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DATA PROCESSING OF LUNAR INFRARED MEASUREMENTS AT HIGH SPATIAL AND RADIOMETRIC RESOLUTION TO OBTAIN BRIGHTNESS TEMPERATURES

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ABSTRACT

A unique data processing of lunar infrared measurements at high spatial and radiometric resolution to obtain brightness temperature is presented. This system takes into account all the instrumental parameters and observing conditions, including amount of ozone, carbon dioxide, and precipitable water along the path. Possible drifts in the instrument or changes in the sky emittance are also handled by the system. Moreover, for each line of scan the accuracy in the location of the resolution element on the lunar disk is also given, taking into account systematic errors such as the differential atmospheric refraction between visible and infrared rays.

The programming used in the data processing package produces a compact simplified data file oriented towards ease of retrieval of various forms (i.e., plotting of different subsets of the data). The techniques used to obtain this data file depend on a high degree of separation of different phases of the data-reduction. This separation is reflected in the organization of the program as a very simple supervisory program with many subroutines, each performing highly specific calculations.

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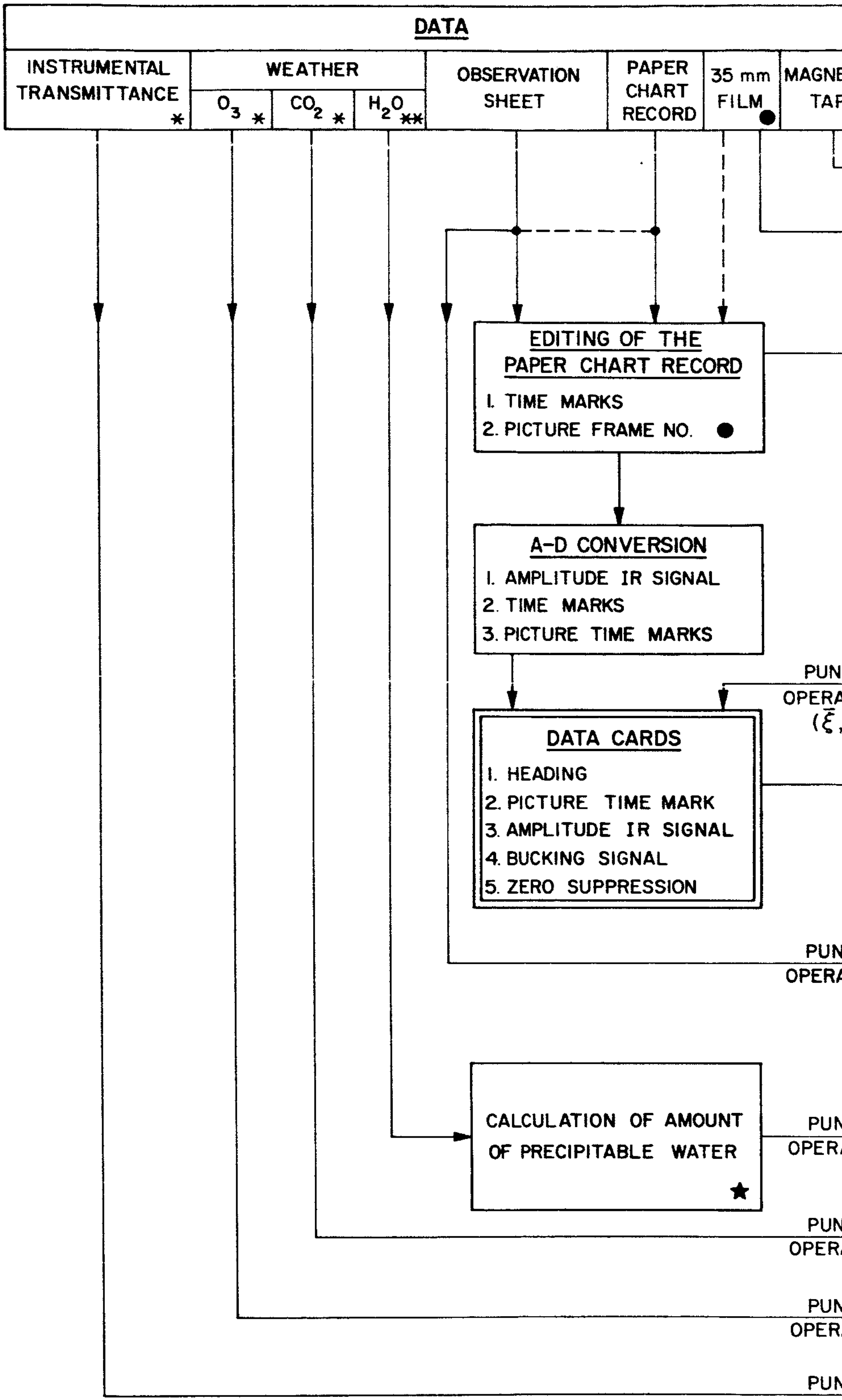
I. INTRODUCTION

This report will discuss in detail the data processing of lunar infrared measurements to obtain brightness temperature by means of an electronic computer. This program is tailored to reduce the data gathered with the radiation pyrometer developed at Harvard College Observatory (1). The radiometric data are obtained in analog form, and the astrometric data photographically.

The observational technique for this data-reduction scheme is divided into two aspects: astrometric and radiometric. Since it is of paramount interest to correlate the radiometric measurements with the visual features of the lunar surface, we gave equal weight to both aspects of the measurements.

The observational technique and data-reduction procedures assume that absolute, as well as relative, measurements will be carried out. This implies that serious consideration has been given to the problem of the atmospheric transmittance and changes in atmospheric emission during a scan (drift assumed linear).

The data are processed by means of the IBM 7094 computer and special care has been taken to minimize handling. Since the block diagram of the data flow given in Figure 1 is self-explanatory, we feel that it does not require further description.



NOTE:

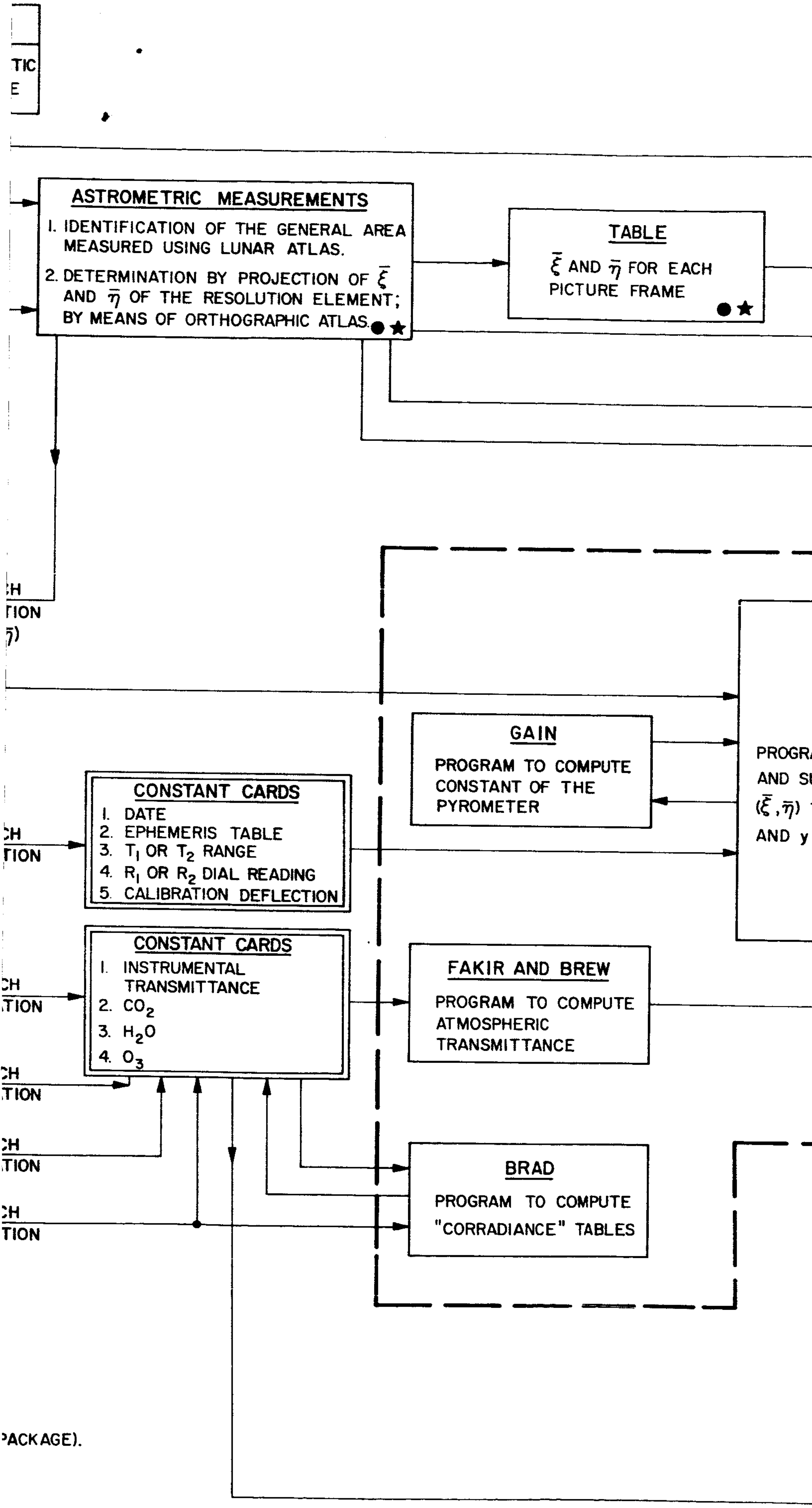
* TABULATED VALUES.

** DATA OBTAINED FROM DAILY BALLOON SOUNDINGS.

★ MANUAL OPERATION.

--- INDICATES ELECTRONIC DATA PROCESSING PHASES (LUNAR

● ASTROMETRIC PHASES OF THE FLOW DIAGRAM.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2. DETERMINATION BY PROJECTION OF $\bar{\xi}$ AND $\bar{\eta}$ OF THE RESOLUTION ELEMENT; BY MEANS OF ORTHOGRAPHIC ATLAS. ● ★
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2. EPHEMERIS TABLE
3. T_1 OR T_2 RANGE
4. R_1 OR R_2 DIAL READING
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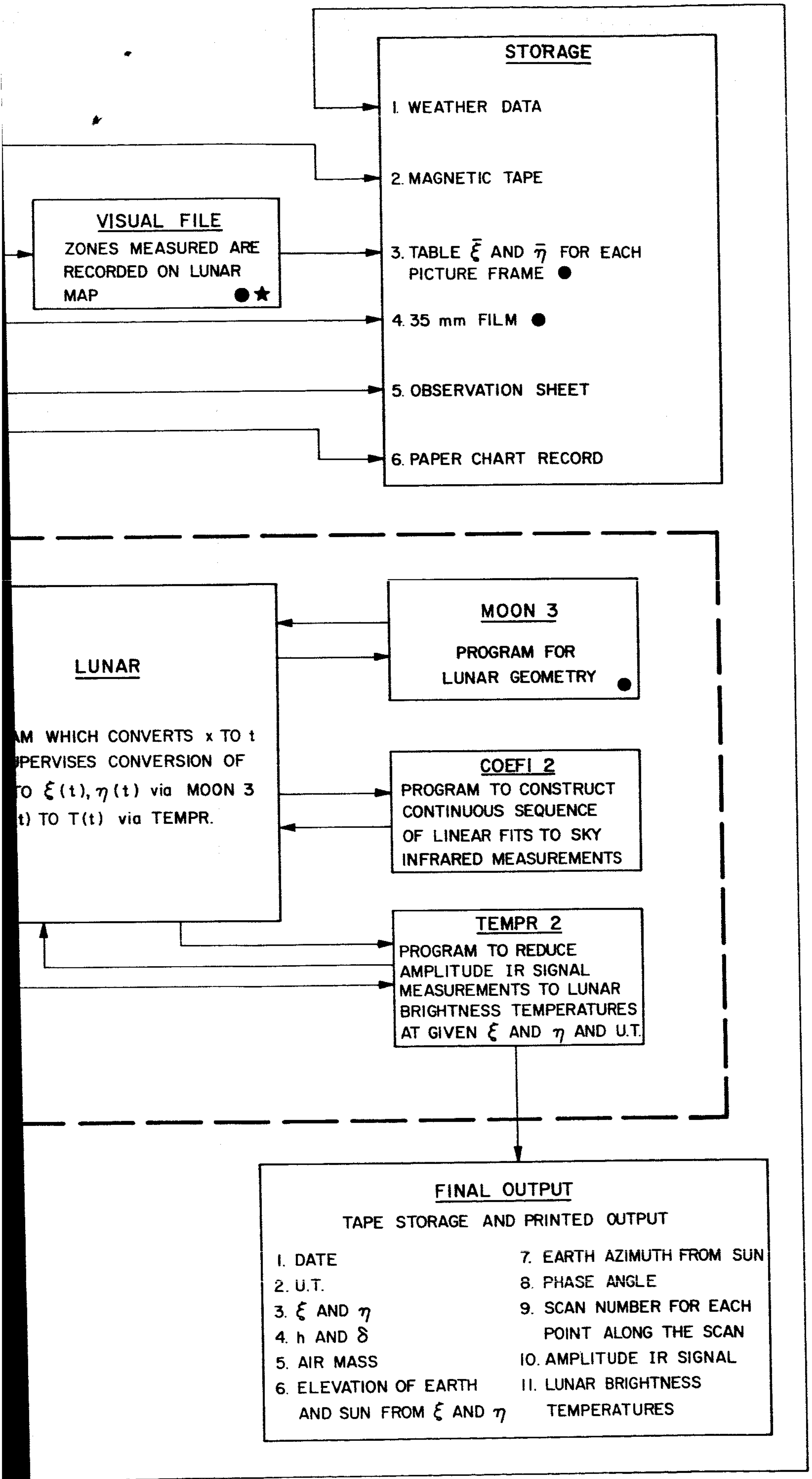


FIG. 1. Block diagram of the Data Processing system developed at Harvard College Observatory.

II. BASIC EQUATIONS RELEVANT TO THE REDUCTION OF RADIOMETRIC AND ASTROMETRIC MEASUREMENTS

The equations and observational technique related to the radiometric measurements have been described in previous reports (1,2). This report will include the equations that have direct bearing on the data-reduction scheme.

Figure 2 shows the block diagram of the electronic circuitry of the radiation pyrometer relevant to the signal processing. The diagram also gives the voltages at each node produced by the radiant power I on the detector.

In the present form of our pyrometer the output is recorded in analog form by means of a pen recorder. The measurement d of the total deflection of the recording pen on the paper chart recorder is proportional to the radiant power I. The factor of proportionality K(t), called constant of the pyrometer, is expressed by

$$K(t) = \frac{I}{d(t)} \tag{1}$$

where the time dependence allows for the possible changes with time in the constant of the pyrometer.

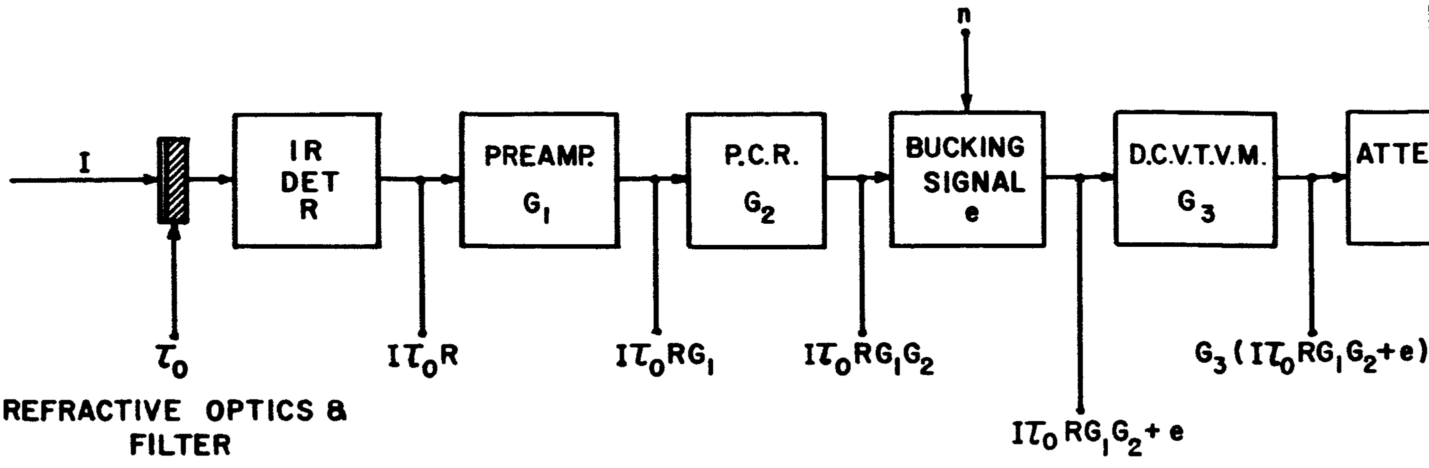
The measurement d is related to the instrumental parameters and readings by:

$$d_m K(t) = dK(t) + [\pm nc \pm 0.25K(t)N \pm qK(t)] \tag{2}$$

where

d_m = observed deflection of the recording pen on the paper chart recorder, mm

$K(t)$ = constant of the pyrometer, W mm^{-1}



A = ATTENUATION RATIO AT THE INPUT OF TH

a = ZERO SUPPRESSION, V

b = PEN CENTERING VOLTAGE, V

c = CONSTANT OF THE BUCKING SIGNAL COUN

d = TOTAL DEFLECTION OF THE RECORDING P

d_m = OBSERVED DEFLECTION OF THE RECORDI

e = BUCKING SIGNAL, V

G_1 = PREAMPLIFIER VOLTAGE GAIN

G_2 = PHASE CONTROL RECTIFIER VOLTAGE GA

G_3 = DIRECT CURRENT VACUUM TUBE VOLTM

G_4 = AMPLIFIER GALVANOMETER GAIN

I = RADIANT POWER ON THE DETECTOR, W

K(t) = CONSTANT OF THE PYROMETER, W mm^{-1}

N = ZERO SUPPRESSION, GIVEN IN COUNTER R

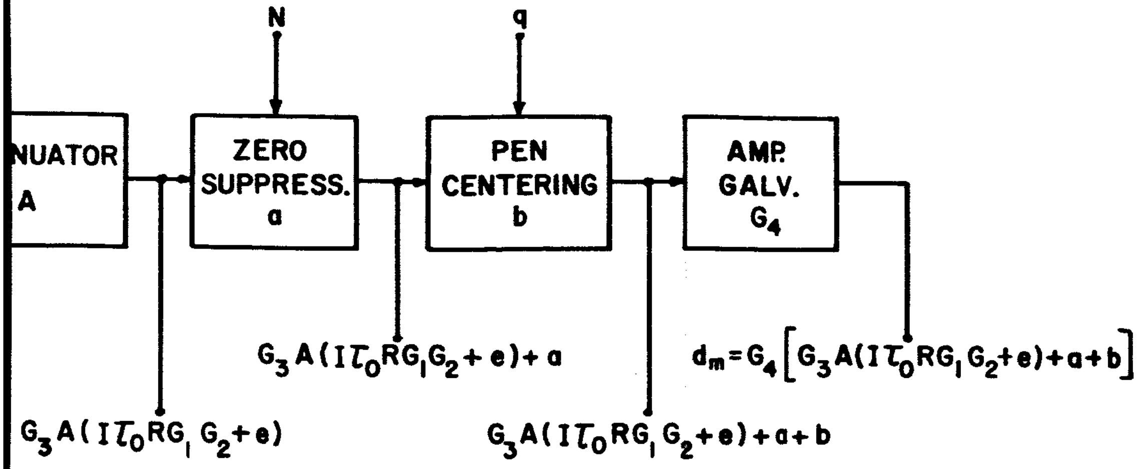
n = BUCKING SIGNAL, GIVEN IN COUNTER REA

q = PEN CENTER DEFLECTION, mm

R = DETECTOR RESPONSIVITY, V W^{-1}

τ_0 = INSTRUMENTAL TRANSMITTANCE

4-1



E AMPLIFIER GALVANOMETER

TER (watts per increment)
EN, mm
NG PEN, mm

IN
ETER GAIN

EADING
DING

FIG. 2. Block diagram of the electronic circuitry of the radiation pyrometer, relevant to the processing of the radiant power on the infrared detector.

n = bucking signal given in counter reading

c = constant of the bucking signal counter

N = zero suppression given in counter reading

q = pen center deflection, mm

The values of n, N, and q are supplied in the observation sheet and the value of c is measured following the same procedure as for K(t).

The radiant power I of the calibration signal is related by Eq. (1) and by the following expression:

$$K(t_c)\,d_c = \frac{\pi A_d}{4F_c^2}\left\{S[T_C(t_c)]-S[T_R(t_c)]\right\} \tag{3}$$

where

d_c = total deflection of the recording pen due to the calibration signal, mm

A_d = area of the detector, cm^2

F_c = f-number in the calibration mode of operation

$$S[T_C(t_c)] = \varepsilon_C \int_0^\infty N[\lambda, T_C(t_c)]\,\tau_d(\lambda)\,\tau_f(\lambda)\,d\lambda \tag{4}$$

$$S[T_R(t_c)] = \varepsilon_R \int_0^\infty N[\lambda, T_R(t_c)]\,\tau_d(\lambda)\,\tau_f(\lambda)\,d\lambda \tag{5}$$

where

$N[\lambda, T_C(t_c)]$ = spectral radiance of the calibration blackbody, $W\ cm^{-2} sr^{-1} \mu^{-1}$

$\tau_d(\lambda)$ = spectral radiant transmittance of the window of the detector

$\tau_f(\lambda)$ = spectral radiant transmittance of the filter

$N[\lambda, T_R(t_c)]$ = spectral radiance of the reference blackbody, W $cm^{-2} sr^{-1} \mu^{-1}$

$T_R(t_c)$ = temperature of the reference blackbody at calibration time t_c, °K

$T_C(t_c)$ = temperature of the calibration blackbody at calibration time t_c, °K

ε_c = radiant emissivity of the calibration blackbody

ε_R = radiant emissivity of the reference blackbody

In Eq. (3) the value of $\pi A_d/4F_c^2$ is called the instrumental constant R_c.

For our pyrometer the following values have been adopted:

$A_d = (0.035 \text{ cm})^2$

$F_c = 5.25$

$\varepsilon_c = 0.96 \pm 1\%$

$\varepsilon_R = 0.98 \pm 1\%$

When measurements are carried out with the pyrometer-telescope combination, Eq. (1) is still valid. The relationship between the infrared measurement, d(t), and the lunar spectral radiance for an area at a temperature T and an assumed blackbody radiator is given by:

$$K(t)d(t) = \frac{\pi A_d \rho_0^2}{4F_{eff}^2} \bar{\tau}_A[T(\xi,\eta), m, \omega_0] \; S[T(\xi,\eta)] \qquad (7)$$

where

ρ_0 = radiant reflectance of the mirror (aluminized) of the telescope

F_{eff} = effective f-number of the optical system during measurements

$\bar{\tau}_A[T(\xi,\eta),m,\omega_0]$ = mean atmospheric radiant transmittance

$T(\xi,\eta)$ = brightness temperature, °K

m = air mass along the line of sight

ω_0 = amount of precipitable water along the path, mm

$S(T)$ = blackbody radiance corrected for instrumental transmittance, W $cm^{-2}sr^{-1}$

The radiance S(T) is expressed by the following relationship

$$S(T) = \int_0^\infty N(\lambda,T)\tau_0(\lambda)\,d\lambda \qquad (8)$$

where $N(\lambda,T)$ is the spectral blackbody radiance, and the spectral instrumental transmittance $\tau_0(\lambda)$ is given by

$$\tau_0(\lambda) = \tau_d(\lambda)\tau_f(\lambda) \qquad (9)$$

In Eq. (7) the value of $\pi A_d\rho_0^2/4F_{eff}^2$ is called instrumental constant R_M.

For the 61-inch telescope at Agassiz Station the following values have been adopted

ρ_0 = 0.98* (at 10μ)

F_{eff} = 5.58

The values of the amount of precipitable water ω are obtained from the data gathered by balloon sounding. For Agassiz Station we used the data from the U.S. Weather Bureau soundings at Albany (New York), Portland (Maine), and Nantucket

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*G. Hass, "Mirror Coatings," Chapter 8, Applied Optics and Optical Engineering, edited by R. Kingslake (New York, Academic Press, 1965), Vol. III, p. 316.

(Massachusetts).* During observation the zenith distance z of the moon never exceeds 45°; this condition allows the use of the following relationship for the air mass m:

$$m - m_0 \sec z \tag{10}$$

where m_0 is the unit air mass.

The equations for recuding the astrometric data from the photographic channel of our pyrometer are given in detail in a previous report (2).

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*The values of ω_0 are obtained by plotting atmospheric pressure versus dewpoint on a pseudo-adiabatic chart. Step integration and multiplication by the proper factors give the value of ω_0 in millimeters.

III. COMPUTING PROCEDURE

A. Introduction

The integrated data-reduction package is designed to accommodate all calibration data, instrumental parameters, and astronomic data relevant to a given set of scans in one computer run, and to output a large accumulating file of lunar brightness temperatures.

The input data, the observational technique, and the data-reduction approach have all been described in previous reports (1) (2). One major data-reduction algorithm has been added to those described in a previous report (2). The additional procedure is that required to convert infrared signal intensity to average brightness temperature of the resolution element. This procedure is embodied in LUNAR as a subroutine, as are all the specific calculations detailed in a previous report (2). The temperature-conversion routine TEMPR2 will be discussed in detail, but the other subroutines will only be outlined. Primary emphasis here is on the data-processing aspects of the integrated package, LUNAR.

B. DESCRIPTION OF LUNAR

LUNAR is written in FORTRAN II and FAP for operation under SAOFMS (Smithsonian Astrophysical Observatory Fortran Monitor System), whose relevant characteristics will be described.

1) Input Data Structure

Input data groups have been hierarchically ordered so that the most invariant tables and instrumental parameters can be precomputed and selected from a small set for insertion into the input deck as program parameter cards. These lowest-level data groups include ephemeris tables, coefficients of atmospheric transmittance, and the spectral blackbody radiance tables corrected for instrumental transmittance* given by:

---

*Hereafter referred to as CORRADIANCE.

$$S(T) = \int_0^\infty N(\lambda,T)\tau_0(\lambda)d\lambda \tag{11}$$

where $N(\lambda,T)$ is the spectral blackbody radiance and $\tau_0(\lambda)$ the spectral instrumental transmittance. For example, the CORRADIANCE tables used in the temperature conversion routine TEMPR2 and the atmospheric model routine FAKIR are pre-computed by the program BRAD and inserted as a small card-group near the beginning of the data input to LUNAR. BRAD should be considered a partner to, but not a member of, the package LUNAR, since its job can be done once and for all for any instrumental transmittance.

The next highest level of input data is the set of parameters describing the operating settings of the radiation pyrometer as well as the signals introduced at the different stages of the electronics (see Fig. 2). These signals, bucking (n) and zero-suppression (N), are used to expand the dynamic range of the pyrometer and may occur in any scan in the sequence of scans to be processed. Such occurrences are signaled to LUNAR in an early card group. LUNAR stores the values of these scaling signals and proceeds to the next highest level of input data; i.e., periodic calibration traces which are output from the pyrometer while it is "looking" at a calibration blackbody. LUNAR reads these calibration traces all at once, stores them, and computes from them the constant K(t) of the pyrometer over the time range of the scans to be processed in the current run (i.e., they are embodied in the coefficients of a Lagrange interpolation polynomial).

Finally, LUNAR reads the highest-level input data group: y-x digital pairs representing infrared signal intensity versus time in digitizer counts. The x's are interspersed with periodic heading cards specifying the initiation of the x (or time) scale and with cards that distinguish the output data of the photographic channel from any given scan. This last card-group defines the lunar orthographic coordinates $(\overline{\xi},\overline{\eta})$ of the points "seen" during the scan. These define, using MOON3 (the subroutine for lunar geometry*), the

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*For the analytical description, see Reference 2.

location of the resolution element for each point along the scan. Note that only at the highest level are there data-groups requiring differing interdependent program interpretations. This approach allows us to dispense with elaborate and time-consuming data-edits and minimizes the number of passes through the data. The hierarchical ordering of data groups is reflected in the ordering of such groups in the input data-deck, which allows one-time calls to many of the component subroutines. This strategy allows for overlays of one-time tasks by subroutines which come into play when we begin processing the highest-level data. If the introduction of further functions of the state of the experimental configurations which vary rapidly in time should require more memory space, the ability to overlay program could easily provide extra storage.

2) Output Data Structure

Design of the output file was guided by two primary objectives: simplicity and maximum use of tape storage capacity. The need for simplicity was determined by the desired use of the file: to provide a thermal history covering one lunar month over large regions of the moon's surface. From this file, then, we must be able to retrieve isotherms $T(\xi,\eta,t) = T_c$ over a given time span $t_0 \leq t \leq t_n$, where $t_0 - t_n$ is a small interval in the scale of the lunar month. Or, we must retrieve from the complete file a time-series in brightness temperature $T(\xi,\eta,t)$ for a given set of coordinates: (ξ_0,η_0), (ξ_1,η_1), ..., (ξ_n,η_n). It is envisaged that such displays could best be generated on digital-display equipment that has photographed cathode-ray-tube (CRT) output with several possible levels of grey, such as the Stromberg-Carlson Model 4020 (SC4020); or, better, on the next generation of display devices, such as the IBM 2280. In either case, economical retrieval calls for independent unit temperature-records that require no search for key-records or header-records to complete the data vector (T,t,ξ,η). In fact, each unit-record should be completely independent from all other output records and the file should contain only records of one type (i.e., essentially just $[T,t,\xi,\eta]$). A few additional data on the output points recorded are in fact retained: terrestrial topocentric location of the resolution element, selenocentric location of earth and sun, air mass, and an identifying scan number to facilitate editing out "bad" scans. But nothing further from the data-reduction process is "remembered" in the final output file.

A full history of the data-reduction for a given run, including the input parameters used, is provided in the printed output as a double-check on the magnetic tape-recorded output. This will aid the investigator to locate "bad" scans--e.g., scans in which the constant K(t) of the pyrometer was varying wildly and too rapidly. The printed output then provides all "post mortem"; the permanent multi-reel tape file contains only one kind of unit record that is sufficient to plot a point. Such simplicity of file-structure greatly facilitates the searches and sorts required to make the plots.

The need for maximum compression of output is dictated by the potential size of the file. Output in conventional FORTRAN II binary records (256 words per block) would give us an estimated 125 full reels of data. Therefore the output records are blocked: 133 logical records (15 words each of 36 bits) are stored per physical record or block. This number was chosen to comply with the most efficient sort available (viz. IBM 90 SORT operating under IBSYS), which requires blocks having a maximum length of 2000 computer words.* It is estimated that the large "blocking factor" (133) will reduce the required number of reels in the file to 26.

One additional convention is adopted: that no physical record shall contain the data from more than one scan. This device enhances the speed and accuracy of editing at the cost of a minor increase (approximately 15%) in storage required.

C. PROGRAMS

The main programs and subroutines are listed in Appendix B. The specific titles of the programs and subroutines are as follows:

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*FAP subroutines READR and WRITR perform the large-block input-output with error checking.

1) LUNAR -- Supervises the whole package

2) MOON3 -- Calculates the lunar coordinates (ξ, η)

3) COEFI2 -- Generates base level

4) TEMPR2 -- Calculates brightness temperature T of lunar surface

5) FAKIR
6) BREW
-- Compute the mean atmospheric radiant transmittance $\bar{\tau}_A(T,m,\omega_0)$ as function of of lunar temperature T, air mass m, and amount of precipitable water ω_0 at zenith

7) GAIN -- Computes the constant of the pyrometer K(t)

8) GT (mnemonic LAGR) -- Subfunction to interpolate K(t) table

9) BRAD -- Computes CORRADIANCE tables

10) COPY
11) READR
12) WRITR
-- Maintain permanent tape files

Listings of the following subroutines are available from Harvard College Observatory, Infrared Laboratory:

13) HYPLOT -- Subroutine to plot display residuals

14) TABLE -- Second-order interpolation routine for tabulated angles in radians (coded in FAP)

15) SIDNEY -- Computes sidereal time at 0 hour U.T.

16) UNFIX -- Converts fixed-point data to floating-point and will ignore numbers already in floating-point form

17) FRENCH -- Parabolic interpolation routine

The following subroutines from the SHARE Library of the Harvard Computing Center are used by FAKIR:

18) ERR -- Computes values of the error-function

19) SIMEQ -- Solves sets of simultaneous equations

20) ICE3 -- Variable stepsize integration routine

21) ACOS -- Computes arccosine

22) ASIN -- Computes arcsine

23) ARTN -- Computes arctangent

The following are special features of SAOFMS:

24) REREAD -- Re-scans the input buffer with a new format without physically moving tape

25) WORDSF -- Picks up free field input of alphabetic variables

D. DISCUSSION OF THE PROGRAMS

1) Main Program LUNAR

LUNAR assigns a time-coordinate to each data-point and, via calls to MOON3, assigns lunar orthographic coordinates (ξ,η) to each data-point. LUNAR is a data-handling program which interfaces the analog-to-digital conversion process with the computational routines (sections of MOON3 for geometry, FAKIR for atmospheric model, TEMPR2 for brightness-temperature computation). The specific data-handling procedures of LUNAR are as follows: converts time from digitized counts into total seconds (which combined with the date will give the time in U.T. and E.T.); corrects the infrared measurements for any lateral drift of the paper during digitizing of the measurements; supervises the whole data-reduction package; and keeps count and supervises the permanent tape files of the output.

a) Input

A separate DATA DECK MAKEUP (see Appendix A) has been written. The input deck is divided into four classes, which are all punched in card form:

Constant Cards. These include the date, the ephemeris tables, calibration constants, instrumental transmittance, CO_2, amount of precipitable water at zenith, O_3 and CORRADIANCE tables.

Data Cards. These are of three kinds: 1) Heading card, which has two known times, given in hours, minutes, and seconds, with corresponding linear paper-chart coordinates, given in counts of an x-y digital plotter. 2) Picture time-mark card, which has a time element measured in counts and the orthographic lunar coordinates $\bar{\xi}$ and $\bar{\eta}$ obtained from a match of the photograph with the Orthographic Lunar Atlas. 3) Amplitude infrared signal card, which contains five data points, each having one time element and one infrared measurement digitized from a paper-chart trace. In addition, each data card has the identifying scan number and each picture card has a frame number.

Control Cards and Switches. Control cards to distinguish a new scan, to end a run, etc., are provided and are described in detail in Appendix A. Some of them have zeros punched at different places to facilitate use of the free field format (G format of SAOFMS) on all the other data cards. G format does not recognize blank cards but distinguishes the zeros. A special switch called KEY is set up to facilitate the entering of subroutines MOON3, TEMPR2, and COEFI2 at different entry points.

Elaborate switching systems in the program are used to distinguish the many different input and control cards, all of which are necessary in a large data-reduction package. They should be self evident in the program.

b) Sequence of Operations

Read in Date Card and Constant Cards. The date is read in by LUNAR and the constant cards by subroutines MOON3 and TEMPR2, which are called by LUNAR.

Heading Card and Picture Time-Mark Card Processing. A scan usually has 4 or 5 heading cards, each of which is followed by one or two picture time-mark cards. It is also possible that no time-mark is available during the time interval covered by a heading card. In this case, no picture time-mark card follows.

LUNAR reads in each heading card and the subsequent picture time-mark cards. Then the following actions take place:

1) Each heading card is indexed so that it can be referred to when the data cards are processed.

2) The time count of each picture time-mark card is converted into total seconds by linearly interpolating the times given by the heading card.

3) A call to subroutine MOON3 performs a series of coordinate transformations and computes the topocentric hour angle and declination of the center of the reticle for each photograph. MOON3 also indexes and stores this information.

Steps (1), (2) and (3) are repeated until the end of a scan.

SCAN/DRIFT Card Processing. This control card causes LUNAR to call subroutine MOON3 and to enter it at the third entry point (see statement 500, Appendix B--Program Listing). MOON3 will act in one of two ways, according to whether the card has the words SCAN or DRIFT on it. The analytical treatment of the two modes of operation has been described previously (2). If the telescope remains stationary during the scan (DRIFT mode of operation), the program takes the mean hour angle and declination; if the telescope had a uniform motion in declination and hour angle (SCAN mode of operation), the program finds by the method of least squares the uniform motion in each coordinate that best fits the data. In either case, the hour angle and declination can then be interpolated for any specific time.

At this point LUNAR resets the index of the heading card to 1 and is ready to receive the data card.

Data Card Processing. Each data card has five data points plus the scan number. LUNAR checks the scan number first, then treats each data point as follows:

1) The time count of each picture time-mark card is converted into total seconds by linearly interpolating the times given by the appropriate heading card.

2) These data enter MOON3 through the fourth entry point (see statement 562, Appendix B--Program Listing). This subroutine computes the hour angle and declination for this specific time. The coordinate transformations are then repeated in reverse order to find the orthographic lunar coordinates. MOON3 returns to the main program these values plus a decision as to whether the current data point is on the lunar disk or not (ON/OFF decision).

3) LUNAR then calls subroutine COEFI2 which classifies each data point according to the ON/OFF decision just received and how far away (measured by the time element) the point is from the edge. Eventually, as shown in Figure 3, for one scan, those points on the lefthand side of the lunar disk form one group and those on the right form another. The average infrared measurement ($\bar{y}_\ell$) in counts and the time this occurs ($\bar{t}_\ell$) are calculated as follows:

For the left:

$$\bar{y}_\ell = \frac{1}{j} \sum_{i=1}^{j} y_i \qquad (12)$$

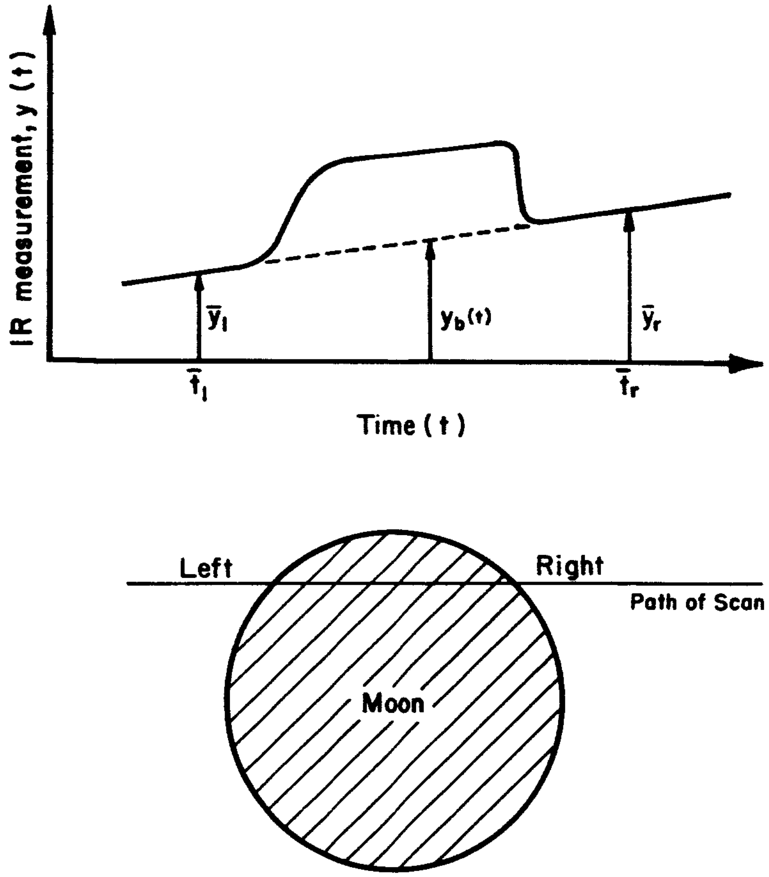

FIG. 3. Scheme showing the linear interpolation between the average infrared measurements $\bar{y}_l$ on the left of the lunar disk and the measurements $\bar{y}_r$ on the right to obtain the sky level baseline $y_b(t)$ during a scan. This operation is performed by the subroutine COEFI2.

and

$$\bar{t}_\ell = \frac{1}{j} \sum_{i=1}^{j} t_i \frac{y_i}{\bar{y}_\ell} , \tag{13}$$

where j is the number of data points, y_i the infrared measurements and t_i the times when y_i was measured. Expressions similar to Eqs. (12) and (13) can be written for the points on the right of the lunar disk to yield $\bar{y}_r$ and $\bar{t}_r$. A sky level baseline, $y_b(t)$, is then determined from the following linear relationship:

$$y_b(t) = [(\bar{y}_r - \bar{y}_\ell)/(\bar{t}_r - \bar{t}_\ell)](t - \bar{t}_\ell) . \tag{14}$$

These values, $y_b(t)$, are subtracted from the on-moon infrared measurements, y_i, to yield the net measurement $y(t) = y_i - y_b(t_i)$. This correction for each on-moon point will not take place until the end of each scan. There may be a great many of these points and each of them requires 15 words of storage. The IBM 7094 computer has 32,768 words of storage, and could spare only about 12,000 of them for this purpose. Hence, a temporary tape is needed to accommodate these points.

4) After COEFI2, the data of each data point, with an index number if it is on-moon, will be stored on a temporary tape. This index number tells which sky level is to be used as the base line.

5) After the above step, LUNAR processes the next data point taken either from the same card or from the next card, as the case may be.

6) Steps (1)-(5) are repeated until a control card is encountered, which immediately increments the index number of the heading cards. Then the whole sequence of operations is repeated until the end of a scan.

7) The scan number on a data card, together with a control card, signals the beginning of the next scan. The operation

returns to step (2) and processes new heading cards and picture time-mark cards and then repeats itself until all the scans of a run are finished.

Tape File Count. At the end of each scan LUNAR counts the number of physical records needed. Each record accommodates 133 data points of 15 words each.

A record on the permanent tape file may be half filled at the end of a scan. The next scan will always start with a new record. This will facilitate editing the file if it is needed in the future.

At the end, the total number of physical records needed for the run is calculated. Each tape will accommodate 1680 records. A message is printed out which gives the number of records left from the last run. This number should be on the date card of a run. From it the program will decide whether to fill up the original file or to start using a new file. A new tape is started by punching "0" on the date card, which means "no records left from last run, start with new tape."

First Pass Termination. The end of the first pass is signaled by a control card. Before turning control to TEMPR2 to perform the temperature conversion, the END card signals the program to:

1) Calculate the total number of physical records needed for the run, as mentioned above.

2) Call COEFI2 to finish up the last base line.

3) Determine whether or not there is still room on the original tape to accommodate the data of this run. If there is, LUNAR calls subroutine COPY, which transfers all the records to a new tape. Thus the original records on the tape will always be protected from accidental loss during writing. If there is no room on the original tape, COPY will be skipped.

4) Convert the time element of the last data card into hours, minutes, and seconds. The time is used to label each tape file if it is so desired later.

Conversion to Brightness Temperature. LUNAR turns over control to TEMPR2, which reads in the data points one by one from the temporary tape and, together with FAKIR and BREW, performs the conversion to brightness temperature.

Printed output and permanent tape filing are all done by TEMPR2 without going back to the main program LUNAR.

2) Subroutine MOON3

The MOON3 subroutine is a revision of MOON2 (3). It is rewritten as a subroutine to be an integrated part of the whole data reduction package. The changes concern mostly the switch functions and the sequence and format of the input and output, which are now transmitted internally rather than through card forms. MOON3 has four different entry points and the main program selects them appropriately with the aid of a switch (called KEY, Appendix B--Program Listing).

a) Input

When MOON3 is called the first time, it reads in the following information:

Place Card. This card gives the name of the observing site; the longitude in hours, minutes, and seconds; the latitude in degrees, minutes, and seconds; and the height in meters above sea level.

Refraction Card. Because of atmospheric dispersion, the photographic channel and the radiometric channel will be affected in different amounts by refraction. To allow for this difference, MOON3 reads in photographic and infrared detector effective wavelengths in that order; either angstroms or microns may be used.

The hour angles and declinations computed for the center of the reticle of the photographs will then be corrected for differential refraction between the two effective wavelengths (but not for the whole refraction at either wavelength). With panchromatic film and yellow filter the approximate effective wavelength is 6000 Å and for the infrared detector and broad band filter* it is 10.7 μ.

Radial Ephemeris (Table A). The semi-diameter and horizontal parallax are tabulated for every 0.5 day of E.T. Table A is limited to 50 entries.

Geocentric Angular Ephemeris (Table B). The apparent right ascension and declination are tabulated for every hour of E.T. Table B is limited to 500 entries.

Physical Ephemeris (Table C). The earth's selenocentric longitude and latitude, the sun's selenocentric colongitude and latitude, and the position angle of the lunar axis are tabulated for 0^h U.T.

In general, there should be at least two entries in each table both before and after all times of observation. MOON3 prints out all the above information for each run.

b) Sequence of Operations

Compute Hour Angle (h) and Declination (δ) of the Center of Reticle for Each Photograph. The picture time-mark cards of a scan are grouped together and read in by the main program LUNAR. At the second entry point (see statement 400, Appendix B--Program Listing), MOON3 obtains from each picture time-mark card the time in total seconds, and the orthographic lunar coordinates $\bar{\xi}$ and $\bar{\eta}$ of the projected center of the reticle, which is the homologous point of the barycenter of the infrared detector. The U.T. and E.T., which are the arguments of several tables, are calculated as follows:

---

*Spectral transmittance as defined in Reference 1.

$$\text{U.T.} = \text{day} + t(\text{sec})/86400 \ ,$$

$$\text{E.T.} = \text{day} + [t(\text{sec}) + 35]/86400 \ .$$

The remaining steps for obtaining the hour angle and declination of each photograph remain the same as previously described (2). Then the values of h and δ are converted into practical units (degrees instead of radians) and printed out. These values are also indexed and stored.

Correction due to the Motion of the Telescope. When MOON3 is called through the third entry point, it treats the h's and δ's of a scan according to one of the following three situations: the telescope was stationary; the telescope had a uniform motion in hour angle and declination; or it was uncertain whether the telescope moved or not. Detailed treatment of this problem has appeared previously (3).

MOON3 prints out the means of all the times, the h's and δ's with the corresponding subsolar point and topocentric disk center.

The residuals of each h and δ are calculated. When the telescope was known or determined by the program to have been moving uniformly, any point with residuals of 10 arcsec or bigger from the computed mean value of the path of the scan is considered to be unreliable and is discarded. In the event that only one or two points remain, the reduction stops and the calculation is based on these one or two points. When a satisfactory set of residuals is obtained, the rms (root mean square) residual in position (both coordinates combined) is calculated and printed out, together with a graph of the residuals as a function of time.

The output of the orthographic coordinates obtained from the photographs of all scans in a run are placed together by MOON3.

Ephemeris Data for Each Observation at Time t. MOON3 receives the time (in seconds) and the infrared measurement of each data point at the fourth entry point. MOON3 calculates the ephemeris data and determines whether the infrared measurement is on or off the lunar disk. All these are transmitted back to the main program LUNAR, which in turn calls subroutine COEFI2 to generate the correct base level for this scan and then stores all the results on a temporary tape. As mentioned before, the output of the ephemeris data is combined with the brightness temperature and printed out at the end of a run.

Process a New Scan. The last two steps are repeated for a new scan. MOON3 poses no limit to the number of scans that can be processed, except that they should all belong to the same date and should use the constants included in the tables read into MOON3.

3) Subroutine COEFI2

COEFI2 corrects the infrared measurement caused by the presence of the zero-suppression or bucking signal. The zero-suppression and bucking signals for each scan are read in by TEMPR2. It is understood that they are constant throughout a scan. COEFI2 selects the corresponding zero-suppression and bucking signal for each scan and corrects the infrared measurements accordingly. If no such information exists, the infrared measurement is left intact.

COEFI2 also generates a continuous sequence of linear fits to sky deflections so that they can serve as the base level that is subtracted from the moon deflection.

a) Input

COEFI2 is supervised by the main program LUNAR. COEFI2 is called after each data point has been processed by MOON3. Hence, two data are available for COEFI2. They come from LUNAR and MOON3 respectively, and are:

1) time in seconds (TSEC); and

2) whether the infrared measurement is on or off the lunar disk.

With this information, COEFI2 divides all the data points of a run into five categories. They are in time sequence and come to COEFI2 one by one. Figure 4 shows the sequence in the five categories.

b) Sequence of Operations

The sequence of operations is as follows:

1) Starting from point "a" COEFI2 stores time and infrared measurements for each point until it reaches point "b", the first on-moon point.

2) It then backtracks 3 seconds from "b" to "c" and discards the points in between because the infrared measurements of this region are now affected by lunar radiation. The mean value of the infrared measurements between "a" and "c" and the time when they occur are then calculated, indexed, and stored.

3) Information relating to each on-moon point between "b" and "d" is then stored on temporary tape. This tape contains the scan number, U.T., ephemeris, date, and the revised infrared measurement. COEFI2 also assigns each point an index number (KD) so that the corresponding base level will be subtracted from the infrared measurement.

Each on-moon data point generates 12 items of information. It is possible that several on-moon scans may be grouped together. If that is the case, more than 1500 data points will be accumulated and at least 18,000 words of storage will be needed. Therefore a temporary tape and a second pass are needed to accomplish the complete data reduction.

4) Continuing from "d", COEFI2 ignores the data between "d" and "e", which are 3 seconds apart, for the same reason given in step (2). From "e", time and infrared measurements are again stored until the next on-moon point "f" is reached.

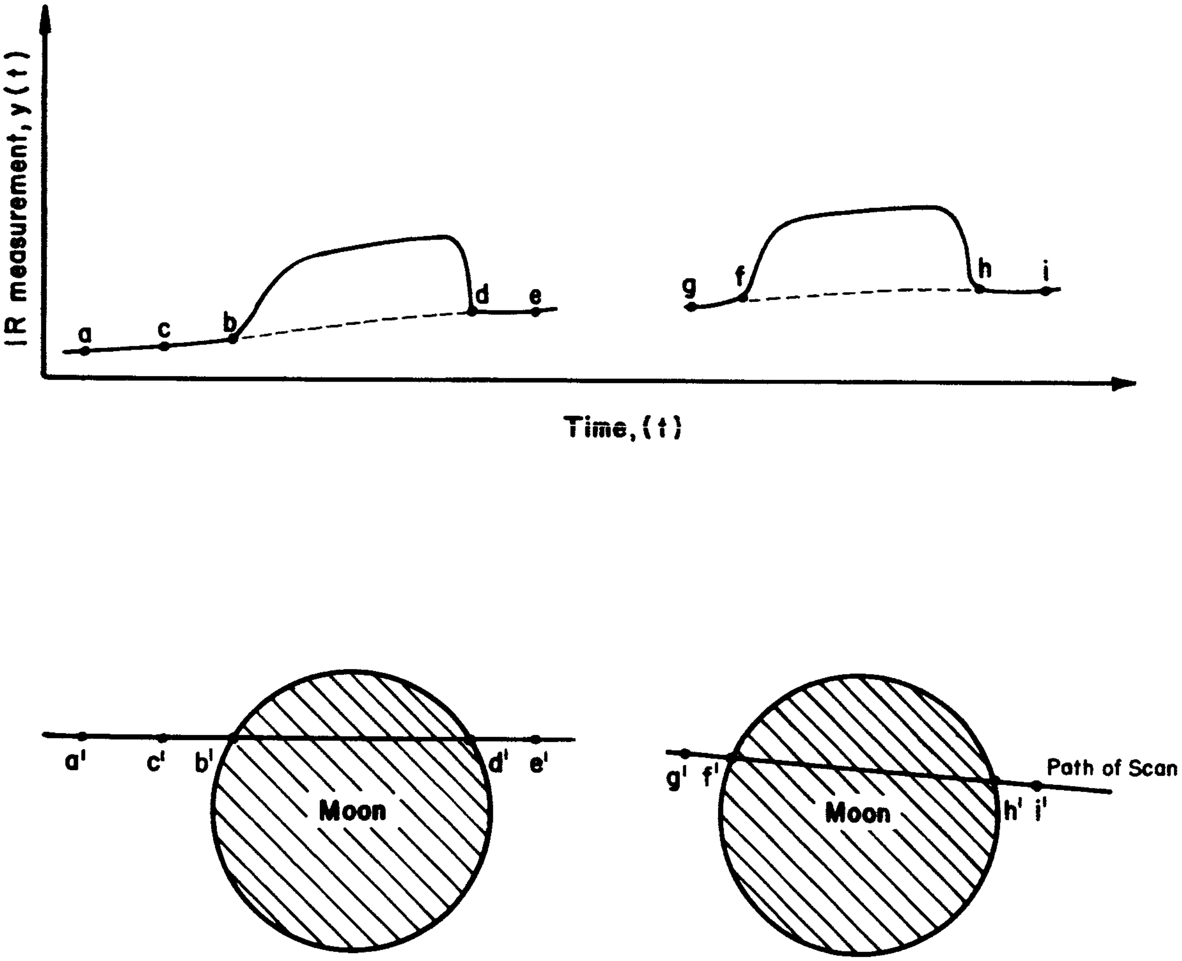

FIG. 4. Scheme showing the linear interpolation to obtain the sky level base line $y_b(t)$ for a series of scans.

5) COEFI2 backtracks again 3 seconds to point "g". The mean value of the infrared measurements between "e" and "g" and the time they occur are again calculated, indexed, and stored. These data, with the information from step (2), completely determine the first base level.

From point "f" the program repeats itself from step (3) and treats point "f" as point "b". Thus the terminal point of the first base level becomes the starting point of the second. COEFI2 then completes the last base level with the signal of the last card of the run.

If for any reason it is necessary to repeat the run of some particular scan and the brightness temperatures calculated do not come out exactly as before, the discrepancies may be due to the fact that the scan was previously run together with the adjacent scans. The base level was previously dependent on all the off-limb points between them, but in the repeat run is dependent on the points of this particular scan alone. In practice, however, the difference is usually very small and will not show up since the result in degrees Kelvin is accurate within 4 significant figures.

4) Subroutine TEMPR2

To find the brightness temperature of a given data point, the main reduction program solves the following non-linear integral equation:

$$K(t)y(t) = R\bar{\tau}_A[T(\xi,\eta),m,\omega_0]S[T(\xi,\eta)] \; , \qquad (15)$$

where $y(t)$ is the infrared measurement at a point with coordinates (ξ,η); $K(t)$ is the constant of the pyrometer obtained as described under GAIN and LAGR, R is an instrumental constant described in GAIN, $\bar{\tau}_A[T(\xi,\eta),m,\omega_0]$ as computed in FAKIR and $S[T(\xi,\eta)]$ as computed in BRAD. Since these variables are bounded and tabulated, this problem is solved to adequate accuracy by inverse linear interpolation (Regula Falsi method). Note here that TEMPR2 fills out by linear interpolation the $\bar{\tau}_A$ table in A(T), B(T), C(T)--the parameters of the atmospheric model computed by FAKIR--to the full 85°K to 410°K range in increments of 1°K compatible with tables in the CORRADIANCE, S(T).

To put it more generally, we are to find the zero of a tabular function, F(T), where:

$$F(T) = \frac{K \cdot y}{R\bar{\tau}_A(T, m, \omega_0)} - S(T) \; . \tag{16}$$

(Note that the T here is really the <u>average</u> brightness temperature of the lunar region covered by the resolution element.) Both the integral, S(T), and the mean atmospheric radiant transmittance, $\bar{\tau}_A$, are known to be monotonic in T. This consideration might argue for a Newton-Raphson approach. However, in view of the lack of analytical expressions for the derivative of F(T), the work proceeds more efficiently with the Regula Falsi method. This is especially true since within any one scan we can take the final root, T, for the preceding time point and make it the starting root for the next. At the beginning of the scan, F(T) is tabulated and the T's on either side of a sign change are selected as starting points, T_0 and T_1:

$$\text{Step A:} \quad T' = [F(T_1)T_0 - F(T_0)T_1]/[F(T_1) - F(T_0)] \tag{17}$$

$$\text{Step B:} \quad T' \longrightarrow T_0 \text{ if } F(T') < 0 \tag{18}$$

$$T' \longrightarrow T_1 \text{ if } F(T') > 0 \tag{19}$$

$$\text{Step C:} \quad \text{Return to step A until } |T_0 - T_1| \leq \Delta T(T) ,$$

where ΔT(T) is the temperature resolution determined by the noise level of the pyrometer. Actually, in the present case, one iteration is quite sufficient.

a) Input

TEMPR2 reads bucking and zero-suppression signal. These are held in COMMON for use by COEFI2. The principal inputs to TEMPR2 are the current CORRADIANCE tables, S(T) (which are read from constant cards selected for the instrumental transmittance that is applicable to the scans currently being processed); current infrared measurement, y(t) (corrected for base level and bucking and zero-suppression signals); and K(t) (the constant of the pyrometer). In addition, the mean atmospheric radiant transmittance is obtained through communication with subroutine FAKIR (refer to Fig. 1).

b) Sequence of Operations

One segment of TEMPR2 is used to read the constant cards under supervision by LUNAR. TEMPR2 then executes calls to FAKIR and GAIN, to obtain the mean atmospheric radiant transmittance values for the entire time interval covered by the scans in the current run and to obtain a polynomial form for the constant of the pyrometer in the same time interval. Finally, TEMPR2 executes the entire second pass through all the data points, subtracting the base level corrections computed by COEFI2 and adding brightness temperature to the data vector describing each point.

5) Subroutine FAKIR

This subroutine computes the mean atmospheric radiant transmittance $\bar{\tau}_A(m_j,T_i)$. A set of temperatures, T_i, covering the lunar temperature range (85°K to 410°K) is selected, and for each T_i a small set of air mass values, m_j (which cover the range m = 1.0-4.0), is selected. The mean transmittance is calculated:

$$\bar{\tau}_A(m_j,T_i) = \frac{\int_0^\infty N(\lambda,T_i)\,\tau_0(\lambda)\,\tau_A(m_j,\lambda)\,d\lambda}{\int_0^\infty N(\lambda,T_i)\,\tau_0(\lambda)\,d\lambda}, \qquad (20)$$

where $N(\lambda,T_i)$ is the spectral blackbody radiance, $\tau_0(\lambda)$ the spectral instrumental transmittance, and $\tau_A(m_j,\lambda)$ the spectral atmospheric radiant transmittance computed according to one of the atmospheric models previously described (2).

The denominator in Eq. (20) is selected from the CORRADIANCE tables pre-computed by BRAD and the numerator is evaluated by use of subroutine ICE3. Note that it is not feasible to pre-compute the numerator, since the $\tau_A(m_j,\lambda)$ computed by BREW is dependent on the amount of precipitable water along the path, ω, which covers a wide range. Also, peculiarities in the atmospheric conditions over some time may require the selection of differing models. Thus $\tau_A(m_j,\lambda)$ is really $\tau_A(m,\lambda,\omega,\text{model})$. After the $\bar{\tau}_A$ has been computed for each of the m_j, a least-squares fit of $\bar{\tau}_A$ is made to the analytic form:

$$\bar{\tau}_A(m_j,T_i) = \exp\ (-cm^p)\quad , \tag{21}$$

where $p = A \log_{10} m + B$.

This process is repeated for all of the T_i and the result is a $\bar{\tau}_A$ analytic in m with coefficients tabular in T:

$$\bar{\tau}_A(m_j,T_i) = \exp\ [-C(T_i)m^{p(T_i)}] \tag{22}$$

where

$$p(T_i) = A(T_i)\ \log_{10} m + B(T_i)\quad . \tag{23}$$

To find $\bar{\tau}_A(m,T_x)$ where $T_i < T_x < T_j$, simple linear interpolation in the tables of $[A(T_i),B(T_i),C(T_i)]$ is adequate, since $\bar{\tau}_A$ is a slowly changing function of T.

6) Subroutine BREW

This subroutine used by FAKIR calculates a spectral atmospheric radiant transmittance $\tau_A(m,\lambda)$, according to one of three possible analytic models previously described (2). τ_A also depends on the amount of precipitable water, ω_0, at the zenith. The technique used by BREW has been described previously (2).

7) Subroutine GAIN

This subroutine computes the constants of the pyrometer $K(t_c)$. Periodically interspersed with lunar scans are calibration passes in which the infrared detector is "looking at" a calibration blackbody at temperature T_C with an enclosure reference blackbody at temperature T_R. Let $y(t_c)$ be the amplitude in digitizer counts of the calibration infrared signal. Now we can calculate a pyrometer constant (i.e., calibration or scaling constant) from:

$$K(t_c)y(t_c) = R_c\{S[T_C(t_c)] - S[T_R(t_c)]\} \qquad (24)$$

where the t_c are times of calibration passes, R is an instrumental constant, and S is CORRADIANCE as obtained by linear interpolation in our BRAD-created tables. If our times of calibration, t_c, span the time region covered by the scans to be processed, we have in the values $K(t_c)$ a discrete table of pyrometer constants as a function of time.

8) Subroutine GT (mnemonic LAGR)

The LAGR subroutine performs Lagrange-interpolation in the table $K(t_c)$ to obtain $K(t)$ at any time of a data-point. Thus, depending on the number of calibration times, t_c $(c = 1, 2, \ldots, n)$, a polynomial of arbitrarily high degree (n) is available to describe the drift of the pyrometer constant:

$$K(t) = \sum_{c=1}^{n}\left\{K(t_c)\prod_{\substack{j=1\\ \neq c}}^{n}\frac{(t - t_j)}{(t_c - t_j)}\right\} . \qquad (25)$$

This information is called for at each data point from the temperature-conversion program TEMPR2.

9) Subroutine BRAD

The program BRAD is not incorporated in LUNAR, but performs a set of computations which are pre-tabulated before a run of the LUNAR package. A selected BRAD output set is submitted with each run of LUNAR. BRAD produces tables of blackbody radiances, corrected for proper instrumental transmittance (CORRADIANCE), as a function of temperature, T. The spectral instrumental transmittance, $\tau_0(\lambda)$ is input to BRAD. $\tau_0(\lambda)$ may be tabulated in any given interval, $\Delta\lambda$, over any range of λ (here we are concerned specifically with the 8.0-15.0 micron "window"). BRAD evaluates the integral:

$$S(T) = \int_0^\infty N(\lambda,T)\tau_0(\lambda)\,d\lambda \quad , \qquad (26)$$

where

$$N(\lambda,T) = \frac{c_1}{\lambda^5[\exp(c_2/\lambda T) - 1]} \quad , \qquad (27)$$

and

$$c_1 = c^2h \ ,$$

$$c_2 = ch/k \ ,$$

where c is the velocity of light in vacuum, h is the Planck constant, and k is Boltzmann's constant.

For a given spectral instrumental transmittance, $\tau_0(\lambda)$, a table of CORRADIANCES, S(T), is output for the temperature range 85°K to 410°K. To evaluate the integral, BRAD uses ICE3, a variable stepsize integration routine employing a modified Adams-Moulton method with error control (via stepsize halving to estimate error). Interpolation in the table, $\tau_0(\lambda)$ is provided by a parabolic interpolation routine, FRENCH. The tabular interval $\Delta T = 1°K$ is quite adequate since the CORRADIANCES, S(T), are clearly quite well-behaved and monotonic.

IV. COMPUTER OUTPUT

The Table shows a typical output of the data processed by the computer program discussed in this report. Column 1 gives the scan number arbitrarily assigned to each scan. Column 2 gives the data point number in sequence. Columns 3, 4, 5, and 6 give the date expressed in days, hours, minutes, and seconds at which the respective data point has been obtained. Columns 7 and 8 give the orthographic coordinates of each data point. Column 9 gives the air mass through which the point of given coordinates has been measured. Columns 11, 12, 13, and 14 give the elevation of the sun and earth at the given orthographic coordinates, earth azimuth from the sun, phase angle, and brightness temperature. The print out "off" at the bottom of the Table means "off the lunar disk". Thus, this output gives not only the brightness temperature but also other relevant astronomical data for further interpretation of the brightness temperature data.

TABLE

COMPUTER OUTPUT OF THE DATA PROCESSING OF LUNAR INFRARED MEASUREMENTS AT HIGH SPATIAL AND RADIOMETRIC RESOLUTION TO OBTAIN BRIGHTNESS TEMPERATURE AND OTHER RELEVANT ASTROMETRIC DATA

```
     EPHEMERIS AND TEMPERATURE DATA OF LUNAR SURFACE                                  SCAN    1

SCAN  DATA 1965 APR                                   AIR   ELEVATION OF  EARTH AZH. PHASE          TEMPERATURE
 NO.   NO.  D   H   M  SEC       XI        ETA        MASS   EARTH   SUN    FROM SUN   ANGLE          DEGREE K
   1   560  15  1   7 41.60   -0.8281   -0.3512     2.057    22.6   11.5      0.3     11.2            295.02
   1   561  15  1   7 41.80   -0.8315   -0.3495     2.057    22.3   11.1      0.3     11.2            293.03
   1   562  15  1   7 42.01   -0.8350   -0.3477     2.057    21.9   10.8      0.3     11.2            289.99
   1   563  15  1   7 42.21   -0.8384   -0.3460     2.057    21.6   10.4      0.3     11.2            286.84
   1   564  15  1   7 42.41   -0.8419   -0.3442     2.057    21.2   10.0      0.4     11.2            286.84
   1   565  15  1   7 42.57   -0.8445   -0.3429     2.057    20.9    9.8      0.4     11.1            285.76
   1   566  15  1   7 42.82   -0.8487   -0.3407     2.057    20.5    9.3      0.4     11.1            283.58
   1   567  15  1   7 43.08   -0.8531   -0.3384     2.057    20.0    8.8      0.5     11.1            283.58
   1   568  15  1   7 43.18   -0.8548   -0.3375     2.057    19.8    8.6      0.5     11.1            283.58
   1   569  15  1   7 43.39   -0.8584   -0.3357     2.057    19.4    8.2      0.5     11.1            282.47
   1   570  15  1   7 43.59   -0.8619   -0.3338     2.057    19.0    7.8      0.5     11.1            280.21
   1   571  15  1   7 43.85   -0.8664   -0.3315     2.057    18.4    7.3      0.5     11.1            279.06
   1   572  15  1   7 44.00   -0.8691   -0.3301     2.057    18.1    7.0      0.6     11.1            276.72
   1   573  15  1   7 44.20   -0.8725   -0.3283     2.057    17.7    6.6      0.6     11.1            275.53
   1   574  15  1   7 44.41   -0.8761   -0.3263     2.057    17.2    6.1      0.6     11.1            271.85
   1   575  15  1   7 44.61   -0.8798   -0.3244     2.057    16.8    5.6      0.6     11.1            270.59
   1   576  15  1   7 44.82   -0.8834   -0.3224     2.057    16.3    5.2      0.7     11.1            268.00
   1   577  15  1   7 45.02   -0.8871   -0.3204     2.057    15.8    4.7      0.7     11.1            265.34
   1   578  15  1   7 45.23   -0.8909   -0.3184     2.057    15.3    4.2      0.7     11.1            266.67
   1   579  15  1   7 45.43   -0.8946   -0.3163     2.057    14.7    3.6      0.7     11.1            263.96
   1   580  15  1   7 45.63   -0.8982   -0.3143     2.057    14.2    3.1      0.8     11.1            263.96
   1   581  15  1   7 45.84   -0.9021   -0.3122     2.057    13.6    2.5      0.8     11.1            259.71
   1   582  15  1   7 46.04   -0.9060   -0.3100     2.057    13.0    1.9      0.8     11.1            255.21
   1   583  15  1   7 46.25   -0.9099   -0.3078     2.057    12.4    1.3      0.8     11.1            250.41
   1   584  15  1   7 46.45   -0.9139   -0.3055     2.057    11.8    0.6      0.8     11.1            247.02
   1   585  15  1   7 46.66   -0.9180   -0.3032     2.057    11.0   -0.1      0.9     11.1            245.26
   1   586  15  1   7 46.81   -0.9211   -0.3014     2.057    10.5   -0.6      0.9     11.1            239.68
   1   587  15  1   7 47.07   -0.9261   -0.2984     2.057     9.5   -1.6      0.9     11.1            235.67
   1   588  15  1   7 47.22   -0.9294   -0.2964     2.057     8.9   -2.2      0.9     11.1            235.67
   1   589  15  1   7 47.42   -0.9339   -0.2936     2.057     7.9   -3.2      1.0     11.1            224.28
   1   590  15  1   7 47.63   -0.9387   -0.2907     2.057     6.8   -4.3      1.0     11.1            224.27
   1   591  15  1   7 47.83   -0.9438   -0.2873     2.057     5.5   -5.6      1.0     11.1            216.10
   1   592  15  1   7 48.04   -0.9496   -0.2833     2.057     3.8   -7.3      1.0     11.1            216.09
   1   593  15  1   7 48.24   -0.9528   -0.2822     2.057     0.     0.       0.       0.     OFF      -0.
   1   594  15  1   7 48.45   -0.9556   -0.2810     2.057     0.     0.       0.       0.     OFF      -0.
   1   595  15  1   7 48.65   -0.9585   -0.2798     2.057     0.     0.       0.       0.     OFF      -0.
   1   596  15  1   7 48.85   -0.9614   -0.2785     2.057     0.     0.       0.       0.     OFF      -0.
   1   597  15  1   7 49.06   -0.9643   -0.2773     2.057     0.     0.       0.       0.     OFF      -0.
   1   598  15  1   7 49.21   -0.9664   -0.2764     2.057     0.     0.       0.       0.     OFF      -0.
   1   599  15  1   7 49.42   -0.9693   -0.2752     2.057     0.     0.       0.       0.     OFF      -0.
   1   600  15  1   7 49.62   -0.9722   -0.2739     2.057     0.     0.       0.       0.     OFF      -0.
   1   601  15  1   7 49.83   -0.9750   -0.2728     2.057     0.     0.       0.       0.     OFF      -0.
   1   602  15  1   7 50.03   -0.9779   -0.2715     2.057     0.     0.       0.       0.     OFF      -0.
   1   603  15  1   7 50.23   -0.9807   -0.2703     2.057     0.     0.       0.       0.     OFF      -0.
   1   604  15  1   7 50.44   -0.9836   -0.2691     2.057     0.     0.       0.       0.     OFF      -0.
   1   605  15  1   7 50.64   -0.9865   -0.2679     2.057     0.     0.       0.       0.     OFF      -0.
   1   606  15  1   7 50.85   -0.9894   -0.2666     2.057     0.     0.       0.       0.     OFF      -0.
   1   607  15  1   7 51.05   -0.9922   -0.2655     2.057     0.     0.       0.       0.     OFF      -0.
   1   608  15  1   7 51.26   -0.9951   -0.2642     2.057     0.     0.       0.       0.     OFF      -0.
   1   609  15  1   7 51.46   -0.9979   -0.2630     2.057     0.     0.       0.       0.     OFF      -0.
   1   610  15  1   7 51.67   -1.0008   -0.2618     2.057     0.     0.       0.       0.     OFF      -0.
   1   611  15  1   7 51.87   -1.0037   -0.2605     2.057     0.     0.       0.       0.     OFF      -0.
   1   612  15  1   7 52.07   -1.0066   -0.2593     2.057     0.     0.       0.       0.     OFF      -0.
   1   613  15  1   7 52.23   -1.0088   -0.2584     2.057     0.     0.       0.       0.     OFF      -0.
   1   614  15  1   7 52.48   -1.0123   -0.2569     2.057     0.     0.       0.       0.     OFF      -0.
   1   615  15  1   7 52.69   -1.0151   -0.2557     2.057     0.     0.       0.       0.     OFF      -0.
```

APPENDIX A

SAMPLE DECK MAKE UP

1. DATE CARD--Besides year, month, and day, this card also gives the number of physical records remaining on the tape from the last run. Punch "0" after "date" to start a new tape.

   Example:

```
            Column  1  4 6
                    1965 APRIL 15 0
                        ↑
                        one blank in between
```

2. EPHEMERIS CARDS

   Ephemeris cards are of five types. They are normally read in the order given below; also, there is a blank card to terminate this group.

   a) PLACE card (Observer's coordinates)

      This has PLACE in columns 1-5, the name of the place in cols. 7-18 followed by the longitude (+ West, - East) in hours, minutes, and seconds; the latitude in degrees, minutes, and seconds; and the height in meters above sea level. The format is similar to that for the list of Observatories in the Ephemeris.

   b) REFRACTION card

      This card has REFRACTION beginning in column 1, followed by the photographic and detector effective wave lengths in that order; either angstroms or microns can be used as units. The hour angles and declinations of the resolution element obtained from the photographs will then be corrected for differential refraction between the two wavelengths (but not for the whole refraction at either wavelength). If the refraction card is omitted, no correction will be made.

Approximate effective wavelengths are:

Photographic Channel

panchromatic film, no filter: 5000Å

panchromatic film, yellow filter: 6000Å

panchromatic film, red filter: 6200Å

Visual Channel

5500Å

Radiometric Channel with the Addition of Broadband Filter

10.7μ

c) TABLEA card (Radial Ephemeris)

This has TABLEA in columns 1-6, followed by the year, month, and day; and the lunar semidiameter and horizontal parallax. The month should be separated from the year by a single blank. The day ends with .0 or .5, just as in the Ephemeris. This table is limited to a maximum of 50 entries.

d) TABLEB card (Angular Ephemeris)

This has TABLEB in the first 6 columns; the year, month, and day as above; the hour of the day; the R.A. and declination of the Moon as given in the Ephemeris. This table is limited to a maximum of 500 entries.

e) TABLEC card (Physical Ephemeris)

This has TABLEC in columns 1-6; year, month, and day as before; the Earth's selenocentric longitude and latitude; the Sun's selenocentric colongitude and latitude; and position angle of the Moon's axis. This table is limited to a maximum of 25 entries.

In general, there should be at least two entries in each table both before and after all times of observation.

3. CONSTANT CARDS FOR TEMPERATURE REDUCTION

a) Constant of the bucking-signal counter cards

These constant cards are expressed in watts per bucking signal count; it is inherently positive. This constant appears alone on the card in columns 11-22, and should be right-justified (i.e., leading blanks are acceptable, but blanks trailing into column 22 are not).

Example:

```
Column   12     19 20 21 22
         ↓       ↓        ↓
         +  .1206  -   0  9
```

This is E-format, where the last three characters must be a sign for the exponent and a two-character exponent--the + sign in column 12 is optional. The above represents the quantity 1.206×10^{-10}. If no bucking signal is to be used for a run, nevertheless one blank card must replace this card.

b) Scan-Bucking signal cards

These are one or more cards specifying alternately a scan number and one associated bucking signal. One card accommodates seven such pairs. The first and succeeding cards of this group must contain the letters BUC in columns 1-3, and the last card of the group must be totally blank. If there is no bucking signal among all the scans, then only the blank card is needed to represent this group.

Example:

```
Column   1   7   11     17  21     27  31
         ↓   ↓   ↓      ↓   ↓      ↓   ↓
         BUC 025 -97.5  026 +63.2  100 +125
```

The above lists three scans in the present run in which bucking signals were present. The three-place integer field specifies the scan number and is followed by a five-place decimal field which expresses in units of the bucking-signal counter the additive bucking voltage which was present throughout that scan. The sign of the bucking signal is determined as follows: if it has increased the height of the deflection trace, then the sign is positive; if the presence of the bucking signal has made the y-deflection trace smaller by a constant (i.e., smaller than it would have been in the absence of a bucking signal), then the sign is negative. If three digits of non-fractional significance are desired in the bucking counts, any fraction of a count must be dropped, and the decimal point occupies the last position in the field (as with the entry for scan 100 in the above example). For sake of internal efficiency, if more than one BUC card will be needed to list all scans with bucking signals and their associated bucking counts, the first BUC card should be filled with all the seven pairs it will accommodate. No more than twenty scans with bucking signals should be run at once. Each scan with a bucking signal must have an entry for it in a BUC card even though the same signal may persist through several contiguous scans.

c) Scan-Zero suppression cards (see Fig. 1)

The same conventions and formats apply here as to the scan-bucking signal cards in group b), with the following exceptions:

(1) The first three columns of the card must contain the characters ZER (followed by three blanks as above).

(2) Zero suppression counts are entered in units of digitized deflection counts (four counts per millimeter of deflection).

Again, a blank card must always be present in this group, even if a set of ZER cards is not needed and is not present. Thus, in a run of scans in which bucking signal and zero-suppression are not relevant, the data deck would begin with three blank cards--one for each of the three data groups so far described.

d) Convolution of the blackbody radiance and instrumental transmittance table cards

This group will already have been prepared. Three such groups are currently available:

one for the wide-band filter plus window;

one for the narrow-band filter plus window;

one for the rectangular filter plus window.

Each set comprises 54 cards. If any filter other than those listed above is used, a new group of table cards must be prepared in advance.

e) FAKIR control cards

Card 1 gives the amount of precipitable water in millimeters, for one air mass measured during the lunar observations; the amount of precipitable water used for the atmospheric model (this amount, 3.0 millimeters, has been derived from the data collected by Gates and Harrop, but if the experimental data input to the FAKIR program should change, the quantity should be changed accordingly); and a name, LIN, for the order of interpolation to be used in the experimental data. Five columns of this card are allotted to each of the above control quantities, beginning in column 1, except for the last name, LIN, which occupies only three columns.

Example:

```
Column  1     6     11    16
        ↓     ↓     ↓     ↓
        15.23 03.00 GREV* LIN
```

---

*A name for the model that determines the use of the coefficients coming from the experimental data being used. This name should always appear starting in Column 11.

As opposed to numerics, the names must be left-justified in their allotted fields.

Card 2 specifies three quantities that control treatment of continuous absorption by FAKIR: the first control is one letter--either an H or an A--which specifies whether or not continuous absorption is to be due to H_2O (H stands for H_2O and 3.0 millimeters has been selected as the amount of precipitable water as the source of continuous absorption and should always be used with the current experimental data). The next control is the coefficient of continuous absorption for the choice made in the first control. For H_2O as the cause of continuous absorption, this coefficient should be 0.01075; it should be 0.06 if H_2O is not the cause. The third control has two alternatives: either blank cards or the word NOT in the last three columns of the card. If NOT is used, continuous absorption will be ignored. Generally do not ignore it (i.e., do not put NOT).

Example:

```
Column  1        10
        ↓        ↓
        H  0.01075
```

This, in fact, is the card that should generally be used; but the choice may be subject to reconsideration for scans that took place during times when the amounts of precipitable water were exceedingly low.

Card group 3 contains the experimental data which supply the coefficients for the various small-step models (2). These cards have already been prepared and should simply be inserted as a group at this point. (Always check to be sure that the last of these cards has a 1 in column 80 to signal the end of this group.)

Card group 4 - Instrumental transmittance. This is the tabular form of the spectral transmittance of the filter and window mentioned in Chapter 4. Again, this is a pre-generated group of cards which should match the radiance table (above) in its identification; at present, this includes only wide-band, narrow-band, and rectangular.

Card group 5 - Temperature list. This list specifies a convenient set of temperatures within the working range at which FAKIR will compute the tabular coefficients of $\bar{\tau}_A$. All other values of the coefficients in steps of 1°K are then picked up by linear interpolation in the set of "exact" values at the temperatures in the present list.

The present pre-generated cards for this list are adequate, but if a change is ever desired, punch ten temperatures per card separated by blanks--free field--using as many cards as desired, and end the list with a negative temperature.

Card 6 - Extrapolation card (for BREW). This card selects an extrapolation between the experimental data and the CO_2 theoretical data. Six fields are present on this card. The first is a ten-column field starting in column 21 which specifies the beginning of the IR-region (expressed in microns) in which an extrapolation will be made from preceding data; this field is in decimals. The next field is alphabetic and either contains the word EQUAL in columns 31-35 or is left blank. If the word EQUAL does appear, the extrapolation will be made to the wavelength at which the amount of CO_2 absorption becomes comparable with that attributed to H_2O in the region from which the extrapolation is made, or to the upper limit on the region in which extrapolation is made (this is entered in the next field). If EQUAL does not appear, extrapolation will be made to the upper limit punched in the next field, which is again decimal and occupies card columns 41-50. Here is entered the upper limit of the IR-region in which extrapolation is necessary (because of lack of experimental data). The next field occupies card columns 51-60 (always inclusive) and gives in microns the lower limit of the IR-region from which the extrapolation is to be made. The fifth field occupies columns 61-70 and gives the upper limit of the IR-region from which the mean is extrapolated. The final field, columns 79 and 80, contains either the word NO or blanks. If the word NO is present, no extrapolation is performed.

Example:

```
Column   21--------30   31---35   41---------50
                    ↓         ↓                ↓
               12.543     EQUAL          14.100

         51--------60   61---------70   79-80
                    ↓               ↓    ↓  ↓
               12.000          12.500    N  O
                                           or
                                         BLANKS
```

Here an extrapolation is made in the range 12.543 to 14.100 microns or to the wavelength at which the amount of CO_2 is comparable with that of H_2O; the extrapolation is made from the available data in the IR-range 12.0 to 12.5 microns. This card is pre-generated and all data are right justified.

f) Calibration Constant K(t) cards

These cards contain a table of the calibration constant, K(t), as a function of universal time. Values of K(t) are expressed in units of watts per millimeter of the deflection trace. Values for the whole time range covered by the scan are batched together in one run: specifically, a value for the calibration constant for a time earlier than the earliest time a data-point was recorded in the first scan, and a value at a time later than the latest data-point in the last scan should be entered, along with their associated times according to the format specified. Handling discontinuous changes in K(t) may be ignored as long as the bucking-signal and zero-suppression remain the only means by which the output level of the deflection trace can be changed by discrete amounts. However, the CHANGE card containing the time greater than any of the data-point times embodied in the scans must be present.

Format

Format	Entry	Columns
A6	Card Type	1-6
I3	Day	7-9
I3	Hour	10-12
I3	Minutes	13-15
F6.2	Seconds	16-21
E10.4	K(t)	22-31

Card Type

(1) The first card cannot be a CHANGE card and will have blanks in columns 1-6.

(2) On every card representing data recorded at the time of a discrete change of the gain setting, the word CHANGE should be entered in columns 1-6.

(3) After the last data card in the deck, a card with only the word FINALI in columns 1-6 should be included.

(4) The card immediately preceding a FINALI card must be a CHANGE card with a time greater than any preceding time.

Example:

Column	1	6	89	11	12	14	15	17	18	19	20	21
	↓	↓	↓↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	CHANGE or FINALI or BLANKS		18	1	3	3	1	1	9	.	2	5

23	24	25	26	27	28	29	30	31
↓	↓	↓	↓	↓	↓	↓	↓	↓
.	0	8	3	4	1	E	-	9

4. SCAN CARDS

There are six different card types under this group. They are:

a) Heading cards

b) Picture cards

c) SCAN or DRIFT cards

d) Data cards

e) 000 cards

f) Scan ending cards

They are arranged as follows:

a) Heading Card: This card is generated by the digitizer and contains the deflection and time (hour, minute, and second) counts at the beginning and the end of each scan.

Format (free field format of 150):

No. of Field	SCAN	1	XLO	2	990*	H	M	S	1	XHI	2	990*	H	M	S
	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

b) Picture Cards: One or more picture cards relating to the same scan as the heading card are grouped together. The orthographic lunar coordinates XI and ETA and the identifying picture frame number are all punched on these cards. Free field format of 8G is used:

No. of Field	Scan	1	XLO	2	990*	No. of Frame	XI	ETA
	↓	↓	↓	↓	↓	↓	↓	↓
	1	2	3	4	5	6	7	8

A scan usually has more than one heading card; a) and b) are then repeated from here for the whole scan.

---

*990 distinguishes these cards from the data cards.

c) SCAN or DRIFT Card: This card has a 0 (zero) punched in column 2. The rest of the card may be blank or may contain an indication of the scanning mode, beginning in or after column 7; the mode is indicated by the word SCAN if the telescope is moving during the scan, or the word DRIFT if a drift curve is taken with the telescope fixed.

d) DATA Cards: All the data cards of a given scan are grouped together but subgroups are subdivided by 000 cards.

e) 000 Card: A card with 000 punched at columns 1-3 separates each sub-group of data cards that are under different heading cards. (Hence, the number of 000 cards of a scan is always one less than the number of heading cards.)

f) Scan Ending Card: This card has 0 (zero) punched in columns 2, 4, 6, and 8. It signals the end of one scan and the beginning of the next scan. It may be omitted if only one scan is being processed.

NEXT SCAN: At this point the SCAN CARDS of Section 4 may be repeated for the next scan. The number of scans that can be processed in a run should all be under the same DATE CARD and the constant cards of Sections 2 and 3. However, the number of scans that can be processed using bucking signal and zero suppression is limited to twenty.

5. END OF RUN CARD

This card has 0 (zero) punched in column 2 and the word FIN on columns 4, 5, and 6. It immediately precedes the END OF FILE card.

APPENDIX B

PROGRAM LISTING

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CMAIN PROGRAM LUNAR TO COMPUTE TEMPERATURE DISTRIBUTION ON MOONS SURFACE
C     LUNAR SUPERVISES SUBROUTINES MOON3,COEFI2 AND TEMPR2
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH20,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20)
      DIMENSION Y11(200),U1(200),C(200)
      DIMENSION CT(20),TI(20,20),GN(20,20),NK(20)
      DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
      DIMENSION LIST(21),XLIST(21),REMARK(12),NRPS(20) ,TEST(2)
      DIMENSION TIME1(90),XLO(90),YZERO(90),SLOPE(90),RATE(90),XHI(90)
      DIMENSION BUFR(15,133),LBUFR(15,133)
      EQUIVALENCE(BUFR,LBUFR)
      EQUIVALENCE(LIST,XLIST)
C     NTAP=LOGICAL TAPE NUMBER FOR TAMPORARY SCRATCH USE
      NTAP=4
      NTP1=9
      NTP2=10
      BLANK=1H
      CENTER=6HCENTER
      SUBSOL=6HSUBSOL
      ERASE KD,CSW
      ERASE NSCAN,IH,NDPS,NRT,NDT
      ERASE BUFR
      NSC=1
C     READ DATE CARD.  NRL IS THE NO. OF PHYSICAL RECORDS LEFT ON TAPE
C     FROM LAST RUN.  PUNCH 0 FOR NRL IF TO START A NEW TAPE
      READ INPUT TAPE5,1,IYR,AMON,IDAY,NRL
    1 FORMAT (1G,A3,2G)
      WRITE OUTPUT TAPE6,99,IYR,AMON,IDAY
   99 FORMAT(1H1,I4,1XA3,I3,26X-LUNAR SCAN PROCESSING-)
      DAY=IDAY
      ERASE KEY
C     KEY IS THE SWITCH FOR DIFFERENT ENTRY POINTS OF SUBROUTINES.
C     READ PLACE + REFRACTION CARDS + EPHEMERIS TABLES BY MOON3
      CALL MOON3 (IYR,AMON,DAY,TSEC,KEY,SPOT,XI,ETA,AIR,ALTOBS,NFRAME,
     1ALTSOL,AZOUT,PHASE,NSCAN,EDGE,DATUM)
C     READ 6 GROUPS OF CONTROL CARDS BY CALLING TEMPR
      CALL TEMPR2 (NTAP,IP1,NPB,NPZ,DAY,KEY,TEMP,NTP1,BUFR,LBUFR,
     1IYR,AMON,IDAY)
      KEY=1
C     READ HEADING CARDS AND PICTURE CARDS OF ONE WHOLE SCAN.
   10 READ INPUT TAPE5,2,(LIST(I),I=1,9)
    2 FORMAT(8G,A6)
      IF(LIST-NSCAN)100,270,100
C     SET UP FOR EACH HEADING CARD
  100 IF (LIST) 3, 30,168
  168 NSCAN=LIST
  169 READINPUTTAPE99,7,(LIST(I),I=1,15)
    7 FORMAT (15G)
  170 IH=IH+1
C     IH IS THE COUNT OF HEADING CARDS
      IF(LIST(10)-LIST(3))3,3,101
    3 CALL REREAD
      READ INPUT TAPE5,4,REMARK
    4 FORMAT(12A6)
```

```
      WRITE OUTPUT TAPE6,5,REMARK
    5 FORMAT(1H0,12A6,6X23HCARD ERROR OR MISPLACED)
      CALL EXIT
  101 IF(LIST(2)-1)3,103,3
  103 IF(LIST(4)-2)3,104,3
  104 IF(LIST(11)-2)3,105,3
  105 DO106 J=3,15
  106 CALL UNFIX(XLIST(J))
      TIME1(IH)=XLIST(6)*3600.+XLIST(7)*60.+XLIST(8)
      TIME2=XLIST(13)*3600.+XLIST(14)*60.+XLIST(15)
      XLO(IH)=XLIST(3)
      XHI(IH)=XLIST(10)
      YZERO(IH)=XLIST(5)
      YONE=XLIST(12)
      SLOPE(IH)=(YONE-YZERO(IH))/(XHI(IH)-XLO(IH))
  110 RATE(IH)=(TIME2-TIME1(IH))/(XHI(IH)-XLO(IH))
C     RATE IS IN SECONDS PER COUNT.
      IF(RATE(IH))3,3,10
C
B 270 IF(XLIST(9)/BLANK)271,273,271
B 271 IF(XLIST(9)/CENTER) 272,274,272
B 272 IF(XLIST(9)/SUBSOL) 169,275,169
  273 ERASE SPOT
      GO TO 200
  274 SPOT=-1.
      GO TO 200
  275 SPOT=+1.
  200 IF(LIST(2)-1)3,201,3
  201 IF(LIST(4)-2)3,202,3
  202 IF(LIST(5)-700)3,3,203
  203 X=XLIST(3)
      CALL UNFIX(X)
C     TO CHECK IF X IS IN BETWEEN XLO AND XHI
      IF((X-XLO(IH))*(XHI(IH)-X)) 3,204,204
  204 TSEC=TIME1(IH)+RATE(IH)*(X-XLO(IH))
      NFRAME=LIST(6)
      XI=LIST(7)
      ETA=LIST(8)
C
C     PROCESS THE OBSERVED PICTURE CARDS BY MOON3
      CALL MOON3 (IYR,AMON,DAY,TSEC,KEY,SPOT,XI,ETA,AIR,ALTOBS,NFRAME,
     1ALTSOL,AZOUT,PHASE,NSCAN,EDGE,DATUM)
      GO TO 10
C     NOW TO CHECK IF IT IS A DRIFT CARD OR NOT
   30 KEY=2
      CALL REREAD
      CALL MOON3 (IYR,AMON,DAY,TSEC,KEY,SPOT,XI,ETA,AIR,ALTOBS,NFRAME,
     1ALTSOL,AZOUT,PHASE,NSCAN,EDGE,DATUM)
      NH=IH
C     NH=NUMBER OF HEAD CARDS OF ONE SCAN
C
C     NOW READ DATA CARDS OF WHOLE SCAN
      IH=1
      KEY=3
   40 READ INPUT TAPE5,6,LIST
    6 FORMAT (21G)
      IF (LIST-NSCAN) 120,370,120
  370 ITEM=2
```

```
      IF (LIST(ITEM)-1)3,380,3
  380 IF(LIST(ITEM+2)-2)3,400,3
C     NDPS=NUMBER OF DATA PER SCAN
  400 NDPS=NDPS+1
  402 IF(LIST(ITEM+3)-700)403,3,3
C     Y READING ABOVE 700 IS A MIXED POINT CARD
  403 X=XLIST(ITEM+1)
      CALL UNFIX(X)
      IF((X-XLO(IH))*(XHI(IH)-X)) 3,404,404
  404 TSEC=TIME1(IH)+RATE(IH)*(X-XLO(IH))
      Y=XLIST(ITEM+3)
      CALL UNFIX(Y)
      Y=Y-(YZERO(IH)+SLOPE(IH)*(X-XLO(IH)))+1000.
      DATUM=Y
C
      CALL MOON3 (IYR,AMON,DAY,TSEC,KEY,SPOT,XI,ETA,AIR,ALTOBS,NFRAME,
     1ALTSOL,AZOUT,PHASE,NSCAN,EDGE,DATUM)
C
      CALL COEFI2 (NTAP,IP1,NPB,NPZ,DAY,TSEC,KEY,EDGE,DATUM,KD,CSW,LSCAN
     1)
C
      WRITE TAPE NTAP,TSEC,XI,ETA,AIR,ALTOBS,ALTSOL,AZOUT,PHASE,NSCAN,
     1EDGE,DATUM,KD
      IF(ITEM-18)405,40,40
  405 ITEM=ITEM+4
      IF(LIST(ITEM)-1)40,406,40
  406 IF(LIST(ITEM+2)-2)40,400,40
C
  120 CALL REREAD
      READ INPUT TAPE 5,8,TEST
    8 FORMAT (2A3)
      HCARD=3H000
B     IF(TEST/HCARD)60,50,60
C     000 CARD KEEPS THE COUNT OF HEADING CARDS
   50 IH=IH+1
      IF(IH-NH)40,40,3
   60 KEY=1
      FIN=3HFIN
      CSCAN=3H0 0
C     TO CALCULATE NUMBER OF PHYSICAL RECORDS NEEDED PER SCAN.  EACH
C     RECORD CONTAINS 1995 WORDS AND EACH MEASURED DATA GENERATE 15
C     WORDS OUTPUT.  HENCE EACH RECORD WILL ACCOMONDATE INFORMATIONS
C     FROM 133 DATA POINTS.  NO RECORD WILL HAVE INFORMATION FROM
C     DIFFERENT SCANS
C     NRPS=NUMBER OF RECORD NEEDED PER SCAN
      IF (XMODF (NDPS,133)) 71,70,71
   70 NRPS(NSC)=NDPS/133
      GO TO 72
   71 NRPS(NSC)=(NDPS/133)+1
   72 NDT=NDT+NDPS
B     IF(TEST(2)/FIN) 69,80,69
B  69 IF(TEST(2)/CSCAN)3,73,3
C     PREPARE FOR NEXT SCAN
   73 ERASE NSCAN,IH,NDPS
      NSC=NSC+1
      GO TO 10
C
C     START TO PROCESS FIN CARD
```

```
   80 CONTINUE
      CALL COEFI2 (NTAP,IP1,NPB,NPZ,DAY,TSEC,KEY,EDGE,DATUM,KD,CSW,NSCAN
     1)
      DO 81   I=1,NSC
   81 NRT=NRT+NRPS(I)
C     NRT=TOTAL PHYSICAL RECORD NEEDED FOR THIS RUN
C     TO PREPARE FOR OUTPUT
      NRL=NRL-NRT
      IF (NRL)501,502,502
C     TO START WITH A NEW TAPE
C     EACH 2200 FEET TAPE WILL HAVE 1680 PHYSICAL RECORDS
C     CALL COPY LATER
  501 REWIND NTP1
      NRL=NRL+1680
      GO TO 503
  502 REWIND NTP1,NTP2
C     FOLLOWING IS THE DATE OF THE LAST DATA OF THIS RUN
  503 NDAY=DAY+TSEC/86400.
      NHOUR=MODF(TSEC/3600.,24.)
      NMIN=MODF(TSEC/60.,60.)
      SEC=MODF(TSEC,60.)
      WRITE OUTPUTTAPE 6,82,IYR,AMON,NDAY,NHOUR,NMIN,SEC,NSC,NDT ,NRT,
     1NRL
   82 FORMAT(39H0LUNAR TEMPERATURE MEASUREMENTS ENDING ,I4,1X,A3,I3,I3,
     15H HOUR,I3,4H MIN,F6.2,5H SEC,/7H COVER ,I2,6H SCANS,I5,27H DATA P
     2OINTS.  FOR THIS RUN,I3,29H PHYSICAL RECORDS ARE NEEDED./30H AFTER
     3 THIS RUN THERE WILL BE ,I4,34H PHYSICAL RECORDS LEFT ON THE TAPE)
      WRITE TAPE NTAP,LIST
      END FILE NTAP
      REWIND NTAP
      CALL TEMPR2 (NTAP,IP1,NPB,NPZ,DAY,KEY,TEMP,NTP1,BUFR,LBUFR,
     1IYR,AMON,IDAY)
      CALL EXIT
      END
```

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CTEMPR2
C     SUBROUTINE TEMPR2 TO COMPUTE TEMPERATURE DISTRIBUTION OF MOON SUR-
C     FACE. REVISED FROM TEMPR,JAN.1966 BY Y.C.HU
      SUBROUTINE TEMPR2 (NTAP,IP1,NPB,NPZ,DAY,KEY,TEMP,NTP1,BUFR,LBUFR,
     1IYR,AMON,IDAY)
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH2O,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20)
      DIMENSION Y11(200),U1(200),C(200)
      DIMENSION CT(20),TI(20,20),GN(20,20),NK(20)
      DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
      DIMENSION CST(3,340),F(340),S(340)
      DIMENSION BUFR(15,133),LBUFR(15,133)
      IF (KEY)  9999,5100,5200
C     NTEM=NUMBER OF TEMPERATURES
 5100 NTEM=324
      R=2.502E-5
C     TO=INITIAL TEMPERATURE-1
      TO=85.0
      AMICRO=1.0E-6
C     NTAP=LOGICAL TAPE NUMBER FOR TEMPORARY SCRATCH USE
      ERASE BUCK,ZERO
      ZER=3HZER
      BUC=3HBUC
C     READ BUCKING SIGNAL CONSTANT IN COUNTS/MILLIMETER
      READ INPUT TAPE 5,1024,BSCON
 1024 FORMAT(10X,F12.6)
      N=1
      NPB=7
C     READ IN TABLE OF BUCKING SIGNALS
 1019 READ INPUT TAPE 5,1020,TYPE,(NSB(I),BUCK(I),I=N,NPB)
 1020 FORMAT(A3,3X,7(I3,1X,F5.1,1X))
      N=N+7
      NPB=NPB+7
B     IF(BUC/TYPE)1021,1019,1021
 1021 IF(NSB(NPB)) 1011,1012,1011
 1012 IF(NPB-1) 1013,1011,1013
 1013 NPB=NPB-1
      GO TO 1021
 1011 N=1
      NPZ=7
C     READ IN TABLE OF ZERO SUPPRESSION VALUES
 1022 READ INPUT TAPE 5,1020,TYPE,(NSZ(I),ZERO(I),I=N,NPZ)
      N=N+7
      NPZ=NPZ+7
B     IF(ZER/TYPE)1023,1022,1023
 1023 IF(NSZ(NPZ)) 1014,1015,1014
 1015 IF(NPZ-1) 1016,1014,1016
 1016 NPZ=NPZ-1
      GO TO 1023
 1014 ERASE SLAST
C     READ RADIANCES FROM PRE-COMPUTED TABLES
      READ INPUT TAPE5,1,(S(I),I=1,NTEM)
 1    FORMAT(6F13.6)
      CALL FAKIR(S,CST,TO,NTEM)
```

```
      NTEM=NTEM
      NTMI1=NTEM-1
C     READ IN THE ARRAY OF GAIN COEFFICIENTS
      CALL GAIN(IP1)
 9999 RETURN
C
 5200 REWIND NTAP
      IP1=IP1+1
      I=1
      OFF=3HOFF
      ERASE SAVE
      ERASE KOUNT,L,N,BUFR
      M=134
  111 READ  TAPE NTAP,TSEC,XI,ETA,AIR,ALTOBS, ALTSOL,AZOUT,PHASE,NSCAN,
     1EDGE,DATUM,KD
      NDAY=DAY+TSEC/86400.
      NHOUR=MODF(TSEC/3600.,24.)
      NMIN=MODF(TSEC/60.,60.)
      SEC=MODF(TSEC,60.)
B 112 IF (OFF/EDGE)113,637,113
  113 UT=DAY+TSEC/86400.
      YP=C(KD)*(TSEC-U1(KD))+Y11(KD)
C     YB=VALUE OF Y AFTER THE LINEAR ADDITION IS MADE
      YB=(DATUM-YP)
C     GENERATE THE FUNCTION F FOR EVERY TEMPERATURE AT THE GIVEN TIME
      IF(AIR-SLAST)200,4999,200
  200 DO 201 K=1,NTEM
 201  F(K)=R*S(K)*EXPF(-CST(3,K)*AIR**(CST(1,K)*LOG10F(AIR)+CST(2,K)))*
     1AMICRO
C     MICRO SCALES RADIANCES,S, TO WATTS PER CM**2 RATHER THAN MICROWATS
      SLAST = AIR
 4999 SIGNAL=YB*GT(UT,IP1)
C
      DO 8000 K=1,NTEM
 8000 F(K)=F(K)+SAVE-SIGNAL
      SAVE=SIGNAL
      SENSE LIGHT 0
C     DETERMINE SIGN CHANGE OF F
      DO 2000 K=1,NTMI1
      IF (F(K)*F(K+1))30,32,2000
   30 IF (SENSE LIGHT 2)35,34
   35 WRITE OUTPUT TAPE 6,7001,UT
 7001 FORMAT (26H0ADDITIONAL ZERO FOR TIME=F10.6)
      SENSE LIGHT 2
      GO TO 2000
C     DETERMINE THE TEMPERATURE BY INVERTING F
   34 TL=F(K)
      TR=F(K+1)
      TK1=K
      SENSE LIGHT 1
      SENSE LIGHT 2
 2000 CONTINUE
C
      IF (SENSE LIGHT 1)45,637
  637 TEMP=-0.
      GO TO 2005
C
   45 XL=TK1+TO
```

```
      XR=XL+1.0
C     INVERT F BY USING GENERAL FORMULA FOR REGULA FALSI
      TEMP=((XR*TL)-(XL*TR))/(TL-TR)
      GO TO 2005
C
C     TEMP=TEMPERATURE FOR TIME UT
   32 IF(F(K))824,824,823
  823 TEMP=K+1
      TEMP=TEMP+TO
      GO TO 2005
C
 824  TEMP=FLOATF(K)+TO
 2005 IF (TSEC)308,308,301
  301 KOUNT=KOUNT+1
      L=L+1
      M=M-1
      IF(KOUNT-1)302,302,303
  302 N=NSCAN
C     WRITE PAGE HEADING
      WRITE OUTPUT TAPE6,888,NSCAN,AMON,IDAY,IYR,IYR,AMON
  888 FORMAT(1H1,10X,47HEPHEMERIS AND TEMPERATURE DATA OF LUNAR SURFACE,
     124X,4HSCAN,I5,6X,A3,I3,I5//
     25X,11HSCAN  DATA ,I4,1XA3,7H       ,23X,55HAIR   ELEVATION OF  EAR
     3TH AZH. PHASE        TEMPERATURE /
     46X,101HNO.   NO.  D  H  M  SEC        XI        ETA       MASS    EART
     5H  SUN    FROM SUN   ANGLE        DEGREE K /)
  303 IF(N-NSCAN)304,305,304
  304 ERASE KOUNT,L
      M=134
C     CALL WRITE LATER
      GO TO 301
  305 IF(L-55)307,307,306
C     TITLE FOR EACH PAGE OF PRINTED OUTPUT
  306 WRITE OUTPUT TAPE6,888,NSCAN,AMON,DAY,IYR,IYR,AMON
      ERASE L
  307 WRITE OUTPUT TAPE6,999,NSCAN,KOUNT,NDAY,NHOUR,NMIN,SEC,XI,ETA,AIR,
     1ALTOBS,ALTSOL,AZOUT,PHASE,EDGE,TEMP
  999 FORMAT  (4X2I5,1X3I3,F6.2,1X2F9.4,F9.3,2X,2F6.1,2F9.1,3X,A3,F9.2)
C     STORE OUTPUT IN BUFFER AND THEN TRANSFER TO TAPE
C     EACH DATA GENERATES 15 WORDS OUTPUT.   EACH PHYSICAL RECORD WILL
C     HAVE 1995 WORDS OUTPUT OF 133 DATA POINTS.
      LBUFR(15,M)=NSCAN
      LBUFR(14,M)=KOUNT
      LBUFR(13,M)=DAY
      LBUFR(12,M)=NHOUR
      LBUFR(11,M)=NMIN
      BUFR(10,M)=SEC
      BUFR(9,M)=XI
      BUFR(8,M)=ETA
      BUFR(7,M)=AIR
      BUFR(6,M)=ALTOBS
      BUFR(5,M)=ALTSOL
      BUFR(4,M)=AZOUT
      BUFR(3,M)=PHASE
      BUFR(2,M)=EDGE
      BUFR(1,M)=TEMP
      IF (M-1)308,308,111
  308 CONTINUE
```

```
C       CALL WRITE LATER
        M=134
        GO TO 111
        END
```

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CMOON3 REVISED TO BE SUBROUTINE OF LUNAR.  JAN.1966 BY Y.C.HU
C      PROGRAM FOR LUNAR COORDINATES WITH DIFFERENTIAL REFRACTION.
C
      SUBROUTINE MOON3 (IYR,AMON,DAY,TSEC,KEY,SPOT,XI,ETA,AIR,ALTOBS,
     1NFRAME,ALTSOL,AZOUT,PHASE,NSCAN,EDGE,DATUM)
      DIMENSION ALPHA(500),DELTA(500),TSUBB(500),S(50),PIE(50),TSUBA(50)
     X,DECODE(7),RECORD(20),TSUBC(25),EL(25),BE(25),COLONG(25),SLAT(25),
     XC(25),TIME(90),XIOBS(90),ETAOBS(90),DELTAT(1),TOPDEC(90),HAT(90)
      DIMENSION T(90),H(90),D(90),FRAME(90)
      EQUIVALENCE(YEARA,IYEARA)
C      TSUBA IS ARGUMENT FOR S, PIE
C      TSUBB IS ARGUMENT FOR ALPHA,DELTA
C      TSUBC IS ARGUMENT FOR PHYSICAL EPHEMERIS
C
C
C      ORDER INPUT PARAMETERS AS FOLLOWS.....
C
C      FIRST TABLES   MOON FOR 0 AND 12 HOURS  E.T.
C      FORMAT -- YEAR,MON,DATE,SEMIDIAMETER,PARALLAX.
C
C      SECOND TABLES     HOURLY EPHEMERIS.
C      FORMAT -- YEAR,MON,DAY,HOUR,ALPHA,DELTA
C
C      THIRD TABLES     PHYSICAL EPHEREMIS
C      FORMAT -- YEAR,MON,DAY,EARTH-S LONG.+LAT.,SUN-S COLONG.+LAT.,P.A.
C
C      THEN SCAN DATA.....
C      YEAR,MON,DAY,HOUR,MIN,SEC(U.T.),XI,ETA,SCAN NO., FRAME NO.
C
      DATA DECODE(36HPLACE REFRACTABLEATABLEBTABLEC      ),DELTAT(35.)
C      PLACE    = STATION COORDINATES.
C     REFRACTION  = WAVELENGTHS FOR DISPERSION.
C     TABLEA   = SEMIDIAMETER AND HORIZONTAL PARALLAX DATA.
C     TABLEB   = GEOCENTRIC LUNAR COORDINATES.
C     TABLEC   = PHYSICAL EPHEMERIS.
C      POINT    = PHOTOGRAPHIC LOCATION CARD.
C      BLANK CARD SIGNALS END OF SCAN.
C      DELTAT IS E.T.-U.T.(SECONDS).
      DIMENSION SCALE(60)
      DATA SCALE(360H-10SEC                -9 SEC                -8 SEC
     X   -7 SEC                -6 SEC                -5 SEC                -4 SEC
     X         -3 SEC                -2 SEC                -1 SEC           -0 SEC+0
     XSEC      +1 SEC                +2 SEC                +3 SEC                +4
     XSEC            +5 SEC                +6 SEC                +7 SEC
     X   +8 SEC                +9 SEC                +10SEC)
C     PLUS AND MINUS 10 SECONDS FOR GRAPH.
      IF(KEY-1) 1601,400,1602
 1602 IF(KEY-2) 400,500,562
 1601 SECTP=4.85E-5
      SECTM=-SECTP
      CALL SET(39,X)
      ERASE XMON,NTBL,NOBS ,DNM1
      PIHLF=1.5707963
      TWOPI=4.*PIHLF
      DEGRAD=57.2957795
```

```
      PARSEC=DEGRAD*3600.
      RALPH=DEGRAD*240.
C      --- RALPH CONVERTS SECONDS OF TIME TO RADIANS)
      WRITEOUTPUTTAPE6,9
9     FORMAT(27H0LUNAR EPHEMERIS INPUT DATA)
C
10    READ INPUTTAPE5,5,CODE
5     FORMAT(12A6)
20    DO 1  I=1,6
1000  IF(CODE-DECODE(I))1,2,1
2     CALL REREAD
      GO TO(600,700,100,200,300,9000), I
1     CONTINUE
      WRITEOUTPUTTAPE6,4,CODE
4     FORMAT(15H0ILLEGAL CODE (A6,1H))
3     CALL REREAD
      READINPUTTAPE5,5,(RECORD(I),I=1,12)
      WRITEOUTPUTTAPE6,6,(RECORD(I),I=1,12)
6     FORMAT(16H0DATA CARD ERROR/1H0,12A6)
      CALL EXIT
C      STOP IF BAD DATA.
C
C     READ PLACE DATA.
C
600   READ INPUT TAPE 5,601,PLACE1,PLACE2,(RECORD(I),I=1,7)
601   FORMAT(6X,2A6,7G)
C      (PLACE) IS FOLLOWED BY STATION NAME (12 SPACES), LONGITUDE WEST
C         IN TIME UNITS, LATITUDE, HEIGHT IN METERS.
      DO 602  I=1,7
602   CALL UNFIX(RECORD(I))
      HEIGHT=RECORD(7)
      FREQUENCY608(1,0,0),609(1,0,0)
608   IF(ABSF(RECORD(4))-90.)609,3,3
609   IF(ABSF(RECORD(1))-24.)610,3,3
610   K=4
      DO 611 I=1,4
      N=K/2
      FREQUENCY 607(0,0,1)
607   IF(RECORD(N)*(60.-RECORD(N)))3,612,612
612   K=K+3
C      N=2,3,5,6
611   CONTINUE
      WLONG=(RECORD(1)*3600.+(RECORD(2)*60.+RECORD(3)))/RALPH
      PHI=(RECORD(4)*3600.+(SIGNF(RECORD(5),RECORD(4))*60.+SIGNF(RECORD(
     X6),RECORD(4))))/PARSEC
C      PHI IS ASTRONOMICAL LATITUDE.
      SINPHI=SINF(PHI)
      COSPHI=COSF(PHI)
      IH=RECORD(1)
      IM=RECORD(2)
      ID=RECORD(4)
      IDM=RECORD(5)
      WRITEOUTPUTTAPE6,603,PLACE1,PLACE2,IH,IM,RECORD(3),ID,IDM,RECORD(6
     X),RECORD(7)
603   FORMAT(1H0,2A6/10H0  H  M  S/2I3,F6.2,12H W.LONGITUDE/1H0,2I3,F5.1
     X,9H LATITUDE/19H0ELEVATION (METERS)F6.0)
      HELP=SQRTF(1.-.00672267*SINPHI**2)/(1.+1.567794E-7*RECORD(7))
      RHOCOS=COSPHI/HELP
```

```
      RHOSIN=SINPHI*.99327732/HELP
C      ELEVATION CORRECTION IS APPROXIMATE BUT CLOSE ENOUGH.
C      ERROR IS BELOW 1 ARCSEC FOR H BELOW 10 KM.
      GO TO 10
C
C     READ REFRACTION WAVELENGTHS.
C
700   READINPUTTAPE5,701,PGL,SIGL
701   FORMAT(2G)
C     -REFRACTION- IS FOLLOWED BY PHOTOGRAPHIC AND DETECTOR
C             EFFECTIVE WAVELENGTHS (ANGSTROMS OR MICRONS).
      CALL UNFIX(PGL)
      CALL UNFIX(SIGL)
      IF(PGL-1000.)702,702,703
703   PGL=PGL/10000.
C     CONVERT TO MICRONS IF IN ANGSTROMS.
702   IF(SIGL-1000.)704,704,705
705   SIGL=SIGL/10000.
704   PIGL=1./PGL**2
      SIGLL=1./SIGL**2
C     USE EDLEN FORMULA.
      DNM1=2.94981E-2*(1./(146.-PIGL)-1./(146.-SIGLL))+2.554E-4*(1./(41.
     X-PIGL)-1./(41.-SIGLL))
      DNM1=DNM1*EXPF(-HEIGHT/8000.)
C     ASSUME 8 KM SCALE HEIGHT.
      PIGL=DNM1*PARSEC
      WRITEOUTPUTTAPE6,710,PGL,SIGL,PIGL
710   FORMAT(1H0/24H0PHOTOGRAPHIC WAVELENGTH F6.3,21H  DETECTOR WAVELENG
     1TH F7.3,26H   DIFFERENTIAL REFRACTION F5.1,7H ARCSEC)
      GO TO 10
C
C      TABLE A DATA -- DISTANCE DATA.
C
100   NSUBA=NSUBA+1
      FREQUENCY 151(1,0,0)
151   IF(NSUBA-50)150,150,10
150   READ INPUTTAPE5,99,(RECORD(I),I=1,7)
99    FORMAT(1G,A3,19G)
      YEARA=RECORD
      FREQUENCY 152(0,1,0)
152   IF(XMON-RECORD(2))50,101,50
50    ERASE NSUBA,NSUBB,NSUBC
      XMON=RECORD(2)
      GO TO 20
      FREQUENCY 101(0,5,1)
101   IF(NTBL-1)102,103,102
102   WRITEOUTPUTTAPE6,104,YEARA,XMON
104   FORMAT(17H3RADIAL EPHEMERIS/1H0,I4,1X,A4,5X12HSEMIDIAMETER5X8HPARA
     XLLAX/1X)
      NTBL=1
103   DO 106 I=3,7,2
106   CALL UNFIX(RECORD(I))
      WRITEOUTPUTTAPE6,105,(RECORD(I),I=3,7)
105   FORMAT(F10.1,I8,F7.2,I9,F8.3)
      CALL UNFIX(RECORD(4))
      CALL UNFIX(RECORD(6))
      S(NSUBA)=(60.*RECORD(4)+RECORD(5))/PARSEC
      PIE(NSUBA)=(60.*RECORD(6)+RECORD(7))/PARSEC
```

```
      TSUBA(NSUBA)=RECORD(3)
C       ***** TABLE A ROW DONE. *****
      GO TO 10
C       TABLE B -- LUNAR POSITION EPHEMERIS.
C
200   NSUBB=NSUBB+1
      FREQUENCY 251(1,0,0)
251   IF(NSUBB-500)250,250,10
250   READ INPUTTAPE5,99,(RECORD(I),I=1,10)
      YEARB=RECORD
      FREQUENCY252(0,1,0),201(1,10,1)
252   IF(XMON-RECORD(2))50,201,50
201   IF(NTBL-2)202,203,202
202   WRITEOUTPUTTAPE6,204,YEARB,XMON
204   FORMAT(//18H2ANGULAR EPHEMERIS/1H0I4,1XA4,2X4HHOUR,4X5HALPHA14X5HD
     XELTA/1X)
205   FORMAT(I9 ,I6,I5,I4,F8.3,I7,I4,F7.2)
      NTBL=2
203   WRITEOUTPUTTAPE6,205,(RECORD(I),I=3,10)
      DO 206 I=3,10
206   CALL UNFIX(RECORD(I))
      FREQUENCY 253(0,0,1)
253   IF(RECORD(5)*(24.-RECORD(5)))3,220,220
220   K=12
      DO 210  I=1,4
      N=K/2
C     TEST FOR RPOPER MINUTES AND SECONDS VALUES.
      FREQUENCY 254(0,0,1),211(1,0,0)
254   IF(RECORD(N))3,211,211
211   IF(RECORD(N)-60.)212,3,3
212   K=K+3
C     N=6,7,9,10
210   CONTINUE
      ALPHA(NSUBB)=((3600.*RECORD(5)+(RECORD(6))*60.+RECORD(7)))/RALPH
      DELTA(NSUBB)=((3600.*RECORD(8)+SIGNF(RECORD(9),RECORD(8))*60.)+
     XSIGNF(RECORD(10),RECORD(8)))/PARSEC
      TSUBB(NSUBB)=RECORD(3)+RECORD(4)/24.
C       ***** TABLE B ROW DONE. *****
      GO TO 10
C
C       READ PHYSICAL EPHEMERIS.
C
300   NSUBC=NSUBC+1
      FREQUENCY 351(1,0,0)
351   IF(NSUBC-25)350,350,10
350   READINPUTTAPE5,99,(RECORD(I),I=1,8)
      YEARC=RECORD
      FREQUENCY 352(0,1,0),301(1,5,0)
352   IF(XMON-RECORD(2))50,301,50
301   IF(NTBL-3)302,303,302
302   WRITEOUTPUTTAPE6,304,YEARC,XMON
304   FORMAT(//30H3GEOCENTRIC PHYSICAL EPHEMERIS/1H0I4,1XA6,53HEARTH-S S
     XELENOGRAPHIC   SUN-S SELENOGRAPHIC   P.A. OF/13X19HLONGITUDE  LATI
     XTUDE6X7HCOLONG.4X4HLAT.7X4HAXIS/1X)
305   FORMAT(I9,F11.2,F10.2,F15.2,F8.2,F12.2)
      NTBL=3
      DO 310  I=4,8
310   CALL UNFIX(RECORD(I))
```

```
303    WRITEOUTPUTTAPE6,305,(RECORD(I),I=3,8)
C      CONVERT ANGLES TO RADIANS AFTER RANGE CHECK.
       DO 311  I=4,8
353    IF(ABSF(RECORD(I))-360.)311,3,3
       FREQUENCY353(1,0,0)
311    RECORD(I)=RECORD(I)/DEGRAD
       FREQUENCY 354(0,0,1),312(0,0,1)
354    IF(RECORD(6))3,312,312
312    IF(RECORD(8))3,313,313
313    EL(NSUBC)=RECORD(4)
       BE(NSUBC)=RECORD(5)
       COLONG(NSUBC)=RECORD(6)
       SLAT(NSUBC)=RECORD(7)
       C(NSUBC)=RECORD(8)
       TSUBC(NSUBC)=FLOATF(RECORD(3))
       GO TO 10
C      *****PHYSICA EPHEMERIS NOW HAVE BEEN FINISHE READIND
9000   READ INPUT TAPE5,9001,BLANK
9001   FORMAT (A6)
       RETURN
C
C      400 SERIES PROCESS OBSERVED LUNAR POINT CARDS
C
400    IF(NOBS)3,420,902
C      ***********PLACE INCONSISTENCY TESTS HERE **************************
420    IF(YEARA-YEARB)430,401,430
401    IF(YEARB-YEARC)430,402,430
402    IF(IYR-IYEARA)430,403,430
430    WRITEOUTPUTTAPE6,431
431    FORMAT(38H3TABLES DO NOT REFER TO THE SAME YEAR.)
       GO TO 3
  403 IF(AMON-XMON)435,497,435
  435 WRITE OUTPUT TAPE6,436
436    FORMAT(27H4DATA REFER TO WRONG MONTH.)
       GO TO 3
  497 YEAR=FLOATF(YEARA)
      IDAY=DAY
      WRITE OUTPUT TAPE 6,421,NSCAN,IYR,AMON,IDAY
  421 FORMAT(20H1LUNAR SCAN GEOMETRY,26X,4HSCAN,I5,30XI4,1XA3,I3/
     X7X,18HU.T.          FRAME,18X,                           75HH
     XOUR ANGLE  DECLINATION    AIR     ELEVATION OF  EARTH AZIMUTH  PHA
     XSE  SCAN/21X,3HNO.6X2HXI5X3HETA30X4HMASS5X40HEARTH     SUN     FROM
     X SUN    ANGLE   NO./16H   D   H   M   S)
      ERASE NTBL
  902 IF(NOBS-90)404,1100,1100
1100   WRITEOUTPUTTAPE6,1101
1101   FORMAT(44H0TOO MANY DATA...  PROGRAM CONTINUES READING )
       RETURN
C      ********* ALL TIMES ARE DAYS AND DECIMALS.
C       *********  ALL ANGLES ARE RADIANS.
404    NOBS=NOBS+1
C      MAKE SURE XI AND ETA WERE SCALED
       CALL UNFIX(XI)
       CALL UNFIX(ETA)
       IF(ABSF(XI)-1.)446,445,445
  445 XI=XI/1000.
  446 IF(ABSF(ETA)-1.)448,447,447
  447 ETA=ETA/1000.
```

```
  448 FRAME(NOBS)=NFRAME
      XIOBS(NOBS)=XI
      ETAOBS(NOBS)=ETA
      UT=DAY+TSEC/86400.
      TIME(NOBS)=UT
      ET=DAY+(TSEC+DELTAT)/86400.
C
C      ARGUMENT OF TABLES A AND B IS E.T., ARG OF TABLE C IS U.T.
C
      TANGLE=6.2831853*MODF(UT,1.)
      AG=TABLE(ALPHA,TSUBB,ET,NSUBB)
      DG=TABLE(DELTA,TSUBB,ET,NSUBB)
      SINDG=SINF(DG)
      COSDG=COSF(DG)
      HOT=TANGLE*1.00273791-WLONG-AG
      JDAY=UT
      HAGDAY=JDAY
      HAG=SIDNEY(YEAR,XMON,HAGDAY)+HOT
C      --- SIDNEY GIVES SIDEREAL TIME OF 0 H U.T. IN RADIANS.
      SINHAG=SINF(HAG)
      COSHAG=COSF(HAG)
      COSZG=SINDG*SINPHI+COSDG*COSPHI*COSHAG
      FREQUENCY 1004(0,0,1)
 1004 IF(COSZG)410,411,411
 410  NOBS=NOBS-1
      WRITEOUTPUTTAPE6,412,PLACE1,PLACE2,(RECORD(I),I=1,6)
 412  FORMAT(22HOMOON BELOW HORIZON AT 2A6,I6,1X,A3,3F4.0,F5.1)
      GO TO 3
 411  SINZG=SQRTF(1.-COSZG**2)
      PIG=TABLE(PIE,TSUBA,ET,NSUBA)
      SPIG=SINF(PIG)
      SIGMA=PIG*SINZG*(1.+.0168*COSZG)
C      SIGMA IS TOPOCENTRIC PARALLAX.
      SINQ=SINHAG*COSPHI/SINZG
      COSQ=(SINPHI-COSZG*SINDG)/(COSDG*SINZG)
      Q=ARTNF(SINQ,COSQ)
      SEA=TABLE(C,TSUBC,UT,NSUBC)
      QMC=Q-SEA
      BEG=TABLE(BE,TSUBC,UT,NSUBC)
      DL=-SIGMA*SINF(QMC)/COSF(BEG)
      TOPLNG=TABLE(EL,TSUBC,UT,NSUBC)+DL
      TOPB=BEG+SIGMA*COSF(QMC)
C
C     TOPLNG AND TOPB ARE TOPOCENTRIC LIBRATIONS.
      CL=COSF(TOPLNG)
      SL=SINF(TOPLNG)
      CB=COSF(TOPB)
      SB=SINF(TOPB)
      TOPC=SEA+DL*SB-SIGMA*SINQ*SINDG/COSDG
C
C     TOPC IS TOPOCENTRIC POSITION ANGLE OF LUNAR POLE.
C
C      NOTE THAT I DEGREE OF LUNAR LONGITUDE OR LATITUDE = 15 ARCSEC ON
C     THE SKY.   0.1 LUNAR DEGREE = 1.5 SEC = .0016 IN LUNAR STANDARD
C     COORDINATES.   THUS .001 ON MOON IS ABOUT 1 ARCSEC OR 1 MILE.
C
C      USE N.A. AUXILIARY VARIABLES..... (EXP.SUPP., P.60)
      AX=COSDG*SINHAG
```

```
      BX=COSDG*COSHAG-RHOCOS*SPIG
      CX=SINDG-RHOSIN*SPIG
      DX=AX**2+BX**2
      FX=SQRTF(DX+CX**2)
      SX=SQRTF(DX)
      HTOP=ARTNF(AX,BX)
      DECTOP=ATANF(CX/SX)
C      HTOP AND DECTOP ARE TOPOCENTRIC HOUR ANGLE AND DECL. OF CENTER.
C
C     TOPOCENTRIC LIBRATIONS AND POSITION ARE NOW KNOWN.
C
      FREQUENCY 907(1,40,1)
907   IF(SPOT)904,905,906
904   XI=SL*CB
      ETA=SB
      GO TO 905
906   SOLONG=PIHLF-TABLE(COLONG,TSUBC,UT,NSUBC)
      SOLAT=TABLE(SLAT,TSUBC,UT,NSUBC)
      XI=SINF(SOLONG)*COSF(SOLAT)
      ETA=SINF(SOLAT)
905   ZETA=SQRTF(1.-XI**2-ETA**2)
      CLOD=XI*SL+ZETA*CL
C     CONVERT TO RECTANGULAR AXES TO OBSERVER AND LUNAR POLE.
      X=XI*CL-ZETA*SL
      Y=ETA*CB-SB*CLOD
      Z=ETA*SB+CB*CLOD
C     NEXT, TRANSFER ORIGIN TO OBSERVER AND ROTATE TO PUT X AND Y AXES
C      EAST AND NORTH, RESPECTIVELY.
      COSC=COSF(TOPC)
      SINC=SINF(TOPC)
      R=3.670*FX/SPIG
      XP=-X*COSC+Y*SINC
      YP=X*SINC+Y*COSC
      ZP=R-Z
C     NOW ROTATE Z-AXIS DOWN TO EQUATOR.
      SD=CX/FX
      CD=SX/FX
      BIGX=XP
      BIGY=ZP*SD+YP*CD
      BIGZ=ZP*CD-YP*SD
C
C      CONVERT TO EQUATORIAL ANGULAR COORDINATES.
C
      DAP=ATANF(BIGX/BIGZ)
      DELTAP=ATANF(BIGY/SQRTF(BIGX**2+BIGZ**2))
C     COLLECT FOR MEANS.
      HAT(NOBS)=HTOP-DAP
      SINDEL=SINF(DELTAP)
      COSDEL=COSF(DELTAP)
      COSZT= SINDEL*SINPHI+COSDEL*COSPHI*COSF(HAT(NOBS))
      AIR=1./COSZT
      AIR=AIR*(1.-.0012*(AIR*AIR-1.))
C     MAKE REFRACTION CORRECTIONS.
C     CORRECT ONLY FOR ATMOSPHERIC DISPERSION.
      REFR=DNM1*AIR/COSDEL
C     AIR IS  NEARLY SEC Z.
      HAT(NOBS)=HAT(NOBS)-REFR*SINF(HAT(NOBS))*COSPHI
      TOPDEC(NOBS)=DELTAP+REFR*(SINPHI-COSZT*SINDEL)
```

```
C     STORE TIME(NOBS,NSCAN)  HAT(NOBS,NSCAN) AND TOPDEC(NOBS,NSCAN)
C
C     PREPARE FOR OUTPUT
C
      ID=DAY+TSEC/86400.
      IH=MODF(TSEC/3600.,24.)
      IM=MODF(TSEC/60.,60.)
      SEC=MODF(TSEC,60.)
      HAH=HAT(NOBS)*RALPH/3600.
      IHAH=HAH
      IHAM=ABSF(MODF(HAH,1.)*60.)
      HAS=ABSF(MODF(HAH*60.,1.)*60.)
      DEC=TOPDEC(NOBS)*DEGRAD
      IDEG=DEC
      IDM=ABSF(MODF(DEC,1.)*60.)
      DECSEC=ABSF(MODF(DEC*60.,1.)*60.)
C
C     FIND ANGLES TO SUN AND OBSERVER, AND PHASE ANGLE.
C
C      IGNORE SOLAR PARALLAX.
      SOLONG=PIHLF-TABLE(COLONG,TSUBC,UT,NSUBC)
      SOLAT=TABLE(SLAT,TSUBC,UT,NSUBC)
      COSOL=COSF(SOLAT)
      COSLNG=COSF(SOLONG)
      XISUN=SINF(SOLONG)*COSOL
      ETASUN=SINF(SOLAT)
      ZETASN=COSLNG*COSOL
      COSZ=XI*XISUN+ETA*ETASUN+ZETA*ZETASN
      COSS=COSZ
      SINS=SQRTF(1.-COSS**2)
      ALTSOL=DEGRAD*(PIHLF-ACOSF(COSZ))
C     ALTSOL IS SOLAR ALTITUDE IN DEGREES.
C
C     NOW FOR OBSERVER-S COORDINATES FROM POINT ON MOON.
C     FIRST GET VECTOR (POINT-OBSERVER) IN (X,Y,Z) SYSTEM.
      XOBS=-X
      YOBS=-Y
      ZOBS=ZP
C     REMEMBER THAT ZP=R-Z.
C     NOW CONVERT TO DIRECTION COSINES.
      CLOD=ZOBS*CB-YOBS*SB
      XIO=XOBS*CL+CLOD*SL
      ETAO=YOBS*CB+ZOBS*SB
      ZETAO=-XOBS*SL+CLOD*CL
C      NORMALIZE.
      CLOD=SQRTF(XIO*XIO+ETAO*ETAO+ZETAO*ZETAO)
      XIO=XIO/CLOD
      ETAO=ETAO/CLOD
      ZETAO=ZETAO/CLOD
      COSZ=XI*XIO+ETA*ETAO+ZETA*ZETAO
      COSE=COSZ
      SINE=SQRTF(1.-COSE**2)
      ALTOBS=DEGRAD*(PIHLF-ACOSF(COSZ))
C     ALTOBS IS ALTITUDE OF OBSERVER IN DEGREES.
      COSES=XIO*XISUN+ETAO*ETASUN+ZETAO*ZETASN
      PHASE=ACOSF(COSES)*DEGRAD
      AZOUT=ACOSF((COSES-COSS*COSE)/(SINS*SINE))*DEGRAD
C
```

```
C       NOW OUTPUT RESULTS FOR THIS FRAME.    ***************
C
      WRITEOUTPUTTAPE6,499,ID,IH,IM,SEC,NFRAME,XI,ETA,IHAH,IHAM,HAS,IDEG
     X,IDM,DECSEC,AIR,ALTOBS,ALTSOL,AZOUT,PHASE,NSCAN
499   FORMAT(I3,2I4,F7.2,I6,F9.3,F8.3,2(I5,I3,F5.1),F8.3,2F8.1,2F11.1,I5
     X)
      RETURN
C
C***********************************************************************
C             NOW THE FUN BEGINS     $$$$$$$$$$$$$
C***********************************************************************
C
500   READ INPUTTAPE5,99,STEP
C     STEP REFERS TO TRACE MODE ONLY.
      WRITEOUTPUTTAPE6,542,PLACE1,PLACE2
542   FORMAT(1H073X32HNOTE -- -EARTH- MEANS OBSERVER (2A6,1H))
      ERASE TRACER
543   CODE=WORDSF(X)
      FREQUENCY 1005(20,1,20)
1005  IF(CODE-5HTRACE)544,545,544
545   TRACER=STEP
      CALL UNFIX(STEP)
      STEP=STEP/86400.
      GO TO 543
544   IF(CODE)540,541,540
541   CODE=1H
540   ERASE TMEAN,HATMEN,DTMEAN
      DO 501 I=1,NOBS
      TMEAN=TMEAN+TIME(I)
      HATMEN=HATMEN+HAT(I)
501   DTMEAN=DTMEAN+TOPDEC(I)
      OBSNO=NOBS
      TMEAN=TMEAN/OBSNO
      HATMEN=HATMEN/OBSNO
      DTMEAN=DTMEAN/OBSNO
C      NOW WE HAVE MEAN TIME, HOUR ANGLE, AND  DECLINATION.
      IH=MODF(TMEAN,1.)*24.
      IM=MODF(TMEAN*24.,1.)*60.
      SEC=MODF(TMEAN*1440.,1.)*60.
      DELTA=DTMEAN*DEGRAD
      IDEG=DELTA
      IDM=ABSF(MODF(DELTA,1.)*60.)
      DECSEC=ABSF(MODF(DELTA*60.,1.)*60.)
      HA=HATMEN*RALPH/3600.
      IHAH=HA
      IHAM=ABSF(MODF(HA,1.)*60.)
      HAS=ABSF(MODF(HA*60.,1.)*60.)
      UT=TMEAN
C
      ET=UT+DELTAT/86400.
      TANGLE=6.2831853*MODF(UT,1.)
      AG=TABLE(ALPHA,TSUBB,ET,NSUBB)
      DG=TABLE(DELTA,TSUBB,ET,NSUBB)
      SINDG=SINF(DG)
      COSDG=COSF(DG)
      HOT=TANGLE*1.00273791-WLONG-AG
      JDAY=UT
      HAGDAY=JDAY
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      HAG=SIDNEY(YEAR,XMON,HAGDAY)+HOT
      SINHAG=SINF(HAG)
      COSHAG=COSF(HAG)
      COSZG=SINDG*SINPHI+COSDG*COSPHI*COSHAG
      SINZG=SQRTF(1.-COSZG**2)
      PIG=TABLE(PIF,TSUBA,ET,NSUBA)
      SIGMA=PIG*SINZG*(1.+.0168*COSZG)
      SINQ=SINHAG*COSPHI/SINZG
      COSQ=(SINPHI-COSZG*SINDG)/(COSDG*SINZG)
      Q=ARTNF(SINQ,COSQ)
      QMC=Q-TABLE(C,TSUBC,UT,NSUBC)
      BEG=TABLE(BF,TSUBC,UT,NSUBC)
      DL=-SIGMA*SINF(QMC)/COSF(BEG)
      TOPLNG=TABLE(EL,TSUBC,UT,NSUBC)+DL
      TOPB=BEG+SIGMA*COSF(QMC)
C
      XI=SINF(TOPLNG)*COSF(TOPB)
      ETA=SINF(TOPB)
C      XI AND ETA ARE TOPOCENTRIC DISC CENTER.
      SOLONG=PIHLF-TABLE(COLONG,TSUBC,UT,NSUBC)
      SOLAT=TABLE(SLAT,TSUBC,UT,NSUBC)
      XISUN=SINF(SOLONG)*COSF(SOLAT)
      ETASUN=SINF(SOLAT)
C     WE NOW HAVE COORDINATES OF SUBSOLAR POINT.
      WRITEOUTPUTTAPE6,505,IH,IM,SEC,XISUN,ETASUN,XI,ETA,IHAH,IHAM,HAS,
     XIDEG,IDM,DECSEC
505   FORMAT                                        (1H0/1H415X24HCOORDINAT
     XES AT MID-SCAN,2I3,F5.1,5H U.T./1H05X32HSUBSOLAR POINT     CENTER O
     XF DISC6X23HHOUR ANGLE  DECLINATION/8X2HXI6X3HETA7X2HXI6X3HETA/46X7
     XHH  M  S6X8H0  -  --/2X,2(F10.3,F8.3),3X,2(I5,I3,F5.1))
C
C       NOW FIND H.A. AND DEC. PREDICTION LAWS.
C
      ERASE DHDT,DDDT
      FREQUENCY 1006(0,1,10)
1006  IF(NOBS-1)507,550,510
C      550 IS PROCESS BLOCK.
507   WRITEOUTPUTTAPE6,508
508   FORMAT(36H0DATA ERROR -- NO FILMS BEFORE SCAN.)
      GO TO 3
C      NORMALIZE VARIABLES.
510   DO 511 I=1,NOBS
      T(I)=TIME(I)-TMEAN
      H(I)=HAT(I)-HATMEN
511   D(I)=TOPDEC(I)-DTMEAN
C        WITH MEANS REMOVED, LINEAR FCNS. MUST PASS THROUGH (0,0).
C     SEE WHETHER FITTING MODE IS SPECIFIED ON - S/D - CARD BEFORE DATA.
C      CARD MUST HAVE, BEGINNING ON OR AFTER COL. 7 ....
C             SCAN   -- FOR MOVING TELESCOPE.
C             DRIFT  -- FOR TELESCOPE FIXED.
C     IF NEITHER IS SPECIFIED, PROGRAM WILL MAKE UP ITS OWN MIND.
C
      IF(CODE-5HDRIFT)530,515,530
      DIMENSION REJ(90)
C      530 IS LINEAR FIT, 515 IS FIXED FIT.
C
C     NOW DO LINEAR FIT.
530   ERASE TSQ,TH,TD
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```
      DO 531 I=1,NOBS
      TSQ=TSQ+T(I)**2
      TH=TH+T(I)*H(I)
531   TD=TD+T(I)*D(I)
      DHDT=TH/TSQ
      DDDT=TD/TSQ
      DO 532 I=1,NOBS
C      REDUCE H AND D TO RESIDUALS.
      H(I)=H(I)-DHDT*T(I)
532   D(I)=D(I)-DDDT*T(I)
C       GO LOOK FOR BAD DATA.
515   ERASE SUM,VAR
      TOL=23.5E-10
C       TOL = (10 ARCSEC) SQUARED.
      DO 516 I=1,NOBS
      H(I)=H(I)*COSF(TOPDEC(I))
C     CONVERT RESIDUALS TO ARC SECONDS.
      REJ(I)=H(I)**2+D(I)**2
      IF(REJ(I)-TOL)517,517,516
517   VAR=VAR+REJ(I)
C     POINT IS ACCEPTED.
      ERASE REJ(I)
516   SUM=SUM+REJ(I)
      FREQUENCY 1008(0,20,1)
1008  IF(SUM)3,518,519
C
C      REJECTION HERE.
519   ERASE TOL
      DO 520 I=1,NOBS
      IF(TOL-REJ(I))521,520,520
521   TOL=REJ(I)
      LOP=I
520   CONTINUE
C      LOP IS NOW INDEX OF WORST POINT.
      H(LOP)=H(LOP)*PARSEC
      D(LOP)=D(LOP)*PARSEC
C      CONVERT OFFENDERS TO SECONDS.
      WRITEOUTPUTTAPE6,522,FRAME(LOP),H(LOP),D(LOP),CODE
522   FORMAT(13H0REJECT FRAMEF5.0,6X22HERRORS IN H.A. AND DEC/30X2F8.1,
     X4X6HARCSEC6XA6)
      DO 523 I=LOP,NOBS
      TIME(I)=TIME(I+1)
      XIOBS(I)=XIOBS(I+1)
      ETAOBS(I)=ETAOBS(I+1)
      TOPDEC(I)=TOPDEC(I+1)
      HAT(I)=HAT(I+1)
523   FRAME(I)=FRAME(I+1)
      NOBS=NOBS-1
      GO TO 540
C
518   IF(DHDT**2+DDDT**2)1501,1500,1501
1501  HRATE=DHDT*RALPH/86400.
      DRATE=DDDT*PARSEC/86400.
      WRITEOUTPUTTAPE6,1502,HRATE,DRATE
1502  FORMAT(26H0MOTION PER SECOND OF TIME 19XF7.3,2H SF13.3,7H ARCSEC)
1500  STAR=SQRTF(VAR/OBSNO)*PARSEC
      SINDEL=SINF(DTMEAN)
      COSDEL=COSF(DTMEAN)
```

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      COSZT=SINDEL*SINPHI+COSDEL*COSPHI*COSF(HATMEN)
      REFR=DNM1/(COSDEL*COSZT)
      REFRH=-REFR*SINF(HATMEN)*COSPHI*RALPH
      REFRD=REFR*(SINPHI-COSZT*SINDEL)*PARSEC
      WRITEOUTPUTTAPE6,524,REFRH,REFRD,STAR,CODE
524   FORMAT(36H0DIFFERENTIAL REFRACTION CORRECTIONS5X2F13.1/
     X       28H0R.M.S. RESIDUAL IN POSITIONF5.2,13H ARCSEC FROM A6/2(1H
     X0/),51H0RESIDUALS IN H.A. (H) AND DEC (D) ARE ON NEXT PAGE)
526   TEDGE=.005*(T(NOBS)-T)
      XLO=T-TEDGE
      XHI=T(NOBS)+TEDGE
C
C     NOW CHECK FOR NEGLIGIBLE RATES.
C
550   IF(CODE-6H      )560,551,560
551   IF(NOBS-2)552,552,553
C      FORCE DRIFT-CURVE FIT FOR TWO OR FEWER POINTS.
552   CODE=5HDRIFT
      GO TO 540
      FREQUENCY 553(1,0,20)
553   IF(DHDT**2+DDDT**2-VAR/((OBSNO-1.)*TSQ))552,552,555
C      NOW PROCEED TO GENERATE EPHEMERIS.
555   CODE=4HSCAN
560   WRITEOUTPUTTAPE6,561,NSCAN,CODE,NOBS
561   FORMAT(19H0EPHEMERIS FOR SCANI4,15H THEN WILL USE A6,15HMETHOD BAS
     XED ONI3,9H  POINTS.)
      CALL LIMITS(XLO,XHI,SECTM,SECTP)
      DO 525 I=1,NOBS
      CALL POINTS(T(I),H(I),17)
525   CALL POINTS(T(I),D(I),13)
      CALL GRID(T,T(NOBS)-T,SECTM,SECTP)
      CALL GRAPH(SCALE)
C
C***********************************************************************
C      NOW READ DATA AND GENERATE EPHEMERIS.
C***********************************************************************
C
      ERASE KOUNT
      FREQUENCY 1010(1,10,1)
1010  IF(TRACER)800,569,800
C     SIMULATE CARDS VIA TRACE OPERATIONS.
800   SPUMON=47434.89/PARSEC
C     MEAN MOTION OF MOON, RADIANS PER DAY.
      HRATE=DHDT-(TWOPI-SPUMON*.916/(COSF(DTMEAN))**2)
C     LAST TERM IS SIDEREAL MOTION IN R.A.
      DRATE=ABSF(DDDT)-ABSF(SPUMON*SINF(ABSF(DTMEAN)-.410))
C     ADOPT SLOWEST REASONABLE RATE.
C     HRATE AND DRATE ARE NOW MOTIONS OF TELESCOPE RELATIVE TO MOON.
      SPEED=SQRTF(HRATE**2+DRATE**2)
      UT=UT-.011/SPEED
C     LUNAR DIAMETER NEVER EXCEEDS .011 RADIAN.
C     THUS,BACK UP AT LEAST ONE DIAMNETER TO START TRACE.
805   UT=UT+STEP
C     STEP IS INCREMENT FOR TRACE PROCEDUTE.
801   JDAY=UT
      NHOUR=MODF(UT,1.)*24.
      NMIN=MODF(UT*24.,1.)*60.
      SEC=MODF(UT*1440.,1.)*60.
```

```
      HAGDAY=JDAY
C     SET UP FOR SIDNEY.
      WRITEOUTPUTTAPE6,861,NSCAN,CODE,NOBS,YEARA,XMON
  861 FORMAT(20H1TRACE BASED ON SCANI4,8H, USING A6,15HMETHOD BASED ONI3
     X,9H  POINTS./1H0,I4,3X,A6,4HU.T.22X3HAIR5X36HELEVATION OF   EARTH
     XAZIMUTH   PHASE/24X60HXI       ETA      MASS      EARTH     SUN      FRO
     XM SUN       ANGLE/16H    D    H    M    S)
C     TITLE HEADING FOR TRACE MOOD NOW DONE
      GO TO 570
C     TRACE ROUTINE SKIPS READ SECTION.
  562 UT=DAY+TSEC/86400.
570   ET=UT+DELTAT/86400.
      TANGLE=6.2831853*MODF(UT,1.)
      AG=TABLE(ALPHA,TSUBB,ET,NSUBB)
      DG=TABLE(DELTA,TSUBB,ET,NSUBB)
      SINDG=SINF(DG)
      COSDG=COSF(DG)
      HOT=TANGLE*1.00273791-WLONG-AG
      JDAY=UT
      HAGDAY=JDAY
      HAG=SIDNEY(YEAR,XMON,HAGDAY)+HOT
      SINHAG=SINF(HAG)
      COSHAG=COSF(HAG)
      COSZG=SINDG*SINPHI+COSDG*COSPHI*COSHAG
      SINZG=SQRTF(1.-COSZG**2)
      PIG=TABLE(PIE,TSUBA,ET,NSUBA)
      SPIG=SINF(PIG)
      SIGMA=PIG*SINZG*(1.+.0168*COSZG)
      SINQ=SINHAG*COSPHI/SINZG
      COSQ=(SINPHI-COSZG*SINDG)/(COSDG*SINZG)
      Q=ARTNF(SINQ,COSQ)
      SEA=TABLE(C,TSUBC,UT,NSUBC)
      QMC=Q-SEA
      BEG=TABLE(BE,TSUBC,UT,NSUBC)
      DL=-SIGMA*SINF(QMC)/COSF(BEG)
      TOPLNG=TABLE(EL,TSUBC,UT,NSUBC)+DL
      TOPB=BEG+SIGMA*COSF(QMC)
      CL=COSF(TOPLNG)
      SL=SINF(TOPLNG)
      CB=COSF(TOPB)
      SB=SINF(TOPB)
      TOPC=SEA+DL*SB-SIGMA*SINQ*SINDG/COSDG
      AX=COSDG*SINHAG
      BX=COSDG*COSHAG-RHOCOS*SPIG
      CX=SINDG-RHOSIN*SPIG
      DX=AX**2+BX**2
      FX=SQRTF(DX+CX**2)
      SX=SQRTF(DX)
      HTOP=ARTNF(AX,BX)
      DECTOP=ATANF(CX/SX)
C     TOPOCENTRIC LIBRATIONS AND POSITION ARE NOW KNOWN.
      T=UT-TMEAN
      HA=HATMEN+DHDT*T
      DEC=DTMEAN+DDDT*T
C      NOW HAVE TOPOCENTRIC HA AND DEC OF SCAN POINT FOR GIVEN TIME.
      DA=HTOP-HA
C     DA IS RA OF POINT MINUS RA OF LUNAR CENTER.
      R=3.670*FX/SPIG
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```
      CDEC=COSF(DEC)
      BIGX=SINF(DA)*CDEC
      BIGY=SINF(DEC)
      BIGZ=COSF(DA)*CDEC
C     NOW HAVE DIRECTION COSINES REL. TO LUNAR MERIDIAN AND CEL. EQUATOR.
      SD=CX/EX
      CD=SX/EX
      XP=BIGX
      YP=BIGY*CD-BIGZ*SD
      ZP=BIGY*SD+BIGZ*CD
C      NOW HAVE Z-AXIS ROTATED TO LUNAR CENTER.
C     NOW SET ZP=R.
      ZIP=R/ZP
      XP=XP*ZIP
      YP=YP*ZIP
C     ZP=R, BUT CARRY MENTALLY.
      COSC=COSF(TOPC)
      SINC=SINF(TOPC)
      EDGE=1H
      X=YP*SINC-XP*COSC
      Y=XP*SINC+YP*COSC
C     Z=R-ZP=0.
C      WE NOW HAVE AXES IN MOON, DIRECTED TO LUNAR POLE.
C      NOW CORRECT DISTANCE TO POINT.
      RIM=X*X+Y*Y
      RSQ=R*R
      RAT=RIM/RSQ
      RAD=(RAT+1.-RIM)/RSQ
      FREQUENCY 1012(1,0,20)
1012  IF(RAD)564,565,566
  564 EDGE=3HOFF
1013  IF(TRACER)810,565,810
C     NO CORRECTION IF NOT ON MOON.
810   IF(KOUNT)3,805,569
C     TRY NEXT POINT ON TRACE IF OFF MOON, UNLESS DONE.
C     CORRECTION IS DIFFERENTIAL BECAUSE R=200.
566   DELTA=RAT+SQRTF(RAD)
      WOUND=1.-DELTA
      X=X*WOUND
      Y=Y*WOUND
      Z=R*DELTA
      SLOP=X*X+Y*Y+Z*Z-1.
      FREQUENCY 1014(100,0,1)
1014  IF(ABSF(SLOP)-2.E-4)565,567,567
567   SLOP=SQRTF(1.+SLOP)-1.
      WRITEOUTPUTTAPE6,568,NDAY,NHOUR,NMIN,SEC,SLOP
568   FORMAT(I3,2I4,F7.2,4X30HPOINT MISSES LUNAR SURFACE BY E9.2)
      KOUNT=KOUNT+1
      FREQUENCY 1015(1,10,1)
1015  IF(TRACER)805,591,805
565   CLOD=Z*CB-Y*SB
      XI=X*CL+CLOD*SL
      ETA=Y*CB+Z*SB
      ZETA=CLOD*CL-X*SL
C      PREPARE FOR OUTPUT.
      COSZT=SINF(DEC)*SINPHI+COSF(DEC)*COSPHI*COSF(HA)
      AIR=1./COSZT
      AIR=AIR*(1.-.0012*(AIR*AIR-1.))
```

```
      FREQUENCY1016(1,20,0)
B1016 IF(EDGE/606060606060)575,580,575
575   ERASE ALTOBS,ALTSOL,AZOUT,PHASE
      GO TO 590
C      NO FURTHER RESULTS IF OFF MOON.
580   SOLONG=PIHLF-TABLF(COLONG,TSUBC,UT,NSUBC)
      SOLAT=TABLF(SLAT,TSUBC,UT,NSUBC)
      COSOL=COSF(SOLAT)
      COSLNG=COSF(SOLONG)
      XISUN=SINF(SOLONG)*COSOL
      ETASUN=SINF(SOLAT)
      ZETASN=COSLNG*COSOL
      COSZ=XI*XISUN+ETA*ETASUN+ZETA*ZETASN
      COSS=COSZ
      SINS=SQRTF(1.-COSS**2)
      ALTSOL=DEGRAD*(PIHLF-ACOSF(COSZ))
C     ALTSOL IS SOLAR ALTITUDE IN DEGREES.
C     NOW FOR OBSERVER-S COORDINATES FROM POINT ON MOON.
      XOBS=-X
      YOBS=-Y
      ZOBS=R-Z
C     NOW CONVERT TO DIRECTION COSINES.
      CLOD=ZOBS*CB-YOBS*SB
      XIO=XOBS*CL+CLOD*SL
      ETAO=YOBS*CB+ZOBS*SB
      ZETAO=-XOBS*SL+CLOD*CL
C      NORMALIZE.
      CLOD=SQRTF(XIO*XIO+ETAO*ETAO+ZETAO*ZETAO)
      XIO=XIO/CLOD
      ETAO=ETAO/CLOD
      ZETAO=ZETAO/CLOD
      COSZ=XI*XIO+ETA*ETAO+ZETA*ZETAO
      COSE=COSZ
      SINE=SQRTF(1.-COSE**2)
      ALTOBS=DEGRAD*(PIHLF-ACOSF(COSZ))
C     ALTOBS IS ALTITUDE OF OBSERVER IN DEGREES.
      COSES=XIO*XISUN+ETAO*ETASUN+ZETAO*ZETASN
      PHASE=ACOSF(COSES)*DEGRAD
      AZOUT=ACOSF((COSES-COSS*COSE)/(SINS*SINE))*DEGRAD
C
  590 CONTINUE
  595 IF(TRACER)592,591,592
  592 WRITE OUTPUT TAPE6,599,JDAY,NHOUR,NMIN,SEC,XI,ETA,AIR,ALTOBS,
     XALTSOL,AZOUT,PHASE,EDGE
  599 FORMAT(I3,2I4,F7.2,F9.3,F8.3,F9.3,2F8.1,F11.1,F13.1,2XA6)
      GO TO 805
C
569   ERASE NOBS
  591 RETURN
C     TO READ NEXT DATUM.
C
      END
```

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CCOEFI2
C     SUBROUTINE TO COMPUTE COEFFICIENTS OF YBAR
C     COEFI2 IS SUPERVISED BY MAIN PROGRAM LUNAR
C     COEFI2 GENERATES THE BASE LEVELS FOR TEMPR2
C
      SUBROUTINE COEFI2 (NTAP,IP1,NPB,NPZ,DAY,TSFC,KEY,EDGE,DATUM,KD,
     1CSW,NSCAN)
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH2O,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20)
      DIMENSION Y11(200),U1(200),C(200)
      DIMENSION CT(20),TI(20,20),GN(20,20),NK(20)
      DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
      DIMENSION TSFC1(120),Y1(120),TSEC2(120),Y2(120)
      IF(KEY-2) 504,601,601
  601 IF(CSW) 603,603,602
  603 CSW=1.
C     TTT=TIME BETWEEN OFF READING AND EDGE OF THE MOON FOR WHICH THE
C     VALUE OF Y DOES NOT ENTER THE CALCULATIONS OF THE COEFFICIENTS.
      TTT=3.
      REWIND NTAP
      ERASE ASW,BSW,I,J,MC,AT1,AT2,AY1,AY2,NSCT
C     DETERMINE IF THIS IS A NEW SCAN AND SELECT THE VALUES
C     OF BUCKING SIGNAL AND ZERO SUPPRESSION
  602 UT=DAY+TSEC/86400.
      IF(NSCAN-NSCT)1037,1040,1037
 1037 ERASE BS,ZS
C     TEST FOR BUCKING SIGNAL
      DO 1030 IB=1,NPB
      IF (NSCAN-NSB(IB))1030,1031,1030
 1030 CONTINUE
      GO TO 1033
 1031 BS=BUCK(IB)
C     TEST FOR ZERO SUPPRESSION
 1033 DO 1032 IZ=1,NPZ
      IF (NSCAN-NSZ(IZ))1032,1034,1032
 1032 CONTINUE
      GO TO 1035
 1034 ZS=ZERO(IZ)
 1035 CS=0.25
 1039 NSCT=NSCAN
 1040 DATUM=(DATUM-ZS)*CS-BS*BSCON/GT(UT,IP1)
C     CS TRANSFORMS Y-DEFLECTION IN COUNTS TO MILLIMETERS
C     NOW TEST OFF/ON MOON CONDITION
B     IF(EDGE/606060606060)1,2,1
    1 IF(ASW)401,101,401
C     START WITH FIRST OFF LIMB GROUP.  I IS THE COUNT
  101 I=I+1
C
      TSFC1(I)=TSFC
      Y1(I)=DATUM
      GO TO 900
C
    2 IF(BSW)501,3,501
    3 IF(MC)201,201,900
```

```
C
C     GENERATE U1 AND Y1 OF LEFT SKY LEVEL
  201 ET1=TSEC
C
  202 IF (TSEC1(I)-(ET1-TTT)) 204,204,203
  203 I=I-1
      GO TO 202
  204 DO 205 IA=1,I
      AT1=AT1+TSEC1(IA)*Y1(IA)
  205 AY1=AY1+Y1(IA)
      KD=KD+1
      U1(KD)=AT1/AY1
      ZI=I
      Y11(KD)=AY1/ZI
      ASW=1.
      MC=1
      ERASE NC
      GO TO 900
C     NOW WITH SECOND OFF LAMB GROUP, J IS THE COUNT
  401 IF(NC) 403,402,403
  402 ET2=TSEC+TTT
      NC=1
  403 IF(TSEC-ET2)900,404,404
  404 J=J+1
      TSEC2(J)=TSEC
      Y2(J)=DATUM
      BSW=1
      IF(J-1) 900,900,405
  405 GAP=TSEC2(J)-TSEC2(J-1)
      IF(GAP-1800.) 900,406,406
  406 J=J-1
      GO TO 504
C     NOW GENERATE U2 AND Y2 OF RIGHT SKY LEVEL
  501 ET3=TSEC
  502 IF (TSEC2(J)-(ET3-TTT))504,504,503
  503 J=J-1
      GO TO 502
  504 DO 505 JA=1,J
      AT2=AT2+TSEC2(JA)*Y2(JA)
  505 AY2=AY2+Y2(JA)
      U2=AT2/AY2
      ZJ=J
      Y2=AY2/ZJ
C     C=SLOPE BETWEEN LEFT AND RIGHT SKY-LEVEL DEFLECTIONS
C     C IS IN COUNT PER SECOND
      C(KD)=(Y2-Y11(KD))/(U2-U1(KD))
C
C     NOW FOR THE NEXT SLOPE
      IF(GAP-1800.)506,507,507
  506 KD=KD+1
      U1(KD)=U2
      Y11(KD)=Y2
      ERASE BSW,J,AT2,AY2,NC
      RETURN
C
  507 I=1
      TSEC1(1)=TSEC
      Y1(1)=DATUM
```

```
      ERASE   ASW,BSW,MC,J,AT1,AY1,AT2,AY2,GAP,NC
  900 RETURN
      END
```

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CGAINS
C     SUBROUTINE TO COMPUTE GAIN COEFFICIENTS
      SUBROUTINE GAIN(IP1)
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH2O,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20)
      DIMENSION Y11(200),U1(200),C(200)
      DIMENSION TI(20 ,20),GN(20 ,20),NK(20),CT(20)
      DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
C     CT=ARRAY OF TIMES AT WHICH MANUAL TIME CHANGE WAS MADE
      ERASE CT(1)
      J=1                                                               SG4
      FINALI=6HFINALI
      CHANGE=6HCHANGE                                                   SG6
      ERASE I,NK,IP1                                                    SG7
    4 I=I+1
    5 READ INPUT TAPE 5,50,CARD,NDAY,NHOUR,NMIN,SEC,GA                  SG10
   50 FORMAT(A6,3I3,F6.2,F10.4)                                         SG11
      HOUR=NHOUR                                                        SG13
      DAY=NDAY                                                          SG12
      AMIN=NMIN                                                         SG14
      UT=DAY+(HOUR/24.)+(AMIN/1440.)+(SEC/86400.)                       SG15
B     IF (FINALI/CARD)6,10,6
B   6 IF(CHANGE/CARD)7,9,7                                              SG17
C     GN=ARRAY OF GAIN VALUES
    7 GN(I,J)=GA                                                        SG18
      TI(I,J)=UT                                                        SG19
      NK(J)=NK(J)+1                                                     SG9
      GO TO 4                                                           SG20
    9 J=J+1                                                             SG21
      ERASE I,NK(J)
      I=I+1                                                             SG23
C     IP1=NUMBER OF CHANGE CARDS
      IP1=IP1+1                                                         SG24
      NK(J)=NK(J)+1                                                     SG25
      TI(I,J)=UT                                                        SG26
      CT(J)=UT                                                          SG27
      GN(I,J)=GA                                                        SG28
      GO TO 4                                                           SG29
   10 RETURN                                                            SG30
      END                                                               SG31
```

```
*     LIST8
*     LABEL
CFAKIR
      SUBROUTINE FAKIR(RAD,CST,TO,NTEM)
C     SUBROUTINES INCLUDED ARE BREW,ANDY,ICE,HIPLOT,FRENCH,ERR169,ISIMEQ
C     REVISED 3/10/65 TO DO PARABOLIC FIT TO TRANSMISSION LAW
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH2O,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20),Y11(200),U1(200)
      DIMENSION C(200),CT(20),TI(20,20),GN(20,20),NK(20)
      DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
      DIMENSION ALAMDA(200),TAU(200),          SEZ(10),FLAM(200),F(200)
      DIMENSION ICEST(5),               S(50,10),ARG(200),TEM(50)
      DIMENSION PTRAN(50,10)
      DIMENSION XT(20),           PARAM(3,50),POWER(5,50),AMAT(5,5),X2(20)
      DIMENSION RAD(340),CST(3,340)
      PLANCKF(A,T)=1.19064E10/(A**5*(EXPF(1.43879E+4/(A*T))-1.))
C     CONTROL CARD, WH2O IN MM. OF WATER, PLAN TELLS WHAT MODEL TO
C     CHOOSE  FIT=DIS OR LIN FOR INTEGRATION, NGRAPH=1 IF WANT NO GRAPHS
C     WHGATE = MM. OF H2O THAT GATES HAD
      QS=(+4HSKIP)
      QL=(+3HLIN)
      FLOGT=2.302585
1     READ INPUT TAPE 5,2,WH2O,WHGATE,PLAN,FIT,SKIP
 2    FORMAT(2F5.2,A5,A3,55X,A4)
      ERASE PRINEX
C     CONTINUOUS ABS. PARAMETER, IGNORE ONLY IF AVOIDC=NOT,
C     IF WATER IS THE CULPRIT PUT CAUSE=H
10    READ INPUT TAPE 5,11,CAUSE,COEF,AVOIDC
11    FORMAT(A1,F9.5,67X,A3)
      WRITE OUTPUT TAPE 6,4,WH2O,PLAN,CAUSE,COEF,AVOIDC,FIT,WHGATE
4     FORMAT (18H1ABS. PROGRAM FOR ,F5.2,19HMM. OF WATER USING A5,6H MOD
     1EL/24H0CONTINUOUS ABS. DUE TO A1,12H WITH COEF.=F6.4,6H WILL ,A3,8
     2H BE USED/5H0FIT=,A3/10H0WHGATE = ,F5.2)
B     IF(SKIP/QS) 18,101,18
C     INPUT OF BAND ABSORBTION CARDS, UP TO 200 ALLOWED, BLANKS=-0.
C     ELEMENT BY FIRST LETTER, ADD 1. TO COEFICIENT PREFERRED
18    DO 29 I=1,200
20    READ INPUT TAPE 5,21,ALAMB(I),ELEMNT(I),C1(I),C2(I),C3(I),JEND
21    FORMAT (F6.3,1X,A1,2X,3F10.5,39X,I1)
      IF(JEND) 29,29,19
19    IMAX=I
      GO TO 22
29    CONTINUE
22    WRITE OUTPUT TAPE 6,23,(ALAMB(I),ELEMNT(I),C1(I),C2(I),C3(I),I=1,I
     1MAX)
23    FORMAT ( 1H0,39X,27HBAND ABSORBTION COEFICIENTS/20H0WAVELENGTH(MIC
     1RONS)5X,11HCONSTITUENT,5X,13HSTRONG RANDOM,2X,11HWEAK RANDOM,4X,14
     2HSTRONG REGULAR /1H ,39X,12H(PER MM.1/2),4X,9H(PER MM.),7X,10H(PER
     3 ATM.) /1H /(1H ,F13.3,15X,A1,F22.7,F14.7,F16.7))
C     READ IN FILTER TRANSMISSION DATA
      N1=1
30    N2=N1+2
      READ INPUT TAPE 5,31,(ALAMDA(I),TAU(I),I=N1,N2)
31    FORMAT(6F10.5)
C     TEST FOR END OF DATA   BLANK FIELD = -0.
B     IF(ALAMDA(N2)/400000000000) 36,40,36
36    N1=N1+3
```

```
      GO TO 30
C     N2 IS NUMBER OF DATA ITEMS
40    N2=N2-1
B     IF(ALAMDA(N2)/400000000000) 101,40,101
C     READ IN VALUES OF TEMPERATURE AND ZENITH ANGLES (IN UNITS OF SECZ)
 101  SEZ(1)=1.0
      SEZ(2)=1.5
      SEZ(3)=2.0
      SEZ(4)=2.5
      SEZ(5)=3.0
      SEZ(6)=4.0
 104  NZ=6
      MLO=1
      MHI=10
109   READ INPUT TAPE 5,106,(TEM(M),M=MLO,MHI)
106   FORMAT(10G)
      IF(TEM(MHI)) 107,107,108
108   MLO=MLO+10
      MHI=MHI+10
      GO TO 109
107   MHI=MHI-1
      IF(TEM(MHI)) 107,107,112
112   NTEMP=MHI
C     GET RADIANCES ADJUSTED TO INDEX1
      IDX=(TEM(1)-TO+.1)
      DO 800 I9=IDX,NTEM
      I8=I9+1-IDX
 800  RAD(I8)=RAD(I9)
      NTEM=NTEM-IDX+1
      TO=TEM(1)-1.0
      DO 199 IZ=1,NZ
      SECZ=SEZ(IZ)
      CALL BREW(ALAMDA,TAU,N2,SECZ,WHGATE,FLAM,F)
      LAMEND=LAMEND
      DO 198 IT=1,NTEMP
      TEMP=TEM(IT)
      STEPSZ=1.
      DO 110 LAM=2,LAMEND
110   STEPSZ=MIN1F(STEPSZ,FLAM(LAM)-FLAM(LAM-1))
      FLAMAX=FLAM(LAMEND)
      WAVE=FLAM(1)
      SDOT=F(1)*PLANCKF(WAVE,TEMP)
      N=1
      KK=1
      LAM=1
      ERASE AREA
145   CALL ICE(STEPSZ,WAVE,FLAMAX,5.E-6,.0001,N,AREA,SDOT,ICEST,JJ)
146   GO TO (147,148,171,141),JJ
148   JJ=XICEF(A)
      GO TO 146
B 147 IF(FIT/QL) 127,126,127
127   IF(LAM-LAMEND) 120,122,122
120   IF(WAVE-0.5*(FLAM(LAM)+FLAM(LAM+1))) 122,123,123
123   LAM=LAM+1
122   SDOT=F(LAM)*PLANCKF(WAVE,TEMP)
      GO TO 148
126   IF(LAM-LAMEND+1) 124,128,128
124   IF(WAVE-FLAM(LAM+1)) 128,129,129
```

```
129    LAM=LAM+1
128    SDOT=(F(LAM)+(F(LAM+1)-F(LAM))*(WAVE-FLAM(LAM))/(FLAM(LAM+1)-FLAM(
      1LAM)))*PLANCKF(WAVE,TEMP)
       GO TO 148
141    WRITE OUTPUT TAPE 6,250,LAM,WAVE,SDOT,STEPSZ,SECZ,TEMP,KK
250    FORMAT (15H0NONCONVERGENCE/1H0,I3,5F16.5,I6)
171    S(IT,IZ)=AREA
       I7=(TEMP-TO+.1)
198    PTRAN(IT,IZ)=S(IT,IZ)/RAD(I7)
199    CONTINUE
C      NOW SOLVE FOR BEST PARABOLIC FIT TO A,B,K
502    ERASE SX,SX2,SX3,SX4
       DO 510 IZ=1,NZ
       XT(IZ)=LOG10F(SEZ(IZ))
       X2(IZ)=XT(IZ)**2
       SX=SX+XT(IZ)
       SX2=SX2+X2(IZ)
       SX3=SX3+X2(IZ)*XT(IZ)
510    SX4=SX4+X2(IZ)**2
       DO 500 IT=1,NTEMP
       ERASE SY,SXY,SXXY
       DO 501 IZ=1,NZ
       YT=LOG10F(-LOG10F(PTRAN(IT,IZ)))
       SY=SY+YT
       SXY=SXY+XT(IZ)*YT
501    SXXY=SXXY+X2(IZ)*YT
       AMAT(1,1)=NZ
       AMAT(1,2)=SX
       AMAT(1,3)=SX2
       AMAT(1,4)=SY
       AMAT(2,1)=SX
       AMAT(2,2)=SX2
       AMAT(2,3)=SX3
       AMAT(2,4)=SXY
       AMAT(3,1)=SX2
       AMAT(3,2)=SX3
       AMAT(3,3)=SX4
       AMAT(3,4)=SXXY
       CALL ISIMEQ(AMAT,5,3,1)
C      PARAMETERS ARE A,B,K IN ORDER 1,2,3
       PARAM(3,IT)=EXPF(ELOGT*AMAT(1,4))*ELOGT
       PARAM(1,IT)=AMAT(3,4)
       PARAM(2,IT)=AMAT(2,4)
       DO 530 K=1,5
       AK=K
 530   POWER(K,IT)=PARAM(1,IT)*LOG10F(AK)+PARAM(2,K)
500    CONTINUE
       WRITE OUTPUT TAPE 6,351,(TEM(IT),(PARAM(J,IT),J=1,3),(POWER(K,IT),
      1K=1,5),IT=1,NTEMP)
351    FORMAT  (1H1, 50X,-ABSORPTION LAW COEFICIENTS- /-0T(ABSOLUTE-   ,
      18X,1HA,12X,1HB,12X,1HK,8X,  -POWER(1)- ,5X,-POWER(2)- ,5X, -POWER(
      23)-,5X, -POWER(4)- ,5X,-POWER(5)-/  (F9.3,4X,3E13.6,F10.5,4F13.6))
       WRITE OUTPUT TAPE 6,352
352    FORMAT (1H0/-0TRANSMISSION = EXPF(-K*SEC(Z)**POWER)-  /-0POWER = A
      1*LOG10F(SEC(Z)) + B-)
       N9=1
       DO 820 J=1,3
       K=1
```

```
      TEMP=T0
      DO 820 I=1,NTEM
      TEMP=TEMP+1.0
807   IF(TEMP-TEM(K))808,809,810
808   K=K+1
      GO TO 807
809   CST(J,I)=PARAM(J,K)
      GO TO 820
810   IF(TEMP-TEM(K+1))811,812,813
811   CST(J,I)=(PARAM(J,K+1)-PARAM(J,K))*(TEMP-TEM(K))/(TEM(K+1)-TEM(K))
     1+PARAM(J,K)
      GO TO 820
812   K=K+1
      GO TO 809
813   K=K+1
      GO TO 810
820   CONTINUE
      RETURN
      END
```

```
*       LIST8
*       LABEL
CLAGR
C       FUNCTION SUBPROGRAM TO COMPUTE GAIN
        FUNCTION GT(UT,IP1)
        COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
       1C1,C2,C3,PLAN,WH20,CAUSE,COEF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
        DIMENSION ALAMB(200),ELEMNT(200),C1(200),C2(200),C3(200)
        DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20),Y11(200),U1(200)
        DIMENSION NK(20),TI(20 ,20),GN(20 ,20),CT(20),C(200)          FG2
        DO 91 KJ=1,IP1                                                FG3
        J=KJ-1                                                        FG4
        IF (UT-CT(KJ))93,92,91
     91 CONTINUE                                                      FG6
     92 J=J+1                                                         FG7
     93 N=NK(J)                                                       FG8
        ERASE GT
        DO 96 L=1,N                                                   FG10
        POL=1.0                                                       FG11
        DO 95 M=1,N                                                   FG12
        IF (L-M)94,95,94                                              FG13
     94 POL=POL*(UT-TI(M,J))/(TI(L,J)-TI(M,J))                        FG14
     95 CONTINUE                                                      FG15
     96 GT=GT+GN(L,J)*POL                                             FG16
        RETURN                                                        FG17
        END                                                           FG18
```

```
*     LIST8
*     LABEL
CBREW  COMPUTES AND MULTIPLIES TOGETHER ATMOSPHERIC TRANSMISSIONS
      SUBROUTINE BREW(ALAMDA,TAU,N2,SECZ,WHGATE,FLAM,F)
C     REVISED 3/5/65 TO INCLUDE ERROR FUNCTION TO APPROX CO2 DATA
C     SUBROUTINE ANDY IS CALLED TWICE
      COMMON BUCK,ZERO,BSCON,NSB,NSZ,Y11,U1,C,CT,TI,GN,NK,ALAMB,ELEMNT,
     1C1,C2,C3,PLAN,WH2O,CAUSE,COFF,AVOIDC,IMAX,PRINEX,FIT,LAMEND
      DIMENSION BUCK(20),ZERO(20),NSB(20),NSZ(20),Y11(200),U1(200)
      DIMENSION C(200),CT(20),TI(20,20),GN(20,20),NK(20)
      DIMENSION F(200),         FLAM(200),ALAMB(200),ELEMNT(200)
      DIMENSION C1(200),C2(200),C3(200),ALAMDA(200),TAU(200)
C     MULTIPLICATION OF FILTER,CONTINUOUS,AND BAND ABSORBTIONS
C     ACCORDING TO SETTING OF PLAN, EXTRAPOLATION ACCORDING TO EXTRAP,
C     CONTINUOUS ABSORBTION ACCORDING TO AVOIDC
      IF(PRINEX) 2,2,8
C     EXTRAPOLATION IN ATM. DATA CARD, EXTRAPOLATE TO ENDEXT OR WHEN
C     CODEXT=EQUAL TO NEXT SET OF DATA WITH LESS TRANSMISSION
C     NO EXTRAPOLATION WHEN EXTRAP=NO, DATA AFTER EXTRAP. ASSUMED
2     READ INPUT TAPE 5,1,BEGEXT,CODEXT,ENDEXT,BPEXT,EPEXT,EXTRAP
1     FORMAT (20X,F10.5,A5,5X,3F10.5,8X,A2)
      PRINEX=1.
      QNO=(+2HNO)
      QEQ=(+5HEQUAL)
      QNOT=(+3HNOT)
      QH=(+1HH)
      QS=(+5HSTRAN)
      QW=(+5HWKRAN)
      QE=(+5HELSAS)
      QG=(+5HGATES)
      QD=(+5HDEVEL)
      QGR=(+4HGREV)
      QC=(+1HC)
      QO=(+1HO)
      QN=(+1HN)
B     IF(EXTRAP/QNO) 3,8,3
3     WRITE OUTPUT TAPE 6,4,BEGEXT,CODEXT,ENDEXT,BPEXT,EPEXT
4     FORMAT (35H1AN EXTRAPOLATION WILL BE MADE FROM,F7.3,4H TO A5,F7.3/
     125H USING COMPUTED DATA FROM,F7.3,2HTO,F7.3)
      PINTER=EPEXT-BPEXT
8     ERASE NEL,F,FLAM,FEXTR
      KLAM=1
      SQSECZ=SQRTF(SECZ)
      SQSZW=SQRTF(SECZ*WH2O)
      SQSZGW=SQRTF(SECZ*WHGATE)
      WSECZ=WH2O*SECZ
      GWSECZ=WHGATE*SECZ
B     IF(CODEXT/QEQ) 6,5,6
5     ENDX=15.
      GO TO 9
6     ENDX=ENDEXT
B 9   IF(AVOIDC/QNOT) 67,69,67
69    TCONT=1.
      GO TO 7
B 67  IF(CAUSE/QH) 74,73,74
73    TCONT=EXPF(-COEF*WSECZ)
      GO TO 7
74    TCONT=EXPF(-COEF*SECZ)
```

```
7       WRITE OUTPUT TAPE 6,190,SECZ,TCONT
190     FORMAT(10H0SEC(Z) = ,F6.3/21H0CONTINUOUS TRANS. = ,F6.4)
        DO 10 LAM=1,200
C       KLAM IS IND. VARIABLE FOR BAND ABS. COEFICIENTS
C       LAM IS IND. VARIABLE FOR PRODUCT ABS.
C       WHICH REGION     EXTRAPOLATION, PREPARING, OR OTHER
B       IF(EXTRAP/QNO) 20,11,20
20      IF(ALAMB(KLAM)-BEGEXT) 11,21,21
21      IF(ALAMB(KLAM)-ENDX) 22,11,11
C       IN EXTRAPOLATION REGION
22      FLAM(LAM)=FLAM(LAM-1) +0.05
        F(LAM) =FEXTR
        IF(FLAM(LAM)-ALAMB(IMAX)) 24,121,121
C       DOES DATA EXIST
24      IF(ALAMB(KLAM)-FLAM(LAM)) 25,25,10
C       NOW PAST A DATA POINT
B 25    IF(CODEXT/QEQ) 23,26,23
26      LOOK=1
        GO TO 13
23      KLAM=KLAM+1
        GO TO 10
11      LOOK=0
C       WHICH PLAN TO BE USED
B 13    IF(PLAN/QS) 14,15,14
15      X=C1(KLAM)
        NX=1
        GO TO 40
B 14    IF(PLAN/QW) 16,17,16
17      X=C2(KLAM)
        NX=2
        GO TO 40
B 16    IF(PLAN/QE) 18,19,18
19      X=C3(KLAM)
        NX=3
        GO TO 40
B 18    IF(PLAN/QG) 36,30,36
30      IF(C1(KLAM)-1.) 31,31,15
31      IF(C2(KLAM)-1.) 33,33,17
33      IF(C3(KLAM)-1.) 199,199,19
B 36    IF(PLAN/QD) 38,37,38
B 38    IF(PLAN/QGR) 198,30,198
B 37    IF(FLEMNT(KLAM)/QH) 19,39,19
39      IF(C1(KLAM)-1.) 41,41,15
41      IF(C2(KLAM)-1.) 197,197,17
40      IF(X) 51,51,70
C       SEARCH FOR ANOTHER COEFFICIENT
51      IF(NX-2) 52,58,54
52      IF(C2(KLAM)-1.) 54,54,53
53      X=C2(KLAM)
        NX=2
        GO TO 70
54      IF(C3(KLAM)-1.) 196,196,55
55      X=C3(KLAM)
        NX=3
        GO TO 70
58      IF(C3(KLAM)-1.) 59,59,55
59      IF(C1(KLAM)-1.) 196,196,62
62      X=C1(KLAM)
```

```
          NX=1
          GO TO 70
   64     IF(C1(KLAM)-1.) 65,65,62
   65     IF(C2(KLAM)-1.) 196,196,53
   C      PRODUCT OF CONTINUOUS AND BAND ABSORBTION PLACED IN F
   70     IF(X-1.) 71,71,72
   72     X=X-1.
   71     IF(NX-2) 76,77,78
   B 76   IF(PLAN/QGR) 300,301,300
   B 301  IF(ELEMNT(KLAM)/QH) 302,300,302
   302    F(LAM)=TCONT*EXPF(-X*SQSZGW)
          GO TO 80
   300    F(LAM)=TCONT*EXPF(-X*SQSZW)
          GO TO 80
   B 77   IF(PLAN/QGR) 310,311,310
   B 311  IF(ELEMNT(KLAM)/QH) 312,310,312
   312    F(LAM)=TCONT*EXPF(-X*GWSECZ)
          GO TO 80
   310    F(LAM)=TCONT*EXPF(-X*WSECZ)
          GO TO 80
   78     ERARG=X*SQSECZ
          F(LAM)=TCONT*(1.0-ERR169(ERARG))
          IF(F(LAM)) 79,80,80
   79     F(LAM)=0.
    80    IF(LOOK) 110,110,81
   C      CHECK IF CAN NOW END THE EXTRAPOLATION, YES IF TRANS BY DATA LESS
   81     IF(FEXTR-F(LAM)) 83,82,82
   82     ENDX=FLAM(LAM)
   C      USE TRANS. AT DATA POINT HAVE JUST PASSED
          GO TO 110
   83     F(LAM)=FEXTR
          KLAM=KLAM+1
          GO TO 10
   110    FLAM(LAM)=ALAMB(KLAM)
   B      IF(EXTRAP/QNO) 111,115,111
   111    IF(FLAM(LAM)-BPEXT) 115,112,112
   112    IF(FLAM(LAM)-EPEXT) 120,115,115
   C      IN PREPARING REGION
   120    DLAM=0.5*(ALAMB(KLAM+1)-ALAMB(KLAM-1))
          FEXTR=F(LAM)*DLAM/FINTER+FEXTR
   115    KLAM=KLAM+1
          IF(FLAM(LAM)-ALAMB(IMAX)) 10,121,121
   121    LAMEND=LAM
          GO TO 210
   199    WRITE OUTPUT TAPE 6,200,ALAMB(KLAM),ELEMNT(KLAM),C1(KLAM),C2(KLAM)
         1,C3(KLAM)
   200    FORMAT(23H0NO PREFERENCE IN GATES/1H0,5F12.4)
          CALL EXIT
   198    WRITE OUTPUT TAPE 6,201,PLAN
   201    FORMAT(26H0I KNOW OF NO PLAN CALLED ,A6)
          CALL EXIT
   197    WRITE OUTPUT TAPE 6,202,ALAMB(KLAM),ELEMNT(KLAM),C1(KLAM),C2(KLAM)
         1,C3(KLAM)
   202    FORMAT(35H0NO PREFERENCE GIVEN FOR WATER ABS./1H0,5F12.4)
          CALL EXIT
   196    WRITE OUTPUT TAPE 6,203,PLAN,ALAMB(KLAM),ELEMNT(KLAM),C1(KLAM),C2(
         1KLAM),C3(KLAM)
   203    FORMAT(17H0FIRST OPTION IN ,A6,30H NOT ALLOWED AND NO PREFERENCE/1
```

```
     1H0,5F12.4)
      CALL EXIT
10    CONTINUE
      WRITE OUTPUT TAPE 6,204
204   FORMAT(13H0BREW IS FULL)
      CALL EXIT
C     SECOND TIME THROUGH
210   DO 220 LAM=1,LAMEND
      ALAM=FLAM(LAM)
220   F(LAM)=F(LAM)*FRENCH(ALAM,ALAMDA,TAU,N2)
      RETURN
      END
```

```
CBRAD2
C  BLACKBODY RADIANCE FOR LUNAR THERMAL SCANNINGS                 001
    DIMENSION ICEST(5),ALAMDA(400),TAU(400),SOUT(9000)
C   IMPROVED VALUES OF RADIATION CONSTS. TO PLANCK FUNCTION.
     PLANCKF(ALAM,TEMP)=1.19064E10/(ALAM**5*(EXPF(1.43879E+4/(ALAM*
   1TEMP))-1.))
C  FSTTMP ,FINTMP ARE FIRST AND LAST VALUES OF TEMPERATURE        008
    K=0
999 READ INPUT TAPE 5,5,STEPSZ,FSTTMP,FINTMP
 5  FORMAT(3F10.2)
      N1=1                                                        011
  10  N2=N1+2                                                     012
    READ INPUT TAPE 5,15,(ALAMDA(I),TAU(I),I=N1,N2)               013
  15 FORMAT(6F10.5)                                               014
C   TEST FOR END OF DATA** BLANK FIELD=-0                         015
B      IF(ALAMDA(N2)/400000000000)16,20,16                        016
  16  N1=N1+3                                                     017
      GO TO 10                                                    018
C  N2 IS NUMBER OF DATA ITEMS                                     019
  20  N2=N2-1                                                     020
B      IF(ALAMDA(N2)/400000000000)22,20,22                        021
 22 ERASE BADSW
    DO 1000 I=2,N2
    STEPSZ=MIN1F(STEPSZ,ALAMDA(I)-ALAMDA(I-1))
    IF(ALAMDA(I)-ALAMDA(I-1))1001,1000,1000
1001 BADSW=1.
    WRITEOUTPUTTAPE6,1002,ALAMDA(I),ALAMDA(I-1)
1002 FORMAT(18H0DATA OUT OF ORDER F10.5,8H FOLLOWS F10.5)
1000 CONTINUE
      TEMP=FSTTMP-1.                                              040
C  VALUE OF INTEGRAL PRINTED AT UPPER LIMIT                       082
    IF(BADSW)300,300,999
 300  TPRNTS=ALAMDA(N2)                                           083
      N=1                                                         051
C  INITIAL CONDITIONS FOR INTEGRATION                             054
 201  ALAM=ALAMDA(1)                                              055
      TEMP=TEMP+1.                                                056
      TAU1=TAU(1)                                                 057
C  INITIALIZE S TO 0 BEFORE NEXT INTEGRAL EVALUATED               088
       S=0                                                        089
    ANLAM=PLANCKF(ALAM,TEMP)
       SDOT=ANLAM*TAU1                                            060
  50 CALL ICE(STEPSZ,ALAM,TPRNTS,5.E-6,.0001,N,S,SDOT,ICEST,JJ)
  51  GO TO (211, 52,400,500),JJ
  52 JJ=XICEF(A)                                                  065
      GO TO 51                                                    066
C  INTERPOLATION ROUTINE                                          067
 211 SDOT=PLANCKF(ALAM,TEMP)
    IF(SDOT)206,52,52
206 ERASE SDOT
    GO TO 52
 400 K=K+1
    SOUT(K)=S
    IF(K-36)432,430,430
 430 WRITE OUTPUT TAPE 7,443,(SOUT(I),I=1,K)
 443 FORMAT(6E13.6)
    K=0
 432 IF(TEMP-FINTMP) 201,431,431
```

```
 500 WRITE OUTPUT TAPE6,505,TEMP
 505 FORMAT(1H1,40HTHE INTEGRAL DOES NOT CONVERGE FOR TEMP=,F4.0)
431  CALL EXIT
     END
```

62 CARDS

```
*IO   FAP
      ENTRY  READR
      ENTRY  WRITR
*UNITS LIMITED TO B-CHANNEL
*CALLING SEQUENCE TO READR IS
*     CALL READR(BUFR,EOF,ERR,NTP)
*WHERE BUFR IS OUTPUT ARRAY NAME
*EOF IS END OF FILE SIGNAL NEGATIVE WHEN EOF READ
*ERR IS HOPELESS TAPE SIGNAL NEGATIVE WHEN TAPE HOPELESS
*WHERE  NTP IS THE B-CHANNEL TAPE USED-- FORTRAN2 INTEGER
 UNIT MACRO
      CLA*   4,4
      PDC    0,7
      CLA    $(IOU)
      STA    *+1
      CLA    **,7
      ADD    =020
      PAC    0,7
 UNIT END
 READR LMTM
      UNIT                     (GET TAPE-UNIT CHANNEL B)
      STZ*   3,4               (CLEAR HOPELESS TAPE SWITCH)
      STZ*   2,4               (CLEAR END OF FILE SWITCH)
      CLA    =30               (NUMBER TRYS BAD READ)
      STO    ERCT
      CLA    1,4               (ADDRESS TOP OF BUFFER)
      SUB    WRDS              (SIZE OF BUFFER -1)
      STA    INPT              (BOTTOM OF BUFFER)
 R1   RDS    0,7               (READ TAPE)
      RCHB   INPT
      TCOB   *                 (CP DELAY ON CHANNEL)
      TRCB   ERR               (CHECK FOR PARITY ERROR)
      TEFB   OUT               (LOOK FOR END OF FILE)
      TRA    4,4               (NORMAL RETURN)
 OUT  SSM                      (SET EOF SWITCH)
      STO*   2,4
      TRA    4,4               (RETURN WITH EOF=NEGATIVE)
 ERR  BSR    0,7               (BACK OVER BAD RECORD)
      CLA    ERCT
      SUB    =1
      STO    ERCT
      TPL    R1                (GO TRY AGAIN)
      STO*   3,4               (RETURN WITH ERR=NEGATIVE)
      TRA    4,4               (INPUT TAPE HOPELESS)
 INPT IORT   **,,1995          (CHANNEL COMMAND)
 ERCT OCT    0
 WRDS DEC    1994
*CALLING SEQUENCE TO WRITR IS
*     CALL WRITR(BUF,IBAD,TAPND,NTP)
*WHERE  BUF IS INPUT ARRAY NAME
*IBAD IS A COUNTER OF NUMBER BLANK RECORDS WRITTEN
*TAPND IS RETURNED NEGATIVE WHEN END OF TAPE IS
*PREMATURELY REACHED
*WHERE  NTP IS THE B-CHANNEL TAPE USED-- FORTRAN2 INTEGER
*UNITS LIMITED TO B-CHANNEL
*
*
```

```
WRITR LMTM
      UNIT
      CLA     1,4                 (BUFFER ADDRESS)
      SUB     WRDS
      STA     OTPT
*
*
*
*
 W1   WRS     0,7                 (WRITE TAPE)
      RCHB    OTPT
      TCOB    *
      ETTB                        (TEST FOR END OF TAPE)
      TRA     TEND                (TAPE END TEST SET)
W2    TRCB    WER                 (BAD WRITE TEST)
      CLA     GDR                 (GOOD RECORD COUNT)
      ADD     =1
      STO     GDR
      TRA     4,4                 (NORMAL RETURN)
WER   BSR     0,7                 (BACK TAPE OVER BAD RECORD)
      CLA     GDR
      SUB     =1
      TZE     W3
      TMI     W3
      BSR     0,7                 (BACK OVER GOOD RECORD)
      RDS     0,7                 (DUMMY-READ GOOD RECORD)
      RCHB    DUMM
      TCOB    *
W3    STZ     GDR                 (RESET GOOD RECORD COUNT)
      WRS     0,7
      WRS     0,7
      WRS     0,7
      WRS     0,7
      WRS     0,7                 (BLANK 19 INCHES BAD TAPE)
      CLA*    2,4
      ADD     =01000000
      STO*    2,4                 (BLANKED RECORD COUNT)
      TRA     W1
TEND  SSM
      STO*    3,4                 (SIGNAL TAPE PREMATURELY ENDED)
      TRA     W2
DUMM  IORTN   0,,2000             (DUMMY READ COMMAND)
OTPT  IORT    **,,1995            (OUTPUT COMMAND)
GDR   OCT     0
      END
     END
```

```
*     LIST8
*     LABEL
*     SYMBOL TABLE
CCOPY
C     SUBROUTINE COPY TO TRASFER DATA FROM TAPE FILE TO NEW TAPE BEFORE
C     ADDING ON NEW DATA- HENCE AVAID LOSING  ORIGINAL DATA
      SUBROUTINE COPY (BUFR,LBUFR,IBAD,NRL,NTP1,NTP2)
      DIMENSION BUFR(15,133),LBUFR(15,133)
   60 ERASE LSCAN,KT,NT
C     KT IS NO. OF RECORDS PER SCAN AND NT IS NO. OF RECORDS COPIED
   61 CALL READR (BUFR,EOF,ER1,NTP1)
C     BUFR IS OUTPUT ARRAY NAME AND HAS 1995 STORAGE SPACES
C     EOF IS END OF FILE SIGNAL.  NEGATIVE WHEN SIGNAL ENCOUNTERED.
C     ER1 IS HOPELESS TAPE SIGNAL.  NEGATIVE WHEN TAPE IS HOPELESS.
      IF (EOF) 62,63,63
   62 RETURN
   63 IF (ER1) 64,66,66
   64 WRITE OUTPUT TAPE6,65,LBUFR(15,133),LBUFR(14,133)
   65 FORMAT ( 9H1SCAN NO.,I4,4HWITH ,I4,88HDATA POINTS HAVE BEEN TRANSF
     1ERED  COPY STOPPED BECAUSE IT COULD NOT READ THE NEXT RECORD )
      CALL EXIT
   66 CALL WRITR (BUFR,IBAD,TAPND,NTP2)
C     IBAD IS A COUNTER OF NO.BLANK RECORDS WRITTEN
C     TAPND MEANS END OF RECORD PREMATURELY REACHED
C     SET UT COUNTER FOR BACK SPACE PURPOSE
      IF(LSCAN-LBUFR(15,133)) 67,68,67
   67 LSCAN=LBUFR(15,133)
      KT=1
      GO TO 69
   68 KT=KT+1
   69 NT=NT+1
      IF(TAPND) 70,73,73
   73 NRL=NRL-IBAD
      IF (NRL)70,61,61
C     NEGATIVE TAPND MEANS END OF TAPE PREMATURELY REACHED
   70 DO 71 I=1,KT
      BACKSPACE NTP1
   71 BACKSPACE NTP2
      NT=NT-KT
      END FILE NTP2
      CALL UNLOAD (NTP2)
      WRITE OUTPUT TAPE6,72, LBUFR(15,133)
   72 FORMAT(17H1DATA OF SCAN NO.,I4,31H AND THEREAFTER ARE ON NEW TAPE)
      NTP2=19
      NRL=NRL+NT
      GO TO 60
      END
```

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NOTATIONS AND UNITS

$A(T)$ = parameter of the atmospheric model computed by FAKIR

A_d = area of the detector, cm^2

$B(T)$ = parameter of the atmospheric model computed by FAKIR

$C(T)$ = parameter of the atmospheric model computed by FAKIR

c = constant of the bucking signal counter

c = velocity of light in vacuum, $2{,}997{,}929 \times 10^{10}$ cm s^{-1}

d_c = total deflection of the recording pen due to the calibration signal, mm

d_m = observed deflection of the recording pen, mm

$d(t)$ = total deflection of the recording pen, mm

F_c = f-number in the calibration mode of operation

F_{eff} = effective f-number of the optical system during measurements

h = Planck's constant, 6.6252×10^{-34} W sec^2

I = radiant power on the detector, W

j = index at integral values of brightness temperature in CORRADIANCE Tables

j = index of data points

j = index air mass at points selected for least square fit

$K(t)$ = constant of the pyrometer, W mm^{-1}

$K(t_i)$ = constants of the pyrometer at calibration time t_i, W mm^{-1}

k = Boltzmann's constant, 1.38042×10^{-23} W sec $°K^{-1}$

m = air mass at a given data point (along the line of sight)

m_j = air mass at points selected for the least squares

m_0 = unit air mass

N = zero-suppression given in counter reading

$N(\lambda,T)$ = spectral blackbody radiance, W $cm^{-2} sr^{-1} \mu^{-1}$

$N[\lambda,T_C(t_c)]$ = spectral radiance of the calibration blackbody, W $cm^{-2} sr^{-1} \mu^{-1}$

$N[\lambda,T_R(t_c)]$ = spectral radiance of the reference blackbody, W $cm^{-2} sr^{-1} \mu^{-1}$

n = bucking signal given in counter reading

q = pen center deflection, mm

R_c = instrumental constant in the calibration mode of operation, cm^2 sr

R_m = instrumental constant, cm^2 sr

$S(T)$ = blackbody radiance corrected for instrumental transmittance (CORRADIANCE), W $cm^{-2}sr^{-1}$

$S[T(\xi,\eta)]$ = CORRADIANCE at specific orthographic coordinates, W $cm^{-2}sr^{-1}$

T_C = temperature of the calibration blackbody, °K

T_c = constant temperature level of a given isotherm, °K

T_j = a particular integral value of T, °K

T_R = temperature of the reference blackbody, °K

$T_R(t_c)$ = temperature of the reference blackbody at calibration time t_c, °K

$T(t)$ = brightness temperature, °K

T_x = a particular brightness temperature, non-integral, °K

$T(\xi,\eta)$ = brightness temperature, °K

$\Delta T(T)$ = temperature resolution of the pyrometer, °K

t = time, sec

t_c = time of a calibration measurement, sec

t_i = time at which y_i is measured, sec

$\bar{t}_\ell$ = time at which $\bar{y}_\ell$ is measured, sec

$\bar{t}_r$ = time at which $\bar{y}_r$ is measured, sec

x = time given in digitized counts from an arbitrary origin

$y_b(t)$ = sky level baseline in digitized counts

y_i = infrared measurement at a specific time with respect to an arbitrary level and given in digitized counts

$\bar{y}_\ell$ = average sky infrared measurement to the left of the lunar disk, given in digitized counts

$\bar{y}_r$ = average sky infrared measurement to the right of the lunar disk, given in digitized counts

$y(t)$ = digitized lunar infrared measurement

$y(t_c)$ = infrared measurement at a calibration, in digitized counts

z = zenith angle, deg

ε_c = radiant emissivity of the calibration blackbody

ε_R = radiant emissivity of the reference blackbody

η = lunar horizontal orthographic coordinate

$\bar{\eta}$ = horizontal orthographic coordinate of the barycenter of the resolution element

η_n = specific value of lunar horizontal orthographic coordinate

$\eta(t)$ = horizontal orthographic coordinate of a measured lunar region as a function of time

λ = wavelength, μ

ξ = lunar vertical orthographic coordinate

$\bar{\xi}$ = vertical orthographic coordinate of the barycenter of the resolution element

ξ_n = specific value of lunar vertical orthographic coordinate

$\xi(t)$ = vertical orthographic coordinate of a measured lunar region as a function of time

ρ_0 = radiant reflectance of the mirror (aluminized) of the telescope

$\tau_A(m_j, \lambda)$ = spectral atmospheric radiant transmittance

$\bar{\tau}_A[T(\xi, \eta), m, \omega_0]$ = mean atmospheric radiant transmittance

$\bar{\tau}_A(m_j, T_i)$ = mean atmospheric radiant transmittance for a given ω_0

$\tau_d(\lambda)$ = spectral radiant transmittance of the window of the detector

$\tau_f(\lambda)$ = spectral radiant transmittance of the filter

$\tau_0(\lambda)$ = spectral instrumental transmittance

ω = amount of precipitable water along the path

ω_0 = amount of precipitable water for one air mass

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