A COMPUTER PROGRAM TO SOLVE THE HEAT-CONDUCTION EQUATION IN THE LUNAR SURFACE FOR TEMPERATURE-DEPENDENT THERMAL PROPERTIES

by

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ABSTRACT

A computer program is presented to solve the heat conduction equation for boundary conditions appropriate to the lunar surface during an eclipse and during a lunation. This program allows for very general representations of the temperature- and depth-dependent thermal properties in a multilayer model. Both infrared and microwave brightness temperatures may be predicted for the Moon and similar rotating bodies in which thermal conduction and radiative transfer are the most significant forms of energy transport near the surface.

Author

CONTENTS

I. INTRODUCTION

Since the classic studies of thermal conduction beneath the lunar surface, made by Wesselink (1948) and by Piddington and Minnett (1949), interest in this problem has been stimulated by detailed observations made possible by advances in instrumentation, and by the expectation of directly investigating the lunar surface itself. Because thermal conduction may, under certain astrophysical conditions, play an important role in energy transport, its basic equations have been applied to studies of the Martian surface by Sinton and Strong (1960), to the solar corona, and to the planet Mercury. As the result of the accumulation of more detailed infrared and microwave data, it has become important to solve the problem of thermal conduction beneath the lunar surface for less-idealized models than present analytical methods allow. A computer program has therefore been written to compute infrared and microwave brightness temperatures during both an eclipse and a lunation for very general assumed thermal properties and surface structures.

The simplest model of the lunar surface consists of a homogeneous plane-parallel medium with temperature- and depth-independent thermal properties. Although this model lends itself readily to analytical solution, Piddington and Minnett (1949) and Jaeger and Harper (1950) first showed its inconsistency with the data, and suggested that less-idealized models are necessary. More recently, several analytical solutions have been obtained for microwave brightness temperatures directly, rather than for their lowest Fourier harmonics. Such exact solutions are necessary to interpret increasingly refined millimeter wave observations. Using Fourier techniques, Muncey (1958, 1963) has derived both infrared and microwave temperatures for the case of thermal properties linearly dependent on temperature in a homogeneous medium with a plane boundary. Copeland (1965) has obtained analytical expressions for the microwave radiation from a two-layer model with temperature-independent thermal properties. Also using Laplace transform techniques, Bhatnagar (1965) has solved the problem, including radiative conductivity, for a material whose density is allowed to vary smoothly with depth. Unfortunately, the complexity of these solutions for the simple cases under consideration strongly suggests that for more realistic geometrical structures and temperature-dependent thermal properties, including the simulation of radiative transfer in the medium, this problem may not be amenable to analytical solution.

Rewriting the heat conduction equation in terms of finite differences permits numerical solutions of a much larger class of problems. These problems include calculations of infrared brightness temperatures on the basis of two-layer models by Jaeger and Harper (1950), models with temperature-dependent thermal properties by Watson (1961), and models including both complications by Ingrao, Young and Linsky (1965)*.

Ideally, one desires a computing scheme which predicts both infrared and microwave brightness temperatures during an eclipse and a lunation for postulated lunar materials with arbitrarily temperature- and depth-dependent thermal and electric properties. Such a scheme must be numerical, but should not be unnecessarily limited by either the approximations inherent in the finiteness of the differences or by the analytical representations of the material parameters allowed. In addition, if this computing scheme closely simulates the actual physical situation, one could readily alter the representation of these parameters and the boundary conditions imposed. Thus the ability to adequately solve more refined lunar conduction problems would be limited by the suitability of the model itself, and not by the difficulty of devising a new numerical solution.

The present scheme, a generalization of that used in Paper I, is an attempt to incorporate each of these features with a minimum waste of computation time. The scheme has been written in FORTRAN II, which, with certain nonstandard subroutines as noted below, should be compatible with any IBM 7090 or 7094 system. We will describe how each part of the program operates and will note the modifications that can be made to take into account other forms of energy transport or different representations of the thermal or electromagnetic properties.

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*Hereafter referred to as Paper I.

II. BASIC EQUATIONS

With the assumption of a plane-parallel geometry, the heat conduction equation is of the form:

$$\rho c(x,T) \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left[k(x,T) \frac{\partial T}{\partial x} \right] + Q(x,t) \tag{1}$$

where
- x = depth beneath the surface
- T = absolute temperature
- ρ = density
- $c(x,T)$ = specific heat
- $k(x,T)$ = thermal conductivity
- $Q(x,t)$ = source term

The source term $Q(x,t)$ could arise from absorbed solar radiation in a partially transparent medium, as considered by Buettner (1963), or from radioactive decay. Eq. (1) may be written in terms of finite differences as

$$\rho c(x,T) \frac{\partial T}{\partial t} = \frac{\left[k(x,T) \frac{\partial T}{\partial x} \right]_{x+\frac{\Delta x}{2}} - \left[k(x,T) \frac{\partial T}{\partial x} \right]_{x-\frac{\Delta x}{2}}}{\Delta x} + Q(x,t) \quad . \tag{2}$$

In this program the medium is divided into six layers, each consisting of an arbitrary number of sublayers or depth integration steps. A continuous depth dependence of $\rho c(x,T)$ and $k(x,T)$ may be approximated by specifying their values or their parameters in these six or more layers. One may specify different values of the depth integration step Δx in each layer to allow, for example, a more accurate representation of the temperature distribution near the surface where large temperature gradients exist. At the boundary of two layers we take such changes of the integration step into account.

The program considers explicitly three models of the lunar surface material, in each of which $Q(x,t)$ is assumed to be zero.

Model 1 Temperature-independent properties

$$c(x,T) = c(x)$$
$$k(x,T) = k(x)$$

Model 2 Radiative conductivity included

$$c(x,T) = c(x)$$
$$k(x,T) = k(x) + 4\,\bar{\varepsilon}_M \sigma T^3(x)\,s(x)$$

where $\bar{\varepsilon}_M$ and $s(x)$, as defined more fully in Paper I, are the radiant infrared emissivity and effective mean spacing of radiating surfaces.

Model 3 Linearly temperature-dependent properties

$$c(x,T) = c_o(x)T$$
$$k(x,T) = k_o(x)T \quad .$$

Using forward and central differences and writing the temperature at a time $n(\Delta t)$ and depth $m(\Delta x)$ as T_m^n, one may write the heat conductivity equation in a layer as follows:

Models 1 and 2

$$T_m^n = T_m^{n-1} + A_L \left\{ \left[K_L + 4\,\bar{\varepsilon}_M \sigma s_L (T_m^{n-1})^3\right] \left[T_{m+1}^{n-1} - 2T_m^{n-1} + T_{m-1}^{n-1}\right] + \left[3\,\bar{\varepsilon}_M \rho s_L (T_m^{n-1})^2\right] \left[(T_{m+1}^{n-1})^2 - 2T_{m+1}^{n-1}\,T_{m-1}^{n-1} + (T_{m-1}^{n-1})^2\right] \right\} , \tag{3}$$

where

$$A_L = \frac{\Delta t}{\rho_L c_L (\Delta x)_L^2}$$

Model 3

$$T_m^n = T_m^{n-1} + A_L \left\{ (T_{m+1}^{n-1} - 2T_m^{n-1} + T_{m-1}^{n-1}) + \frac{1}{4T_m^{n-1}} \left[(T_{m+1}^{n-1})^2 - 2T_{m+1}^{n-1}\,T_{m-1}^{n-1} + (T_{m-1}^{n-1})^2\right] \right\} , \tag{4}$$

where

$$A_L = \left(\frac{k_o}{\rho c_o}\right) \frac{\Delta t}{(\Delta x)^2} \quad .$$

At the boundary of two layers, L and L+1, Eq. (2) may be written as:

Models 1 and 2

$$T_m^n = T_m^{n-1} + B \left\{ \left[K_{L+1} + 4\bar{\epsilon}_M \sigma s_{L+1} \left(\frac{T_{m+1}^{n-1} + T_m^{n-1}}{2} \right)^3 \right] \left[\frac{T_{m+1}^{n-1} - T_m^{n-1}}{(\Delta x)_{L+1}} \right] - \left[K_L + 4\bar{\epsilon}_M \sigma s_L \left(\frac{T_m^{n-1} + T_{m-1}^{n-1}}{2} \right)^3 \right] \left[\frac{T_m^{n-1} - T_{m-1}^{n-1}}{(\Delta x)_L} \right] \right\} , \quad (5)$$

where

$$B = \frac{4(\Delta t)}{(\rho_L c_L + \rho_{L+1} c_{L+1}) \left[(\Delta x)_L + (\Delta x)_{L+1} \right]} ,$$

Model 3

$$T_m^n = T_m^{n-1} + \frac{B}{T_m^{n-1}} \left[k_{o,L+1} \left(\frac{T_{m+1}^{n-1} + T_m^{n-1}}{2} \right) \left(\frac{T_{m+1}^{n-1} - T_m^{n-1}}{(\Delta x)_L} \right) - k_{o,L} \left(\frac{T_m^{n-1} + T_{m-1}^{n-1}}{2} \right) \left(\frac{T_m^{n-1} - T_{m-1}^{n-1}}{(\Delta x)_L} \right) \right] , \quad (6)$$

where

$$B = \frac{4(\Delta t)}{(\rho_L c_L + \rho_{L+1} c_{L+1}) \left[(\Delta x)_L + (\Delta x)_{L+1} \right]} .$$

Other representations of c(x,T) and k(x,T), for example, by a power series in T or a tabular set of values, and the inclusion of source terms, may be readily accomplished by inserting difference equations similar to (3), (4), (5), and (6) in subroutine EXTRA. In addition, heat conductivity equations for different geometries, such as spherical geometry, can be taken into consideration in this manner.

The surface boundary condition at a position on the lunar surface with rectangular coordinates (ξ,η) may be written:

$$k(x,T)\left(\frac{\partial T}{\partial x}\right)_{x=0} = \bar{\varepsilon}_M \sigma T_S^4 - \bar{\varepsilon}_b I(\xi,\eta,t) \quad , \tag{7}$$

where the insolation $I(\xi,\eta,t)$, when the Sun is above the horizon, is

$$I(\xi,\eta,t) = f(t)\sigma T_S^4 \left[-\xi \sin \frac{2\Pi t}{P} + \left(1-\eta^2-\xi^2\right)^{\frac{1}{2}} \cos\left(\frac{2\Pi T}{P}\right)\right] \quad , \tag{8}$$

and

$$\bar{\varepsilon}_b = 1 - A_b$$

where $\bar{\varepsilon}_b$ = bolometric emissivity computed from the bolometric albedo A_b for solar irradiance
P = synodic period of revolution
T_S = theoretical subsolar point temperature, (assuming no heat conducted inward)
$f(t)$ = reduction in insolation during penumbral eclipse .

In computing the surface temperature T_o, Newton's method is used to solve the equations:

<u>Models 1 and 2</u>

$$K_1 \left[\frac{-T_2^n+4T_1^n-3T_o^n}{2(\Delta x)_1}\right] + 4\bar{\varepsilon}_M \sigma s_1 \left[\frac{T_1^n+T_o^n}{2}\right]^3 \left[\frac{T_1^n-T_o^n}{(\Delta x)_1}\right]$$
$$= \bar{\varepsilon}_M \sigma (T_o^n)^4 - \bar{\varepsilon}_b I(\xi,\eta,t) \quad , \tag{9}$$

<u>Model 3</u>

$$- k_o \left(\frac{T_o^n+T_1^n}{2}\right) \left[\frac{3T_o^n-4T_1^n+T_2^n}{2(\Delta x)_1}\right] = \bar{\varepsilon}_M \sigma (T_o^n)^4 - \bar{\varepsilon}_b I(\xi,\eta,t) \quad . \tag{10}$$

As in the case of the above heat conductivity equations, k(x,T) can be included by writing the corresponding difference equations in subroutine EXTRA. One could also consider a rough surface in a statistical manner here. As a lower boundary condition we have assumed the temperature to be a constant, but a constant-flux lower boundary condition can be specified by holding the temperatures constant at the two lowest depths.

Radio brightness temperatures $T_B(t)$ are evaluated from the temperature distributions T(x,t) in the Rayleigh-Jeans approximation by the equation

$$T_S(t) = (1-R)\left[a \sec\theta_{in} \int_o^{xmax} T(x,t)e^{-ax \sec\theta_{in}} dx + T(x_{max},t)e^{-ax_{max} \sec\theta_{in}}\right] , \qquad (11)$$

where R = Fresnel reflection loss

a = electromagnetic absorption coefficient;

the assumed form of, a, is

$$a = a_o\lambda^p \qquad (12)$$

with a_o and p, parameters. θ_{in}, the angle from the normal for a ray leaving the surface at the observer's zenith angle θ, is obtained from the index refraction, n, by use of Snell's law

$$\sin\theta = n\sin\theta_{in} \quad . \qquad (13)$$

Assuming negligible permeability and homogeneity of the lunar surface material, the Fresnel reflection loss at the surface for nonpolarized radiation is given by

$$R = \frac{1}{2}\left[\frac{\tan^2(\theta_{in}-\theta)}{\tan^2(\theta_{in}+\theta)} + \frac{\sin^2(\theta_{in}-\theta)}{\sin^2(\theta_{in}+\theta)}\right] . \qquad (14)$$

Evaluation of $T_B(t)$ for a statistical distribution of slopes and the evaluation of its net polarization could be done by modifying this basic computation procedure.

III. COMPUTING PROCEDURE

The solution of Eqs.(3) - (10) to obtain the temperature distribution T(x,t) during an eclipse is performed by the MAIN Program, and during a lunation by subroutine MONTH. In addition, the subroutines SOLUX, STATIC, EXTRA and NOCAL are called by these programs to perform specific operations. The non-standard features, subroutines HYPLOT, ICE3, and GIOH, the REREAD version of (TSH) and the function FRENCH, will be discussed below.

A. MAIN Program

This program computes surface temperatures and temperature distributions beneath the surface during an eclipse, and serves as a central-control routine which reads in most of the data and supervises the logical flow of computation. If one wishes to compute temperatures based on an assumed temperature distribution beneath the surface prior to eclipse, one can read in these temperatures U(I,1), for each depth integration step I by means of the TEMPERATURES card described below. In general, one does not know what initial temperature distribution is appropriate, and errors of 5°K or more may occur in the surface temperature during eclipse, especially for multilayer models. Thus one should allow the assumed initial temperature distribution to relax over the course of a complete lunation and should use the resulting temperature distribution as the pre-eclipse distribution. This may be done automatically by putting NMONTH = 1, 2, or 3 and NECLIP = 1 on the CONTROL card described below.

The MAIN program initially reads in all the data it will use, as well as reading in all or part of the data used by subroutines MONTH, NOCAL, and STATIC. It then switches control to subroutine MONTH if a number of lunations are to be simulated first and assumes that the last temperature distribution computed there is the appropriate pre-eclipse distribution. The pre-eclipse insolation is computed from the local solar zenith angle and from the value of the assumed theoretical equilibrium blackbody-temperature (TEMAX) read in by subroutine MONTH. This irradiance is reduced during penumbral eclipse by the factor f(t) computed by subroutine SOLUX for the end of each integration step.

For each time integration step N, the temperature at a depth M, U(M,N), is computed first inside each layer according to Eqs.(3), (4), or an analogous equation in subroutine EXTRA. At each interlayer boundary depth K, U(K,N) is computed from Eqs.(5), (6), or substitute in EXTRA. This process is then continued throughout the penumbral and umbral phases of eclipse and as far into the succeeding penumbral and post-eclipse phases as is specified. At certain intervals of elapsed time, determined by the value of TECLIP read in by subroutine STATIC, control is switched to STATIC for the evaluation of radio brightness temperatures, using the present temperature distribution for T(x,t) in Eq.(11). If, for the thermal parameters and values of Δt and Δx used, the difference equations become unstable, the program automatically decreases the value of Δt and restarts the eclipse simulation.

Finally, the program computes surface brightness temperatures for each five minutes of elapsed time, using subroutine NOCAL; computes, every thirty minutes, the ratio of these surface temperatures and the temperature distribution to the pre-eclipse surface temperature; and plots out and prints all these results.

To process efficiently the many kinds of data needed by this program, we have used the card rescanning feature of the REREAD version of subroutine (TSH) and the free-field G-type format of subroutine HUGIOH. The manner in which a card is to be read and the kind of data expected is determined by the first six letters of a code word at the beginning of the card. These cards need not be used in any special order, except that the CONTROL card must be last. When no card is read in, previous data are assumed. For each card or group of cards, we include the code word, its meaning, and the data expected on the card, in that order.

	CODE WORD		
1.	POSITION	--	Specified position on lunar surface
	ETA	--	Rectangular North-South coordinate
	XI	--	Rectangular East-West coordinate
2.	ECLIPSE	--	Photometric data and circumstances of eclipse
	E	--	Mean infrared emissivity near wavelength of maximum emission
	EBOL	--	Bolometric emissivity for solar irradiance
	TOE	--	Duration of penumbral eclipse in seconds at (ξ,η)
	TIME	--	Total duration of penumbral and umbral eclipse in seconds at (ξ,η)
	PEN	--	Time past end of umbral phase in units of TOE to continue computation

3. THERMAL -- Specification of thermal properties

LAYER -- Data on this card pertain to this and all lower layers

BV -- Conductivity (cal $cm^{-1} \circ K^{-1} sec^{-1}$)

BR -- Density (gm cm^{-3})

BC -- Specific heat (cal $gm^{-3} \circ K^{-1}$)

RAT -- Ratio of radiative to conductive flux at 350°K. This is used to determine value of S(x)

MODEL -- Model number. If MODEL = 4, 5, 6, or 7, then MAIN and MONTH will use equations in subroutine EXTRA.

Note: If these parameters are to vary with depth, several cards are needed, one for each layer or adjacent layers with the same parameters. These cards must be in descending order according to depth.

4. GAMMAS -- Alternative method of specifying thermal properties subject to the same conditions as in the above Note.

LAYER, RAT, MODEL -- Same as before.

GA -- Thermal parameter $(K\rho c)^{-\frac{1}{2}}$ $(cal^{-1}\ cm^{2} \circ K\ sec^{-\frac{1}{2}})$ (assuming ρ = 1 gm cm^{-3} and c = 0.2 cal $gm^{-3} \circ K^{-1}$)

5. DEPTHS -- Depth integration data

J(I) -- Cumulative number of integration steps at the base of the ith layer (The surface is step 1.)

X(I) -- Length of integration steps in Ith layer (cm).

6. TEMPERATURES

U(I, 1) -- Initial temperature distribution if eclipse calculation is to be performed immediately. Ten temperatures per card in descending order of depth are expected. The surface is designated by I = 1.

7. REDUCE -- Data required by subroutine NOCAL described below.

8. CONTROL -- This card initiates computations of eclipse or lunation temperature distributions.

These code symbols have the following meanings:

NMONTH = 0 No lunation.

= 1 Lunation done after reading in initial temperature distribution and other data in subroutine MONTH.

= 2 Lunation done using previous initial temperature distribution.

= 3 Lunations done using temperature distribution at end of previous lunation computation.

NECLIP = 0 No eclipse

= 1 Simulate an eclipse after temperature distribution is relaxed during a lunation if called for.

LRADIO = 0 No microwave brightness temperatures calculated.

= 1 Calculate microwave brightness temperatures assuming unit microwave emissivity.

= 2 (Subroutine STATIC called) Compute microwave brightness temperatures using previous electromagnetic absorption parameters.

NSOLUX = 0 Expect penumbral eclipse data in subroutine SOLUX.

= 2 Don't expect this data.

T = Time integration step (Δt) in seconds for the MAIN Program.

TMONTH = Time integration step (Δt) in seconds for subroutine MONTH.

B. Subroutine MONTH

This subroutine performs the same kind of calculations as the MAIN Program except with the insolation computed for the lunar surface feature considered for different times during a month according to Eq. (8). If the value of NMONTH is 1, this subroutine reads in two sets of data in this order:

1. TOL -- Duration of a month in units of a synodic month. (This allows for application to other planets or satellites rotating with different periods.)

TIME -- Duration of integration in units of a synodic month.

TEMAX -- The value of T_S in °K in Eq. (8).

2. UBEG(1) -- Initial temperature distribution in order of increasing depth with ten temperatures per card.

After a few checks to see whether the data are reasonable and that the computations will not be implausibly long, this subroutine uses the initial temperature distribution and the data read in by MAIN for the determination of subsequent surface temperatures and internal temperature distributions. Periodically, it also checks to see whether the equations are stable; if they are not, it restarts these computations with a smaller value of Δt. The integration in Eq. (11) for microwave temperatures is evaluated at intervals specified by the value of TIMER computed in subroutine STATIC. Every six hours it prints out the temperature distribution as well as the local zenith angle of the Sun, the surface brightness temperature, the elapsed time in hours, and the number of hours in darkness during nighttime. As further output, the program plots the interval temperature distribution every two days.

C. Subroutine STATIC

This subroutine performs the integral in Eq. (11) each time it is called, for several wavelengths and for several values of the electromagnetic absorption coefficient parameters. These data are read in when STATIC is first called by the MAIN Program, if LRADIO = 1, by two groups of cards. Each of these cards contains data for one case.

1. FRACT -- Index of refraction.
   ABS -- Value of a_o in Eq. (12) (cm^{-1}).
   POWER -- Exponent of the wavelength dependence of the absorption coefficient.
2. TMON -- Interval of days during a lunation at which STATIC is called.
   WAVE -- Microwave wavelengths (cm) for evaluation of Eq. (11). Up to five wavelengths may be specified. In this subroutine, reflections at the layer interfaces are ignored.

The integral is performed by the SHARE distributed subroutine ICE3, using parabolic interpolations of the present temperature distribution U(M,N) by function FRENCH. Near interlayer boundaries linear interpolations are used to allow for large changes in the depth integration step. After a full lunation has been simulated, the subroutine does a least squares analysis of the resulting brightness temperatures, obtaining the mean temperatures $\overline{T}_B$, amplitudes of the first harmonic A, and phase lags ϕ relative to insolation, in the equation

$$T_B = \overline{T}_B + A \cos\left(\frac{2\pi t}{p} - \phi\right) \quad . \tag{15}$$

D. Subroutine SOLUX

SOLUX computes values of f(t), the fractional insolation during the penumbral eclipse, by considering the geometrical area of the Sun occulted by the Moon and solar limb darkening. The latter data are read in as up to ten coefficients in the power series

$$I(x) = \sum_{i=1}^{10} A_i \sin^{(i-1)} \alpha \quad . \tag{16}$$

where α is the zenith angle of the Moon at a point on the Sun, and the parameters, A, are least square coefficients to limb darkening data $I(\alpha)$. We have used the values of $I(\alpha)$ at 6000 Å tabulated by Allen (1963).

E. Subroutine EXTRA

Alternative versions of the conductivity equations and surface boundary conditions will be used by the MAIN Program and by MONTH if added to this subroutine and the code symbol MODEL has the value 4, 5, 6, or 7. Up to four such sets of equations can be included.

F. Subroutine NOCAL

This subroutine reduces surface temperatures to brightness temperatures corresponding to a decrease in the emitted flux by the factor $(1-\bar{\varepsilon}_M)$. To do this, the data needed and read in by the MAIN Program consist of a number of blackbody surface temperatures DTDS, per one-percent decrease in irradiance detected in the infrared spectral interval under consideration.

IV. NON-STANDARD FEATURES IN THE PROGRAM

A. HUGIOH

A SHARE Distribution Agency subroutine (number 3330), written by Dr. Owen Gingerich of the Smithsonian Astrophysical Observatory, revises the regular version of the system library routine IOH to include a free-field G-format. In this format, numerical data are read in either as exponential, fixed, or floating-point numbers as specified by the variable name, and alphabetic characters are ignored. At least one blank space must separate one datum from another.

B. REREAD Version of (TSH)

This SHARE Distribution Agency subroutine (number 1497), also written by Dr. Gingerich, permits the multiple reading of data cards. Logically equivalent to the statement BACKSPACE N, where N is the input tape number, this subroutine stores the image of the data card immediately preceding the CALL REREAD statement for rescanning by the next READ INPUT TAPE statement. One may use the standard version of the system library subroutine (TSH) in the MAIN program by placing the code word on one card and the data on the subsequent one.

C. ICE3

This SHARE Distribution Agency subroutine (number 411) integrates an analytical expression or tabular set of data using a variable integration step to keep extrapolation errors within specified limits.

D. HYPLOT

This is a graph-plotting subroutine written by Dr. Andrew T. Young of Harvard College Observatory. Entry points are SET, LIMITS, REMARK, HOLLER, POINTS, GRID, and GRAPH. Copies of HYPLOT and FRENCH are available upon request from Jeffrey L. Linsky.

E. FRENCH

The function FRENCH, also written by Dr. Young, performs parabolic interpolation to a tabular set of data.

V. THE PROGRAMS

These programs have been thoroughly tested by the author for the conditions appropriate to the lunar surface and using the three models explicitly described above.

A listing of each of these programs and a typical set of data cards are included in the Appendix.

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APPENDIX
PROGRAM LISTING

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CECLIP   ECLIPSE IIIP MAIN PROGRAM    JULY 19,1965
C        NEED SUBROUTINES MONTH,SOLUX,HYPLOT,ICE3,FRENCH,STATIC,EXTRA,NOCAL
         COMMON  SCALE,DEPTH,E,A,B,AA,BB,X,V,R,C,S,J,JA,JB,AAA,EBOL,TEMAX
         DIMENSION U(42,22),X(10),V(10),R(10),C(10),J(10),JA(10),JB(10)
         DIMENSION A(10),B(10),UIN(30),PB(3000),SCALE(60)
         DIMENSION ZM(100),SURTEM(100),FRACT(100),STROM(100)
         DIMENSION  DEPTH(30),S(10),AA(10),BB(10)
         DIMENSION GAM(6),GAM3(6),DIF(6),DIF3(6)
         DIMENSION  AAA(10), RATIO(10),DECODE(20),FRAC(42)
         DECODE(1)=6HPOSITI
         DECODE(2)=6HECLIPS
         DECODE(3)=6HTHERMA
         DECODE(4)=6HGAMMAS
         DECODE(5)=6HDEPTHS
         DECODE(6)=6HTEMPER
         DECODE(7)=6HCONTRO
         DECODE(8)=6HREDUCE
         N5=5
         N6=6
56       DO 55 I=1,60
55       SCALE(I)=1H
         SCALE(1)=4H100K
         SCALE(11)=4H150K
         SCALE(21)=4H200K
         SCALE(31)=4H250K
         SCALE(41)=4H300K
         SCALE(51)=4H350K
         SCALE(60)=4H395K
         CUBE=350.**3
C        SB=STEPHAN-BOLTZMANN CONST. IN CAL/((CM**2)*(DEGK**4)*SEC)
         SB=1.37E-12
C        INPUT OF DATA   BETWEEN 200 AND 260
200      READ INPUT TAPEN5,210,CODE
210      FORMAT(A6)
         DO 212 I=1,8
         IF(CODE-DECODE(I)) 212,213,212
213      CALL REREAD
         GO TO (220,225,4,230,250,61,260,270),I
212      CONTINUE
         WRITE OUTPUT TAPEN6,215,CODE
215      FORMAT(13HILLEGAL CODE,A6)
         GO TO 200
C        CONTROL CARD STARTS THE WORKS GOING
270      CALL NOCAL(DUM,DUM,DUM,DUM,1)
         GO TO 200
C        POSITION CARD  ETA RECTANGULAR N-S  AND XI  E-W POSITION ON MOON
C        NOTE-----SUN RISES IN THE WEST, IE XI POSITIVE
220      READ INPUT TAPEN5,75,ETA,XI
         SELMA=ETA*ETA+XI*XI
         COSZ=SQRTF(1.-SELMA)
C        COSZ=COSINE OF LOCAL ZENITH ANGLE IGNORING LIBRATIONS
C        AND INCLINATION OF MOON TO ECLIPTIC
         IF (SELMA) 221,222,221
221      WHERE=1H
         GO TO 200
222      WHERE=6HSUBSOL
         GO TO 200
C        T=DELTA T, E=EMISSIVITY, TOE=DURATION OF PEN PHAZE IN SEC.
```

```
C      TIME=DURATION OF PEN+UMBRAL PHAZES IN SEC.
C      PEN=TIME PAST END OF TOTALITY IN UNITS OF TOE TO CALCULATE FOR
225    READ INPUT TAPEN5,75,E,EBOL,TOE,TIME,PEN
       AMOUNT=(1.-E)*100.
       TTOTAL=TIME+TOE
       GO TO 200
C      J(I) IS COMMULATIVE NUMBER OF INTEGRATION STEPS AT BOTTOM OF
C         ITH LAYER
250    READ INPUT TAPEN5,3,(J(I),I=1,6),(X(I),I=1,6)
3      FORMAT(12G)
       J6=J(6)
       DEPTH(1)=0.
       L=1
       DO 1050 JJ=2,J6
       IF(JJ-J(L)) 1051,1051,1052
1052   L=L+1
1051   DEPTH(JJ)=DEPTH(JJ-1)+X(L)
1050   CONTINUE
       GO TO 200
C      X=THICKNESS OF EACH SUBLAYER(INTEGRATION STEP)
C      V=CONDUCTIVITY, R=DENSITY, C=SPECIFIC HEAT, S=SEPARATION OF
C      RADIATING LAYERS IN CM.,RAT=RATIO  OF RADIATIVE TO CONDUCTIVE
C      FLUX AT 350 DEGREES K
230    BR=1.
       BC=.2
       READ INPUT TAPEN5,3,LAYER,GA,RAT,MODEL
       BV=1./(GA*GA*BR*BC)
       GO TO 2
4      READ INPUT TAPEN5,3,LAYER,BV,BR,BC,RAT,MODEL
2      DO 235 I=LAYER,6
       RATIO(I)=RAT
       V(I)=BV
       R(I)=BR
       C(I)=BC
235    S(I)=V(I)*RATIO(I)/(4.*SB*E*CUBE)
       GO TO(232,233,234,236,236,236,236),MODEL
232    WORD=6HT IND.
       GO TO 200
233    WORD=6HRADIAT
       GO TO 200
234    WORD=6HLINEAR
       GO TO 200
236    WORD=1H
       GO TO 200
61     READ INPUT TAPEN5,75,(U(I,2),I=1,10)
       IF(J6-10) 72,72,73
73     READ INPUT TAPEN5,75,(U(I,2),I=11,J6)
75     FORMAT(10G)
72     TEMAX=U(1,2)
       GO TO 200
260    READ INPUT TAPEN5,75,NMONTH,NECLIP,LRADIO,NSOLUX,T,TMONTH
62     WRITE OUTPUT TAPEN6,6,T,E,EBOL,TOE,TIME
6      FORMAT (56H1LUNAR ECLIPSE PROGRAM VERSION IIIP WRITTEN BY J. LINSK
      1Y/      51H    BASED IN PART ON AN EARLIER VERSION BY R. MUNRO/
      211H0DELTA T = ,F5.1/16H IR EMISSIVITY =F5.3/ 25H BOLOMETRIC EMISSI
      3VITY = ,F5.3/    26H DURATION OF PEN. PHASE = ,    F6.0,   5H SEC.
      435H DURATION OF PEN. + UMBRAL PHASES =,     F6.0)
       WRITE OUTPUT TAPEN6,53,ETA,XI,WHERE,COSZ,MODEL,WORD
```

```
53     FORMAT (17HOPOSITION ON MOON/6H0ETA =,  F6.3,5X,  4HXI =,F6.3,
      12X,A6,2X,8HCOS(Z) =,F7.4/8H0MODEL   ,I2,5X,A6)
       DO 12 K=1,6
       IF(MODEL-3) 14,13,14
14     GAM(K)=1./SQRTF(V(K)*R(K)*C(K))
       GAM3(K)=0.
       DIF(K)=V(K)/(R(K)*C(K))
       DIF3(K)=0.
       GO TO 12
13     GAM3(K)=1./SQRTF(V(K)*R(K)*C(K)*350.**2)
       GAM(K)=0.
       DIF3(K)=V(K)/(R(K)*C(K))
       DIF(K)=0.
12     CONTINUE
       WRITE OUTPUT TAPEN6,7
7      FORMAT  (120H0DELTA X(CM) CONDUCTIVITY   DENSITY    SPECIFIC HEA
      1T  RATIO     S(CM)   GAMMA GAM(350)   DIFFUSIVITY  DIFFUSIVITY(350
      2))
       WRITE OUTPUT TAPEN6,8,(X(I),V(I),R(I),C(I),RATIO(I),   S(I),GAM(I)
      1,     GAM3(I),DIF(I),DIF3(I),I=1,6)
8      FORMAT (1H /(1H F8.3,2X,E12.5,7X,F4.1,7X,E12.5,F7.3,3X,F7.4,F10.1,
      1F9.1,2E12.3))
       WRITE OUTPUT TAPEN6,9,(J(I),I=1,6)
     9 FORMAT (1H0,12HLAYER DEPTHS6I6)
       IF(LRADIO-1) 59,54,52
54     KODE=1
       GO TO 58
52     KODE=0
58     U(1,1)=XI
       U(2,1)=ETA
       CALL STATIC(U,COSZ,J6,TIMER,KODE)
       GO TO 57
59     TIMER=1.E+30
57     DO 1012 L=1,6
       JA(L)=J(L)-1
1012   JB(L)=J(L)+1
       NCOUNT=1
       NPEN=TOE/300.
       NUMB=TIME/300.
       NPEN2=TTOTAL/300.
       IF(NMONTH-1) 63,64,64
64     CALL MONTH(XI,COSZ,WHERE,UIN,LRADIO,TMONTH,NMONTH,MODEL)
       IF(NECLIP) 56,56,67
67     DO 65 I=1,J6
C      U(I,2) IS PRE-ECLIPSE TEMPERATURE DISTRIBUTION
65     U(I,2)=UIN(I)
       GO TO 66
63     WRITE OUTPUT TAPEN6,76
76     FORMAT (1H0,40HINITIAL CONDITIONS WITH NO LUNATION DONE)
66     IF(T-TLAST) 68,69,68
68     CALL SOLUX(T,TOE,PB,NSOLUX)
69     TLAST=T
       DO 1010  L=1,6
       A(L)=T*V(L)/(R(L)*C(L)*X(L)*X(L))
       AA(L)=4.*SB*E*S(L)*T/(R(L)*C(L)*X(L)*X(L))
       BB(L)=4.*SB*E*S(L)/X(L)
1010   B(L)=V(L)/X(L)
       DO 1011  I=1,5
```

```
1011  AAA(I)=4.*T/((R(I)*C(I)+R(I+1)*C(I+1))* (X(I)+X(I+1)))
      IF(LRADIO) 70,70,71
71    CALL STATIC(U,DUMMY,2,TIMER,4)
70    TIMAX=TIME+TOE*PEN
      W=0.
      P=300.
      FIRST=U(1,2)
      CALL NOCAL(FIRST,AFTER,DUM,AMOUNT,4)
      NT=1
      ZMM=0.
      TEM=U(1,2)
      WRITE OUTPUT TAPEN6,282
282   FORMAT (33H1INITIAL TEMPERATURE DISTRIBUTION)
      GO TO 100
284   DO 287 I=1,J6
287   U(I,1)=U(I,2)
C     QA=30 MIN IN SECONDS
      QA=1800.
      ZMM=1.
      NCOUNT=2
C     NOTE THAT THE SUBSOLAR POINT INSOLATION (FLT) IS BEING DEFINED
C     IN TERMS OF A THEORETICAL EQUILIBRIUM BLACKBODY TEMPERATURE(TEMAX)
C     ASSUMING NO HEAT TRANSFER INTO THE MATERIAL.
      FLT=SB*EBOL*COSZ*TEMAX**4
      VA=1.5*V(1)
      EA=SB*E*X(1)
      EB=4.*SB*S(1)
100   DO 11 N=2,20
      N1=N-1
      IF(ZMM) 281,281,286
C     LOWER BOUNDARY CONDITION   TEMPERATURE HELD CONSTANT
286   U(J6,N)=U(J6,N1)
      W=W+1.
      DO 1020 L=1,6
      IF(L-1) 1021,1021,1022
1021  LOW=2
      GO TO 1023
1022  LOW=JB(L-1)
1023  LHI=JA(L)
      DO 1025 M=LOW,LHI
C     DIFFERENCE EQUATION FOR TEMP(M,N) IN A LAYER
C     M DESIGNATES DEPTH AND N DESIGNATES TIME
      GO TO (1026,1027,1027,1028,1028,1028,1028),MODEL
1027  UMN1=U(M,N1)
      UMP=U(M+1,N1)
      UMM=U(M-1,N1)
      IF(MODEL-2) 700,701,700
701   UMN2=UMN1**2
      U(M,N)=UMN1+(A(L)+AA(L)*UMN2*UMN1)*(UMP-2.*UMN1+UMM)+0.75*AA(L)*
     1UMN2*(UMP**2-2.*UMP*UMM+UMM**2)
      GO TO 1025
1026  UMN1=U(M,N1)
      U(M,N)=UMN1 + A(L)*(U(M+1,N1)-2.*UMN1+U(M-1,N1))
      GO TO 1025
700   U(M,N)=UMN1+A(L)*((UMP-2.*UMN1+UMM) +0.25*(UMP**2-2.*UMP*UMM+
     1UMM**2)/UMN1)
      GO TO 1025
1028  CALL EXTRA(U,MODEL,1,L,M,N,FLX)
```

```
1025  CONTINUE
1020  CONTINUE
      DO 1030 L=1,5
      K=J(L)
      KA=JA(L)
      KB=JB(L)
C     DIFFERENCE EQUATION FOR TEMP(M,N).AT BOUNDARY OF TWO LAYERS
      TM=U(K,N1)
      TMP=U(KB,N1)
      TMM=U(KA,N1)
      GO TO (1031,1032,710,1036,1036,1036,1036),MODEL
1032  U(K,N)=TM+AAA(L) *((B(L+1)+BB(L+1)*0.125 * (TMP+TM)**3)*(TMP-TM)-
     1   (B(L)+BB(L)*0.125*(TM+TMM)**3) * (TM-TMM))
      GO TO 1030
1031  U(K,N)=TM + AAA(L)*(TMP*B(L+1)-TM*(B(L)+B(L+1)) +TMM*B(L))
      GO TO 1030
710   TM2=TM**2
      U(K,N)=TM+(AAA(L)/TM) * (B(L+1)*(TMP**2-TM2) -B(L)*(TM2-TMM**2))
      GO TO 1030
1036  CALL EXTRA(U,MODEL,2,L,K,N,FLX)
1030  CONTINUE
91    U(1,N)=U(1,N1)
C     Z=ELAPSED TIME IN SECONDS SINCE BEGINNING OF ECLIPSE
      Z=T*W
      IF (TOF-Z) 501,501,500
C     PENUMBRAL PHAZE INSOLATION
501   IF(Z-TIME) 502,503,503
503   IF(NT-1) 505,505,504
504   FLX=FLT*PB(NT-1)
      NT=NT-1
      GO TO 24
505   FLX=FLT
      GO TO 24
500   FLX=FLT*PB(NT)
      NT=NT+1
      GO TO 24
502   FLX=0.
C     SURFACE BOUNDARY CONDITION----NEWTONS METHOD USED
24    UN=U(1,N1)
      U2N=U(2,N)
      U3N=U(3,N)
      IF(MODEL-2) 25,726,25
726   SE=E*SB
      BF=1.5*B(1)
      BI=BB(1)/4.
      C4=SE+BB(1)/8.
      T2N=U2N
      T2N3=T2N**3
      C5=T2N*BI
      C6=BF-T2N3*BI
      C7=FLX - 0.5*B(1)*(-4.*T2N + U3N)    + BI*T2N3*T2N/2.
25    UN3=UN**3
      GO TO (721,723,720,724,724,724,724),MODEL
724   CALL EXTRA(U,MODEL,3,1,1,N,FLX)
      TEM=U(1,N)
      GO TO 725
721   FO=EA*UN**4-FLX*X(1)+V(1)*(1.5*UN-2.*U2N+.5*U3N)
      FI=4.*EA*UN3+VA
```

```
      GO TO 722
723   FO=C4*UN3*UN + C5*UN3 + C6*UN - C7
      FI=4.*C4*UN3 + 3.*UN*UN*C5 + C6
      GO TO 722
720   FO=EA*UN**4  +0.75*V(1)*UN*UN  +0.25*V(1)*((-U2N+U3N)*UN+
     1(-4.*U2N+U3N)   *U2N)  -FLX*X(1)
      FI=4.*EA*UN3  +1.5*V(1)*UN + 0.25*V(1)*(-U2N+U3N)
722   TEM=UN-FO/FI
      ATEM=ABSF((TEM-UN)/TEM)
      IF(ATEM-1.E-05) 21,21,22
22    UN=TEM
      GO TO 25
21    U(1,N)=TEM
725   IF(Z-QA) 137,131,131
  131 QA=QA+1800.
      ZMM=Z/60.
C     TEMPERATURE DISTRIBUTION EVERY 30 MIN.
281   WRITE OUTPUT TAPEN6,132,ZMM,(DEPTH(I),U(I,N),I=1,J6)
132   FORMAT (1H0,F9.2, 15HMINUTES ELAPSED/(1H ,10F10.3))
      IF(ABSF(U(10,N))-1000.) 1014,1015,1015
1015   IF(T) 1016,1016,1017
1017   T=T-20.
      WRITE OUTPUT TAPEN6,1018 ,T
1018  FORMAT(22H0BLOWUP    NOW TRY T=  ,F6.1)
      NCOUNT=1
      IF(NMONTH-1) 63,67,67
1016  GO TO 56
1014  DO 280 I=1,J6
280   FRAC(I)=U(I,N)/FIRST
      WRITE OUTPUT TAPEN6,283,(DEPTH(I),FRAC(I),I=1,J6)
283   FORMAT (22H RATIO OF TEMPERATURES/   (1H ,10F10.4))
      GO TO 206
137   IF(Z-P) 601,206,206
206   ZM(NCOUNT) =Z/60.
      SURTEM(NCOUNT)=TEM
C     CONVERSION OF SURFACE TEMPERATURES TO BRIGHTNESS TEMPERATURES
      CALL NOCAL(TEM,AFTER,FR,AMOUNT,3)
      FRACT(NCOUNT)=FR
      STROM(NCOUNT) =AFTER
      IF(NCOUNT-1) 284,284,285
285   NCOUNT=NCOUNT+1
      P=P+300.
601   IF(TIMAX-Z) 598,598,111
111   IF(Z-TIMER) 11,112,112
112   CALL STATIC(U,DUMMY,N,TIMER,4)
   11 CONTINUE
      DO 30 M=1,J6
30    U(M,1)=U(M,20)
      GO TO 100
C     PLOT OF SURFACE TEMPERATURES EVERY 5 MINUTES
598   TMAX=TIMAX/60.
      CALL SET(39,DUMMY)
      CALL LIMITS(0.,TMAX,100.,395.)
      CALL REMARK(30.,110.,5,5H30MIN)
      DO 596 I=1,NCOUNT
      IF(I-NPEN) 595,595,597
597   IF(I-NUMB) 594,594,593
593   IF(I-NPEN2) 595,595,592
```

```
592    JJ=10
       GO TO 596
595    JJ=25
       GO TO 596
594    JJ=30
596    CALL POINTS(ZM(I),SURTEM(I),JJ)
       CALL GRID(0.,30.,100.,50.)
       CALL GRAPH(SCALE)
       NCOUNT=NCOUNT-1
       WRITE OUTPUT TAPEN6,590,(ZM(I),SURTEM(I),STROM(I),FRACT(I),I=1,
      1NCOUNT)
590    FORMAT (16HOMINUTES ELAPSED5X34HSURFACE TEM BRIGHT TEM.   FRACTION
      1 //(1H ,F11.2,    10X,F8.2,2F12.4))
599    IF(LRADIO) 113,113,114
114    CALL STATIC(U,DUMMY,N,Z,5)
113    GO TO 56
       END
```

0365*CARDS

```
      SUBROUTINE MONTH(XI,SQEX,WHERE,UIN,LRADIO,T,NMONTH,MODEL)
CMONTH  LUNATION BEGINS AT FULL MOON
      COMMON  SCALE,DEPTH,E,A,B,AA,BB,X,V,R,C,S,J,JA,JB,AAA,EBOL,TEMAX
      DIMENSION U(42,22),X(10),V(10),R(10),C(10),J(10),JA(10),JB(10)
      DIMENSION A(10),B(10),UIN(30),SCALE(60),GT(70,30),DEPTH(30)
      DIMENSION S(10),AA(10),BB(10),UBEG(42),AAA(10)
      N5=5
      N6=6
      SB=1.37E-12
      AMOUNT=(1.-E)*100.
      J6=J(6)
1019  DO 1010  L=1,6
      A(L)=T*V(L)/(R(L)*C(L)*X(L)*X(L))
      AA(L)=4.*SB*E*S(L)*T/(R(L)*C(L)*X(L)*X(L))
      BB(L)=4.*SB*E*S(L)/X(L)
1010  B(L)=V(L)/X(L)
      DO 1011  I=1,5
1011  AAA(I)=4.*T/((R(I)*C(I)+R(I+1)*C(I+1))* (X(I)+X(I+1)))
      IF(NMONTH-2) 3,2,1
C     T=DELTA T,  TOL=TIME OF LUNATION IN UNITS OF A SYNODIC MONTH
C     TIME=TIME TO RUN IN UNITS OF A SYNODIC MONTH
C     TEMAX=THEORETICAL SUBSOLAR EQUILIBRIUM BLACKBODY TEMPERATURE
3     READ INPUT TAPEN5,4,TOL,TIME,TEMAX
      READ INPUT TAPEN5,4,(UBEG(I),I=1,J6)
4     FORMAT(10G)
C     SYNOD=NUMBER OF SECONDS IN A SYNODIC MONTH
      SYNOD=0.2551443E07
      TOL=TOL*SYNOD
      TIME=TIME*SYNOD
      TIMEX=TIME
2     DO 51  I=1,J6
51    U(I,1)=UBEG(I)
      TIME=TIMEX
      GO TO 90
1     DO 91  I=1,J6
91    U(I,1)=UIN(I)
      TIME=TIMEX
90    TOLM=TOL/SYNOD
      TIMEM=TIME/SYNOD
      WRITE OUTPUT TAPEN6,6,T,TOL,TOLM,TIME,TIMEM,TEMAX
6     FORMAT ( 20H1LUNATION PARAMETERS/  10H0DELTA T =,F5.1/  20H TIME F
     1OR LUNATION =,E20.7   ,5H SEC.,5X,F7.4,7H MONTHS/   18H DURATION O
     2F RUN =,  E20.7, 5H SEC.,5X,F7.4,7H MONTHS/ 20H SUBSOLAR POINT TEM
     3P,  F8.2)
      BEFORE=U(1,1)
      CALL NOCAL(BEFORE,AFTER,FRACT,AMOUNT,2)
      WRITE OUTPUT TAPEN6,99,AFTER,(DEPTH(I),U(I,1),I=1,J6)
   99 FORMAT (1H0,68HINITAL CONDITIONS (ALL DEPTHS ARE IN CM. AND TEMPER
     1ATURES IN DEG. K)/   1H ,9X,F9.3/(1H ,10F9.3))
C     CHECK FOR A FEW BLUNDERS
      IF(TIME/SYNOD -3.1) 909,909,906
909   IF(U(J6,1)) 906,906,907
907   IF(E) 906,906,910
906   WRITE OUTPUT TAPEN6,908
908   FORMAT(37H0I WILL NOT RUN UNDER SUCH CONDITIONS)
      RETURN
910   IF(LRADIO) 7,7,8
8     IF(TIME-1.01*SYNOD) 10,7,7
```

```
10      CALL STATIC(U,SQEX,1,TIMER,2)
        GO TO 9
7       TIMER=1.E+30
9       SUBSOL=6HSUBSOL
        W=0.
        IFIRST=1
        ILAST=-1
        NGRAPH=8
        NCOUNT=1
        VA=1.5*V(1)
        EA=SB*E*X(1)
        EB=4.*SB*E*S(1)
C       TOL2=ANGULAR FREQUENCY OF LUNATION
        TOL2=6.2831853/TOL
        IF(-XI) 183,185,186
183     TOL1=ATANF( SQEX/XI)/TOL2
        GO TO 184
185     TOL1=0.25*TOL
        GO TO 184
186     TOL1=ATANF( SQEX/XI)/TOL2+TOL/2.
184     TOL3=TOL1+TOL/2.
        TOL1D=TOL1/86400.
        TOL3D=TOL3/86400.
        WRITE OUTPUT TAPEN6,85,TOL1D,TOL3D
85      FORMAT ( 10HOSUNSET AT, F7.3,4HDAYS/  11HOSUNRIZE AT,F7.3,4HDAYS)
        TOLN=TOL
        TIMEH=TIME/3600.
C       PQ=NUMBER OF SEC. IN 6 HOURS
        PQ=21600.
        AO=SB*EBOL*X(1)*TEMAX**4
100     DO 11 N=2,20
        N1=N-1
        U(J6,N)=U(J6,N1)
        W=W+1.
        DO 1020 L=1,6
        IF(L-1) 1021,1021,1022
1021    LOW=2
        GO TO 1023
1022    LOW=JB(L-1)
1023    LHI=JA(L)
        DO 1025 M=LOW,LHI
C       DIFFERENCE EQUATION FOR TEMP(M,N) IN A LAYER
        GO TO (1026,1027,1027,1028,1028,1028,1028),MODEL
1028    CALL EXTRA(U,MODEL,1,L,M,N,AO)
        GO TO 1025
1027    UMN1=U(M,N1)
        UMP=U(M+1,N1)
        UMM=U(M-1,N1)
        IF(MODEL-2) 700,701,700
701     UMN2=UMN1**2
        U(M,N)=UMN1+(A(L)+AA(L)*UMN2*UMN1)*(UMP-2.*UMN1+UMM)+0.75*AA(L)*
       1UMN2*(UMP**2-2.*UMP*UMM+UMM**2)
        GO TO 1025
1026    UMN1=U(M,N1)
        U(M,N)=UMN1 + A(L)*(U(M+1,N1)-2.*UMN1+U(M-1,N1))
        GO TO 1025
700     U(M,N)=UMN1+A(L)*((UMP-2.*UMN1+UMM) +0.25*(UMP**2-2.*UMP*UMM+
       1UMM**2)/UMN1)
```

```
1025   CONTINUE
1020   CONTINUE
       DO 1030 L=1,5
       K=J(L)
       KA=JA(L)
       KB=JB(L)
C      DIFFERENCE EQUAT+ON FOR TEMP(M,N) AT BOUNDARY OF TWO LAYERS
       TM=U(K,N1)
       TMP=U(KB,N1)
       TMM=U(KA,N1)
       GO TO (1031,1032,710,1036,1036,1036,1036),MODEL
1036   CALL EXTRA(U,MODEL,2,L,K,N,AO)
       GO TO 1030
1032   U(K,N)=TM+AAA(L) *((B(L+1)+BB(L+1)*0.125 * (TMP+TM)**3)*(TMP-TM)-
     1   (B(L)+BB(L)*0.125*(TM+TMM)**3) * (TM-TMM))
       GO TO 1030
1031   U(K,N)=TM + AAA(L)*(TMP*B(L+1)-TM*(B(L)+B(L+1)) +TMM*B(L))
       GO TO 1030
710    TM2=TM**2
       U(K,N)=TM+(AAA(L)/TM) * (B(L+1)*(TMP**2-TM2) -B(L)*(TM2-TMM**2))
1030   CONTINUE
C      Z=ELAPSED TIME IN SEC. SINCE LAST FULL MOON
       Z=T*W
       IF (Z-TOL1) 17,18,18
    18 IF (Z-TOL3) 19,19,17
C      SURFACE BOUNDARY CONDITION----NEWTONS METHOD USED
C      NO INSOLATION
19     IN=-1
       HIC=(Z-TOL1)/3600.
       FLX=0.
       COSZ=0.
       GO TO 202
C      SUN ABOVE HORIZON
    17 IN=1
       HIC=0.
201    TOLZ=TOL2*Z
       IF(WHERE-SUBSOL) 88,89,88
89     COSZ=COSF(TOLZ)
       GO TO 24
88     COSZ=-XI*SINF(TOLZ)+SQEX*COSF(TOLZ)
24     IF(IN) 200,200,202
202    UN=U(1,N1)
       U2N=U(2,N)
       U3N=U(3,N)
       IF(MODEL-2) 241,20,241
20     SE=E*SB
       FLX=AO*COSZ/X(1)
       BF=1.5*B(1)
       BI=BB(1)/4.
       C4=SE+BB(1)/8.
       T2N=U2N
       T2N3=T2N**3
       C5=T2N*BI
       C6=BF-T2N3*BI
       C7=FLX - 0.5*B(1)*(-4.*T2N + U3N)    + BI*T2N3*T2N/2.
241    GO TO (720,721,726,731,731,731,731),MODEL
731    FLX=AO*COSZ/X(1)
       CALL EXTRA(U,MODEL,3,1,1,N,FLX)
```

```
      GO TO 732
720   FO=EA*UN**4-AO*COSZ+V(1)*(1.5*UN-2.*U2N+.5*U3N)
      FI=4.*EA*UN**3+VA
      GO TO 728
721   UN3=UN**3
      FO=C4*UN3*UN + C5*UN3 + C6*UN - C7
      FI=4.*C4*UN3 + 3.*UN*UN*C5 + C6
      GO TO 728
726   FO=EA*UN**4  +0.75*V(1)*UN*UN  +0.25*V(1)*((-U2N+U3N)*UN+
     1(-4.*U2N+U3N)   *U2N)  -AO*COSZ
      FI=4.*EA*UN**3+1.5*V(1)*UN + 0.25*V(1)*(-U2N+U3N)
728   TEM=UN-FO/FI
      ATEM=ABSF((TEM-UN)/TEM)
      IF(ATEM-1.E-05) 21,21,22
22    UN=TEM
      GO TO 241
21    U(1,N)=TEM
732   IF(IFIRST) 1040,1040,1041
1041  IFIRST=-1
      GO TO 67
1040  IF(Z-TIMER) 27,28,28
28    CALL STATIC(U,COSZ,N,TIMER,2)
27    IF(Z-PQ) 25,26,26
   26 PQ=PQ+21600.
      IF(IN) 201,201,200
200   ZH=Z/3600.
      IF(WHERE-SUBSOL) 1050,1051,1050
1050  DEG=ACOSF(COSZ)*57.3
      ZHNEXT=TOL/3600.-ZH
      GO TO 60
1051  TIMES=1.
      DEG=TOL2*Z*57.3
62    IF(DEG-360.)601,61,61
61    DEG=DEG-360.
      TIMES=TIMES+1.
      GO TO 62
601   ZHNEXT=(TOL/3600.)*TIMES-ZH
60    IF(ILAST) 1043,1043,32
1043  BEFORE=U(1,N)
      CALL NOCAL(BEFORE,AFTER,FRACT,AMOUNT,2)
      WRITE OUTPUT TAPEN6,5,ZH,ZHNEXT,DEG,HIC,AFTER,(DEPTH(I),U(I,N),I=1
     1,J6)
5     FORMAT (  1H0,15HHOURS ELAPSED =, F7.2/  19H NEXT FULL MOON IN ,F7
     1.2,  6H HOURS/  21H ZENITH ANGLE OF SUN ,  F6.2,26H DEGREES   IN D
     2ARKNESS FOR,F8.2,  6H HOURS/    25H TEMPERATURE DISTRIBUTION/1H ,
     39X,F9.3,33H (SURFACE BRIGHTNESS TEMPERATURE)/  (1H ,10F9.3))
C     CHECK FOR BLOWUP
      IF(ABSF(U(10,N))-1000.) 1014,1015,1015
1015   IF(T) 1016,1016,1017
1017   T=T-20.
      WRITE OUTPUT TAPEN6,1018 ,T
1018  FORMAT(22HOBLOWUP    NOW TRY T = ,F6.1)
      IF(NMONTH-2) 1009,1009,1008
1009  NMONTH=2
      GO TO 1019
1008  NMONTH=3
      GO TO 1019
1016  RETURN
```

```
1014    IF(NGRAPH) 67,67,68
68      NGRAPH=NGRAPH-1
        GO TO 25
67      DO 69 M=1,J6
69      GT(NCOUNT,M)=U(M,N)
        NGRAPH=8
        NCOUNT=NCOUNT+1
25      IF(Z-TIME) 905,1042,1042
905     IF(Z-TOLN) 11,87,87
87      W=0.
        TIME=TIME-TOLN
        PQ=0.
        IF(LRADIO) 11,11,904
904     CALL STATIC(U,COSZ,N,TIMER,2)
        GO TO 11
1042    ILAST=1
        GO TO 26
   11   CONTINUE
        DO 30 M=1,J6
C       MATRIX SWITCHOVER
30      U(M,1)=U(M,20)
        GO TO 100
C       PLOT OF TEMP DISTRIBUTION EVERY 2 DAYS
32      CALL SET(39,DUMMY)
        CALL LIMITS(0.,30.,100.,395.)
        DO 73 I=1,NCOUNT,5
        DO 74 JJ=1,5
        L=I+JJ-1
        IF(L-NCOUNT) 71,71,74
71      DO 75 K=1,J6
        AK=K
75      CALL POINTS(AK,GT(L,K),L)
74      CONTINUE
        CALL GRID(0.,5.,100.,50.)
        CALL REMARK(5.,110.,1,1H5)
73      CALL GRAPH(SCALE)
        BEFORE=U(1,N)
        CALL NOCAL(BEFORE,AFTER,FRACT,AMOUNT,2)
        WRITE OUTPUT TAPEN6,5,TIMEH,ZHNEXT,DEG,HIC,AFTER,(DEPTH(I),U(I,N),
       1I=1,J6)
        DO 56 I=1,J6
56      UIN(I)=U(I,N)
C       PLOT OF INITIAL TEMP DISTRIBUTION BEFORE ECLIPSE
        CALL LIMITS(0.,30.,100.,395.)
        DO 66 I=1,J6
        AI=I
66      CALL POINTS(AI,UIN(I),11)
900     CALL GRID(0.,5.,100.,50.)
        CALL REMARK(5.,110.,1,1H5)
        CALL GRAPH(SCALE)
        IF(LRADIO) 901,901,902
902     CALL STATIC(U,TOL2,N,Z,3)
901     RETURN
        END
```

0286*CARDS

```
      SUBROUTINE STATIC(U,COSZ,N,TIMER,KODE)
CSTATIC  CALCULATES RADIO BRIGHTNESS TEMPERATURES
C     MODEL IN THIS SUBROUTINE REFERS TO A SET OF ELECTROMAGNETIC
C      PARAMWTERS AND NOT A SET OF THERMAL PARAMETERS
      COMMON SCALE,DEPTH
      DIMENSION SCALE(60),DEPTH(30),U(42,22),WAVE(10),FLECT(10),
     1TEMP(42),FRACT(10),ABS(10),POWER(10),COSTIN(10),TRAD(10,5,70),
     2AV(10),TICKER(70),BLACK(5),THIN(10)
      DIMENSION TEM(70),AMP(10),PHAZE(10)
      N5=5
      N6=6
C        KODE =2,3 FROM MONTH   4,5 FROM ECLIPSE
C     CONSIDERING A POINT FIXED ON THE MOON WITH THE EARTH STATIONARY
C      AND THE SUN REVOLVING ABOUT THE MOON
      IF(KODE-1) 5,1,50
1     I=0
      SECDAY=3600.*24.
4     I=I+1
C     FLECT=INTERNAL REFLECTANCE AT SURFACE, FRACT=INDEX OF REFRACTION
C     ABS=ABSORPTION COEFFICIENT, POWER=EXPONANT OF ITS WAVE LENGTH
C      DEPENDENCE
C     UP TO 10 SUCH SETS OF DATA ARE ALLOWED
      READ INPUT TAPEN5,2,FRACT(I),ABS(I),POWER(I)
2     FORMAT(3G)
      IF(FRACT(I)) 3,3,4
3     IMAX=I-1
      READ INPUT TAPEN5,6,TMON,TECLIP,(WAVE(I),I=1,5)
6     FORMAT(7G)
C        TMON AND TECLIP ARE INTERVALS OF DAYS AND MIN RESPECTIVELY AT
C        WHICH A RADIO TEMPERATURE DISTRIBUTION IS TO BE MADE
      DO 7 I=1,IMAX
      TH=ACOSF(COSZ)
      Q=FRACT(I)**2
      COSTIN(I)=SQRTF(1.-(1.-COSZ**2)/Q)
      THIN(I)=ACOSF(COSTIN(I))
      DIF=THIN(I)-TH
      SUM=THIN(I)+TH
7     FLECT(I)=0.5*(TANF(DIF)**2/(TANF(SUM)**2) +SINF(DIF)**2/(SINF(SUM)
     1**2))
5     J6=N
      WRITE OUTPUT TAPE 6,9,(I,FLECT(I),FRACT(I),ABS(I),POWER(I),COSTIN(
     1I),I=1,IMAX)
9     FORMAT (29H0RADIO COMPUTATION PARAMETERS/6H0MODEL   4X74HREFLECTIV
     1ITY  INDEX OF REFRACTION   ABS. COEFFICIENT  POWER  COS(THETA,IN)
     2        //(1H ,I3,F14.4,F15.3,E27.5,F10.4,F11.5))
      DO 30 K=1,5
      IF(WAVE(K)) 31,31,30
30    CONTINUE
      LAMAX=5
      GO TO 34
31    LAMAX=K-1
34    XI=U(1,1)
      ETA=U(2,1)
      E2=ETA**2
      SE2=SQRTF(1.-E2)
C     POSLAG=POSITIONAL PHASE LAG FOR POINT OF LUNAR SURFACE RELATIVE
C      TO THE CENTRAL MERIDIAL
      POSLAG=ACOSF(E2+(SQRTF(1.-E2-XI**2))*SE2)/SE2
```

```
      IF(XI) 32,32,33
33    POSLAG=-POSLAG
32    POSLGD=POSLAG*57.29578
      NTIME=1
      RETURN
C
C        NOTE---RAYLEIGH - JEANS ASSUMED
50    NTIME=NTIME
      J6=J6
      IF(NTIME-1) 56,56,57
56    TIMER=0.
57    IF(KODE-3) 51,51,52
51    TICKER(NTIME)=TIMER/SECDAY
      GO TO 53
52    TICKER(NTIME)=TIMER/60.
53    DO 55 J=1,J6
55    TEMP(J)=U(J,N)
      DO 90 MODEL=1,IMAX
      AMR=1.-FLECT(MODEL)
      SECT=1./COSTIN(MODEL)
      DO 89 LAMDA=1,LAMAX
      P=POWER(MODEL)
      AK=SECT*ABS(MODEL)*WAVE(LAMDA)**P
      YINT=0.
      X=0.
      SLOPE=(TEMP(2)-TEMP(1))/(DEPTH(2)-DEPTH(1))
      IND=1
      DER=TEMP(1)
      XMAX=DEPTH(J6)
      CALL ICE(5.,X,XMAX,5.E-06, .001,1,YINT,DER,BLACK,JJ)
65    GO TO (60,61,62,63),JJ
61    JJ=XICEF(DUMMY)
      GO TO 65
C     LINEAR INTERPOLATION NEAR INTERLAYER BOUNDARY
C     THERE SHOULD BE AT LEAST 2 INTEGRATION STEPS BETWEEN LOWEST
C     INTERLAYER BOUNDARY AND BASE OF LOWEST LAYER
60    D=DEPTH(IND)
      DP=DEPTH(IND+1)
      IF(X-D) 70,71,71
70    IND=IND-1
      GO TO 79
71    IF(X-DP) 73,73,72
72    IND=IND+1
79    D=DEPTH(IND)
      DP=DEPTH(IND+1)
      SLOPE=(TEMP(IND+1)-TEMP(IND))/(DP-D)
73    IF(DEPTH(IND-1)+DP-2.*D-.01) 74,74,75
74    IF(D+DEPTH(IND+2)-2.*DP-.01) 76,76,75
76    DER=FRENCH(X,DEPTH,TEMP,J6)*EXPF(-AK*X)
      GO TO 61
75    DER=(TEMP(IND)+(X-D)*SLOPE)*EXPF(-AK*X)
      GO TO 61
63    WRITE OUTPUT TAPEN6,64,MODEL,LAMDA,NTIME,X,DER,YINT,XMAX,JJ,TIME,
     1KODE,(BLACK(I),I=1,5)
64    FORMAT(15HONONCONVERGENCE,3I4,4E16.6,I3,E16.6,I4/1H0,5E16.6)
      RETURN
62    TRAD(MODEL,LAMDA,NTIME)=(YINT+TEMP(J6)*EXPF(-AK*XMAX)/AK)*AMR*AK
89    CONTINUE
```

```
90     CONTINUE
       GO TO (96,93,99,92,100),KODE
92     NTIME=NTIME+1
       TIMER=TIMER+TECLIP*60.
       RETURN
93     NTIME=NTIME+1
       TIMER=TIMER+TMON*SECDAY
96     RETURN
99     OMEGA=COSZ
       TLAG=POSLAG/OMEGA
C
C      END OF MONTH OR ECLIPSE -- PLOT OUT RADIO TEMPERATURES AND
C      TABULATE FOR EACH MODEL AND LAMDA
100    ANT=NTIME
       DO 150 MODEL=1,IMAX
       CALL SET(39,DUMMY)
       IF(KODE-3) 101,101,102
101    CALL LIMITS(0.,30.,100.,395.)
       CALL REMARK(5.,110.,5,5H5DAYS)
       WORD=4HDAYS
       GO TO 104
102    TIMAX=TICKER(NTIME)
       CALL LIMITS(0.,TIMAX,100.,395.)
       CALL REMARK(30.,110.,5,5H30MIN)
       WORD=3HMIN
104    DO 106 LAMDA=1,LAMAX
       DO 105 NT=1,NTIME
105    CALL POINTS(TICKER(NT),TRAD(MODEL,LAMDA,NT),LAMDA)
106    CONTINUE
       CALL GRID(1000.,50.,100.,500.)
       WRITE OUTPUT TAPEN6,109,MODEL,FLECT(MODEL),FRACT(MODEL),ABS(MODEL)
      1,POWER(MODEL),COSTIN(MODEL),WORD,(WAVE(LAMDA),LAMDA=1,5),
      2(TICKER(NT),(TRAD(MODEL,LAMDA,NT),LAMDA=1,5),NT=1,NTIME)
109    FORMAT(29H1RADIO TEMPERATURES FOR MODELI3,23H RAYLEIGH-JEANS ASSUM
      1ED/   75H0REFLECTIVITY  INDEX OF REFRACTION   ABS. COEFFICIENT  PO
      2WER  COS(THETA,IN) /1H ,F8.4,F15.3,E27.5,F10.4,F11.5/    1H0A6,
      35F12.3,  23H   (WAVELENGTHS IN CM.)//  (1H ,F6.2,5F12.3))
C         MEAN AND FIRST FOURIER COS COMPONANTS OF RADIO TEMPERATURES
       IF(KODE-4) 110,110,150
110    DO 112 I=1,10
       AV(I)=0.
       AMP(I)=0.
112    PHAZE(I)=0.
       DO 140 LAMDA=1,LAMAX
       SUM=0.
       SUMC2=0.
       SUMS2=0.
       SUMYC=0.
       SUMYS=0.
       SUMSC=0.
       DO 139 NT=1,NTIME
       TEM(NT)=TRAD(MODEL,LAMDA,NT)
139    SUM=SUM+TEM(NT)
       AV(LAMDA)=SUM/ANT
       DO 138 NT=1,NTIME
       Y=TEM(NT)-AV(LAMDA)
       ARG=OMEGA*(TICKER(NT)*SECDAY+TLAG)
       ST=SINF(ARG)
```

```
      CT=COSF(ARG)
      SUMC2=SUMC2+CT**2
      SUMS2=SUMS2+ST**2
      SUMSC=SUMSC+ST*CT
      SUMYC=SUMYC+Y*CT
138   SUMYS=SUMYS+Y*ST
      DET=SUMC2*SUMS2-SUMSC**2
      A=(SUMYC*SUMS2-SUMSC*SUMYS)/DET
      B=(SUMC2*SUMYS-SUMYC*SUMSC)/DET
      AMP(LAMDA)=SQRTF(A**2+B**2)
140   PHAZE(LAMDA)=ACOSF(A/AMP(LAMDA))*57.29578
      WRITE OUTPUT TAPEN6,111,(AV(L),L=1,5),(AMP(L),L=1,5),(PHAZE(L),L=1
     1,5),POSLGD
111   FORMAT(7H0MEAN T5F12.3/11H0AMP OF COSF8.3,4F12.3/10H0PHASE LAG
     1F9.3,4F12.3,2X32HGEOMETRICAL PHASE LAG OF CRATER F8.3,8H DEGREES
     2)
150   CALL GRAPH(SCALE)
      TIMER=0.
      NTIME=1
      RETURN
      END
```

0195*CARDS

```
      SUBROUTINE SOLUX(DT,TOE,FL,NSOLUX)
CSOLUX  CALCULATION OF FRACTIONAL SOLAR INSOLATION DURING PEUUMBRAL
C          PHASE OF ECLIPSE
      DIMENSION Y(101),A(10),FL(3000),SCALE(60)
C     JSTEP=NUMBER OF STEPS TO BREAK UP SUN INTO
      N5=5
      N6=6
      IF(NSOLUX-1) 105,105,104
105   JSTEP=50
C     10 PARAMETER FIT TO SOLAR LIMB DA-KENING CURVE   AT 6000A
      READ INPUT TAPEN5,102,(A(I),I=1,10)
102   FORMAT(10X,5E14.7/5E14.7)
104   WRITE OUTPUT TAPEN6,103,JSTEP,(A(I),I=1,10)
103   FORMAT (15H1PENUMBRAL FLUX/   8H0JSTEP =, I6/  32H0SOLAR LIMB DARK
     1ENING PARAMETERS/  1H0,5E14.7/  1H ,5E14.7)
C     GRAPH WILL TAKE UP TO AN 80 MIN PENUMBRAL PHAZE
      YHI=59./60.
      CALL LIMITS(0.,4800.,0.,YHI)
      CALL SET(39,DUMMY)
      DO 12 I=1,60
12    SCALE(I)=1H
      SCALE(1)=6H80 MIN
      SCALE(13)=3H0.2
      SCALE(25)=3H0.4
      SCALE(37)=3H0.6
      SCALE(49)=3H0.8
      Z=0.
      L=1
      CJ=JSTEP
      JA=JSTEP+1
      RB=1.
      RA=RB/.279277
      SA=RA+RB-SQRTF(RA*RA-RB*RB)
      AAA=0.
      QA=RB/CJ
      DX=QA
      SB=2.*RB/TOE
      DO 1 I=1,JA
      QB=I-1
      QC=QA*QB
    1 Y(I)=6.2831853*((((((((((A(10)*QC+A(9))*QC+A(8))*QC+A(7))*QC+A(6))*
     1QC+A(5))*QC+A(4))*QC+A(3))*QC+A(2))*QC+A(1))*QC
      GO TO 200
2     IA=AAA
      CALL POINTS(Z,FL(L),IA)
      Z=Z+DT
      L=L+1
      GA=SB*Z
      GB=RA+RB-GA
      IF(GA-2.*RB)3,4,4
    4 FLO=0.
      GO TO 300
3     IF(GA-RB) 5,5,6
    5 BA=GA/CJ
      DX=BA
      BB=RB-GA
      AAA=1.
      Y(1)=0.
```

```
      DO 8 K=2,JA
      E=K-1
      BC=BB+E*BA
      BD=(BC*BC+GB*GB-RA*RA)/(2.*BC*GB)
      BE=ATANF(SQRTF(1.-BD*BD)/BD)
    8 Y(K)=2.*BE*((((((((((A(10)*BC+A(9))*BC+A(8))*BC+A(7))*BC+A(6))*BC+A
     1(5))*BC+A(4))*BC+A(3))*BC+A(2))*BC+A(1))*BC
      GO TO 200
    6 IF(GA-SA)10,11,11
   11 CA=(2.*RB-GA)/CJ
      DX=CA
      CB=GA-RB
      AAA=3.
      Y(1)=0.
      DO 9 K=2,JA
      EA=K-1
      CC=CB+EA*CA
      CD=(CC*CC+GB*GB-RA*RA)/(2.*CC*GB)
      CE=ATANF(-CD/SQRTF(1.-CD*CD))
      CF=1.5707963-CE
    9 Y(K)=2.*CF*((((((((((A(10)*CC+A(9))*CC+A(8))*CC+A(7))*CC+A(6))*CC+A
     1(5))*CC+A(4))*CC+A(3))*CC+A(2))*CC+A(1))*CC
      GO TO 200
   10 DA=(2.*RB-GA)/CJ
      DX=DA
      DB=GA-RB
      AAA=2.
      Y(1)=0.
      DO 15 K=2,JA
      EB=K-1
      DC=DB+EB*DA
      DD=(DC*DC+GB*GB-RA*RA)/(2.*DC*GB)
      IF(RA*RA-GB*GB-DC*DC)20,21,21
   21 DE=ATANF(-DD/SQRTF(1.-DD*DD))
      DF=1.5707963-DE
      GO TO 15
   20 DE=ATANF(SQRTF(1.-DD*DD)/DD)
      DF=3.1415926-DE
   15 Y(K)=2.*DF*((((((((((A(10)*DC+A(9))*DC+A(8))*DC+A(7))*DC+A(6))*DC+A
     1(5))*DC+A(4))*DC+A(3))*DC+A(2))*DC+A(1))*DC
  200 U=0.
      DO 201 I=2,JSTEP,2
  201 U=U+4.*Y(I)
      V=0.
      DO 202 I=3,JSTEP,2
202   V=V+2.*Y(I)
      AREA=(Y(1)+U+V+Y(JA))*DX/3.
      IF(AAA)203,203,204
  203 WRITE OUTPUT TAPEN6,120,AREA
  120 FORMAT (1HO,6HAREA =F10.7)
      FLT=AREA
C     FL=FRACTIONAL AMOUNT OF FLUX LEFT
      FL(1)=1.
      GO TO 2
  204 IF(AAA-2.)205,206,206
205   FL(L)=(FLT-AREA)/FLT
      GO TO 2
206   FL(L)=AREA/FLT
```

```
      GO TO 2
300   CALL GRID(0.,600.,0.,.2)
      WRITE OUTPUT TAPEN6,207,(FL(I),I=1,L)
207   FORMAT(22H0FRACTIONAL INSOLATION//(1H ,10F8.3))
      CALL GRAPH(SCALE)
      RETURN
      END
```

0123 *CARDS

```
      SUBROUTINE NOCAL (BEFORE,AFTER,FRACT,AMOUNT,KODE)
CNOCAL REDUCES SURFACE TEMPERATURES TO INFRARED BRIGHTNESS TEMPERATURES
      DIMENSION  DTDS(50),T(50)
      GO TO (7,4,4,4),KODE
7     MIN=1
      MAX=5
C     DATA NEEDED IS DECREASE IN BRIGHTNESS TEMPERATURE (DTDS) PER
C      ONE PERCENT DECREASE IN IRRADIANCE DETECTED IN SPECTRAL INTERVAL
5     READ INPUT TAPE 5,1,(T(I),DTDS(I),I=MIN,MAX)
1     FORMAT(10G)
      IF(DTDS(MAX)) 2,3,2
2     MIN=MIN+5
      MAX=MAX+5
      GO TO 5
3     MAX=MAX-1
      IF(DTDS(MAX)) 6,3,6
6     WRITE OUTPUT TAPE 6,8,(T(I),DTDS(I),I=1,MAX)
8     FORMAT(-1TEMPERATURES......DT/DS- /(1H ,2F10.4))
      RETURN
4     AFTER=BEFORE-FRENCH(BEFORE,T,DTDS,MAX)*AMOUNT
      IF(KODE-3) 20,30,40
20    RETURN
40    FIRST=AFTER
30    FRACT=AFTER/FIRST
      RETURN
      END
```

0026 *CARDS

```
      SUBROUTINE EXTRA (U,MODEL,NASA,L,M,N,FLX)
CEXTRA    NEW HEAT CONDUCTION DIFFERENCE EQUATIONS AND SURFACE BOUNDARY
C           CONDITION EQUATIONS MAY BE INSERTED IN THIS SUBROUTINE
      COMMON  SCALE,DEPTH,E,A,B,AA,BB,X,V,R,C,S,J,JA,JB,AAA
      DIMENSION U(42,22),A(10),B(10),AA(10),BB(10),SCALE(60),DEPTH(30)
      DIMENSION  X(10),V(10),R(10),C(10),J(10),JA(10),JB(10),S(10)
      DIMENSION  AAA(10)
C         ENTRY TO EXTRA WHEN MODEL = 4,5,6,7
C         NASA=1 FOR CONDUCTIVITY EQ. IN A LAYER
C              2 FOR CONDUCTIVITY EQ. AT A BOUNDARY
C              3 FOR SURFACE BOUNDARY CONDITION
      GO TO (10,20,30),NASA
10    RETURN
20    RETURN
30    RETURN
      END
```

0016*CARDS

LISTING OF SAMPLE INPUT CARDS

```
POSITION  ETA=-.685  XI=-.140          TYCHO
ECLIPSE  E=.93  EBOL=.93  TOE=3360.  TIME=12240.  PEN=2.0
REDUCE     50.  0.  60.  0.  70.  0.  80.  .046  90.  .063
             100.  .080  110.  .097  120.  .112  130.  .130  140.  .150
          150.  .170  160.  .195  180.  .245  200.  .300  220.  .360
          240.  .425  260.  .492  280.  .570  300.  .650  320.  .735
          340.  .822  360.  .915  380.  1.015  400.  1.115  420.  1.215
          440.  1.318  460.  1.420  0.  0.  0.  0.  0.  0.
DEPTHS    4  10  16  22  25  30  .13333  .4  1.  2.  4.  8.
THERMA     LAYER 1  BV=2.24E-08  R=1.  C=5.71E-04  RAT=0.  MODEL=3
THERMA     LAYER 2  BV=2.28E-07  R=1.  C=5.71E-04  RAT=0.  MODEL=3
CONTROL  NMONTH 1  NECLIP  1  LRADIO 1  NSOLUX 00  T  30.  TMONTH 150.
FRACT=1.675  ABS=.1  POWER=-1.
0.  0.  0.
TMON=1.  TECLIP=30.  .10  .33  .43  .86  1.25
MONTH  TOL=1.  TIME=2.  395.
361.  352.  343.  335.  332.  329.  327.  324.  321.  319.
312.  306.  300.  294.  288.  283.  272.  262.  255.  251.
248.  245.  237.  232.  229.  227.  228.  229.  230.  230.
DARKENING  1.0001440E 00-1.2120554E 01 7.4067371E 01-1.6611420E 02 1.6100212E 02
 5.7434130E 01 .
```

21 *CARDS

ILLUSTRATIVE SAMPLE INPUT

LUNAR ECLIPSE PROGRAM VERSION IIIP WRITTEN BY J. LINSKY
BASED IN PART ON AN EARLIER VERSION BY R. MUNRO

DELTA T = 30.0
IR EMISSIVITY =0.930
BOLOMETRIC EMISSIVITY = 0.930
DURATION OF PEN. PHASE = 3360. SEC. CURATICN OF PEN. + UMBRAL PHASES =12240.

POSITION ON MOON

ETA =-0.685 XI =-0.140 CCS(Z) = C.7150

MODEL 3 LINEAR

DELTA X(CM)	CONDUCTIVITY	DENSITY	SPECIFIC HEAT	RATIO	S(CM)	GAMMA	GAM(350)	DIFFUSIVITY	DIFFUSIVITY(350)
0.133	0.22400E-07	1.0	0.57100E-03	C.	C.	C.	798.9	0.	0.392E-04
0.400	0.22800E-06	1.0	0.57100E-03	C.	C.	C.	250.4	0.	0.399E-03
1.000	0.22800E-06	1.0	0.57100E-03	C.	C.	C.	250.4	0.	0.399E-03
2.000	0.22800E-06	1.0	0.57100E-03	C.	0.	C.	250.4	0.	0.399E-03
4.000	0.22800E-06	1.0	0.57100E-03	C.	C.	C.	250.4	0.	0.399E-03
8.000	0.22800E-06	1.0	0.57100E-03	C.	C.	C.	250.4	0.	0.399E-03

LAYER DEPTHS 4 10 16 22 25 30

RADIO COMPUTATION PARAMETERS

MODEL	REFLECTIVITY	INDEX OF REFRACTION	ABS. COEFFICIENT	POWER	COS(THETA,IN)
1	0.0745	1.675	0.100CCE-CC	-1.CCC0	0.9C872

LUNATION PARAMETERS

DELTA T =150.0
TIME FOR LUNATION = 0.2551443E 07 SEC. 1.0000 MONTHS
DURATION OF RUN = 0.5102886E 07 SEC. 2.0000 MONTHS
SUBSOLAR POINT TEMP 395.00

INITAL CONDITIONS (ALL DEPTHS ARE IN CM. AND TEMPERATURES IN DEG. K)
354.561

0.	361.000	0.133	352.000	0.267	343.000	0.400	335.000	0.800	332.000
1.200	329.000	1.600	327.000	2.000	324.000	2.400	321.000	2.800	319.000
3.800	312.000	4.800	306.000	5.800	300.000	6.800	294.000	7.800	288.000
8.800	283.000	10.800	272.000	12.800	262.000	14.800	255.000	16.800	251.000
18.800	248.000	20.800	245.000	24.800	237.000	28.800	232.000	32.800	229.000
40.800	227.000	48.800	228.000	56.800	229.000	64.800	230.000	72.800	230.000

SUNSET AT 8.291DAYS

SUNRIZE AT 23.057DAYS

HOURS ELAPSED = 6.00
NEXT FULL MOON IN 702.73 HOURS
ZENITH ANGLE OF SUN 43.83 DEGREES IN DARKNESS FOR 0. HOURS
TEMPERATURE DISTRIBUTION
355.524 (SURFACE BRIGHTNESS TEMPERATURE)

0.	361.997	0.133	353.650	0.267	345.123	0.400	336.410	0.800	333.809
1.200	331.220	1.600	328.645	2.000	326.086	2.400	323.544	2.800	321.021
3.800	314.714	4.800	308.559	5.800	302.581	6.800	296.807	7.800	291.266
8.800	285.988	10.800	275.732	12.800	266.874	14.800	259.567	16.800	253.730
18.800	249.052	20.800	245.171	24.800	238.214	28.800	233.181	32.800	230.252
40.800	227.436	48.800	228.026	56.800	228.994	64.800	229.882	72.800	230.000

HOURS ELAPSED = 12.00
NEXT FULL MOON IN 696.73 HOURS
ZENITH ANGLE OF SUN 43.47 DEGREES IN DARKNESS FOR 0. HOURS
TEMPERATURE DISTRIBUTION
356.133 (SURFACE BRIGHTNESS TEMPERATURE)

0.	362.627	0.133	354.575	0.267	346.354	0.400	337.957	0.800	335.451
1.200	332.955	1.600	330.470	2.000	327.999	2.400	325.544	2.800	323.105
3.800	317.009	4.800	311.054	5.800	305.268	6.800	299.677	7.800	294.307
8.800	289.180	10.800	279.188	12.800	270.370	14.800	262.794	16.800	256.433
18.800	251.179	20.800	246.885	24.800	239.444	28.800	234.336	32.800	231.294
40.800	227.909	48.800	228.099	56.800	228.983	64.800	229.790	72.800	230.000

HOURS ELAPSED = 18.00
NEXT FULL MOON IN 690.73 HOURS
ZENITH ANGLE OF SUN 43.27 DEGREES IN DARKNESS FOR 0. HOURS
TEMPERATURE DISTRIBUTION
356.491 (SURFACE BRIGHTNESS TEMPERATURE)

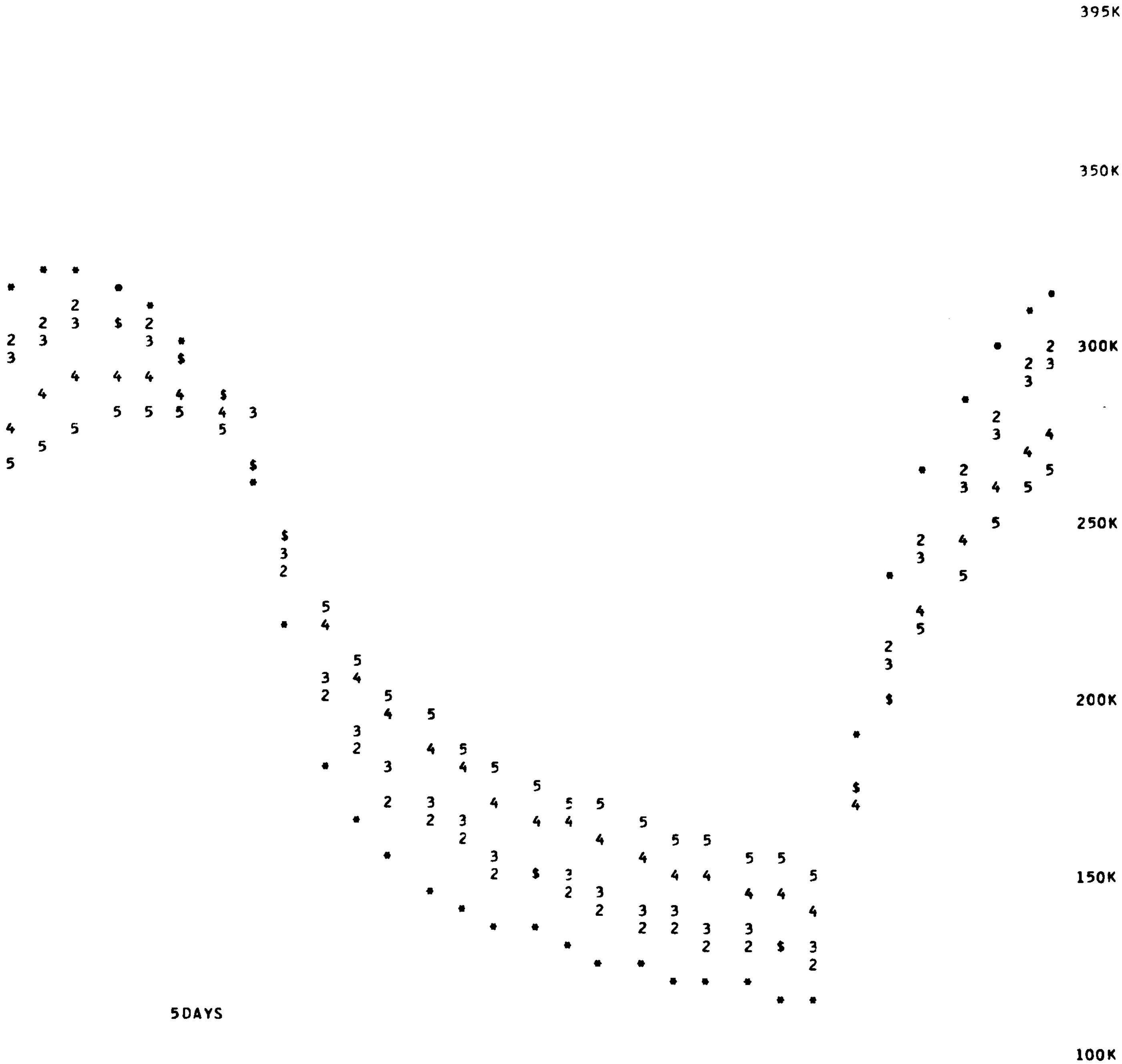
0.	362.998	0.133	355.257	0.267	347.356	0.400	339.290	0.800	336.883
1.200	334.484	1.600	332.094	2.000	329.715	2.400	327.348	2.800	324.996
3.800	319.113	4.800	313.354	5.800	307.745	6.800	302.310	7.800	297.070
8.800	292.046	10.800	282.216	12.800	273.407	14.800	265.685	16.800	259.058
18.800	253.482	20.800	248.879	24.800	240.881	28.800	235.506	32.800	232.268
40.800	228.400	48.800	228.211	56.800	228.976	64.800	229.719	72.800	230.000

HOURS ELAPSED = 24.00
NEXT FULL MOON IN 684.73 HOURS
ZENITH ANGLE OF SUN 43.25 DEGREES IN DARKNESS FOR 0. HOURS
TEMPERATURE DISTRIBUTION

RADIO TEMPERATURES FCR MODEL 1 RAYLEIGH-JEANS ASSUMED

REFLECTIVITY	INDEX CF REFRACTICN	ABS. COEFFICIENT	POWER	COS(THETA,IN)
0.0745	1.675	0.10C00E-0C	-1.0CCC	C.90872

DAYS	0.100	0.330	0.430	0.86C	1.250	(WAVELENGTHS IN CM.)
0.	311.767	297.377	292.408	275.277	264.259	
1.00	316.416	303.537	298.965	282.648	271.656	
2.00	317.614	306.506	302.437	287.385	276.785	
3.00	315.346	306.300	302.840	289.485	279.618	
4.00	309.398	302.775	300.045	288.839	280.048	
5.00	299.273	295.568	293.720	285.173	277.836	
6.00	283.917	283.964	283.144	28C.915	272.618	
7.00	260.842	266.036	280.911	266.203	263.376	
8.00	221.438	236.310	239.608	246.294	247.480	
9.00	179.572	200.410	205.884	219.94C	225.745	
10.00	165.208	184.229	189.627	204.872	212.274	
11.00	155.949	173.543	178.730	194.165	2C2.346	
12.00	149.091	165.566	170.533	185.836	194.437	
13.00	143.656	159.204	163.973	179.045	187.877	
14.00	139.173	153.944	158.534	173.326	182.281	
15.00	135.373	149.481	153.910	168.41C	177.420	
16.00	132.089	145.622	149.906	164.117	173.141	
17.00	129.208	142.236	146.391	160.322	169.331	
18.00	126.646	139.232	143.269	156.933	165.910	
19.00	124.355	136.542	140.471	153.881	162.811	
20.00	122.286	134.113	137.944	151.113	159.988	
21.00	120.405	131.906	135.647	148.587	157.4C5	
22.00	118.684	129.887	133.545	146.269	155.C22	
23.00	117.101	128.032	131.612	144.137	152.818	
24.00	191.030	178.343	175.963	173.163	174.639	
25.00	234.046	217.404	212.969	202.198	198.408	
26.00	262.396	245.014	239.838	225.172	218.139	
27.00	282.663	265.626	260.217	243.589	234.521	
28.00	297.411	281.155	275.788	258.368	248.068	
29.00	307.764	292.620	287.465	270.023	259.C78	
29.53	311.692	297.250	292.262	275.052	263.959	
MEAN T	212.316	214.508	215.437	216.153	216.429	
AMP OF COS	105.209	91.654	87.786	72.3C8	62.149	
PHASE LAG	36.122	42.393	44.940	51.334	55.637	GEOMETRICAL PHASE LAG CF CRATER 11.071 CEGREES


395K
350K
300K
250K
200K
150K
100K
5DAYS

PENUMBRAL FLUX

JSTEP = 50

SOLAR LIMB DARKENING PARAMETERS

```
 0.1000144E 01-0.1212055E 02 0.7406737E 02-0.1661142E 03 0.1610021E 03
-0.5743413E 02-0.            -0.            -0.            -0.
```

AREA = 2.4045744

FRACTIONAL INSOLATION

1.000	0.999	0.998	0.996	0.993	0.990	0.986	0.982	0.978	0.973
0.968	0.962	0.957	0.951	0.944	0.938	0.931	0.923	0.916	0.908
0.900	0.892	0.883	0.875	0.866	0.856	0.847	0.837	0.827	0.817
0.807	0.797	0.786	0.775	0.764	0.753	0.742	0.731	0.720	0.709
0.698	0.687	0.676	0.666	0.655	0.644	0.634	0.623	0.613	0.602
0.592	0.582	0.571	0.561	0.551	0.540	0.529	0.519	0.508	0.497
0.487	0.476	0.466	0.455	0.444	0.433	0.422	0.411	0.400	0.389
0.377	0.365	0.354	0.342	0.330	0.317	0.305	0.293	0.281	0.269
0.257	0.245	0.233	0.221	0.210	0.198	0.187	0.176	0.165	0.155
0.144	0.134	0.124	0.115	0.105	0.096	0.088	0.079	0.071	0.063
0.055	0.048	0.041	0.035	0.029	0.023	0.018	0.013	0.009	0.006
0.003	0.001	0.000	0.						

INITIAL TEMPERATURE DISTRIBUTION

0. MINUTES ELAPSED

0.	361.178	0.133	352.842	0.267	344.332	0.400	335.638	0.800	333.043
1.200	330.463	1.600	327.898	2.000	325.350	2.400	322.821	2.800	320.312
3.800	314.043	4.800	307.924	5.800	301.974	6.800	296.211	7.800	290.652
8.800	285.311	10.800	274.829	12.800	265.334	14.800	256.900	16.800	249.569
18.800	243.356	20.800	238.249	24.800	229.494	28.800	224.375	32.800	222.207
40.800	221.187	48.800	223.509	56.800	226.230	64.800	228.368	72.800	230.000

RATIO OF TEMPERATURES

0.	1.0000	0.1333	0.9769	0.2667	0.9534	0.4000	0.9293	0.8000	0.9221
1.2000	0.9150	1.6000	0.9079	2.0000	0.9008	2.4000	0.8938	2.8000	0.8869
3.8000	0.8695	4.8000	0.8526	5.8000	0.8361	6.8000	0.8201	7.8000	0.8047
8.8000	0.7899	10.8000	0.7609	12.8000	0.7346	14.8000	0.7113	16.8000	0.6910
18.8000	0.6738	20.8000	0.6596	24.8000	0.6354	28.8000	0.6212	32.8000	0.6152
40.8000	0.6124	48.8000	0.6188	56.8000	0.6264	64.8000	0.6323	72.8000	0.6368

30.00MINUTES ELAPSED

0.	313.107	0.133	329.688	0.267	334.357	0.400	333.006	0.800	332.024
1.200	330.161	1.600	327.894	2.000	325.464	2.400	322.979	2.800	320.488
3.800	314.237	4.800	308.129	5.800	302.189	6.800	296.434	7.800	290.882
8.800	285.546	10.800	275.071	12.800	265.578	14.800	257.141	16.800	249.802
18.800	243.578	20.800	238.456	24.800	229.667	28.800	224.510	32.800	222.307
40.800	221.224	48.800	223.514	56.800	226.224	64.800	228.363	72.800	230.000

RATIO OF TEMPERATURES

0.	0.8669	0.1333	0.9128	0.2667	0.9257	0.4000	0.9220	0.8000	0.9193
1.2000	0.9141	1.6000	0.9078	2.0000	0.9011	2.4000	0.8942	2.8000	0.8873
3.8000	0.8700	4.8000	0.8531	5.8000	0.8367	6.8000	0.8207	7.8000	0.8054
8.8000	0.7906	10.8000	0.7616	12.8000	0.7353	14.8000	0.7120	16.8000	0.6916
18.8000	0.6744	20.8000	0.6602	24.8000	0.6359	28.8000	0.6216	32.8000	0.6155
40.8000	0.6125	48.8000	0.6188	56.8000	0.6264	64.8000	0.6323	72.8000	0.6368

60.00MINUTES ELAPSED

0.	210.941	0.133	264.271	0.267	297.874	0.400	319.103	0.800	323.732
1.200	325.470	1.600	325.390	2.000	324.218	2.400	322.415	2.800	320.256
3.800	314.361	4.800	308.324	5.800	302.402	6.800	296.656	7.800	291.110
8.800	285.779	10.800	275.312	12.800	265.822	14.800	257.381	16.800	250.035
18.800	243.800	20.800	238.663	24.800	229.839	28.800	224.646	32.800	222.407
40.800	221.262	48.800	223.519	56.800	226.218	64.800	228.357	72.800	230.000

RATIO OF TEMPERATURES

0.	0.5840	0.1333	0.7317	0.2667	0.8247	0.4000	0.8835	0.8000	0.8963
1.2000	0.9011	1.6000	0.9009	2.0000	0.8977	2.4000	0.8927	2.8000	0.8867
3.8000	0.8704	4.8000	0.8537	5.8000	0.8373	6.8000	0.8214	7.8000	0.8060
8.8000	0.7912	10.8000	0.7623	12.8000	0.7360	14.8000	0.7126	16.8000	0.6923
18.8000	0.6750	20.8000	0.6608	24.8000	0.6364	28.8000	0.6220	32.8000	0.6158
40.8000	0.6126	48.8000	0.6189	56.8000	0.6263	64.8000	0.6323	72.8000	0.6368

40.8000	0.6127	48.8000	0.6189	56.800C	0.6263	64.8000	0.6322	72.8000	0.6368

120.00MINUTES ELAPSED

0.	189.391	0.133	231.761	0.267	266.204	0.400	295.019	0.800	302.420
1.200	307.934	1.600	311.723	2.000	313.992	2.400	314.963	2.800	314.859
3.800	312.699	4.800	308.097	5.800	302.652	6.800	297.053	7.800	291.553
8.800	286.239	10.800	275.790	12.800	266.3C5	14.800	257.860	16.800	250.499
18.800	244.241	20.800	239.075	24.800	230.185	28.800	224.917	32.800	222.609
40.800	221.339	48.800	223.530	56.800	226.206	64.800	228.346	72.800	230.000

RATIO OF TEMPERATURES

0.	0.5244	0.1333	0.6417	0.2667	C.7370	0.4C00	0.8168	0.8000	0.8373
1.2000	0.8526	1.6000	0.8631	2.0000	0.8694	2.4C00	0.8720	2.8000	0.8718
3.8000	0.8658	4.8000	0.8530	5.8000	0.8380	6.8000	0.8225	7.8000	0.8072
8.8000	0.7925	10.8000	0.7636	12.8000	C.7373	14.8C00	0.7139	16.8000	0.6936
18.8000	0.6762	20.8000	0.6619	24.8000	C.6373	28.8CCC	0.6227	32.8000	0.6163
40.8000	0.6128	48.8000	0.6189	56.8000	C.6263	64.8C00	0.6322	72.8000	0.6368

150.00MINUTES ELAPSED

0.	186.020	0.133	226.471	0.267	259.766	0.400	287.995	0.800	295.347
1.200	301.131	1.600	305.443	2.000	308.407	2.400	31C.164	2.800	310.869
3.800	310.674	4.800	307.312	5.800	302.484	6.800	297.143	7.800	291.738
8.800	286.455	10.800	276.027	12.800	266.546	14.800	258.098	16.800	250.730
18.800	244.461	20.800	239.281	24.800	230.357	28.800	225.053	32.800	222.710
40.800	221.378	48.800	223.536	56.800	226.201	64.800	228.341	72.800	230.000

RATIO OF TEMPERATURES

0.	0.5150	0.1333	0.6270	0.2667	C.7192	0.4C00	0.7974	0.8000	0.8177
1.2000	0.8337	1.6000	0.8457	2.0000	0.8539	2.4C00	0.8588	2.8000	0.8607
3.8000	0.8602	4.8000	0.8509	5.8000	0.8375	6.8000	0.8227	7.8000	0.8077
8.8000	0.7931	10.8000	0.7642	12.8000	C.7380	14.8C00	0.7146	16.8000	0.6942
18.8000	0.6768	20.8000	0.6625	24.8000	C.6378	28.8C00	0.6231	32.8000	0.6166
40.8000	0.6129	48.8000	0.6189	56.8000	C.6263	64.8C00	0.6322	72.8000	0.6368

180.00MINUTES ELAPSED

0.	183.379	0.133	222.327	0.267	254.620	0.400	282.208	0.800	289.454
1.200	295.339	1.600	299.933	2.000	303.322	2.400	305.610	2.800	306.911
3.800	308.265	4.800	306.116	5.800	3C2.040	6.800	297.089	7.800	291.858
8.800	286.640	10.800	276.258	12.800	266.785	14.800	258.335	16.800	250.961
18.800	244.681	20.800	239.486	24.800	230.529	28.800	225.189	32.800	222.811
40.800	221.418	48.800	223.542	56.800	226.195	64.800	228.336	72.800	230.000

RATIO OF TEMPERATURES

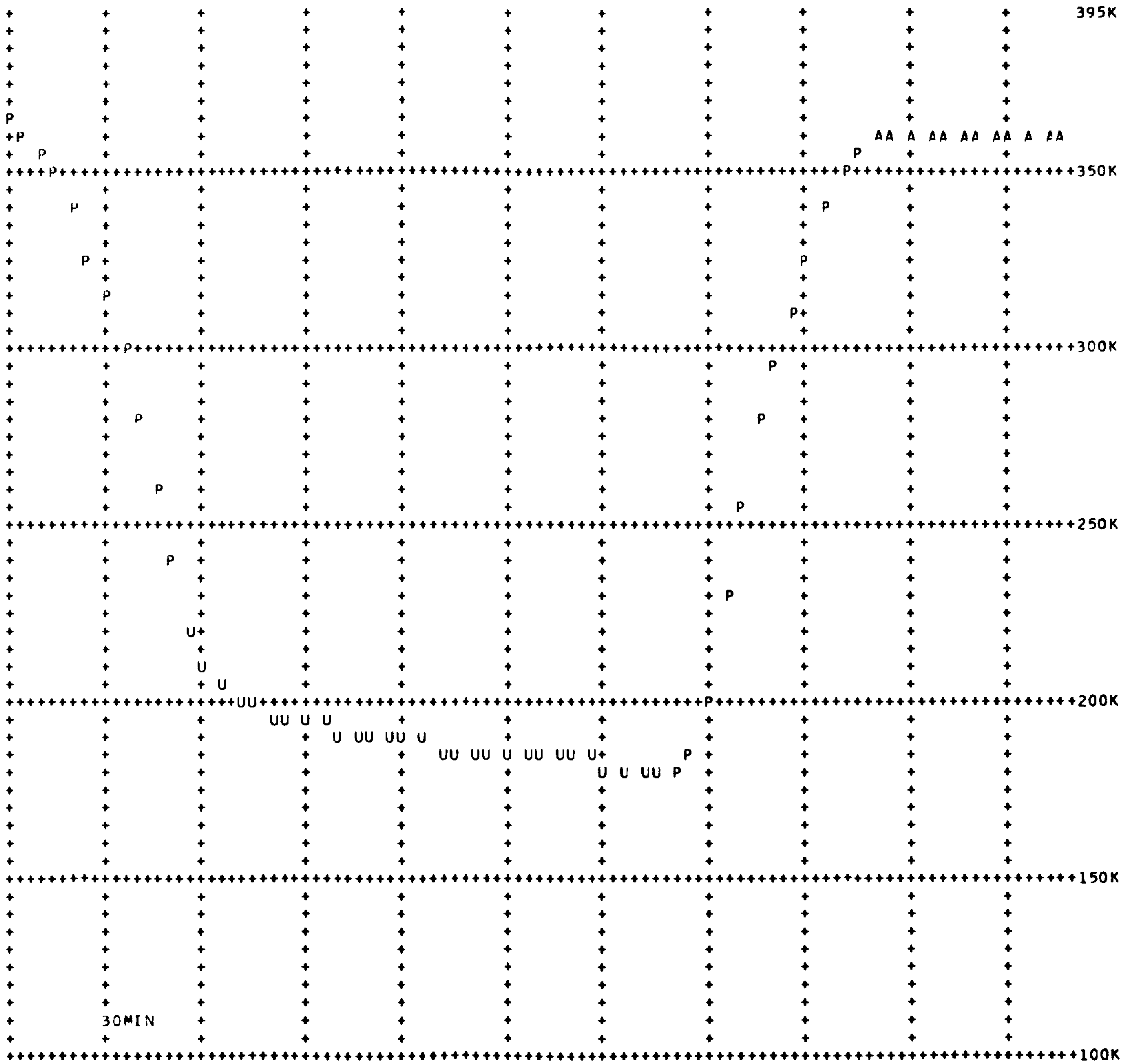
0.	0.5077	0.1333	0.6156	0.2667	C.7050	C.4000	0.7814	0.8000	0.8014
1.2000	0.8177	1.6000	0.8304	2.0000	0.8398	2.4000	0.8461	2.8000	0.8497
3.8000	0.8535	4.8000	0.8475	5.8000	C.8363	6.8C00	0.8226	7.8000	0.8081
8.8000	0.7936	10.8000	0.7649	12.8000	C.7387	14.8000	0.7153	16.8000	0.6948
18.8000	0.6775	20.8000	0.6631	24.8000	0.6383	28.8000	0.6235	32.8000	0.6169
40.8000	0.6130	48.8000	0.6189	56.8000	0.6263	64.8C00	0.6322	72.8000	0.6368

210.00MINUTES ELAPSED

0.	202.788	0.133	222.959	0.267	250.877	C.400	277.294	0.800	284.369
1.200	290.281	1.600	295.044	2.000	298.720	2.400	301.387	2.800	303.135
3.800	305.696	4.800	304.633	5.800	301.341	6.800	296.866	7.800	291.884
8.800	286.772	10.800	276.479	12.800	267.021	14.800	258.571	16.800	251.190
18.800	244.899	20.800	239.691	24.800	230.702	28.800	225.325	32.800	222.913
40.800	221.457	48.800	223.548	56.800	226.189	64.800	228.331	72.800	230.000

RATIO OF TEMPERATURES

0.	0.5615	0.1333	0.6173	0.2667	C.6946	C.4C00	0.7677	0.8000	0.7873
1.2000	0.8037	1.6000	0.8169	2.0000	0.8271	2.4000	0.8345	2.8000	0.8393
3.8000	0.8464	4.8000	0.8434	5.8000	0.8343	6.8000	0.8219	7.8000	0.8081
8.8000	0.7940	10.8000	0.7655	12.8000	0.7393	14.8C00	0.7159	16.8000	0.6955
18.8000	0.6781	20.8000	0.6636	24.8000	C.6387	28.8C00	0.6239	32.8000	0.6172


395K
350K
300K
250K
200K
150K
100K
30MIN

MINUTES ELAPSED	SURFACE TEM	BRIGHT TEM.	FRACTION
0.	361.18	354.7334	1.0000
5.00	359.26	352.8829	0.9948
10.00	354.22	348.0109	0.9810
15.00	346.55	340.5868	0.9601
20.00	336.53	330.8814	0.9328
25.00	325.37	320.0675	0.9023
30.00	313.11	308.1690	0.8687
35.00	298.88	294.3598	0.8298
40.00	280.99	276.9745	0.7808
45.00	260.11	256.6679	0.7236
50.00	238.40	235.4607	0.6638
55.00	219.30	216.7932	0.6111
60.00	210.94	208.6159	0.5881
65.00	206.11	203.8831	0.5748
70.00	202.60	200.4467	0.5651
75.00	199.94	197.8376	0.5577
80.00	197.85	195.7917	0.5519
85.00	196.16	194.1407	0.5473
90.00	194.77	192.7725	0.5434
95.00	193.58	191.6106	0.5402
100.00	192.55	190.6021	0.5373
105.00	191.64	189.7097	0.5348
110.00	190.83	188.9071	0.5325
115.00	190.08	188.1750	0.5305
120.00	189.39	187.4994	0.5286
125.00	188.75	186.8699	0.5268
130.00	188.15	186.2786	0.5251
135.00	187.58	185.7194	0.5235
140.00	187.03	185.1878	0.5220
145.00	186.52	184.6799	0.5206
150.00	186.02	184.1928	0.5192
155.00	185.54	183.7243	0.5179
160.00	185.08	183.2723	0.5166
165.00	184.64	182.8352	0.5154
170.00	184.20	182.4116	0.5142
175.00	183.79	182.0006	0.5131
180.00	183.38	181.6010	0.5119
185.00	182.98	181.2120	0.5108
190.00	182.60	180.8330	0.5098
195.00	182.22	180.4632	0.5087
200.00	181.85	180.1022	0.5077
205.00	184.16	182.3716	0.5141
210.00	202.79	200.6320	0.5656
215.00	228.51	225.8029	0.6365
220.00	254.85	251.5357	0.7091
225.00	277.70	273.7747	0.7718
230.00	295.79	291.3620	0.8214
235.00	311.07	306.1909	0.8632
240.00	324.75	319.4617	0.9006
245.00	336.99	331.3342	0.9340
250.00	346.60	340.6402	0.9603
255.00	353.31	347.1258	0.9786
260.00	356.42	350.1378	0.9870
265.00	357.33	351.0137	0.9895
270.00	357.89	351.5547	0.9910
275.00	358.27	351.9197	0.9921
280.00	358.54	352.1804	0.9928

285.00	358.74	352.3757	0.9934
290.00	358.90	352.5282	0.9938
295.00	359.02	352.6518	0.9941
300.00	359.13	352.7551	0.9944
305.00	359.22	352.8439	0.9947
310.00	359.30	352.9217	0.9949
315.00	359.37	352.9911	0.9951

RADIO TEMPERATURES FCR MCDEL 1 RAYLEIGH-JEANS ASSUMEC

REFLECTIVITY	INDEX CF REFRACTICN	ABS. COEFFICIENT	POWER	COS(THETA,IN)
0.0745	1.675	0.10C00E-00	-1.0CC0	0.90872

MIN	0.100	0.330	0.430	0.86C	1.250 (WAVELENGTHS IN CM.)
0.	311.692	297.250	292.262	275.052	263.959
30.00	304.352	294.797	290.392	274.187	261.487
60.00	282.024	286.426	283.827	270.828	261.110
90.00	269.518	280.271	278.816	268.094	259.210
120.00	262.230	275.764	275.031	265.921	257.666
150.00	256.644	271.913	271.742	263.966	256.265
180.00	251.918	268.476	268.769	262.154	254.958
210.00	249.767	265.952	266.499	260.700	253.887
240.00	270.595	271.871	270.859	262.647	255.193
270.00	285.568	277.434	275.140	264.785	256.655
300.00	291.101	280.266	277.403	265.986	257.510
316.00	293.037	281.427	278.350	266.512	257.893