequentially unpacked. The scanline time is used to interpolate for the satellite subpoint latitude, longitude, and altitude. These values along with frame number, scan number, and gain data are stored in single words. The pixel values (six per 36-bit word) are repacked 10 per 60-bit word. The repacked scanline is a logical record of 156 words. Six logical records are stored in one output tape record. An output tape record is 1012 CDC words. The first word gives the number of valid data words in the record.

6) When six successive repacked records have been stored in the output buffer IW, the contents of the buffer are written to tape or a permanent file. If the data is written to a permanent file on disk, processing and throughput time is greatly reduced.

Program PIXEL uses the following subprograms: subroutine EPHEM to read the satellite ephemeris data from a file into the table array; subroutine ICS1VU which needs subroutine UERTST for cublic spline interpolation of ephemeris values; subroutine UNPK610 to unpack pixel values (36 bits to six 6-bit values) and to repack pixel values (10 six-bit values to 60 bits).

Program PIXEL2 continues the preprocessing steps, using the output file of program PIXEL:

7) Scanlines are selected by time interval, scan number range, or a set of scan numbers, and successively unpacked and processed.

8) The selected scanlines are unpacked.

9) A listing is made:

a) If LIST = 0, an abbreviated listing is made, one line per scanline: each line gives the scan no., satellite subpoint latitude, longitude, altitude, time, and the pixel no. and values of minimum and maximum pixels in the scanline.

b) If LIST = 1, a geographic mapping of values is printed. For each selected scanline, along with the values printed in the abbreviated listing, each pixel number, pixel value, and pixel latitude, longitude, azimuth heading, and great-circle arc distance from the satellite subpoint on the target surface is printed.

Program PIXEL2 uses the following subprograms: subroutine NXSCAN reads and unpacks successive scanlines sequentially or unpacks only selected scanlines; subroutine SATCO is called once per scanline to compute values needed for further computation of geographic coordinates of the pixels; subroutine PIXCO is called once per pixel to compute the geographic coordinates of a given pixel no. of a scanline; subroutine PRNT is called to 1) read hollerith information for printout and format statements needed for printing, and 2) print output lines.

3.2 Program Description

Program descriptions follow, in order of first call. The descriptions of the main programs include input and ouput descriptions.

3.2.1 Program PIXEL

Given a DMSP pixel data file (scan lines containing header data and 1464 pixel values per scanline) with data packed in a special 36-bit word format, the program PIXEL repacks the data in 60-bit word format along with satellite subpoint location data (latitude, longitude, and transformed data expedites processing and analysis of the data by a CDC 6600 computer.

Input Data Tapes. Two input tapes are required: 1) the DMSP data tape with 36-bit word format; 2) a tape or permanent file with ephemeris data to locate the satellite subpoint position in time. Both files are sequential. The time sequence of the scan lines are in reverse order: first scanline in is latest time.

The DMSP Data Tape. The first record (68 CDC words) contains field data which is ignored. The remaining records (672 CDC words each) contain scan data. Because of the 36-bit format, logical records cross record boundaries. Fifteen tape records must be read into a buffer at one time. This buffer will contain a word count (no. of valid 36-bit words of data in the buffer) followed by 64 249-word (36-bit) logical records. Each logical record contains the data of one scan line. There are five 36-bit words in each three CDC buffer words.

The data in each scanline, in octal representation, is:

Word 1	XXXXXXYYYYYY	frame no. and scanline no.
Word 2	XXXXXXXXXXXX	synchronization code
Word 3	112233445566	six pixel values (0 thru 99 decimal)
Word 4		next six pixel values
.		
.		
.		
Word 246		last six pixel values (1464 in all)
Word 247	XXXXXXYYYYYY	time in day seconds times 1024
Word 248	XXXXXXYYYYYY	gain value and housekeeping code
Word 249	XXXXXXYYYYYY	gain value and satellite ID

The time number in word 247 must be floated and divided by 1024. to obtain the time in day seconds.

The Ephemeris Data File. This permanent file is generated upon request by the SUWA branch of AFGL. It contains ephemeris data for the satellite for a specified time interval and time increment. It is read by the FORTRAN statement READ(KTAPE)N,(E(J),J=1,N). If N=7, the record is skipped; if N=1, there are no data records left. Each read provides the data values for one entry into the ephemeris array, EPH(1000,4). Time, latitude, longitude, and altitude are stored in EPH(NE,1 thru 4) where NE is the next entry pointer. Time is day-seconds converted from hours, minutes, and seconds stored in IE(5 thru 7); geodetic latitude, West longitude, and altitute come from E(19),E(20), and E(15).

Procedure.

1) The beginning and ending times T1 and T2 are read.
2) The ephemeris data is read into array EPH(1000,4). Subroutine EPHEM.
3) The header record of the DMSP data tape is read in and ignored.
4) Fifteen records are read into buffer array ID and processing begins.
5) The 10080 words of ID are unpacked into the 16256 words of JD (actually only 15937 words of valid data). Three successive words of ID are unpacked into 5 successive words of JD. Each word of JD contains 36 bits of information right-adjusted.
6) JD contains a word count (no. of valid 36-bit data); Logical records begin at word 2. Each logical record (scanline of data) is 249 words (described above).
7) Each logical record is unpacked:
   a) The first word of the logical record pointed to by I is unpacked into frame no. and scan no.
   b) The second word is ignored (synchronization code).
   c) The 247th word is converted to time in day seconds.and used three times to interpolate in EPH(n,2), EPH(n,3), EPH(n,4) for latitude, longitude, and altitude. (Subroutine ICS1VU)
   d) Words 2 thru 246 (JD(I1) thru JD(I2)) are unpacked (six values) into six successive words of temporary buffer KD. The values

in KD are then repacked ten to a word in the output buffer subarray IW(J1) thru IW(J2) - words 10 thru 156 of the logical output record. The other unpacked values or values just to be transferred form a 156 word logical output record.

e) When six logical output records of data have been stored in the output buffer IW, the data in IW is written to tape. An output tape record is 1012 words. The first word gives the number of valid data words in IW.

8) When the 64 logical input records of JD are processed, the steps beginning at 4) are repeated.

The Data Output Tape. The only output of program PIXEL is the repacked data with satellite subpoint coordinates added and written to a tape or permanent file. Each output tape record is 1012 words and contain as first word the count of words with valid data followed by up to 64 logical records 64 scanlines) of 156 CDC words each.

These logical output records contain the following data:

Word 1	Frame number
Word 2	Scan number
Word 3	Time in day seconds
Word 4	Latitude in degrees
Word 5	Longitude in degrees
Word 6	Altitude in kilometers
Word 7	Gain and housekeeping data
Word 8	Gain and satellite ID
Word 9	Not used
Words 10 thru 156	1464 pixel values (ten per word)

3.2.2 Subroutine EPHEM(KTAPE,NE,EPH)

Subroutine EPHEM reads a permanent file or tape containing ephemeris data and stores a part of the data into the array EPH(1000,4) This data table is used to interpolate using IMSL Library subroutine ICS1VU (cubic spline interpolation). See Ephemeris Data Tape. Note: this routine requires IMSL routine UERTST.

3.2.3 Subroutine ICS1VU(F,X,N,M,G,H,IER)

Subroutine ICS1VU is an IMSL Library routine that performs one-dimensional cubic spline interpolation. F is the array of function values, X the array of argument values, both of dimension N. These argument values are in ascending order and may be unequally spaced. The argument values for which function values are sought are in array G of length M. Each argument in G is replaced by the interpolated value for the argument. H is a work area array of dimension 8*N+M. IER is the error parameter. This subroutine requires the IMSL routine UERTST which prints error messages.

3.2.4 Subroutine UNPK610(IDO,I1,I2,K,ID,JD)

Subroutine UNPK610 unpacks (IDO=0) or pack (IDO=1) an array of 1464 pixel values (six bits). For unpacking, the packed array is in ID(I1) thru ID(I2). For each packed word, six values are unpacked and stored in six words of JD. The six values in a word of ID are in the rightmost 36 bits. For packing, the array of unpacked values is in JD(I1) thru ID(I2) packed ten to a word.

This routine is used in the conversion process to transform 36-bit packed data to 60-bit packed data.

3.2.5 Program PIXEL2

Given the repacked DMSP data base created by program PIXEL, program PIXEL2 expands selected scanlines into pixels with latitude, longitude, azimuth heading, and great-circle distance from the satellite subpoint on a target surface. Two printouts are optionally chosen: 1) an abbreviated printout, one line per scanline, which for survey purposes gives the scan no., time(hours,minutes,seconds U.T.), satellite subpoint latitude, longitude, azimuth heading, and satellite altitude, and the pixel nos. and values of the minimum and maximum pixel values of the scanline; 2) a full printout providing for each pixel, a printout of its number, value, latitude, longitude, azimuth heading, great circle arc distance from the satellite subpoint for a given target height.

Data Inputs. The data input tape is the data output tape of program PIXEL. It is described under Data Output Tape above.

The following control input data is read in:

1) The first control data input is read by subroutine PRNT with IDO=0. 1+LH+2+1+2*LF cards are read in. LH cards have hollerith text which is printed in a box on the first outpout page to identify the job. 2*LF cards provide the format statements needed for listing.

2) Tne next input card provides integer values for LSCAN,LIST,IB,IE,HGT (no format):

   a) LSCAN=0 is used to exit the program.
      LSCAN=1,2,3 gives three options for selecting scanlines.

   b) IB and IE give the range of pixel values to be used in listing. The pixel nos. range from -732 to 732. If IB and IE contain 0 or are omitted, they are set to -732 and 732.

   c) LIST=0 provides an abbreviated printout.
      LIST=1 provides a full printout.

   d) HGT gives the value of the height of the target surface above the earth's surface in kilometers.

3) The next (and last for a single printout task) input is determined by LSCAN:

   a) If LSCAN=1, two integers IS(1) and IS(2) are read (no format) to give the first and last scan nos. of the scan no. range to be selected.

   b) If LSCAN=2, then NS,(IS(I),I=1,NS) is read to select asset of scanline numbers.

   c) If LSCAN=3, then the time values TB and TE in day-seconds are read (no format). All scanlines between times TB and TE are selected.

Procedure.

1) The control data inputs above are read.

2) The next scan no. to be unpacked is selected and stored in NEXT.

3) Subroutine NXSCAN reads tape records sequentially until it finds the scanline record (six in buffer) that has the scan no. of NEXT. (If LSCAN=3, the next sequential scanline record with time within TB,TE is selected. The scanline record is unpacked into ISCAN(1) thru ISCAN(9) and JSCAN(1) to JSCAN(1464). See Subroutine NXSCAN.

4) Subroutine UTIME converts time in SCAN(3) into hours, minutes, and seconds for printout.

5) The pixel values in JSCAN are searched for minimum and maximum values.

6) If LIST=0, scan no, time in hours, minutes, seconds, latitude, longitude, azimuth heading, minimum and maximum pixel values and their numbers are moved to the print buffer IOUT and printed out with subroutine PRNT using a format statement previously read by PRNT. Return is made to step 2) .

   If LIST=1,

   a) Subroutine SATCO computes constants for the scanline used to compute coordinates for the pixels of the scanline.

   b) For each selected pixel no., subroutine PIXCO computes latitude, longitude, azimuth heading, and great circle arc distance from the satellite subpoint at the target surface height, HGT.

   c) The values are stored in the page print buffer IPRT. When the values fill a page or at the end of data, a page of values with the abbreviated line values is printed out. When the printout is complete, return is made to step 2 to select the next scanline.

3.2.6 Subroutine UTIME(T,IHR,IMN,SEC)

Given the time (T) in day seconds, the corresponding time in hours IHR, minutes MIN, and seconds SEC is computed for printout.

3.2.7 Function NPIX(J)

NPIX returns the pixel number of the Jth pixel in array JSCAN(1) thru JSCAN(1464). The pixel number ranges from -732 to 732 (there is no pixel no. 0) and determines the scan angle from the vertical.

3.2.8 Subroutine SATCO(XLT,XLO)

The latitude and longitude (XLT and XLO) of the satellite subpoint are converted from degrees to radians (ZETA0 and PSI0) and then used to compute the earth radius (R) and sines and cosines (SZETA0,CZETA0,SPSI0, CPSI0). These values are needed by subroutine PIXCO. They are constant for a scanline.

3.2.9 Subroutine PIXCO

Given a pixel number (IPIX), the subroutine PIXCO computes the pixel latitude (ZETA), longitude (PSI), azimuth heading (AZT), and great circle distance (GDR) on the target surface (specified by HGT). above the earth's surface from the satellite's subpoint (ZETA0,PSI0, AZ0) on the target surface.

3.2.10 Subroutine PRNT(IDO,FMT,IOUT,NOUT)

Subroutine PRNT performs two input-output functions: 1) reads in job identification data to be printed as a first output page, and format statements to be used when printing data; 2) prints text and data lines (one line per call).

If IDO=0, identification and format statement arrays are read as input. The input has the following form:

Card 1 - an integer LH that specifies the number of job identification cards (hollerith 8A10) that follow.

Card 2 - first line of identification text (8A10)

.

.

.

Card LH+1 - line LH of identification text (8A10)

Card LH+2 - an integer 0 to skip reading page header text (will be given by a format statement)

Card LH+3 - an integer 0 to skip reading column header text (will be given by a format statement)

Card LH+4 - an integer LF that specifies the number of format statement arrays that follow. Each format statement array is read as 13A10 so that two cards must be used for each format statement even though the second may be blank. Each format statement begins and ends with a parenthesis.

Card LH+5 - first card of first format statement

Card LH+6 - second card of first format statement

.

.

.

Card 1+LH+2+1+2*LF - second card of last format statement.

The job identification data is printed on the first page as text. The format statements are required by PRNT when it prints with IDO=777.

4. Processing of Rocket-Borne Electrostatic Analyzer Data

This report describes the processing of electrostatic analyzer data of flight IC819.08-1 for the ICECAP Chemistry project.

To measure electron current at different energies, a periodic sweep voltage is applied to the inner plate of a pair of spherical octants (the outer plate is grounded). The sweep voltage has a fast peak rise time followed by an exponentially decreasing positive voltage. For a given sweep voltage value, electrons within a narrow angle and energy band will pass through the plates without striking the surfaces, and enter the window of a scintillator with an aluminum cover at positive potential to attract low energy electrons. A photomultiplier amplifies the scintillator output.

The sensor data output must precisely correlate in time with the sweep voltage to obtain a sensitive measure of the current at each energy. The critical parameter to obtain this correspondence is the sweep start time. To obtain a precise time for the start of each sweep, the sweep voltage is sampled every .0002 seconds to assure one millisecond precision in start time (when the sweep voltage rises above a given threshold).

4.1 Processing Procedure

The data of each instrument is processed separately. Two channels of data are required, one for the sensor data, one for the sweep voltage data.

4.1.1 Digitization

The sweep data is sampled at .0002 second intervals, and the sensor data at .001 second intervals. Each unpacked time-data frame contains time (day seconds) followed by four sweep values and a sensor data value repeated three times. The digitized data is in FM counts (-1638 to 1638)

4.1.2 TM Volts vs FM Counts Calibration

The FM count values of the inflight calibration voltage steps of 0.0, 2.5, 5.0 volts provide linear equations to transform the data in FM counts to TM corrected volts.

4.1.3 Determination of Sweep Characteristic Values

The sweep parameters of interest for assessing data quality and to correlate electron flux with energy are: the sweep start time (seconds after launch), total sweep time, sweep peak voltage, and synch time of sweep peak voltage (time relative to sweep start time).

These parameters for each sweep are obtained by sequentially scanning the sweep data, beginning with a designated first sweep start time and a designated total sweep time. A sweep is recognized if the sweep voltage rises above a designated threshold voltage (positive ongoing) and if the next time it rises above this threshold positive ongoing, the time interval is within five milliseconds of the designated total sweep time.

A data listing of these parameter values is made, and cards punched, one card per sweep, giving the values: sweep no., sweep start time, total sweep time, peak voltage, peak voltage time relative to sweep start time, and also the altitude at sweep start time.

Because of channel transmission noise, a number of sweeps were not recognized by the above criteria. By examination of plots and listings, a full set of sweep cards was obtained. The quality of the data was indicated for each sweep by punching comments in the rightmost columns of each sweep card. If the sweep data or sensor data was of very poor quality, a minus sign was punched in the first column of the card.

4.1.4 Determination of Electron Energy from Sweep Synch Time

An energy (kev) value versus TM volt value calibration table was provided for each instrument by the initiator. A number of successive good sweeps were superimposed to obtain a profile of sweep TM volt values versus sweep synch time (time relative to peak voltage time). Using the electron energy versus TM volts correspondence, the volt versus synch time values are transformed to electron energy versus synch time values. In this way, even though a sweep voltage is corrupted by noise, the corresponding sweep synch time determines a good energy value.

4.1.5 Determination of Current from Sensor Data TM Corrected Volts

For each instrument, calibration values are supplied by the initiator to establish a correspondence between the sensor data in TM volts and the current. Each voltage value serves as an argument to interpolate for the current in log amperes which is then converted to the ampere current value.

4.1.6 Determination of Noise Current

For a synch sweep time interval at the tail of the sweep, designated by the initiator, the sensor TM voltage values are averaged. The resulting value provides the argument for an interpolated value of noise current which when averaged with the value obtained from the preceding sweep provides the average noise current for this sweep.

4.1.7 Determination of Change in Electron Intensity with Energy

The change in electron intensity with change in energy is computed using a reduced equation provided by the initiator:

$$DJ/DE = K\ (I - I_n)\ /\ E\ (E + E_{pa})\ S_E'$$

where

DJ/DE is the change in electron intensity (cm^2-sec-sr-kev)

K is a constant particular to each instrument

I is the current (amperes) measured at energy E (kev)

I_n is the average noise current value for the sweep

E is the energy at at given synch time

E_{pa} is energy added by the post-accelerator voltage

S_E^1 is a normalized sensitivity factor that adjusts for the instrument response at a particular energy (E + E_{pa})

S_E^1 is obtained by interpolation from a table of values (S_E^1 versus E+E_{pa}).

All other physical values of interest can be simply computed from the values determined above.

4.2 Programs

The following programs were used to process the data:

1) Program SWPTIME scanned the data to obtain the sweep start times, peak voltage and peak voltage times.

2) Program ULWLST transformed the FM count values to corrected TM volt values and listed the data.

3) Program OVERPLT, a revised version of SWPTIME, provided superimposed plots of sweeps, logarithmic volts versus time.

4) Program ESAS, using the sensor and sweep data tape, the sweep card parameter values, and the calibration tables described above, provides the data listings for each sweep.

5. Processing of Balloon-Borne Ultraviolet Spectrometer Data

Ultraviolet spectrometer measurements of solar radiation intensity are used to determine flux in photons/cm^2/sec. The wavelengths of interest lie between 1700Å and 3500Å, and the calculated flux is to be plotted as a function of wavelength. The data supplied by the initiator is on a packed tape (five 12-bit words per 60-bit CDC word) and includes a major time (days, hours, minutes, seconds) at the beginning of each physical record, followed by several frames of data. Each of these frames begins with a minor-time word (milliseconds) and includes a synch word, wavelength word and photon count word. The wavelength word is in integer form with 13 increments per whole wavelength, and need to be interpolated within the unpacking program. Also, a great number of initiator-supplied wavelength corrections are applied within the unpacking program. Additionally, instrumental corrections for wavelength, detector nonlinearity, and scattered light backgrounds are made according to the procedure supplied by the initiator, of polynomial fits to laboratory measurements. There are two modes of output. The first mode lists and plots the data normally for each wavelength, and the second mode lists and plots the data after it has been smoothed by deresolving the data. This derosolution may be either 3Å or 6Å.

5.1 Outputs

The programming provides a number of data listing options and plots.

1) Listings

Unpacked data. Time, wavelength, and photon counts.

Corrected data. Time from launch, wavelength, corrected wavelength, raw count, raw count corrected, and flux.

Average flux. Wavelength, average flux per one Ångstrom or per ten Ångstroms.

2) Plots of flux vs. corrected wavelength

   The ordinate (flux) has a log scale from 10^{10} to 10^{14}, and the abscissa (corrected wavelength) has ten Ångstroms per inch with tic marks every two Ångstroms.

3) The same listing (except for uncorrected data) and plotting can be obtained with smoothing.

5.2 Program Description

The task is accomplished by running four modular programs (five when deresolution is required - program DANG) that are run as one job. Program HON730 unpacks the digitized data tape and subroutine FIX applies the initiator-determined data corrections. HON370 is a modified version of the general PCM unpacking program HON316, for which there is ample documentation. Program DANG (optional) creates a 3Å (or 6Å) deresolution by computing a 39- (or 78-) point weighted average for each wavelength value.

Program WARCO performs the instrumental corrections, i.e., wavelength, detector nonlinearity, and scattered light background corrections. This is accomplished using relationships and coefficients supplied by the initiator. The resultant output may be plotted using program PLTQ, or it may be used as input to program AVEFLUX which finds the average flux per Ångstrom (or per ten Ångstroms) for for each wavelength. The output of AVEFLUX can be fed back into PLTQ for plotting.

5.3 Control Card Setup Example

The following control cards serve as an example of how set up the program modules for a single job run for the CDC computer.

```
JOB,T250,CM177000,TP1.
MAP,ON.
VSN(TAPE9=CC2201)
REQUEST,TAPE9,HY,S,E.
ATTACH,PEN,ONLINEPEN.
REQUEST,PLOT,*Q.
```

```
LIBRARY,PEN.
DISPOSE,PLOT,*PL.
LDSET,PRESET=ZERO.
FTN,SL,R=3,PL=99999.
LGO.
REWIND,TAPE1.
REWIND,LGO.
FTN,SL,R=3,PL=99999.
LGO.
REWIND,TAPE69.
REWIND,LGO.
FTN,SL,R=3,PL=99999.
LGO.
REWIND,TAPE99.
REWIND,LGO.
FTN,SL,R=3,PL=999999.
LGO.
REWIND,TAPE99.
REWIND,LGO.
FTN,SL,R=3,PL=99999.
LGO.
7/8/9    (multipunch)
Program modules
7/8/9
Data options
6/7/8/9
```

5.4 Flowcharts

Analysis and program flowcharts follow.

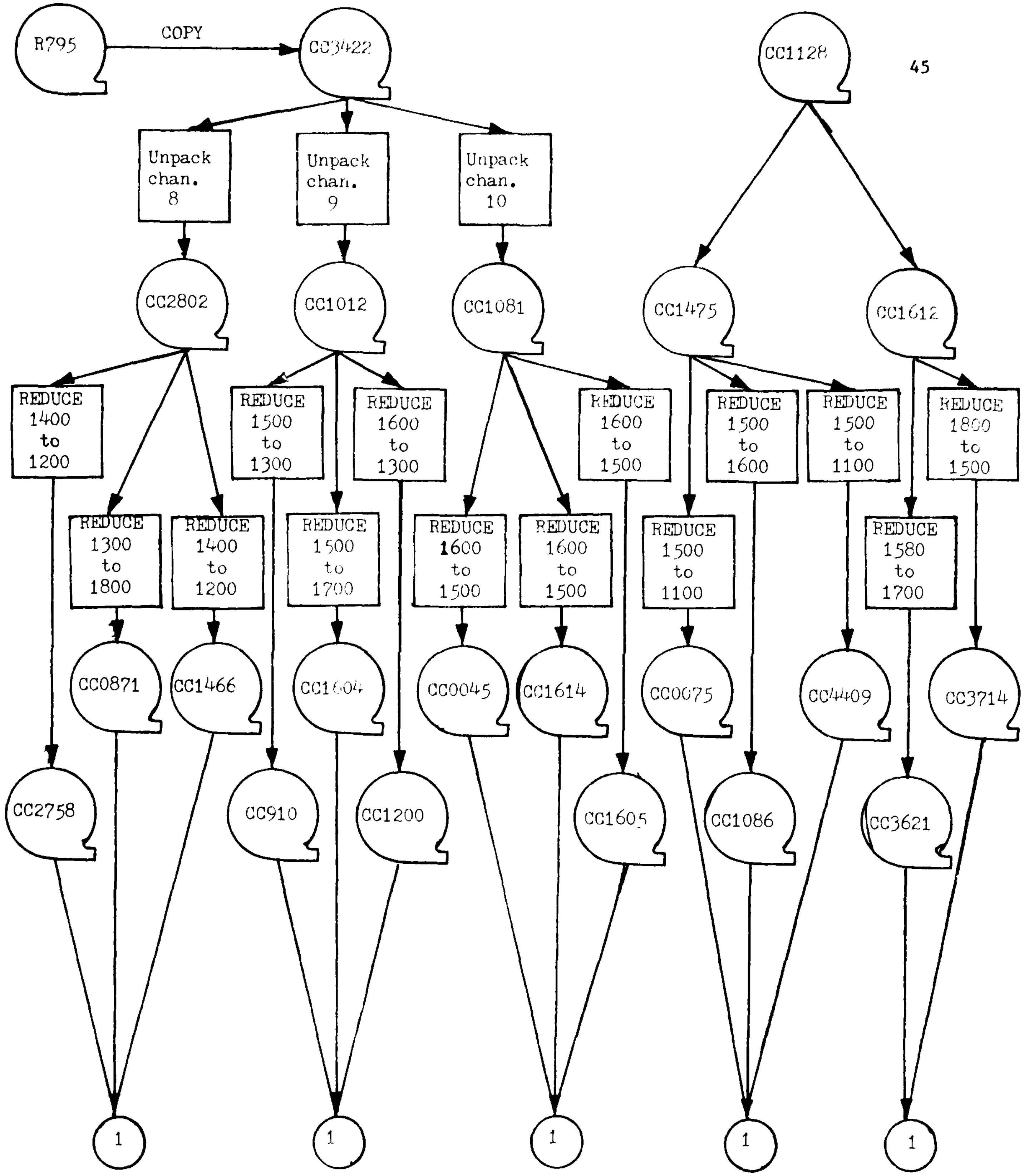

Figure 10. Flowchart of Analysis

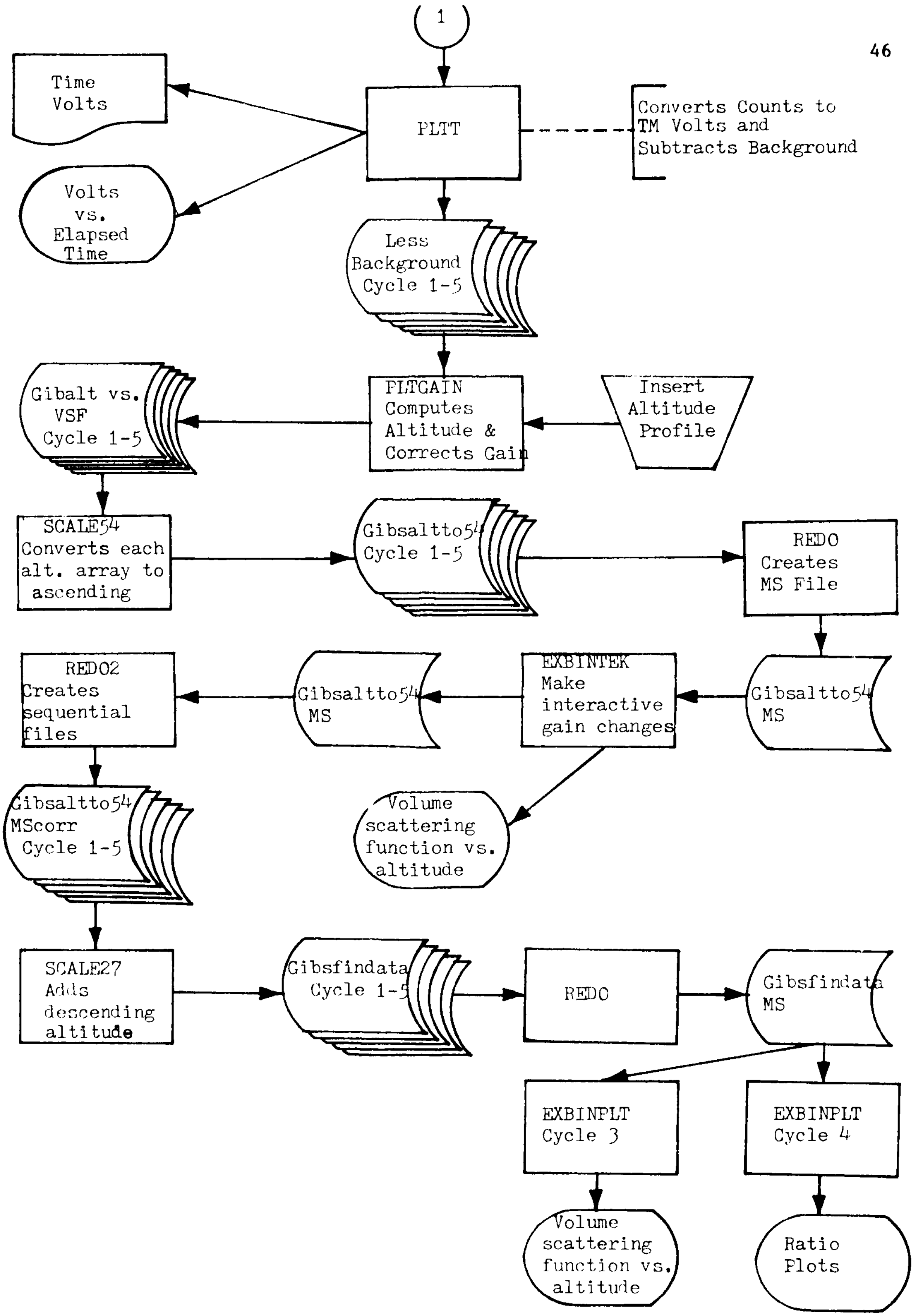

Figure 10. Flowchart of Analysis (cont'd)

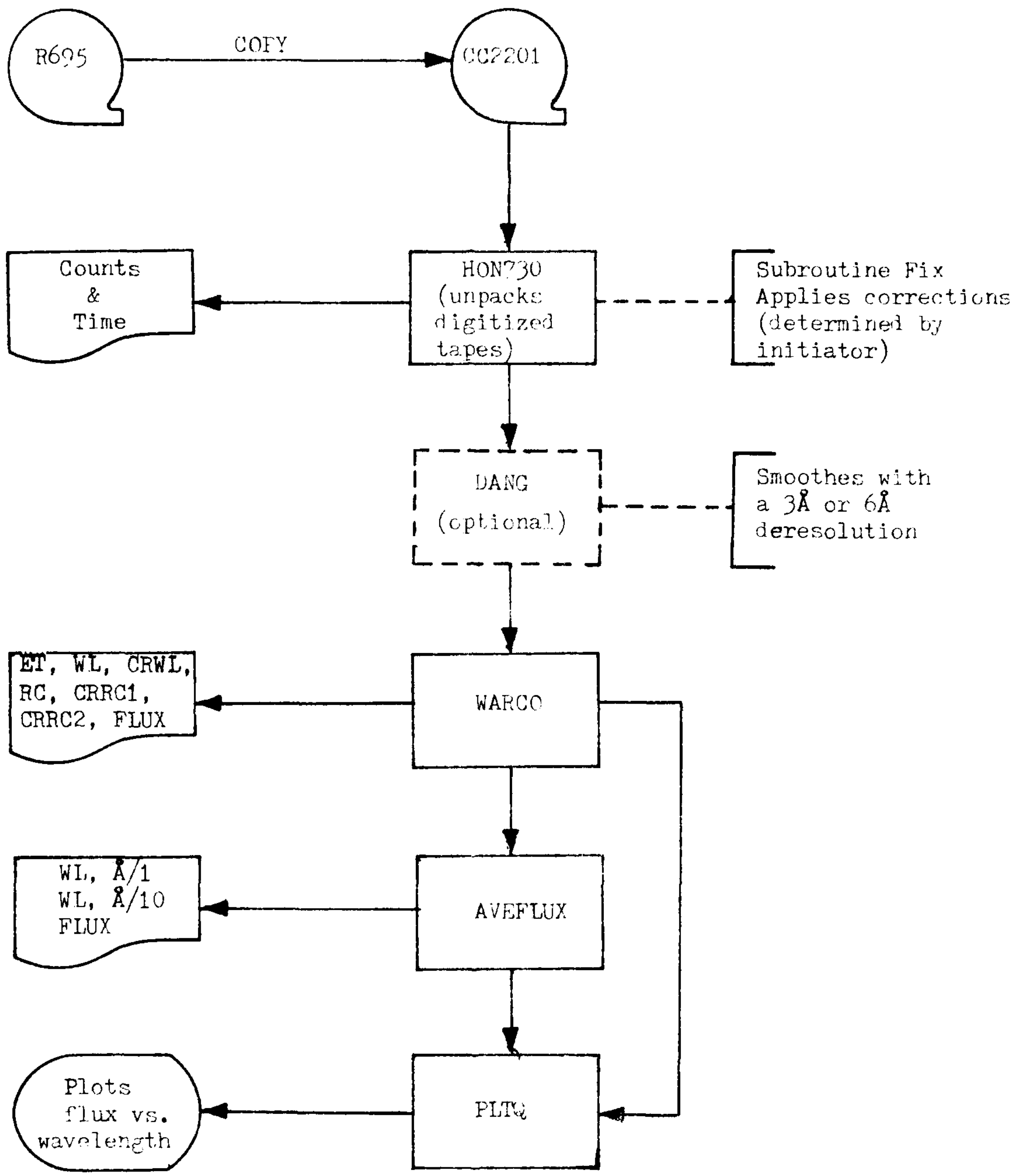

Figure 11. Flowchart of Programs

6.0 Interactive Graphics System to Facilitate Data Correction

During the transmission of balloon-borne nephelometer data, midflight gain changes were necessary to adjust for the reduced signal received when less dense atmosphere is encountered (less photon scattering). This was directed remotely by the researcher on the ground. To utilize the Tektronix 4014 interactive graphics terminal to locate those portions of the data where gain changes occurred and determine and apply correction coefficients a program EXBINTEK was written.

6.1 User Procedure

The user is prompted to input at the console of the Tektronix 4014 the particular photometer/filter wheel desired (30 combinations). The CRT then plots the Volume Scattering Function versus Altitude and displays the light button options. Next the user selects light button 5 ZOOM (enters the number 5 at the console) to zoom in on that portion of the data where a gain change was made (this is easily determined, as can be seen in the figures). The user next selects 7 ADJ (7) and inputs via the cross-hair cursor three points:

1) 1 1ST X= the starting point of the gain change.
2) 3 OLD Y= a point lying on the plot of the data immediately after the gain change.
3) 4 NEW Y= a point lying on the plot of the data immediately prior to the gain change.

The latter two selections are made by the researcher. The program displays all the choices made as well as the correction coefficient determined by the last two selections. The button for replotting (6 REPLOT) is selected, and the entire array is plotted. Next, that portion of the data where the gain change ends is zoomed in on, light 7 ADJ is picked, and the end of the gain change is marked (2 2ND X=). If the correction factor is satisfactory, the user may now select button 5 CORR, which causes the correction factor to be applied, followed by a plot of the corrected data.

When desirable, the average of two computed correction factors can be determined and applied. This is done by selecting 8 AVCORR rather than 5 CORR. Enter the most recently determined correction factor as AVCORR1 by picking 1 RR1=, then selecting 6 REPLOT, followed by 2 DATA and the desired filter wheel/photometer combination. Determine the correction coefficient for this array following the same procedure detailed earlier, and now select 2 CORR2= followed by 3 AVCORR and finally 4 APPLY. The average correction factor has now been applied to this array. To apply this average factor to the first array, replot it by selecting 2 DATA and the first array (photo/filter wheel combination) and then select 7 ADJ and 5 CORR.

Xerographic copies of the Tektronix display can be made at various stages of the above procedure. The attached series of figures depicts the stages in the determination and application of a single correction coefficient and an average correction coefficient.

6.2 Possible Modifications and Improvements

Presently, the program has an input configuration of 30 arrays of data on a mass storage random access file. Any array can be selected for display by using the appropriate key. The maximum dimension of any array is 1200, and the actual dimensions are stored in an array, which is read in after opening the input file. Although this maximum dimension may not be changed, the number of arrays (records) on the input file as well as the key statement function may be changed for different data bases if there are consistent changes in dimension statements and calls to OPENMS, READMS, and WRITMS. It is necessary to keep a backup copy of the data base since the program actually alters the data. Because the Tektronix 4014 operates through Intercom, Intercom limits on time and core apply. Additional tasks can be added to the program. However, since the display is a storage-type CRT, addional light buttons might cause excessive clutter. All scaling automatic.

6.3 Functional Description

The Tektronix demonstration program discussed in Chapter 16 of the AFGL User's Guide was the basis for this program, and the following light buttons and their overlays are unchanged: 1 PLOT, 3 REPEAT, 4 LENGTH, 5 ZOOM, and 8 END. This program differs from the demonstration program in two significant respects. First, it uses a random access mass storage file as input and output; and second, it allows the user to interact and modify the data.

After program execution has begun and TAPE1, the mass storage file, has been opened, the user is prompted to enter the number of the photometer (IC) and the number of the filter wheel (IP) desired. The Statement Function, IRX(I,J,K)=I+(J-1)*6+(K-1)*30, uses this data to create the index key to fill the X and Y arrays as follows:

```
CALL READMS(1,X,LX(IC),IRX(IP,IC,1))
CALL READMS(1,Y,LX(IC),IRX(IP,IC,2))
```

where LX(IC) is the photometer dimension.

The above is performed whenever the data overlay is called. Control passes from here to the plot overlay which plots the data with automatic scaling and also accepts input in the form of light buttons. Control now passes to the overlay selected by light button. There are three levels of light buttons:

1) 1 PLOT, 2 DATA, 3 REPEAT, 4 LENGTH, 5 ZOOM, 6 PEN
   7 ADJ, 8 END

2) 1 LST X=, 2 2ND X=, 3 OLD Y=, 4 NEW Y=, 5 CORR, 6 REPLOT,
   7 ZOOM, 8 AVCORR

3) 1 CORR1=, 2 CORR2=, 3 AVCORR, 4 APPLY.

After the selection of light buttons 1-6 in level one, control returns to level one. Button 8 terminates the program, and button 7 passes control to level two. After the selection of buttons 1-4 in level two, control returns to level two. Buttons 5,6, and 7 will return control to level one. Button 8 passes control to level three. Buttons 1,2, and 3 in level three will return control to level two after selection. Button 4 will return control to level one.

The overlay at level two determines 1ST X (first element in the Y array to be corrected) with button 1; 2ND X (last element in the Y array to be corrected) with button 2. The ratio of the values returned by buttons 3 and 4 (NEW Y/OLD Y) is the correction factor. When button 5 is picked, the values of the elements in the Y array corresponding to the elements in the X array from 1ST X= to 2ND X are multiplied by the correction factor. If button 6 is selected, the entire array of data is plotted. Button 7 allows one to zoom in still closer. The average of two correction coefficients can be applied by using button 8.

Two series of figures follow which provide 1) an example of how a single correction coefficient is determined and applied; and 2) an example of how an average correction coefficient is determined and applied.

6.4 Input Format Example

The following FORTRAN statements provide an example of coding to read a particular input format:

```
DIMENSION LX(5),INX(63,6),X(1200),Y(1200)
IRX(I,J,K)=I+(J-1)*6+(K-1)*30
CALL OPENMS(1,INX(1,6),63,0)
CALL READMS(1,LX,5,61)
CALL READMS(1,X,LX(IC),IRX(IP,IC,1))
CALL READMS(1,Y,LX(IC),IRX(IP,IC,2))
```

6.5 Program Setup Example

The following sequence of commands at the Tektronix 4014 will begin program execution for a particular data file:

```
LOGIN,User Name + No., 8614444,SUP
ATTACH,TAPE1,USERMASSSTORAGEFILES,ID=USER
ATTACH,LGO,EXBINTEKX3451,ID=GLEASON2
ATTACH,TEK,TEKLIB
ATTACH,DIR,TEKDIR
ETL,400
LIBRARY,TEK
XEQ,LDSET,PRESET=ZERO,LOAD=LGO,NOGO
EDITLIB,I=DIR
XEQ,LIBLOAD=TEKLIB,SPLOT,EXECUTE
```

The user will now be prompted for photometer no. and filter wheel no.

6.6 Description of Illustration Sequence

6.6.1 Determining and applying a single correction factor

1) Photometer2/Filter2. Zoom coordinates are selected.

2) First gain change. 1ST X, OLD Y, and NEW Y are selected and the correction factor is determined. The data is uncorrected.

3) Return to plot of entire array and zoom in on 2nd gain change.

4) Select 2ND X and apply correction factor.

5) Photometer2/Filter2 after correction.

6.6.2 Determining and applying an average correction factor

6) Photometer3/Filter1. Zoom coordinates are selected.

7) First gain change. 1ST X and OLD Y are selected. New zoom coordinates are chosen.

8) NEW Y is chosen and a correction factor is determined. Correction one is set equal to this factor.

9) Coordinates for zooming onto the second gain change are selected.

10) 2ND X is chosen.

11) First gain change coordinates are chosen for Photometer3/Filter2.

12. Correction is determined by OLD Y and NEW Y. Correction two is set equal to this new correction factor and an average correction factor is determined.

13. Photometer3/Filter1after application of the average correction factor.

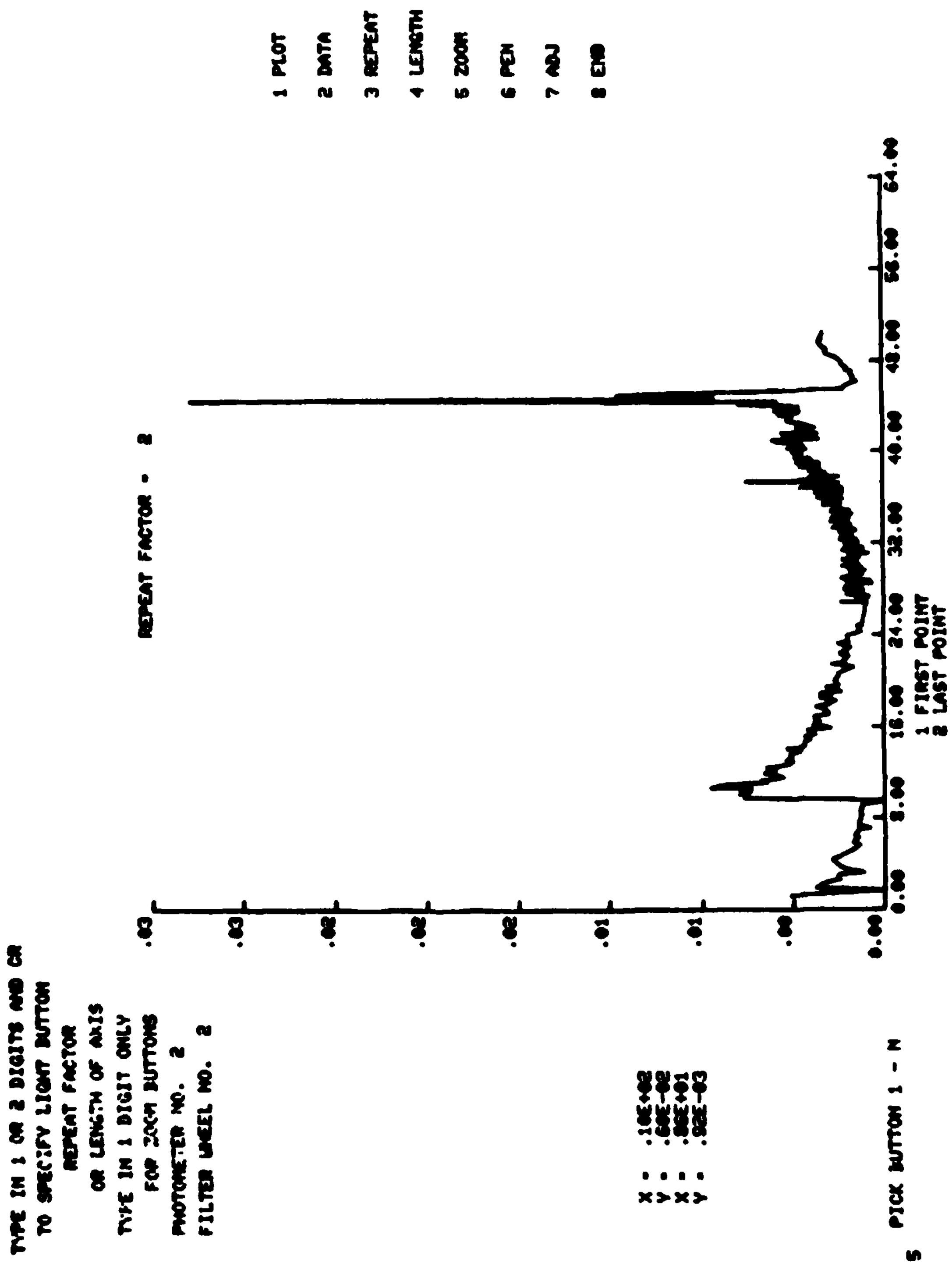

Figure 12. Single Correction Factor - Step 1

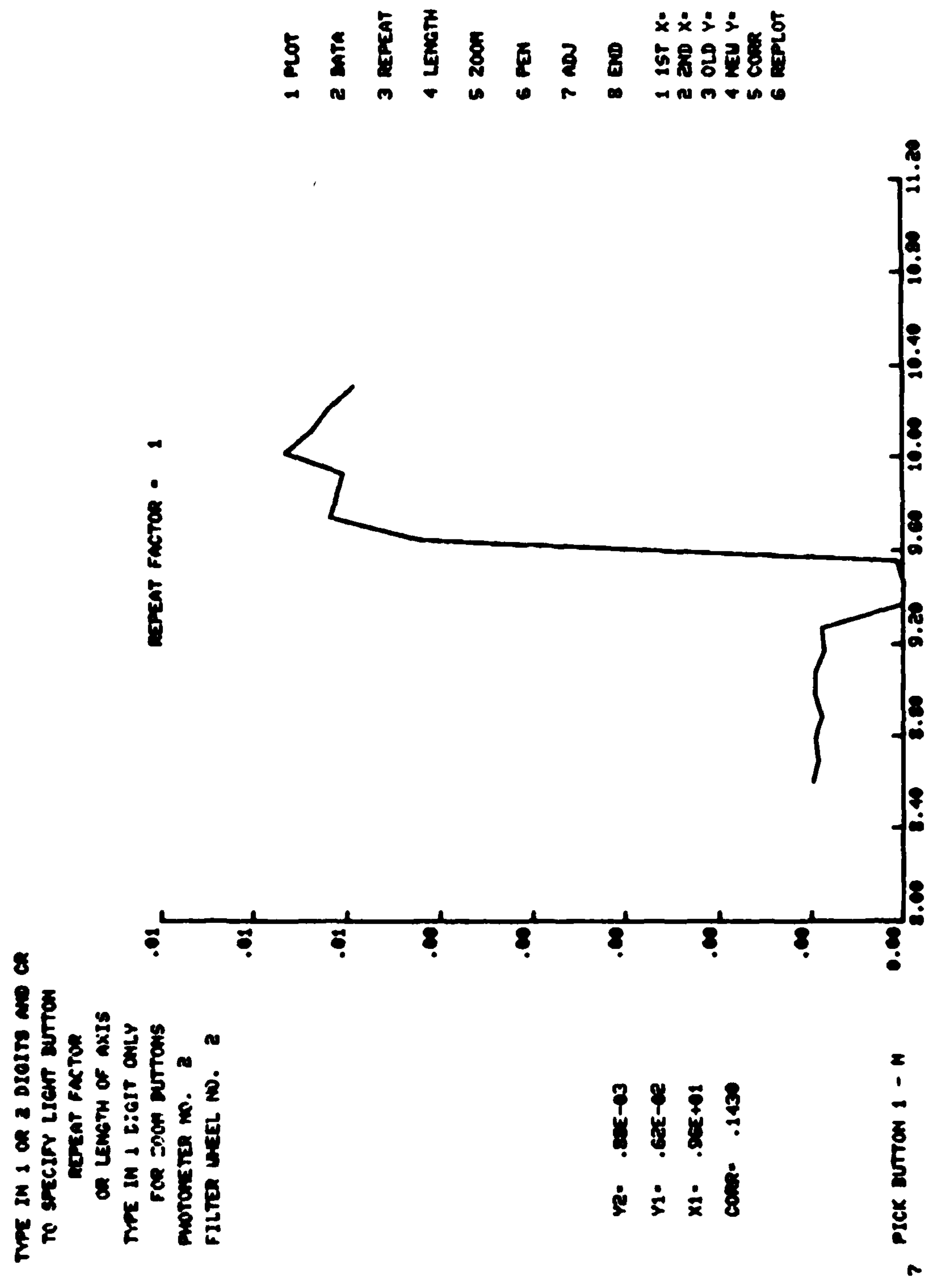

Figure 13. Single Correction Factor - Step 2

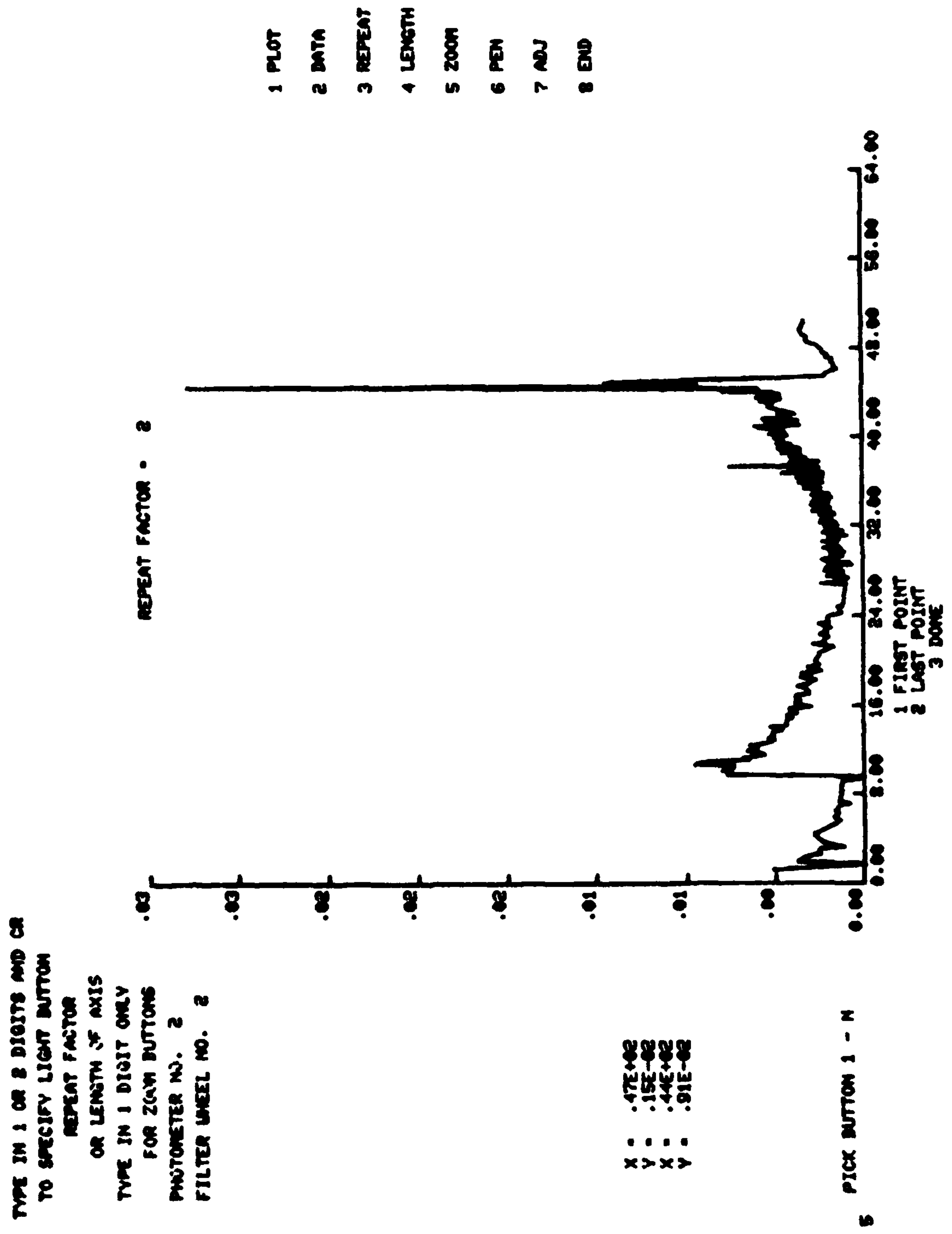

Figure 14. Single Correction Factor - Step 3

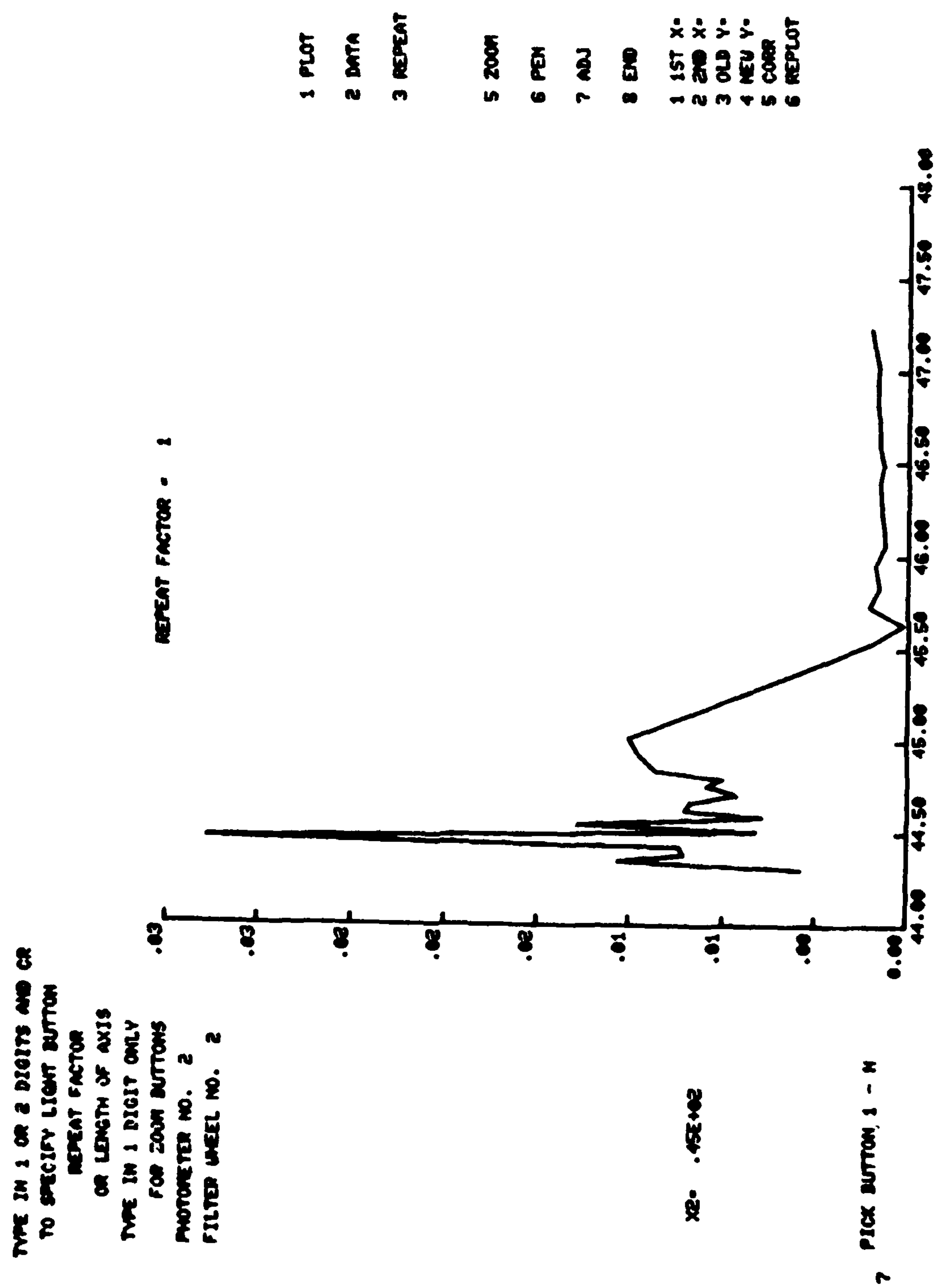

Figure 15. Single Correction Factor - Step 4

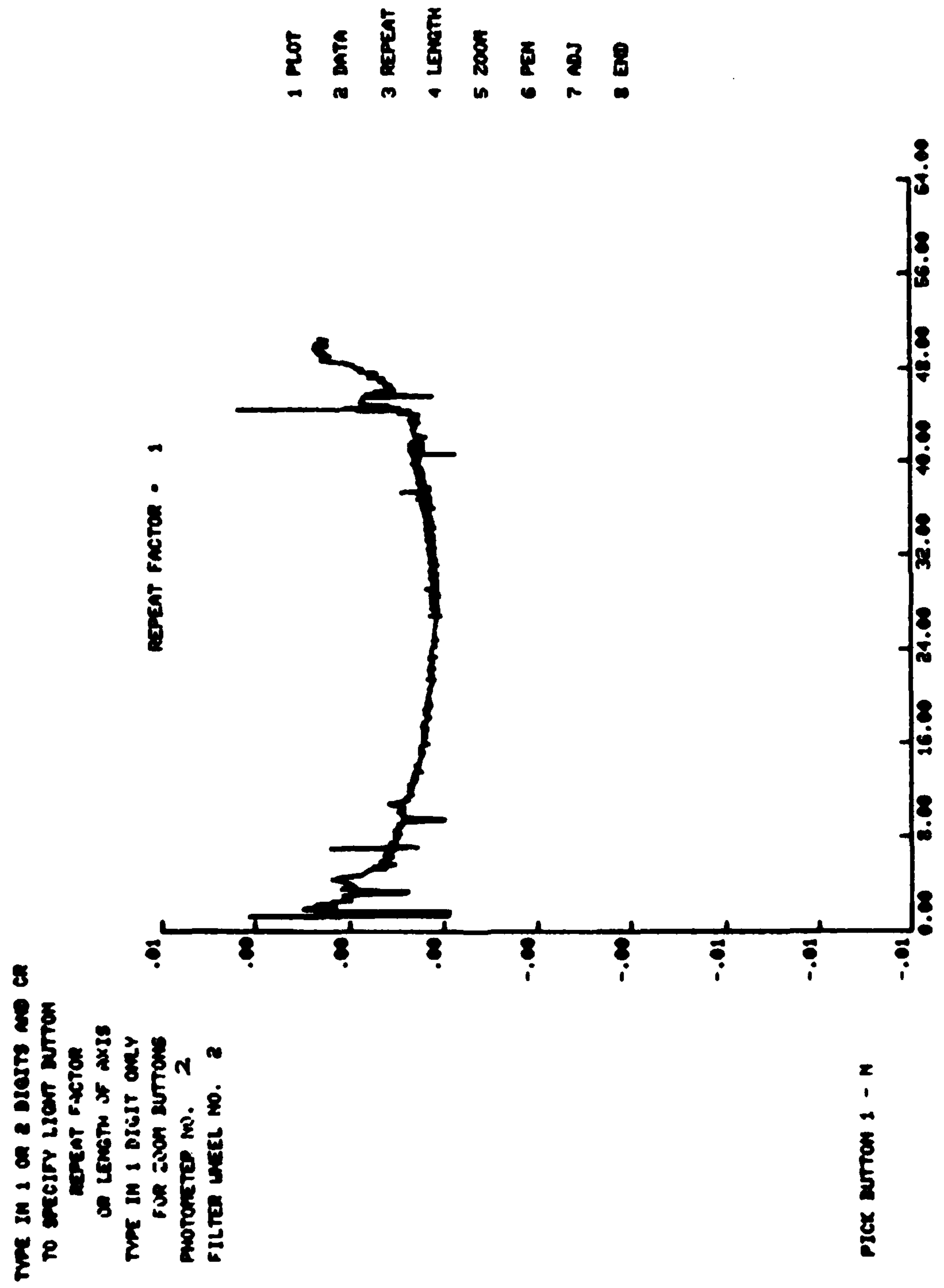

Figure 16. Single Correction Factor - Step5

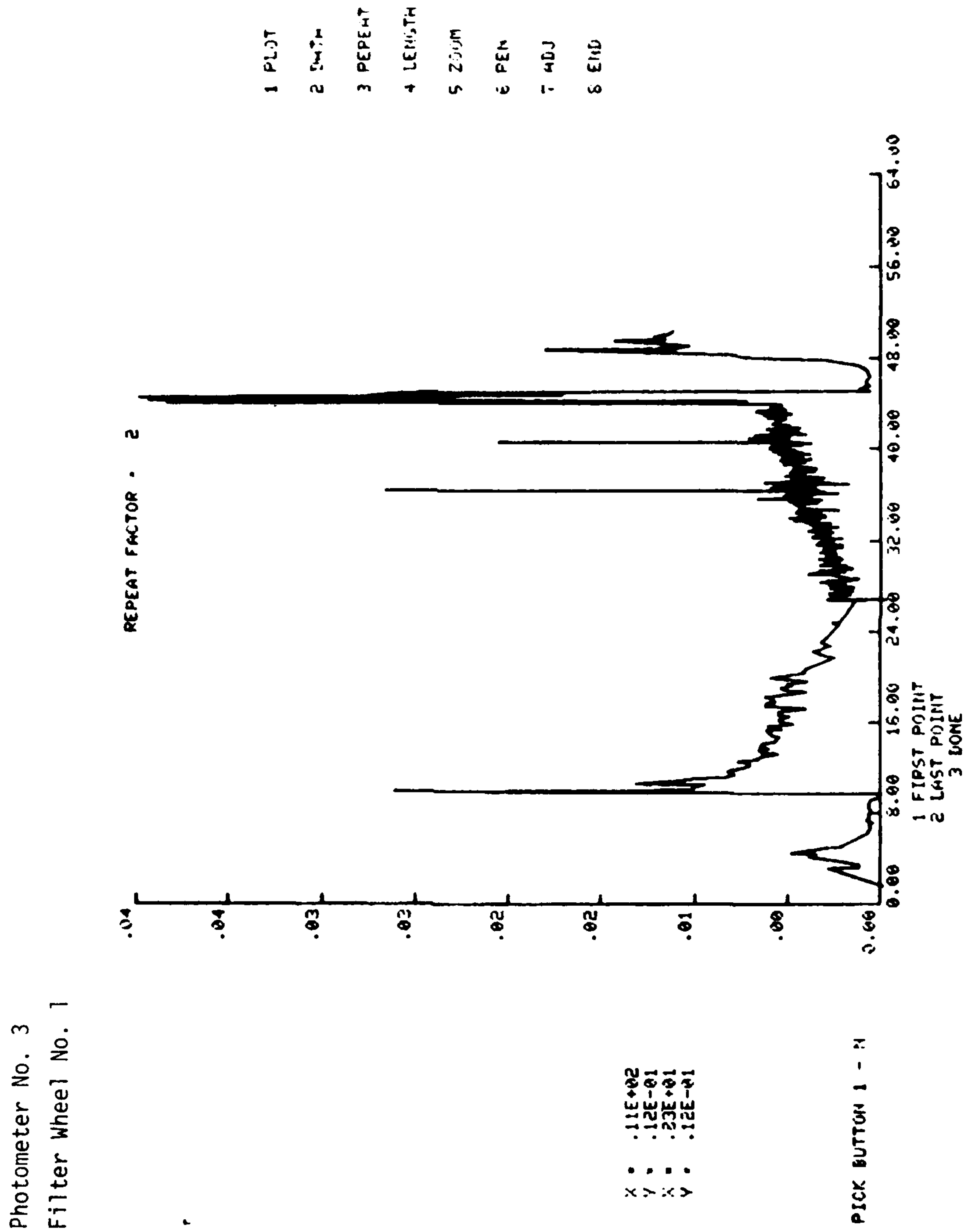

Figure 17. Average Correction Factor - Step 1

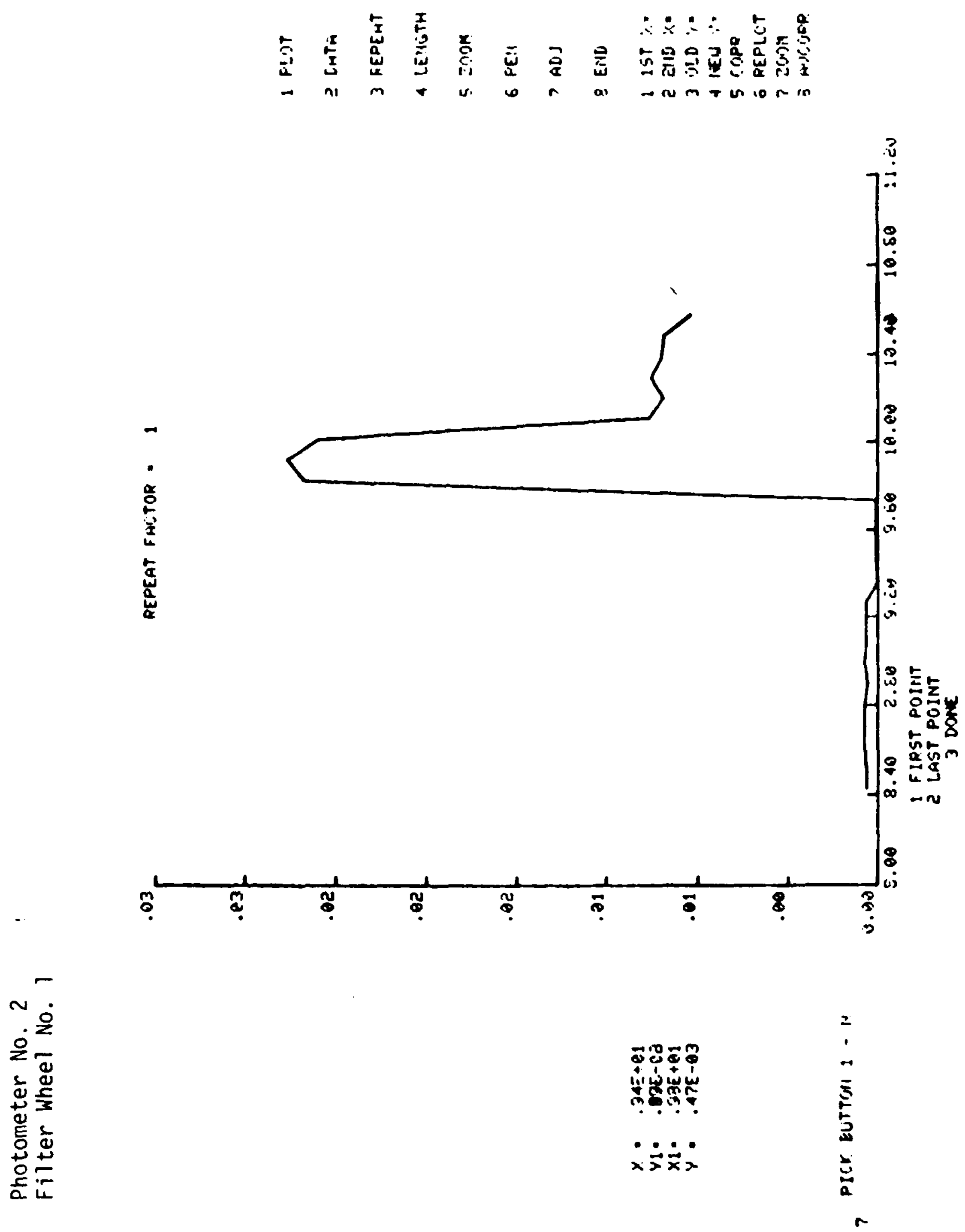

Figure 18. Average Correction Factor - Step 2

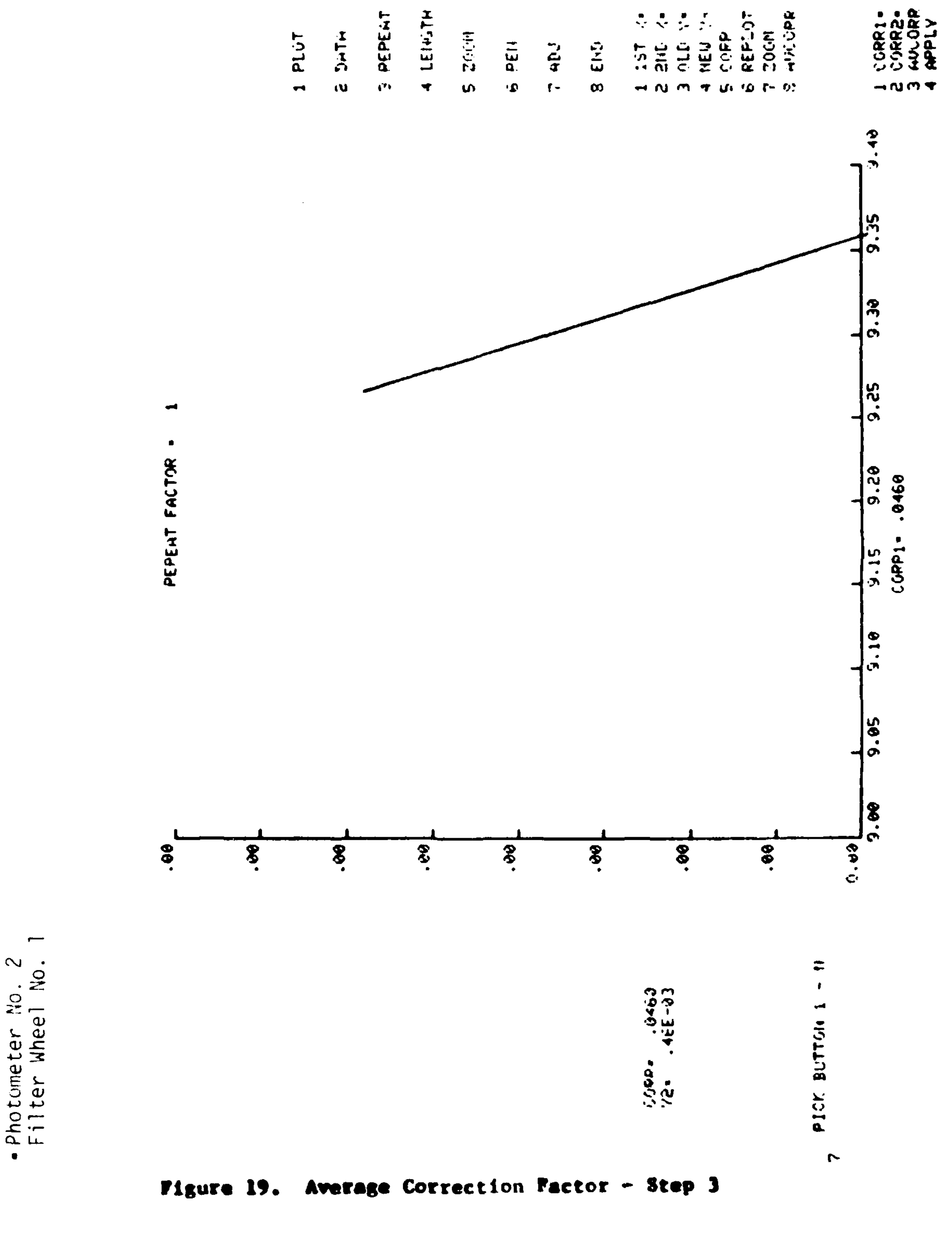

Figure 19. Average Correction Factor - Step 3

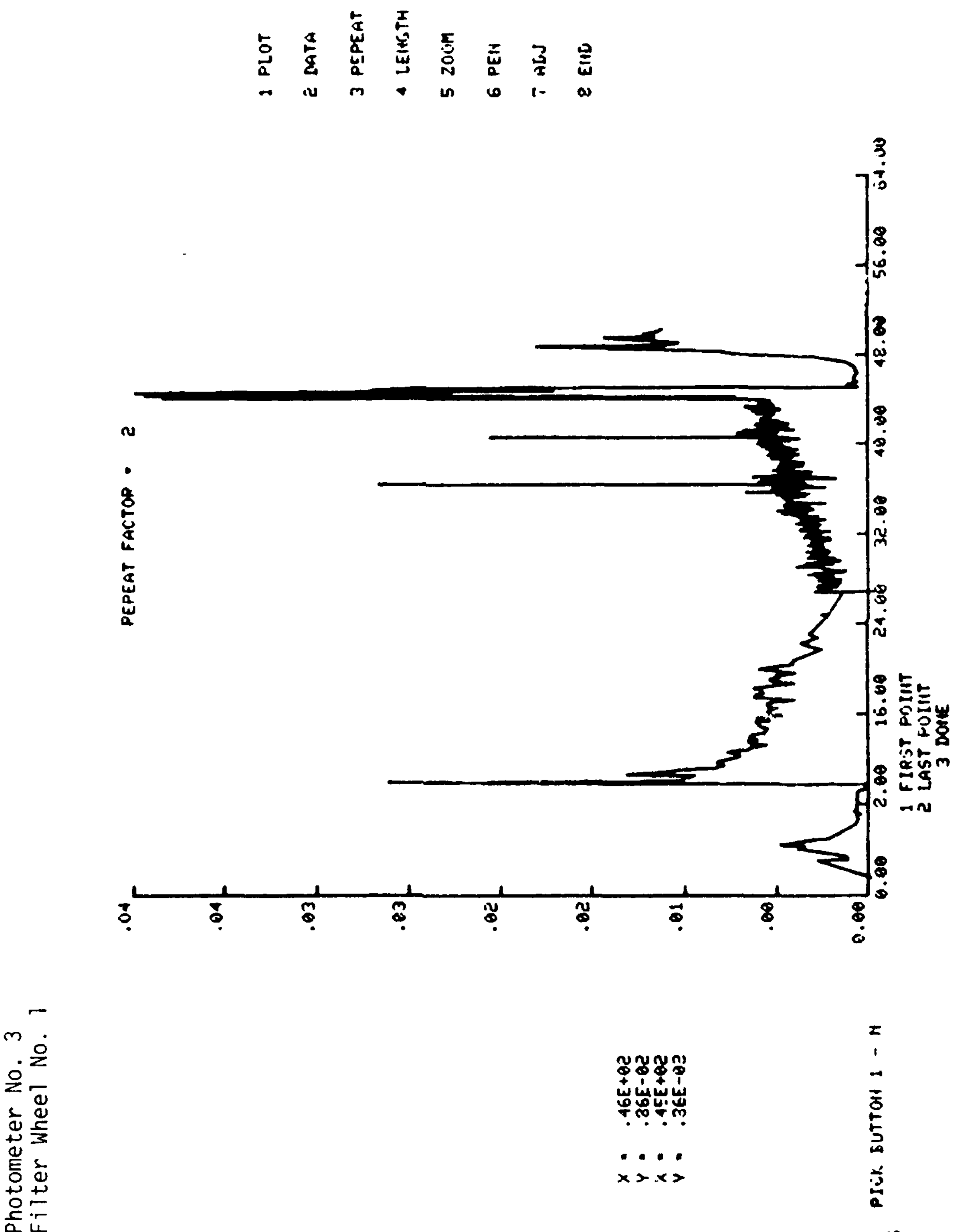

Figure 20. Average Correction Factor - Step 4

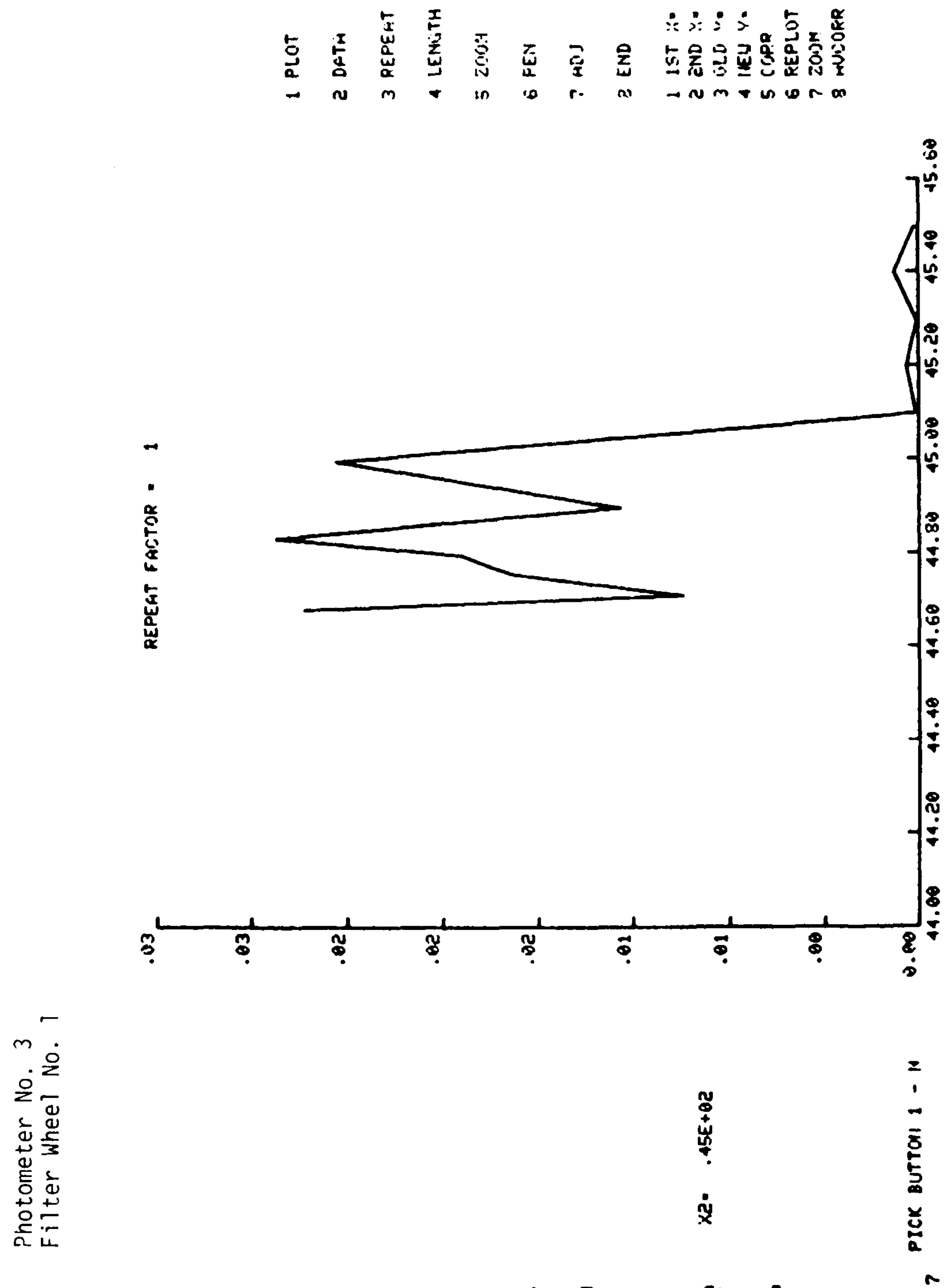

Figure 21. Average Correction Factor - Step 5

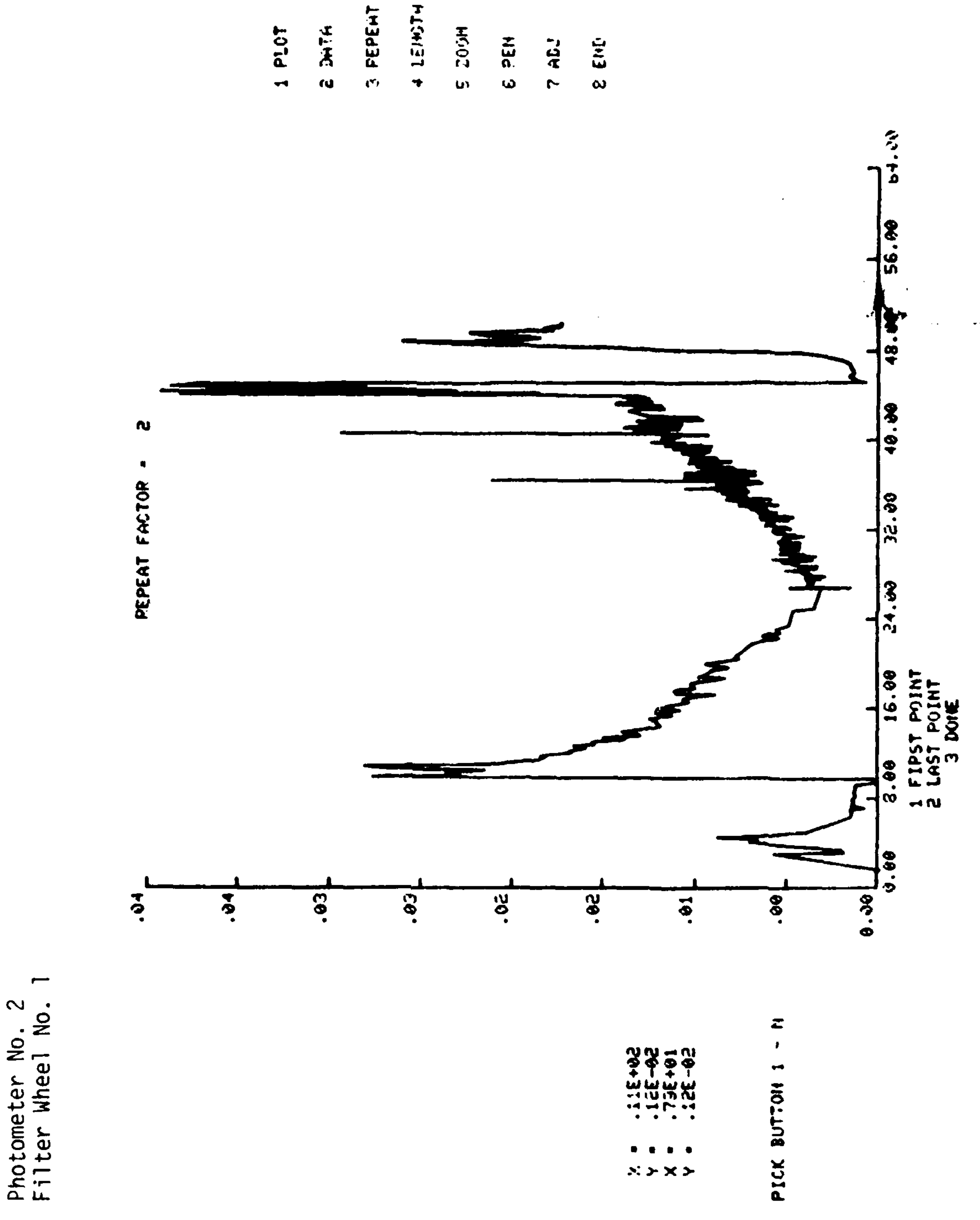

Figure 22. Average Correction Factor - Step 6

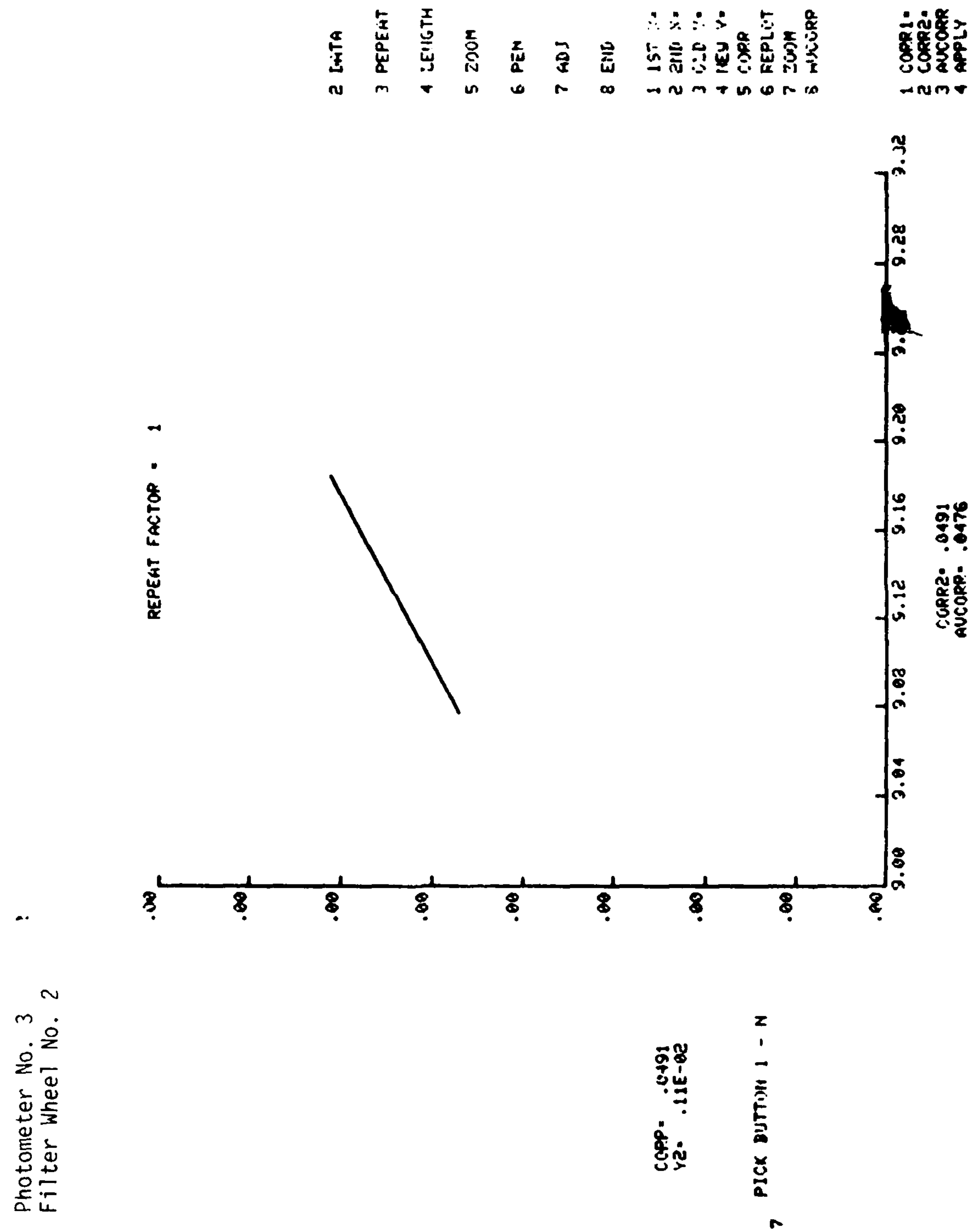

Figure 23. Average Correction Factor - Step 7

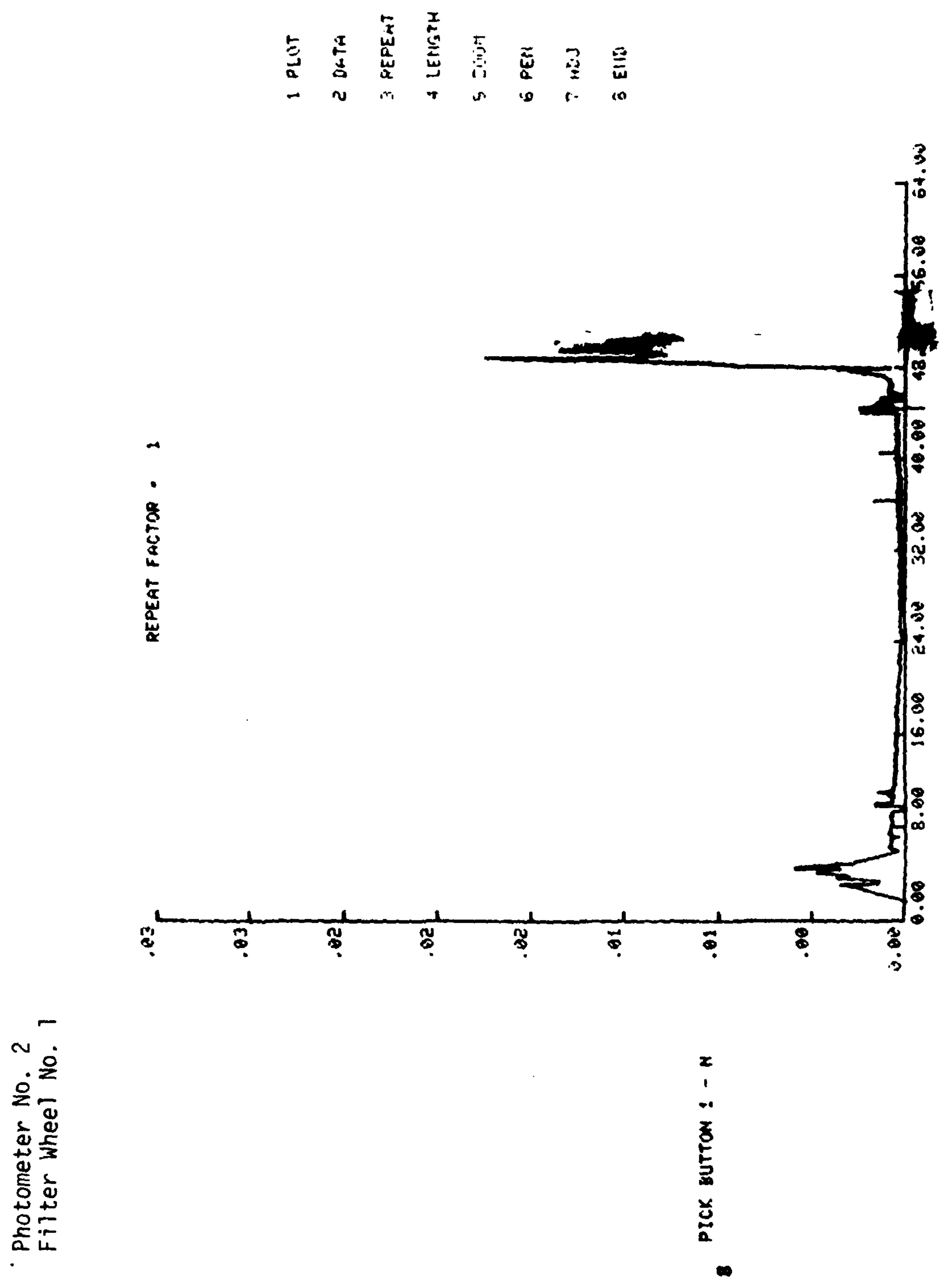

Figure 24. Average Correction Factor - Step 8