EPA-660/2-73-003
August 1973

Environmental Protection Technology Series

Statistical Prediction Of Equilibrium Temperature From Standard Meteorological Data Bases

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY STUDIES series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

EPA REVIEW NOTICE

EPA-660/2-73-003
August 1973

STATISTICAL PREDICTION OF EQUILIBRIUM TEMPERATURE FROM STANDARD METEOROLOGICAL DATA BASES

By

C. Michael Hogan
Leda C. Patmore
Harry Seidman

Project 16130 GSD
Program Element 1BA032

Project Officer

Dr. Bruce A. Tichenor
National Environmental Research Center
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

Prepared for

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.55

ABSTRACT

A computer program has been written and applied to investigate the stochastic distribution of equilibrium temperature as determined from a standard meteorological data base. The equilibrium temperature at an air-water interface is the temperature which would be attained by the surface if the net heat flow through it were zero. Since it is a basic factor in the prediction of actual water temperatures, the distribution of equilibrium temperature, and hence of water temperature, is an important statistic.

In the process, data from three cities (Fresno, California; Boston, Massachusetts; and Portland, Oregon) and for several time periods were compared through use of U.S. Weather Bureau hourly observations of surface and solar weather data, collected over 10 years. The conclusions arrived at concern both the use of the data and the computation of the distribution of equilibrium temperature.

This report was submitted by the Environmental Systems Laboratory of ESL Incorporated in fulfillment of Contract No. 68-01-0167 under the sponsorship of the Office of Research and Development, Environmental Protection Agency. The authors are C. Michael Hogan, Leda C. Patmore, and Harry Seidman.

CONTENTS

FIGURES

FIGURES -- Continued

FIGURES -- Continued

FIGURES -- Continued

TABLES

SECTION I
CONCLUSIONS

In this project the Environmental Systems Laboratory of ESL Incorporated investigated the stochastic distribution of equilibrium temperature (E) as determined from a standard meteorological data base. In the process, data from three cities and for several time periods was compared through use of U.S. Weather Bureau hourly observations of surface and solar weather data, collected over 10 years. The conclusions arrived at concern both the use of the data and the computation of the distribution of E:

1. In attempting to decouple the five basic meteorological variables, by considering the correlation coefficient of pairs of such variables, it was found that patterns of strong and weak correlations differed with the location and time period analyzed. This difference extended also to the independence of these variables in the sense of their effect on the computation of E.

2. The distribution of E can be computed by means of a computer program which reads data from standard U.S. Weather Bureau tapes. For this computation, a 2-year time span leads to the same general distribution as a 10-year span.

3. In addition, a method of analytically determining the distribution of E by decomposing the joint distribution of meteorological variables into products of single and pairwise distributions and applying a change of variables transformation has been initiated and shows promise of leading to somewhat more general techniques than are presently available.

SECTION II
RECOMMENDATIONS

The application of the computer programs for the calculation of the distribution of equilibrium temperature can yield valuable information in three directions. The data bases studied should be expanded to cover more area geographically (10 years of data from Fresno and Boston, and 1 year of data from Portland, Oregon were employed in this study), and temporally (only two midday summer time periods were studied in detail). Such an extension could lead to a generality of results in examining the distribution of E in like regions and seasons (such as Fresno and Phoenix).

A further area of study is the simplification of the joint distribution of the meteorological variables into products of single and paired distributions. This procedure was initiated during the present investigation and shows promise of proving a successful technique. If so, it would allow a more analytic representation of the final distribution, thereby requiring a smaller data base to achieve comparable results.

Along these same lines, a third investigation is appropriate. Since January 1, 1965, most Weather Bureau stations have been reporting data at intervals of 3 hours, rather than hourly as in the data bases already considered. These observations are at 0000 GMT, 0300 GMT, 0600 GMT, etc. The distribution of E computed from hourly 10-year data should be compared with the distribution which would be computed based on 3-hourly data by using only the appropriate values from the 10-year tapes. The results from such an analysis would provide guidelines for using more current data (and therefore, perhaps, a larger selection of reporting stations) than has been employed to date; the set of 10-year hourly tapes represents 1952-1963 at a fixed number of locations.

In choosing an analytic model for the equilibrium temperature for use with these procedures, it is recommended that some emphasis be placed on the development and use of coefficients in the model which are not based on daily averages. (For instance, the Brunt coefficient is based on such daily averages and does not appear suitable for all ranges of E considered in this project.)

SECTION III
INTRODUCTION

The equilibrium temperature at an air-water interface is the temperature which would be attained by the surface if the net heat flow through it were zero. The equilibrium temperature itself is not a directly measurable quantity in natural waters whose temperature in general varies continually. However, it is a basic factor in the prediction of actual water temperatures. When assessing the effects of industrial heated waste water discharges, the more accurately water temperatures can be predicted, the better the ecological side effects of such discharges can be determined. In particular, the distribution of equilibrium temperature, and hence of water temperature, is an important statistic. While it is useful to know that a certain heated discharge may raise the mean temperature of the receiving waters a given amount, the variations from the average are also important.

A stochastic method of calculating the distribution of the equilibrium temperature, E, is presented here; subsequently a distribution of water temperature can be computed. A model for the equilibrium temperature was established and its sensitivity to measurement error in the meteorological parameters ascertained. From the model and available meteorological data a program to calculate a distribution for E was written and applied to analyze several localities and time periods.

This section discusses the theoretical outline and procedures followed in selecting a model, developing a stochastic form of the model with respect to five important meteorological parameters, choosing and testing the data base, and computing the distribution of E. The following Section (IV) presents the results obtained by applying these procedures.

The Model for the Equilibrium Temperature

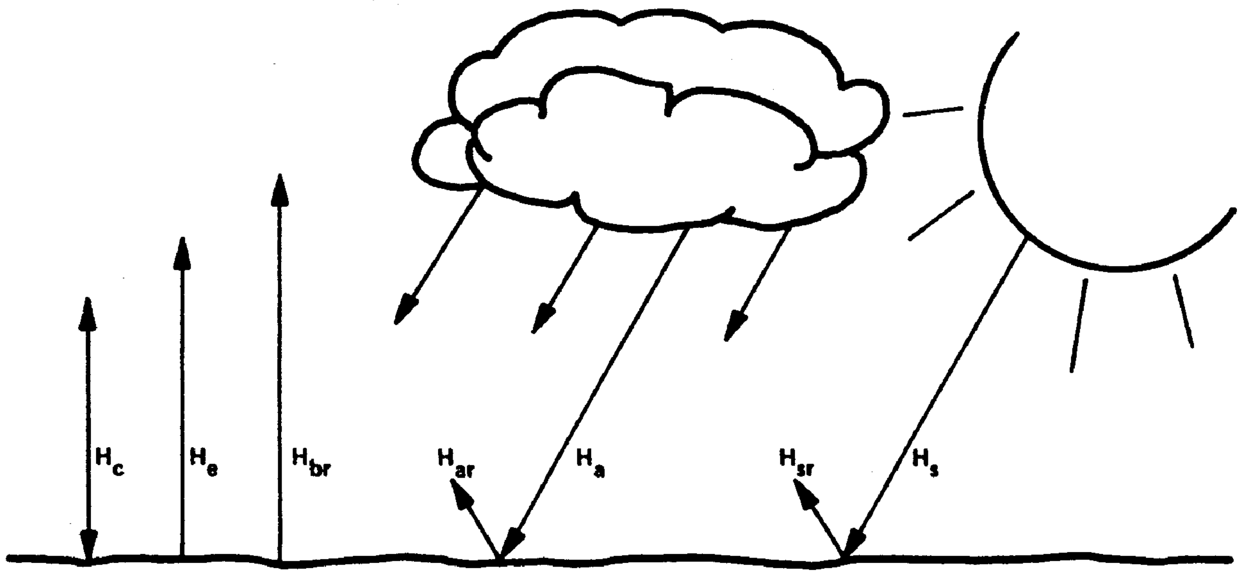
From an analysis of heat flow balance at the earth's surface, illustrated in Figure 1, Edinger and Geyer[1] have derived an approximate implicit equation for the equilibrium temperature, E. This equation has been validated with Lake Colorado City data. This section presents the equation and discusses the evaluation of E and the calculation of its sensitivity to changes in meteorological inputs and to small model changes. A modification used for the calculation of the heat exchange coefficient, due to Thackston and Parker[2], is presented with the detailed model description in Section IV.

Parameters of the Model

The basic meteorological parameters of the Edinger and Geyer formulation are:

T_a	air temperature (degrees Fahrenheit)
w	wind speed (mph)
H_s	incoming short-wave solar radiation (BTU ft^{-2} day^{-1})
r_h	relative humidity (percent)
cc	cloud cover (tenths of total sky cover)

In addition to these, the extraterrestrial radiation (that received at the top of the atmosphere) is one of the subsidiary values required in the calculations. This quantity can be calculated; however, in the present project it was considered simpler to accept the values appearing on the U.S. Weather Bureau Solar Radiation tapes which comprised part of the data set employed.



H_s	SHORT-WAVE SOLAR RADIATION	ABSORBED RADIATION, INDEPENDENT OF SURFACE TEMPERATURE
H_a	LONG WAVE ATMOSPHERIC RADIATION	
H_{sr}	REFLECTED SOLAR RADIATION	
H_{ar}	REFLECTED ATMOSPHERIC RADIATION	
H_{br}	LONG WAVE BACK RADIATION	TEMPERATURE-DEPENDENT TERMS
H_c	CONDUCTIVE HEAT LOSS (OR GAIN)	
H_e	EVAPORATIVE HEAT LOSS	

Figure 1. Components of Heat Transfer at a Water Surface

The Equation for E

The equation used for E was:

$$E + \frac{0.051E^2}{K} = \frac{H_r-1801}{K} + \frac{K - 15.7}{K}\left(\frac{e_a-C(\beta)}{0.26+\beta} + \frac{0.26T_a}{0.26+\beta}\right) \quad (0)$$

where

K = 15.7 + (0.26 + β) (a + bw); the exchange coefficient BTU FT^{-2} DAY^{-1}

H_r = net radiation input (BTU ft^{-2} day^{-1})

$\left.\begin{matrix}\beta \\ C(\beta)\end{matrix}\right\}$ = characteristics of the curve of water temperature versus vapor pressure

e_a = atmospheric vapor pressure (mm Hg)

Details of the computation are given in Section IV.

Development of a Stochastic Form of the Model

Since the five meteorological parameters upon which E explicitly depends are stochastic and cannot be predicted with certainty for future times, it is desirable to formulate the model in such a way that it directly addresses this stochastic nature of the meteorological input. Furthermore consideration must be given to the fact that the meteorological parameters may be interdependent.

A stochastic model was derived through the following process:

(a) Development of a transformation of variables technique which represents E as a stochastic parameter which is driven by stochastic inputs from the five meteorological parameters.

(b) Testing the interdependency of the meteorological parameters.

(c) Development of joint distribution functions which could be used in calculating the stochastic distribution of E.

The Data Base and Processing Techniques

Three data bases were employed: 10 years of hourly observations of all five meteorological variables from both Fresno, California, and Boston, Massachusetts, and 1 year of all variables except solar radiation from Portland, Oregon. Two time periods were analyzed from these data; hours 11-14 and 16-19 for the months of June through August (the maximally heated portion of the year).

The data was processed

- by calculating interdependences of the meteorological parameters using nonparametric correlation tests

- by assembling empirical joint distribution functions of the meteorological variables

- by calculating the sensitivity of E with respect to each of the five meteorological parameters

- by performing other joint distribution and sensitivity calculations needed to develop a stochastic model for E.

The Distribution of E

The distribution of E was exhibited by plotting values of E computed from the meteorological data base. In addition a semianalytic joint distribution was selected as a candidate for applications of the change of variables technique. The final project result is a computer program that will plot the distribution of E from the data for any set of standard Weather Bureau surface and solar tapes.

SECTION IV
RESULTS

A stochastic model for the equilibrium temperature has been developed, computer codes for implementing the stochastic model have been produced and the computer codes have been applied to actual data bases to calculate the stochastic distribution of E.

Development of a Stochastic Model for the Equilibrium Temperature

Three steps were required in development of a stochastic model for E: development of a technique for relating stochastic E to the meteorological joint distributions, testing interdependency of meteorological parameters, and development of joint distribution functions used in calculating the stochastic distribution of E. These steps will now be individually discussed.

Development of a Technique for Relating Stochastic E to Meteorological Joint Distributions

The equation for equilibrium temperature used in this study was derived by Edinger and Geyer[1]. The equation was obtained by performing an analysis of the heat flow balance of the earth's surface. This equation has been validated using Lake Colorado City data and is as follows:

$$\mathrm{EQUIL} + \frac{0.051\ \mathrm{EQUIL}^2}{\mathrm{K}} = \frac{\mathrm{HR} - 1801}{\mathrm{K}} + \frac{\mathrm{K} - 15.7}{\mathrm{K}} \left[\frac{\mathrm{EA} - \mathrm{CBETA}}{0.26 + \mathrm{BETA}} + \frac{0.26\mathrm{TA}}{0.26 + \mathrm{BETA}} \right]$$

The parameters of this and other equations are defined in Table 1, and are written in terms of their FORTRAN names. The terms of this equation that are assumed to be known inputs are the air temperature, TA, the wind speed, W, the measured incoming short-wave solar radiation, HS, the extra-terrestrial solar radiation, HSC, the relative humidity, RH, the cloud cover, CC, and the solar angle, SA.

Solving this equation for EQUIL one has

$$\text{EQUIL} = \frac{-1 + \sqrt{1. + 4. \left(\frac{0.051}{K}\right)\left[\frac{HR-1801}{K} + \left(\frac{K-15.7}{K}\right)\left(\frac{EA-CBETA+0.26TA}{0.26+BETA}\right)\right]}}{2\left(\frac{0.051}{K}\right)} \tag{1}$$

Table 1. Definition of Parameters

Parameter	Definition
TA	Air Temperature (degrees Fahrenheit)
W	Wind Speed (Miles per Hour)
HS	Incoming short-wave solar radiation (BTU Ft^{-2} Day^{-1})
RH	Relative Humidity (Percent)
CC	Cloud Cover (tenths of total cover)
EA	Atmospheric Vapor Pressure (mm Hg)
ES	Saturation Vapor Pressure (mm Hg)
BETA	Slope of the tangent to the saturation vapor pressure vs. temperature curve
CBETA	Y intercept of the tangent to the saturation vapor pressure vs. temperature curve
SA	Solar angle with respect to the horizon
HSC	Extra-terrestrial solar radiation (BTU Ft^{-2} day^{-1})
A, B	Characteristics of the evaporation formula
HA	Long wave atmospheric radiation (BTU Ft^{-2} day^{-1})
HAR	Reflected atmospheric radiation (BTU Ft^{-2} day^{-1})
HSR	Reflected Solar radiation (BTU Ft^{-2} day^{-1})
HR	Net radiation input (BTU Ft^{-2} day^{-1})
K	Exchange coefficient (BTU Ft^{-2} day^{-1})
BC	Coefficient of Brunt's formula, determined by TA and HS

Table 1. -- Continued.

Parameter	Definition
RSR	Reflectivity of short-wave solar radiation
CAPA, CAPB, CAPD	Intermediate values used in computer program
EQUIL	Equilibrium Temperature, E (degrees Fahrenheit)
A1PRME, A2PRME	Transmission coefficients, functions of optical air mass in and water content of the atmosphere
DA, DS	Total dust depletion
RG	Total reflectivity of the ground.

The net radiation input, HR, is the sum of long wave atmospheric radiation, HA, and the incoming short wave solar radiation, HS, less the reflected atmospheric radiation, HAR, and the reflected solar radiation HSR.

HA is calculated as follows:

$$HA = 4.15 \times 10^{-8} \; (TA + 460)^4 \; (BRUNTC + .031 \quad EA \quad) \tag{2}$$

where BRUNTC is dependent upon air temperature, TA, and the ratio of measured solar radiation to clear sky radiation, HS/HSCl. Clear sky radiation is calculated according to the following equation[2]

$$HSC1 = HSC \; \frac{A2PRME + .5 \; (1. - A1PRME - DS) - DA}{1 - .5 \; RG \cdot (1 - A1PRME + DS)}$$

BRUNTC can be obtained from Figure 2. EA is the atmospheric vapor pressure, depends upon the relative humidity and air temperature, and is found using Figure 3. In the computer program the values for BRUNTC and EA are stored in a two-dimensional array. The actual value needed is found using a routine that performs a two-dimensional linear fit to the data.

HAR and HSR are calculated as follows:

$$HAR = .03 \; HA \tag{3}$$

$$HSR = RSR * HS \tag{4}$$

where RSR is dependent upon the cloud cover and solar angle and may be found using Figure 4. Once again these values are stored in the program as a two-dimensional array.

Then

$$HR = HA - HAR + HS - HSR \tag{5}$$

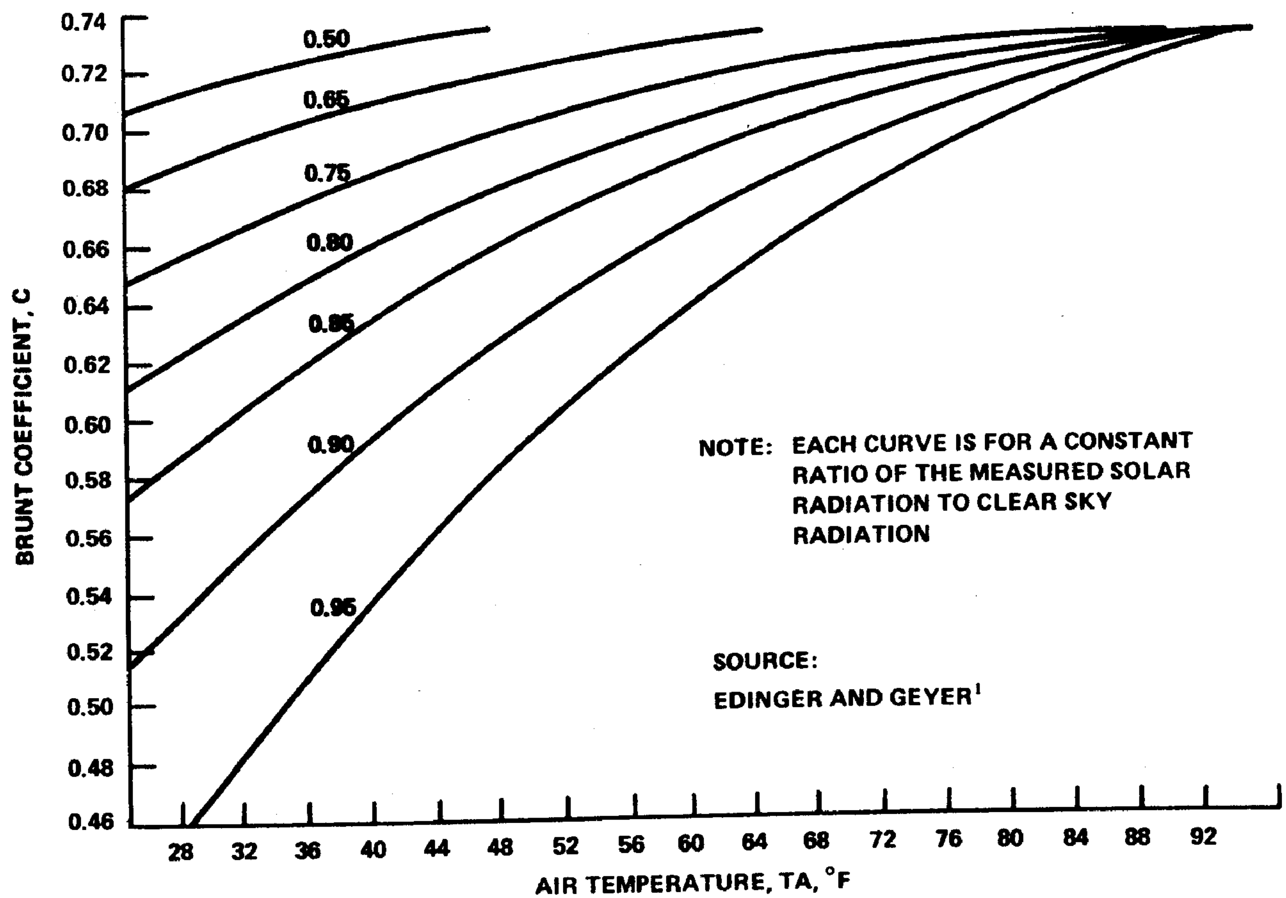


Figure 2. BRUNTC Coefficient From Air Temperature, TA and Ratio Measured Solar Radiation to Clear Sky Radiation (After Koberg, 1962)

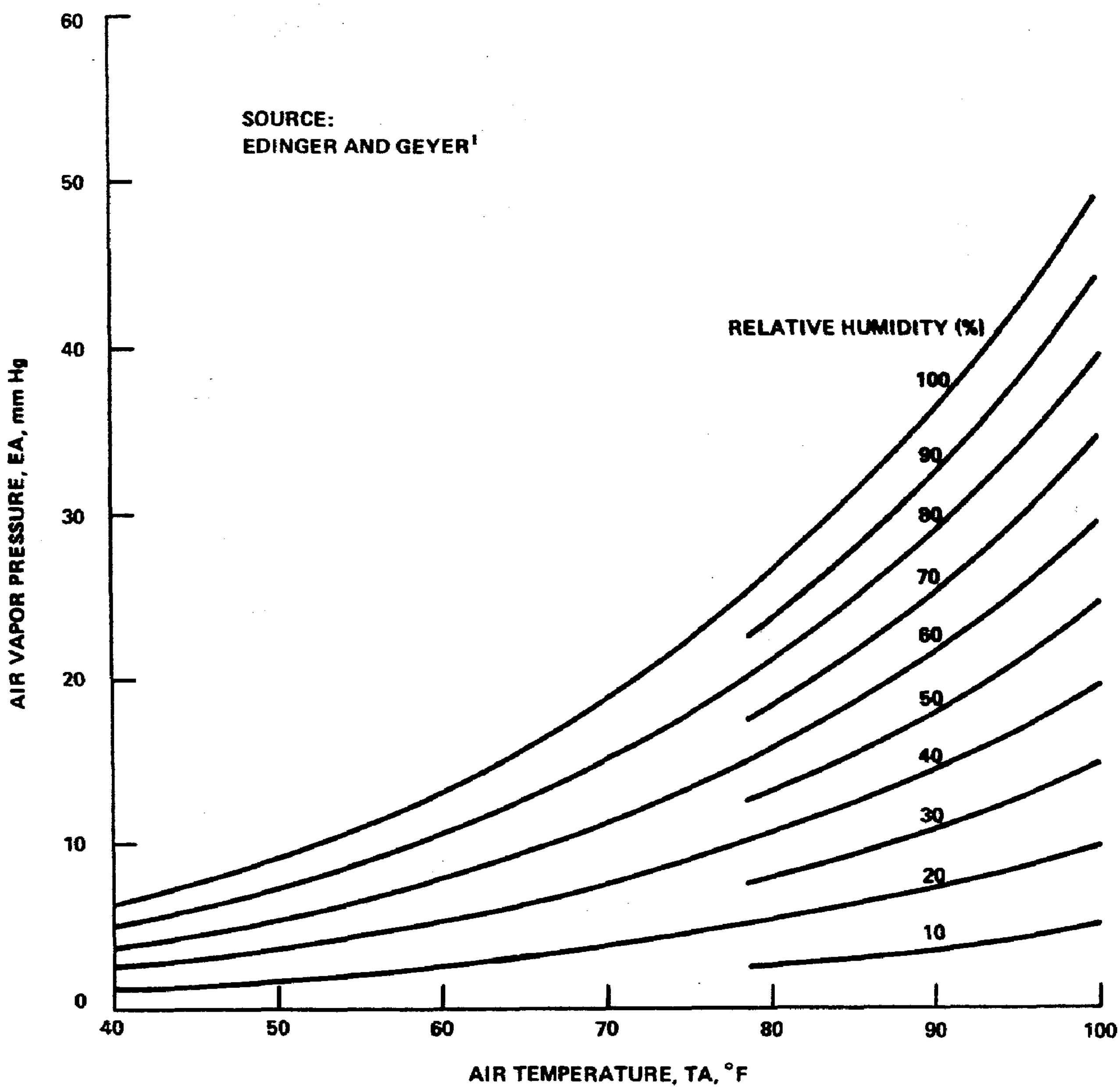


Figure 3. Air Vapor Pressure, EA, From Air Temperature, TA, and Relative Humidity, RH

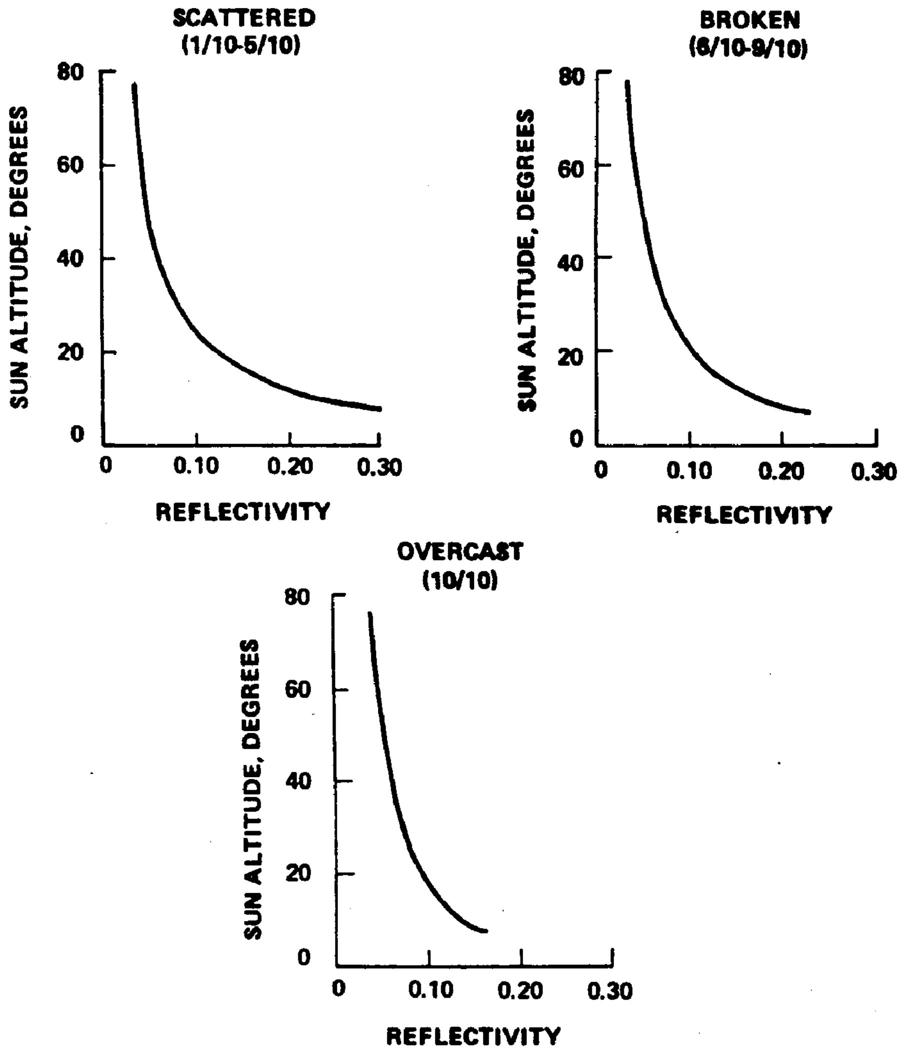


Figure 4. Short-Wave Solar Reflectivity, RSR, for a Water Surface

The exchange coefficient, K, was linearized by Edinger and Geyer and defined as follows:

$$K = 15.7 + (0.26 + BETA)\ (A + B \cdot W) \qquad (6)$$

where BETA is the slope of a line tangent to the saturated vapor pressure curve at the equilibrium temperature. An equation that approximates the saturated vapor pressure curve, ES, was developed at Vanderbilt University[2] and is:

$$ES = 25.4 * EXP\ [17.62 - 9501/(EQUIL+460)]\ \text{mm Hg} \qquad (7)$$

the slope of the curve at the equilibrium temperature is then

$$BETA = \frac{25.4 * 9501.}{(EQUIL+460)^2}\ EXP \left[17.62 - \frac{9501.}{(EQUIL+460)}\right] \qquad (8)$$

Since the equilibrium temperature is not known at this point an iterative method was used until the percentage change in equilibrium temperature was less than a preset value, such as 1 percent.

A and B in Equation 6 are empirical values and were found to be 0 and 11.4 respectively in the Lake Colorado City Study.

Equation 1 was broken down into the following steps for the purpose of the computer program.

$$CAPA = 0.051/K \qquad (9)$$

$$CAPB = - \left[\frac{HR-1801}{K} + \frac{K-15.7}{K} \left(\frac{EA-CBETA + 0.26TA}{0.26+BETA} \right) \right] \quad (10)$$

$$CAPD = \sqrt{1 - 4 * CAPA * CAPB} \quad (11)$$

$$EQUIL = (-1 + CAPD)/(2 * CAPA) \quad (12)$$

where CBETA is the intercept of the tangent line to the saturation vapor pressure curve and is found as follows:

$$CBETA = ES - (EQUIL*BETA) \quad (13)$$

Sensitivity of the Model

It was desirable to investigate the sensitivity of the equilibrium temperature to the five important meteorological parameters;
1) short-wave solar radiation, 2) air temperature, 3) wind speed,
4) relative humidity, and 5) cloud cover.

This was performed by computing the partial derivatives of intermediate variables (Equations 2 thru 13) and applying the chain rule. These calculations are given in Table 2.

The partials of BRUNTC, EA, and RSR with respect to the appropriate meteorological parameters were calculated using numerical differentiation and stored in two dimensional tables for a table look-up in the computer program.

It should be noted that if one equation and its partials are changed there is no need to change any other part of the calculations or coding.

Table 2. Equations Used in the Sensitivity Analysis

$$\frac{\partial HA}{\partial HS} = 4.15 \times 10^{-8} * (TA + 460)^4 * \frac{\partial BRUNTC}{\partial HS} \quad (14)$$

$$\frac{\partial HA}{\partial TA} = 4.15 \times 10^{-8} * \left[(4 * (TA + 460)^3 * (BRUNTC+.031 \sqrt{EA}) + (TA+460)^4 * \left(\frac{\partial BRUNTC}{\partial TA} + \frac{.031*.5}{\sqrt{EA}} \frac{\partial EA}{\partial TA} \right)\right] \quad (15)$$

$$\frac{\partial HA}{\partial W} = 0 \quad (16)$$

$$\frac{\partial HA}{\partial CC} = 0 \quad (17)$$

$$\frac{\partial HA}{\partial RH} = 4.15 * 10^{-8} * (TA+460)^4 * \frac{.031*.5}{\sqrt{EA}} * \frac{\partial EA}{\partial RH} \quad (18)$$

$$\frac{\partial HAR}{\partial HS} = .03 \quad \partial HA/\partial HS \quad (19)$$

$$\frac{\partial HAR}{\partial TA} = .03 \quad \partial HA/\partial TA \quad (20)$$

$$\frac{\partial HAR}{\partial W} = .03 \quad \partial HA/\partial W \quad (21)$$

Table 2. -- Continued

$$\frac{\partial HAR}{\partial CC} = .03 \quad \partial HA/\partial CC \tag{22}$$

$$\frac{\partial HAR}{\partial RH} = .03 \quad \partial HAR/\partial RH \tag{23}$$

$$\frac{\partial HSR}{\partial HS} = RSR \tag{24}$$

$$\frac{\partial HSR}{\partial TA} = 0 \tag{25}$$

$$\frac{\partial HSR}{\partial W} = 0 \tag{26}$$

$$\frac{\partial HSR}{\partial CC} = \frac{\partial RSR}{\partial CC} * HS \tag{27}$$

$$\frac{\partial HSR}{\partial RH} = 0 \tag{28}$$

$$\frac{\partial HR}{\partial HS} = \frac{\partial HA}{\partial HS} - \frac{\partial HAR}{\partial HS} + 1 - \frac{\partial HSR}{\partial HS} \tag{29}$$

$$\frac{\partial HR}{\partial TA} = \frac{\partial HA}{\partial TA} - \frac{\partial HAR}{\partial TA} - \frac{\partial HSR}{\partial TA} \tag{30}$$

Table 2. -- Continued

$$\frac{\partial HR}{\partial W} = \frac{\partial HA}{\partial W} - \frac{\partial HAR}{\partial W} - \frac{\partial HSR}{\partial W} \tag{31}$$

$$\frac{\partial HR}{\partial CC} = \frac{\partial HA}{\partial CC} - \frac{\partial HAR}{\partial CC} - \frac{\partial HSR}{\partial CC} \tag{32}$$

$$\frac{\partial HR}{\partial RH} = \frac{\partial HA}{\partial RH} - \frac{\partial HAR}{\partial RH} - \frac{\partial HSR}{\partial RH} \tag{33}$$

$$\frac{\partial K}{\partial HS} = 0 \tag{34}$$

$$\frac{\partial K}{\partial TA} = 0 \tag{35}$$

$$\frac{\partial K}{\partial W} = (.26 + BETA) * B \tag{36}$$

$$\frac{\partial K}{\partial CC} = 0 \tag{37}$$

$$\frac{\partial K}{\partial RH} = 0 \tag{38}$$

Table 2. -- Continued

$$\frac{\partial CAPA}{\partial HS} = \frac{-.051 \quad \partial K/\partial HS}{K^2} \tag{39}$$

$$\frac{\partial CAPA}{\partial TA} = \frac{-.051 \quad \partial K/\partial TA}{K^2} \tag{40}$$

$$\frac{\partial CAPA}{\partial W} = \frac{-.051 \quad \partial K/\partial W}{K^2} \tag{41}$$

$$\frac{\partial CAPA}{\partial CC} = \frac{-.051 \quad \partial K/\partial CC}{K^2} \tag{42}$$

$$\frac{\partial CAPA}{\partial RH} = \frac{-.051 \quad \partial K/\partial RH}{K^2} \tag{43}$$

$$\frac{\partial CAPB}{\partial HS} = - \left[\frac{K \ \partial HR/\partial HS \ - \ (Hr - 1801) \ \partial K/\partial HS}{K^2} + \left(\frac{K \ \partial K/\partial HS \ - \ (K-15.7) \ \partial K/\partial HS}{K^2} \right) \left(\frac{EA - CBETA+.26TA}{.26+BETA} \right) \right] \tag{44}$$

Table 2. -- Continued

$$\frac{\partial CAPB}{\partial TA} = - \left[\frac{K\ \partial HR/\partial TA - (HR-1801)\ \partial K/\partial TA}{K^2} + \frac{K-15.7}{K} * \right.$$

$$\left\{ \frac{\left(\frac{\partial EA}{\partial TA} + .26\right)}{.26+BETA} \right\} + \left(\frac{K\ \frac{\partial K}{\partial TA} - (K-15.7)\ \partial K/\partial TA}{K^2} \right) *$$

$$\left. \left(\frac{EA - CBETA+.26TA}{.26+BETA} \right) \right] \qquad (45)$$

$$\frac{\partial CAPB}{\partial W} = - \left[\frac{K\ \frac{\partial HR}{\partial W} - (HR-1801)\ \partial K/\partial W}{K^2} + \right.$$

$$\frac{K(\partial K/\partial W) - (K-15.7)\ \partial K/\partial W}{K^2} *$$

$$\left. \left(\frac{EA-CBETA+.26TA}{.26+BETA} \right) \right] \qquad (46)$$

Table 2. -- Continued

$$\frac{\partial CAPB}{\partial CC} = - \left[\frac{K\ \partial HR/\partial CC - (HR-1801)\ \frac{\partial K}{\partial CC}}{K^2} + \right.$$

$$\frac{K\ \partial K/\partial CC - (K-15.7)\ \partial K/\partial CC}{K^2} *$$

$$\left. \frac{EA-CBETA + .26TA}{.26+BETA} \right] \qquad (47)$$

$$\frac{\partial CAPB}{\partial RH} = - \left[\frac{K\ \partial HR/\partial RH - (HR-1801)\ \partial K/\partial RH}{K^2} + \right.$$

$$\left. \left(\frac{K\ \partial K/\partial RH - (K-15.7)\ \partial K/\partial RH}{K^2} \right) \left(\frac{EA-CBETA+.26TA}{.26+BETA} \right) \right] \qquad (48)$$

$$\frac{\partial CAPD}{\partial HS} = \frac{.5}{\sqrt{1.-4.*CAPA*CAPB}} * -4 \left(\frac{\partial CAPA}{\partial HS}\ CAPB + \frac{\partial CAPB}{\partial HS}\ CAPA \right)$$

(49)

$$\frac{\partial CAPD}{\partial TA} = \frac{.5}{\sqrt{1.-4.*CAPA*CAPB}} *-4 \left(\frac{\partial CAPA}{\partial TA} \; CAPB + \frac{\partial CAPB}{\partial TA} \; CAPA\right) \quad (50)$$

$$\frac{\partial CAPD}{\partial W} = \frac{.5}{\sqrt{1.-4.*CAPA*CAPB}} *-4 \left(\frac{\partial CAPA}{\partial W} \; CAPB + \frac{\partial CAPB}{\partial W} \; CAPA\right) \quad (51)$$

$$\frac{\partial CAPD}{\partial CC} = \frac{.5}{\sqrt{1.-4.*CAPA*CAPB}} *-4 \left(\frac{\partial CAPA}{\partial CC} \; CAPB + \frac{\partial CAPB}{\partial CC} \; CAPA\right) \quad (52)$$

$$\frac{\partial CAPD}{\partial RH} = \frac{.5}{\sqrt{1.-4.*CAPA*CAPB}} *-4 \left(\frac{\partial CAPA}{\partial RH} \; CAPB + \frac{\partial CAPB}{\partial RH} \; CAPA\right) \quad (53)$$

$$\frac{\partial EQUIL}{\partial HS} = \frac{CAPA \; \partial CAPD/\partial HS \; - \; (-1.+CAPD) \; \partial CAPA/\partial HS}{2\,(CAPA)^2} \quad (54)$$

$$\frac{\partial EQUIL}{\partial TA} = \frac{CAPA \; \partial CAPD/\partial TA \; - \; (-1.+CAPD) \; \partial CAPA/\partial TA}{2\,(CAPA)^2} \quad (55)$$

Table 2. -- Continued

$$\frac{\partial EQUIL}{\partial W} = \frac{CAPA\ \partial CAPD/\partial W\ -\ (-1.+CAPD)\ \partial CAPA/\partial W}{2(CAPA)^2} \tag{56}$$

$$\frac{\partial EQUIL}{\partial CC} = \frac{CAPA\ \partial CAPD/\partial CC\ -\ (-1.+CAPD)\ \partial CAPA/\partial CC}{2(CAPA)^2} \tag{57}$$

$$\frac{\partial EQUIL}{\partial RH} = \frac{CAPA\ \partial CAPD/\partial RH\ -\ (-1.+CAPD)\ \partial CAPA/\partial RH}{2(CAPA)^2} \tag{58}$$

Change of Variables Technique for Analytically Determining the Distribution of the Equilibrium Temperature

From a model equation for E, and the known joint distribution of the five basic meteorological parameters, the change of variables technique may be applied to determine the distribution of E. In the present case, the joint distribution needed is not yet fully specified; however, one of the tasks of the present project has been to initiate this specification. The equation for change of variables as applied to E is presented here to show the use to which the derived distribution would be put.

Consider the following equation for E which is equivalent to Equation 1:

$$[15.7 + .26\ (a + bw)\ ]\ E + .051\ E^2 + (a + bw)\ e_E$$
$$= H_r - 1801 + (a + bw)\ e_a + .26\ (a + bw)\ T_a. \qquad (59)$$

Let $\gamma = a + bw$, then 59 becomes

$$[15.7 + .26\ \gamma]\ E + .051\ E^2 + \gamma e_E = H_r - 1801 +$$
$$\gamma e_a + .26\gamma T_a \qquad (60)$$

For simplicity, suppose that γ is treated as a discrete random variable taking on the positive values, $\gamma_1, \ldots, \gamma_n$ with the probabilities $p_1, \ldots, p_n$, respectively, and that $E>0$.

Let $f_i(E)$ be defined by

$$f_i(E) = (15.7 + .26\ \gamma_i)\ E + .051\ E^2 + \gamma_i\ e_E,\ E>0,$$

for i = 1, ... , n. Since e_E is a monotonically increasing function of E, it follows that $f_i(E)$ is monotonically increasing and therefore invertible. From Equation 60 one has

$$f_i(E) = H_r - 1801 + \gamma_i\ e_a + .26\ \gamma_i T_a\ . \tag{61}$$

Thus, $f_i(E)$ is a random variable whose distribution may be determined from 61 provided that the joint distribution of $(H_r,\ e_a,\ T_a)$ is known, or of H_r, e_a, T_a expressed in terms of other meteorological variables whose joint distribution is known.

Suppose that for each i, (i=1, ..., n) we have determined the distribution density function for $f_i(E)$ denoted $p_{f_i}(y)$. Then the conditional density of E given γ_i, denoted $q_{E,i}$, satisfies

$$q_{E,i}(x) = p_{f_i}\ (f_i(x))\ f_i'\ (x) \tag{62}$$

where f_i' denotes the derivative of f_i. The unconditioned density of E, denoted q_E, is then given by

$$q_E(x) = \sum_{i=1}^{n} p_i q_{E,i}(x). \tag{63}$$

Thus, once the density functions p_{f_i} have been obtained, it is relatively straightforward to obtain the density of E. The preceding two equations are the master equations for calculating the distribution of E.

One method of obtaining the density functions p_{f_i} is a change of variables technique which will now be described. Let S be the set of points (x_1, x_2) satisfying.

$$\underline{x}_1 \leq x_1 \leq \overline{x_1}, \ \underline{x}_2 \leq x_2 \leq \overline{x_2}$$

Let F be a real valued function defined on S, with the property that for all points (x, x_2), (z, x_2) in S, if $x \neq z$, then $F(x, x_2) \neq F(z, x_2)$, (assumption of a single valued function.) Let Ω be the set of all points $(F(x_1, x_2)$ such that (x_1, x_2) belongs to S. Then there exists a unique function H, defined on Ω, such that

$$y = F(H(y, x_2), x_2)$$

for all points (y, x_2) in Ω, and

$$\text{Range } H(., x_2) = [\underline{x}_1, \bar{x}_1]$$

for $\underline{x}_2 \leq x_2 \leq \bar{x}_2$, where $H(\cdot, x_2)$ is considered a function of the first coordinate only, with x_2 fixed. Also, suppose that H is continuously differentiable; this follows immediately from the implicit function theorem provided that F is continuously differentiable and

$\frac{\partial F}{\partial x_1} \neq 0$ on S.[5]

Let X_1, X_2 be random variables such that the range of (x_1, x_2) is contained in S, and let the random variable Y be defined by the relation

$$Y = F(X_1, X_2) \ .$$

Let $p(x_1, x_2)$ be the joint density for (X_1, X_2). Then it can be shown that the joint density for (Y, X_2) is given by

$$\begin{aligned} q(y, x_2) &= p(H(y, x_2), x_2) \ \frac{\partial H}{\partial y}\ , \text{ for } (y, x_2) \ \varepsilon \ \Omega \\ &= 0 \text{ otherwise}, \end{aligned} \tag{64}$$

The density for Y alone is given by

$$\begin{aligned} p_Y(y) = \int_{\Omega_Y} q(y, x_2)\, dx_2 = \int_{\Omega_Y} p(H(y, x_2), x_2) \\ \frac{\partial H}{\partial y} \ dx_2\ , \end{aligned} \tag{65}$$

$$\text{for } y \ \varepsilon \text{ Range } F$$

$$= 0 \text{ otherwise}$$

where Ω_y, for each fixed y, is the set of all points (y, x_2) in Ω, i.e., the section of Ω consisting of all points in Ω whose first coordinate is y.

In summary, the above method for determining the distribution density function of E consists of three parts. First, one determines the density of $f_i(E)$, defined in 61 for i = 1, ..., n; one technique for doing this is the change of variables technique described above. Secondly, the conditional density for E, given γ_i, is obtained from 62. Thirdly, the unconditioned density for E is obtained by taking the weighted average of the conditional densities for E, as indicated by 63.

Testing Interdependency of Meteorological Parameters.

Because E must be calculated using the joint distribution of the five meteorological parameters, a basic goal is the reduction of that joint distribution to the simplest possible form -- preferably a form that can be treated analytically. Therefore, the interdependency of the meteorological parameters was tested with a view toward discovering factorizations that can be made in the total joint distribution function. Several alternate forms of parameter independence tests were made. The Spearman rank non-parametric correlation test was conducted pair-wise upon the meteorological variables. Another non-parametric dependence test was conducted upon all the meteorological variables at once. A direct dependence test was conducted by determining the empirical distribution functions for each single meteorological parameter and comparing the product of those single distributions (two, three, and four at a time) with the corresponding empirical joint distribution. This test provided a direct test of possible factorization of the joint distribution. Sensitivity analyses were performed to ascertain the influence of each meteorological parameter upon E. Finally the sensitivity results were used with dependence tests to determine whether factorization of the joint distribution can be made without sacrifice to the accuracy of calculating E. The meteorological parameters of the data bases from Boston, Fresno, and Portland were investigated to determine whether one or more could be considered essentially a variable uncorrelated with the other meteorological variables.

This investigation was carried out for meteorological data from Fresno, Portland, and Boston (June through August, hours 1100-1400, 1100-1200 and 1600-1900) based upon 2 and 10 years of data. Due to computer program size limitations data was only sampled, every 1st, 3rd, or 5th point as required to keep the total number of times collected under 1000. Tables 3 through 5 are the results of computing the Spearman rank correlation coefficient for all pairs of data in the tables; their correlations are given in order of increasing correlation. It is interesting to note that in terms of patterns of strong and weak correlations, two years of data give essentially the same result as ten years; in fact, one year may be sufficient but is probably not a good choice due to the presence of a single meteorologically deviant year.

The nonparametric correlation coefficient used was the Spearman rank correlation coefficient.[3] The method used for goodness of fit tests was Kolmogorov Smirnov. Both procedures employed subroutines from the IBM Scientific Subroutine Package[4] and are described in more detail in Appendix A. The goodness of fit tests are described in later pages and results shown in Table 6.

However, except for the strongest correlation (between temperature and relative humidity) the results are not general for all localities and times. In fact, the hoped for conclusion that wind speed is functionally independent of the other variables, which appears valid for the midday Fresno and Boston data, does not carry over to the later period in Fresno, or to Portland.

Table 3. Spearman Rank Correlation Coefficient For Pairs of Meteorological Variables; Boston

Months	6-8		6-8		6-8		6-8		6-8	
Hours	11-14		11-14		11-12		16-19		16-19	
No. of Years	10		2		2		10		2	
No. of Points	695		593		297		687		557	
Critical r_s	.07		.08		.11		.07		.08	
	*	r_s	*	r_s	*	r_s	*	r_s	*	r_s
	1-4	-.12	1-2	~~-.02~~	1-2	~~-.08~~	1-4	-.11	1-4	-.14
	1-2	.13	1-4	-.16	1-3	-.15	1-5	.29	1-2	.16
	1-5	.14	1-3	-.16	1-4	-.21	1-2	.30	1-5	.29
	1-3	-.22	1-5	.22	2-5	.24	2-5	.31	2-4	-.29
	2-5	.30	2-5	.26	1-5	.27	4-5	-.33	5-4	-.29
	2-4	-.35	2-4	-.34	2-4	-.34	2-4	-.34	2-5	.30
	3-5	-.55	3-5	-.50	2-3	-.51	1-3	-.36	1-3	-.34
	3-4	.56	3-4	-.54	3-5	-.54	3-5	-.46	3-5	-.44
	2-3	-.59	2-3	-.56	3-4	.58	3-4	.52	3-4	.50
	5-4	-.75	5-4	-.63	5-4	-.63	2-3	-.61	2-3	-.59

*Paris of meteorological variables, arranged in order of increasing correlation. Coding is:

1. Wind speed
2. Temperature
3. Relative humidity
4. Cloud cover
5. Solar radiation

r_s Spearman rank correlation coefficient. A slash (/) through a value indicates that it is not significantly different from zero at the 5 percent level.

Table 4. Spearman Rank Correlation Coefficient For Pairs of Meteorological Variables; Fresno

Months Hours No. of Years No. of Points Critical r_s	6-8 11-14 10 708 .07		6-8 11-14 2 587 .08		6-8 11-12 2 293 .11		6-8 16-19 10 699 .07		6-8 16-19 2 528 .08	
	*	r_s	*	r_s	*	r_s	*	r_s	*	r_s
	1-4	~~-.04~~	1-5	~~.00~~	1-5	~~.09~~	1-5	~~-.06~~	1-5	~~.00~~
	1-2	~~-.05~~	3-5	~~.07~~	2-4	-.13	1-3	-.09	1-2	~~-.05~~
	1-5	~~-.07~~	1-2	~~-.08~~	1-3	.14	1-4	-.10	1-4	~~-.08~~
	3-5	.11	1-4	~~.08~~	1-4	.15	1-2	-.11	2-4	-.09
	2-4	-.12	1-3	~~-.08~~	3-4	.21	2-4	-.12	1-3	-.13
	1-3	.16	2-4	-.12	1-2	-.22	4-5	-.13	5-4	-.13
	3-4	.18	3-4	.18	2-5	-.26	3-4	.24	3-4	.21
	2-5	-.23	5-4	-.26	5-4	-.28	2-5	.41	2-5	.32
	4-5	-.31	2-5	-.43	3-5	-.35	3-5	.41	3-5	.41
	2-3	-.54	2-3	-.58	2-3	-.45	2-3	-.55	2-3	-.50

*Pairs of meteorological variables, arranged in order of increasing correlation. Coding is:

1. Wind speed
2. Temperature
3. Relative humidity
4. Cloud cover
5. Solar radiation

r_s Spearman rank correlation coefficient. A slash (/) through a value indicates that it is not significantly different from zero at the 5 percent level.

Table 5. Spearman Rank Correlation Coefficient For Pairs For Meteorological Variables; Portland

Months	6-8		6-8		1-12		6-8	
Hours	11-14		11-12		11-12		16-19	
No. of Years	1		1		1		1	
No. of Points	368		184		730		368	
Critical r_s	.10		.14		.07		.10	
	*	r_s	*	r_s	*	r_s	*	r_s
	1-4	-.25	1-2	~~.14~~	1-3	~~-.03~~	1-4	-.33
	1-2	.27	1-4	-.17	1-2	~~-.06~~	1-3	-.34
	1-3	-.30	1-3	-.23	1-4	.10	1-2	.34
	3-4	.51	2-3	-.49	2-4	-.33	3-4	.61
	2-3	-.63	3-4	.52	2-3	-.52	2-4	-.64
	2-4	-.63	2-4	-.61	3-4	.52	2-3	-.77

* Pairs of meteorological variables, arranged in order of increasing correlation. Coding is:

1 Wind speed
2 Temperature
3 Relative humidity
4 Cloud cover
5 Solar radiation

r_s Spearman rank correlation coefficient. A slash (/) through a value indicates that it is not significantly different from zero at the 5 percent level.

The above dependence among meteorological variables was also confirmed by a non-parametric dependence test conducted upon all the five variables together. Furthermore, attempts to show product factorization of joint distribution functions for two, three and four meteorological variables failed to show a satisfactory fit between products of the single distribution functions and the empirical joint distributions.

A supplementary calculation was carried out to test the hypothesis that one or more variables was independent in the sense that changing that variable made the same difference to the equilibrium temperature calculation if the change was alone or in concert with another variable. Using a program to calculate E for various inputs, such variable changes were simulated. The results of this procedure were essentially the same as the results of the independence tests; no variables were clearly independent, and no general results appeared for Boston, Fresno, and Portland. As with the independence tests, Boston and Portland were more alike than either Boston and Fresno or Portland and Fresno. For this sensitivity a model and computer code for the sensitivity of E to each meteorological variable was used. This model is described in more detail earlier in this section.

In addition, all variables from the Fresno time windows 1100-1400 and 1600-1900 were checked for normality; Table 6 shows the results of this check, which indicates the Gaussian fit is not satisfactory.

On the basis of these results, it was decided to assume that all variables were correlated to a significant degree in the general case. At this point, also, the decision was made to perform all further tests and analyses with the two year data set, at a significant savings in computer time.

Table 6. Test of Fit to Normal Distribution for Fresno Data; Two Year Span, June Through August.

Time Window (Hours)	Meteorological Variable	Sample Mean	Sample Standard Deviation	No. of Points In Sample Statistic	No. of Points In Test	ERR*
1600-1900	Wind Speed	7.6	2.7	123	489	.02
	Air Temperature	89.1	8.5	123	489	.05
	Relative Humidity	30.1	10.3	123	489	.01
	Cloud Cover	1.2	2.5	123	489	.0
1100-1400	Wind Speed	4.9	2.4	123	489	.0
	Air Temperature	88.3	8.0	123	489	.005
	Relative Humidity	33.0	9.2	123	489	17.
	Cloud Cover	.98	2.4	123	489	.0

* ERR = X implies that the hypothesis that the set tested is from a normal probability density can be rejected with X per cent probability of being incorrect.

Development of Joint Distribution Functions Used in Calculating the Stochastic Distribution of E

Because of the important dependencies coupling the meteorological variables the hypothesis was made that most of the dependence is accounted for by pair wise coupling among the variables. This hypothesis was successfully tested as described in the following.

Let us define probability $y = p(x^1_{r_1}, x^2_{r_2}, x^3_{r_3}, x^4_{r_4}, x^5_{r_5})$ as the probability that variable one will fall in class r_1, variable two will fall in class r_2, etc. The hypothesis that the full distribution can be approximated by pair wise coupling is then expressed as:

$$y = p_1(x^1_{r_1})\, p_2(x^2_{r_2})\, p_3(x^3_{r_3})\, p_4(x^4_{r_4})\, p_5(x^5_{r_5})$$

$$- \sum_{n,q=1}^{5} c_{nq}\, p_{nq}\left(x^n_{r_n}, x^q_{r_q}\right)$$

where variable ranges are reported as discrete classes (for ease in accumulating joint distributions), and

$p_i(x_i)$ is the probability that variable i is in class x_i

$p_{kl}(x_k, x_l)$ is the joint probability that variables k and l are in class x_k and x_l, respectively

$c_{ij} = p_{ij}(x_i, x_j) - p_i(x_i)\, p_i(x_j)$ is the empirical correction required to simulate the total joint distribution by product of the single distributions corrected by pair wise correlations

r_n is the variable class of variable n.

The basic components of this equation are the single variable probabilities and the c_{ij} matrices. The option to compute these matrices, and to test empirical probabilities against theoretical distributions, was incorporated into the overall computer program. Hand calculations to check the validity of the equation were performed, and the resulting approximations to the joint probability were, in general, lower than the observed values by about 30 percent. This is a great improvement over the product of the single distributions which yields values in error by a factor of two to ten.

If higher accuracy is required the functional approximations for triplet distributions can be employed.

Application of the Stochastic Model for E

Figures 5 through 14 are plots of the equilibrium temperature occurrences for Fresno and Boston, June through August, hours 1100-1400, 1100-1200, and 1600-1900, based on two and ten years of data. The horizontal scale represents the number of occurrences of each parameter value on the vertical scale. (In these plots, values near and below 32°F are not correct. This inaccuracy arises from two factors. First, the model used does not take into account the change in processes occurring near the freezing point of water. Second, the incoming long wave radiation used is low due to a low value being obtained for the Brunt coefficient. The equilibrium temperature is an artificial quantity; calculating its values over a few hours based on a coefficient which was developed from daily averaged data has led to inaccuracies in the nighttime (or low E) results. These two factors, however, do not affect the accuracy of the midday results; this accuracy is discussed in a later section.)

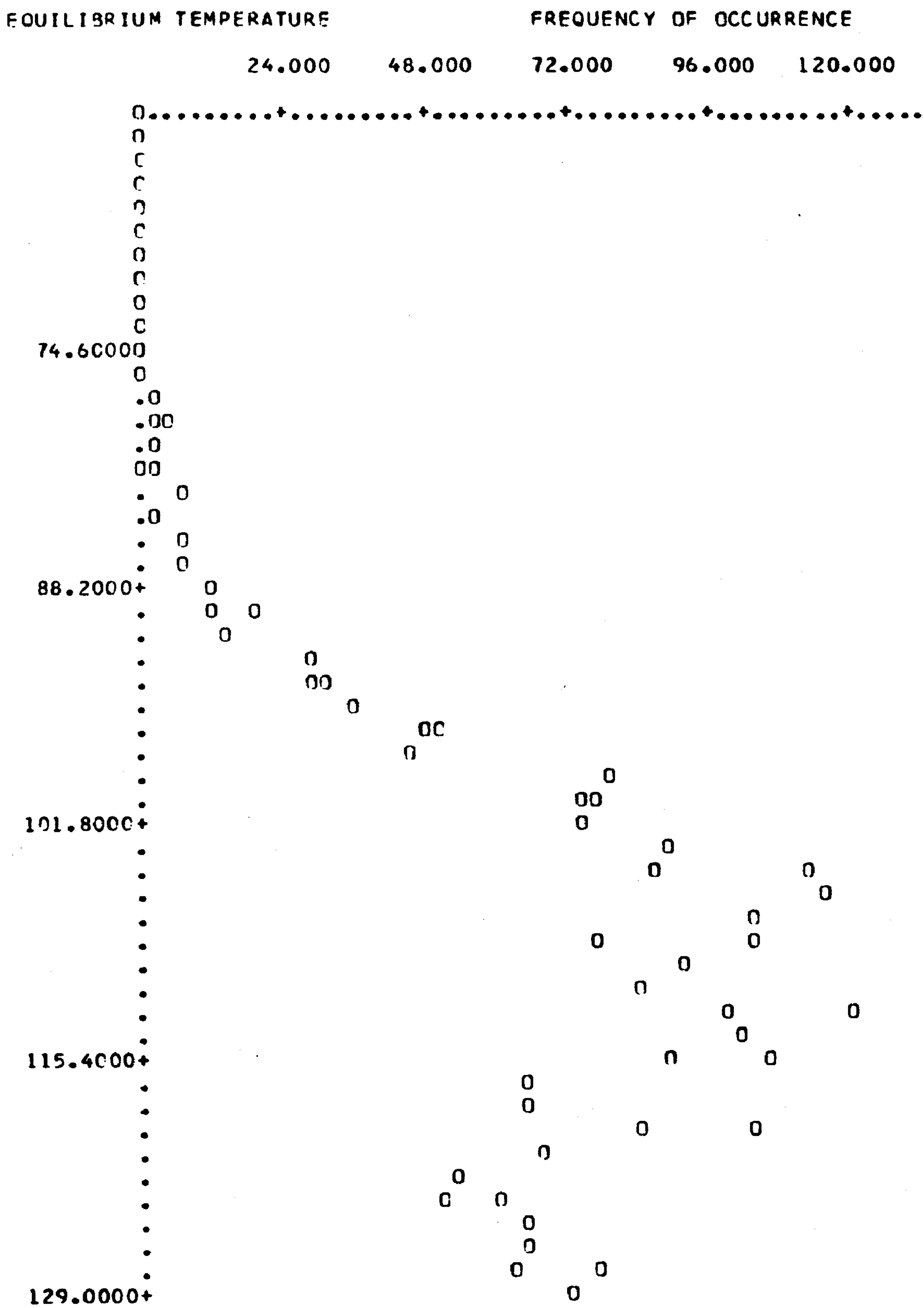


Figure 5. Distribution of Equilibrium Temperature; Fresno, June Through August, 1100-1400; 10 year Span; 3529 Points

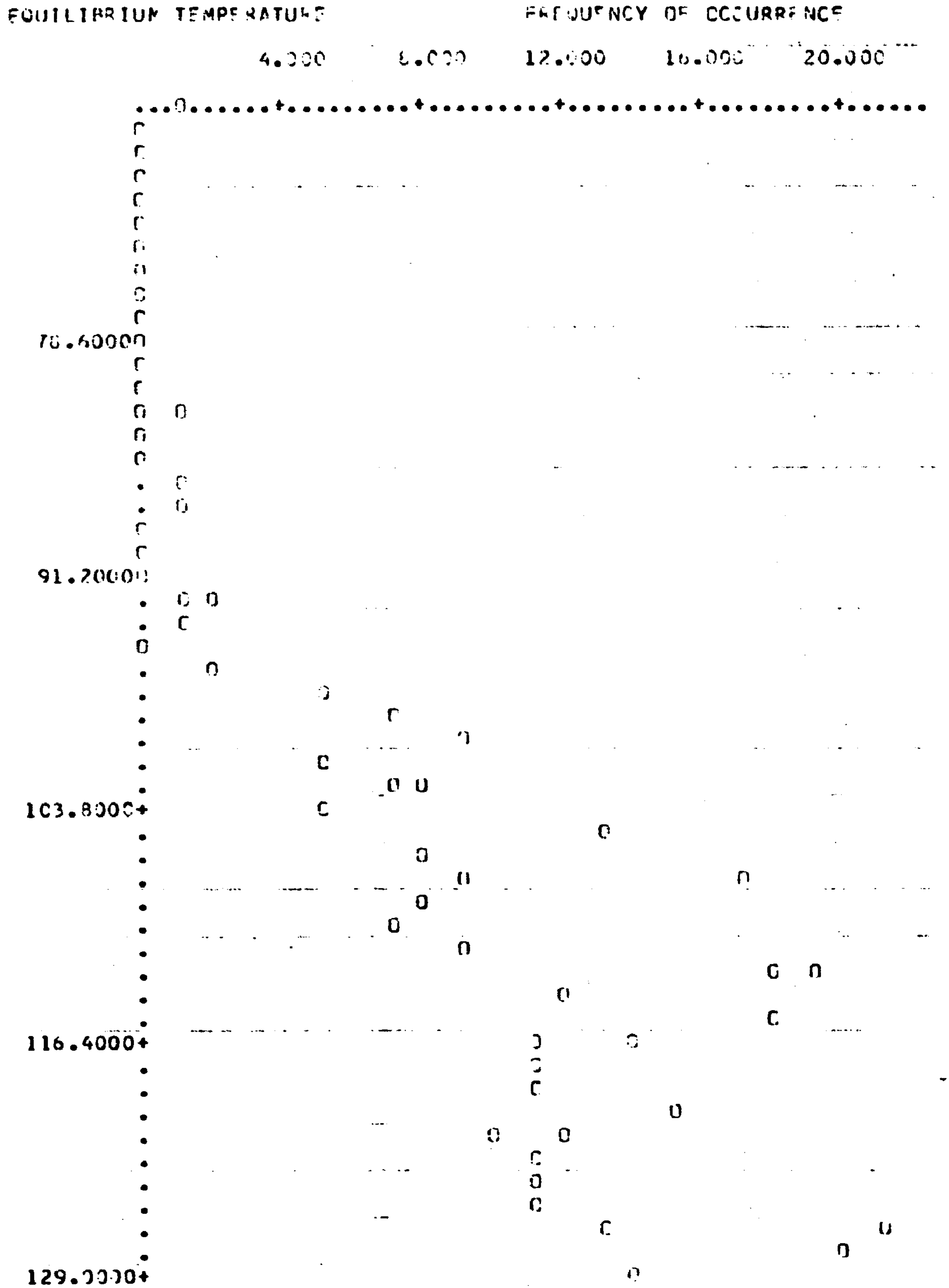


Figure 6. Distribution of Equilibrium Temperature; Fresno, June Through August, 1100-1400; 2 Year Span; 587 Points

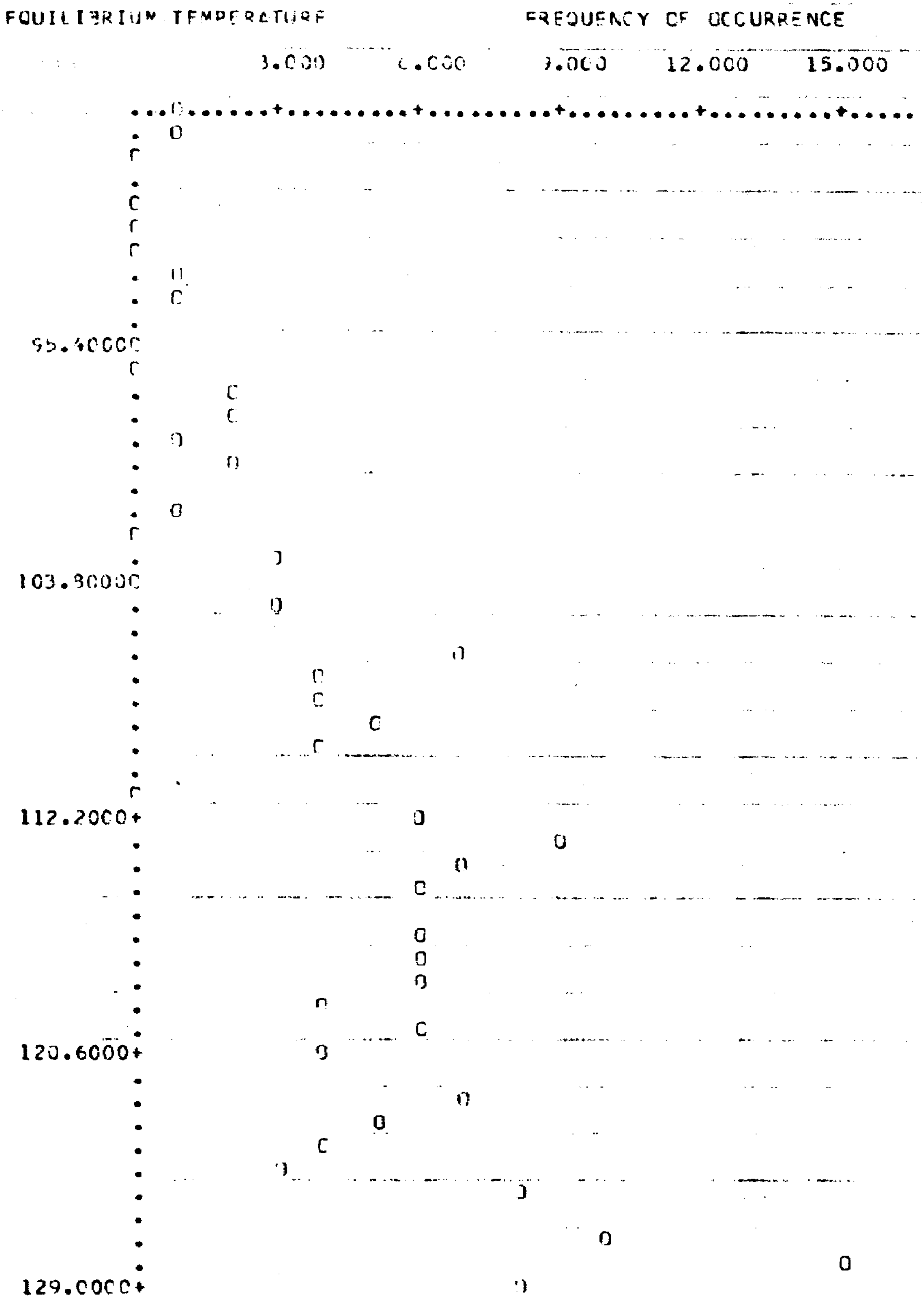


Figure 7. Distribution of Equilibrium Temperature; Fresno, June Through August, 1100-1200; 2 Year Span; 293 Points

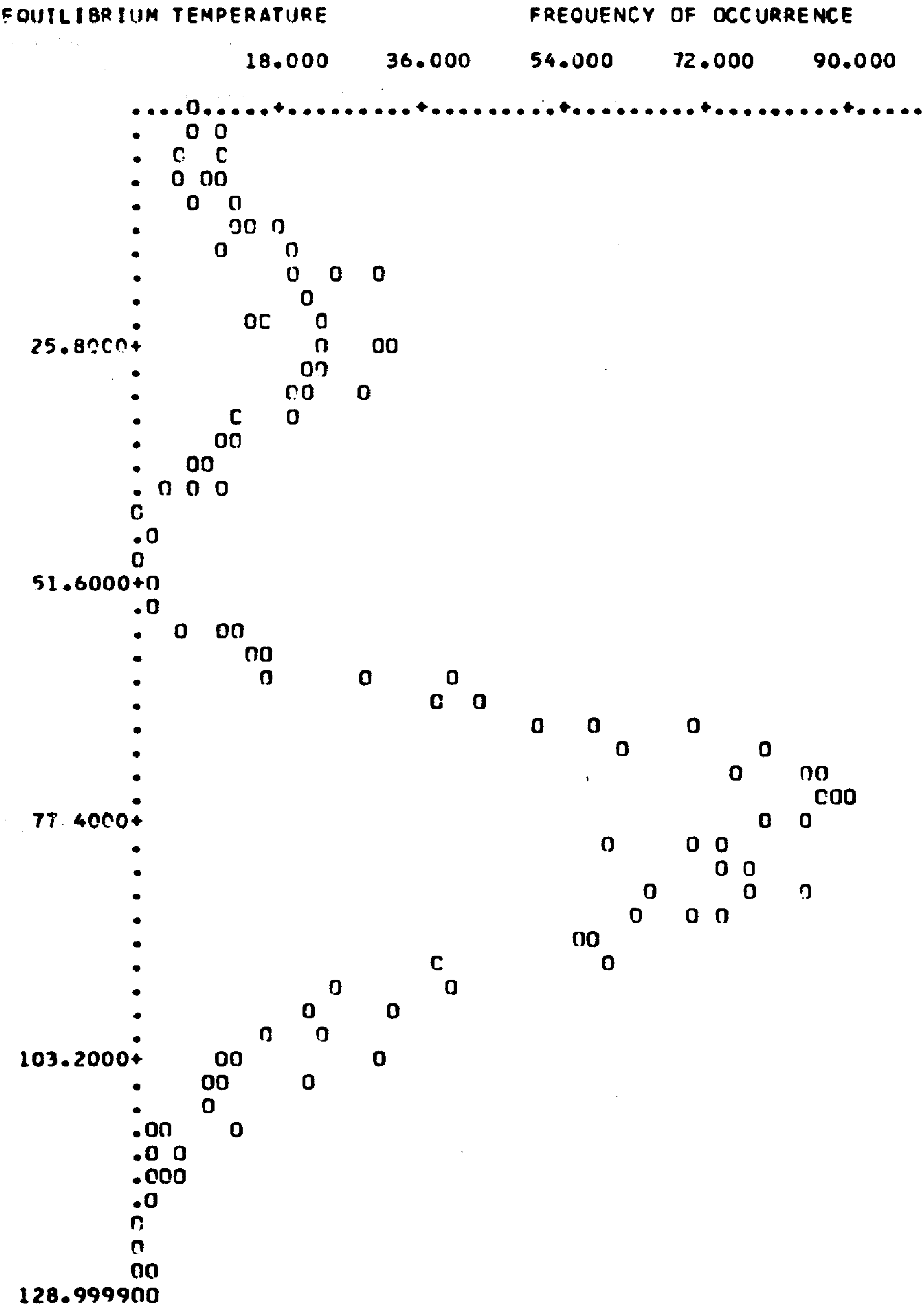


Figure 8. Distribution of Equilibrium Temperature; Fresno, June Through August, 1600-1900; 10 Year Span; 2296 Points

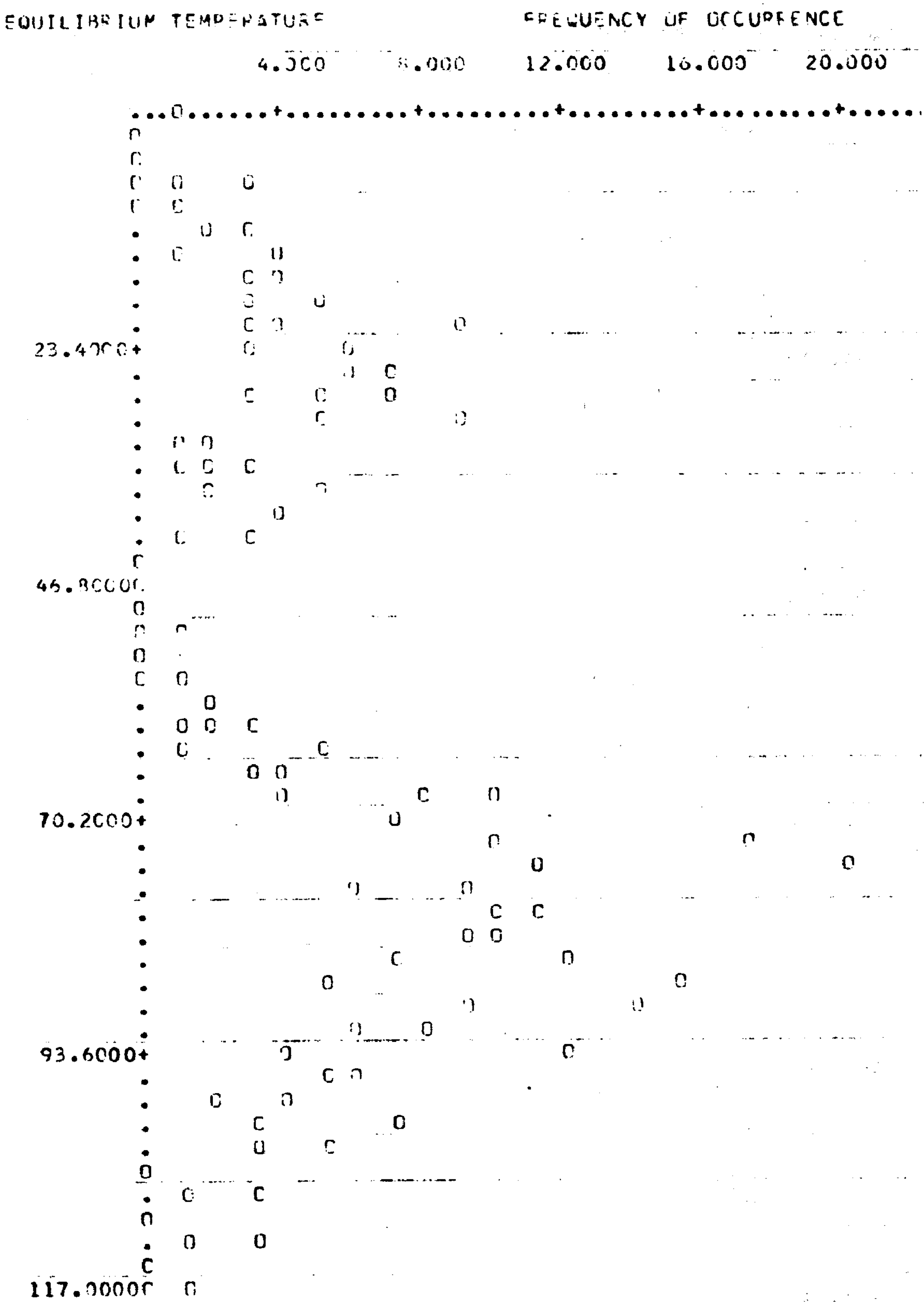


Figure 9. Distribution of Equilibrium Temperature; Fresno, June Through August; 1600-1900; 2 Year Span; 344 Points

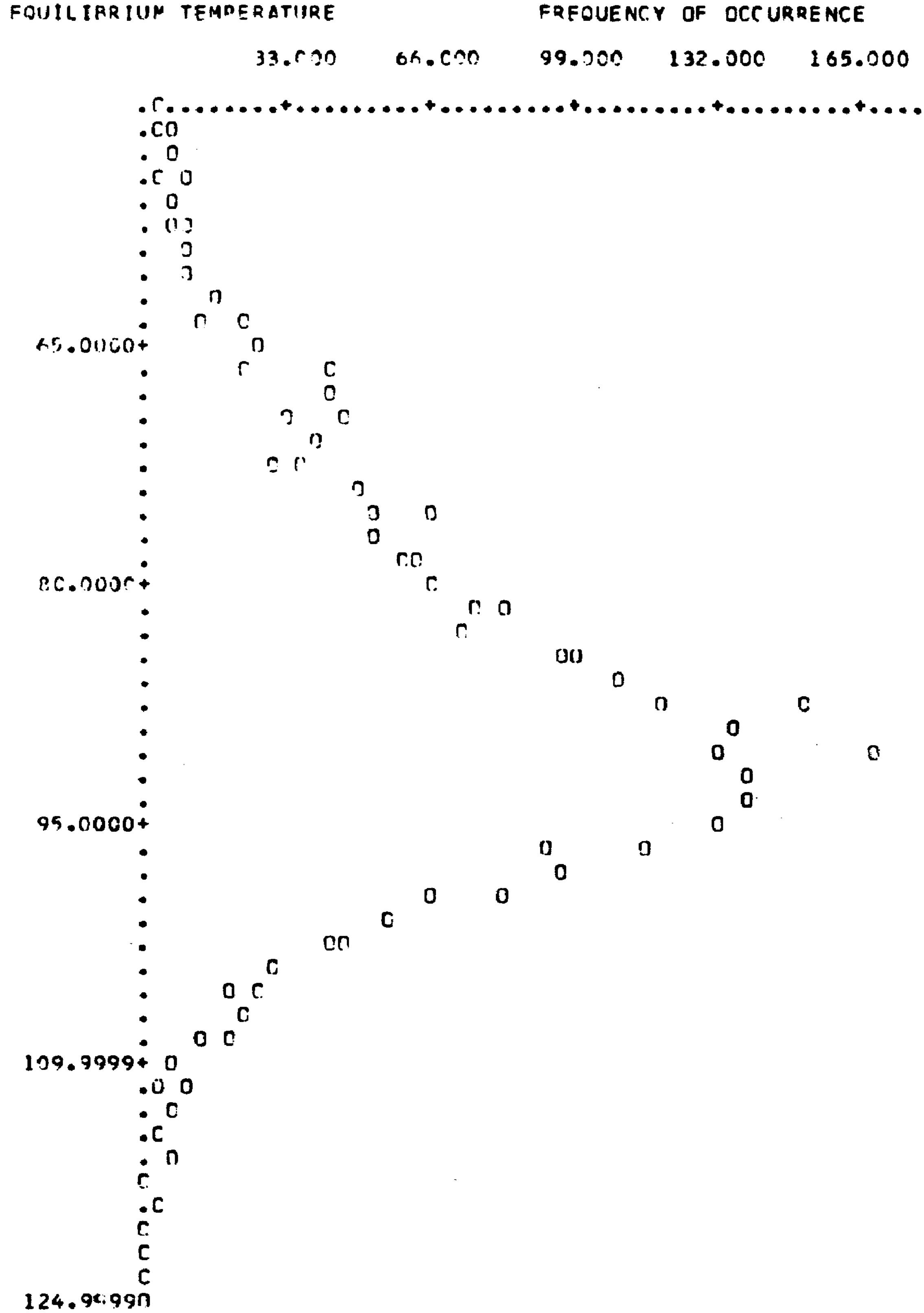


Figure 10. Distribution of Equilibrium Temperature; Boston, June Through August; 1100-1400, 10 Year Span; 3449 Points

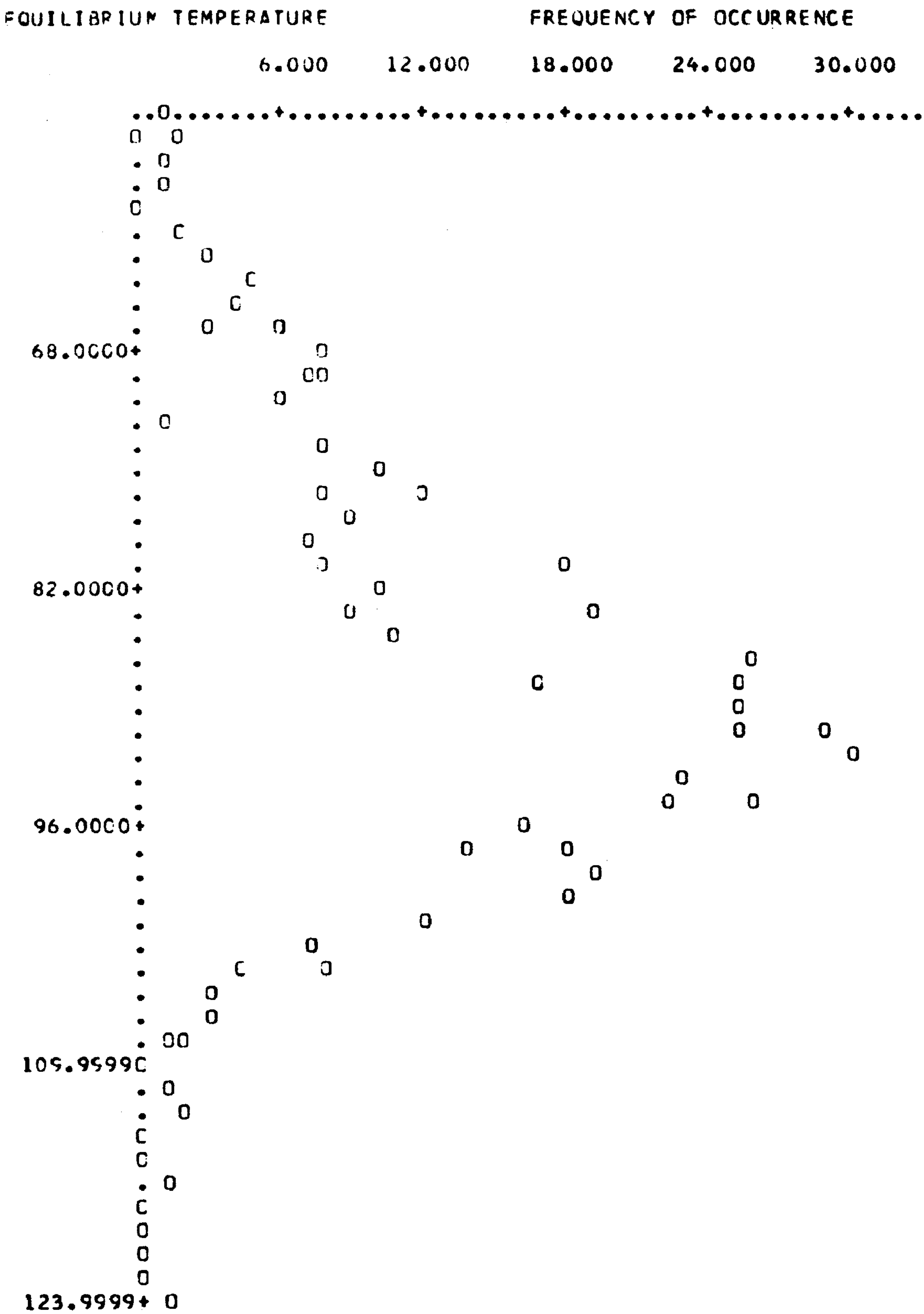


Figure 11. Distribution of Equilibrium Temperature; Boston, June Through August; 1100-1400, 2 Year Span; 593 Points.

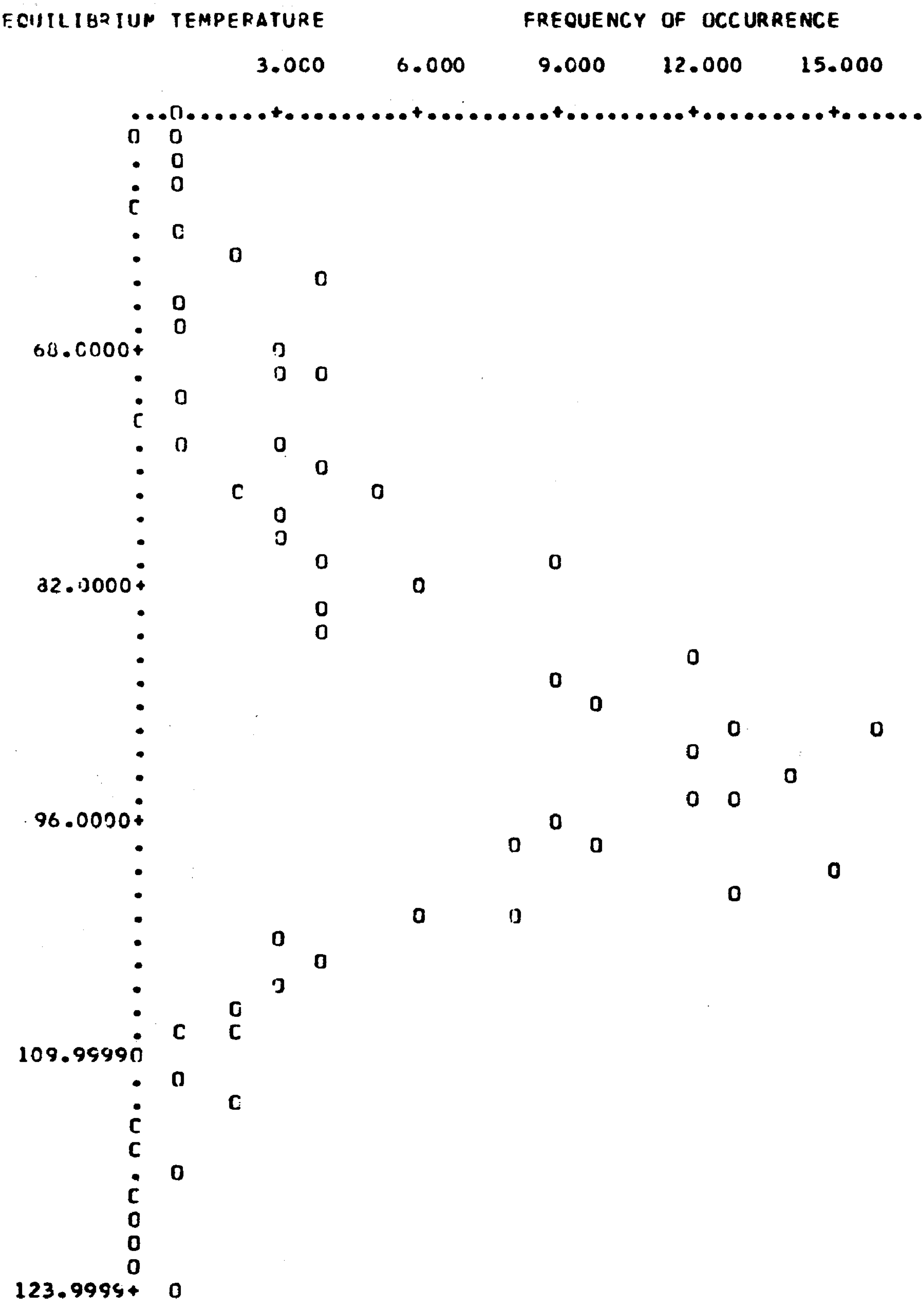


Figure 12. Distribution of Equilibrium Temperature; Boston, June Through August; 1100-1200; 2 Year Span; 297 Points

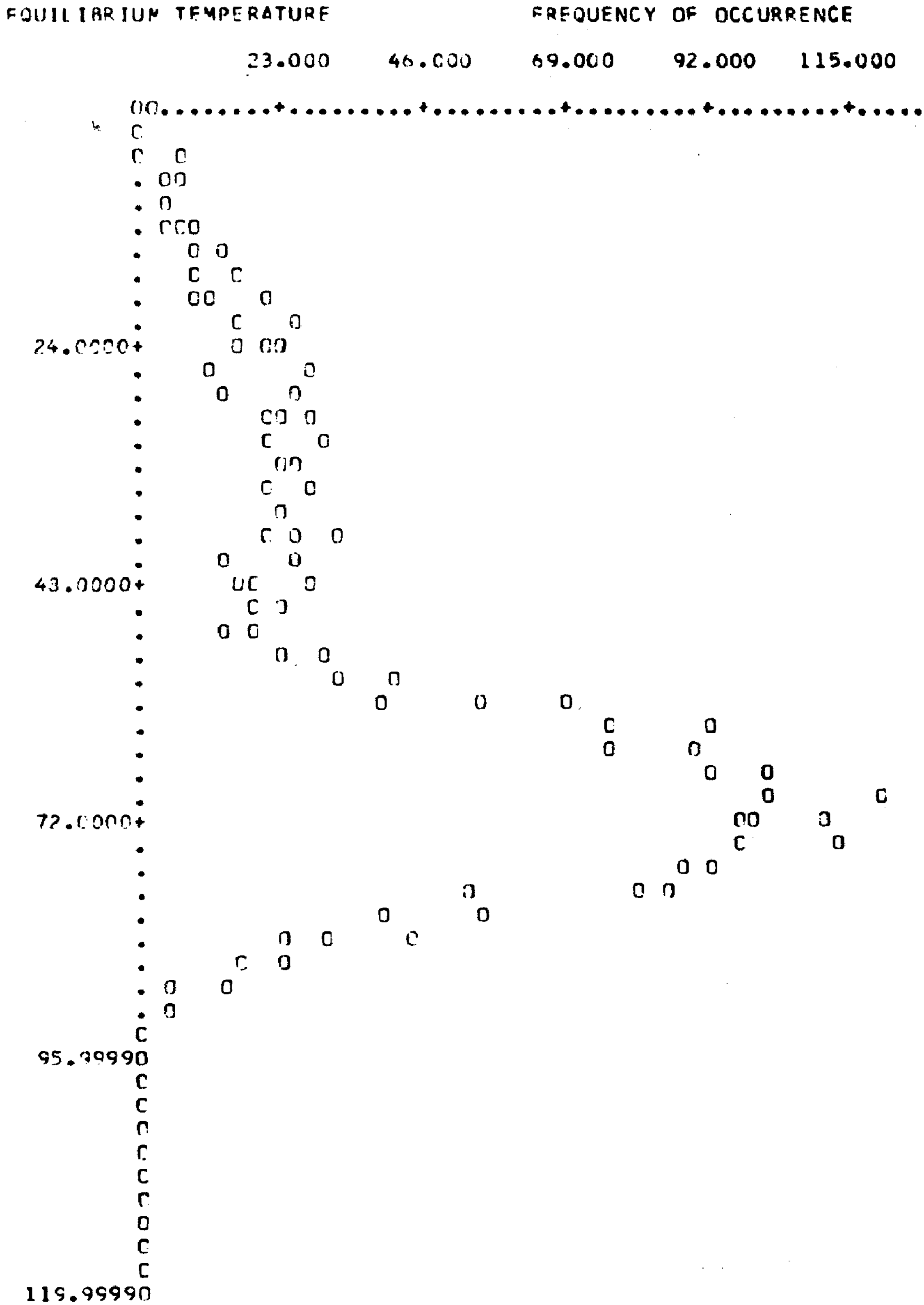


Figure 13. **Distribution of Equilibrium Temperature; Boston, June Through August; 1600-1900; 10 Year Span; 2770 Points**

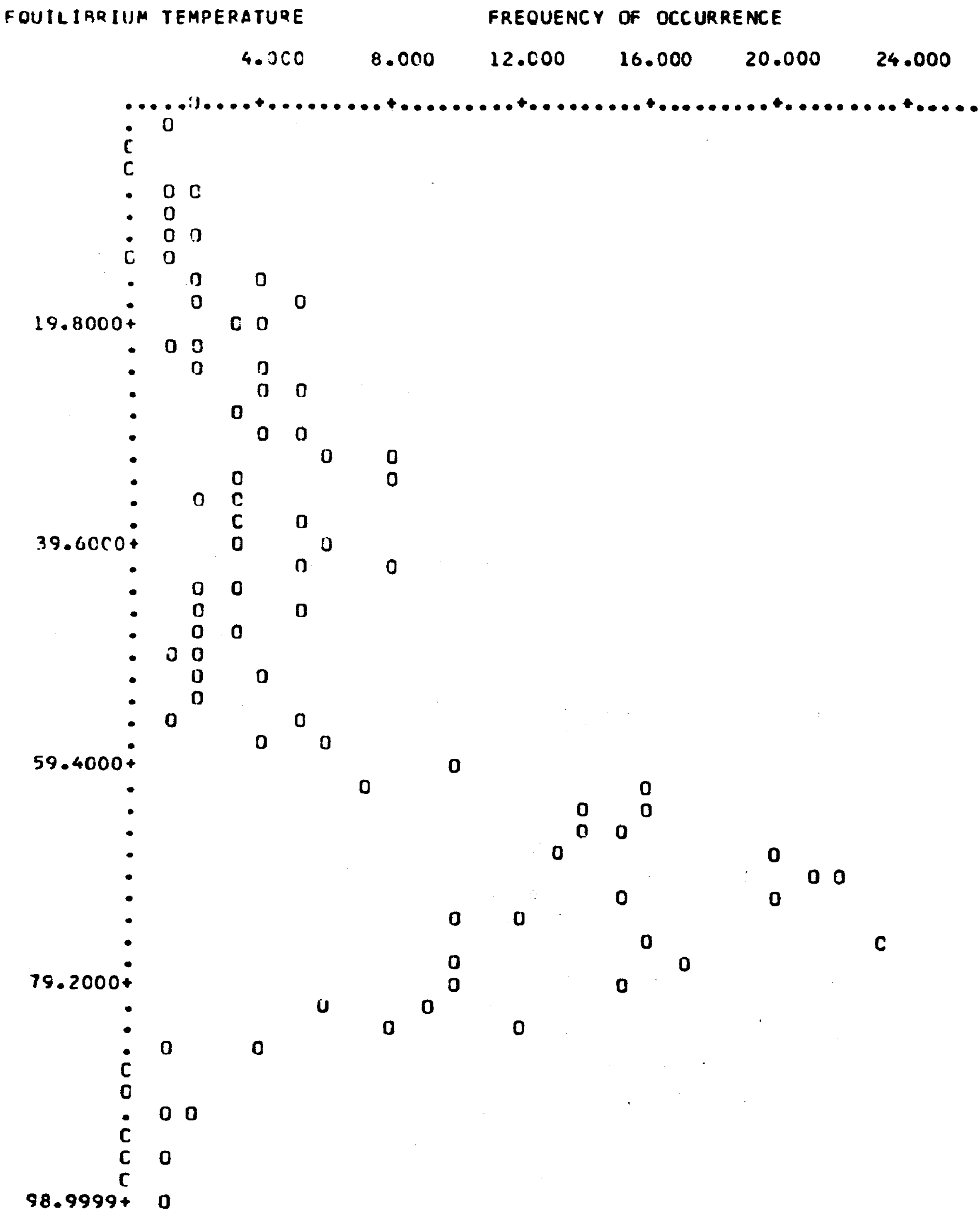


Figure 14. Distribution of Equilibrium Temperature; Boston, June Through August; 1600-1900; 2 Year Span; 476 Points

There are four ways in which these plots may be viewed as sources of information. First, they can supply a value that the equilibrium temperature can be expected to exceed for any fraction of the time for the given time window. (or, any other simple statistic may be computed.) In addition, the horizontal scale divided by the number of points is the expected probability of occurrence for each value of E.

Table 7 summarizes the 5 percent level for the plots given. These values lead to two more analyses: the equivalence of results for different time periods, and at different geographical locations. In this case, by inspection of both the plots and Table 7, it can be seen that two years of data produces essentially the same result as ten (at a difference of a factor of five in computer time). And, in fact, for the 1100-1400 hour period, two hours produce essentially the same results as four in this respect. However, the results for Boston and Fresno cannot be interchanged, nor can the two diurnal time periods for a single location.

Table 7. Level Which Equilibrium Temperature Can be Expected to Exceed Approximately 5 Percent of the Time (Degrees Fahrenheit) During June through August for the Specified Hours.

	1100 - 1400		1100 - 1200	1600 - 1900	
	10 yrs	2 yrs	2 yrs	10 yrs	2 yrs
Fresno	126	129	128	100	96
Boston	100	102	102	79	83

The fourth type of information available concerns the underlying meteorology causing the particular shape of the E distribution. Figures 15 through 19 are plots of the five basic meteorological variables associated with the plots of Figure 2; Figures 20 through 24 are the corresponding plots for Figure 8. The high wind speeds and low solar radiations of the latter set correlate with the bulge on the low end of the equilibrium temperature distribution for the 1600-1900 period, a set of circumstances which do not appear during the 1100-1400 time slot. From the preceding information it seems reasonable to extrapolate a general procedure for predicting the distribution of equilibrium temperature at any site during periods of maximal heating (or any other time periods). A two-year data base is sufficient for use with this program, and produces results in time with the general accuracy of the model and the data, when compared with a ten-year data set.

This following section discusses in some detail accuracy of the data, and the sensitivity of the model for E to this accuracy.

Sensitivity of the Model and Accuracy of the Data Base

Sensitivity analysis in the present context implies the ability to compute partial derivatives of one or more quantities (say, equilibrium temperature and exchange coefficient) with respect to the meteorological parameters. The numerical values taken on by these derivatives for any given example display two important properties of the model. First, they show which parts of the model itself are of greatest weight in the determination of the final result. Second, they exhibit explicitly the effect of errors or inaccuracies in the basic measurements.

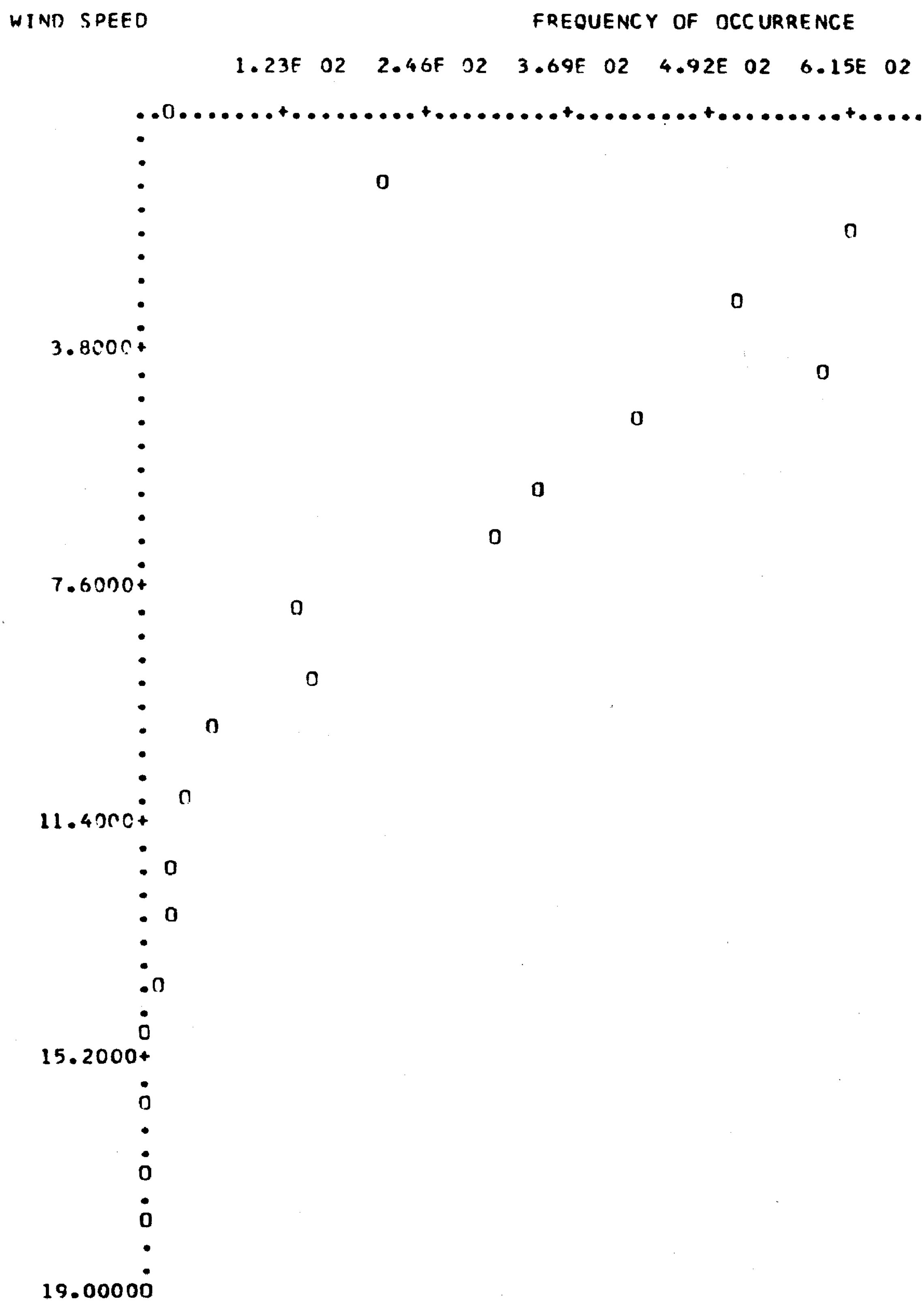


Figure 15. Distribution of Wind Speed, Knots; Fresno, June Through August; 1100-1400; 10 Year Span; 3529 Points

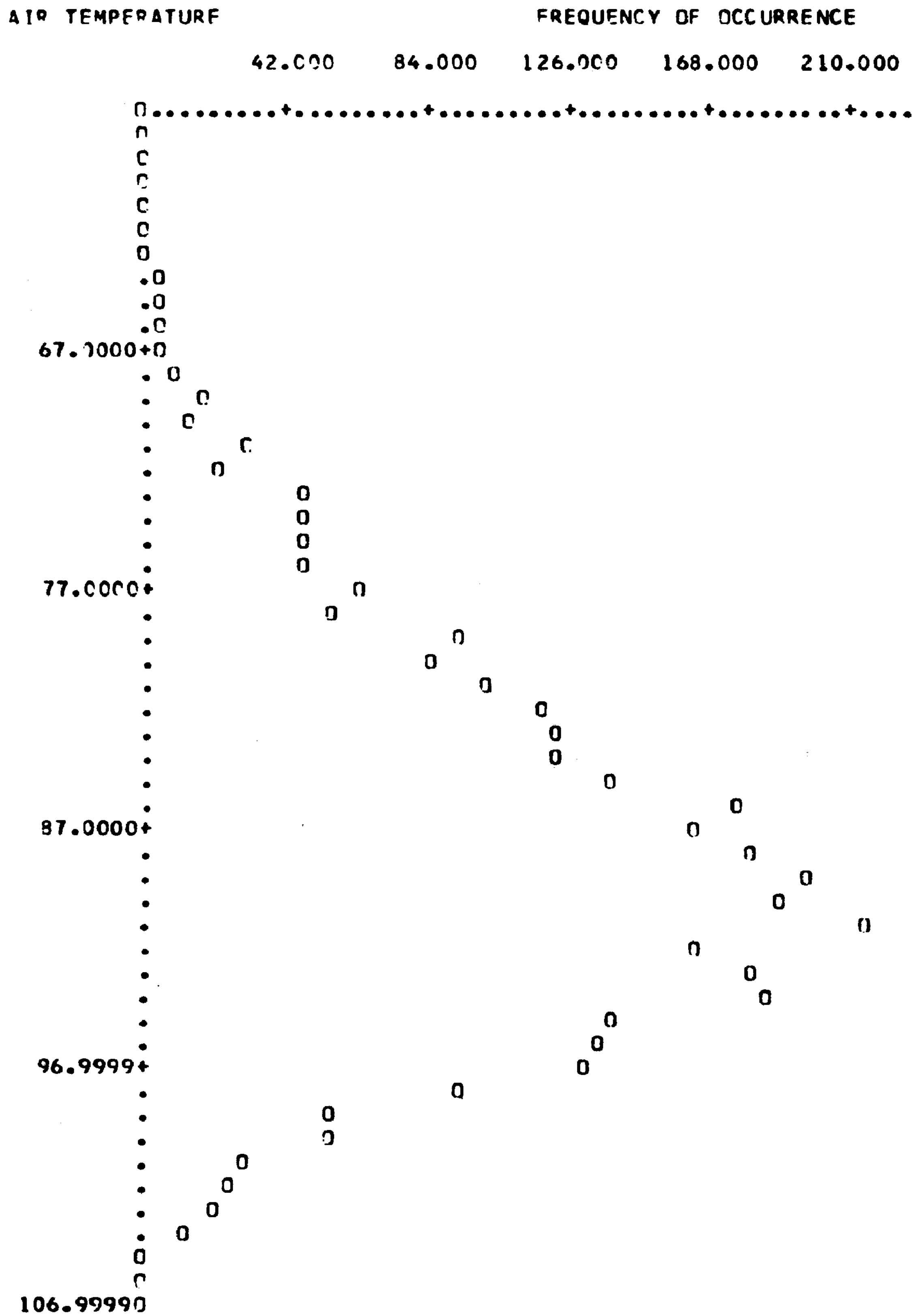


Figure 16. Distribution of Air Temperature, °Fahrenheit; Fresno, June Through August, 1100-1400; 10 Year Span; 3529 Points

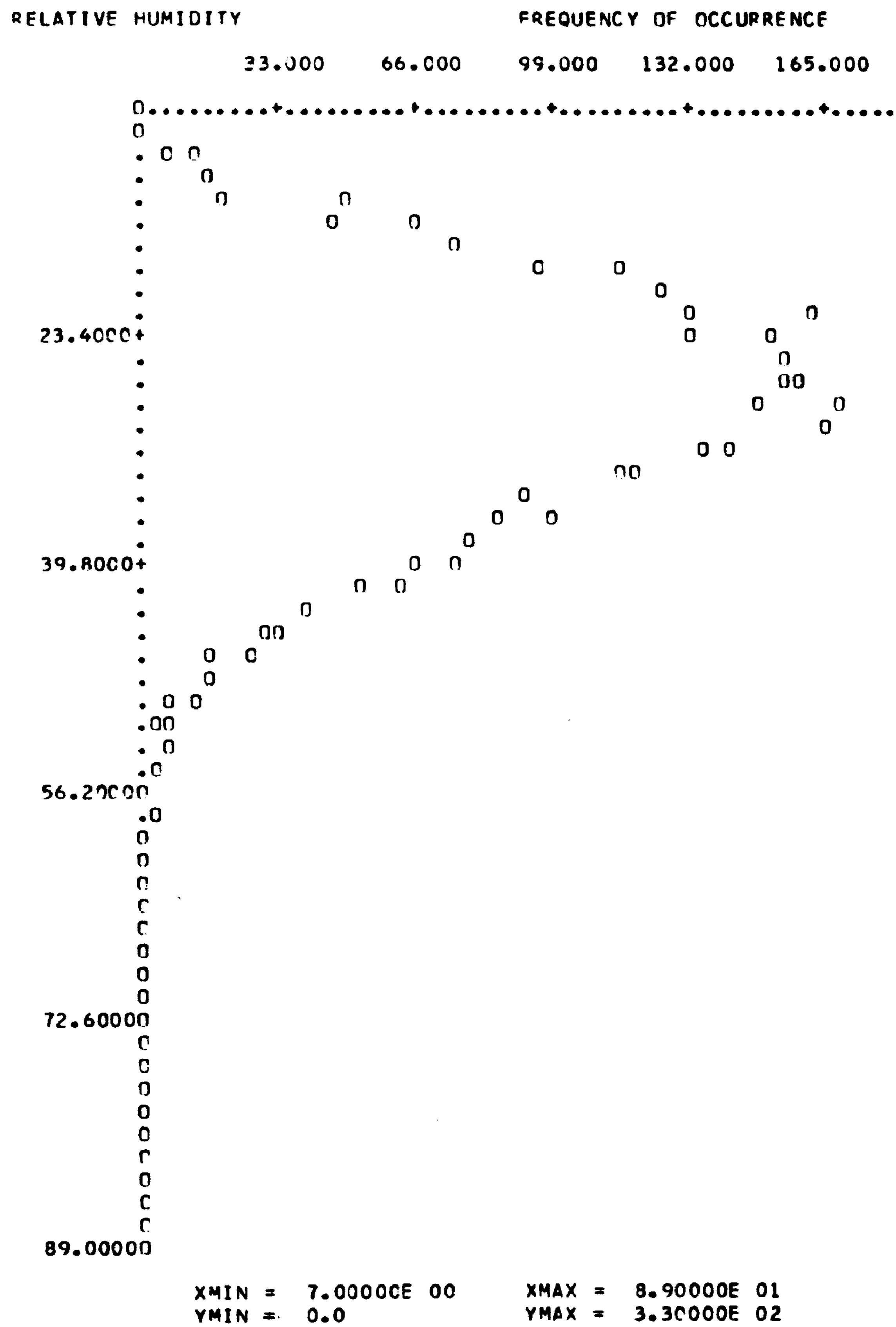


Figure 17. Distribution of Relative Humidity, Percent; Fresno, June Through August; 1100-1400; 10 Year Span; 3529 Points

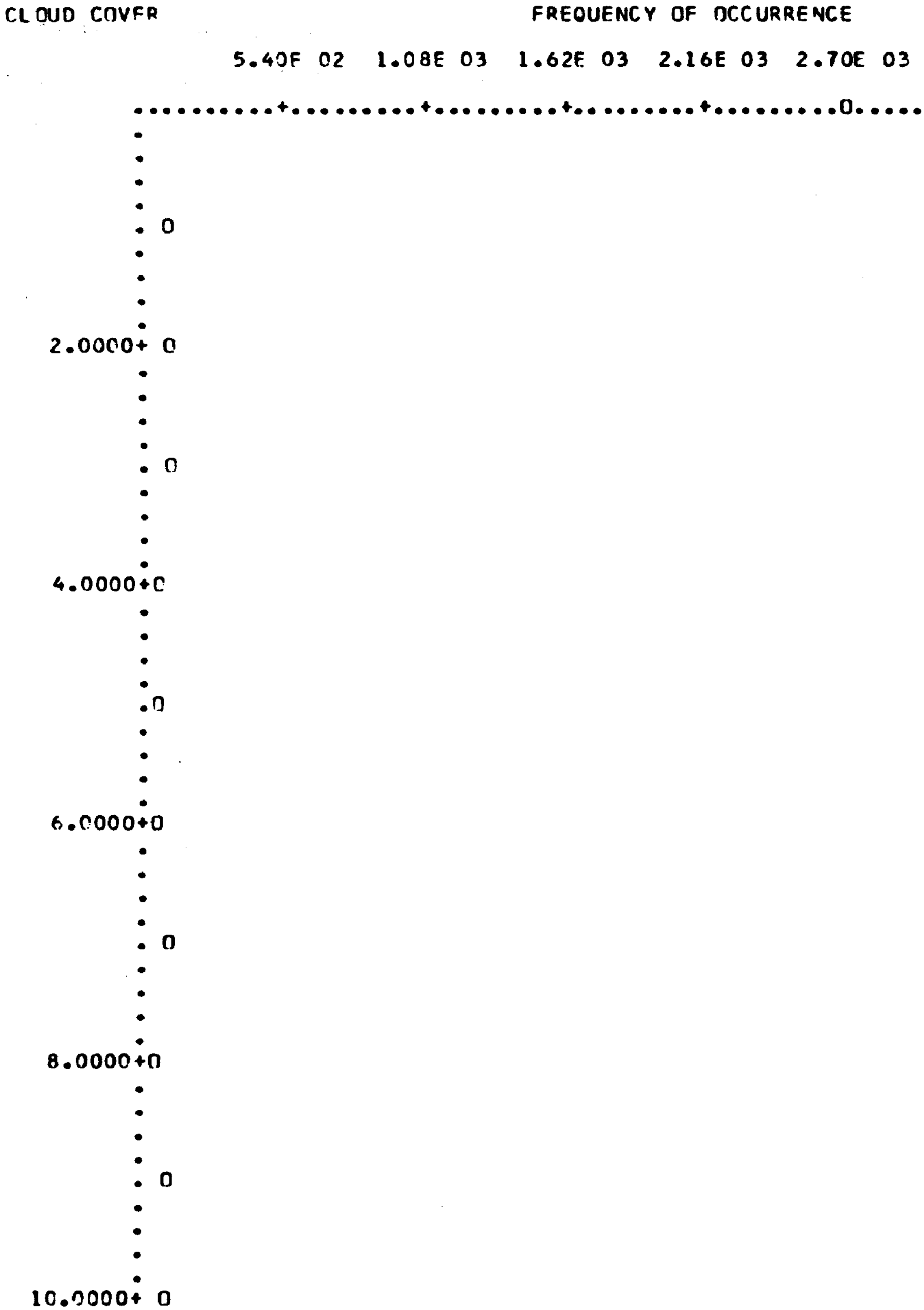


Figure 18. Distribution of Cloud Cover, Tenths; Fresno, June Through August, 1100-1400; 10 Year Span; 3529 Points

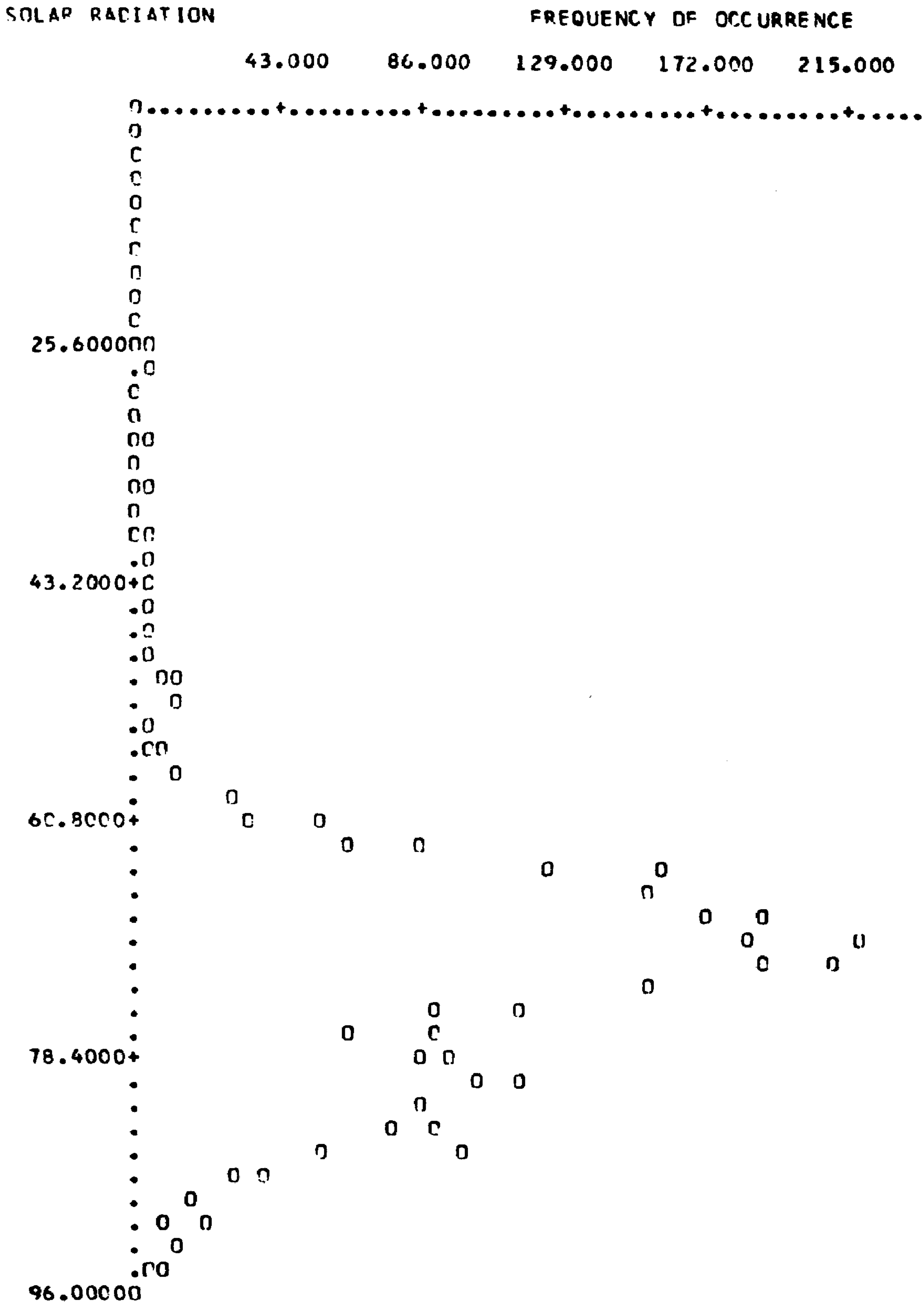


Figure 19. Distribution of Solar Radiation, Langleys/hr; Fresno, June Through August, 1100-1400; 10 Year Span; 3529 Points

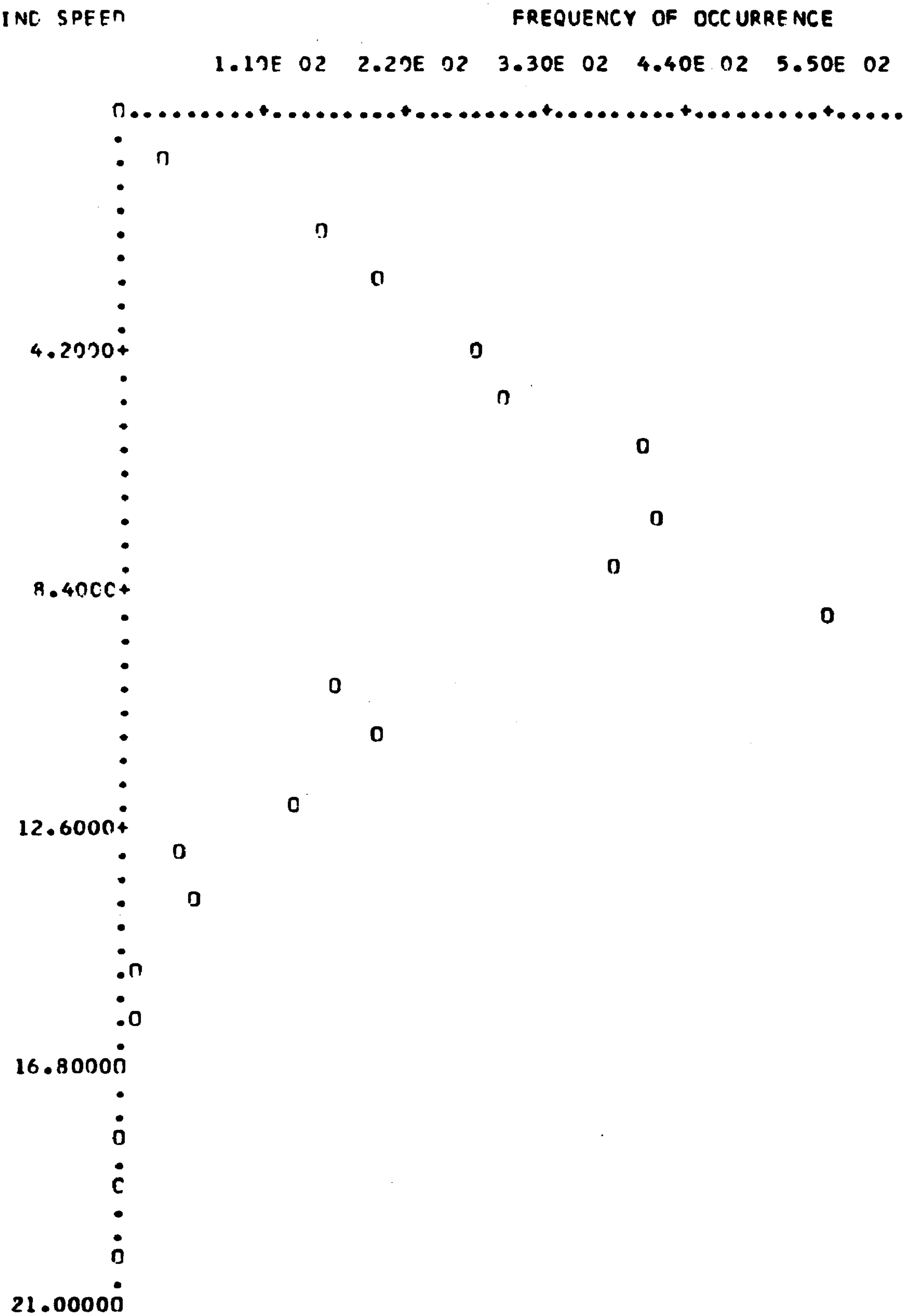


Figure 20. Distribution of Wind Speed, Knots; Fresno, June Through August, 1600-1900; 10 Year Span; 3529 Points

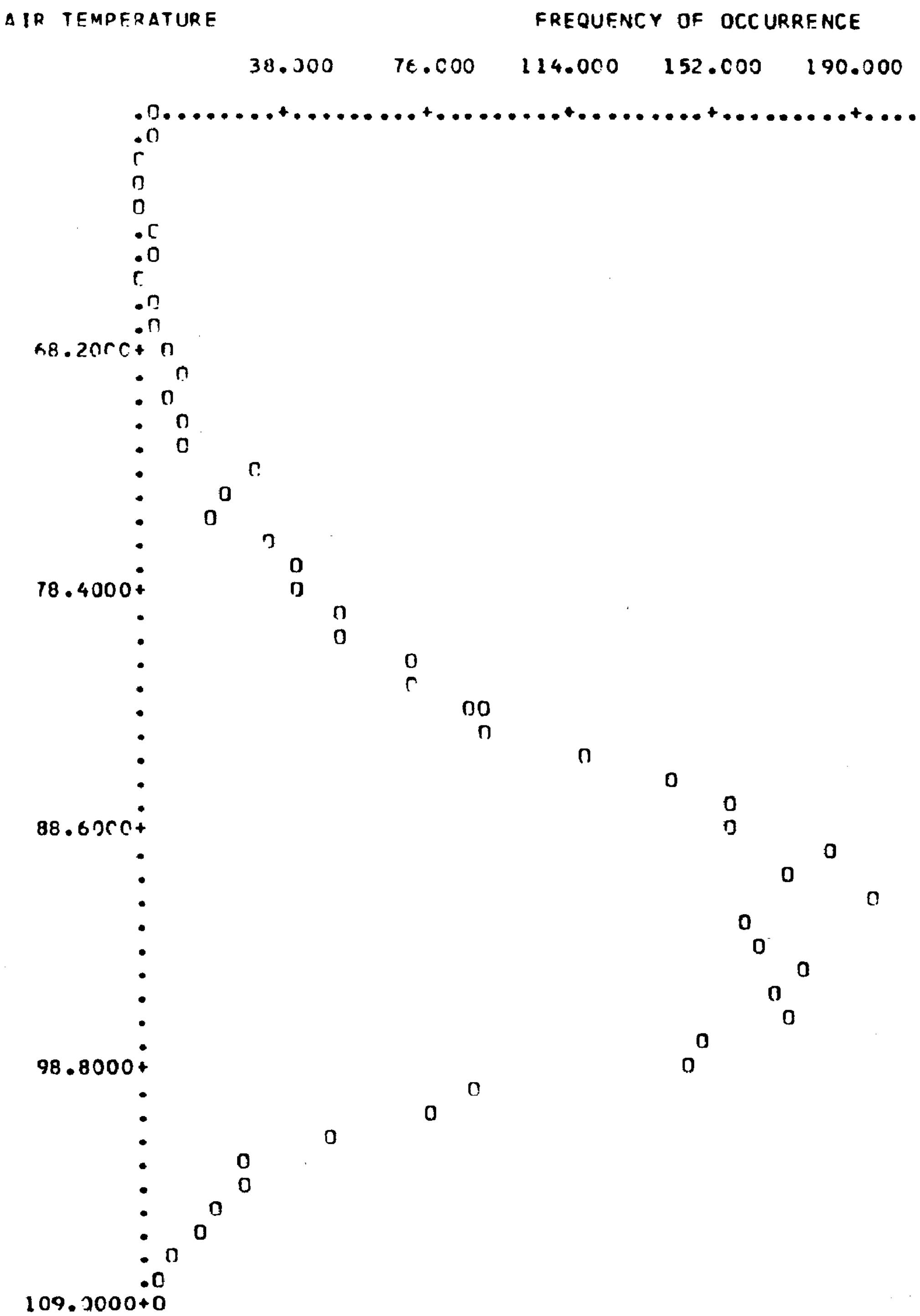


Figure 21. Distribution of Air Temperature, °Fahrenheit; Fresno, June Through August, 1600-1900; 10 Year Span; 3529 Points

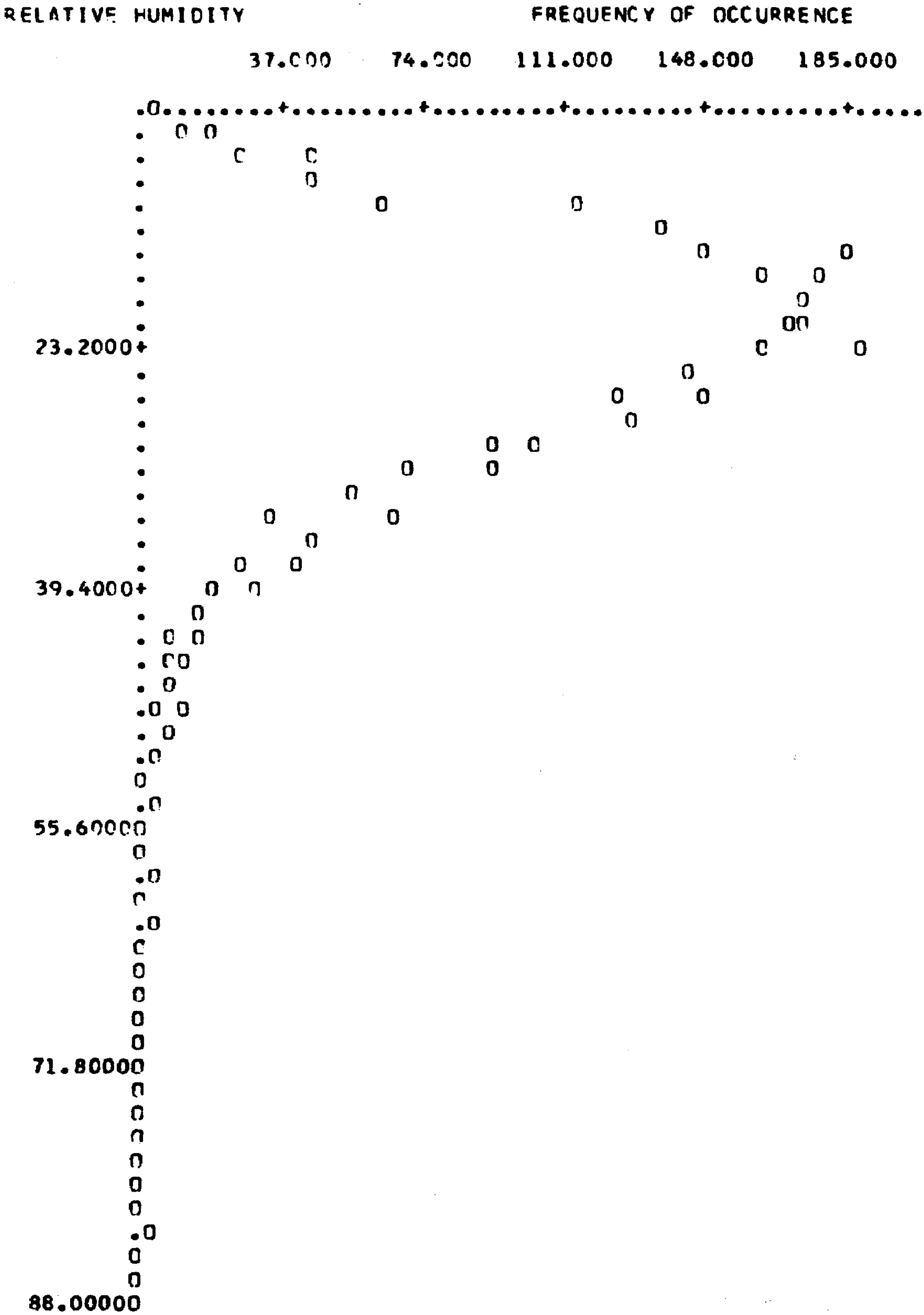


Figure 22. Distribution of Relative Humidity, Percent, Fresno, June Through August; 1600-1900; 10 Year Span; 3529 Points

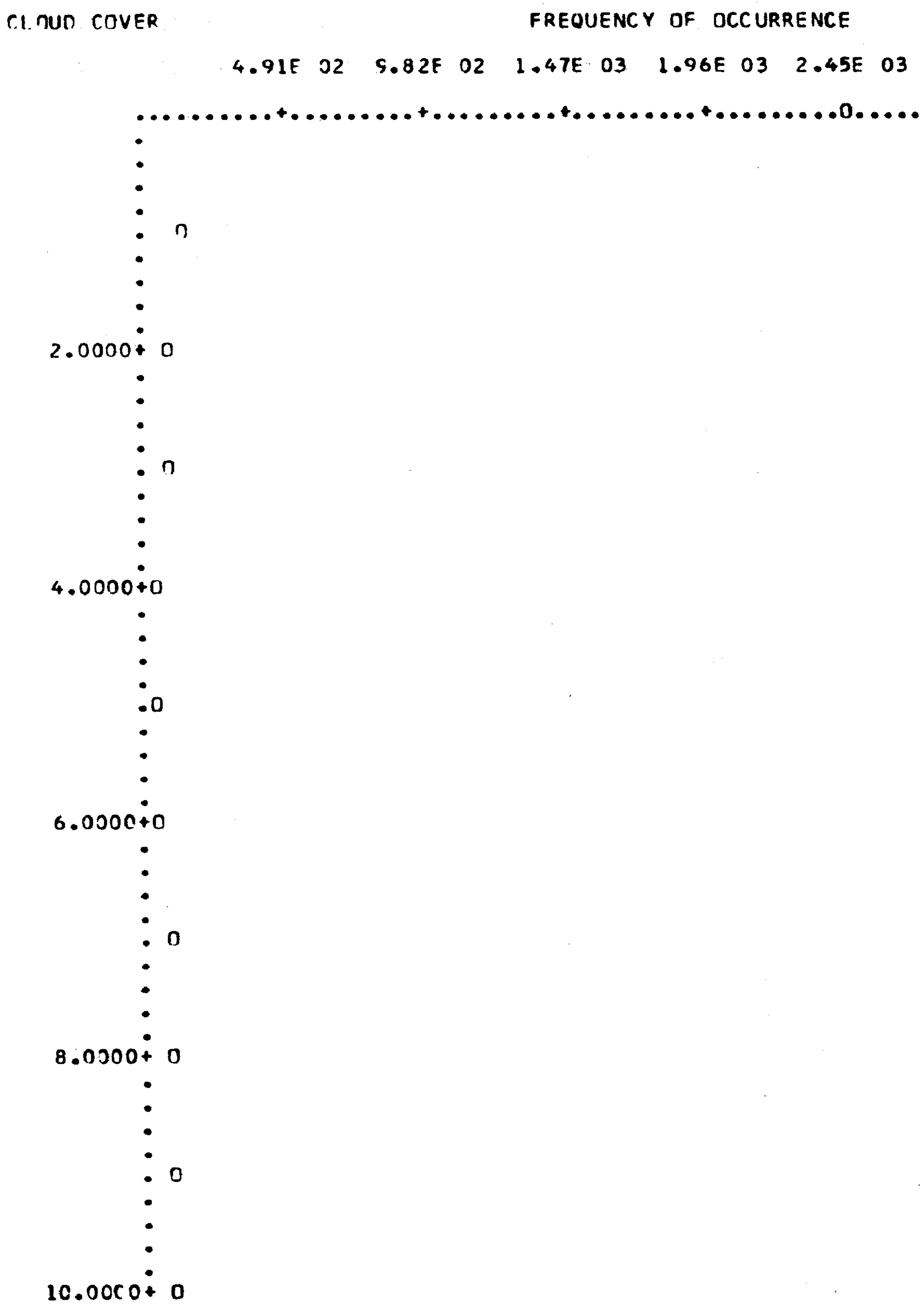


Figure 23. Distribution of Cloud Cover, Tenths; Fresno, June Through August; 1600-1900; 10 Year Span; 3529 Points

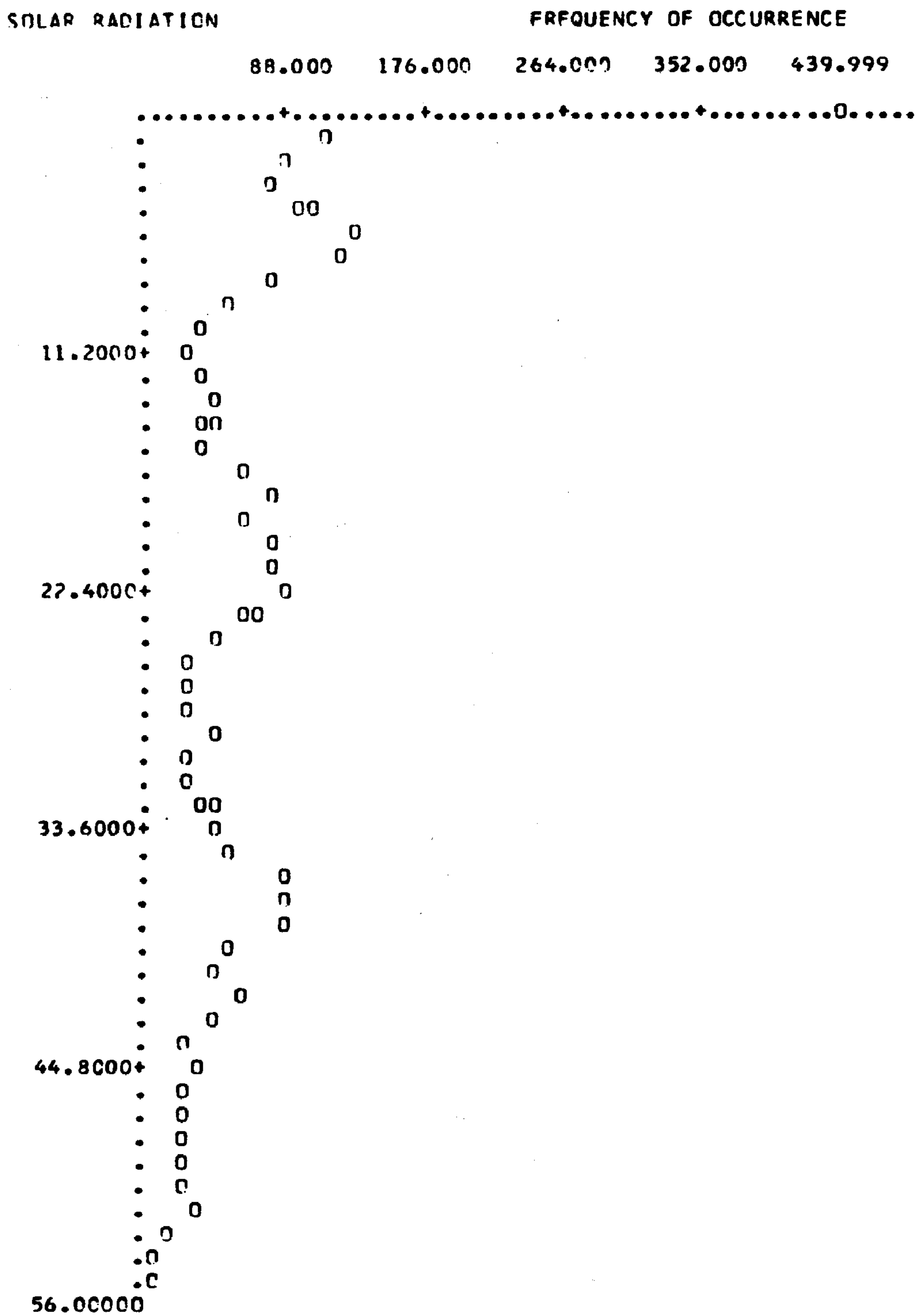


Figure 24. Distribution of Solar Radiation, Langleys/1 hr; Fresno, June Through August; 1600-1900; 10 Year Span; 3529 Points

The partial derivatives themselves have been listed above. Note that they have been formed (and coded) in such a way that they can be easily changed if any components of the model are changed. That is, the final partials of E with respect to each meteorological variable are formed by application of the chain rule; a model change generally implies the need for only a change to one element of the chain.

The sensitivity of the model for E to variations in the five basic meteorological parameters was computed for several ranges of these parameters. Table 8 summarizes these results for three parameters. For wind speed and solar radiation however, the sensitivity may be much greater. Figures 25 and 26 are plots of the sensitivity of E to wind speed for different values of solar radiation, and to solar radiation for varying values of wind speed, respectively. (The remaining parameters are fixed.) Note that although the values along vertical scale in Figure 23 are small, they represent a change in E for one BTU ft^{-2} day^{-1}; variations in this parameter from hour to hour are regularly on the order of 1000.

This information may be combined with some assumptions as to the accuracy of the data to draw quantitative decisions as to the accuracy of the predictions for E, and the likelihood of bias in the results.

Table 8. Sensitivity of E to RH, CC, TA

For a change of	In	The change in E is Less than or equal to
.1	Cloud Cover (CC)	.1°F
1%	Relative Humidity (RH)	.8°F
1°F	Air Temperature (TA)	1°F

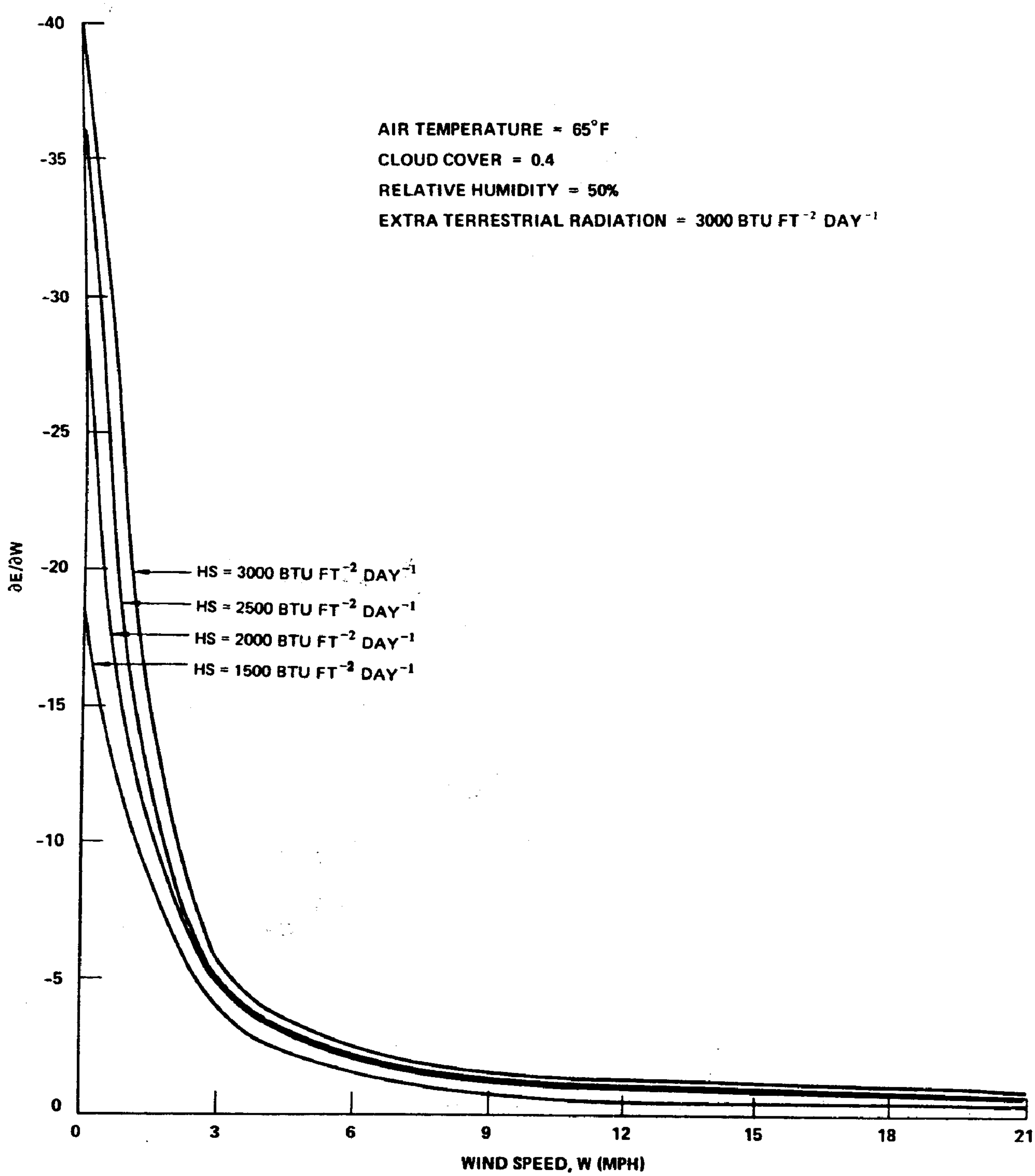


Figure 25. Sensitivity of E to Wind Speed for Different Values of HS

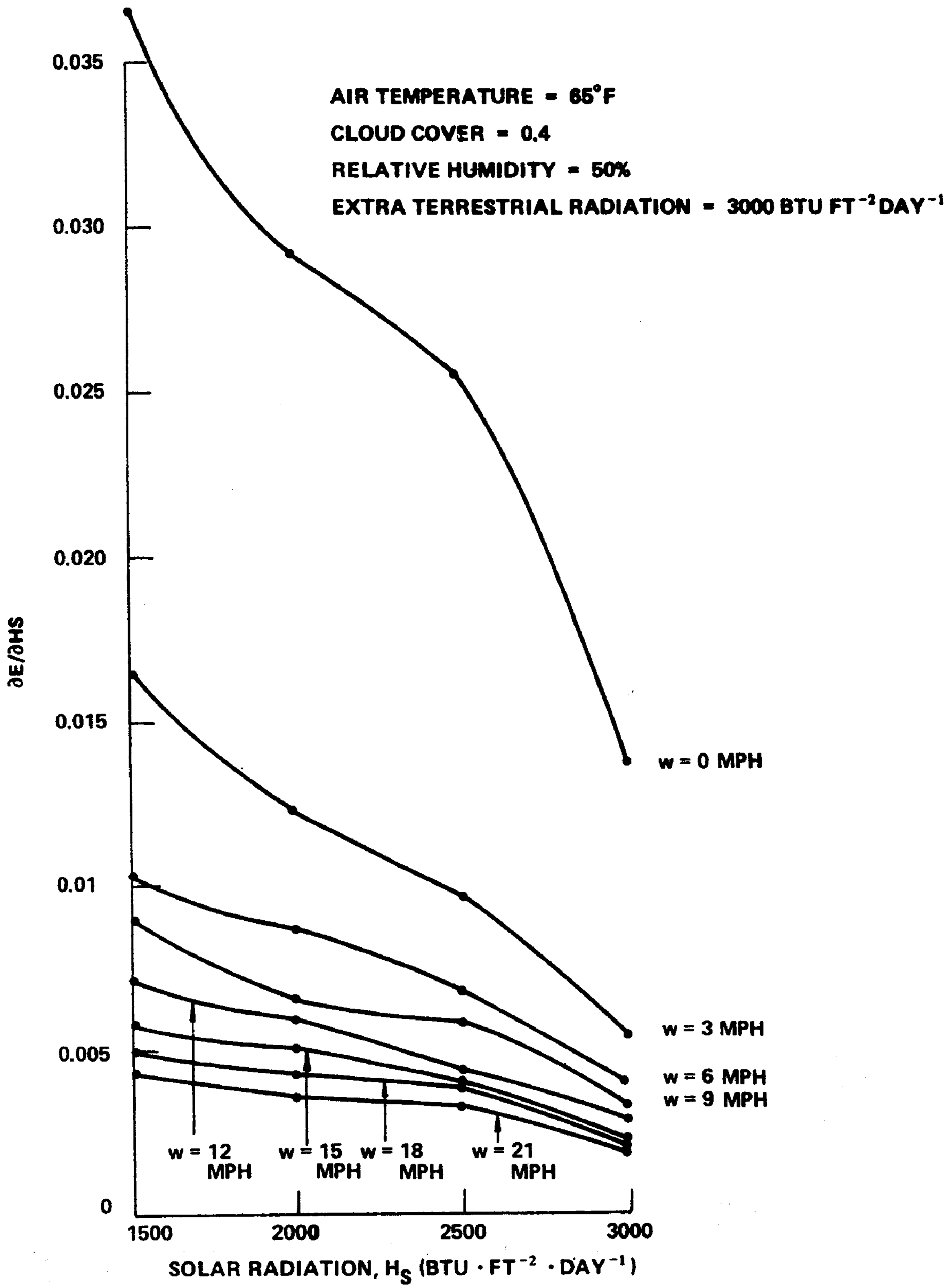


Figure 26. Sensitivity of E to Solar Radiation for Different Values of Wind Speed

Cloud cover is reported on the Weather Bureau tapes in tenths of total sky cover; relative humidity, air temperature and wind speed in whole (integer) percent, degrees Fahrenheit and knots, respectively, and solar radiation in tenths of Langleys per hour. One knot is roughly equivalent to one mile per hour (for the purposes of this analysis); one tenth Langley per hour is 8.85 BTU ft^{-2} day^{-1}. A reasonable assumption seems to be that the sky cover, relative humidity and air temperature are reported fairly accurately; that the reporting error is less than five units of measurement (even less for sky cover). This is borne out by data such as the plots in Figures 15 through 19 and Figures 21 through 24, where there appears to be no strong preference for any one value over neighboring values. For wind speed, however, the situation is just the opposite; Figures 20 and 27-30 exhibit a strong inclination for one wind speed to be reported in preference to speeds one knot more or less especially over a two-year period. The error near the most prevalent wind speed may then be as much as two knots. So far, then, for wind speeds above 3 mph, the error in E (if the model is correct) is less than 5 degrees; for wind speeds less than 3 mph the error in E depends on the accuracy of the wind speed. Then, assuming with Edinger and Geyer[1] that the solar radiation measurements are accurate to at least 250 BTU ft^{-2} day^{-1}, the error in E due to inaccuracies in this measurement can be estimated as less than four degrees for wind speeds less than 3 miles per hour.

Errors in the data then seem to lead to errors in the calculation of E of a maximum of 10° and probably much less, except for inadequately reported low wind speeds. These data errors are of about the same order of magnitude as the accuracy of the model. Therefore, the statistical results reported for the distribution of E should be considered more in the light of the deviation of the 5 percent level from the mean than in terms of absolute temperature values.

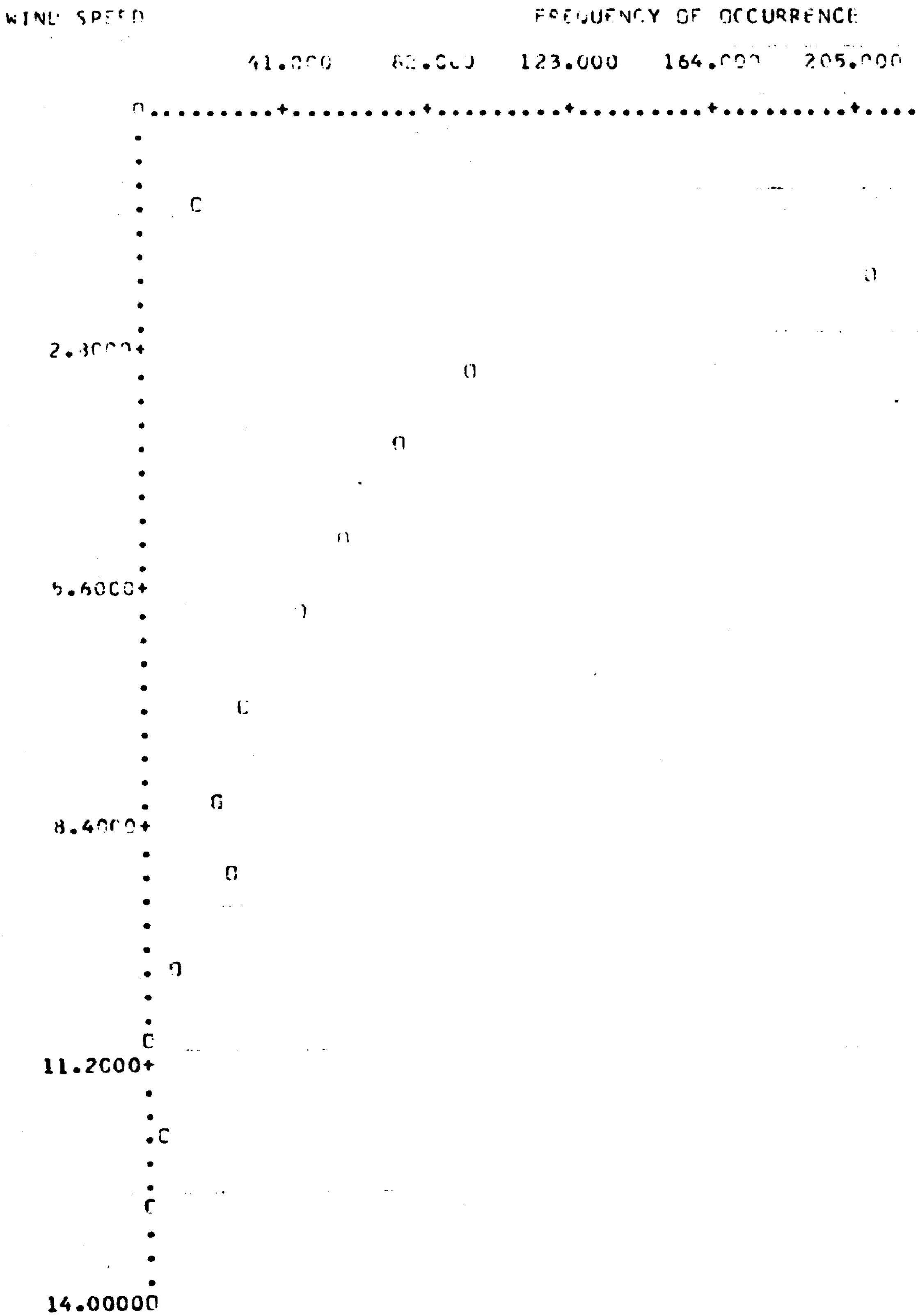


Figure 27. Distribution of Wind Speed, Knots; Fresno, June Through August, 1100-1400; 2 Year Span; 587 Points

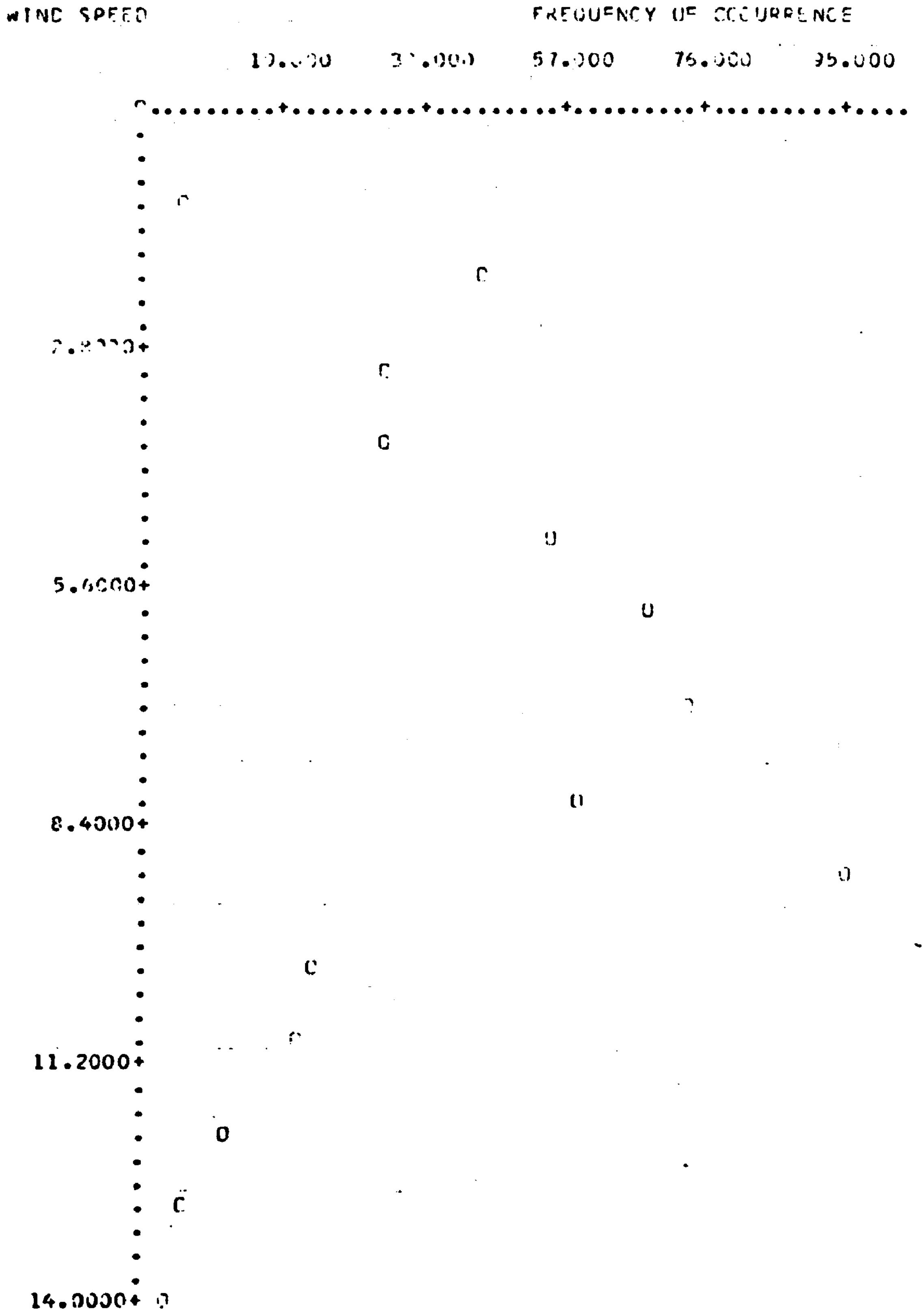


Figure 28. Distribution of Wind Speed, Knots; Fresno, June Through August, 1600-1900; 2 Year Span; 344 Points

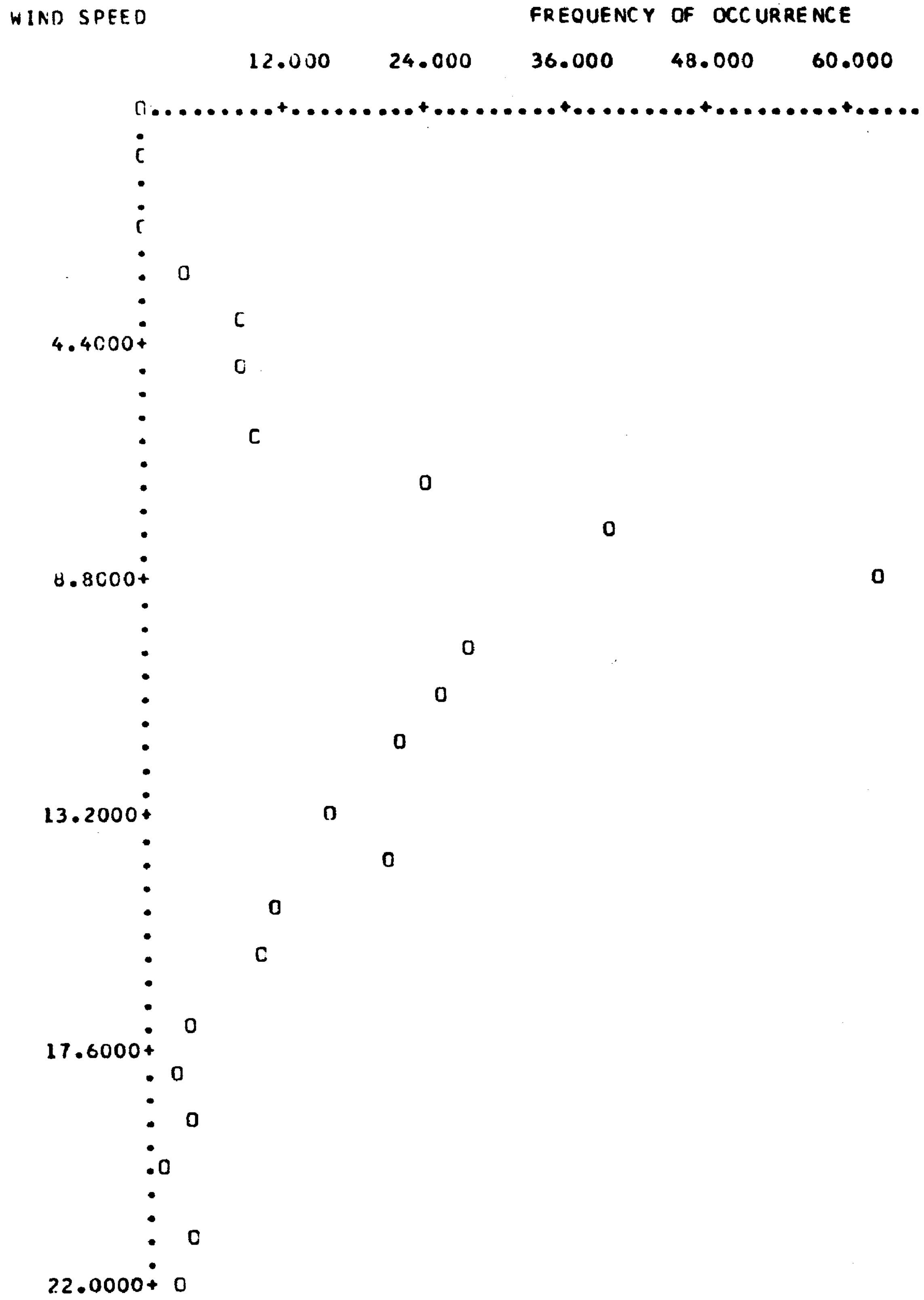


Figure 29. Distribution of Wind Speed, Knots; Boston, June Through August; 1100-1200; 2 Year Span; 297 Points

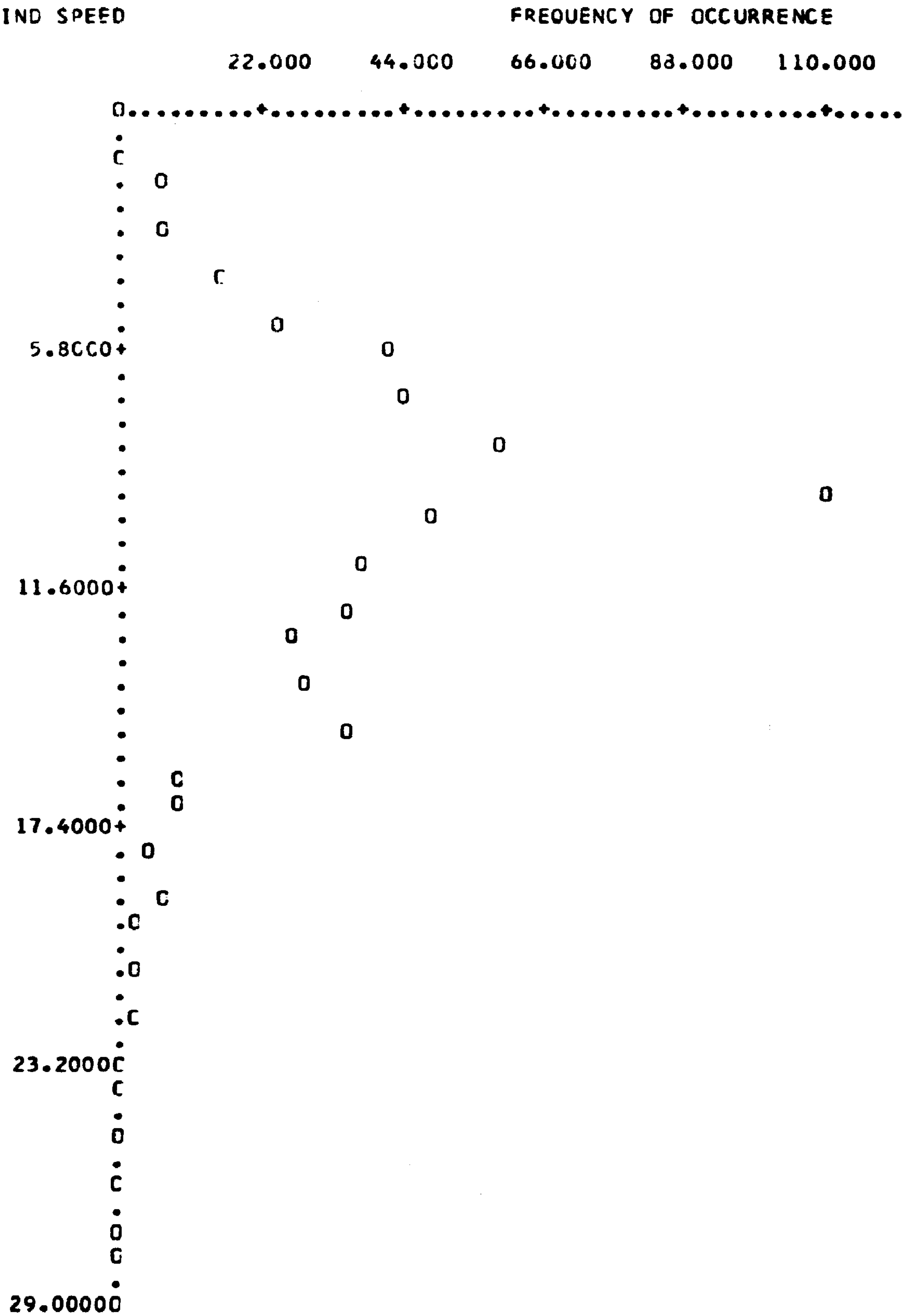


Figure 30. Distribution of Wind Speed, Knots; Boston, June Through August; 1600-1900; 2 Year Span; 476 Points

SECTION V

ACKNOWLEDGEMENT

This investigation was supported by the Office of Research and Development, Environmental Protection Agency. Much of the information as to Weather Bureau data sources and modelling of the equilibrium temperature, and advice as to the practical course which the project followed, was provided by the project officer, Dr. Bruce A. Tichenor, EPA, Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

SECTION VI
REFERENCES

1. J.E. Edinger and J.C. Geyer, *Heat Exchange in the Environment*, Edison Electric Institute, 750 Third Avenue, New York City, New York; 1965.

2. E.L. Thackston and F.L. Parker, *Effect of Geographical Location on Cooling Pond Requirements and Performance*, Vanderbilt University, for Water Quality Office, Environmental Protection Agency, Project No. 16130 FDQ, March 1971.

3. S. Seigel, *Nonparametric Statistics for the Behavioral Sciences*, McGraw-Hill, New York; 1956.

4. *System 360 Scientific Subroutine Package Version III*, IBM Application Program, Number H20-0205-3, 1968.

5. Rudin, Walter, *Principles of Mathematical Analysis*, McGraw-Hill, New York; 1964.

APPENDIX A

SOFTWARE DESCRIPTION AND USAGE

Introduction

Five programs were written during the course of this project. Two were quite large; three were small. In addition, several tapes were purchased from the Weather Bureau, copied and in some cases reformatted. This appendix describes the programs and tapes with the intent of providing the most comprehensive detail possible to a program user of any level of computer sophistication. All programs run on an IBM System 360 or 370 with at least two tape drives and a FORTRAN G compiler.

The largest of the five programs (THERMOS) employs the data from the tapes to form histograms, plot equilibrium temperature, or perform nonparametric independence tests or tests of goodness of fit to specified distributions. This program (which is most suited to the batch processing mode) and its subprograms are described below. A modification of THERMOS which can be used to process the 1-year Portland data is also described in this section.

Following this is a description of the tapes used; their original format, new format and Job Control Language (JCL). Three types of Weather Bureau tapes are employed: the Airways Surface Observation Tapes, Series TDF 14; the Solar Radiation tapes, Series Hourly 280; and a special tape made from DECK 144 surface observation cards for Portland, Oregon, 1963. These will be referred to in the following sections as the surface, solar, and Portland tapes, respectively.

A description is also given of the short program needed to convert the solar tapes to a chronological format compatible with the surface tapes. Included in this appendix is a reproduction of the Weather

Bureau documentation provided for these tapes, annotated where necessary to indicate misleading or inaccurate information.

Two small programs, suitable for use at the terminal or in a batch, are used to compute equilibrium temperature (E) alone, or E and the sensitivity of E to the basic meteorological variables. These programs are described following the Weather Bureau documentation.

The THERMOS Program

The THERMOS program picks out a selected subset of the meteorological variables from the Weather Bureau tapes and processes these data through one of four options. The main (control program) reads and synchronizes tape operation, assembles data, and routes control to the option subroutines. Communications between routines are provided through labelled and blank COMMON; all input is accomplished by use of NAMELIST.

The subset of the meteorological variables used in the analysis is defined by choosing every n^{th} point in a given time window. The time window consists of a period starting at IYAR and extending for IYEAR years (all symbols for the THERMOS program are defined in Table A-4); from MONTH1 to MONTH2 within each year, and including only MHOUR through NHOUR of each day. In certain options this subset must be chosen in conformance with data storage restrictions.

The five meteorological variables have each been assigned a number descriptor. The variables, their numbers, and their units are given in Table A-1.

Table A-1. Meteorological Variables

1	Wind Speed	Knots
2	Temperature (dry bulb)	°F
3	Relative Humidity	Percent
4	Total Skycover	Tenths of Total Cloud Cover
5	Solar Radiation	Tenths of Langleys/ Hour

The options available through this program and their related subroutines are given in Table A-2.

Table A-2. Program Options

Option Number	Tasks	Component Subroutines
1	Plot Equilibrium Temperature and/or meteorological variables	EQSUB, EQPLT, PPLOT, FBETA, TWOFIT BLK DA
2	Compute joint distributions, conditional probabilities, etc. (Histogram Option)	HIST
3	Test pairwise independence of meteorological variables	INDTST
4	Test single variable goodness of fit to specified distributions	DIST

Each of these subroutines is described in detail in the following sections. In addition, subroutines from the IBM Scientific Subroutine Package have been employed. Table A-3 lists these subroutines and their associated calling routines of Table A-2.

Table A-3. IBM Scientific Subroutine Package (SSP) Routines Employed

CALLING ROUTINE	SSP ROUTINE CALLED
INDTST	RANK, SRANK, WTEST
DIST	KOLMO (modified)

The following subsection describes the major variables and storage location functions for, first, the program input and second, each major option. In the next subsection the input method (NAMELIST) is described and a sample input deck shown. Examples of THERMOS main program output and a flow chart are given in the subsections which follow. Examples of output, flow charts, and possible areas of modification for the options are included. Listings of the entire program comprise a subsection to follow. A short description of the program to process the Portland tapes is given; this program is a subset of THERMOS.

THERMOS Major Variables and Storage Locations

The important input, output, and temporary storage locations are listed in Tables A-4 (input) and A-5 (all other). Each location is described by its FORTRAN name and DIMENSION and its purpose. Ordering in the table is in a logical manner within each functional area; that is, all variables used mainly (or first) in the main program are given, then all variables for option 1 (E and meteorological variable plots) next, etc. Variables appear in roughly the order in which a user could be expected to make up input, etc.

Where applicable, a program value is given for each variable; this is the value which appears in a DATA or other initialization statement. It is the value which the variable will assume if it is not superseded by an input value. (Input is all in the NAMELIST format, which implies that only variables whose value is to be changed from a program or previous case value need be read in.)

All O characters in variable names are alphabetic (i.e., numeric zeros are not used in names.) Normal FORTRAN conventions are followed: variable names beginning with the letters I through N are fixed-point integers (no decimal point); other variables are not.

a. Every case begins with the characters &TEMPS and ends with an &END.

   All cards must begin in column two and have no imbedded blanks (blanks within the name of an input quantity).

b. Data for each case are enclosed within the &TEMPS and &END. Data can be punched in any card column except column one. Data are of two forms:

   (1) Variable name = constant. The variable name may be a subscripted array name or a single variable name. Subscripts must be integer constants.

   NHIST(5) = 1, MNTH1 = 7, WMULT = 1.15

   (2) Array name = set of constants (separated by commas). The array name is not subscripted. The number of constants must be less than or equal to the number of elements in the array.

   NHIST = 1, 2, 5, 0, MBASE = 0, 15, 50,

c. Literal constants must be enclosed in quotes.

HEAD = 'BOSTON TEST',

d. Integers (variables whose names begin with I, J, K, L, M, or N) cannot have decimal points. Real variables (variables whose names do not begin with I, J, K, L, M, or N) require decimal points.

e. Namelist cases may be stacked. Namelist variables initialized in one case hold for all successive cases until they are changed.

If a program value is given (as in Table A-4) but is subsequently changed in one case, the variable will not revert to the program value unless it is reset so in a succeeding case.

Figure A-1 is an example THERMOS input deck which will cause the program to run through all four options (in four cases) for a single data base. Note that this input makes use of certain assigned program values which do not have to be read specifically, unless a change is desired. All THERMOS output examples given in this appendix were produced using this input, unless otherwise noted.

Table A-4. Input Variable Descriptions

Functional Area	Name (Dimension)	Program Value	Description
MAIN	IYAR	0	Year (-1900) at which data processing is to start (i.e., IYAR = 60 for 1960). If IYAR = 0 processing starts at the first year on the surface data tape.
	IYEAR	2	Number of years of data which are to be extracted from the tape.
	MNTH1	6	Beginning month in each year for data extraction. If MNTH1 = 0, MNTH1 is set = 1.
	MNTH2	8	Last month in each year for data extraction. If MNTH2 = 0, MNTH2 is set = 12.
	MHOUR	11	Beginning hour in the day for data extraction, on a 24-hour clock. (12 o'clock midnight = 0 hours).
	NHOUR	14	Ending hour in the day for data extraction, on a 24-hour clock.
	NDELT	1	Every NDELTth data point within the time window selected is accepted for the final analysis. This point is not necessarily a valid point (one in which all variables are present; see option descriptions). If NDELT = 0, NDELT is set = 1. NDELT <u>must</u> be used for options 3 and 4 in

Table A-4. -- Continued

Functional Area	Name (Dimension)	Program Value	Description
MAIN			which actual data, rather than frequencies of data occurrences, are saved; this is discussed further in the input sections for these options.
	IOUT	0	Every IOUTth set of input tape records is written out exactly as read in. If IOUT = 0, no such output is written. This type of output is primarily for debug purposes.
	HEAD(20)	(blanks)	Label information which is output as the first line of each case. (The input characters must be enclosed in ' '.)
	ISURF		The station number of the Weather Bureau Station as on the surface observations tape. If the tape and NAMELIST numbers do not match the run is terminated.
	ISLST		The station number of the Weather Bureau Station as on the solar radiation tape. If ISLST = 0, the solar tape is not required. If ISLST ≠ 0 and does not match the corresponding number on the tape (after passing any beginning blank records), the run is terminated.

Table A-4. -- Continued.

Functional Area	Name (Dimension)	Program Value	Description
	IPTN		Option indicator, as in Table B-2.
	NHIST(5)	5*0	Vector in which meteorological variables to be processed for a given run are specified. If NHIST(1)=K, variable K of Table B-1 is included. NHIST(I) = 0 terminates the list. From 1-5 variables may be chosen, depending on the option; see descriptions of separate option inputs for further information.
PLOT (IPTN=1)	IFLAG	0	If IFLAG = 0, the area in which the frequency of occurrence of each value of each variable is accumulated is cleared before use. IFLAG = 1 allows accumulation of this function over several cases (in the same run). The number of data points printed out for the second, third, etc. cases is the number of additional points; not the total number of points.
	IPLOT(6)	6*1	if: IPLOT(1) = 1 plots distribution of Equilibrium temperature IPLOT(2) = 1; wind IPLOT(3) = 1; air temperature IPLOT(4) = 1; relative humidity

Table A-4. -- Continued.

Functional Area	Name (Dimension)	Program Value	Description
			IPLOT(5) = 1; cloud cover IPLOT(6) = 1; solar radiation
PLOT	NHIST		Not used for this option.
	WSMULT	1.15	Scale factor for wind speed. Wind speed must be in miles per hour for equilibrium temperature calculation. If WSMULT = 1, input is in miles per hour; if WSMULT = 1.15 input is in knots (as on surface tapes).
	HSMULT	88.47	Scale factor for solar radiation. Solar radiation must be in BTU ft^{-2} day^{-1} for equilibrium temperature calculation. If HSMULT = 1, input is in tenths of BTU ft^{-2} day^{-1}; if HSMULT = 88.47 input is in tenths of Langleys per hour (as on the solar radiation tapes).
	TMERR	.01	The equilibrium temperature is found by an iterative method that stops when the change is less than TMERR times the equilibrium temperature
	A, B	0, 11.4	Characteristics of the evaporation formula.
	A1PRME, A2PRME	.81, .708	Transmission coefficients, functions of optical air mass in and water content of the atmosphere
	DA, DS	.070, 0.	Total dust depletion
	RG	.20	Total reflectivity of the ground.

Table A-4. -- Continued.

Functional Area	Name (Dimension)	Program Value	Description
HISTOGRAM DATA, ETC. (IPTN = 2)	NHIST(5)	5*0	From 1 to 4 meteorological variables may be chosen for the computation of joint distribution frequencies, etc. A variable is chosen by reading its number (from Table B-1) into NHIST(I), I = 1, 2, 3 or 4. If NHIST(I) = 0, the list of variables is considered finished. Even if NHIST(5) ≠ 0, it is not used.
	MHIST(4) MBASE(4)	4*0	For each variable selected in NHIST, the range of that variable is divided into 9 intervals, or classes, by the user. For the variable specified in NHIST(I), MHIST(I) is the size of the interval; MBASE(I) is the value at the beginning of the first interval. For instance, an appropriate set of values for wind speed in summer-time Boston, if it were the first variable chosen would be: NHIST(1) = 1 (wind speed) MHIST(1) = 2 (interval size of 2 knots) MBASE(1) = 0 (beginning at 0 knots), which would separate wind speed occurrences into distinct classes of 2 knots each up to 16 knots, and place all higher speeds in a single class.

Table A-4. -- Continued.

Functional Value	Name (Dimension)	Program Value	Description
			The classes are used to accumulate a count of the frequency of occurrence of all combinations of the meteorological variables selected. It is desirable to span all possible values of the variables in as even a manner as possible; to avoid having most classes with little or no occurrences and one or two classes into which most of the data falls. If no prior knowledge of the data base being used is available, it is advisable to plan on making an initial short run when using this option, after which MHIST and MBASE may have to be adjusted. Alternately, option 1 might be employed to gain the necessary preliminary information.
INDEPENDENCE TESTS (IPTN = 3)	NHIST(5)		This option computes the nonparametric Spearman rank correlation coefficient for all pairs of the specified variables. Therefore, between 2 and 5 meteorological variables from Table B-1 must be chosen in NHIST, as described in the MAIN input section
	NDELT		Up to 1000 data points are saved (a data point for this option is a combination of all selected variables at a single time). NDELT should be chosen so that no more than 1000 points in the time window are included. It should not be a multiple of (NHOUR - MHOUR + 1);

Table A-4. -- Continued.

Functional Value	Name (Dimension)	Program Value	Description
			such a multiple would tend to collapse the time window to 1 or 2 hours. Slightly more than 1000 points may be allowed for since the lack of a valid observation of any one variable deletes that point. If 1000 points have been stored before the end of the time specified, a message is printed, tape processing stops, and independence testing begins.
TEST OF FIT TO DISTRIBUTIONS (IPTN = 4)	NHIST(5)	5*0	This option tests distributions of single variables for goodness of fit. From 1 to 5 meteorological variables from Table B-1 must be chosen in NHIST, as described in the MAIN input section.
	NDELT } IINT }		Up to 1000 values of each single meteorological variable are saved. Within the time window specified, each NDELTth point is accepted in the sense that all observations of the chosen variables are used. However, each IINTth of these points is used for the sample statistics; the sample mean and standard deviation. The remaining points are stored for the distribution fit. When 1000 values of any one variable have been stored before the time selected is exhausted a message is printed, tape processing is stopped, and fit testing is begun.

Table A-4. -- Continued.

Functional Area	Name (Dimension)	Program Value	Description
			(There may be a different number of points stored for each variable due to occurrences of invalid data.) Neither IINT nor NDELT should be a multiple of (NHOUR - MHOUR + 1), or the time window for either data selection or sample statistic calculations, or both, may collapse to represent only a subset of the hours expected in the distribution.
	IDPT(3)		IDPT(I) is used to select the distributions to be tested. Up to three such tests may be selected. If IDPT(I) = 0, testing is terminated after (I-1) tests. Otherwise, IDPT = 1, distribution is normal IDPT = 2, distribution is exponential IDPT = 5, distribution is user coded (See description of DIST)

Table A-5. Other Storage Descriptions

Functional Area	Name (Dimension)	Description
MAIN		
	IKD	Counter for total number of acceptable data points.
	IDELT	Counter for accepting every NDELTth points.
	ICMP	Counter for output of every IOUTth tape record.
	ND	Number of non-zero entries in NHIST.
	ISOL	Index in NHIST of solar radiation parameter specification; i.e., NHIST (ISOL) = 5. Set = 0 if solar tape ends before surface tape, or if solar radiation parameter is. not chosen.
	MHR	MHOUR + 1
	NHR	NHOUR + 1
	ISTAT	First, ISTAT is the number of the Weather Bureau Station read from the surface tape. Later it is the station number from the solar tape (if required), on initial read to check station numbers.
	ISY	Year read from surface or solar tape on initial read to find correct year.
	IMN	Month read from surface, then solar, tape on initial read.
	KSL	Flag to indicate whether surface and solar tapes are synchronous; KSL = 0 if they are (after statement number 85).

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
	IYUR	Last year to be read.
	IDATA(4)	Identification information from each surface tape record (only one per day is stored). IDATA(1) = station number IDATA(2) = year IDATA(3) = month IDATA(4) = day
	IDD(8, 24)	One full day of selected surface observation data. For the Ith hour, IDD(1, I) = hour IDD(2, I) = integer, low order digit of wind speed IDD(3, I) = hexadecimal, high order digit of wind speed IDD(4, I) = integer, two low order digits of dry bulb temperature IDD(5, I) = hexadecimal, high order digit of dry bulb temperature IDD(6, I) = integer, 2 low order digits of relative humidity IDD(7, I) = hexadecimal, high order digit of relative humidity IDD(8, I) = cloud cover (hexadecimal),

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
		in the units given in Table A-1. The split of variables into integer and hexadecimal parts is due to the Weather Bureau practice of overpunching some fields so that they are not directly interpretable as numbers by FORTRAN. For further information, see the tape descriptions, the Weather Bureau Appendix, and the description of storage array HEX.
	ISLD(4)	Identification information from each solar tape record. (Only one per day is stored). ISLD contains the same information, in the same order, as IDATA.
	ISLR(4, 16)	One full day of selected solar observation data. This data results from pre-sorting, translating and extracting data from the Weather Bureau solar radiation tapes, as described in a later section. For each daylight hour between 0400 and 1900, ISLR(1, I) = hour ISLR(2, I) = solar radiation (tenths of langleys/hour) ISLR(3, I) = solar elevation (degrees) ISLR(4, I) = extra terrestrial radiation (langleys per hour)
	ISV(7)	Temporary storage for a full set of values of the meteorological variables at a given time and for the two extra variables from the

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
		solar tape used in the equilibrium temperature plot option. ISV(I) < 0 implies no valid reporting of the variable specified in NHIST(I) at this time.
	KDEX	Index in ISLR of present hour.
	ITST	Temporary storage for single variable being collected. EQUIVALENT to TST.
	ILOC(4)	List of locations in IDD in which variable I starts.
	AST	asterisk — Hexadecimal representations of the possible Weather Bureau codes; used for translating data in IDD to integers.
	BL	Blank — Hexadecimal representations of the possible Weather Bureau codes; used for translating data in IDD to integers.
	HEX(10, 3)	X, +, or non-over-punched digits — Hexadecimal representations of the possible Weather Bureau codes; used for translating data in IDD to integers.
	XHEX	X — Hexadecimal representations of the possible Weather Bureau codes; used for translating data in IDD to integers.
	IND(4)	Histogram option; if NHIST(I) = 0, IND(I) = 1 NHIST(I) ≠ 0, IND(I) = 10 A set of counters used for limits of DO Loops.
	JHIST(4)	Histogram option; JHIST(I) is used to indicate in which class the current value of the variable specified in NHIST(I) falls. Class 10 is used for invalid data.
	IHIST(10, 10, 10, 10)	Histogram option. This area is INTEGER *2 storage, EQUIVALENT to IZR for ease in clearing. IHIST (J1, J2, J3, J4) contains

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
		the number of occurrences of a meteorological set in which the variable chosen in NHIST(1) falls in Class J1; in NHIST(2) falls in Class J2, etc. Invalid observations are counted as Class 10.
	X(1000, 5)	EQUIVALENT to IHIST. Used for storage of data in the independence or distribution test options.
	KD(5)	Distribution test; number of values of each variable saved.
	KMN(5)	Distribution test; number of values of each variable used to compute sample statistics.
	MEAN(5)	Distribution test; sum of data values for sample mean.
	MSD(5)	Distribution test; sum of squares of data values for sample standard deviation.
	ITSD	Distribution tests; counter for IINTth points for sample statistics.
PLOT (FBETA)	TM	Temperature at which BETA1 and CBETA1 are calculated.
	BETA1	Slope of the Saturation Vapor Pressure Curve at temperature TM.
	CBETA1	Intercept of a straight line with slope BETA1 starting on the Saturation Vapor Pressure Curve at temperature TM.

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
PLOT (EQSUB)	YEQ(200) YW(200) YTA(200) YRH(200) YCC(200) YHS(200)	Arrays used for storing the number of occurrences of Equilibrium Temperature, wind speed, air temperature, relative humidity, cloud cover, and solar radiation respectively.
	W	Wind speed converted to miles per hour
	TA	Air Temperature (°F)
	RH	Relative Humidity (Percent)
	CC	Cloud Cover (Tenths)
	HS	Solar radiation converted to BTU Ft^{-2} Day^{-1}
	SA	Solar Elevation (degrees)
	HSC	Extraterrestrial solar radiation converted to BTU Ft^{-2} Day^{-1}
	TM	Used to store equilibrium temperature from previous iteration and is used in test to determine if the iterative process can be ended. First iteration TM = TA.
	RATSR	Ratio of solar radiation to extraterrestrial solar radiation

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
	BC1	Brunt C coefficient calculated using TA and RATSR
	EA1	Air vapor pressure calculated using TA and RH
	RSR1	Reflectivity of short-wave solar radiation
	HA	Long wave solar radiation
	HAR	Reflected Atmospheric Radiation
	HSR	Reflected Solar Radiation
	HR	Net Radiation Input
	K	Exchange Coefficient
	A, B, D	Internal Storage
	EQUIL	Equilibrium Temperature
PLOT (EQPLT)	XEQ(200), XW(200), XTA(200), XRH(200), XCC(200), XHS(200)	Arrays containing the values at which equilibrium temperature, wind speed, air temperature, relative humidity, cloud cover and solar radiation can be plotted, respectively.
	YEQ(200), YW(200), YTA(200), YRH(200), YCC(200), YHS(200)	Arrays containing the number of occurrences for equilibrium temperature, wind speed, air temperature, relative humidity, cloud cover and solar radiation, respectively.

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
	XMIN, XMAX YMIN, YMAX	Minimum and maximum values used for the plot.
	TITLE(20)	Storage for headings to be printed on plots.
	MPAGES	Input value used for PPLOT.
JOINT DISTRIBUTIONS (HIST)	IPUT(10, 10, 3)	Storage for pairwise distributions; the joint frequencies stored in IHIST are separated into pairwise frequencies, where the variable specified in NHIST(1) is always the first variable of each pair.
	ISV(10)	Number of occurrences of data in each class of variable given in NHIST(1).
	PMS(10)	Sample mean of second variable, by class.
	APUT(10, 10)	INPUT, normalized by division by class mean.
	FACT	Normalizing factor for APUT.
	MAX	Used for output of maximum frequencies.
INDEPENDENCE TESTS (INDTST)	XR(1000, 5)	Temporary storage. The meteorological variables are ranked; the vectors of ranks are stored in XR.
	XX(5000)	Temporary storage which destroys the input vector of data. The meteorological variables must be reordered into rows for subroutine WTEST; the new vectors are stored consecutively in XX. XX is EQUIVALENT to X.

Table A-5. -- Continued.

Functional Area	Name (Dimension)	Description
	WORK(2000)	Temporary storage required by subroutine WTEST.
	TAU	Correlation coefficient output from SRANK, WTEST. (See INDTST discussion.)
	SD	Significance parameter output from SRANK, WTEST. (See INDTST discussion for details.)
	I, IJ	Indices to run over all pairs of meteorological variables for SRANK testing.
DISTRIBUTION FITS (DIST)	SMEAN	Sample mean.
	SDEV	Sample standard deviation.
	ISRT	Flag for modified KOLMO; if ISRT ≠ 0, data in X has been sorted before entry to KOLMO.
	Z	Output from KOLMO; measure of goodness of fit. (See DIST discussion.)
	PROB	Significance parameter from KOLMO (See DIST discussion).
	IER	Error indication from KOLMO. If IER ≠ 0, SDEV is not entered correctly for the distribution chosen. Check IDPT input.

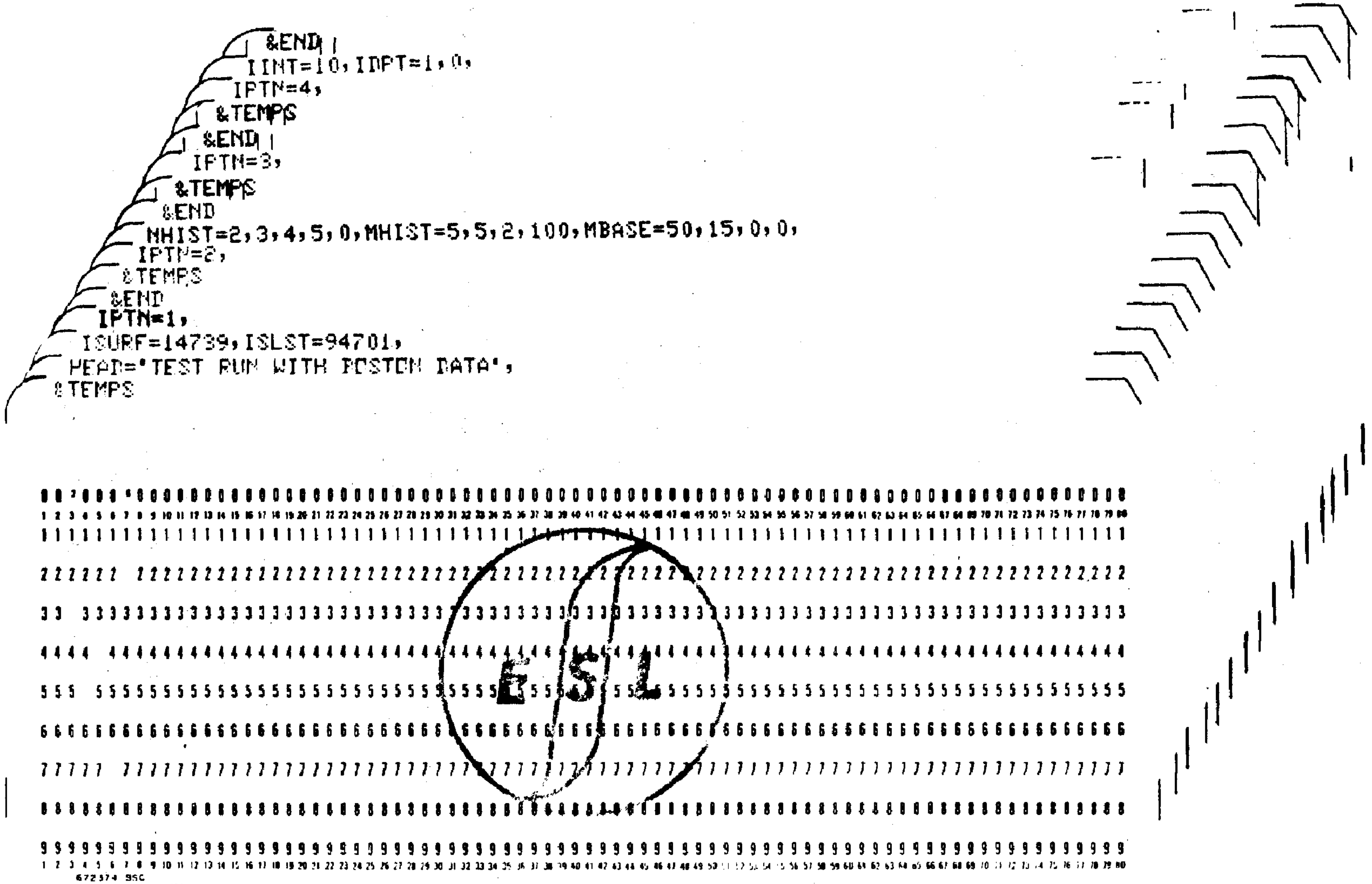


Figure A-1. Example THERMOS Input Deck

Flow Charts - Main Program

Three flow charts are given for the main program. Figure A-2 is an overall flow chart which shows little detail. Figures A-3 and A-4 are more detailed diagrams of the tape reading logic and data extraction process, respectively. Later sections, describing the individual options, contain detailed flow charts for each option subroutine.

In each flow diagram, numbers on the upper left edge of most boxes correspond to statement numbers in the code. Letter-number pairs on the upper right edge refer to the figure numbers associated with the detailed flow charts.

Plot Option

The purpose of this option is to plot the distribution of the equilibrium temperature, and of the important meteorological parameters. This option uses five subroutines; EQSUB, TWOFIT, FBETA, EQPLT, and PPLOT which are described herein.

When the plot option is in effect,EQSUB is called every time a valid set of values of the first five meteorological parameters is read from the tapes. A set of meteorological data consists of the wind speed, air temperature, relative humidity, cloud cover, solar radiation, solar angle, and extraterrestrial solar radiation. Any number of sets of data can be plotted.

For plotting, the distributions of the values for the first five parameters are stored in arrays YW, YTA, YRH, YCC, and YHS (see Table A-5). The values are stored in the same units as they are read off the input tapes with the exception of solar radiation, which is assumed to be in tenths of units and is converted to whole units. For the Weather Bureau tapes used during this study the wind speed

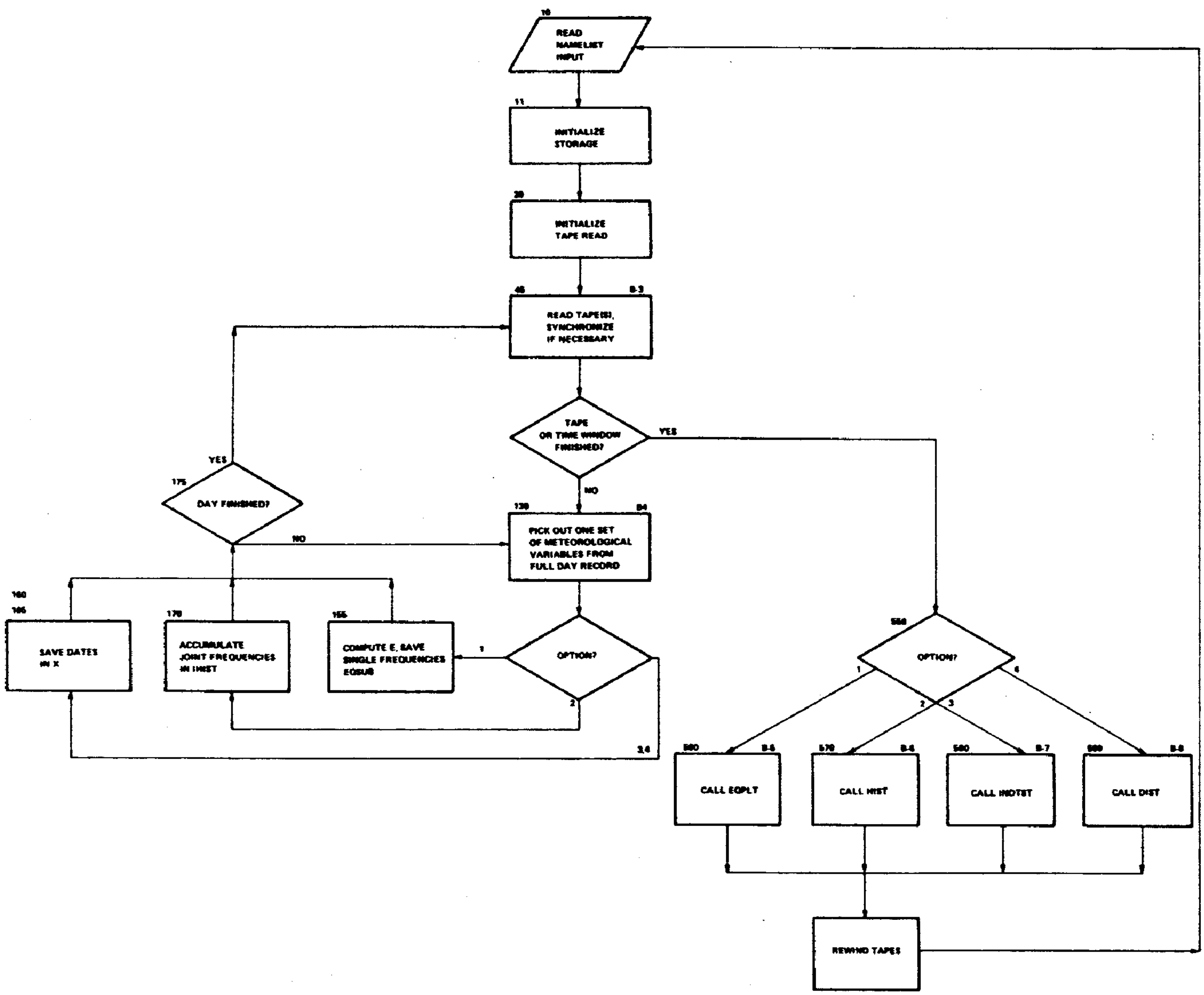


Figure A-2. THERMOS Main Program Flow Chart

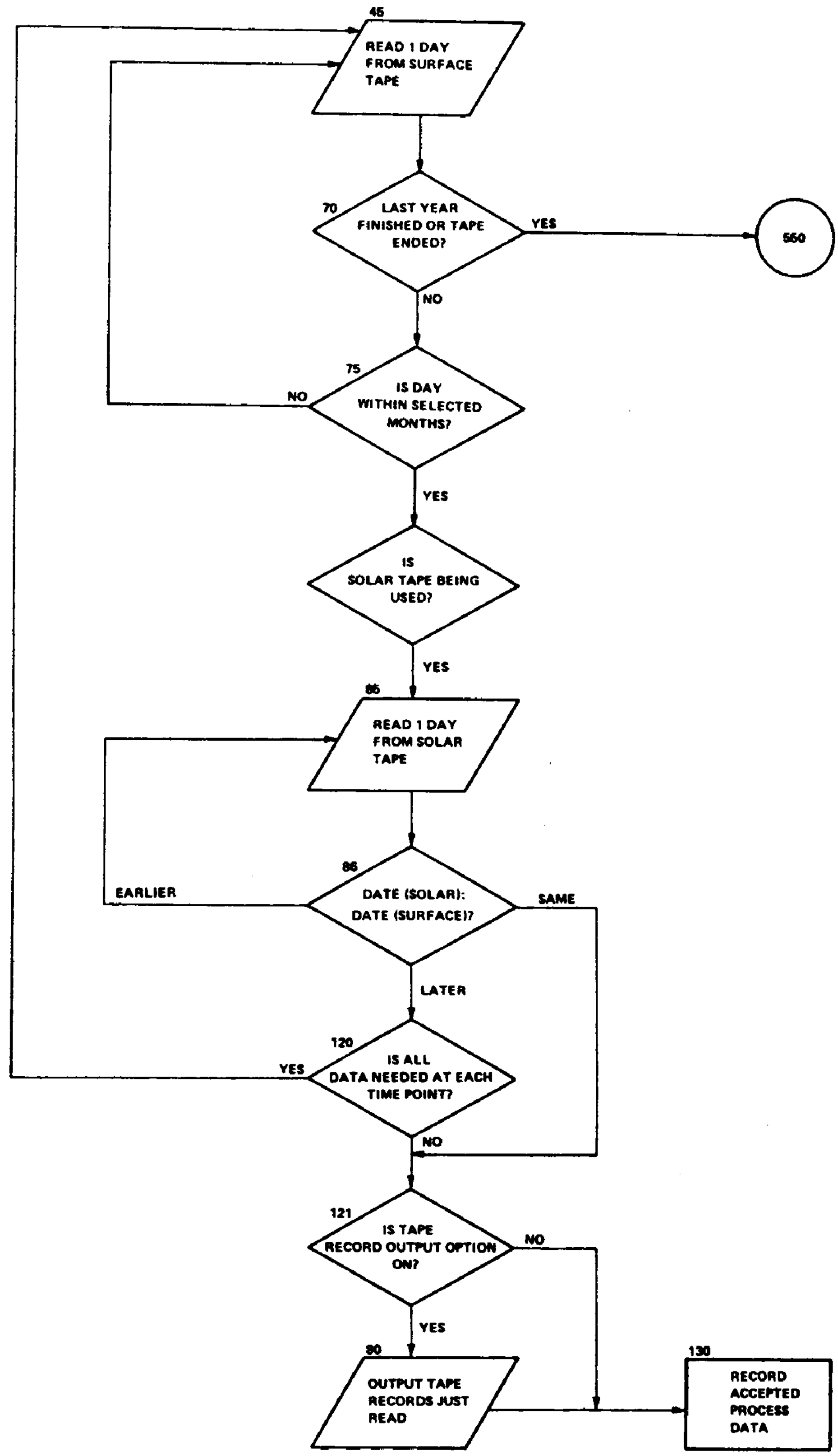


Figure A-3. THERMOS Main Program Tape Logic Flow Chart

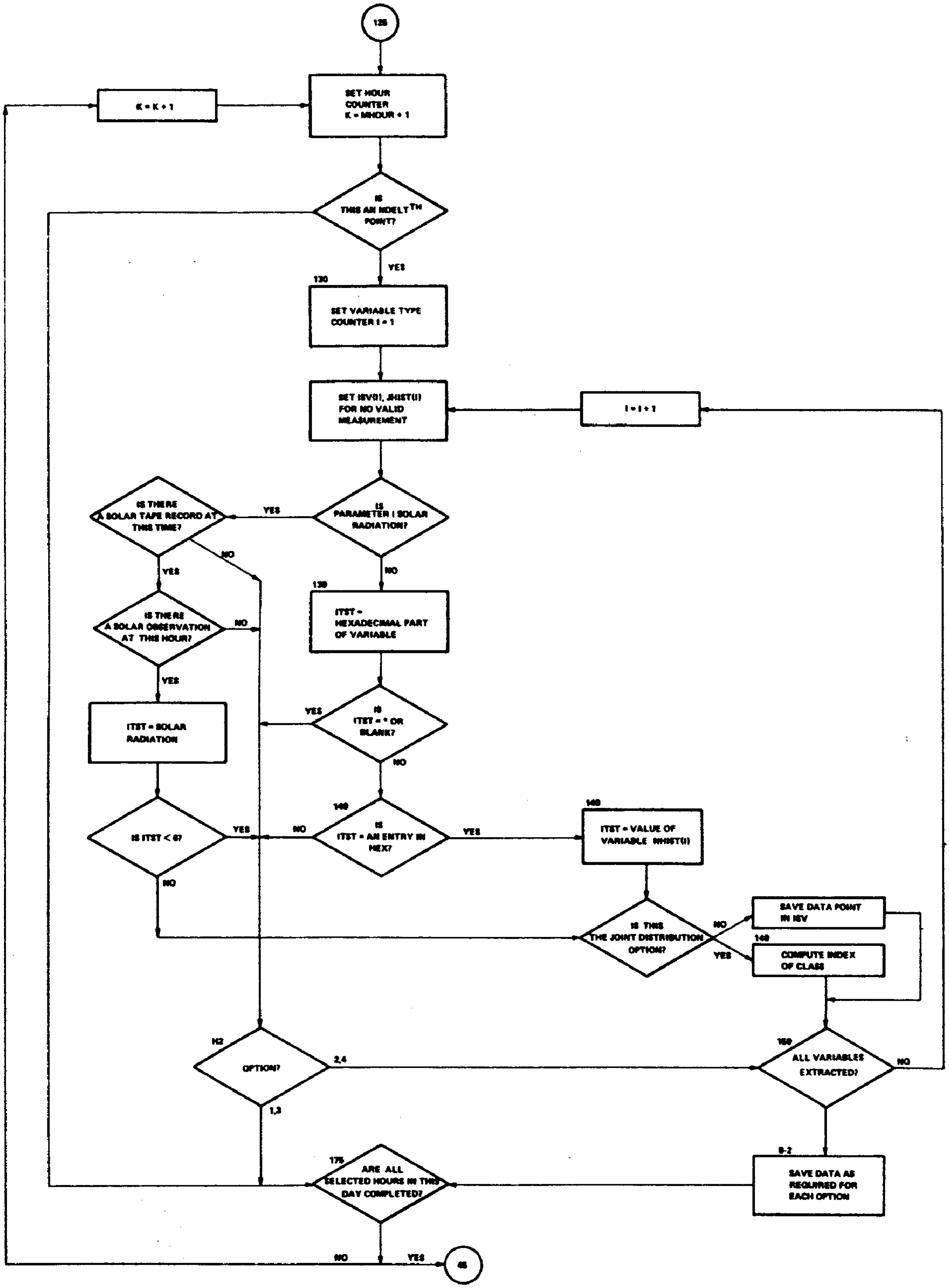


Figure A-4. THERMOS Main Program Data Extraction Flow Chart is stored in knots, the air temperature in degrees Fahrenheit, the relative humidity in percent, the cloud cover in tenths, and the solar radiation in Langleys per hour.

EQSUB converts the wind speed to miles per hour and the solar radiation to BTU Ft^{-2} day^{-1} for internal calculations. This routine also needs the values for the Brunt coefficient, air vapor pressure, and the short wave solar reflectivity. These are found using subroutine TWOFIT which performs a two dimensional linear fit on a table of values stored in the program.

The slope of the saturated vapor pressure found by calling subroutine FBETA. A flow chart of FBETA is shown in Figure A-5. These calculations are made using the equations 8, 9 and 13 of Section IV.

Subroutine EQSUB then calculates the equilibrium temperature, in degrees Fahrenheit using equations 2 thru 12 of Section IV. The model may be modified by changing the equations for the parameters and replacing the FORTRAN coding for those parameters. For example it is possible that one might derive a new equation for AA, the long wave atmospheric radiation. The new equation can be installed without affecting the rest of the coding. It should also be noted that the values for A and B in equation 6 can be changed using namelist input.

The resultant distribution is stored in array YEQ, (see Table A-5), and each pass through EQSUB updates the proper element in the array. Figure A-6 is a flow chart of subroutine EQSUB.

After the last set of data is read from the input tapes, subroutine EQPLT is called to plot the data. The user has the option of plotting both the distribution of equilibrium temperatures and any or all of the five meteorological parameters.

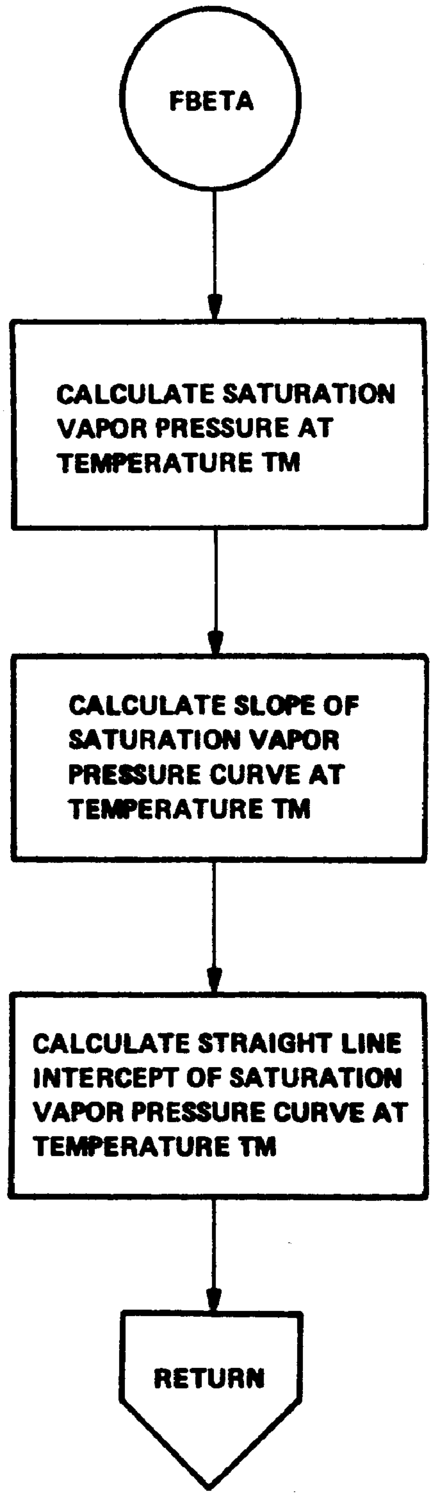


Figure A-5. Flow Chart of Subroutine FBETA

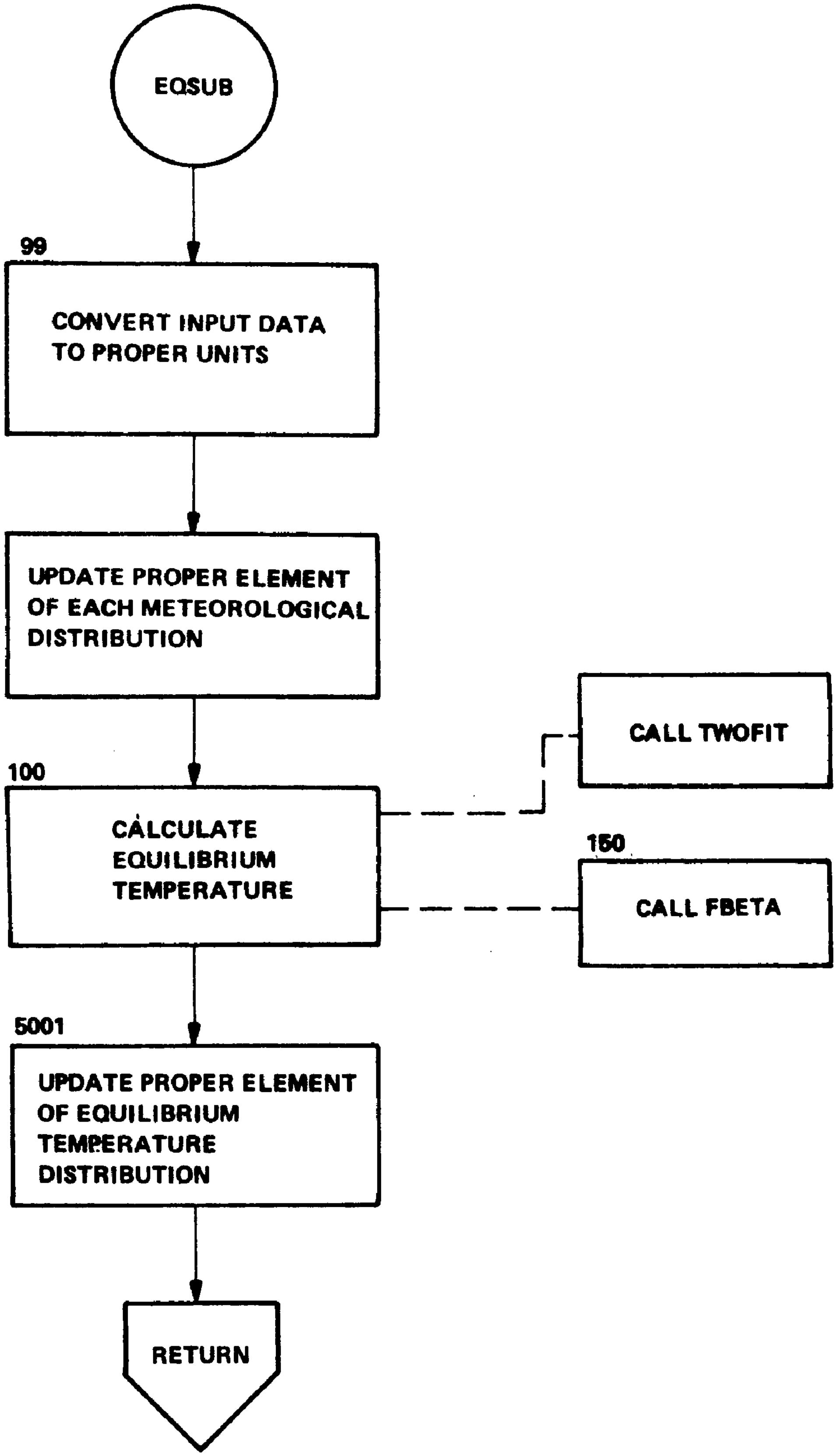


Figure A-6. Flow Chart of Subroutine EQSUB

The routine scales the X axis such that it plots from the minimum equilibrium temperature calculated to the maximum, and between the minimum value and maximum values found for·the other parameters. The Y axis is scaled such that the plot can be trimmed to 8-1/2" x 11" and goes from zero occurances to the maximum number of occurances. A flow chart of EQPLT is shown in Figure A-7.

Subroutine EQPLT calls subroutine PPLOT to perform the actual printer plot. A sample set of outputs is shown in Figures A-8 through A-13.

Joint Distribution Option

The joint distribution option processes and outputs the joint distributions of up to four meteorological variables as stored in IHIST. Subroutine HIST accomplishes two purposes: it outputs normalized pairwise distribution matrices, and a sample set of the maximum frequencies of the variable combinations.

The pairwise matrices are formed by taking all pairs of variables such that the parameter specified in NHIST(1) is the first of each pair. The distribution vector IHIST is split into three (or less) pairwise distributions in IPUT where, for instance IPUT (I, J, 1) is the number of times in the data base when variable 1 falls in class I concurrently with variable 2 falling in class J. (Variable 1 here reflects to the parameter specified in NHIST(1) and may be any of the meteorological parameters).

IPUT is normalized so that each row adds to 100. (This allows plotting of pairwise conditional probabilities normalized on the first parameter.)

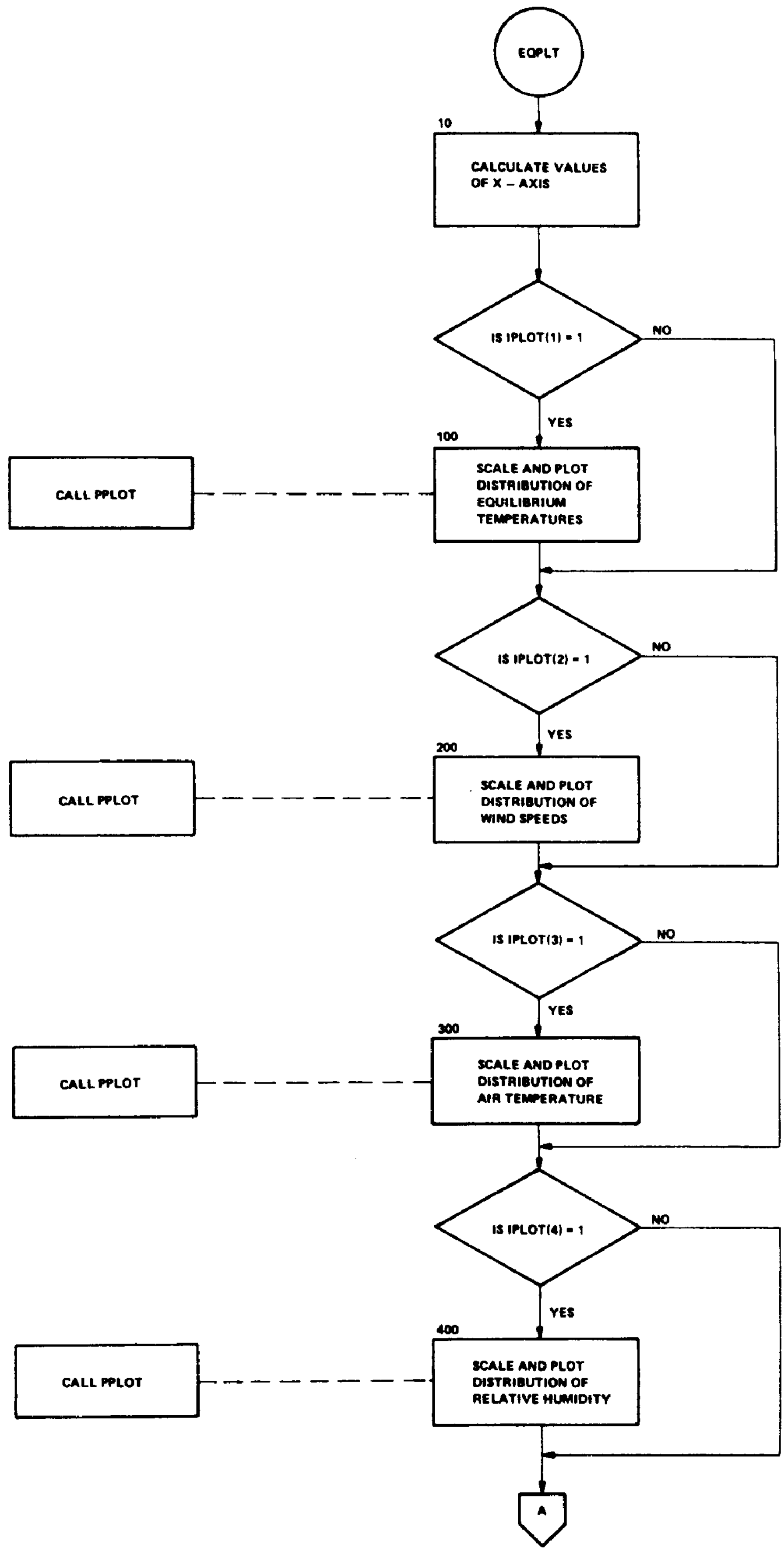


Figure A-7. Flow Chart of Subroutine EQPLT

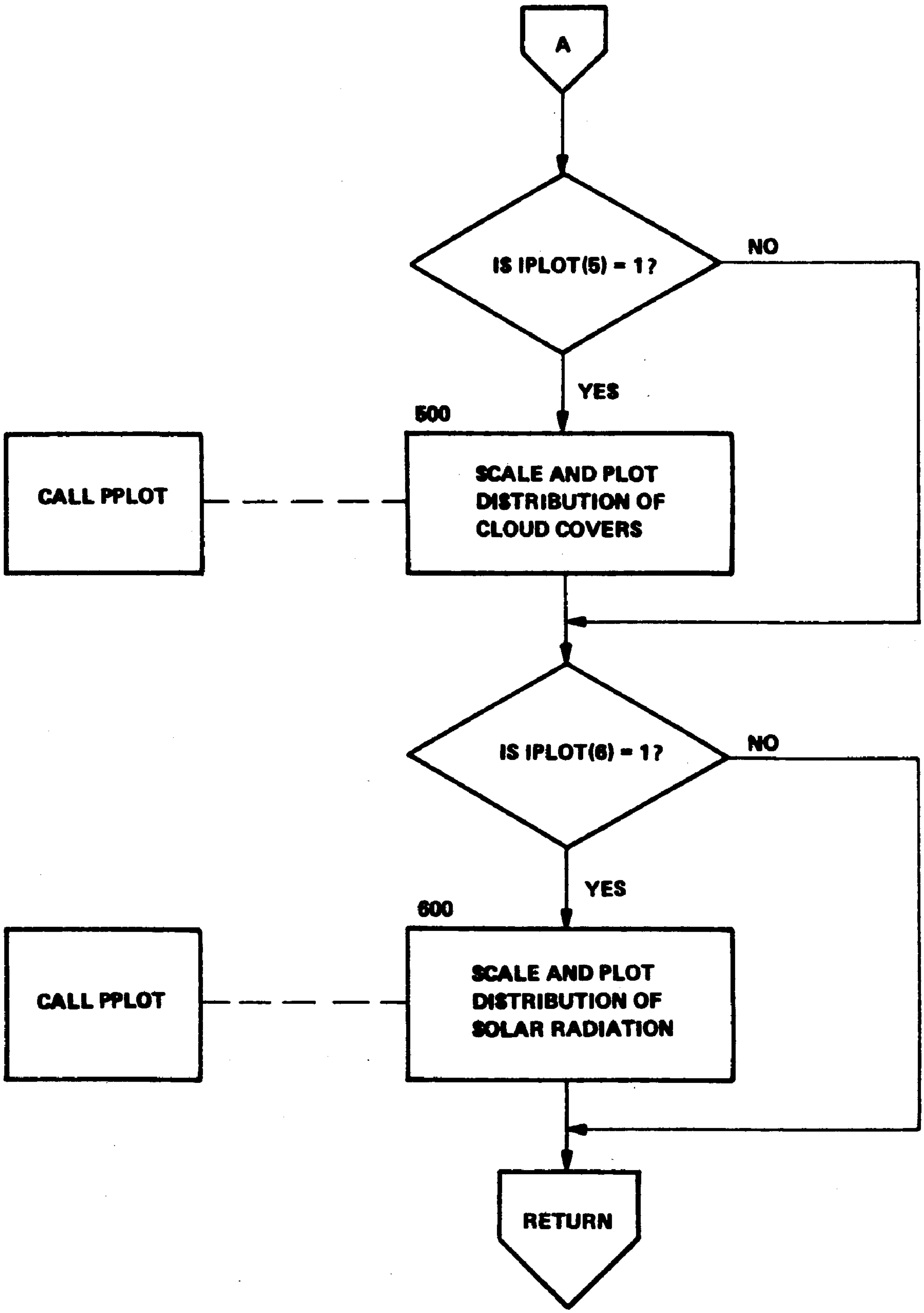


Figure A-7. -- Continued

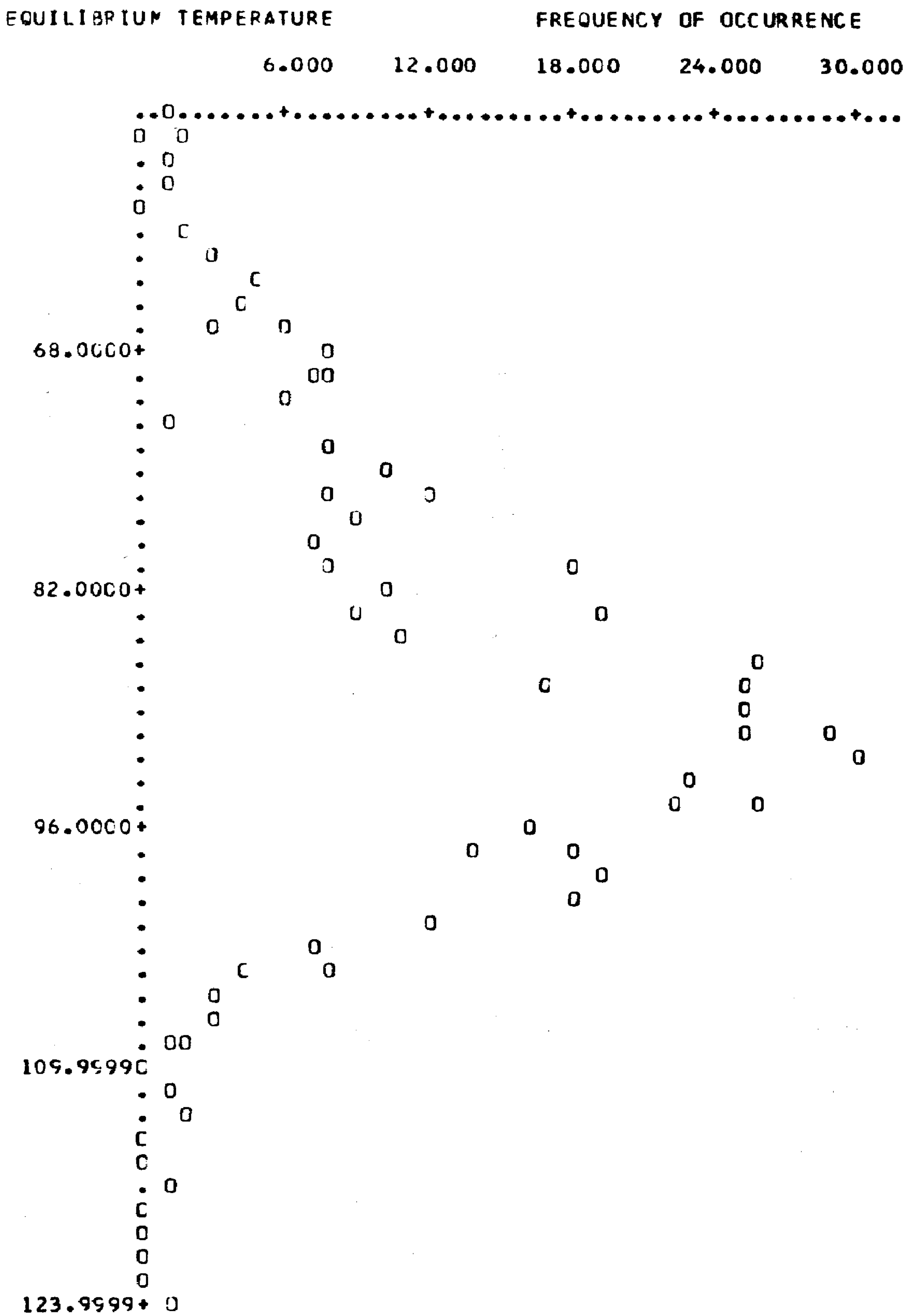


Figure A-8. Sample Distribution of Equilibrium Temperature

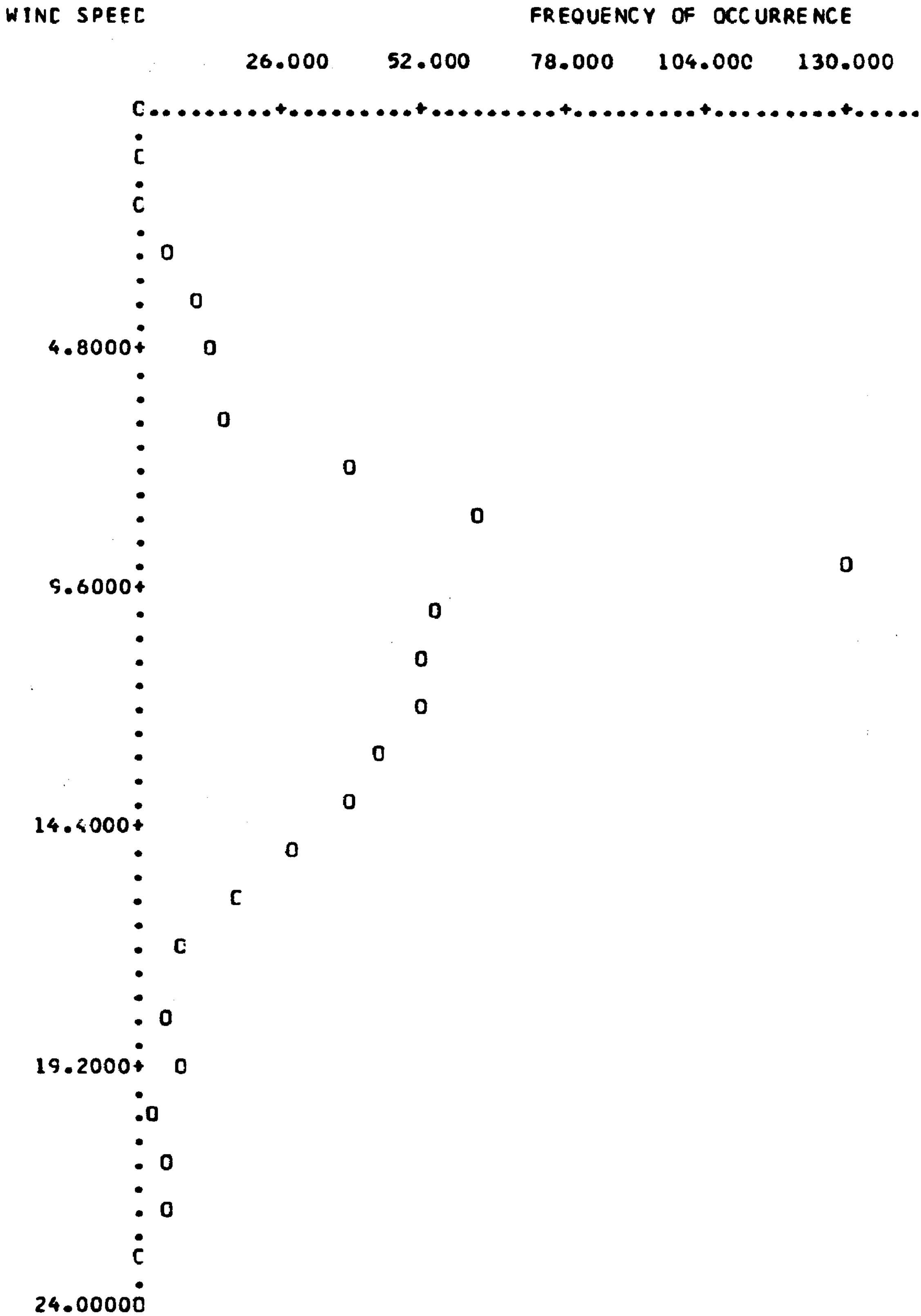


Figure A-9. Sample Distribution of Wind Speed

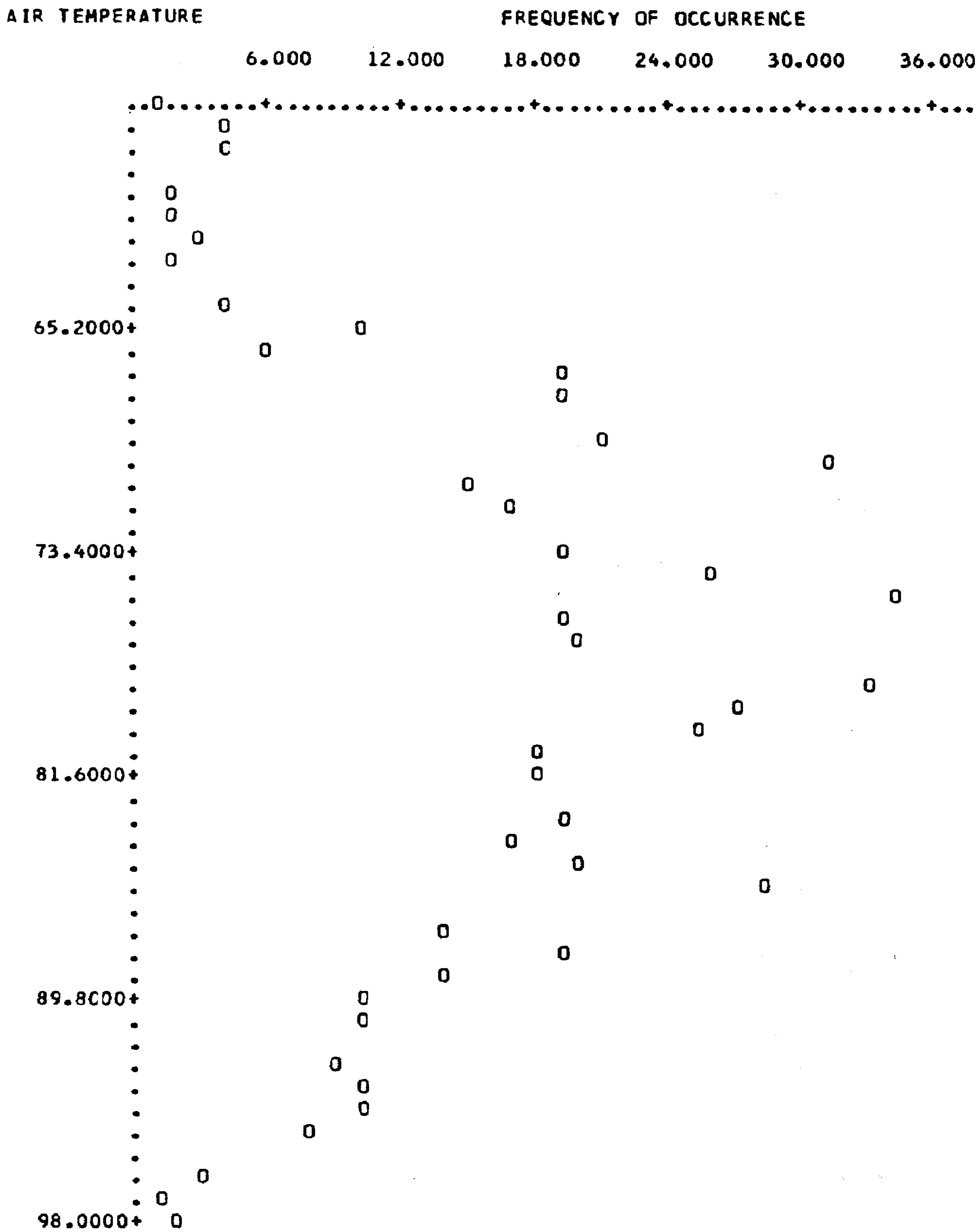


Figure A-10. Sample Distribution of Air Temperature

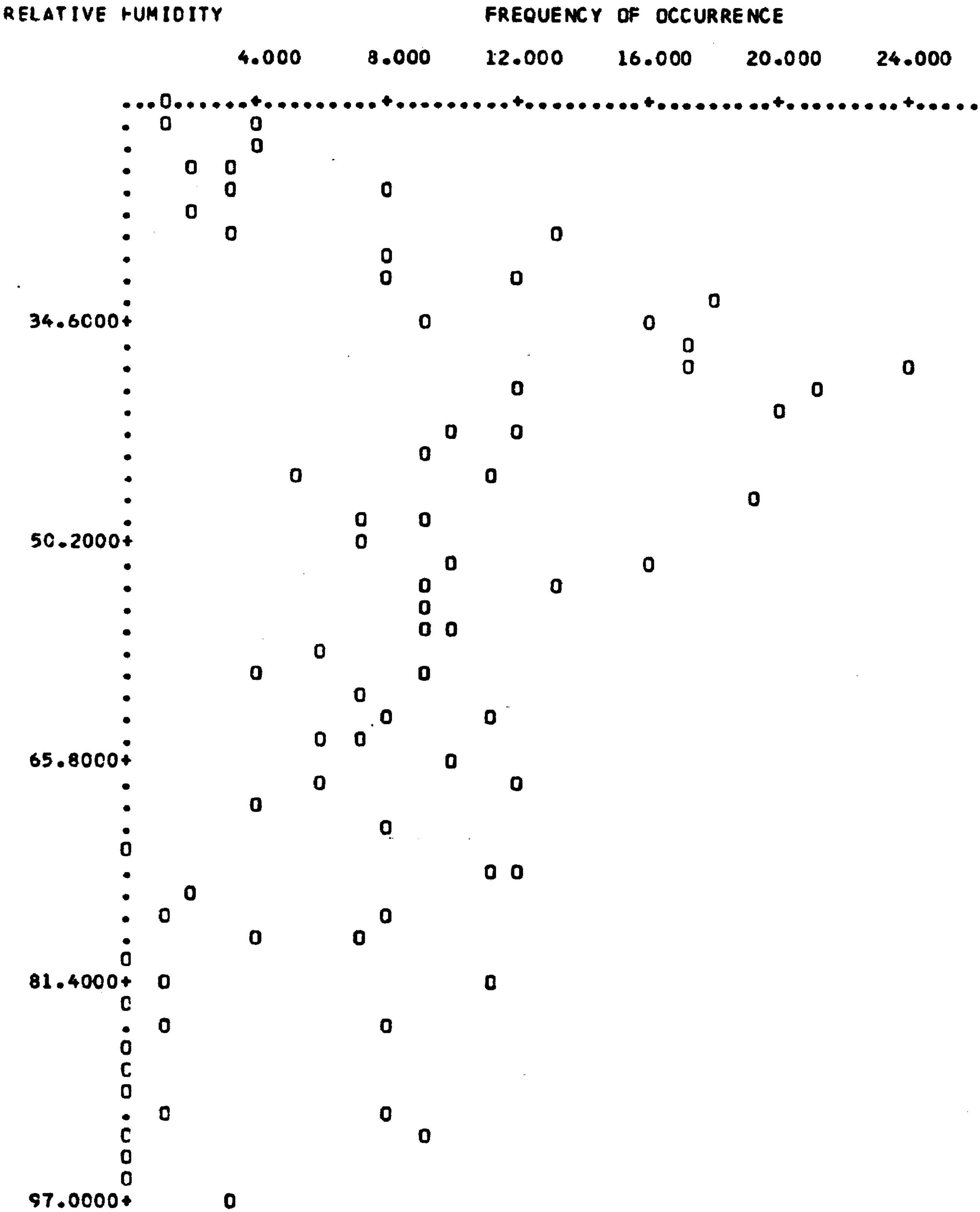


Figure A-11.   Sample Distribution of Relative Humidity

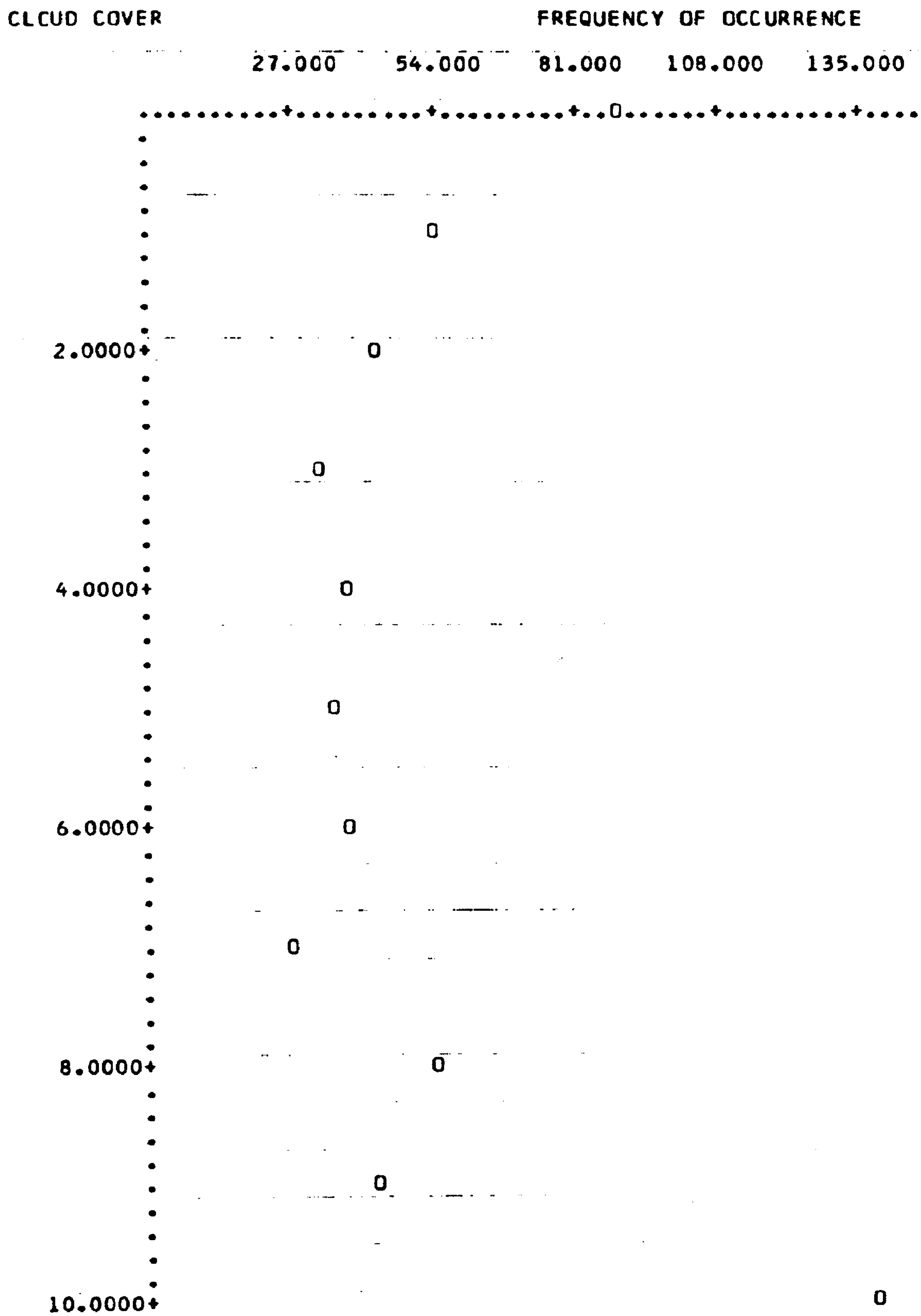


Figure A-12. Sample Distribution of Cloud Cover

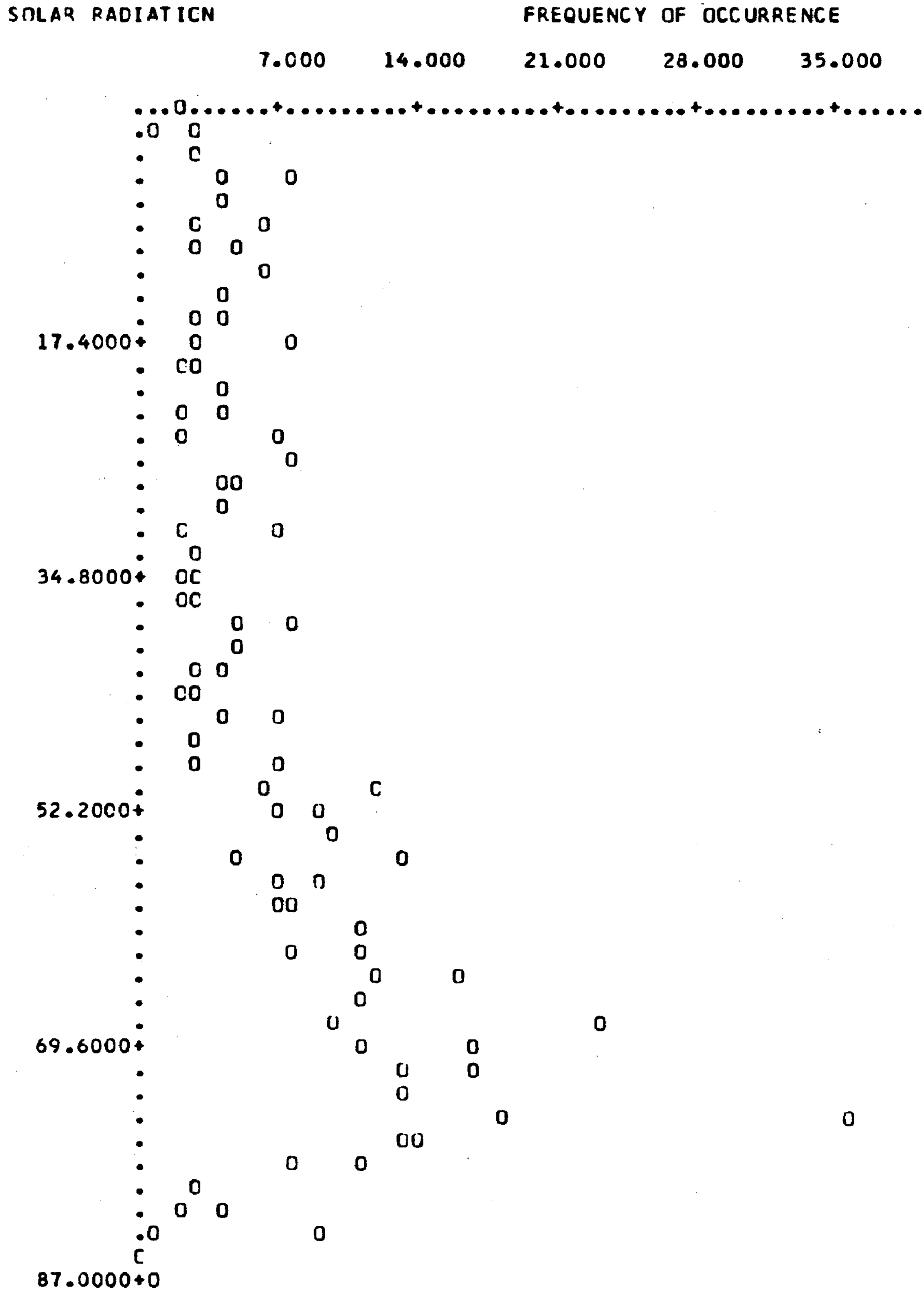


Figure A-13. Sample Distribution of Solar Radiation

The new matrices are output, along with the mean class and the class distribution, normalizing factors, and column (class) means of the second variable of the pair. Following this, the maximum frequencies of data combinations are output.

Figure A-14 is an example of output from HIST. Figure A-15 is a flow chart of subroutine HIST.

Goodness of Fit Option.

Subroutine DIST tests the fit of a set of data to the normal, exponential, or programmer coded distribution. (There are at present none of the latter).

The data is accumulated in matrix X; each column of X contains the data for a single meteorological parameter. The sample mean and standard deviation are computed from a separate data sample, chosen by means of the input parameter IINT.

The test of goodness of fit is made using a modified version of subroutine KOLMO from the IBM scientific subroutine package. The first output from KOLMO is Z; the maximum deviation between the actual distribution of the data and the theoretical distribution, times the square root of the number of points input. The second output is the probability of the statistic being greater than or equal to Z if the hypothesis that the meteorological variable conforms to the distribution being tested is true. For example, PROB = 0.05 implies that the hypothesis that the parameter being tested is from the density under consideration can be rejected with five percent probability of being incorrect. A third KOLMO output is IERR, which is non-zero if an input error has been made.

TEST RUN WITH BOSTON DATA

NOTE - TENTH HISTOGRAM DIVISION REPRESENTS INVALID OR MISSING DATA

PROCESS EVERY 1 RECORDS, FROM BASE YEAR 52 FOR 2 YEARS

TIME WINDOW IS FROM MONTH 6TO MONTH 9HOUR 11TO HOUR 14

2	3	4	5	0 CODE NUMBERS OF PARAMETERS
5	5	2	100	INTERVAL SIZE FOR CLASSES
50	15	0	0	BASE (ZERO POINT) FOR CLASSES

CLASS DEFINITIONS

OUTPUT IS EVERY 0 RECORDS IN WINDOW

YEAR 52 MONTH 7 STATION 14739FOUND

YEAR 52 MONTH 7 STATION 94701FOUND

FREQUENCY TABLES OF DATA BY PAIRS
FIRST PARAMETER SPECIFIED IS ALWAYS FIRST PARAMETER OF EACH PAIR, AND EACH CLASS IS A COLUMN

MEAN CLASS NUMBER FOR PARAMETER NUMBER 2 IS 6.26
FREQUENCIES OF DATA IN EACH CLASS ARE

0	9	13	75	113	137	99	99	67	0

NORMALIZED DATA BY CLASS FOR EACH PAIR FOLLOWS. COLUMN 10 IS NORMALIZING FACTOR
ROW 10 IS MEAN (BY CLASS) FOR EACH COLUMN

← TEMP →

RH (3)	0.0	0.0	0.0	0.0	0.0	100.00	0.0	0.0	0.0	0.01
	0.0	0.0	0.0	7.14	14.29	28.57	0.0	35.71	14.29	0.14
	0.0	0.0	0.0	10.00	13.33	23.33	3.33	20.00	30.00	0.30
	0.0	0.0	0.0	0.0	9.09	24.24	7.58	33.33	25.76	0.66
	0.0	0.0	0.0	3.33	10.00	17.78	15.56	25.56	27.78	0.90
	0.0	0.0	0.0	7.81	21.88	15.63	28.13	7.81	18.75	0.64
	0.0	0.0	0.0	1.82	18.18	16.36	27.27	32.73	3.64	0.55
	0.0	0.0	1.79	3.57	14.29	35.71	21.43	23.21	0.0	0.56
	0.0	0.81	5.08	25.42	25.42	22.88	14.41	2.97	0.0	2.36
	0.0	9.00	8.92	8.25	7.46	6.88	7.15	5.60	4.63	0.0
CC (4)	0.0	1.39	0.0	7.59	17.93	22.07	15.86	19.31	15.86	1.45
	0.0	1.27	2.53	5.06	13.92	22.78	24.05	11.39	18.99	0.79
	0.0	0.0	2.63	5.26	11.84	10.53	17.11	34.21	18.42	0.76
	0.0	5.71	1.43	0.0	20.00	18.57	18.57	25.71	10.00	0.70
	0.0	0.0	0.0	15.15	17.17	29.29	17.17	14.14	7.07	0.99
	0.0	1.40	5.59	28.67	25.17	25.87	9.79	2.80	0.70	1.43
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	3.56	4.77	4.69	3.82	3.73	3.24	2.93	2.45	0.0
HS (5)	0.0	2.70	10.81	59.46	10.81	16.22	0.0	0.0	0.0	0.37
	0.0	2.22	0.0	31.11	33.33	31.11	2.22	0.0	0.0	0.45
	0.0	0.0	4.88	19.51	24.39	17.07	24.39	7.32	2.44	0.41
	0.0	0.0	0.0	5.00	27.50	15.00	17.50	25.00	10.00	0.40
	0.0	0.0	4.88	2.44	17.07	26.83	19.51	14.63	14.63	0.41
	0.0	0.0	0.0	3.57	15.48	22.62	28.57	14.29	15.48	0.84
	0.0	1.64	0.0	10.66	14.75	24.59	15.57	17.21	15.57	1.22
	0.0	3.14	1.89	5.66	16.35	18.37	16.35	25.16	12.58	1.59
	0.0	0.0	8.33	12.50	16.67	41.67	8.33	12.50	0.0	0.24
	0.0	6.33	4.77	3.93	5.23	5.75	6.09	6.52	6.27	0.0

NORMALIZING FACTOR; TO SHOW RELATIVE FREQUENCY WITHIN EACH CLASS (ROW)

JOINT DISTRIBUTION, BY CLASS, TEMPERATURE AND SOLAR RADIATION

SUBSET OF EMPIRICAL DISTRIBUTIONS

4	9	6	1	19
4	9	6	2	12
5	9	6	2	9

Figure A-14. Sample Output From HIST

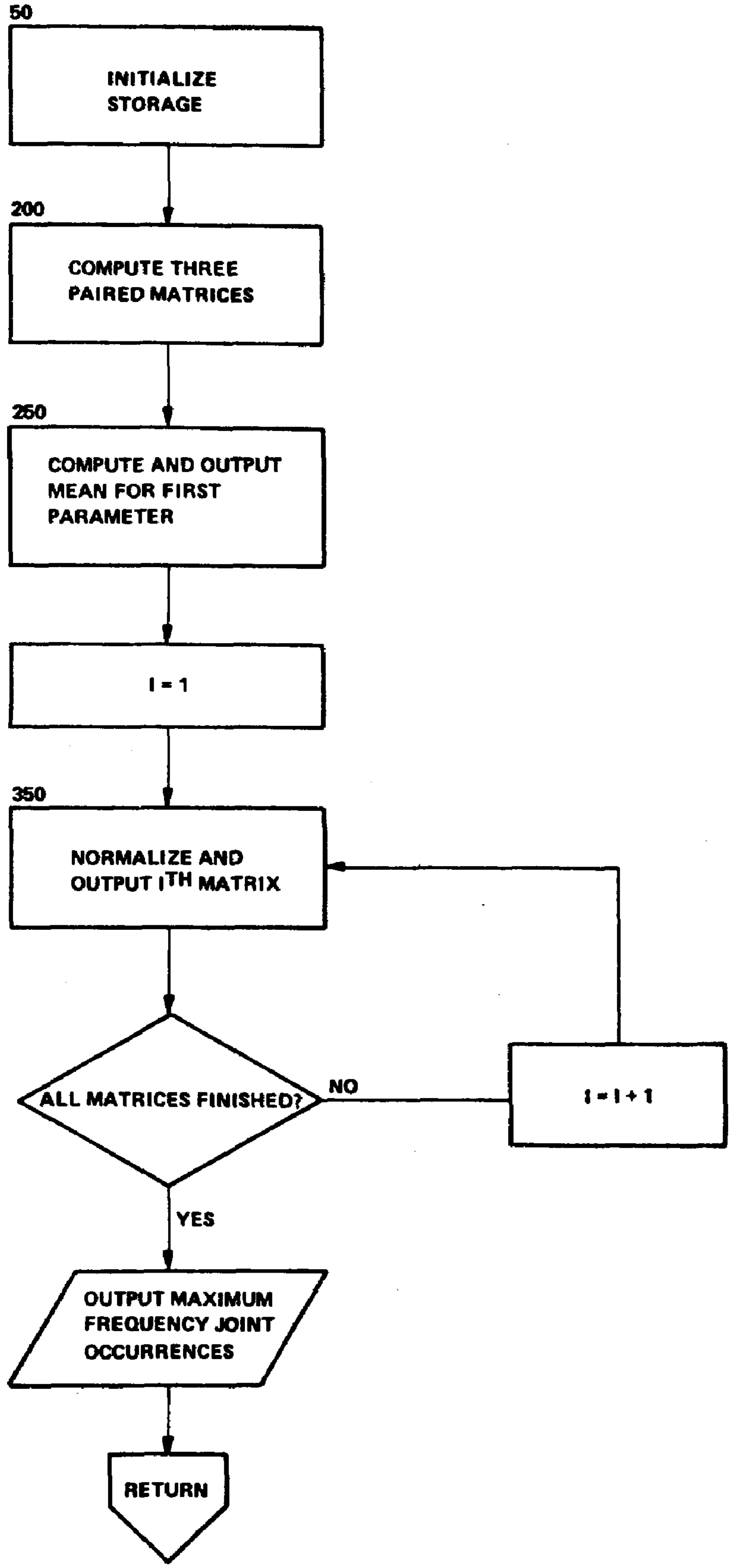


Figure A-15. Subroutine HIST Flow Chart

KOLMO has been modified by adding two new variables to the calling sequence. ISRT, which is set non-zero after the first call to KOLMO for a given parameter, is a flag to indicate that the parameter has already been sorted in non-decreasing order. USEDST is the name of a programmer coded subroutine which computes the cumulative probability distribution for the theoretical distribution under consideration. USEDST is a dummy subroutine at present, but is available for use in testing other distributions.

Figure A-16 is a sample DIST output. Figure A-17 is a flow chart of subroutine DIST.

Independence Test Option

In the independence test option, data values are extracted from the tape and saved in array X. Each variable (as selected in NHIST) is a column of X. All variables are first ranked (that is, each data value is replaced by a number specifying its relative position within the column). The Spearman rank correlation coefficient is then computed and output for each pair of meteorological variables chosen for the data base. Following this, the array X is re-ordered to fit the requirements of subroutine WTEST, which computes the Kendall coefficient of concordance (a measure of the relationship among all variables). That subroutine is called and the results output.

All three subroutines (RANK, SRANK, and WTEST) used are part of the IBM Scientific Subroutine Package[4]. Subroutine RANK operates on one vector, representing a single variable, at a time. The vector is searched for successively larger elements, and ranks assigned accordingly. If ties occur, they are each given the average rank of their position in the input.

```
TEST RUN WITH BOSTON DATA

 NOTE - TENTH HISTOGRAM DIVISION REPRESENTS INVALID OR MISSING DATA

 PROCESS EVERY    1 RECORDS, FROM BASE YEAR 52 FOR   2 YEARS

 TIME WINDOW IS FROM                             MONTH     6TO MONTH     8HOUR    11TO HOUR    14
   2     3     4     5     0 CODE NUMBERS OF PARAMETERS
   5     5     2   100       INTERVAL SIZE FOR CLASSES
  50    15     0     0       BASE (ZERO POINT) FOR CLASSES

 OUTPUT IS EVERY     0 RECORDS IN WINDOW


   YEAR    52 MONTH    7 STATION   14739FOUND

   YEAR    52 MONTH    7 STATION   94701FOUND

 DISTRIBUTION TESTS FOR VARIABLE NUMBER   2
              62 POINTS USED FOR MEAN      550 POINTS USED FOR TEST
               0.7816E 02 SAMPLE MEAN                 0.7958E 01 SAMPLE STANDARD DEVIATION
         KOLMO OPTION  1 Z       0.1779E 01 PROB        0.3571E-02 IER 0
 DISTRIBUTION TESTS FOR VARIABLE NUMBER   3
              62 POINTS USED FOR MEAN      550 POINTS USED FOR TEST
               0.5287E 02 SAMPLE MEAN                 0.1748E 02 SAMPLE STANDARD DEVIATION
         KOLMO OPTION  1 Z       0.3296E 01 PROB        0.0         IER 0

 DISTRIBUTION TESTS FOR VARIABLE NUMBER   4
              62 POINTS USED FOR MEAN      550 POINTS USED FOR TEST
               0.5903E 01 SAMPLE MEAN                 0.3597E 01 SAMPLE STANDARD DEVIATION
         KOLMO OPTION  1 Z       0.4203E 01 PROB        0.0         IER 0

 DISTRIBUTION TESTS FOR VARIABLE NUMBER   5
              59 POINTS USED FOR MEAN      534 POINTS USED FOR TEST
               0.5393E 03 SAMPLE MEAN                 0.2120E 03 SAMPLE STANDARD DEVIATION
         KOLMO OPTION  1 Z       0.3364E 01 PROB        0.0         IER 0
```

INDICATOR FOR OPTION CHOSEN

MEASURE OF DEVIATION, Z

PROBABILITY

RESULTS FOR ONE VARIABLE

Figure A-16. Sample DIST Output (Test for Fit to Normal and Exponential Distribution)

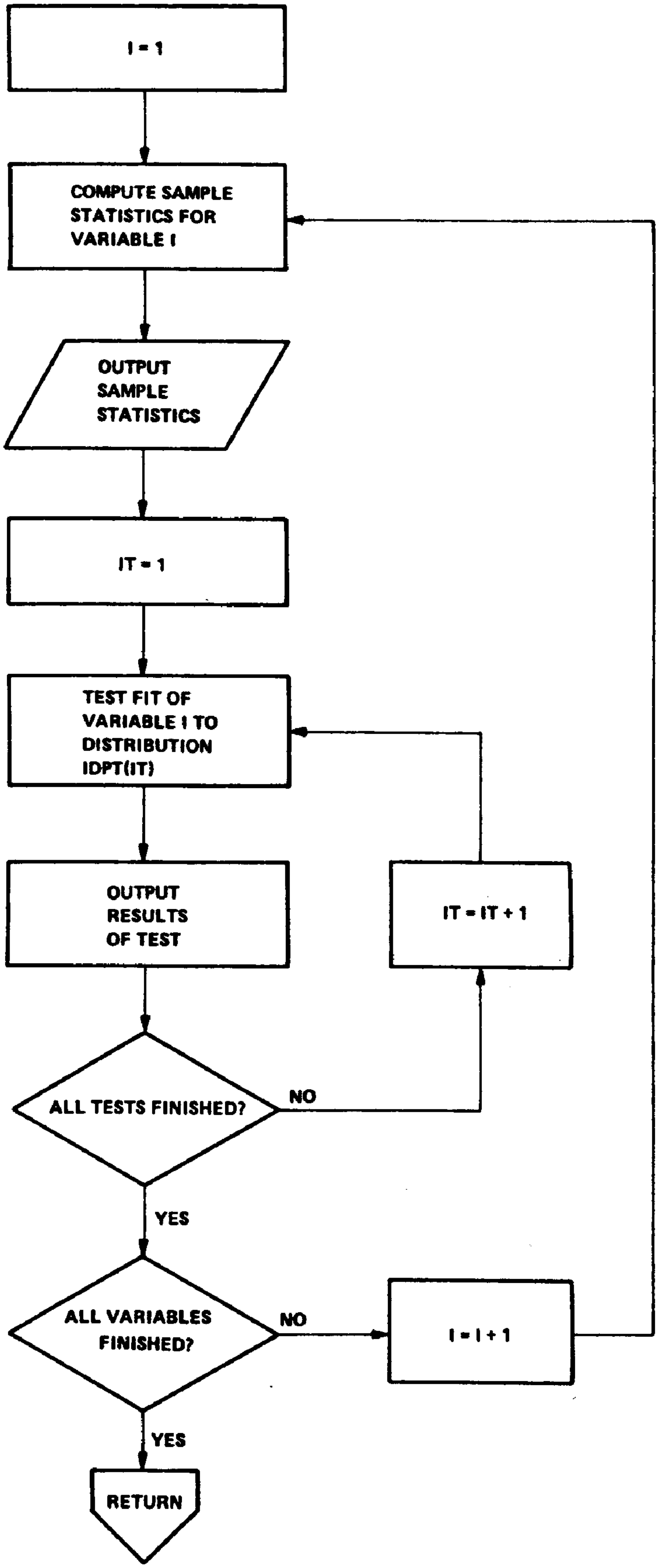


Figure A-17. Subroutine DIST Flow Chart

SRANK tests the correlation between two variables (meteorological parameters) by means of the Spearman rank correlation coefficients r_s. This coefficient is non-parametric, that is, no assumptions are made as to the underlying distributions of the variables. The significance of r_s can be obtained by testing the hypothesis that its value is different from zero. For a large number of observations N(> 10).

$$t = r_s \sqrt{\frac{N-2}{1-r_s^{2}}}$$

is distributed as Student's t with N-2 degrees of freedom. This value (t) is output in the program; the probability that the output value r_s is not zero may be determined for a fixed significance level by referring to Table A-6. A more detailed explanation of both this test and the following one may be found in Siegel, Non Parametric Statistics for the Behavioral Sciences, 1956, pp. 202-223. Table A-6 is abridged from this source.

Table A-6. Table of Critical Values of t

(N-2)	Level of Significance					
	.20	.10	.05	.02	.01	.001
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.358	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

Figure A-18 is an example of the output from INDTST, corresponding to the input of Figure A-1. For the meteorological variables air temperature (2), relative humidity(3), sky cover(4) and solar radiation(5), the correlation of all pairs of variables is computed. The Spearman rank correlation coefficient and the significance is given for each pair. Note that the number of points used is less then the total possible for this interval; the independence test option accepts only those time points at which valid observations are present for all selected variables.

The program also computes the Kendall coefficient of concordance which tests the degree of association among all the data. In this case, the significance (the second number in the line of output marked ALL VARIABLES) is approximately distributed as chi square. That is, the probability that the correlation is non-zero is the probability associated with a value of chi square as large as that output.

This coefficient, as computed by the IBM Scientific Subroutine WTEST,[4] has not been found to be of importance in the present project; however, its computation may be meaningful in other contexts.

Figure A-19 is a flow chart of the INDTST subroutine.

THERMOS Deck Setup

The THERMOS program is run in the OVERLAY mode, since several options are quite lengthy and since any one case utilizes only one option (and its associated subroutines). There are several ways to arrange an overlaid deck; the one which has been used for this work is pictured in Figure A-20.

```
TEST RUN WITH BOSTON DATA

NOTE - TENTH HISTOGRAM DIVISION REPRESENTS INVALID OR MISSING DATA

PROCESS EVERY    1 RECORDS, FROM BASE YEAR 52 FOR  2 YEARS

TIME WINDOW IS FROM                        MONTH     6TO MONTH     8HOUR    11TO HOUR    14
  2    3    4    5     0 CODE NUMBERS OF PARAMETERS
  5    5    2  100       INTERVAL SIZE FOR CLASSES
 50   15    0    0       BASE (ZERO POINT) FOR CLASSES

OUTPUT IS EVERY    0 RECORDS IN WINDOW

  YEAR   52 MONTH   7 STATION  14739FOUND

  YEAR   52 MONTH   7 STATION  94701FOUND
INDEPENDENCE TESTS. NUMBER OF DATA POINTS IS    593

          VARIABLE NUMBER       VS. VARIABLE NUMBER      RANK CORR. COEF       SIGNIFICANCE PARAMETER

                        2                         3    -0.55930579E 00     -0.16402451E 02
                        2                         4    -0.33684438E 00     -0.86971083E 01
                        2                         5     0.25668406E 00      0.64564362E 01
                        3                         4     0.54044139E 00      0.15615264E 02
                        3                         5    -0.50242078E 00     -0.14126491E 02
                        4                         5    -0.63823086E 00     -0.20154312E 02

ALL VARIABLES                                              0.94777644E-01      0.22443346E 03
```

Figure A-18. Sample INDTST Output (Independence Test Option)

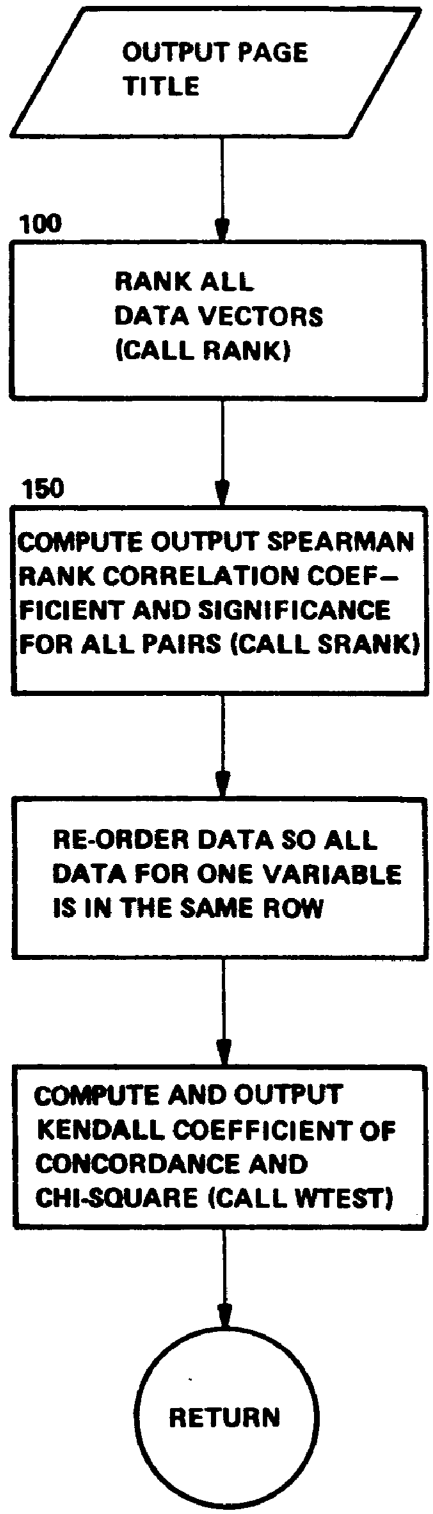


Figure A-19. INDTST Flow Chart

The program uses one or two Weather Bureau tapes; the Job Control Language (JCL) of Figure A-20 reflects this. The tapes, including JCL, are discussed in detail in the next subsection to follow. All examples given are for the standard IBM Operating System; only the JOB card and tape identifications should be installation dependent.

The PORTP Program

In order to process the Portland tape, a subset of THERMOS, called PORTP was written. The following are the differences from the THERMOS program to be found in PORTP:

a. The equilibrium temperature option (IPTN = 1) was removed, since solar radiation information is not available. If IPTN = 1 is input, it is changed to IPTN = 2.

b. The tape reads and synchronization were removed, and a single read statement of the Portland tape format inserted. This reads one hour's data at a time, in a slightly different format from the surface tapes.

c. Data decoding reflects the changed format.

d. The HEAD input has been removed; instead the program prints a notice to differentiate its output from the THERMOS output.

Tapes Used by the THERMOS Program

The THERMOS program, as presently written, uses a specific subset of the data on two types of U.S. Weather Bureau tapes; the Airways Surface Observation Tapes, Series TDF 14 and the Solar Radiation

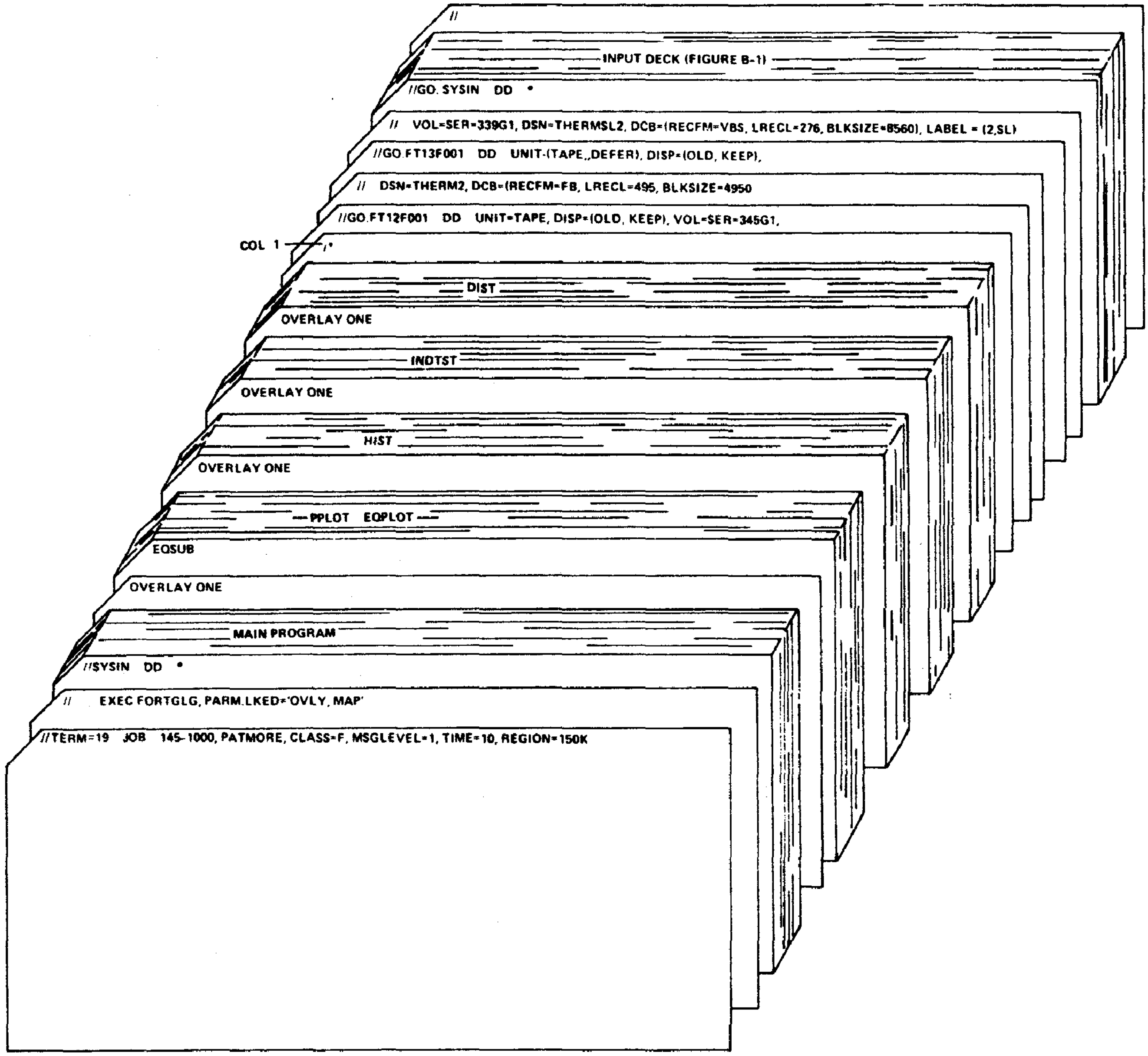


Figure A-20. THERMOS Deck Setup

tapes, Hourly 280. These will be referred to as the surface and solar tapes, respectively. Each tape contains hourly observations spanning approximately ten years; while a variety of locations are available in these series only two (Fresno and Boston) were employed for this project.

The Weather Bureau has published tape descriptions for tape users which appear later in this document. Here an explanation is given of the tape formats used to extract the desired data, the necessary Job Control Language (JCL) for copying the original tapes to standard label blocked tapes, and, in the case of the solar tapes, the program needed to reorder the entire tape.

All surface and solar tapes received for this project were unlabelled, 9 track, 800 bpi. The data on the surface tapes is ordered chronologically; on the solar tapes ten years of data for each month is given, starting with the first month for which observations are present.

An additional tape was also received, which contained one year (1963) of surface data for Portland, Oregon, compiled from Weather Bureau Deck 144 cards. This tape was labelled, 9 track, 800 bpi. Tape format and JCL are described here; the Weather Bureau documentation for DECK 144 follows. The data on the tape may be processed with the PORTP program described previously.

Surface Tapes

The surface tapes can be copied and reblocked using the IBM utility package IEBGENER and the JCL shown in Figure A-21. (The reblocking is not necessary, but economical.) In the figure, SYSUT1 is the input tape; the false volume serial number is a convenience. SYSUT2 is the output tape; note that the tape specifications correspond to those in Figure A-20, FT12F001, except that the new tape number is added to the latter.

The data on the surface tapes contains X-overpunches to indicate various extra pieces of information (such as negative readings). Columns coded in this way are not directly readable as numbers by FORTRAN; the conversion process is cumbersome and time consuming. However, given the choice between preprocessing the tapes or using them as is, it was decided to use them as received. This means that other surface tapes, from other locations can be used in this program without modification. If much processing of this type is to be done, however, reformatting (and the consequent change to THERMOS) should be considered.

At the present time, the THERMOS program reads only that time and meteorological data for which it has a specific use. Since each day is broken into four records of 6 hours each, and since the program reads a day at a time, the code shown in Figure A-22 is used to read IDD and IDATA, as described in Table A-5. This corresponds to reading just those fields checked in the excerpt from the weather documentation shown in Figure A-23 (the full document appears at the end of this section.)

Solar Tapes

The solar tape contains two files of data, each representing approximately 10 years of data from one station. Unfortunately, although the format is as described in the documentation (with the exception of the information relating to missing records), the time sequence has the data arranged on the tape in the following manner:

All years for month 1, all years for month 2, ... all years for month n,

where month 1 is the first month for which data has been reported.

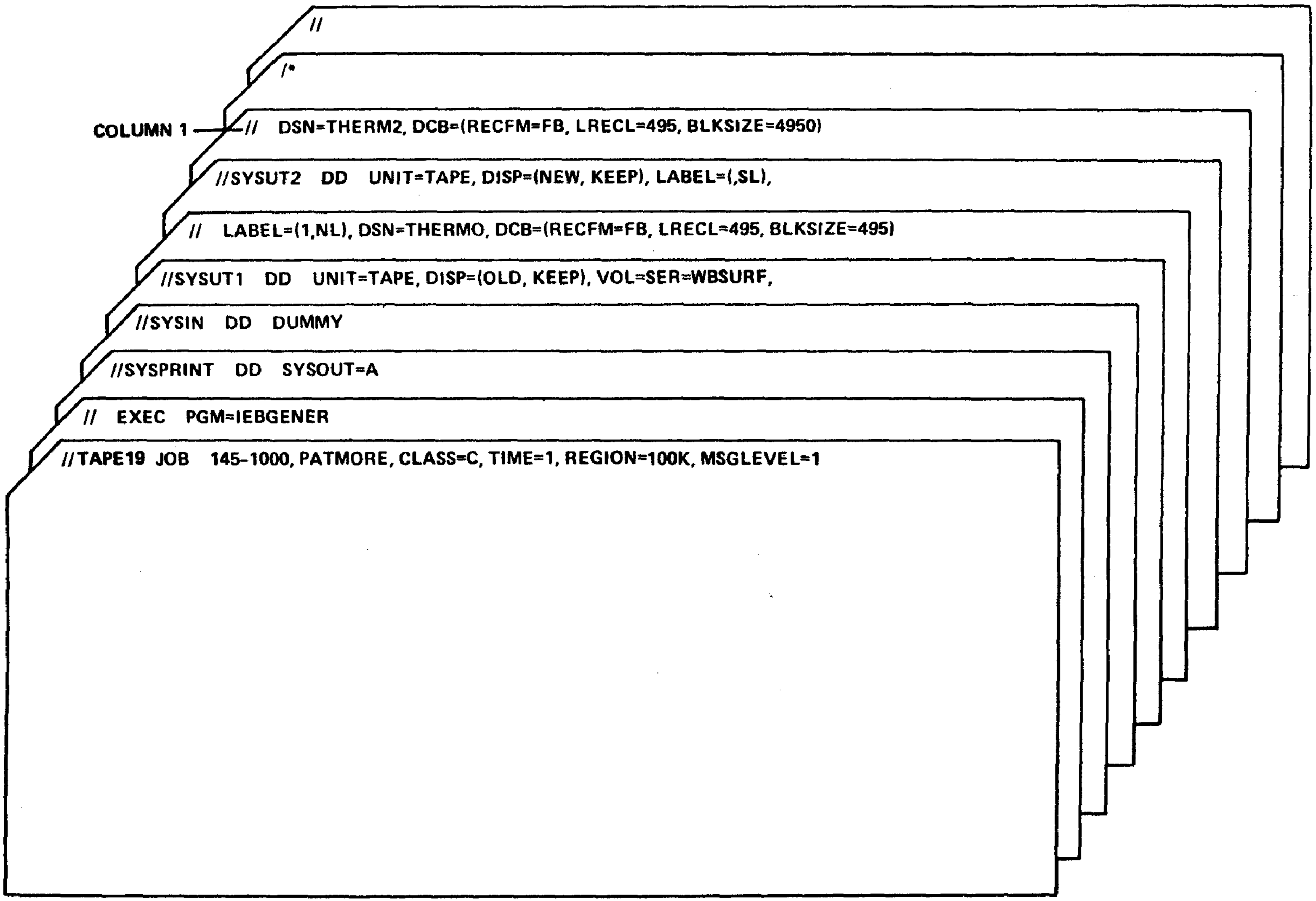


Figure A-21. Control Cards to Copy Surface Tape

```
      DIMENSION IDATA(4), IDD(8, 24)

45    DO 50 J1=1, 24, 6

      J2 = J1+5

50    READ(12, 801, END=550) IDATA, ((IDD(I, J), I=1, 8), J=J1, J2)

801   FORMAT (4X, I5, 3I2, 6 (I2, 10X, I2, A1, I2, 7X, I2, A1,
             14X, A1, 37X))
```

Figure A-22. Code and Format for Reading Meteorological Variables From Surface Tape

The procedure followed in this case consisted of three steps. First, both files of the tape were copied onto a backup tape. The IBM utility program IEBGENER was used, with the JCL as in Figure A-24. Second, one file of the new tape was read into the computer, reordered through use of temporary disk storage, and then read back into core in chronological order and put onto a new unformatted tape. A new 2-file tape was created in this way. Figure A-25 is a flow chart of the program used, which also eliminated overpunch codes and reformatted the data (since an intermediate step was already a necessity in this case). As a result, the output solar tapes contain only that information called for by THERMOS; this information is unformatted and configured so that it can be read directly into the arrays ISLD and ISLR described in Table A-5. (The full description of the original tapes appears in the subsection to follow.)

Figure A-26 is an example of the deck setup and control cards for the program which reorders the solar tape. Note that the JCL for the output tape, FT13F001, is the same as that for the solar input tape in Figure A-20. Figure A-27 is a sample output from the solar

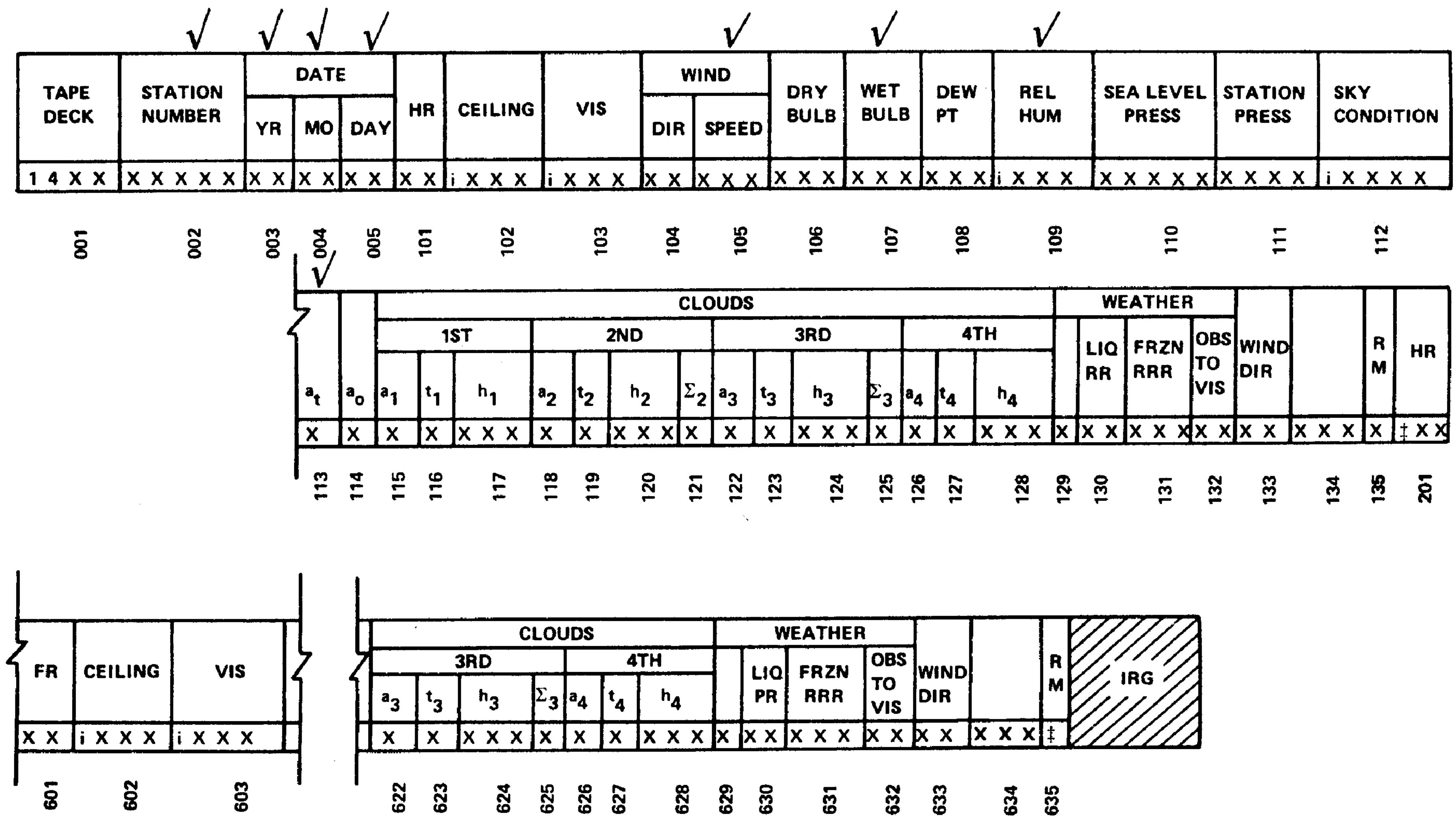


Figure A-23. Fields Used From Surface Tape

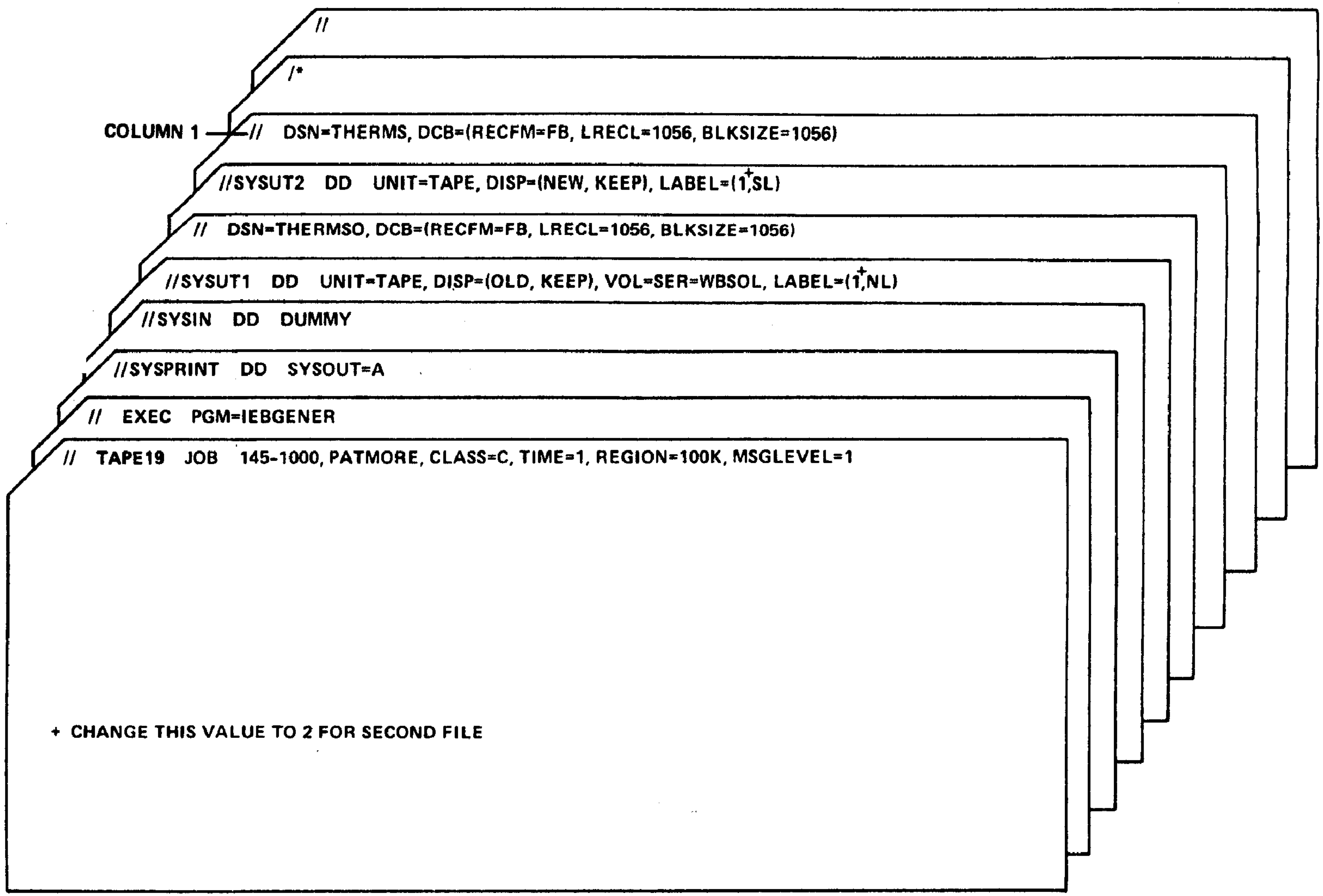


Figure A-24. Control Cards To Copy Solar Tape

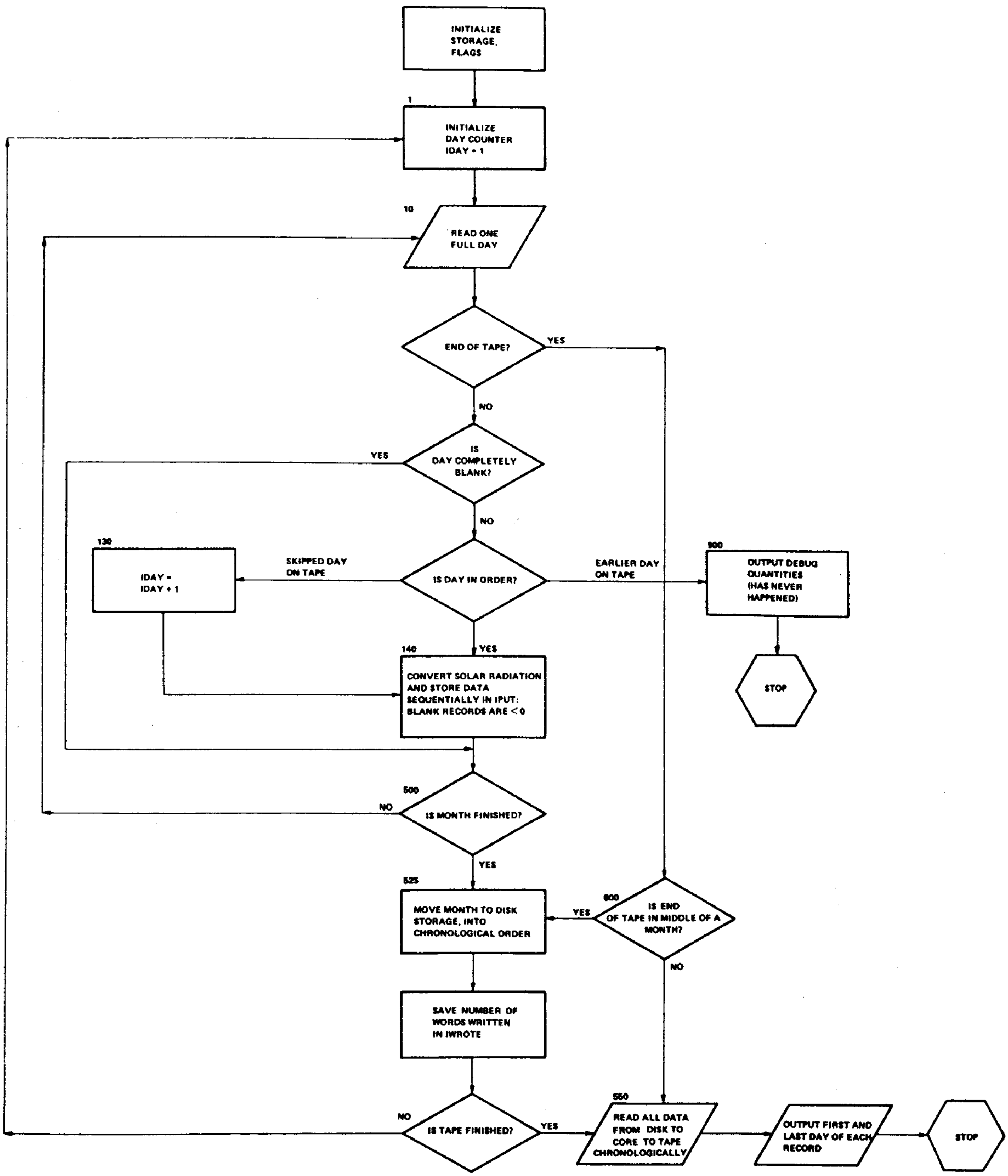


Figure A-25. Flow Chart of Program to Reorder Solar Tapes

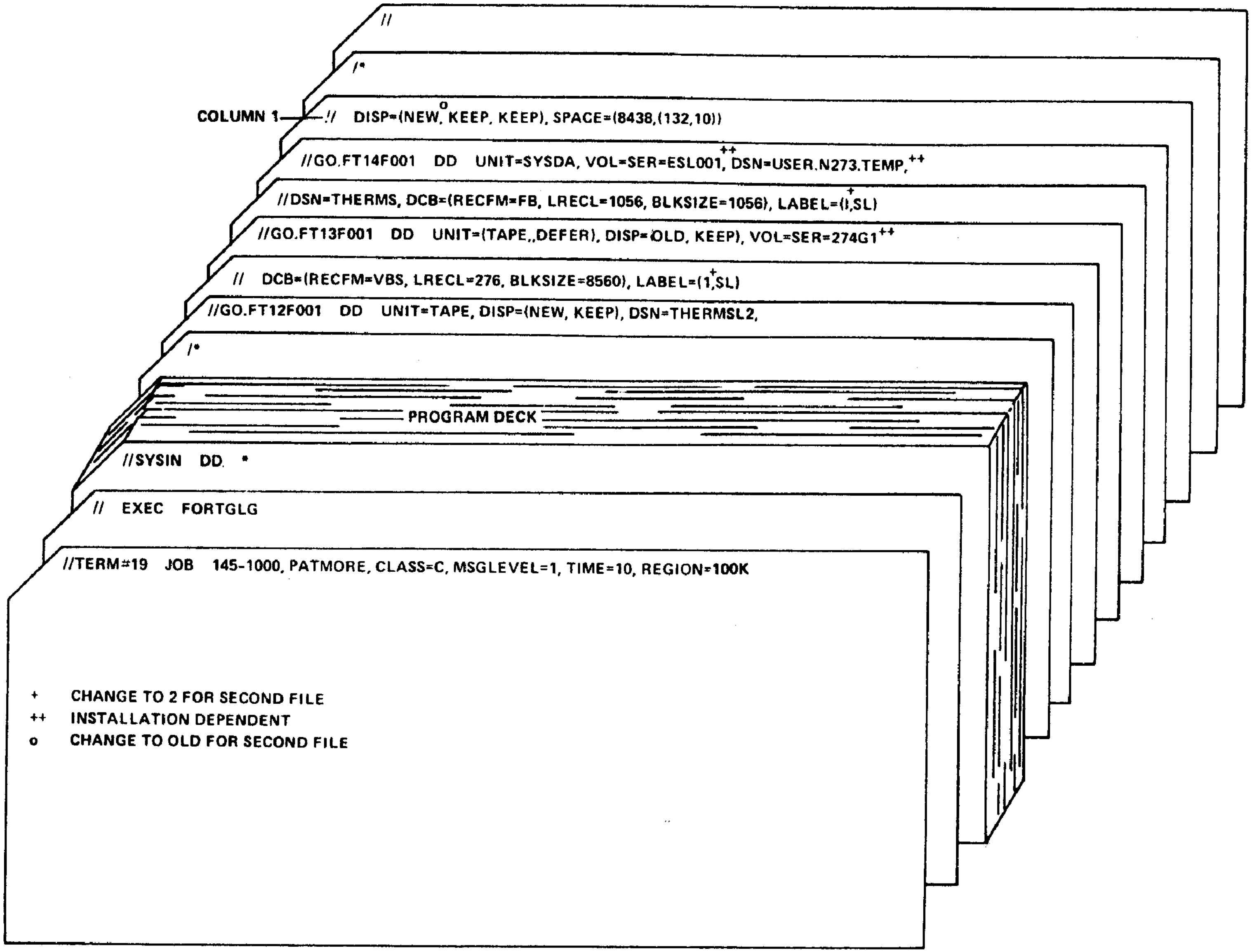


Figure A-26. Solar Program Deck Setup

```
 2040  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1904
 2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040  2108  2108  2040  2108
 2040  2108  2108  1972  2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040
 2108  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1904
 2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1972  2108  2040  2108  2040  2108  2108  2040  2108
 2040  2108  2108  1904  2108  2040  2108  2040  2108  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040
 2108  2108  2040  2108  2040  2108  2108  1904  2108  2040  2108  2040
93193    52    7  1   4    0   0   0   5  62    8  16    6 241  19  38   7 439  31  60   8 614  43  79   9 753  55  95
                 10 839  66 106  11 885  75 112  12 890  75 112  13 858  66 106  14 815  55  95  15 665  43  79  16
                442  31  60  17 253  19  59  18  76   8  16  19   3   0   0
93193    52    7 31   4    0   0   0   5  22    0   0    6 165  17  34   7 340  29  57   8 501  41  76   9 621  52  92
                 10 696  63 104  11 780  70 109  12 801  70 109  13 760  63 104  14 670  52  92  15 526  41  76  16
                353  29  57  17 171  17  34  18  30   0   0  19   0   0   0
93193    52    8  1   0****    0   0   5  14    0   0    6 148  17  34   7 333  28  55   8 505  40  75   9 652  52  92
                 10 738  63 104  11 777  70 109  12 791  70 109  13 759  63 104  14 688  52  92  15 541  40  75  16
                368  28  55  17 184  17  34  18  28   0   0  19   0   0   0
```


Figure A-27. Sample Output From Solar Tape Conversion Program conversion program: Lines 1-7 are a list of the number of words processed in each month's record. The remaining lines are a dump of the first and last record of each month, as written on the tape. The **** represent the code for an invalid (probably blank) data point; a large negative number.

The Portland Tape

The Portland tape is a standard label tape named LJM020. This tape was copied and blocked; as input to PORTP, the JCL for reading it is as follows:

```
//GO.FT12F001 DD UNIT=TAPE, DISP=(OLD, KEEP), DCB=(RECFM=FM,
                 LRECL=80, BLKSIZE=7200)
```

This must be used with an installation volume serial number and data set name.

Weather Bureau Information

The following pages are the Weather Bureau documentation for the solar tape, the surface tape, and the one year Portland tape constructed from a Weather Bureau Deck 144.

Following the Weather Bureau documentation are the FORTRAN listings for THERMOS, PORTP, and for the routine that reorders the solar tape, SOLR.

ATTACHMENT A

COPYS280 - TAPE FORMAT

Record Position	Field
1 - 5	Station Number
6 - 7	Year
8 - 9	Month
10 - 11	Day
12 - 13	Hour
* 14 - 66	1st hour's data
67 - 132	Repeat of 1-66 for 2nd hour's data
133 - 198	" " " " 3rd " "
199 - 264	" " " " 4th " "
265 - 330	" " " " 5th " "
331 - 396	" " " " 6th " "
397 - 462	" " " " 7th " "
463 - 528	" " " " 8th " "
529 - 594	" " " " 9th " "
595 - 660	" " " " 10th " "
661 - 726	" " " " 11th " "
727 - 792	" " " " 12th " "
793 - 858	" " " " 13th " "
859 - 924	" " " " 14th " "
925 - 990	" " " " 15th " "
991 -1056	" " " " 16th " "
Record Gap	

1. 16 daylight hour observations always within the range of 04 through 21; one day's observations comprise a tape record.

2. Blank records are written on the tape for missing observations. Each year-month is assumed to be 31 days in length and 31 records are allotted on tape for each year-month. Missing records are left blank.**

3. There are eleven years of data for each station and a total of 4,092 records (some of which are blank) are written on tape for each station.

4. There are 14 reels of tape. Reels 1-13 contain 2 stations each with one end of file after the first station and 2 end-of-files after the second station. Reel 14 has only 1 station followed by 2 end-of-files.

5. There are a total of 27 stations.

* (BREAK DOWN OF 1st HOURS DATA ATTACHED)

** NOT NECESSARILY TRUE

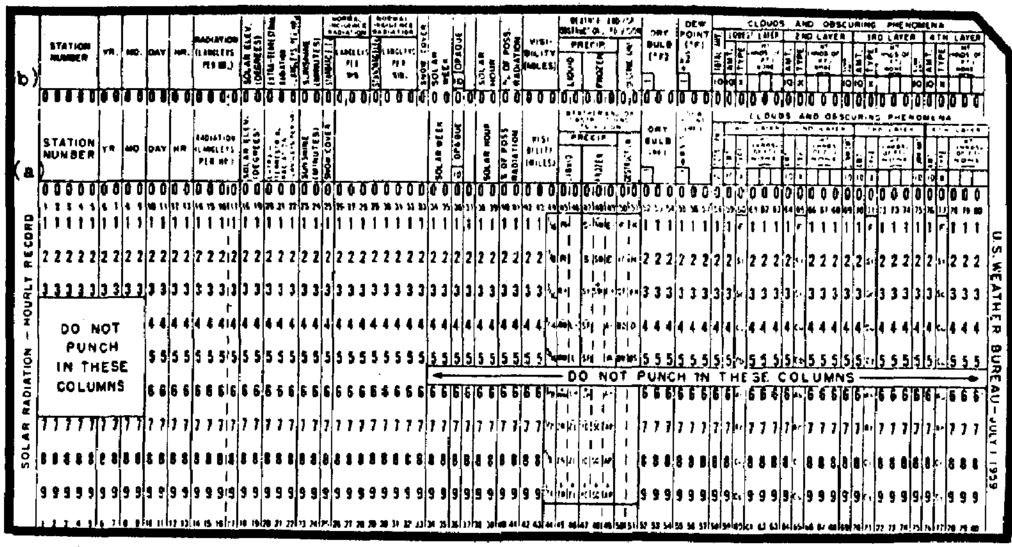
14-17	Radiation 1/10 langley/hr.
18-19	Solar Elevation
20-22	Extra-Terrestrial Radiation (ETR) (langleys/hr)
23-24	Sunshine (minutes)
25	Snow cover
26	Opaque
27	Blank
28-29	Solar hour
30-31	Percent of possible radiation
32-34	Visibility
35-41	Weather and/or obscuration to vision
42	Total Cloud Amount
43	Amount (Layer 1)
44	Type
45-47	Height (hundreds of feet)
48	Amount (Layer 2)
49	Type
50-52	Height
53	Summary Amount (1 and 2)
54	Amount (Layer 3)
55	Type
56-58	Height
59	Summary Amount (1, 2, and 3)
60	Amount (Layer 4)
61	Type
62-64	Height
65	Asterisk
66	Asterisk

COPYS280 (Card Deck 280) (Job 0110)

Period of Record: 7/52 - 6/63 (Missing periods indicated below)

Sta. No.	Station Name	Missing Periods	CABINET	SHELF	REEL
12832	Apalachicola, Fla.	6-8/53; 2,3,7-12/54	~~10~~	3	7 6166
12839	Miami, Florida		66	4	7
12919	Brownsville, Texas	7/56; 1,2/57; 5-7/58			8 6167
13745	Cape Hatteras, N. C.	7/52			11 6170
13880	Charleston, S. C.				10 } 6169
13897	Nashville, Tennessee	8,9/53			10
13941	Lake Charles, La.				12 } 6171
13961	Fort Worth, Texas				12
13983	Columbia, Missouri				11 6170
13985	Dodge City, Kansas	2-6/59			5 6164
14607	Caribou, Maine				6 } 6165
14753	Blue Hill, Mass.				6
14837	Madison, Wisconsin	3/59-2/60; 10/62-6/63			2 6161
14847	Sault Ste Marie, Mich.	9/58-6/63			3 6162
14939	Lincoln, Nebraska	9/55-5/57			13 6172
23044	El Paso, Texas				3 6162
23050	Albuquerque, N. M.				1 } 6160
23154	Ely, Nevada				1
23183	Phoenix, Arizona				2 6161
24011	Bismarck, N. D.				4 } 6163
24143	Great Falls, Mont.				4
24225	Medford, Oregon				5 6164
24233	Seattle, Washington				8 6167
93193	Fresno, California	July 13, 1952 deleted			9 6168
93722	Washington, D. C.	1-7/53; 12/60-6/63			13 6172
94701	Boston, Massachusetts				9 6168
94706	New York, New York	7/59; 11/61-12/62; 3-6/63			14 6173

DECK 280 SOLAR RADIATION - HOURLY RECORD



Card format (a) dated 1 Jul 59, became effective 1 Oct 59. Card format (b) dated 1 Oct 52 was put in use about this date or when stock of previous card became exhausted. In these cards (not shown) dated 1 Jan 51, Columns 34-39 and 55-57 were not punched according to headings but to those in card format (b). See card content.

AREA COVERAGE: Stations in the United States and a few in the Pacific area. See map on page 3 and alphabetic and numeric lists on pages 4, 5 and 6.

PERIOD OF RECORD: Jul 52 -
A few stations have records beginning in Dec 51. Refer to numeric list, pages 4-5, for dates of beginning and ending.

Deck 470 contains hourly, daily and weekly values of solar radiation for the period Jul 15-Jun 52. Deck 480 Solar Radiation - Summary of Day is for the period beginning Jul 52.

OBSERVATION TIME: Hourly surface observations are recorded in Local Standard Time (LST).

Prior to 1 Jun 57, the surface observations were taken 20-30 minutes past the hour punched in Columns 12-13.

1 Jun 57 - 31 Dec 64, the surface observations were taken a few minutes before the hour punched in Columns 12-13.

Hourly radiation, in Langleys per solar hour, and hourly sunshine data for the scheduled time of observation (LST) that occurs within the solar hour (TST) are punched.

Prior to 1 Jul 58, the solar data are for the hour beginning on the hour punched.

1 Jul 58 - present. The solar data are for the hour ending on the hour punched. This change made the hourly data compatible with the times of the surface observation on Form WBAN 10.

Note: See additional remarks on page 2 for the relationship of solar hour (TST) and hour (LST).

CODE: WBAN

SOURCE: Roll-chart recorder forms
WB Form 610-8, "Hemispheric Solar Radiation on a Horizontal Surface - Langleys" (formerly WB Form 1091A)
Form WBAN 10B
Solar radiation hourly cards punched at stations in the contiguous United States.
Deck 144 punched cards, hourly weather observations

MISSING DATA INDICATION: Identification cards are punched for missing data for hours between sunrise and sunset but not when a whole month's record is missing. Missing data are indicated by blanks in the appropriate field. In some instances in Column 25 (Column 33 prior to 1 Oct 59) a blank was used to indicate no snow cover instead of punching "0".

139

COLUMNS AND ELEMENTS PUNCHED: Columns 1-25 and 38-39 are punched. Prior to 1 Jan 65, Columns 36 and 40-80 were punched. Punching of Columns 34-35 was discontinued 1 Jan 63.

Elements punched:

Solar Radiation-Hemispheric (sum of direct and diffuse)
Solar Elevation
Extra-Terrestrial Radiation
Sunshine
Snow Cover
Solar Week (discontinued 1 Jan 63)
Opaque Sky Cover (discontinued 1 Jan 65)
Solar Hour
Percent of Possible Radiation (discontinued 1 Jan 65)
Visibility (discontinued 1 Jan 65)
Weather and/or Obstructions to Vision (discontinued 1 Jan 65)
Dry Bulb Temperature °F (discontinued 1 Jan 65)
Dew Point Temperature °F (discontinued 1 Jan 65)
Amount, Type and Height of Cloud Layers (discontinued 1 Jan 65)

ADDITIONAL REMARKS: Effective with 1 Jul 57 records, solar radiation data have been recorded in the International Pyrheliometer Scale of 1956. This scale provides values that are 2.0% less than those based on the Smithsonian Scale of 1913, the standard previously in use.

Solar radiation data are tabulated in terms of True Solar Time (TST); all data on Form WBAN 10B are entered in terms of Local Standard Time (LST). Since solar time varies continuously with longitude and season, it is frequently different from LST, which is fixed by time zone. It is impossible to match exactly solar hours from the pyrheliometer record with the LST hour entries on Form WBAN 10B. Therefore it is necessary to select an hour of observation (LST) that occurs within the solar hour, True Solar Time (TST), from the pyrheliometer record.

Hourly values of radiation are punched from data on Form WBAN 10B where solar time equivalent of the scheduled time of observation is 0-59 minutes earlier than the true solar time of the end of the hour of radiation, i.e., the solar time ascribed to the tabulated hourly radiation values. A table is prepared for each station to facilitate the pairing of the surface synoptic observation with the hourly data punched in the cards. Because the cards are punched in LST, corrections are obtained from the table, which determine whether an hour should be added or subtracted, or no correction made, to the true solar time of hourly radiation values to obtain the comparable local standard time for punching purposes. See Columns 10-11 and 38-39 of "Card Content".

In some instances the hourly surface observation in the WBAN No. 1 card reproduced into the hourly solar radiation card was from a nearby WBAS station because the station where the solar radiation data were obtained did not have hourly surface observations. Stations using WBAN No. 1 card data from other stations are:

Solar Radiation Station	WBAN No. 1 Station
14743 Blue Hill, Mass.	14739 Boston, Mass. WBAS
94701 Boston, Mass. WBO	14739 Boston, Mass. WBAS
94706 New York, N.Y. (Central Park)	14732 La Guardia Field, N.Y. WBAS
95918 North Omaha, Nebr.	14942 Omaha, Nebr. WBAS

Note: 12832 Apalachicola, Fla. does not have hourly surface observational data from WBAN No.1 card punched into the solar radiation card.

Locations measuring hemispheric solar radiation have a pyrheliometer installed in a suitably exposed location and a recorder installed in the office. Hourly radiation values are obtained at stations equipped with roll-chart recorders. Thermoelectric hemispheric pyrheliometers are used in measuring hemispheric solar radiation. Two types are in use: a "10-junction" type in general use, and a more sensitive "50-junction" type used at selected northern stations during months when solar radiation is less intense.

CORRECTIONS: Any errors detected in this manual should be called to the attention of Director, National Weather Records Center, EDS, Environmental Science Services Administration, or Chief, Data Processing Division, Environmental Technical Applications Center, USAF. Please give specific instances of error, and correct information if available.

HEMISPHERIC SOLAR RADIATION - HOURLY STATIONS

NUMERIC STATION LIST

Station Number*	Station Name	Period of Record	Missing Data Period	Lat. N	Long. W	Elev. Feet ¢	Additional Data (see footnote) (S)	(H)	(A)	(N)
X3492	Grand Lake (Cranby) Colo.	1/57-4/57		40°14'	105°51'	8340		H	A	
X4279	Inyokern, Calif.	1/57-2/57		35 39	117 40	2300		H	A	
X5733	Matanuska Agri. Exp. Sta. Alaska	1/57-3/57		61 34	149 16	150			A	
X7473	Riverside, Calif.	1/57-4/57		33 58	117 20	1050		H	A	
X8815	Tucson, Arizona (Univ. of Arizona)	1/57-4/57		32 14	110 57	2440			A	N
03841	Oak Ridge, Tenn. WBO	7/52-3/57	10/52-12/56	36 01	84 14	940		H	A	
03927	Fort Worth, Texas (See 13961)	5/53-		32 50	97 03	574		H		
03937	Lake Charles, La. WBAS (See 13941)	11/61-		30 07	93 13	60				
04729	Upton, New York	7/52-3/57	11/52-12/56	40 52	72 53	88		H	A	
12832	Apalachicola, Florida	7/52-	6-8/53; 2-3/54; 7-12/54	29 44	84 59	46	S	H		
12839	Miami, Florida WBAS	7/52-		25 48	80 16	41		H		
12919	Brownsville, Texas WBAS	7/52-	7/56; 12/56-2/57; 5-7/58	25 54	97 26	48	S	H		
13745	Hatteras, N. C. (See 93729)	7/52-3/57		35 15	75 40	10	S	H		
13880	Charleston, S. C. WBAS	7/52-		32 54	80 02	69		H		
13897	Nashville, Tenn. WBAS	7/52-	8-9/53	36 07	86 41	614	S	H		
13941	Lake Charles, La. WBAS (See 03937)	7/52-10/61		30 13	93 09	39		H		
13961	Fort Worth, Texas (See 03927)	7/52-5/53		32 49	97 21	706		H		
13983	Columbia, Mo. WBAS	7/52-		38 58	92 22	814	S	H		
13985	Dodge City, Kansas WBAS	7/52-	2-6/59	37 46	99 58	2625	S	H		
14607	Caribou, Maine WBAS	7/52-		46 52	68 01	640		H		
14753	Blue Hill/Milton, Mass.	7/52-		42 13	71 07	670	S	H		N
14820	Cleveland, Ohio WBAS	7/52-7/53		41 24	81 51	871	S		A	
14837	Madison, Wisconsin	7/52-	6-8/58; 3/59-1/60 10/62-2/64;5-7/65	43 08	89 20	889	S	H		N
14847	Sault Ste. Marie, Mich. WBAS	7/52-8/58		46 28	84 22	729	S		A	
14939	Lincoln, Nebr. WBAS	8/52-8/55		40 52	96 46	1189	S	H		N
14971	Lincoln, Nebr. WBO	11/57-12/59		40 49	96 42	1316	S			
23044	El Paso, Texas WBAS	7/52-		31 48	106 24	3954	S	H		
23050	Albuquerque, N. Mex.	7/52-		35 03	106 37	5327	S	H		N
23154	Ely, Nevada WBAS	12/51-		39 17	114 51	6279	S	H		
23174	Los Angeles, Calif. WBAS	1/62-		33 56	118 23	126				
23183	Phoenix, Arizona WBAS	7/52-		33 26	112 01	1139		H		
23236	Santa Maria, Calif.	7/52-11/54		34 56	120 25	234		H		
23273	Santa Maria, Calif.	11/54-		34 54	120 27	289				

142

NUMERIC STATION LIST (Cont.)

Station Number*	Station Name	Period of Record	Missing Data Period	Lat. N	Long. W.	Elev. Feet ¢	Additional Data (see footnote) (S)	(H)	(A)	(N)
24011	Bismark, N. Dakota WBAS	7/52-		46°46'	100°45'	1677	S	H		
24143	Great Falls, Montana WBAS	7/52-		47 29	111 21	3692	S	H		
24225	Medford, Oregon WBAS	11/51-		42 22	122 52	1321		H		
24233	Seattle, Wash.-Tacoma AP	11/51-		47 27	122 18	450		H		
26411	Fairbanks, Alaska WBAS	7/52-4/57	10/52-12/56	64 49	147 52	453		H	A	
26615	Bethel, Alaska WBAS	7/52-4/57	10/52-12/56	60 47	161 48	160			A	
27502	Barrow, Alaska WBAS	7/52-4/57	10/52-12/56	71 18	156 47	52			A	
41606	Wake Island WBAS	7/52-4/57	10/52-12/56	19 17	166 39 E	18			A	
60703	Canton Island WBAS	7/52-4/57	10/52-12/56	02 46 S	171 43	12			A	
93193	Fresno, Calif. WBAS	7/52-		36 46	119 43	336	S	H		
93722	Washington (Silver Hill Obs.,Md.)#	8/53-12/60		38 50	76 57	292				
93725	Washington, D. C. #(See 93734)	7/52-12/52		38 54	77 03	72		H		N
93729	Cape Hatteras, N. C. (See 13745)	3/57-		35 16	75 33	27				
93734	Sterling, Va.Dulles AP (See 93722)	11/60-		38 59	77 28	276				
94701	Boston, Mass. WBO	7/52-	10-12/53; 12/54; 6-7/64	42 21	71 04	157	S	H		
94706	New York, N. Y. (Central Park)	7/52-	7/59; 10/61-12/62; 3-10/63	40 47	73 58	187	S	H		
94918	Omaha, Nebr. WBAS (North Omaha)	6/57-		41 22	96 01	1323				N

¢ Elevation is height of pyrheliometer above MSL.
* WBAN or cooperative number indicated by X.

(S) Sunshine per Hour in Minutes punched in Columns 23-24.
(H) Prior to July 1952 data are available in Card Deck 470.
(A) For additional period of record see original forms or charts.
(N) Station equipped with Normal Incidence Pyrheliometer.

ALPHABETIC STATION LIST

23050	Albuquerque, New Mexico
12832	Apalachicola, Florida
27502	Barrow, Alaska
26615	Bethel, Alaska
24011	Bismark, North Dakota
14753	Blue Hill/Milton, Massachusetts
94701	Boston, Massachusetts
12919	Brownsville, Texas
60703	Canton Island
93729	Cape Hatteras, North Carolina
14607	Caribou, Maine
13880	Charleston, South Carolina
14820	Cleveland, Ohio
13983	Columbia, Missouri
13985	Dodge City, Kansas
23044	El Paso, Texas
23154	Ely, Nevada
26411	Fairbanks, Alaska
03927	Fort Worth, Texas
13961	Fort Worth, Texas
93193	Fresno, California
X3492	Grand Lake/Granby, Colorado
24143	Great Falls, Montana
13745	Hatteras, North Carolina
X4279	Inyokern, California
03937	Lake Charles, Louisiana
13941	Lake Charles, Louisiana
14939	Lincoln, Nebraska
14971	Lincoln, Nebraska
23174	Los Angeles, California
14837	Madison, Wisconsin
X5733	Matanuska, Alaska
24225	Medford, Oregon
12839	Miami, Florida
13897	Nashville, Tennessee
94706	New York, New York
03841	Oak Ridge, Tennessee
94918	Omaha, Nebraska (North Omaha)
23183	Phoenix, Arizona
X7473	Riverside, California
23236	Santa Maria, California
23273	Santa Maria, California
14847	Sault Ste. Marie, Michigan
24233	Seattle, Washington
93734	Sterling, Virginia
X8815	Tucson, Arizona
04729	Upton, New York
41606	Wake Island
93722	Washington, D. C.
93725	Washington, D. C.

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
	Missing Data		Blank	Missing or unknown data	See MISSING DATA INDICATION on page 1.
			X	11 punch	
			X/	X or 11 overpunch	
1-5	Station Number		00001-99999	WBAN Number	A list of stations with their coordinates, elevation and period of record is maintained at the National Weather Records Center, Asheville, N. C. See alphabetic and numeric lists on pages 4, 5, and 6 for period of record beginning July 1952.
			X0001-X9999	Cooperative Station Index Number	
6-7	Year		51-99	Last two digits of year	
8-9	Month		01-12	January - December	
10-11	Day		01-31	Day of month	The day of month is that entered on WBAN 10B.
			X/Col. 10	Solar hour is one hour later than LST	See Columns 38-39, Solar Hour.
			X/Col. 11	Solar hour is one hour earlier than LST	No "X" overpunch in Columns 10 or 11 indicates that the solar hour and the hour in LST coincide.
12-13	Hour LST		00-23	Hour, Local Standard Time	See OBSERVATION TIME on page 1.
14-17	Radiation Langleys per Hour		0000-9999	0.0 - 999.9 Langleys to tenths	The radiation is Hemispheric Solar Radiation and is that received (direct and diffuse) on a horizontal surface. The unit Langley is one gram calorie per square centimeter.
			X/Col. 14	Value partially estimated	Solar radiation data are recorded in solar time. The value is for the solar hour ending at the hour punched in Columns 38-39; prior to 1 Jul 58, it was for the beginning of the hour. The value is ascribed to the hour of observation (LST), Columns 12-13, that occurs within the solar hour (TST).

145

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
18-19	Solar Elevation		01-90	1 - 90 Whole Degrees	Punched for the appropriate solar elevation as recorded on the solar elevation table provided for the station. New tables were put in effect on 1 Jan 65 in agreement with the revised solar constant. See Remarks for Columns 20-22.
20-22	Extra-Terrestrial Radiation		001-999	1 - 999 Whole Langleys per hour	Punched as recorded on the tables supplied each station. Extra-Terrestrial Radiation (ETR) is the solar radiation received outside the earth's atmosphere. New tables were issued, effective 1 Jan 65, based on a solar constant of 2.00 gram calories per square centimeter normal to the incident solar rays. The former value was 1.94.
23-24	Sunshine		00-60	0 - 60 Minutes	The value is for the hour ending at the hour punched in Columns 12-13; prior to 1 Jul 58, it was for the beginning of the hour punched. Where the sunshine record is maintained at a local but separate office, such as a downtown city office, the minutes of sunshine from that location will be used in the absence of data from the pyrheliometer site.
25	Snow Cover		0 or Blank	None or Trace of Snow	Some stations left this column blank to indicate none or trace. The snow cover is at the time of the nearest synoptic hour to the local standard hour in Columns 12-13. Note: This element was punched in Column 33 prior to 1 Oct 59.
			1	One inch or more	
25-28	Normal Incidence Radiation				Normal Incidence Radiation data were not punched. Columns 25-32 were left blank.
25	Standard Elevation		 1 2 3 4 5	Solar Zenith Distance 0.0° 60.0° 70.7° 75.7° 78.7°	These data are tabulated on WB Form 610-9 (formerly 1091B) "Normal Incidence Solar Radiation Intensities" in Langleys per minute and are published monthly for about 7 or 8 stations in "Climatological Data National Summary".
26-28	Langleys per Minute		000-999	0 - 9.99 Langleys to Hundredths per minute	
29-32	Normal Incidence Radiation			See code for Cols. 25-28	See Remarks for Columns 25-28.

146

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
29-32 (Cont.)	Illumination 10's of foot candles		0000-9999	0 - 9999 tens of foot candles	This item was not punched. It was the heading of Columns 29-32 on punch cards dated 1 Jan 51 but was replaced by the normal incidence radiation field on punch cards dated 1 Oct 52.
33	Snow Cover		0	None or Trace of Snow	This column was used for snow cover from the beginning of the program until 1 Oct 59, when it was changed to Column 25. Column 33 was left blank beginning 1 Oct 59. See Remarks for Column 25, Snow Cover.
			1	One inch or more	
34-35	Solar Week		01-52	Solar Week of Year	Punching of solar week was discontinued 1 Jan 63. Solar weeks are seven-day periods with the first week beginning 1 Jan of each year, except that the last solar week of Dec is an eight-day period. During leap year, the solar week beginning 24 Jun is an eight-day period. In punch cards, dated 1 Jan 51, Columns 34-35 were shown as blank; however, the solar week was punched in these columns.
36	Opaque Sky Cover		0	Less than 1 tenth	Tenths of sky hidden by clouds and/or obscuring phenomena. Sky cover through which the sky is visible is disregarded. 1 Jun 62, opaque was re-defined as follows: Those portions of cloud layers or obscurations which hide the sky and/or higher clouds. Translucent sky cover which hides the sky but through which the sun and moon (not stars) may be dimly visible is considered opaque. This column corresponds to Column 79 in card deck 144. Punching of Column 36 was discontinued 1 Jan 65.
			1-9	1 - 9 tenths	
			X	10 tenths	
37	None		Blank		
38-39	Solar Hour		00-23	Solar Hour-True Solar Time	Solar radiation data are tabulated in True Solar Time (TST) in Langleys per solar hour. The scheduled time of observation (LST) that occurs within the solar hour (TST) is punched in Columns 12-13. When the solar hour is one hour later than LST, Column 10 is "X" overpunched; when the solar hour is one hour earlier than LST, Column 11 is "X" overpunched. When the solar hour and the hour in LST coincide, there are no "X" overpunches in Columns 10 or 11. See Remarks for Columns 14-17.

147

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION		REMARKS
40-41	Percent of Possible Radiation		00-99	0 - 99%		Quotient is derived by division of radiation (Columns 14-17) by extra-terrestrial radiation (Columns 20-22).
			X/Col. 40	100% or greater		Punching of Columns 40-80 was discontinued 1 Jan 65.
42-44	Visibility	VVV		Statute Miles	Increments	
			000-006	0 - 3/8 mile	1/16 mile	7/8 and 1-7/8 punched as 3/4 and 1-3/4, respectively. Prior to 1 Jul 52, 7/8 was not reported and prior to 1 May 53, 1-1/8, 1-3/8, 1-5/8 was not reported. Visibilities reported other than standard are punched for the next lower value.
			006-020	3/8 - 2 miles	1/8 mile	
			020-027	2 - 2 1/2 "	1/4 mile	
			027-030	2 1/2 - 3 "	1/2 mile	
			030-150	3 - 15 miles	1 mile	
			150-950	15 - 95 "	5 miles	
			990	100 miles or more		These columns correspond to Columns 21-23 in card deck 144.
45-51	Weather and/or Obstructions to Vision					These columns correspond to Columns 25-31 in card deck 144.
45	Liquid Precipitation		0	None		
		R-	1	Light rain		
		R	2	Moderate rain		
		R+	3	Heavy rain		
		RW-	4	Light rain showers		
		RW	5	Mod. rain showers		
		RW+	6	Heavy rain showers		
		ZR-	7	Light freezing rain		
		ZR	8	Mod. freezing rain		
		ZR+	9	Heavy freezing rain		
46	Liquid Precipitation		0	None		
		L-	4	Light drizzle		
		L	5	Mod. drizzle		
		L+	6	Heavy drizzle		
		ZL-	7	Light freezing drizzle		
		ZL	8	Mod. freezing drizzle		
		ZL+	9	Heavy freezing drizzle		

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
47	Frozen Precipitation		0	None	
		S-	1	Light snow	
		S	2	Mod. snow	
		S+	3	Heavy snow	
		SP-	4	Light snow pellets	
		SP	5	Mod. snow pellets	
		SP+	6	Heavy snow pellets	
		IC-	7	Light ice crystals	Card code 7 was discontinued 1 Apr 63.
		IC	8	Ice crystals	Card code 8 was "Mod. Ice crystals" prior to 1 Apr 63.
		IC+	9	Heavy ice crystals	Card code 9 was discontinued 1 Apr 63.
48	Frozen Precipitation		0	None	
		SW-	1	Light snow showers	
		SW	2	Mod. snow showers	
		SW+	3	Heavy snow showers	
		SG-	7	Light snow grains	
		SG	8	Mod. snow grains	
		SG+	9	Heavy snow grains	
49	Frozen Precipitation		0	None	
		E-	1	Light sleet	Sleet showers is coded as sleet.
		E	2	Mod. sleet	
		E+	3	Heavy sleet	
		A-	4	Light hail	Card code 4 was discontinued 1 Sep 56.
		A	5	Hail	Card code 5 was "Mod. Hail" prior to 1 Sep 56.
		A+	6	Heavy hail	Card code 6 was discontinued 1 Sep 56.
		AP-	7	Light soft hail	Card code 7 was discontinued 1 Sep 56.
		AP	8	Small hail	Card code 8 was "Mod. soft hail" prior to 1 Sep 56.
		AP+	9	Heavy soft hail	Card code 9 was discontinued 1 Sep 56.
50	Obstructions to vision		0	None	
		F	1	Fog	
		IF	2	Ice fog	
		GF	3	Ground fog	
		BD	4	Blowing dust	
		BN	5	Blowing sand	

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
51	Obstructions to vision		0	None	
		K	1	Smoke	
		H	2	Haze	
		KH	3	Smoke and haze	
		D	4	Dust	
		BS	5	Blowing snow	
		BY	6	Blowing spray	Card code 6 was effective 1 Jul 52.
52-54	Dry Bulb Temperature	TTT	000-099	0°F - 99°F whole degrees	Column 52 is punched 0 for 0°F and above.
			100-199	100°F - 199°F	Column 52 is punched 1.
			X01-X99	-1°F - -99°F	Column 52 is punched X for values below zero.
55-57	Dew Point Temperature	T_dT_d	000-099	0°F - 99°F whole degrees	Column 55 is punched 0 for 0°F and above.
			X01-X99	-1°F - -99°F	Column 55 is punched X for values below zero.
					Columns 52-54 correspond to Columns 47-49, and Columns 55-57 correspond to Columns 36-38 in card deck 144.
58-80	Clouds and Obscuring Phenomena				These columns correspond to Columns 56-78 in card deck 144. Provision was made for as many as four layers of cloud and/or obscuring phenomena existing at one time. If more than four layers existed, the data for levels above the fourth were entered in the remarks portion of WBAN 10B, and were not punched. Their presence is indicated by the entry for total sky cover. Layers were punched in ascending order of elevation. All fields above a layer which prevented observation were left blank. If two or more types of clouds were observed at the same height, only the predominating type was punched, their amounts being combined. For each layer, the amount, type and height were punched, and for the second and third layer, the summation amount at the level involved was punched, reflecting the total amount of sky covered by that layer and those below it. The summation total for the fourth layer is obviously the total sky cover. The summation total is not necessarily the sum of the individual layers.
58	Total Amount		0, 1-9 X	Tenths 10 Tenths	

150

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
59	Amount of Lowest Layer		0, 1-9 X	Tenths 10 Tenths	
60	Type of Cloud Lowest Layer		0	None	
		F	1	Fog	
		St	2	Stratus	
		Sc	3	Stratocumulus	
		Cu	4	Cumulus	
		Cb	5	Cumulonimbus	
		As	6	Altostratus	
		Ac	7	Altocumulus	
		Ci	8	Cirrus	
		Cs	9	Cirrostratus	
		Sf	X/2	Stratus Fractus	Prior to 1 May 61, code X/2 was Fractostratus (Fs)
		Cf	X/4	Cumulus Fractus	Prior to 1 May 61, code X/4 was Fractocumulus (Fc)
		Cm	X/5	Cumulonimbus Mamma	
		Ns	X/6	Nimbostratus	
		Acc	X/7	Altocumulus Castellanus	
		Cc	X/9	Cirrocumulus	
			X	Obscuring phenomenon other than fog	
61-63	Height of Lowest Layer		000-990	Hundreds of feet 0 - 99,000 feet	Height was recorded to the nearest 100 feet from the surface to 5000 feet; to the nearest 500 feet between 5,000 and 10,000 feet; and to the nearest 1,000 feet above 10,000 feet.
			888	Unknown height of a cirroform layer	Effective 1 Sep 56.
			XXX	Unlimited vertical visibility	

151

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
64	Amount of Second Layer		0, 1-9 X	Tenths 10 Tenths	
65	Type of Second Layer		0, 1-9 X/	See Column 60	
66-68	Height of Second Layer		000-990 XXX	See Columns 61-63	
69	Summation Amount at Second Layer		0, 1-9 X	Tenths 10 Tenths	
70	Amount of Third Layer		0, 1-9 X	Tenths 10 Tenths	
71	Type of Third Layer		0, 1-9 X/	See Column 60	
72-74	Height of Third Layer		000-990 XXX	See Columns 61-63	
75	Summation Amount at Third Layer		0, 1-9 X	Tenths 10 Tenths	
76	Amount of Fourth Layer		0, 1-9 X	Tenths 10 Tenths	
77	Type of Fourth Layer		0, 1-9 X/	See Column 60	
78-80	Height of Fourth Layer		000-990 XXX	See Columns 61-63	

ATTACHMENT D

TAPE
REFERENCE
MANUAL

AIRWAYS
SURFACE
OBSERVATIONS

TDF 14

GENERAL TAPE INFORMATION

Observations (physical records) are placed on tape in groups (logical records) of six. Thus, the 24 observations for each day are contained in four logical record groups. Space is always retained on tape for 24 observations per day with missing observations being coded blank.

Beginning January 1, 1965 a new program was initiated for most Weather Bureau stations reducing the number of hourly observations being punched from 24 to 8 per day. These 3-hourly observations are punched in local standard time, the hours selected to coincide with the standard international synoptic times of 0000GMT, 0300GMT, 0600GMT, etc. Available taped LST observations will therefore vary depending upon the time zone at a given station. A few Weather Bureau stations that are specially processed and most Air Force and Navy stations continue to be available on a 24 observation/day basis.

The following relationship between tape field and observation time holds true for all tapes in this general format:

Observational Hours

Tape Field	Record No. 1	Record No. 2	Record No. 3	Record No. 4
101	00	06	12	18
201	01	07	13	19
301	02	08	14	20
401	03	09	15	21
501	04	10	16	22
601	05	11	17	23

Notation of a tape position within a field is made according to the following example:

105 (-0) = units position of wind speed
105 (-1) = tens position of wind speed
105 (-2) = hundreds position of wind speed

These notations hold true for all fields.

Each record within the record group consists of 80 character positions, including those for hour, and the position for record mark at the end of each record. Six such records, plus the record-group identification fields of 15 character positions, make up the record group, 495 characters in length. The fields within the first observation of the record group are referred to as fields 101 through 135, those of the second observation as 201 through 235, etc., up to the sixth and last observation, where the fields are numbered 601 through 635. Later in this manual, the coding of each meteorological element is described in detail. All references are made to fields 101 through 135, or to the fields of the first observation of each record group. These references apply by extension to fields 201-235, 301-335, etc., respectively, to the corresponding field or element of any observation within the record group. Following the record mark in the last observation of the record group is the inter-record gap.

The ideal standard tape form would be a coded observation wherein every element is reduced to a single method of representation, regardless of source or original coding scheme. In any actual data family (a group of relatively homogenious weather observations such as surface observations in all their various forms, that have been assimilated into a more-or-less common format); however, this can be accomplished only to a limited degree. Elements reported in numeric values, such as wind speed, temperature, and pressure, may be reduced to a common form, e.g., knots, fahrenheit, millibars. But, elements reported by discrete definitions within code tables, are not always so compatible; examples of these are sky condition and cloud types. By combining all such code tables for a single element into an expanded table containing all definitions, one may approach a uniform code, but in use of such tables one must remember how they were derived. If the combined code contains a value for "high obscuration"; for example, one may tabulate the observations for a station and find no occurrence of "high obscuration", not because it never occurred, but because at the time the observations were recorded, no provision was made in the observing instructions to define a "high obscuration".

This reference manual has been compiled mainly for the person whose primary need is to use the various meteorological parameters as they appear on tape, and who is not vitally concerned with the myriad coding and observing vagaries inherent in these data.

Sufficient tables have been included to enable the user to adequately define the codes found on these tapes. Those desiring more detailed coding and/or observing information may use this manual in conjunction with the appropriate Card Deck reference manual (Card Decks 141,142,144). Observations are on 7 channel tape, written in the BCD mode at 556 BPI.

Δ		This symbol represents a blank or no punch condition.
"_1'		X-punch (11 punch).
*	Invalid	Whenever an invalid configuation appears it means that the
Δ*		punched card values did not conform to the standard report-
ΔΔ*		ing requirements and therefore were unacceptable for
ΔΔΔ*		conversion to tape.

The following octal configurations are applicable to tapes in the TDF 14 series:

Octal	Card Punch	Octal	Card Punch
01	1	61	A (12,1)
02	2	62	B (12,2)
03	3	63	C (12,3)
04	4	64	D (12,4)
05	5	65	E (12,5)
06	6	66	F (12,6)
07	7	67	G (12,7)
10	8	70	H (12,8)
11	9	71	I (12,9)
12	0	72	ε (12,0)
20	Blank		
40	-(11)		
41	J (11,1)		
42	K (11,2)		
43	L (11,3)		
44	M (11,4)		
45	N (11,5)		
46	O (11,6)		
47	P (11,7)		
50	Q (11,8)		
51	R (11,9)		
52	(11,0)		
54	* (11,8,4)		

TAPE DECK	STATION NUMBER	DATE YR	DATE MO	DATE DAY	HR	CEILING	VIS.	WIND DIR	WIND SPEED	DRY BULB	WET BULB	DEW PT	REL. HUM.	SEA LEVEL PRESS.	STATION PRESS.	SKY COND.
1 4 X X	X X X X X	X X	X X	X X	X X	i X X X	i X X X	X X	X X X	X X X	X X X	X X X	i X X X	X X X X X	X X X X	i X X X X
001	002	003	004	005	101	102	103	104	105	106	107	108	109	110	111	112

		CLOUDS 1st			CLOUDS 2nd				CLOUDS 3rd				CLOUDS 4th			WEATHER							
a_t	a_o	a_1	t_1	h_1	a_2	t_2	h_2	Σ_2	a_3	t_3	h_3	Σ_3	a_4	t_4	h_4		LIQ RR	FRZN RRR	OBS TO VIS	WIND DIR		R M	HR
X	X	X	X	X X X	X	X	X X X	X	X	X	X X X	X	X	X	X X X	X	X X	X X X	X X	X X	X X X	±	X X
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	201

HR	CEILING	VIS.
X X	i X X X	i X X X
601	602	603

CLOUDS 3rd				CLOUDS 4th			WEATHER							
a_3	t_3	h_3	Σ_3	a_4	t_4	h_4		LIQ RR	FRZN RRR	OBS TO VIS	WIND DIR		R M	IRG
X	X	X X X	X	X	X	X X X	X	X X	X X X	X X	X X	X X X	±	
622	623	624	625	626	627	628	629	630	631	632	633	634	635	

Standard Tape Form - Airways Observations

IDENTIFICATION FIELDS

FIELD 001 - Tape Deck

14XX — 14 = Primary indicator for observations in this standard format.

XX = Arbitrary numbers assigned to each tape deck and usually are indicative of the punched cards from which the tapes were generated.

i.e.: 1440 = Tape deck 1440 generated from card deck 144.
1420 = Tape deck 1420 generated from card deck 142 etc.

FIELD 002 - Station Number

XXXXX — A five digit number used to identify each individual station. These station identifiers are referred to as WBAN numbers and are permanently assigned for each reporting station.

FIELD 003 - Year

XX — Last two digits of the year. The first two digits are an implied 19.

FIELD 004 - Month

XX — Recorded as the numbered month of the year. 01 = Jan., 02 = Feb., --- 12 = December.

FIELD 005 - Day

XX — Recorded as the numbered day of the month, from 01 through 31.

FIELD 101 - Hour

XX — Hour is based on the 24-hour clock and is recorded as 00 through 23. Times are Local Standard Time unless documentation to the contrary is provided.

OBSERVATIONAL FIELDS

FIELD 102 - Ceiling

iXXX	i = identifier:	1,2,3 = method of conversion to hundreds of feet.
	When used in conjunction with XXX = 999:	"-" = clear,scattered conditions or ceiling above 20,000 feet.
		"&" = (12 punch) clear, scattered conditions or ceiling at 10,000 feet or higher.
		Δ = clear, scattered conditions or partial obscuration. Also appears when no special consideration is indicated (1949 to-date).
	XXX =	Ceiling in hundreds of feet, except:
		888 = ceiling formed of cirroform clouds of unknown height.
		999 = unlimited ceiling.
		ΔΔΔ = unknown
		ΔΔ* = invalid

FIELD 103 - Visibility

iXXX i = identifier: always blank

XXX = visibility in coded statute miles or fractions thereof.

VISIBILITY TABLE

Tape Code	Visibility	Tape Code	Visibility
000	0 miles	017	1-1/2 miles
001	1/16	018	1-5/8
002	1/8	019	1-3/4
003	3/16	020	2
CO4	1/4	024	2-1/4
005	5/16	027	2-1/2
006	3/8	030-090	3-9 miles in increments of 1 mile.
008	5/8	100-950	10-95 miles in increments of 5 miles.
009	3/4		
010	1	990	≥ 100
012	1-1/8	999	unlimited
014	1-1/4		
016	1-3/8		

FIELD 104 - Wind Direction

(See also FIELD 133)

XX Direction from which the wind is blowing, based on the 16 point compass.

WIND DIRECTION TABLE

Tape Code	Direction	Degrees
11	North	349-011
12	North-Northeast	012-033
22	Northeast	034-056
32	East-Northeast	057-078
33	East	079-101
34	East-Southeast	102-123
44	Southeast	124-146
54	South-Southeast	147-168
55	South	169-191
56	South-Southwest	192-213
66	Southwest	214-236
76	West-Southwest	237-258
77	West	259-281
78	West-Northwest	282-303
88	Northwest	304-326
18	North-Northwest	327-348
00	Calm	
ΔΔ	Unknown	
Δ*	Invalid	

FIELD 105 - Wind Speed

XXX Wind Speed in knots.

NOTE: In all cases where position 105 (-0) is a numeric code, it is signed plus, as a device for separating Field 105 from 106. This does not apply if the position is coded Δ or *.

XXX	=	000-199 = calm to 199 knots.
ΔΔΔ	=	Unknown
ΔΔ*	=	Invalid

FIELD 106 - Dry Bulb Temperature

XXX Dry bulb temperature in whole degrees fahrenheit.

NOTE: Position 106 (-0) is signed plus for all positive temperatures and minus for all negative temperatures.

ΔΔΔ	=	Unknown
ΔΔ*	=	Invalid

FIELD 107 - Wet Bulb Temperature

XXX Wet bulb temperature in whole degrees fahrenheit.

NOTE: Position 107 (-0) is signed plus for all positive temperatures and minus for all negative temperatures.

ΔΔΔ	=	Unknown
ΔΔ*	=	Invalid

FIELD 108 - Dew Point Temperature

XXX Dew point temperature with respect to water, in whole degrees fahrenheit.

NOTE: Position 108 (-0) is signed plus for all positive temperatures and minus for all negative temperatures.

ΔΔΔ	=	Unknown
ΔΔ*	=	Invalid

FIELD 109 - Relative Humidity

iXXX Relative humidity, with respect to water, expressed in whole percent.

i = Indicator of the method used to convert dewpoint temperatures and relative humidity percentages, with respect to water, when in certain cases these values were originally computed with respect to ice. With the possible exception of research involving detailed psychrometric investigation this indicator has little significance and therefore is not explained further in this manual.

FIELD 110 - Sea Level Pressure

XXXXX Atmospheric pressure reduced to sea level and expressed in whole millibars and tenths.

FIELD 111 - Station Pressure

XXXX Atmospheric pressure at the elevation of the station, expressed in inches to hundredths of mercury.

FIELD 112 - Sky Condition

iXXXX A descriptive symbolic coding of the state of the sky, referring in general to the amount of the celestial dome covered by clouds or obscuring phenomena.

i = Indicator referring to method of coding. Usually this position contains an eleven punch ("-") prior to June 1951 and is blank from June 1951 onward.

XXXX = Sky condition symbols and/or heights of scattered clouds.

SKY CONDITION TABLE

Tape Code	Symbol	Sky Condition
0	○	Clear or less than 1/10 sky cover
1	−⦶	Thin scattered 1/10-5/10 sky cover
2	⦶	Scattered 1/10-5/10 sky cover
3	+⦶	Dark scattered 1/10-5/10 sky cover
4	−⦷	Thin broken 6/10-9/10 sky cover
5	⦷	Broken 6/10-9/10 sky cover
6	+⦷	Dark broken 6/10-9/10 sky cover
7	−⊕	Thin overcast 10/10 sky cover
8	⊕	Overcast 10/10 sky cover
9	+⊕	Dark overcast 10/10 sky cover
-	X	Obscuration
Δ	−X	Partial obscuration

In the combinations listed below, the four-digit field represents the complete sky condition report. The letter "d" represents a digit from 1 through 9, "hh" represents digits used for coding height of scattered layer reported in position 112 (-0), "0" indicates zero, "-" indicates zone -X, and "b" represents blank coding.

Sky Condition Before June 1951

CODE	PUNCH CODE POSSIBILITIES 112(-3)	112 (-2)	112 (-1)	112(-0)	CODE DEFINITION AND REMARKS
0---	0	X	X	X	Obscuration reported alone
0--0	0	X	X	0	Clear Sky (or less than 1/10 sky cover)
0--b	0	X	X	Blank	Thin obscuration reported alone
0--d	0	X	X	4-9	One symbol reported, not scattered, obscuration, or thin obscuration
0hhd	0	00 thru 95 and 99		1-3	One symbol reported, scattered
d---	4-9	X	X	X	Obscuration reported as the lower of two symbols, the higher one not obscured.
d--b	4-9	X	X	Blank	Thin obscuration reported as the lower of two symbols, the higher one not obscured
d--d	4-9	X	X	4-9	Two symbols reported, the lower not being scattered
dhhd	1-9	00 thru 95 and 99		1-3	Two symbols reported, the lower being scattered
----	X	X	X	X	Obscuration reported above obscuration
---b	X	X	X	Blank	Obscuration reported above thin obscuration
---d	X	X	X	4-6	Obscuration reported as the higher of two symbols, the lower one not scattered or obscured
-hhd	X	00 thru 95 and 99		1-3	Obscuration reported as the higher of two symbols, the lower one being scattered

Height of Scattered Clouds

CODE	CODE DEFINITION	REMARKS
00-95	0 to 95 hundred feet	Recorded in hundreds of feet to nearest 100 feet up to 5000 feet, to nearest 500 feet up to 9750 feet. Height in positions 112(-2 and -1) always applies to the scattered layer reported in position 112 (-0).
99	10,000 feet or higher	
--	No lower scattered clouds	
b,b,**	Invalid	
bb	Unknown	

Sky Condition Before June 1951

CODE	PUNCH CODE POSSIBILITIES				CODE DEFINITION AND REMARKS
	112(-3)	112(-2)	112(-1)	112(-0)	
b---	Blank	X	X	X	Thin obscuration reported above obscuration
b--b	Blank	X	X	Blank	Thin obscuration reported above thin obscuration
b--q	Blank	X	X	4-6	Thin obscuration reported as the higher of two symbols, the lower one being not scattered or obscured
bhhd	Blank	00 thru 95 and 99		1-3	Thin obscuration reported as the higher of two symbols, the lower one being scattered
****	*	*	*	*	If any position was punched invalid (*), the entire field was coded ****
bbbb	Blank	Blank	Blank	Blank	Unknown

Reporting and Coding Beginning in June 1951

Four positions were allowed for punching sky condition, which were reproduced to tape as punched. Beginning in June 1951, the concept of sky condition reporting changed. Instead of reporting two symbols, in descending order, with height of scattered cloud , the report now consisted of as many symbols as necessary to describe the sky, in ascending order. As many as four such symbols were punched, the remaining positions being punched zero if fewer than four symbols were reported. If more than four symbols were reported, the first three and the last symbols were punched, unless the symbol specifying the ceiling was thereby excluded; in that case, the first two symbols were punched in the two left positions, the ceiling symbol in the third position, and the highest symbol in the fourth (right) position.

Also at that time, the definition of the symbol "-X" was changed from thin obscuration to partial obscuration and by definition, all obscurations, both full and partial, are surface based. Obscurations above the ground were reported as scattered, broken, or overcast, depending upon their amounts.

The digits from 0 to 9 continued with the same definitions as before.

Sky Condition Beginning June 1951

CODE	PUNCH CODE POSSIBILITIES 112(-3)	112(-2)	112(-1)	112(-0)	CODE DEFINITION AND REMARKS
0000	0	0	0	0	Clear sky (or less than 1/10 covered)
d000	1-9	0	0	0	One symbol reported, but not obscuration or partial obscuration
dd00	1-9	1-9	0	0	Two symbols reported, but not obscuration or partial obscuration
ddd0	1-9	1-9	1-9	0	Three symbols reported, but not obscuration or partial obscuration
dddd	1-9	1-9	1-9	1-9	Four symbols reported, but not obscuration or partial obscuration
-000	X	0	0	0	Obscuration (10/10 hidden by surface based phenomena)
b000	Blank	0	0	0	Partial obscuration and no other symbol
bd00	Blank	1-9	0	0	Partial obscuration and oneother symbol
bdd0	Blank	1-9	1-9	0	Partial obscuration and two other symbols
bddd	Blank	1-9	1-9	1-9	Partial obscuration and three other symbols
b-00	Blank	X	0	0	Partial obscuration below obscuration
d-00	1-7	X	0	0	Obscuration above one layer
dd-0	1-7	1-7	X	0	Obscuration above two layers
ddd-	1-7	1-7	1-7	X	Obscuration above three layers
****	*	*	*	*	If any position was punched invalid (*), the entire field was coded ****
bbbb	Blank	Blank	Blank	Blank	Unknown

FIELDS 113-128 - Clouds

Provision is made in the standard tape form for coding amount, type, and height of as many as four cloud layers plus total amount and total opaque amount, as well as summation amounts at the second and third layers. Twenty-four character positions are set aside for the cloud fields in accordance with the following outline, comprising sixteen fields.

CLOUDS															
		1st			2nd				3rd				4th		
a_t	a_o	a_1	t_1	h_1	a_2	t_2	h_2	Σ_2	a_3	t_3	h_3	Σ_3	a_4	t_4	h_4
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128

Cloud Fields

Clouds are reported in four layers, plus fields for the total amount and the total opaque amount a_t and a_o respectively. Amounts, types and heights are indicated by symbols a, t, and h respectively; the layers are indicated by subscripts. Summation amounts at the second and third layers are indicated by Σ_2 and Σ_3 respectively.

CLOUD AMOUNT TABLE

The same coding system is used for cloud amount, whether applying to total amount, amount for individual layer, summation amount, or opaque amount.

Tape Code	Definition
0	Clear or less than 1/10
1-5	Scattered or 1/10 through 5/10
6-9	Broken or 6/10 through 9/10
"-"	Overcast or > 9/10

CLOUD TYPE TABLE

The same coding system is used for cloud type in all four positions reportable. Note that X-overpunching was used in the punch card codes, resulting in alphabetic codes for some types.

Tape Code	Definition
0	None
1	Fog
2	Stratus
3	Stratocumulus
4	Cumulus
5	Cumulonimbus
6	Altostratus
7	Altocumulus
8	Cirrus
9	Cirrostratus
K	Stratus Fractus/Fractostratus
M	Cumulus Fractus/Fractocumulus
N	Cumulonimbus mamma
O	Nimbostratus
P	Altocumulus castellanus
R	Obscuring phenomenon
"-"	Obscuring phenomenon other than fog

CLOUD HEIGHT TABLE

Tape Code	Definition
000-999	0 to 99,900 feet (in hundreds of feet)
---	None (no clouds for which a height could be reported).
---	Partial obscuration when appearing in field 117 and field 116 is coded "-".
888	Cirroform clouds of unknown height.
ΔΔΔ	Unknown
ΔΔ*	Invalid code

Heights are recorded in hundreds of feet above station level in the following manner:

Nearest 100 ft.	Surface to 5,000 ft.
Nearest 500 ft.	Between 5,000 and 10,000 ft.
Nearest 1,000 ft.	Above 10,000 ft.

FIELD 129 - 132 - Atmospheric Phenomena

Tape Code

Taken as a whole, the 8 positions may show the absence of all listed atmospheric phenomena, if coded as follows:

Position	Code	Code Definition
129 (-0)	0	No thunderstorm, tornado, or squall
130 (-1)	0	No rain, rain showers, or freezing rain
130 (-0)	0	No rain squalls, drizzle, or freezing drizzle
131 (-2)	0	No snow, snow pellets, or ice crystals
131 (-1)	0	No snow showers, snow squalls, or snow grains
131 (-0)	0	No sleet, hail, or small hail
132 (-1)	0	No fog, ice fog, ground fog, blowing dust, or blowing sand
132 (-0)	0	No smoke, haze, dust, blowing snow, or blowing spray

Wind Phenomena --Position 129 (-0)

Tape Code

Code	Symbol	Code Definition
0		No thunderstorm, tornado, squall, or other listed phenomena
1	T	Thunderstorm
2	T+	Heavy thunderstorm
3	TORNADO	Tornado (Report of tornado or waterspout never abbreviated)

Wind Phenomena - - Position 129 (-0) (Cont'd)

Code	Symbol	Code Definition
4	Q-	Light squall
5	Q	Moderate squall
6	Q+	Heavy squall
7		
8		
9		
b		Unknown
*		Invalid

Liquid Precipitation (No. 1) - - Position 130 (-1) Tape Code

Code	Symbol	Code Definition
0		No rain, rain showers, or freezing rain
1	R-	Light rain
2	R	Moderate rain
3	R+	Heavy rain
4	RW-	Light rain showers
5	RW	Moderate rain showers
6	RW+	Heavy rain showers
7	ZR-	Light freezing rain
8	ZR	Moderate freezing rain
9	ZR+	Heavy freezing rain
b		Unknown
*		Invalid

Liquid Precipitation (No. 2) - - Position 130(-0) Tape Code

Code	Symbol	Code Definition
0		No drizzle , freezing drizzle , or rain squalls
1	RQ-	Light rain squalls
2	RQ	Moderate rain squalls
3	RQ+	Heavy rain squalls
4	L-	Light drizzle
5	L	Moderate drizzle
6	L+	Heavy drizzle
7	ZL-	Light freezing drizzle
8	ZL	Moderate freezing drizzle
9	ZL+	Heavy freezing drizzle
b		Unknown
*		Invalid

Frozen Precipitation (No. 1) - - Position 131 (-2) Tape Code

Code	Symbol	Code Definition
0		No snow, snow pellets, or ice crystals
1	S-	Light snow
2	S	Moderate snow
3	S+	Heavy snow
4	SP-	Light snow pellets
5	SP	Moderate snow pellets
6	SP+	Heavy snow pellets
7	IC-	Light ice crystals
8	IC	Moderate ice crystals
9	IC+	Heavy ice crystals
b		Unknown
*		Invalid

Frozen Precipitation (No. 2) - - Position 131 (-1) Tape Code

Code	Symbol	Code Definition
0		No snow showers, snow grains, or snow squalls
1	SW-	Light snow showers
2	SW	Moderate snow showers
3	SW+	Heavy snow showers
4	SQ-	Light snow squall
5	SQ	Moderate snow squall
6	SQ+	Heavy snow squall
7	SG-	Light snow grains
8	SG	Moderate snow grains
9	SG+	Heavy snow grains
b		Unknown
*		Invalid

Frozen Precipitation (No. 3) - - Position 131 (-0) Tape Code

Code	Symbol	Code Definition
0		No sleet, hail or small hail
1	E-,EW-	Light sleet or sleet showers
2	E, EW	Moderate sleet or sleet showers
3	E+,EW+	Heavy sleet or sleet showers
4	A-	Light hail
5	A	Moderate hail
6	A+	Heavy hail
7	AP-	Light small hail
8	AP	Moderate small hail
9	AP+	Heavy small hail
b		Unknown
*		Invalid

Obstructions to Vision (No. 1) - - Position 132 (-1) Tape Code

Code	Symbol	Code Definition
0		None listed below
1	F	Fog
2	IF	Ice Fog
3	GF	Ground Fog
4	BD	Blowing dust
5	BN	Blowing sand
6		
7		
8		
9		
b		Unknown
*		Invalid

Obstructions to Vision (No. 2) - - Position 132 (-0)

Tape Code

Code	Symbol	Code Definition
0		None listed below
1	K	Smoke
2	H	Haze
3	KH	Smoke and haze
4	D	Dust
5	BS	Blowing snow
6	BY	Blowing spray
7		
8		
9		
b		Unknown
*		Invalid

Conversion Procedures for Deck 144

Atmospheric phenomena as punched in Deck 144 are the model for the standard tape form. Therefore, the element was reproduced as punched, with but minor editing. Each card column was reproduced without consideration of the field as a whole, and edited for the valid codes in each, as are shown in the standard tape code. Columns punched with codes other than those described as a valid meteorological report were reproduced to tape as invalid, "*", and blanks were coded "Δ".

FIELD 133

Special Positions

XX

Beginning January 01, 1964, wind directions were reported in tens of degrees, based on a 36 point compass. These values are entered in this field while directions converted to the 16-point scale are entered in field 104. Analogous coding is done for the remaining related fields of wind speed within each logical record.

The conversion procedure used was:

36 Pt.	to	16 Pt.
35-01		11
02-03		12
04-05		22
06-07		32
08-10		33
11-12		34
13-14		44
15-16		54
17-19		55
20-21		56
22-23		66
24-25		76
26-28		77
29-30		78
31-32		88
33-34		18

FIELD 134

Special Positions

XXX

The three positions in this field are not required for data in Deck 144. These positions are blank and may be used for future data requirements.

FIELD 135

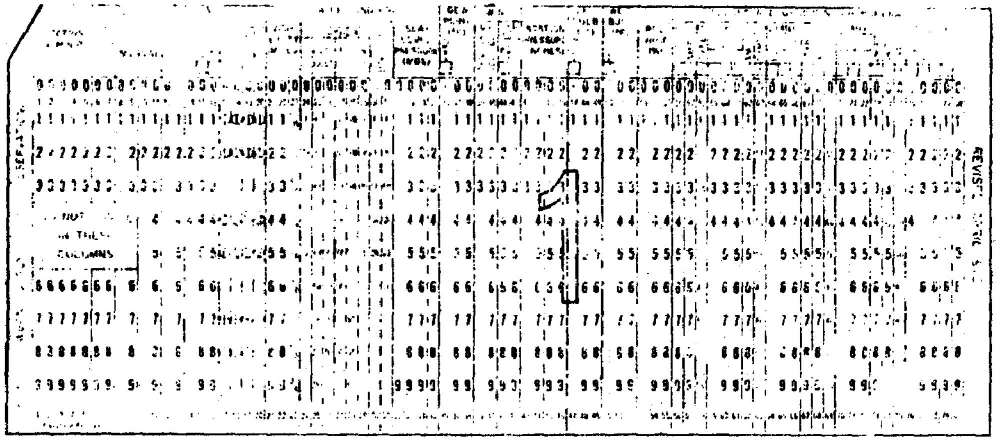
Record Mark

X

The record mark follows the observation to indicate the end of the record.

174

CARD DECK 144 WBAN HOURLY SURFACE OBSERVATIONS



AREA COVERAGE: United States, Caribbean and Pacific Islands and other overseas stations of U. S. Weather Bureau, Air Force and Navy.

PERIOD OF RECORD: Navy Apr 1945- Weather Bureau Jan 1948- Air Force Jan 1949-
Note: Some prior periods are included in this deck. A status of the period of record for each station is maintained at the National Climatic Center, Asheville, North Carolina.

OBSERVATION TIME: Local Standard Time (LST). For information relating to changes in time of observation, refer to SUPPLEMENTARY NOTE A, page 9. Beginning 1 Jan 65, the Weather Bureau reduced the number of hourly observations punched from 24 to 8 per day. These 3-hourly observations correspond to record observations at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 GMT. As a result of special studies, some WB stations may have 24 observations per day punched.

CODES: WBAN and WMO

SOURCE: WBAN Forms 10A, 10B and 10 or similar forms. In addition to WBAN Forms for Weather Bureau, Air Force and Navy, those of FAA and Signal Corps are included. Effective 1 Apr 70, forms redesignated as MF 1-10A, 1-10B and 1-10C. MF indicates Meteorological Form.

MISSING DATA: Blanks in appropriate columns are used to indicate missing data. Identification cards were punched for missing observations at AWS stations unless a whole month's record was missing. Punching of ID cards for AWS stations was phased out from Sep-Dec 1968.

COLUMNS AND ELEMENTS PUNCHED: Columns 1-79 are punched.
Elements punched are: (Index on page 14)

- Ceiling Height
- Sky Condition
  - Clear
  - Scattered
  - Broken
  - Overcast
  - Partial Obscuration
  - Obscuration
- Visibility
- Weather and/or Obstruction to Vision
- Thunderstorm
- Tornado
- Squall
- Rain
- Rain Showers
- Freezing Rain
- Drizzle
- Freezing Drizzle
- Snow
- Snow Pellets
- Ice Crystals
- Snow Showers
- Snow Grains
- *Sleet
- Hail
- *Small Hail
- Fog
- Ice Fog
- Ground Fog
- Blowing Dust
- Blowing Sand
- Smoke and/or Haze
- Dust
- Blowing Snow
- Blowing Spray
- Sea Level Pressure
- Dew Point Temperature
- Wind Direction
- Wind Speed
- Station Pressure
- Dry Bulb Temperature
- Wet Bulb Temperature
- Relative Humidity
- Total Sky Cover
- Amount, Type and Height of Cloud Layers
- Opaque Sky Cover

*Reported as Ice Pellets, effective 1 Apr 70.

ADDITIONAL REMARKS: Card content is generally for recent years. Prior punching or processing procedures are described in "Remarks Column" or in SUPPLEMENTARY NOTES.

Effective 1 Jan 68, the Air Force began the use of the METAR Code at nearly all stations located outside the North American Continent. Observations for these stations are not available on punched cards but on magnetic tape only.

Decks with similar data are listed on page 14.

CORRECTIONS: Any errors detected in this manual should be called to the attention of the Director, National Climatic Center, Environmental Data Service, NOAA; or Chief, Data Processing Division, Environmental Technical Applications Center, USAF. Please give specific instances of error and correct information if available.

175

CARD CONTENT					
COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
21-79	Missing Data	B	Blank	Unknown	Blank indicates unknown or missing data.
1-5	Station Number WBAN		00001-99999	WBAN Number	A five digit number formulated to designate the station. A list of stations with their coordinates, elevation and period of record is maintained at the NCC in Asheville, N. C.
6-7	Year		00-99	Last two digits of year	
8-9	Month		01-12	01 Jan to 12 Dec	
10-11	Day		01-31	Day of month	
12-13	Hour		00-23	LST	For information relating to time of observation changes and reduction of punches from 24 to 8 observations per day, reference SUPPLEMENTARY NOTE A, page 9 and OBSERVATION TIME, page 1.
14-16	Ceiling Height	hhh	000-990	Hundred of feet 0-99,000 feet	Reporting practices are described in SUPPLEMENTARY NOTE B, page 9.
			XXX	Unlimited	
			888	Cirroform ceiling, height unknown	Effective 1 Sep 56. Punching of 888 for Cirroform ceiling, height unknown, was discontinued on 1 Apr 70.
17-20	Sky Condition				Four column field for up to 4 layers. 0 in unused columns.
17	First Sky Cover Layer	○	0	Clear Cloud cover <.05 Columns 18-20 punched 000	Thin sky cover is a designation given any layer for which the ratio of transparency to total sky cover at that level is ½ or more.
18	Second Sky Cover Layer	—⦶	1	Thin scattered	Prior to September 1956 dark scattered, dark broken, and dark overcast were coded 3, 6, and 9, respectively.
19	Third Sky Cover Layer	⦶	2	Scattered Cloud cover .1 thru .5	
20	Fourth Sky Cover Layer	—⦷	4	Thin broken	Reporting practices of sky conditions, etc. are described in more detail in SUPPLEMENTARY NOTE C, pages 9-10.
		⦷	5	Broken Cloud cover .6 thru .9	
		—⊕	7	Thin overcast Cloud cover 1.0	
		⊕	8	Overcast Cloud cover 1.0 Columns 18-20 punched 000	
		-X	Blank	Partial Obscuration Columns 18-20 punched 0-8 0.1 or more but not all sky hidden by surface based layer	
		X	X	Obscuration All of sky hidden by a surface based layer. Columns 18-20 punched 000.	

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
21-23	Visibility	VVV	000-006	0 - 3/8 miles	1/16 mile increments
			006-020	3/8 - 2 miles	1/8 mile increments *
			020-027	2 - 2½ miles	1/4 mile increments
			027-030	2½ - 3 miles	1/2 mile increments
			030-150	3 - 15 miles	1 mile increments
			150-950	15 - 95 miles	5 mile increments
			990	100 miles or more	Refer to Code 3 on page 12. Effective 1 Apr 70, visibilities greater than 7 miles will not be recorded unless a marker is located at a distance greater than 7 miles.
				Visibilities reported other than standard punched for next lower value.	*7/8 was not reported prior to Jul 52; and 1 1/8, 1 3/8, 1 5/8 and 1 7/8 until May 53. 1 1/8, 1 3/8, and 1 5/8 were punched as 1, 1¼, and 1½ until Jan 56. 7/8 and 1 7/8 are punched as 3/4 and 1 3/4.
24-31	Weather and/or Obstruction to Vision				See page 8 for intensity definition Columns 24-31.
24			0	None	
	Thunderstorm	T	1	Thunderstorm	
	Heavy/Severe Thunderstorm	T+	2	Heavy thunderstorm/ Severe thunderstorm	See note, page 8, on thunderstorm intensities. Heavy thunderstorm redefined Severe Thunderstorm 1 Jul 68.
	Tornado Waterspout	Tor	3	Tornado - Land Waterspout - Water	
	Squall	Q	5	Squall	Reported as rain or snow squalls (RQ,SQ) before 1947. Intensity reported prior to 1 Jun 51. Definition is given on page 8.
25	Liquid Precipitation		0	None	
		R-	1	Light rain	
		R	2	Moderate rain	
		R+	3	Heavy rain	
		RW-	4	Light rain showers	
		RW	5	Moderate rain showers	
		RW+	6	Heavy rain showers	
		ZR-	7	Light freezing rain	
		ZR	8	Moderate freezing rain	
		ZR+	9	Heavy freezing rain	
26	Liquid Precipitation		0	None	Codes 1, 2 and 3, light, moderate and heavy rain squalls reported prior to 1949. Drizzle intensity explained in SUPPLEMENTARY NOTE D, page 10.
		L-	4	Light drizzle	
		L	5	Moderate drizzle	
		L+	6	Heavy drizzle	
		ZL-	7	Light freezing drizzle	
		ZL	8	Moderate freezing drizzle	
		ZL+	9	Heavy freezing drizzle	

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
27	Frozen Precipitation		0	None	
		S-	1	Light snow	
		S	2	Moderate snow	
		S+	3	Heavy snow	
		SP-	4	Light snow pellets	
		SP	5	Moderate snow pellets	
		SP+	6	Heavy snow pellets	Code 7, IC - and code 9, IC +; intensity reported prior to 1 Apr 63
		IC	8	Ice crystals	
28	Frozen Precipitation		0	None	
		SW-	1	Light snow showers	
		SW	2	Moderate snow showers	
		SW+	3	Heavy snow showers	Codes 4, 5 and 6, light, moderate and heavy snow squalls reported prior to 1949.
		SG-	7	Light snow grains	
		SG	8	Moderate snow grains	
		SG+	9	Heavy snow grains	
29	Frozen Precipitation		0	None	Prior to 1 Apr 70 Ice Pellets were coded as Sleet (E-, E, E+). On this date Sleet and Small Hail were redefined as Ice Pellets.
		IP-	1	Light Ice Pellets	
		IP	2	Moderate Ice Pellets	Ice Pellet Showers (IPW) are coded as Ice Pellets; Sleet Showers were coded as Sleet.
		IP+	3	Heavy Ice Pellets	
		A	5	Hail	Hail intensities reported prior to 1 Sep 56: Codes 4, 6, 7, and 9, A-, A+, AP- and AP+.
		AP	8	Small Hail	Deleted 1 Apr 70; redefined as Ice Pellets.
30	Obstructions to Vision		0	None	SUPPLEMENTARY NOTE E, Page 10 explains the reporting practices of these elements.
		F	1	Fog	
		IF	2	Ice fog	OBSTRUCTIONS TO VISION are recorded only when the visibility is less than 7 miles.
		GF	3	Ground fog	
		BD	4	Blowing dust	
		BN	5	Blowing sand	
31	Obstructions to vision		0	None	
		K	1	Smoke	
		H	2	Haze	
		KH	3	Smoke and haze	
		D	4	Dust	
		BS	5	Blowing snow	
		BY	6	Blowing spray	Effective 1 Jul 52.

CARD CONTENT					
COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
32-35	Sea Level Pressure	PPPP	0000-9999	Millibars and tenths 0000 = 1000.0 mb 9999 = 999.9 mbs.	Thousands digit not punched. Antarctic stations, see SUPPLEMENTARY NOTE H, page 11. AWS punched 3-hourly only effective 1 Jul 58.
36-38	Dew Point Temperature	$T_dT_dT_d$	000-099 X01-X99	0 to 199 Whole degrees F. -1 to -99 X in Column 36 for negative values.	Before 1949, dew point was computed with respect to ice if temperature was below 32°F. Beginning Jan 49, it was computed with respect to water regardless of temperature.
39-40	Wind Direction	dd	00-36	True direction, in tens of degrees, from which wind is blowing (Code 1, page 12 eff. 1 Jan 64)	Prior to 1964, wind directions were reported according to Code 2, page 12. See SUPPLEMENTARY NOTE H, page 11, for punching procedures at Admundsen-Scott Station, Antarctica.
41-42	Wind Speed	ff	00-99 X/	Knots X overpunch in Column 41 indicates 100 or more knots	Prior to Jan 55 in miles per hour at AF and WB stations; in knots at most Navy stations.
43-46	Station Pressure	PPPP	1000-3999	10.00 to 39.99 inches to Hundreds H_g.	Station pressure is the pressure at the assigned station elevation. AWS punched 3-hourly only effective 1 Jul 58, 6-hourly effective 1 Jan 64, and 3-hourly eff. on receipt of order dated 1 Jun 65.
47-49	Dry Bulb Temperature	TTT	000-199	Whole degrees F. 0 to 199	
			X01-X99 $\frac{X}{100}$ - $\frac{X}{199}$	-1 to -99 -100 to -199	Column 47 punched X or X overpunch for values below zero.
50-52	Wet Bulb Temperature		000-199 X01-X99	Whole degrees F. 0 to 199 -1 to -99	Column 50 punched X for minus. AWS began phasing out punching wet bulb data 1 Jul 58. WB and Navy discontinued punching wet bulb data 1 Jan 65. See SUPPLEMENTARY NOTE F, page 10 for hygrothermometer input. For methods of computation of wet bulb temperature and relative humidity, refer to page 13.
53-55	Relative Humidity	RH	000-100	0 to 100 whole percent Cols.	AWS discontinued punching Columns 53-55 1 Jul 5[illegible]. WB discontinued punching Columns 53-55 1 Jan 65. NWS, effective 1 Apr 70, RH is punched only when entered on Form 1-10B; entry of RH on form is optional. Relative humidity computations respect to ice, etc. reporting practices explained in SUPPLEMENTARY NOTE F, page 10.
56-79	Clouds and Obscuring Phenomena				See SUPPLEMENTARY NOTE G, page 11 for information on cloud layers.
56	Total Sky Cover		0-9 X	Tenths 10 Tenths	

179

CARD CONTENT

COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
57	Amount of Lowest Layer		0-9 X	Tenths 10 Tenths	Weather Bureau stations reported detailed cloud observations(Cols. 56-78) only every 3 hours, based upon the time of synoptic observations, until June 1951 and Jan 1965-present. Only Col. 56, Total Sky Cover, was punched for the intermediate observations. Beginning Jun 51, complete cloud observations were reported and punched (Cols.56-79) for every record obs. as was the practice with Air Force and Navy stations. In all cards of FAA(CAA) stations, Cols. 57-78 are not punched. Note: Air Force stations coverage beginning 1 Jul 58, Cols. 57-79 were reduced from hourly to 3-hourly punching. Except for Korean and down range stations, punching of Cols. 58-61 and 63-79 was discontinued on 1 Jan 64 and Cols. 57 and 62 on 1 Jul 65.
58	Type of Cloud Lowest Layer	 F St Sc Cu Cb As Ac Ci Cs	0 1 2 3 4 5 6 7 8 9	None/clear Fog Stratus Stratocumulus Cumulus Cumulonimbus Altostratus Altocumulus Cirrus Cirrostratus	
		Stfra	X 2	Stratus Fractus	Sf was contraction prior to 1 Apr 70. Fs (Fractostratus) prior to 1 May 61.
		Cufra	X 4	Cumulus Fractus	Cf was contraction prior to 1 Apr 70. Fc (Fractocumulus prior to 1 May 61.
		Cbmam Ns	X 5 X 6	Cumulonimbus mamma Nimbostratus	Cm was contraction prior to 1 Apr 70.
		Accas	X 7	Altocumulus castellanus	Acc was contraction prior to 1 Apr 70.
		Cc	X 9 X	Cirrocumulus Obscuring phenomenon other than fog	
59-61	Height of Lowest Layer		000-990	Hundreds of feet 0 to 99,000 ft.	
			888	Unknown height of a cirroform layer	Effective 1 Sep 56 through 31 Mar 70.
			XXX	Unlimited vertical visibility	Clear, no clouds reported or surface based partial obscuring phenomena (first layer only).
62	Amount of Second Layer		0-9 X	Tenths 10 tenths	
63	Type of Second Layer		0-9 X/	See Column 58	
64-66	Height of Second Layer			See Columns 59-61	

CARD CONTENT					
COLUMN	ITEM OR ELEMENT	SYMBOLIC LETTER	CARD CODE	CARD CODE DEFINITION	REMARKS
67	Summation Amount at Second Layer		0-9 X	Tenths 10 tenths	
68	Amount of Third Layer		0-9 X	Tenths 10 tenths	
69	Type of Third Layer		0-9 X/	See Column 58	
70-72	Height of Third Layer			See Columns 59-61	
73	Summation Amount at Third Layer		0-9 X	Tenths 10 tenths	
74	Amount of Fourth Layer		0-9 X	Tenths 10 tenths	
75	Type of Fourth Layer		0-9 X/	See Column 58	
76-78	Height of Fourth Layer			See Columns 59-61	
79	Total Opaque Sky Cover		0-9 X	Tenths 10 tenths	Effective Jun 51. 1 Jun 62 - Opaque Sky Cover was re-defined: Those portions of cloud layers or obscurations which hide the sky and/or higher clouds. Translucent sky cover which hides the sky but through which the sun and moon (not stars) may be dimly visible will be considered as opaque. 1 Apr 70 - Opaque Sky Cover: The amount (to the nearest tenth) of cloud layers or obscuring phenomena (aloft or surface-based) that completely hides all or a portion of the sky and/or higher clouds that may be present.
80	Not used				

180

181

METHODS FOR DETERMINING INTENSITY OF WEATHER

THUNDERSTORM

1945 -

THUNDERSTORM - Characterized by occasional or fairly frequent flashes of lightning; weak to loud peals of thunder; rainfall, if any, light or moderate, and rarely heavy; hail, if any, light or moderate; wind not in excess of 40 miles per hour or 35 knots; and no large temperature drop with passage of the storm.

Note: Wind speed changed to knots on 1 Jan 1955.

1 Jul 68 - Redefined. A thunderstorm is a local storm produced by cumulonimbus cloud, and is always accompanied by lightning and thunder, usually with strong gusts of wind, and sometimes with hail. The intensity of a thunderstorm is based on the following characteristics, observed within the previous 15 minutes: Wind gusts less than 50 knots and hail, if any, less than 3/4 inch in diameter.

HEAVY THUNDERSTORM - Characterized by nearly incessant, sharp lightning; loud peals of almost continuous thunder; heavy rain showers; hail of any intensity; wind in excess of 40 mph (35 knots) as the storm passes overhead; and a rapid drop of temperature, as much as 20°F in 5 minutes with the passage of the storm.

1 Jul 68 - Redefined as SEVERE THUNDERSTORM. The intensity is based on the following characteristics, observed within the previous 15 minutes: Wind gusts of 50 knots or greater or hail, 3/4 inch or greater.

GUSTS OF WIND

1945 - 1951

*RAIN SQUALLS,*SNOW SQUALLS, SQUALLS

Light - Gusts of 24 mph or less (21 knots)
Moderate - Gusts of 25-39 mph (22-34 knots)
Heavy - Gusts of 40 mph or more (35 knots)

*Squalls reported separately after 1948.
Intensity of squalls discontinued 1 Jun 51

GUSTS OF WIND (CONTINUED)

1 Jun 51 - A SQUALL is a strong wind that increases suddenly in speed, maintains a peak speed of 19 mph (16 knots) or more over a period of two or more minutes, and decreases in speed; similar fluctuations will occur at succeeding intervals. (reported if occurred within 15 minutes of time of observation)

1 Apr 70 - A SQUALL is a sudden increase of wind speed by at least 16 knots and rising to 22 kts or more and lasting for at least one minute. (reported if occurred within 10 min. of obs)

RATE OF FALL

1945 -

RAIN, RAIN SHOWERS, FREEZING RAIN

Also DRIZZLE (1945-1946), SNOW, SNOW SHOWERS, SNOW PELLETS, when accompanied by other precipitation or obstructions to vision.

Light - Trace to 0.10 inch per hour; maximum 0.01 inch in six minutes.
Moderate - 0.11 to 0.30 inch per hour; more than 0.01 to 0.03 inch in six min.
Heavy - More than 0.30 inch per hour; more than 0.03 inch in six minutes.

When measurement of rate of fall was impracticable, the intensity was determined visually.

Jan 47-May 51, whether alone or not, and after May 51, when accompanied by other precipitation or obstructions to vision.

DRIZZLE, FREEZING DRIZZLE

Light - Trace to 0.01 inch per hour
Moderate - More than 0.01 to 0.02 inch/hour
Heavy - More than 0.02 inch per hour.

RATE OF FALL AND ACCUMULATION

1946 -

HAIL,*SMALL HAIL,*SLEET,*ICE PELLETS

1 Apr 70 -*Sleet and*Small Hail redefined as *Ice Pellets

Light - Few pellets falling with no appreciable accumulation.
Moderate - Slow accumulation.
Heavy - Rapid accumulation.

VISIBILITY PRECIPITATION

SNOW, SNOW SHOWERS, SNOW PELLETS, DRIZZLE, FREEZING DRIZZLE, SNOW GRAINS
(when occurring alone)

Light - Visibility 5/8 mile or greater
Moderate - Visibility 5/16 - 1/2 mile, inclusive
Heavy - Visibility 1/4 mile or less

1945 - For all forms of snow, when occurring alone, intensity was determined by visibility, as shown above. Intensity of drizzle, when occurring alone, was determined by visibility in 1945-1946 and after May 1951 -

ICE CRYSTALS with an intensity of greater than "very light" will be rarely observed. Above criteria were referred to if needed.

1 Apr 63 - Reporting of intensities of ICE CRYSTALS was discontinued.

HAZE

1945 -

HAZE - Visibility 6 miles or less, but rarely below 3 miles.
DAMP HAZE - Visibility 6 miles or less, but rarely as low as 1 1/4 miles. Not reported after 1948.

NOTE: The intensity "Very light" (less than "Light") was not used before June 1951. It is punched as "Light" for all elements.

SUPPLEMENTARY NOTE A: OBSERVATION TIME Columns 12-13
The time punched is that of the record observations, taken during the last ten minutes of the hour punched. Prior to Jun 57 the last ten minutes - on the half hour. Minutes are disregarded in punching. All "War Times" and "Standard Meridian Times" were converted to Local Standard Time before punching. For Air Force stations in the United States, the times were punched in accordance with the established time zones. Time entries for Air Force stations outside the United States were edited prior to punching and where necessary converted to the Local Standard Time of the nearest meridian evenly divisible by 15 degrees.

SUPPLEMENTARY NOTE B: CEILING HEIGHT Columns 14-16
Ceiling was recorded in hundreds of feet above the ground to nearest 100 feet up to 5000 feet, to nearest 500 feet up to 10,000 feet, to nearest 1000 feet above that. Before 1949, Air Force stations recorded ceilings up to and including 20,000 feet, above which point the ceiling was classified as unlimited; Weather Bureau and Navy stations recorded ceiling only up to and including 9,500 feet, above which point the ceiling was considered unlimited. Beginning in 1949, ceiling was re-defined to include the vertical visibility into obscuring phenomena not classified as thin, that, in summation with all lower layers, cover 6/10 or more of the sky. Also at that time all limits to height of ceiling were removed, so that unlimited ceiling became simply less than 6/10 sky cover, not including thin obscuration. Then, beginning 1 Jun 51, ceiling heights were no longer established solely on the basis of coverage. The ascribing of ceilings to thin broken or overcast layers was eliminated. A layer became classified as "thin" if the ratio of transparency to total coverage at that level is ½ or more.

SUPPLEMENTARY NOTE C: SKY CONDITIONS Columns 17-20
Jan 1945-Dec 1948: If there is only one cloud symbol, except for low scattered and obscured, Column 17 was punched with appropriate code, Cols. 18-19 with "X" and Col. 20 was left blank. If clouds were high (above 9,500 ft.) Col. 17 was X overpunched. If clouds were low scattered, "0" was punched in Col.17, height in Cols. 18-19, and code in Col. 20. Cols. 18-19 were left blank if height was missing. When two cloud symbols were reported, the higher cloud was punched in Col.17 and the lower in Col. 20. In 1946, obscured

(continued on next page)

TABLE OF SKY CONDITIONS

The table below shows the punching practices in Columns 17-20 for the periods Jan 45 through Dec 48, and Jan 49 through May 51.

SKY CONDITION	REMARKS	1945-1948 17	18	19	20	1949-5/51 17	18	19	20
Clear ○		0	X	X	0	0	X	X	0
Low Scattered ⦶ at 2500 ft		0	2	5	2	0	2	5	2
High Scattered ⦶ /(over 9500 ft)		X 2	X	X		0	9	9	2
Hi Sctd Lwr Sctd ⦶/95 ⦶ at 9500 ft		X 2	9	5	2	2	9	5	2
Broken at 12000 ft 12 ⦷		5	X	X		0	X	X	5
High Brkn Lwr Brkn ⦷/⦷ Ceiling 5000 ft		X 5	X	X	5	5	X	X	5
High Ovc Lwr Sctd at 2500 ft ⊕/⦶		X 8	2	5	2	8	2	5	2
High Ovc Lwr Brkn ⊕/⦷		X 8	X	X	5	8	X	X	5
Overcast ⊕		8	X	X		0	X	X	8
Ovc Sctd at 3000 ft ⊕ 30 ⦶		8	3	0	2	8	3	0	2
Ovc Brkn at 2500 ft ⊕ 25 ⦷		8	X	X	5	8	X	X	5
Obscured X		0	X	X	X	0	X	X	X
Thin Obscured -X		0	X	X		0	X	X	

SUPPLEMENTARY NOTE C (Continued)

sky was reported only when heavy obstructions to vision and/or heavy precipitation reduced the ceiling to zero and/or the visibility to less than ¼ mile; and when the visibility was ¼ mile or more, a sky symbol was always reported. Effective 1 Jan 47, the symbol "X", for obscured sky, received the same latitude of usage as all other symbols. "X" then represented sky cover of 6/10 or more, obscured by precipitation or obstructions to vision either alone or in combination with lower clouds, and irrespective of higher clouds and ceiling and/or visibility limits. In August 1947, the use of "-X", for thin obscured, was authorized. In 1946 if a layer of scattered clouds above a layer of broken clouds was clearly observable, it was so reported. In 1947 and 1948, symbols corresponding to higher cloud layers indicated the amount of sky covered not only by their respective layers, but by all layers below them. In all years, the presence of few clouds (less than 1/10) was recorded in Remarks.

Jan 49 through May 51: When only one sky symbol was reported it was punched in Col. 20. The use of an "X" overpunch for high (/) layers was discontinued. (/ indicates over 9500 ft). The height of scattered clouds above 9500 ft was punched in Cols. 18-19 as 99.

183

Effective 1 Jun 51, the reporting of height of low scattered was discontinued, and provision was made to report any number of sky condition symbols, with the height of each. The ceiling layer was not reported separately as before, but was identified by the entry of a ceiling classification letter immediately preceding the height. Sky condition symbols were reported in ascending order of height, and were punched in that order, unless more than four were reported. In that case, the last (highest) symbol was punched in Column 20, and the first three in Columns 17-19, unless the ceiling symbol was thereby excluded. In the latter case, the first two symbols were punched in Columns 17-18, the ceiling symbol in Column 19, and the highest symbol in Column 20. No symbols were reported in Remarks, as was the practice before June 1951.

Sky condition symbols were also re-defined so that obscuring phenomena aloft and clouds were reported in the same manner (i.e., obscuring phenomena aloft were reported by O, O, and O, rather than X and -X). X and -X were used only to indicate the amount of sky hidden by surface-based phenomena. -X was re-defined as partial obscuration (1/10 to less than 10/10 sky hidden). The symbols X and -X unlike O, O, and O, were defined by the amount of the sky hidden by surface-based phenomena, and -X did not indicate the amount of sky covered. The meaning of "thin" was re-defined. If the total opaque cover created by any layer in combination with lower layers was ½ or less of the summation total cover at that level, the layer was classified as thin. Note that the minus sign, when applied to O, O, or O means "thin"; when applied to X, means "partial".

SUPPLEMENTARY NOTE D: INTENSITY OF DRIZZLE Column 26

In 1946, intensity determined by visibility (as for smoke) only if drizzle occurred alone. When drizzle was accompanied by other forms of precipitation and/or obstructions to vision, its intensity was determined by rate of fall. In 1947, visibility limitations were dropped, and intensity was determined by rate of fall, even though drizzle occurred alone. In June 1951, previous visibility limits were re-instituted. Intensity of freezing drizzle determined in same manner as for drizzle. See page 8 for limits of intensities.

SUPPLEMENTARY NOTE E: OBSTRUCTIONS TO VISION Columns 30-31

Intensity of light, moderate, or heavy were assigned to obstructions to vision, through 1946. Effective Jan 47, the reporting and punching of all intensities of obstructions to vision were discontinued. Prior to 1 Jan 49, the distinction between F and GF was arbitrary, but beginning with that date an objective distinction was established. If the sky was not hidden above an angle of 33° from horizontal (less than 0.6 hidden), the fog was reported as ground fog (GF). Effective 1 Apr 70, Fog (F)-Ground Fog (GF): This hydrometeor is reported as F when it hides more than half (0.5-1.0) of the sky or extends upward into existing cloud layers. Otherwise it is reported as GF.

SUPPLEMENTARY NOTE F: WET BULB TEMP. & RH Columns 50-55

From Aug 60 - Dec 64 at WB stations with a hygrothermometer, wet-bulb temp. was computed and punched at NCC when instrument was operational above -35°F; when non-operational or -35°F and lower, the wet-bulb temp. was punched at the station from values obtained from standby equipment. At stations not equipped with a hygrothermometer, the wet bulb temperature is considered to be the same as the dry bulb temperature whenever the dry bulb temperature is below -35°F. The same value is entered in parenthesis on the WBAN with dew point being computed in

184

SUPPLEMENTARY NOTE F (Continued)

respect to water and this value punched into WBAN Card. The relative humidity would then be computed by machine, same as for stations equipped with a hygrothermometer.

Prior to Jan 49, relative humidity computed with respect to ice if the dry bulb temperature was less than 32°F. Beginning Jan 49, computed with respect to water, regardless of temperature. Relative humidity machine calculated from 1 Aug 60. RH was not punched for FAA (CAA) stations except in special cases.

SUPPLEMENTARY NOTE G: CLOUD LAYERS Columns 56-79

Provisions are made for punching as many as four layers of clouds and/or obscuring phenomena existing at one time. If more than four layers existed, the data for levels above the fourth were entered in the Remarks portion of WBAN 10B, and were not punched. Their presence is indicated by the entry for total sky cover. Layers were punched in ascending order of elevation. All fields above a layer which prevented observation were left blank. If two or more types of clouds were observed at the same height, only the predominating type was punched, their amounts being combined. For each layer, the amount, type, and height were punched, and for the second and third layer, the summation amount at the level involved was punched, reflecting the total amount of sky covered by that layer and those below it. The summation total is not necessarily the sum of the individual layers.

In addition to the total sky cover, provision was made in Jun 51 for recording and punching the total amount of opaque sky cover, which is the amount of sky hidden by clouds or obscuring phenomena, as distinguished from the total amount of sky cover.

The height of the layers of clouds or obscuring phenomena aloft was recorded in hundreds of feet, and for fully obscuring phenomena based on the ground, the vertical visibility into it was recorded, with no prescribed limit. All heights were recorded to the nearest 100 feet from the surface to 5,000 feet; to the nearest 500 feet between 5,000 and 10,000 feet; and to the nearest 1,000 feet above 10,000 feet. For obscuring phenomena prescribed as "thin", a condition reportable from Aug 47 through May 51, the height of the base was punched, and in the case of thin fog, was always zero. Before Jan 47, obscuration was not reportable as a cloud type.

SUPPLEMENTARY NOTE G (Cont.) Columns 56-79

Some Weather Bureau and Navy cards in this deck were punched from the old type of reporting form (the WBAN 10 with which deck 142 is aligned) and in which five cloud layers were reported with no summation totals. In these cases, the summation total columns were left blank, and the five layers, if reported, were condensed into four.

SUPPLEMENTARY NOTE H: ANTARCTICA STATION NOTES Columns 32-35, 39-40

I. ADMUNDSEN-SCOTT STATION:

1. Wind Direction on all cards was punched according to the following system:

   A. A wind from 0° longitude was punched as N or 360.
   B. A wind from 90° east longitude was punched as E or 090.
   C. A wind from 180° longitude was punched S or 180.
   D. A wind from 90° west longitude was punched W or 270.

2. In place of sea level pressure (Column 32-35) the height of the 700 mb surface in whole meters was punched. This applies to the period 1 Dec 57 through Jan 66. Station pressure in millibars and tenths punched beginning Feb 66.

II. BYRD STATION, ANTARCTICA

1. In place of sea-level pressure (Columns 32-35) the height of the 850 mb surface was punched in whole meters through Jan 66. Station pressure in millibars and tenths punched beginning Feb 66.

III. PLATEAU STATION, ANTARCTICA 12/65-12/68

1. In place of sea-level pressure (Columns 32-35) the height of the 700 mb surface was punched in whole meters through Jan 66. Station pressure in millibars and tenths punched beginning Feb 66.

CODE TABLES

When coding a meteorological report, symbolic letters are replaced by figures, which specify the value or the state of the corresponding element. In some cases, the specification of the symbolic letter (or group of letters) is sufficient to permit a direct transcription into figures (e.g., GG or PPP). In other cases, these figures are obtained by means of a special code table (or code, in short) for each element.

The codes elaborated to this end, as far as they are in world-wide use, are called international meteorological code tables. These same codes are used inversely for decoding observations and thus making available the information contained in them.

Besides the specifications given by the code tables in world-wide use, other sets of code tables are established by the WMO for regional use. Further arbitrary codes have been made necessary by the use of data in card decks which were never encoded into WMO forms.

Only codes pertinent to this card deck are included in the present manual. They appear in the order in which the elements were introduced in the description of the card content. They are numbered consecutively, and if applicable, the corresponding WMO code numbers are shown.

Code 1

(1949 WMO Code 23)
(1960 WMO Code 0877)

dd - True direction, in tens of degrees, from which wind is blowing (or will blow)

Code figure		Code figure	
00	Calm	19	185° - 194°
01	5° - 14°	20	195° - 204°
02	15° - 24°	21	205° - 214°
03	25° - 34°	22	215° - 224°
04	35° - 44°	23	225° - 234°
05	45° - 54°	24	235° - 244°
06	55° - 64°	25	245° - 254°
07	65° - 74°	26	255° - 264°
08	75° - 84°	27	265° - 274°
09	85° - 94°	28	275° - 284°
10	95° - 104°	29	285° - 294°
11	105° - 114°	30	295° - 304°
12	115° - 124°	31	305° - 314°
13	125° - 134°	32	315° - 324°
14	135° - 144°	33	325° - 334°
15	145° - 154°	34	335° - 344°
16	155° - 164°	35	345° - 354°
17	165° - 174°	36	355° - 4°
18	175° - 184°		

Code 2

dd - Wind Direction

Code Figure			
00	C	Calm	
11	↓↓	North	349° - 11°
12	↓↙	North Northeast	12° - 33°
18	↓↘	North Northwest	327° - 348°
22	↙↙	Northeast	34° - 56°
32	←↙	East Northeast	57° - 78°
33	←←	East	79° - 101°
34	←↖	East Southeast	102° - 123°
44	↖↖	Southeast	124° - 146°
54	↑↖	South Southeast	147° - 168°
55	↑↑	South	169° - 191°
56	↑↗	South Southwest	192° - 213°
66	↗↗	Southwest	214° - 236°
76	→↗	West Southwest	237° - 258°
77	→→	West	259° - 281°
78	→↘	West Northwest	282° - 303°
88	↘↘	Northwest	304° - 326°

Code 3

VVV - Visibility (Statute Miles)

Code	Miles	Code	Miles
000	0	012	1-1/8
001	1/16	014	1-1/4
002	1/8	016	1-3/8
003	3/16	017	1-1/2
004	1/4	018	1-5/8
005	5/16	019	1-3/4
006	3/8	020	2
007	1/2	024	2-1/4
008	5/8	027	2-1/2
009	3/4	030-150	3-15 *1 mile
010	1	150-950	15-95 *5 mile
		990	100 or more

*increments

DECK 144 WBAN HOURLY SURFACE OBSERVATIONS

AREA COVERAGE

United States, Caribbean and Pacific Islands and other overseas stations of U.S. Weather Bureau, Air Force and Navy. Also included are FAA/CAA stations; stations in Canada, Germany, Korea and a group of other foreign operated stations.

PERIOD OF RECORD

Weather Bureau: 1948 - Air Force: January 1949 - Navy: April 1945 - Note: Some prior periods were included in this deck. A status of the period of record for each station is maintained at the National Weather Records Center, Asheville, North Carolina.

OBSERVATION TIME

On the hour or a few minutes before hour LST (Local Standard Time). Prior to May 1957 observations were begun at 20 minutes after hour. Beginning 1 Jan 1965, Weather Bureau ~~and Naval Weather Service~~ reduced punching of hourly observations to record observations corresponding to 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 GMT. As a result of special studies some stations may have 24 observations per day punched for certain periods.

CODES

WBAN and WMO

SOURCE

WBAN Forms 10, 10A, 10B or similiar forms. WBAN stands for Weather Bureau, Air Force and Navy.

MISSING DATA INDICATION

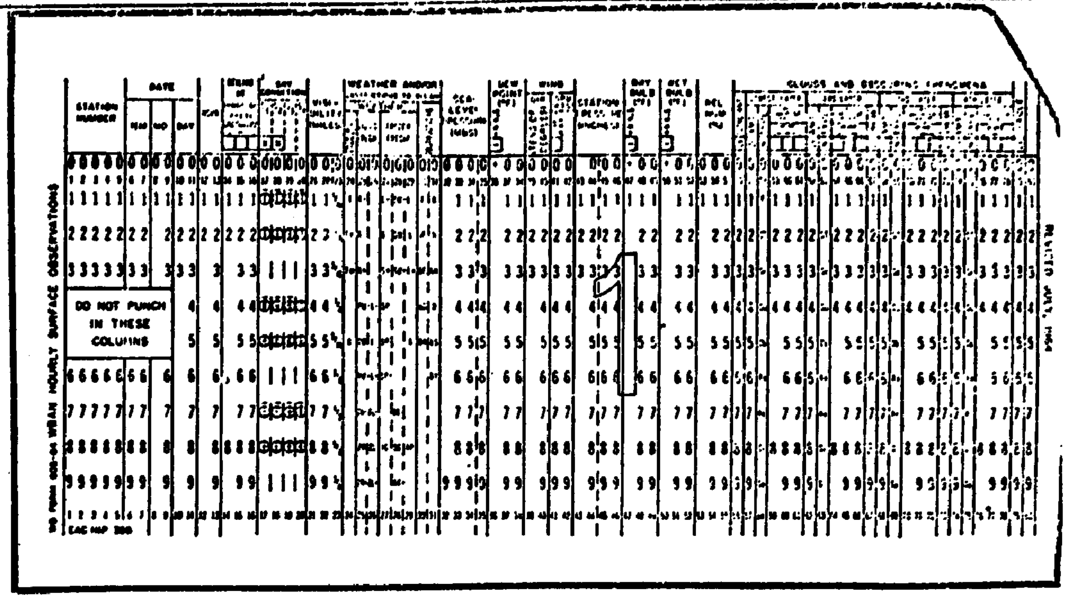
Blanks in appropriate columns are used to indicate missing data. Identification cards were punched for missing observations for AWS stations unless a whole month was missing. Columns 1-13 of the identification card are punched and the remainder of the columns are left blank. Identification cards are not punched for Weather Bureau and Navy stations and for AWS stations when a month or more of record was missing.

COLUMNS AND ELEMENTS PUNCHED

Columns 1-79 were punched for station and observation data. Column 80 was sometimes used for other purposes.

Elements punched are:

Ceiling Height	Drizzle	Dust
Sky Condition	Freezing Drizzle	Blowing Snow
Clear	Snow	Blowing Spray
Scattered	Snow Pellets	Sea Level Pressure
Broken	Ice Crystals	Dew Point Temperature
Overcast	Snow Showers	Wind Direction
Partial Obscuration	Snow Grains	Wind Speed
Obscuration	Sleet	Station Pressure
Visibility	Hail	Dry Bulb Temperature
Weather and/or Obstruction to Vision	Small Hail	Wet Bulb Temperature
Thunderstorm	Fog	Relative Humidity
Tornado	Ice Fog	Total Sky Cover
Squall	Ground Fog	Amount, Type and Height of Cloud Layers
Rain	Blowing Dust	Opaque Sky Cover
Rain Showers	Blowing Sand	
Freezing Rain	Smoke	
	Haze	



ADDITIONAL REMARKS

Card content is generally for recent years. Prior punching or processing procedures are described in "Remarks Column" or in Supplementary Notes. References to these notes are made in the remarks for the appropriate column.

Similar data are in the following card decks:

Deck 141	1937-1945	WBAN Hourly Surface Observations
Deck 142	1946-1948	WBAN Hourly Surface Observations
Deck 132	1946-1951	Canadian Hourly Surface Observations
Deck 134	1951-1953	Canadian Hourly Surface Observations
Deck 135	1950-	Canadian Hourly Surface Observations
Deck 157	1950-1959	Turkish Hourly Surface Observations
Deck 158	1955-	German Hourly Surface Observations (GFMO)
Deck 159	1954-	Korean Hourly Surface Observations (ROK)

CORRECTIONS

Any errors detected in this manual should be called to the attention of Director, National Weather Records Center, EDS, Environmental Science Services Administration, or Chief, Data Processing Division, Environmental Technical Application Center, USAF. Please give specific instances of error, and correct information if available.

CARD CONTENT

Column	Item or Element	Symbolic Letter	Card Code	Card Code Definition	Remarks
16; 21-79	Missing Data	B	Blank X/	Unknown X overpunch	Blank indicates unknown or missing data except for cols. 17-20.
1-5	Station Number WBAN		00001-99999	WBAN Number	A five digit number formulated to designate the station. A list of stations with their coordinates, elevation and period of record is maintained at the NWRC in Asheville, N. C.
6-7	Year		00-99	Last two digits of year	
8-9	Month		01-12	01 Jan to 12 Dec	
10-11	Day		01-31	Day of Month	
12-13	Hour		00-23	Nearest hour, local standard time.	Beginning Jan. 1, 1965 the number of observations punched for Weather Bureau and Navy stations was reduced from a maximum of 24 to a maximum of 8 per day for hourly record observations corresponding to 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 GMT. Obs. time on the hour LST or few minutes before. Prior to May 1957 obs. were begun about 20 minutes past the hour. See Supplementary Note A, page 7
14-16	Ceiling Height	hhh	000-990	Hundred of feet 0-99,000 feet	See Supplementary Note B, page 7
			XXX	Unlimited	
			888	Cirroform ceiling height unknown	Effective Sept. 1, 1956
17-20	Sky Condition				Four column field for up to 4 cloud layers. 0 in unused columns.
17	First Layer	○	0	Clear	<0.05 cloud cover Cols. 18-20 punched 000
		−⦶ ⦶	1 2	Thin scattered Scattered	0.1-0.5 sky cover at and below level of layer aloft. July 1, 1963. Thin Sky Cover redefined: A term applied to a layer when the ratio (of summation amounts at and below the level of the layer) of transparent to total sky cover is 1/2 or more. See Supplementary Note C, page 7
		−◑ ◑	4 5	Thin broken Broken	0.6-0.9 sky cover at and below level of layer aloft
		−⊕	7	Thin overcast	1.0 sky cover at and below level of layer aloft
		⊕	8	Overcast	Cols. 18-20 punched 000.
		−X	Blank	Partial Obscuration	Cols. 18-20 punched 0-8. 0.1 or more but not all sky hidden by surface based layer.
		X	X	Obscuration	All of sky hidden by a surface based layer. Cols. 18-20 punched 000.
18	Second Layer			See Column 17	Note: Prior to 1 Sept 1956 Code 3 Dark Scattered, Code 6 Dark Broken and Code 9 Dark Overcast were used. See Supplementary Note C, page 7
19	Third Layer			See Column 17	
20	Fourth Layer			See Column 17	
21-23	Visibility	VVV	000-004 004-020 020-025 025-030 030-150 150-950 990	0 - 3/8 miles 3/8 - 2 miles 2 - 2 1/2 miles 2 1/2 - 3 miles 3 - 15 miles 15 - 95 miles 100 miles or more	1/16 mile increments 1/8 mile increments 1/4 mile increments 1/2 mile increments 1 mile increments 5 mile increments 7/8 and 1 7/8 punched as 3/4 and 1 3/4. Prior to 1 July 1952 7/8 and prior to 1 May 1953 1 1/8, 1 3/8, 1 5/8 and 1 7/8 not reported. Visibilities reported other than standard punched for next lower value.
24-31	Weather and/or obstructions to vision				See appendix page [illegible] for intensity definition cols. 24-31.
24			0	None	
	Thunderstorm	T	1	Thunderstorm	
	Heavy Thunderstorm	T+	2	Heavy Thunderstorm	
	Tornado Waterspout	Tor	3	Tornado - Land Waterspout - Water	
	Squall		5	Squall See appendix P	Reported as rain or snow squalls (RW, SW) before 1949. Intensity reported prior to 1 June 1951
25	Liquid Precipitation		0	None	
		R-	1	Light rain	
		R	2	Moderate rain	
		R+	3	Heavy rain	

188

CARD CONTENT

Column	Item or Element	Symbolic Letter	Card Code	Card Code Definition	Remarks
25	Liquid Precipitation (cont'd)	RW- RW RW+ ZR- ZR ZR+	4 5 6 7 8 9	Light rain showers Mod. rain showers Heavy raid showers Light freezing rain Mod. freezing rain Heavy freezing rain	
26	Liquid Precipitation	 L- L L+ ZL- ZL ZL+	0 4 5 6 7 8 9	None Light drizzle Mod. drizzle Heavy drizzle Lt. freezing drizzle Mod. freezing drizzle Heavy freezing drizzle	Codes 1, 2 and 3, light, moderate and heavy rain equalls reported prior to 1949. See Supplementary Note D page 7
27	Frozen Precipitation	 S- S S+ SP- SP SP+ IC	0 1 2 3 4 5 6 8	None Light snow Moderate snow Heavy snow Light snow pellets Mod. snow pellets Heavy snow pellets Ice crystals	Code 7, IC - and code 9, IC +; intensity reported prior to 1 April 1963.
28	Frozen Precipitation	 SW- SW SW+ SG- SG SG+	0 1 2 3 7 8 9	None Light snow showers Mod. snow showers Heavy snow showers Light snow grains Mod. snow grains Heavy snow grains	Codes 4, 5 and 6, light, moderate and heavy snow squalls reported prior to 1949.
29	Frozen Precipitation	 E- E E+ A AP	0 1 2 3 5 8	None Light sleet Mod. sleet Heavy sleet Hail Small hail	Sleet showers coded as sleet. Hail intensities reported prior to 1 Sept 1956, Codes 4, 6, 7, and 9, A-, A+, AP- and AP+.
30	Obstructions to vision	 F IF GF BD BN	0 1 2 3 4 5	None Fog Ice fog Ground fog Blowing dust Blowing sand	See Supplementary Note E, page 7
31	Obstructions to vision	 K H KH D BS BY	0 1 2 3 4 5 6	None Smoke Hase Smoke and hase Dust Blowing snow Blowing spray	Effective 1 July 1952.

CARD CONTENT

Column	Item or Element	Symbolic Letter	Card Code	Card Code Definition	Remarks
32-35	Sea Level Pressure	PPPP	0000-0999 9000-9999	Millibars to tenths 1000.0 - 1099.9 900.0 - 999.9	Thousands digit not punched. Antarctic stations, see Supplementary Note I page 8 AWS punched 3-hourly only effective 1 July 1958.
36-38	Dew Point Temperature	T_dT_d	000-099 X01-X99	0 to 99 Whole degrees F -1 to -99	0 in col. 36 indicates plus values X in col. 36 for neg. values. See Supplementary Note F page 7
39-40	Wind Direction	dd	00-36	True direction, in tens of degrees, from which wind is blowing. See Code 1 page 5	Code 1 effective 1 Jan. 1964. See Code 2 for previous code. See Supplementary Note I(1) page 8 for Antarctic stations.
41-42	Wind Speed	ff	00-99 X/	Knots X overpunch in col.41 indicates 100 or more knots.	Prior to Jan. 1955 in miles per hour at AF and WB stations; in knots at most Navy stations.
43-46	Station Pressure	PPPP	1000-3999	10.00 to 39.99 inches to hundreds H_g.	Station pressure is the pressure at the assigned station elevation. AWS punched 3-hrly only eff. 1 July 1955, 6-hrly eff. 1 Jan 1964 and 3-hrly eff. on receipt of order dated 1 June 1965.
47-49	Dry Bulb Temperature	TTT	000-099	Whole degrees F 0 to 99	Col. 47 punched 0 for 0 °F and above.
			100-199	100 to 199	1 punched in col. 47.
			X01-X99	-1 to -99	Col. 47 punched X for values below zero
50-52	Wet Bulb Temperature	T_wT_w	000-099 X01-X99	Whole degrees F. 0 to 99 -1 to -99	Col. 50 punched 0 for 0° F. and plus values. Col. 50 punched X for minus. AWS began phasing out punching cols. 50-52 on 1 July 1958. Wet bulb temperature may be omitted after this date. WB and Navy discontinued punching cols. 50-52 on 1 Jan. 1965. See Supplementary Note G, page 7
53-55	Relative Humidity	RH	000-100	0 to 100 Whole percent Cols. 53-54 punched 0 when not needed.	AWS discontinued punching cols. 53-55 on 1 July 1958. WB and Navy discontinued punching cols. 53-55 on 1 Jan. 1965. See Supplementary Note G, page 7
56-79	Clouds and Obscuring Phenomena				See Supplementary Note H, page 7
56	Total Sky Cover		0-9 X	Tenths 10 Tenths	

CARD CONTENT

Column	Item or Element	Symbolic Letter	Card Code	Card Code Definition	Remarks
57	Amount of Lowest Layer		0-9 X	Tenths 10 Tenths	AWS discontinued punching columns 58-61 and 63-79 on 1 Jan. 1964 and columns 57 and 62 on 1 July 1965 except Korean and down range stations.
58	Type of Cloud Lowest Layer		0	None/clear.	
		F	1	Fog	
		St	2	Stratus	
		Sc	3	Stratocumulus	
		Cu	4	Cumulus	
		Cb	5	Cumulonimbus	
		As	6	Altostratus	
		Ac	7	Altocumulus	
		Ci	8	Cirrus	
		Cs	9	Cirrostratus	
		Sf	X 2	Stratus Fractus	Prior to 1 May 1961 was Fs Fractostratus and Fc Fractocumulus
		Cf	X 4	Cumulus Fractus	
		Cm	X 5	Cumulonimbus mamma	
		Ns	X 6	Nimbostratus	
		Acc	X 7	Altocumulus castellanus	
		Cc	X 9	Cirrocumulus	
			X	Obscuring phenomenon other than fog	
59-61	Height of Lowest Layer		000-990	Hundreds of feet 0 to 99,000 ft.	
			888	Unknown height of a cirroform layer	See remark col. 14-16.
			XXX	Unlimited vertical visibility	Clear or no clouds reported.
62	Amount of Second Layer		0-9 X	Tenths 10 tenths	
63	Type of Second Layer		0-9 X/	See col. 58.	
64-66	Height of Second Layer			See cols. 59-61.	
67	Summation Amount at Second Layer		0-9 X	Tenths 10 tenths	
68	Amount of Third Layer		0-9 X	Tenths 10 tenths	
69	Type of Third Layer		0-9 X/	See col. 58	

CARD CONTENT

Column	Item or Element	Symbolic Letter	Card Code	Card Code Definition	Remarks
70-72	Height of Third Layer			See columns 59-61	
73	Summation Amount at Third Layer		0-9 X	Tenths 10 tenths	
74	Amount of Fourth Layer		0-9 X	Tenths 10 tenths	
75	Type of Fourth Layer		0-9 X/	See column 58.	
76-78	Height of Fourth Layer			See columns 59-61.	
79	Total Opaque Sky Cover		0-9 X	Tenths 10 tenths	Punching began June 1951. June 1, 1962 - Opaque Sky Cover re-defined: Those portions of cloud layers or obscurations which hide the sky and/or higher clouds. Translucent sky cover which hides the sky but through which the sun and moon (not stars) may be dimly visible will be considered as opaque.
80					Not used for punching observations.

CODE TABLES

When coding a meteorological report, symbolic letters are replaced by figures, which specify the value or the state of the corresponding element. In some cases, the specification of the symbolic letter (or group of letters) is sufficient to permit a direct transcription into figures (e.g., GG or PPP). In other cases, these figures are obtained by means of a special code table (or code, in short) for each element.

The codes elaborated to this end, as far as they are in world-wide use, are called international meteorological code tables. These same codes are used inversely for decoding observations and thus making available the information contained in them.

Besides the specifications given by the code tables in world-wide use, other sets of code tables are established by the WMO for regional use. Further arbitrary codes have been made necessary by the use of data in card decks which were never encoded into WMO forms.

Only codes pertinent to this card deck are included in the present manual. They appear in the order in which the elements were introduced in the description of the card content. They are numbered consecutively, and if applicable, the corresponding WMO code numbers are shown.

Code 1

(1949 WMO Code 23)
(1960 WMO Code 0877)

dd - True direction, in tens of degrees, from which wind is blowing (or will blow)

Code figure		Code figure	
00	Calm	19	185° - 194°
01	5° - 14°	20	195° - 204°
02	15° - 24°	21	205° - 214°
03	25° - 34°	22	215° - 224°
04	35° - 44°	23	225° - 234°
05	45° - 54°	24	235° - 244°
06	55° - 64°	25	245° - 254°
07	65° - 74°	26	255° - 264°
08	75° - 84°	27	265° - 274°
09	85° - 94°	28	275° - 284°
10	95° - 104°	29	285° - 294°
11	105° - 114°	30	295° - 304°
12	115° - 124°	31	305° - 314°
13	125° - 134°	32	315° - 324°
14	135° - 144°	33	325° - 334°
15	145° - 154°	34	335° - 344°
16	155° - 164°	35	345° - 354°
17	165° - 174°	36	355° - 4°
18	175° - 184°		

Code 2

dd - Wind Direction

Code Figure			
00	C	Calm	
11	↓↓	North	349° - 11°
12	↓↙	North Northeast	12° - 33°
18	↓↘	North Northwest	327° - 348°
22	↙↙	Northeast	34° - 56°
32	←↙	East Northeast	57° - 78°
33	←←	East	79° - 101°
34	←↖	East Southeast	102° - 123°
44	↖↖	Southeast	124° - 146°
54	↑↖	South Southeast	147° - 168°
55	↑↑	South	169° - 191°
56	↑↗	South Southwest	192° - 213°
66	↗↗	Southwest	214° - 236°
76	→↗	West Southwest	237° - 258°
77	→→	West	259° - 281°
78	→↘	West Northwest	282° - 303°
88	↘↘	Northwest	304° - 326°

APPENDIX

METHODS FOR DETERMINING INTENSITY FOR WEATHER AND OBSTRUCTIONS TO VISION

THUNDERSTORM

1945 -

THUNDERSTORM - Characterized by occasional or fairly frequent flashes of lightning; weak to loud peals of thunder; rainfall, if any, light or moderate, and rarely heavy; hail, if any, light or moderate; wind not in excess of 40 miles per hour; and no large temperature drop with passage of the storm.

Note: Wind speed changed to knots on 1 Jan. 1955. 40 mph is 35 kts

HEAVY THUNDERSTORM - Characterized by nearly incessant, sharp lightning; loud peals of almost continuous thunder; heavy rain showers; hail of any intensity; wind in excess of 40 miles per hour as the storm passes overhead; and a rapid drop of temperature, as much as 20°F., in 5 minutes, with the passage of the storm.

GUSTS OF WIND

1945 - 1951

*RAIN SQUALLS, SNOW SQUALLS, SQUALLS

Intensity of SQUALLS discontinued 1 June 1951.

Light - Gusts of 24 miles per hour or less. 21 knots
Moderate - Gusts of 25 to 39 miles per hour, inclusive. 22-34 kts
Heavy - Gusts of 40 miles per hour or over. 35 knots

*Squalls reported separately after 1948.

SQUALLS 1951 -

1 June 1951. A squall is a strong wind that increases suddenly in speed, maintains a peak speed of 19 mph (16 knots) or more over a period of two or more minutes, and decreases in speed; similar fluctuations will occur at succeeding intervals.

RATE OF FALL

1945 -

RAIN, RAIN SHOWERS, FREEZING RAIN

Also DRIZZLE (1945-1946 only), SNOW, SNOW SHOWERS, SNOW PELLETS, when accompanied by other precipitation or obstructions to vision.

Very light - Less than light; not used before June 1951, punched as light.
Light - Trace to 0.10 inch per hour; maximum 0.01 inch in six minutes.
Moderate - 0.11 inch to 0.30 inch per hour; more than 0.01 inch to 0.03 inch in six minutes.
Heavy - More than 0.30 inch per hour; more than 0.03 inch in six minutes.

When measurement of rate of fall was impracticable, the intensity of rain was determined visually.

Jan 1947-May 1951, whether alone or not, and after May 1951, when accompanied by other precipitation or obstructions to vision.

DRIZZLE, FREEZING DRIZZLE

Light - Trace to 0.01 inch per hour.
Moderate - More than 0.01 to 0.02 inch per hour.
Heavy - More than 0.02 inch per hour.

RATE OF FALL AND ACCUMULATION

1946 -

SLEET, HAIL, SMALL HAIL

Light - A few pellets fall.
Moderate - Pellets fall at a moderate rate; some accumulation on the ground.
Heavy - Pellets fall at a heavy rate; rapid accumulation on the ground.

VISIBILITY PRECIPITATION

SNOW, SNOW SHOWERS, SNOW PELLETS, DRIZZLE, FREEZING DRIZZLE and SNOW GRAINS When occurring alone

Note: In 1945 - for all forms of snow, when occurring alone, intensity was determined by visibility, as shown below. Intensity of drizzle, when occurring alone, was determined by visibility in 1945-1946 and after May 1951 only.

Light - Visibility 5/8 mile or greater.
Moderate - Visibility 5/16 to 1/2 mile, inclusive.
Heavy - Visibility 1/4 mile or less.

Note: Intensity of ICE CRYSTALS greater than "very light" will be rarely observed. Above criteria were referred to if needed. On 1 April 1963 reporting of intensities of ICE CRYSTALS was discontinued.

HAZE

1945 -

HAZE - Visibility 6 miles or less, but rarely below 3 miles.

DAMP HAZE - Visibility 6 miles or less, but rarely as low as 1 1/4 miles. Not reported after 1948.

OBSTRUCTIONS TO VISION

1945 - 1946

FOG, ICE FOG, GROUND FOG, SMOKE, DUST, BLOWING DUST, BLOWING SAND, BLOWING SNOW, DRIFTING SNOW

Note: No indication of intensity was reported for all obstructions to vision after 1946.

Light - Visibility 5/8 mile to 6 miles, inclusive.
Moderate - Visibility 5/16 to 1/2 mile, inclusive.
Heavy - Visibility 1/4 mile or less.

Drifting snow was not reported after 1948.

192

Supplementary Notes

A-Columns 12-13

The time punched is that of the record observations, which generally are taken about 20 minutes past the hour. Minutes are disregarded in punching. All "War Times" and "Standard Meridian Times" were converted to Local Standard Time before punching. For Air Force stations in the United States, the times were punched in accordance with the established time zones. Time entries for Air Force stations outside the United States were edited prior to punching and where necessary converted to the Local Standard Time of the nearest meridian evenly divisible by 15 degrees.

B-Columns 14-16

Ceiling was recorded in hundreds of feet above the ground to nearest 100 feet up to 5000 feet, to nearest 500 feet up to 10,000 feet, to nearest 1000 feet above that. Before 1949, Air Force stations recorded ceilings up to and including 20,000 feet, above which point the ceiling was classified as unlimited; Weather Bureau and Navy stations recorded ceiling only up to and including 9,500 feet, above which point the ceiling was considered unlimited. Beginning in 1949, ceiling was re-defined to include the vertical visibility into obscuring phenomena not classified as thin, that, in summation with all lower layers, cover 6/10 or more of the sky. Also at that time all limits to height of ceiling were removed, so that unlimited ceiling became simply less than 6/10 sky cover, not including thin obscuration. Then, beginning 1 June 1951, ceiling heights were no longer established solely on the basis of coverage. The ascribing of ceilings to thin broken or overcast layers was eliminated. A layer became classified as "thin" if the ratio of opaque coverage to total coverage at that level was 1/2 or less.

C.Columns 17-20

If two or more layers of clouds were reported, two symbols were punched (in column 17 and column 20), unless the lower layer were reported as overcast, in which case the upper layer was reported in Remarks. Symbols reported in Remarks of the reporting form were not punched. When only one sky symbol was reported, it was punched in column 20, column 17 being punched 0. In every case, one of the sky symbols represents the total sky cover. When two symbols are reported, the first symbol always represents the layer at the greater height. In 1946, obscured sky was reported only when heavy obstructions to vision and/or heavy precipitation reduced the ceiling to zero and/or the visibility to less than 1/4 mile; and when the visibility was 1/4 mile or more, a sky symbol was always reported. Effective 1 January 1947, the symbol "X", for obscured sky, received the same latitude of usage as all other symbols. "X" then represented sky cover of 6/10 or more, obscured by precipitation or obstructions to vision either alone or in combination with lower clouds, and irrespective of higher clouds and ceiling and/or visibility limits. In August 1947, the use of "-X", for thin obscured, was authorized. In 1946, if a layer of scattered clouds above a layer of broken clouds was clearly observable, it was so reported. In 1947 and 1948, symbols corresponding to higher cloud layers indicated the amount of sky covered not only by their respective layers, but by all layers below them. In all years, the presence of few clouds (less than 1/10) was recorded in Remarks. The use of the slant (/) to indicate cloud layers to 10,000 feet or higher was discontinued in January 1949, and there is no provision for punching it on this card form.

Effective 1 June 1951, the reporting of height of low scattered was discontinued, and provision was made to report any number of sky condition symbols, with the height of each. The ceiling layer was not reported separately as before, but was identified by the entry of a ceiling classification letter immediately preceding the height. Sky condition symbols were reported in ascending order of height, and were punched in that order, unless more than four were reported. In that case, the last (highest) symbol was punched in column 20, and the first three in columns 17-19, unless the ceiling symbol was thereby excluded. In the latter case, the first two symbols were punched in columns 17-18, the ceiling symbol in column 19, and the highest symbol in column 20. No symbols were reported in Remarks, as was the practice before June 1951.

Sky condition symbols were also re-defined so that obscuring phenomena aloft and clouds were reported in the same manner (i.e., obscuring phenomena aloft were reported by ⦶, ⦷, and ⊕, rather than X and -X). X and -X were used only to indicate the amount of sky hidden by surface-based phenomena. -X was re-defined as partial obscuration (1/10 to less than 10/10 sky hidden). The symbols X and -X unlike ⦶, ⦷, and ⊕, were defined by the amount of the sky hidden by surface-based phenomena, and -X did not indicate the amount of sky covered. The meaning of "thin" was re-defined. If the total opaque cover created by any layer in combination with lower layers was 1/2 or less of the summation total cover at that level, the layer was classified as thin. Note that the minus sign, when applied to ⦶, ⦷, or ⊕ means "thin"; when applied to X, means "partial".

D. Column 26

In 1946, intensity determined by visibility (as for smoke) only if drizzle occurred alone. When drizzle was accompanied by other forms of precipitation and/or obstructions to vision, its intensity was determined by rate of fall. In 1947, visibility limitations were dropped, and intensity was determined by rate of fall, even though drizzle occurred alone. In June 1951, previous visibility limits were re-instituted. Intensity of freezing drizzle determined in same manner as for drizzle. See appendix.

E. Column 30

Intensity of light, moderate, or heavy were assigned to obstructions to vision, through 1946. In 1947 all intensitites were dropped, and any cases of light or heavy which were erroneously reported were punched as moderate. Intensities as used through 1946 are shown in the appendix. Prior to 1 January 1949, the distinction between F and GF was arbitrary, but beginning with that date an objective distinction was established. If the sky was not hidden above an angle of 33° from horizontal (less than 0.6 hidden), the fog was reported as ground fog (GF).

F. Columns 36-38

Before 1949, dew point was computed with respect to ice if temperature was below 32°F. Beginning Jan. 1949, computed with respect to water regardless of temperature.

G. Columns 50-55

From August 1, 1960 punched at stations with hygrothermometer only when dry-bulb sensor was not operational. Normal operational range varies from -30° to -80° F. Machine calculated when hygrothermometer operational.

At dry-bulb temperatures below -35° F, the wet-bulb thermometer is not read therefore relative humidity is not recorded for stations not equipped with a hygrothermometer.

Prior to January 1949, relative humidity computed with respect to ice if the dry-bulb temperature was less than 32° F. Beginning January 1949, computed with respect to water, regardless of temperature. Relative humidity machine calculated from 1 August 1960.

H. Columns 56-79

Provision was made for as many as four layers of clouds and/or obscuring phenomena existing at one time. If more than four layers existed, the data for levels above the fourth were entered in the Remarks portion of WBAN 10B, and were not punched. Their presence is indicated by the entry for total sky cover. Layers were punched in ascending order of elevation. All fields above a layer which prevented observation were left blank. If two or more types of clouds were observed at the same height, only the predominating type was punched, their amounts being combined. For each layer, the amount, type, and height were punched, and for the second and third layer, the summation amount at the level involved was punched, reflecting the total amount of sky covered by that layer and those below it. The summation total for the fourth layer is obviously the total sky cover. The summation total is not necessarily the sum of the individual layers.

Supplementary Notes

H. Columns 56-79 (cont'd.)

In addition to the total sky cover, provision was made in June 1951 for recording and punching the total amount of opaque sky cover, which is the amount of sky hidden by clouds or obscuring phenomena, as distinguished from the total amount of sky cover.

The height of layers of clouds or obscuring phenomena aloft was recorded in hundreds of feet, and for fully obscuring phenomena based on the ground, the vertical visibility into it was recorded, with no prescribed limit. All heights were recorded to the nearest 100 feet from the surface to 5,000 feet; to the nearest 500 feet between 5,000 and 10,000 feet; and to the nearest 1,000 feet above 10,000 feet. For obscuring phenomena prescribed as "thin", a condition reportable from August 1947 through May 1951, the height of the base was punched, and in the case of thin fog, was always zero. Before January 1947, obscuration was not reportable as a cloud type.

Some Weather Bureau and Navy cards in this deck were punched from the old type of reporting form (the WBAN 10 with which deck 142 is aligned) and in which five cloud layers were reported with no summation totals. In these cases, the summation total columns were left blank, and the five layers, if reported, were condensed into four.

I. AMUNDSEN-SCOTT STATION:

1. Wind Direction on all cards was punched according to the following system:

   A. A wind from 0° longitude was punched as N or 360.
   B. A wind from 90° east longitude was punched as E or 090.
   C. A wind from 180° longitude was punched S or 180.
   D. A wind from 90° west longitude was punched W or 270.

2. In place of sea-level pressure (Column 32-35) the height of the 700 mb surface in whole meters was punched. This applies to the period December 1, 1957 through December 31, 1958. (Prior to this period the station pressure in mbs was punched in these columns.)

BYRD STATION, ANTARCTICA

1. In place of sea-level pressure (Columns 32-35) the height of the 850 mb surface in whole meters was punched.

193

COMPUTATION OF WET BULB

Dry Bulb zero and above

$$TW = T - (.034N - .00072N [N - 1]) \ (T + Tdp - 2P + 108)$$

If temperature is less than 100°

TW Rounded = TW + .9 if col. 48 is 0, 1, 2
TW + [.9 - .01 (T + .9)] if col. 48 is 3, 4
TW + .4 if col. 48 is 5 through 9

If temperature is 100° or greater:

TW Rounded = TW + .9.

for Dry Bulb temperatures less than zero:

$$TW = T - (.034N - .006N^2) \ (.6[T + Tdp] - 2P + 108)$$

TW Rounded = TW - .01Tdp

T = dry bulb temperature in °F

TW = wet bulb in °F

Tdp = dew point in °F

$$N = \frac{T - Tdp}{10}$$

P = Station pressure measured in inches of mercury

In all cases TW should be computed to at least two decimal places prior to applying the rounding factor.

194

COMPUTATION OF RELATIVE HUMIDITY

$$RH \cong \left(\frac{173 - .1T + Tdp}{173 + .9T}\right)^8$$

Where T = Air Temp. in °F
T_{dp} = Dew Point Temp. in °F

Reference to the above formula may be found in "An Approximation Formula to Compute Relative Humidity from Dry Bulb and Dew Point Temperatures" by Julius F. Bosen, Monthly Weather Review, Vol. 86, No. 12, Dec. 1958, page 486.

195

OTHER CARD DECKS CONTAINING HOURLY OBSERVATIONS

DECK		GENERAL PERIOD
019	London Airport Hourly Surface	1948-1961
021	USAAF in Great Britain Surface	1942-1946
132	Canadian Hourly Surface Obs.	1946-1951
134	Canadian Hourly Surface Obs.	1951-1953
135	Canadian Hourly Surface Obs.	1950-1967
139	Japanese Airway Obs. Hourly Sfc.	1958-1961
141	WBAN Hourly Surface Obs.	1937-1945
142	WBAN Hourly Surface Obs.	1945-1948
156	British Hourly Obs.	1941-1948
157	Turkish Hourly Surface Obs.	1950-1959
158	German Hourly Obs. GZMO	1955-1961
158	German Hourly Obs. GZMO	1962-1964
159	Korean Hourly Obs. ROK	1954-1964
159	Korean Hourly Obs. ROK	1965-1967
160	Azores Hourly Obs.	1951-1955
171	Nanking Hourly Obs.	1928-1937
172	Yungan Hourly Obs.	1938-1942
175	Taichung Hourly Obs.	1952-1956
928	Hourly Marine Sfc OSV's	1965-

ELEMENTS (ITEMS) PUNCHED

	Page		Page
CEILING	2	SKY CONDITION	2
CLOUDS (4 layers)	6	STATION NUMBER	2
Amount, Type, Height			
Amount Total	5	TEMPERATURE	
Amount Total Opaque	7	Dew Point	5
		Dry Bulb	5
DATE		Wet Bulb	5
Yr Mo Day Hour	2		
		VISIBILITY	3
HUMIDITY Relative %	5		
		WEATHER AND/OR	
PRESSURE		OBSTRUCTIONS TO VISION	3-4
Sea Level	5		
Station	5	WIND	5

CARD DECK 144 ACRONYMS

AF	Air Force
AWS	Air Weather Service
CAA	Civil Aeronautics Administration (same as FAA)
ESSA	Environmental Science Services Administration (NOAA after 3 Oct 1970)
ETAC	Environmental Technical Applications Center
FAA	Federal Aviation Administration (formerly CAA)
GZMO	German Zonal Meteorological Organization
GMT	Greenwich Mean Time
ID	Identification (cards)
METAR	Meteorological Aviation Routine Weather Report
MF	Meteorological Form
NCC	National Climatic Center (formerly National Weather Records Center (NWRC))
NNWS	NOAA National Weather Service (formerly WB)
NOAA	National Oceanic and Atmospheric Administration (eff. 3 Oct 1970)
NWS	Naval Weather Service
OSV	Ocean Station Vessel
ROK	Republic of Korea
USAF	United States Air Force
WB	Weather Bureau (changed to NNWS 3 Oct 1970)
WBAN	Weather Bureau - Air Force - Navy
WMO	World Meteorological Organization

```
C
C     PROGRAM TO PROCESS DATA FROM 10-YEAR SURFACE AND SOLAR WEATHER
C        BUREAU TAPES
C
C     ENVIRONMENTAL SYSTEMS LABORATORY   -L.PATMORE-(408) 734-2244
C
C        THIS PROGRAM PRODUCES JOINT DISTRIBUTIONS(BY CLASS),COMPUTES,
C          PLOTS EQUILIBRIUM TEMPERATURES, PERFORMS INDEPENDENCE TESTS
C          AND FITS TO DISTRIBUTIONS(ON OPTION FLAG).
C
C          PROGRAMS INCLUDED WITH THIS PACKAGE ARE  HIST,INDTST,EQSUB,
C          EQPLT,DIST AND THEIR SUBPROGRAMS.
C
C          THE IBM SCIENTIFIC SUBROUTINE PACKAGE IS USED.
C
C          THE SURFACE OBSERVATION TAPE MUST BE USED. THE SOLAR TAPE IS
C          OPTIONAL.
C
C
C
C     COMMON FOR ALL OPTIONS
      COMMON    IHIST,NHIST,MHIST,MBASE,IND
      INTEGER *2     IHIST(10,10,10,10)
      DIMENSION      NHIST(5),MHIST(4),MBASE(4),IND(4)
     1,              JHIST(5),IDATA(4),ISV(7),IZR(5000)
     2,              IDD(8,24),ISLD(4),ISLR(4,16)
     3,              ASLR(4,16),ILOC(4),HEX(10,3)
     4,              X(1000,5)
      EQUIVALENCE (ISLR(1,1),ASLR(1,1))  , (ITT,ATT)
     1, (JHIST(1),J1), (JHIST(2),J2),(JHIST(3),J3),(JHIST(4),J4)
     2, (IHIST(1,1,1,1),IZR(1))
     3,              (ITST,TST),  (IHIST(1,1,1,1),X(1,1))
C
C     COMMON FOR  EQ. TEMP PLOT
C
      COMMON /INPUT/A,B,HEAD(20),TMERR,WMULT,IFLAG,HSMULT,IPLOT(6)
     1,A1PRME,A2PRME,RG,DA,DS
C
C
C     COMMON FOR  DISTRIBUTION FIT
C
      COMMON   /DSTCM/KMN(5),MEAN(5),MSD(5),KD(5),IDPT(3),IINT
C
C
      DATA     AST/'*   '/,BL/'    '/,ILOC/3,5,7,8/,IOUT/0/,NDELT/1/
     1, IYAR/0/,IYEAR/2/,MNTH1/6/,MNTH2/8/,MHOUR/11/,NHOUR/14/,HEX/
     4 ZC0404040,    ZC1404040,ZC2404040,ZC3404040,ZC4404040,ZC5404040,
     5 ZC6404040,    ZC7404040,ZC8404040,ZC9404040,ZD0404040,ZD1404040,
```

```
     6 ZD2404040,     ZD3404040,ZD4404040,ZD5404040,ZD6404040,ZD7404040,
     7 ZD8404040,     ZD9404040,ZF0404040,ZF1404040,ZF2404040,ZF3404040,
     8 ZF4404040,     ZF5404040,ZF6404040,ZF7404040,ZF8404040,ZF9404040/
     9,XHEX/Z60404040/
C
C
C
      NAMELIST /TEMPS/  IOUT,NMREC,NDELT,IYAR,MNTH,IYEAR,MNTH1,MNTH2
     1,         MHOUR,NHOUR,NHIST,MHIST,MBASE,HEAD
     2,         ISURF,ISLST,IPTN,IINT,IDPT
     3 , TMERR,WMULT,IFLAG,HSMULT,IPLOT,A,B
     4,A1PRME,A2PRME,RG,DA,DS
C
C     READ      OUTPUT OPTION (OUTPUT EVERY ICUT RECORDS)
C               START YEAF MONTH      (IF ZERO USE FIRST ON TAPE)
C                 PROCEED FOR DELTA YEARS,DATA IN MNTH1 TO MNTH2
C     PROCESS DATA IN WINDOW HOUR TO HOUR2, HISTOGRAMS CHOSEN IN NHIST
C      IPTN =   RUN OPTION
C          =1 COMPUTE AND PLOT E
C                    NO CHOICE NECESSARY
C               SECTION 10 IN THIS VERSION IS SAVED FOR INVALID OR
C                MISSING DATA
C
C
C          =2 COMPUTE CONDITIONAL DISTRIBUTIONS,MEANS,ETC.
C                    CHOOSE 1-4 PARAMETERS IN NHIST
C
C
C          =3 INDEPENDENCE TESTS
C                    CHOOSE 2-5 PARAMETERS IN NHIST
C          =4 DISTRIBUTION FITS
C                    CHOOSE 1-5 PARAMETERS, ALSO IDPT AND IINT,BEING SURE
C                     THAT IINT DOES NOT RESULT IN ONLY A SUBSET OF THE
C                     HOURS BEING USED TO COMPUTE THE SAMPLE STATISTICS.
C
C
C     START  RUN WITH EVEFYTHING ZERO  BUT DO NOT FETURN HERE, NEXT CASE
C     TO ALLOW MINIMUM OF CHANGES WITH NAMELIST.
      DO 1 I=1,4
      NHIST(I)=0
      MHIST(I)=0
 1    MBASE(I)=0
      NHIST(5)=0
C     OPTION FOR EQ. PLOT - TO ACCUMULATE DATA FROM CASE TO CASE.
 10     IFLAG=0
      READ(5,TEMPS,END=999)
C
C     INITIALIZE  ALL  CPTIONS
```

```
C
      IKD=0
      IF (MNTH1 .EQ. 0) MNTH1 = 1
      IF (MNTH2 .EQ. 0) MNTH2 = 12
      IF(NDELT .EQ. 0) NDELT=1
      IDELT = NDELT
      ICMP=IOUT
      IF(ICMP .EQ. 0) ICMP=1
      ND=0
      ISOL =0
      IF (IPTN .NE. 1)  GO TO 11
C     EQUILIBRIUM TEMPERATURE OPTION
      ND=5
      ISOL=5
      DO 9 I=1,5
    9 NHIST(I)=I
      GO TO 19
C
C     INITIALIZE HISTOGRAMS,INDEPENDENCE TESTS,DISTRIBUTION FITS
C
   11 CONTINUE
      DO 15  I=1,5
      IF(NHIST(I) .EQ. 0) GO  TO  17
      IF(NHIST(I) .EQ. 5) ISOL=I
      ND=ND+1
   15 CONTINUE
C     CHECK FOR INPUT ERROR IN NHIST FOR THIS OPTION
      IF(IPTN .EQ. 2) ND=4
C
   17 GO TO (19,16 ,19,18),IPTN
C
C     HISTOGRAM OPTION ONLY
   16 DO 12 I=1,4
      JHIST(I)=1
   12 IND(I)=1
      DO 13 I=1,ND
   13 IND(I)=10
      DO 14 J=1,5000
   14 IZR(J)=0
      GO  TO 19
C
C     DISTRIBUTION FITS ONLY
C
   18 CONTINUE
      DO 185 I=1,5
      KD(I)=0
      KMN(I)=0
      MEAN(I)=0
```

```
      MSD(I)=0
185   CONTINUE
      ITSD=IINT
C     NOW HAVE COUNTED NUMBER OF HISTOGRAMS TO DO AND CLEARED SPACE
19    CONTINUE
      WRITE (6,799) HEAD
      WRITE(6,700)  NDELT,IYAR,IYEAR,MNTH1,MNTH2,MHOUR,
     1  NHOUR,NHIST,MHIST,MBASE,IOUT
C
C     INITIALIZATION OF INPUT FINISHED
C
C     NOW LINE UP TAPES APPROXIMATELY.
C
      MHR=MHOUR+1
      NHR=NHOUR+1
C
C     FIND FIRST YEAR,SKIPPING FIRST DAY REGARDLESS (FOR SPEED)
C
C     READ ONE FULL DAY(FOUR RECORDS) AT A TIME
      K=4
20    DO  25 J=1,K
25    READ(12,801,END= 550) ISTAT,ISY,IMN
      IF(IYAR .EQ. 0) IYAR =ISY
      IF(ISTAT  .NE.  ISURF) GO TO  950
C     COMPUTE  NUMBER OF RECORDS TO SKIP
      K=((IYAR-ISY)*365+(MNTH1-IMN-1)*30)*4
      IF( K .GT. 0) GO  TO 20
      WRITE (6,750)  IYAR,IMN,ISTAT
      IF( ISOL .EQ. 0)   GO TO 40
      K=1
C     FIND  DAY CN SOLAR TAPE
29    DO 30 J=1,K
30    READ(13,END=39) ISTAT,ISY,IMN
      IF( ISTAT .NE. ISLST)  GO TO 955
      K= ((IYAR-ISY)*365+(MNTH1-IMN-1)*30)
      IF(K.GT.0) GO TO 29
      WRITE(6,750)  IYAR,IMN,ISTAT
      KSL=0
      GO TO 40
39    WRITE(6,752) ISY
      ISOL=0
C
C     BOTH TAPES ARE SET AT CORRECT YEAR, CLOSE TO CORRECT MONTH
C
40    IYUR = IYAR +IYEAR-1
C     READ A FULL DAY
45    DO 50 J1=1,24,6
      J2=J1+5
```

```
 50   READ(12,801,END=550) IDATA,((IDD(I,J),I=1,8),J=J1,J2)
      IF( IDATA(2)-IYUR) 75,70,550
 70   IF( IDATA (3).GT.  MNTH2)  GO TO 550
C                                          REJECT RECORD
 75   IF(IDATA(3) .LT.MNTH1  .OR. IDATA(3) .GT. MNTH2) GO TO 45
C
C     START AND END OF SURFACE OBSERVATION TAPE
C          CONTROLS RUN.
C
      IF(ISOL .EQ. 0)  GO TO 120
      IF( KSL .NE. 0 )  GO TO 86
      KSL=1
 85   READ(13,END=925) ISLD,ISLR
C
 86   DO 87 I=2,4
C                                   READ  GOOD   NOT READING YET
      IF(ISLD(I)-IDATA(I)) 85,87,120
C
C     FALL THROUGH WITH RIGHT YEAR,MONTH,DAY
C
 87   CONTINUE
      KSL=0
C
C     IF THIS IS E COMPUTE,MUST HAVE A FULL DATA SET
C      (ALSO FOR INDEPENDENCE TESTS DUE TO SSP ROUTINE USED)
C        ASSURE BOTH TAPES ARE IN SYNCH AND REREAD IF NOT
 120  IF (KSL .NE. 0)  GO TO (45,121,45,121),IPTN
C     OUTPUT EVERY IOUT GOOD RECORDS
 121  CONTINUE
      IF(ICMP .NE. IOUT) GO TO 125
      DO  80 K1= 1,24,6
      K2= K1+5
 80   WRITE(6,701) IDATA,((IDD(I,J),I=1,8),J=K1,K2)
      IF(ISOL .NE. 0)  WRITE (6,753) ISLD,ISLR
       ICMP=0
 125  ICMP=ICMP+1
C
C     ACCEPTED RECORD
C
      DO 175 K=MHR,NHR
C
C     USE EVERY IDELT DATA POINTS(NECESSARY FOR OPTIONS WHERE DATA IS
C        BEING SAVED)
C
      IF(IDELT .EQ. NDELT ) GO TO 130
      IDELT= IDELT+1
      GO TO 175
 130  DO  150  I=1,ND
```

```
C
C      DEFAULT VALUES
C      NO DATA
       ISV(I)=-1
       JHIST(I)=10
C      COMBINE NUMERIC AND ALPHA PART OF DATA
C
C      CHECK FOR SOLAR PARAMETER
C
       IF( I.NE. ISOL)   GO TO  139
C      SOLAR RECORD NOT MATCHING
       IF(KSL .NE. 0) GO TO 142
C      HOUR TOO EAPLY (BEFORE DAYBREAK)  OR  TOO LATE
       KHH=K-1
       DO 131  IKM=1,16
       KDEX=IKM
       IF( ISLR(1,IKM)  -   KHH) 131  ,132,142
 131   CONTINUE
C      MATCHING HOUR NOT FOUND
       GO TO 142
 132   CONTINUE
       ITST=ISLR(2,KDEX)
       IF(ITST .LT. 0) GO TO 142
C      GOOD OBSERVATION
       GO TO 148
C
C
 139   CONTINUE
       L=  ILOC(NHIST(I))
       ITST= IOD(L,K)
       IF( TST .EQ. AST  .OR.  TST  .EQ. BL)  GO TO 142
C
C      CHECK FOR CLOUD COVER MEASUREMENT EQUAL TO X -OVERCAST
C
       IF( L .NE. 8 .OR. TST .NE.XHEX) GO TO 1395
       ITST=10
       GO TO 148
 1395  CONTINUE
       DO   140   K2=1,3
       DO   140   K3=1,10
       IF(TST .NE. HEX(K3,K2)) GO TO 140
       ITST=K3-1
       GO TO 145
 140   CONTINUE
 142   GO TO (175,150,175,150),IPTN
 145   IF (L .EQ. 8) GO  TO 148
       ITST = ITST +IOD(L-1,K)*10
       IF( K2 .EQ. 2)  ITST= -ITST
```

```
C       SAVE ALL CATA IF EQUIL OPTION
 148    IF(IPTN .EQ. 2) GO TO 149
        ISV(I)=ITST
        GO TO 150
 149    CONTINUE
        J= ITST-MBASE(I)
        IF(J .LT. 0) J=0
        JHIST(I)= J/MHIST(I) +1
        IF(JHIST(I) .GT. 9) JHIST(I)=9
 150    CONTINUE
        IKD = IKD+1
        IDELT=1
        GO TO (155,170,165,160),IPTN
 155    CONTINUE
        ISV(6)=ISLR(3,KDEX)
        ISV(7)=ISLR(4,KDEX)
        CALL EQSUB(ISV)
        GO TO 175
C       DISTRIBUTIONS - NOT FULL DATA SETS
 160    CONTINUE
C       EACH POINT IS EITHER SAVED OR USED IN SAMPLE STATISTIC.
C
        IF(IINT .NE. ITSD) GO TO 163
        DO 162 I=1,ND
        IJ=ISV(I)
        IF(IJ .LT. 0) GO TO 162
        KMN(I)=KMN(I)+1
        MEAN(I)= MEAN(I)+IJ
        MSD(I) = MSD(I) +IJ*IJ
 162    CONTINUE
        ITSD=1
        GO TO 175
 163    ITSD = ITSD +1
        DO 164 I=1,ND
        IF(ISV(I) .LT. 0) GO TO 164
        IF (KD(I) .EQ. 1000) GO TO 168
        KD(I)=KD(I)+1
        X(KD(I),I)=ISV(I)
 164    CONTINUE
        GO TO 175
C       INDEPENDENCE TESTS - FULL DATA SETS
 165    DO 167 I=1,ND
 167    X(IKD,I)=ISV(I)
C
C       CHECK X STORAGE NOT EXCEEDED
C
        IF (IKD  .LT. 1000) GO TO 175
 168    CONTINUE
```

```
      WRITE (6,754)
      GO TO 550
  170 CONTINUE
      IHIST(J1,J2,J3,J4)=IHIST(J1,J2,J3,J4)+1
  175 CONTINUE
      GO TO 45
C
C
C
C     FINISHED GATHERING DATA TOGETHER AND SORTING
C
  550 CONTINUE
      GO TO (560,570,580,590),IPTN
C
C     EQ. TEMP  AND OTHER PLOTS
C
  560 CALL EQPLT
      GO TO 600
C
C     HISTOGRAMS, CONDITIONAL PROBABILITIES,ETC.
C
  570 CONTINUE
      CALL HIST(ND)
      GO TO 600
C     INDEPENDENCE TESTS
  580 CONTINUE
      CALL INDTST(IKD,ND)
      GO TO 600
C
C     TEST OF FIT TO DISTRIBUTION
C
  590 CONTINUE
      CALL DIST(ND)
  600 CONTINUE
      REWIND 12
      REWIND 13
      GO TO 10
C                                END OF SOLAR TAPE
  925 WRITE(6,752)  ISLR(1,1)
  926 ISOL=0
      GO TO 120
  950 WRITE(6,751) ISTAT,ISURF
      GO TO 999
  955 WRITE(6,751) ISTAT,ISLST
C     CHECK FOR BEGINNING BLANK SPOT FOUND ON SOLAR TAPE
      IF(ISTAT .EQ. 0) GO TO 29
C
C
```

```
999   STOP
C
C
C     REFERENCE - TAPE REFERENCE MANUAL  AIRWAYS SURFACE OBSERVATIONS
C     TDF 14
801   FORMAT(4X,I5,3I2,6(I2,10X,I2,A1,I2,A1,7X,I2,A1,14X,A1,37X))
700   FORMAT('0 PROCESS EVERY ', I4,' RECORDS, FROM BASE YEAR ',I2,
     1' FOR ',I3,' YEARS'/'0 TIME WINDOW IS FROM
     3MONTH',I6,'TO MONTH',I6,'HOUR',I6,'TO HOUR',I6/
     4  5I5,' CODE NUMBERS OF PARAMETERS'/
     5  4I5,5X,' INTERVAL SIZE FOR CLASSES'/
     6  4I5,5X,' BASE (ZERO POINT) FOR CLASSES'/
     7  '0 OUTPUT IS EVERY',I5,' RECORDS IN WINDOW'//)
701   FORMAT('0',I5,2X,3I5/4('0',6(2I3,A1,I3,A1,I3,A1,1X,A1)/))
750   FORMAT( '0   YEAR  ',I3,' MONTH ',I3, ' STATION ',I6,'FOUND')
751   FORMAT( '0  STATION NUMBER ON TAPE IS ',I6,' INPUT IS ',I6)
752   FORMAT( '0 SOLAR DATA ENDED AT YEAR ', I3)
753   FORMAT (4I6, (21I5/))
754   FORMAT('0DATA COLLECTION STOPPED AT 1000 POINTS *************'//)
799   FORMAT('1',20A4/'0 NOTE - TENTH HISTOGRAM DIVISION REPRESENTS INVA
     1LID OR MISSING DATA'/)
      END
```

```
      SUBROUTINE EQSUB(ISV)
C
      REAL*4 K
      COMMON /BRUNTC/ BC(10,17),RATBC(10),TABC(17),DRATBC,DTABC
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),DRHEA,DTAEA
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),DSARSR,DCCRSR
      COMMON /INPUT/ A,B,HEAD(20),TMERR,WMULT,IFLAG,HSMULT,IPLOT(6)
     1,A1PRME,A2PRME,RG,DA,DS
C
      COMMON IHIST(5000),NHIST(5),MHIST(4),MBASE(4),IND(4)
C
      DIMENSION YEQ(200),YW(200),YTA(200),YRH(200),YCC(200),YHS(200),
     1 YHSC(200)
      EQUIVALENCE (IHIST(1),YEQ(1)),(IHIST(201),YW(1)),(IHIST(401),
     1 YTA(1)),(IHIST(601),YRH(1)),(IHIST(801),YCC(1)),(IHIST(1001),
     2 YHS(1))
      DIMENSION ISV(7)
C
C     ISV=
C           1     WIND SPEED
C           2     TEMPERATURE
C           3     RELATIVE HUMIDITY
C           4     CLOUD COVER
C           5     SOLAR RADIATION
C           6     SOLAR ELEVATION
C           7     EXTRA TERRESTRIAL RADIATION
C
      IFLAG=IFLAG+1
      IF(IFLAG.NE.1) GO TO 99
      WRITE(6,5)
    5 FORMAT(' THE FOLLOWING SETS OF DATA GIVE INVALID EQUILIBRIUM TEMPE
     1RATURES'/'             W              TA             RH             CC             HS
     2    SA          HSC')
      DO 10 I=1,1200
      IHIST(I)=0.
   10 CONTINUE
   99 CONTINUE
      W=ISV(1)*WMULT
      TA=ISV(2)
      RH=ISV(3)
      CC=ISV(4)
      HS=.1*ISV(5)*HSMULT
      SA=ISV(6)
      HSMUL2=(A2PRME+.5*(1.-A1PRME*DS)-DA)/(1.-.5*RG*(1.-A1PRME+DS))
      HSC=ISV(7)*HSMULT*HSMUL2
      TM=TA
      IW=ISV(1)
      ITA=TA+1
```

```
      IRH=RH+1
      ICC=CC+1
       IHS=.1*ISV(5)+1
      IHSC=ISV(7)+1
      IF(IW.LT.1.OR.IW.GT.200) IW=200
      IF(ITA.LT.1.OR.ITA.GT.200) ITA=200
      IF(ICC.LT.1.OR.ICC.GT.200) ICC=200
      IF(IRH.LT.1.OR.IRH.GT.200) IRH=200
      IF(IHS.LT.1.OR.IHS.GT.200) IHS=200
      YW(IW)=YW(IW)+1
      YTA(ITA)=YTA(ITA)+1
      YRH(IRH)=YRH(IRH)+1
      YCC(ICC)=YCC(ICC)+1
      YHS(IHS)=YHS(IHS)+1
      DO 5000 IND6=1,25
      IF(HSC.NE.0.) GO TO 100
      HR=0.
      GO TO 150
100   CONTINUE
      RATSP=HS/HSC
C
C        CALCULATE HA, FIRST GET VALUE OF BC AND EA
C
      CALL TWOFIT(BC,RATBC,DRATBC,10,TABC,DTABC,17,RATSR,TA,BC1)
      CALL TWOFIT(EA,RHEA,DRHEA,10,TAEA,DTAEA,7,RH,TA,EA1)
      HA=4.15E-8*(TA+460.)**4*(BC1+.031*SQRT(EA1))
C
      HAR = .03*HA
C
C        CALCULATE HSR, FIRST GET VALUE OF RSR
C
      CALL TWOFIT(RSR,SARSR,DSARSR,9,CCRSR,DCCRSR,3,SA,CC,RSR1)
      HSR=RSR1*HS
C
      HR=HA-HAR+HS-HSR
C
C        CALCULATE EXCHANGE COEFFICIENT , FIRST CALCULATE BETA AND C(B)
C
150   CONTINUE
      CALL FBETA(TM,BETA1,CBETA1)
      K= 15.7 +(.26+BETA1)*(A+B*W)
C
      CAPA= .051/K
      CAPB= -((HR-1801.)/K + ((K-15.7)/K)*((EA1-CBETA1+.26*TA)/
     1 (.26+BETA1)))
      TEST=1.-4.*CAPA*CAPB
      IF(TEST.LT.0.) GO TO 6000
      CAPD=SQRT(TEST)
```

```
C
C     CALCULATE  EQUILIBRIUM TEMPERATURE
C
      EQUIL = (-1.+CAPD)/(2.*CAPA)
C
500   FORMAT (F10.2,6F15.2)
       IF(ABS(EQUIL-TM).LE.(TMERR*TM)) GO TO 5001
      TM=EQUIL
 5000 CONTINUE
5001  CONTINUE
      IEQ=EQUIL+1
      IF(IEQ.LT.1)IEQ=200
      IF(IEQ.GT.200) IEQ=200
      YEQ(IEQ)=YEQ(IEQ)+1
      RETURN
 6000 WRITE(6,6)ISV
 6    FORMAT(7I10)
      RETURN
      END
```

```
      SUBROUTINE TWOFIT (FXY,X,DX,M,Y,DY,N,XX,YY,ANS)
      DIMENSION FXY(M,N),X(M),Y(N)
C
      IX= (XX-X(1))/DX   + 1
      IY= (YY-Y(1))/DY   + 1
C
      IF(IX.LE.1) GO TO 110
      IF(IX.GE.M) GO TO 115
      IX1=IX
      IX2=IX+1
      GO TO 120
  110 IX1= 1
      IX2= 2
      GO TO 120
  115 IX1= M-1
      IX2 = M
  120 CONTINUE
C
      IF (IY.LE.1) GO TO 130
      IF (IY.GE.N) GO TO 140
      IY1=IY
      IY2=IY+1
      GO TO 150
  130 IY1=1
      IY2=2
      GO TO 150
  140 IY1= N-1
      IY2= N
  150 CONTINUE
C
      FY1=FXY(IX1,IY1)+((FXY(IX1,IY2)-FXY(IX1,IY1))*(YY-Y(IY1))/DY)
      FY2=FXY(IX2,IY1)+((FXY(IX2,IY2)-FXY(IX2,IY1))*(YY-Y(IY1))/DY)
C
      ANS = FY1 + (FY2-FY1)*((XX-X(IX1))/DX)
C
      RETURN
      ENTRY TOLOOK(FXY,X,DX,M,Y,DY,N,XX,YY,ANS)
C
      IX=(XX-X(1))/DX +1
      IY=(YY-Y(1))/DY +1
C
      IF(IX.LT.1) IX=1
      IF(IX.GT.M) IX=M
C
      IF(IY.LE.1) GO TO 230
      IF(IY.GE.N) GO TO 240
      IY1=IY
      IY2=IY+1
      GO TO 250
 230  IY1=1
      IY2=2
      GO TO 250
240   IY1=N-1
      IY2=N
```

```
250   CONTINUE
      ANS=FXY(IX,IY1)+((FXY(IX,IY2)-FXY(IX,IY1))*(YY-Y(IY1))/DY)
      RETURN
      END

       SUBROUTINE FBETA(TM,BETA1,CBETA1)
      T=TM+460.
      XNT=9501./T
      XNTT=XNT/T
      YNT=EXP(17.62-XNT)
C
      ES=25.4*YNT
      BETA1=25.4*XNTT*YNT
      CBETA1=ES-(TM*BETA1)
      RETURN
      END
```

```
      BLOCK DATA
      COMMON /BRUNTC/ BC(10,17),RATBC(10),TABC(17),DRATBC,DTABC
      DATA RATBC/.50,.55,.60,.65,.70,.75,.80,.85,.90,.95/,
     1     TABC/28.,32.,36.,40.,44.,48.,52.,56.,60.,64.,68.,72.,76.,80.,
     2        84.,88.,92./,
     3     BC/.71,.705,.70,.69,.675,.655,.62,.59,.535,.45,
     4        .72,.715,.71,.70,.685,.665,.64,.605,.555,.48,
     5        .725,.72,.715,.705,.69,.675,.65,.62,.575,.51,
     6       .73,.725,.72,.71,.70,.685,.66,.635,.595,.54,
     7       .735,.73,.725,.715,.705,.695,.67,.65,.615,.56,
     8       .74,.735,.73,.72,.71,.70,.68,.66,.63,.5825,
     9       .74,.74,.735,.725,.715,.71,.69,.67,.6425,.6025,
     *       .74,.74,.74,.73,.72,.715,.70,.6825,.66,.6225,
     1       .74,.74,.74,.735,.725,.72,.705,.69,.67,.64,
     2       .74,.74,.74,.7375,.73,.7225,.71,.70,.68,.655,
     3         .74,.74,.74,.74,.735,.725,.715,.705,.69,.67,
     4         .74,.74,.74,.74,.7375,.73,.72,.71,.70,.6825,
     5       .74,.74,.74,.74,.74,.7325,.725,.715,.71,.70,
     6         .74,.74,.74,.74,.74,.735,.73,.72,.7175,.7075,
     7        .74,.74,.74,.74,.74,.7375,.735,.725,.72,.7125,
     8        .74,.74,.74,.74,.74,.74,.735,.73,.7275,.72,
     9        .74,.74,.74,.74,.74,.74,.735,.735,.735,.73/
      DATA DRATBC/.05/,DTABC/4./
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),DRHEA,DTAEA
      DATA RHEA/10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
      DATA TAEA/40.,50.,60.,70.,80.,90.,100./
      DATA EA/
     1   .50  ,1.10 ,2.00 ,2.50 ,3.00 ,3.80 ,4.50 ,5.00 ,5.50 ,6.00,
     2   1.00 ,2.00 ,2.80 ,3.90 ,4.80 ,5.50 ,6.50 ,7.50 ,8.20 ,9.10,
     3   1.50 ,2.80 ,4.00 ,5.10 ,6.80 ,8.00 ,9.20 ,10.60,12.00,13.10,
     4   2.00 ,4.00 ,5.50 ,7.50 ,9.30 ,11.20,13.00,15.00,17.00,18.80,
     5   2.50 ,5.20 ,8.00 ,10.50,13.00,15.90,18.10,21.00,23.40,26.00,
     6   3.50 ,7.00 ,10.90,14.00,17.90,21.60,25.00,28.80,32.00,36.00,
     7   5.00,10.00,14.90,19.80,24.50,29.30,34.20,39.10,44.00,49.00/
      DATA DRHEA/10./,DTAEA/10./
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),DSARSR,DCCRSR
      DATA SARSR/0.,10.,20.,30.,40.,50.,60.,70.,80./
      DATA CCRSR/3.,6.5,10./
      DATA RSR/.55,.25,.125,.08,.06,.05,.045,.04,.035,
     1         .45,.18,.10,.07,.06,.05,.045,.04,.035,
     2         .25,.14,.09,.075,.06,.055,.05,.045,.04/
      DATA DSARSR/10./,DCCRSR/3.5/
      COMMON /INPUT/ A,B,HEAD(20),TMERR,WMULT,IFLAG,HSMULT,IPLOT(6)
      DATA A,B /0.,11.4/,HEAD/20*'    '/,TMERR/.01/,WMULT/1.15/,
     1 IFLAG/0/,HSMULT/88.47/,IPLOT/1,1,1,1,1,1/
      END
```

```
      SUBROUTINE EQPLT
C
      REAL*4 K
      COMMON /INPUT/ A,B,HEAD(20),TMERR,WMULT,IFLAG,HSMULT,IPLOT(6)
      COMMON IHIST(5000),NHIST(5),MHIST(4),MBASE(4),IND(4)
      DIMENSION YEQ(200),YW(200),YTA(200),YRH(200),YCC(200),YHS(200),
     1 YHSC(200)
      EQUIVALENCE (IHIST(1),YEQ(1)),(IHIST(201),YW(1)),(IHIST(401),
     1 YTA(1)),(IHIST(601),YRH(1)),(IHIST(801),YCC(1)),(IHIST(1001),
     2 YHS(1)),(IHIST(1201),YHSC(1))
      DIMENSION XEQ(200),XW(200),XTA(200),XRH(200),XCC(200),XHS(200),
     1 XHSC(200)
      EQUIVALENCE(IHIST(1401),XEQ(1)),(IHIST(1601),XW(1)),(IHIST(1801),
     1XTA(1)),(IHIST(2001),XRH(1)),(IHIST(2201),XCC(1)),(IHIST(2401),
     2  XHS(1)),(IHIST(2601),XHSC(1))
      DIMENSION YLIST(51)
      DATA YLIST/51*1.E10/,MPAGES/1/,YMIN/0./
      DIMENSION TITLE(20),TTITLE(26)
       DATA TITLE /'    ','    ','    ','    ','    ','    ',
     * '    ','    ','    ',
     1 ' FRE','QUEN','CY O','F OC','CURR','ENCE',
     2 '    ','    ','    ','    '/
      DATA TTITLE/'EQUI','LIBR','IUM ','TEMP','ERAT','URE ',
     1 'WIND',' SPE','ED  ','AIR ','TEMP','ERAT','URE ',
     2 'RELA','TIVE',' HUM','IDIT','Y   ','CLOU','D CO','VER ',
     3 'SOLA','R RA','DIAT','ION ','    '/
C
      WRITE(6,5) IFLAG
 5    FORMAT(' NUMBER OF DATA POINTS = ',I10)
      DO 10 I=1,200
       XEQ(I)=I-1
      XW(I)=I-1
      XTA(I)=I-1
      XRH(I)=I-1
      XCC(I)=I-1
      XHS(I)=I-1
      XHSC(I)=I-1
 10    CONTINUE
      IF(IPLOT(1).NE.1) GO TO 150
      I1=1
      I2=0
      YMAX=0
      DO 100 I=1,130
      IF(YEQ(I).EQ.0.) GO TO 100
      IF(I2.EQ.0) I1=I
      I2=I
      IF(YEQ(I).GT.YMAX) YMAX=YEQ(I)
 100  CONTINUE
      IYMAX=YMAX/5.
      YMAX=10.*IYMAX
       XMIN=XEQ(I1)
      XMAX=XEQ(I2)
       N=XMAX-XMIN +1
      TITLE(1)=TTITLE(1)
```

```
      TITLE(2)=TTITLE(2)
      TITLE(3)=TTITLE(3)
      TITLE(4)=TTITLE(4)
      TITLE(5)=TTITLE(5)
      TITLE(6)=TTITLE(6)
      CALL PPLOT(TITLE,XEQ(I1),YEQ(I1),N,YLIST,XMIN,XMAX,YMIN,YMAX,
     1 MPAGES)
 150  CONTINUE
      IF(IPLOT(2).NE.1) GO TO 250
      I1=1
      I2=0
      YMAX=0
      DO 200 I=1,100
      IF(YW(I).EQ.0.) GO TO 200
      I2=I
      IF(YW(I).GT.YMAX) YMAX=YW(I)
 200  CONTINUE
      IYMAX=YMAX/5.
      YMAX=10.*IYMAX
      XMIN=XW(I1)
      XMAX=XW(I2)
      N=XMAX-XMIN+1
      TITLE(1)=TTITLE(7)
      TITLE(2)=TTITLE(8)
      TITLE(3)=TTITLE(9)
      TITLE(4)=TTITLE(26)
      TITLE(5)=TTITLE(26)
      TITLE(6)=TTITLE(26)
      CALL PPLOT(TITLE,XW(I1),YW(I1),N,YLIST,XMIN,XMAX,YMIN,YMAX,MPAGES)
 250  CONTINUE
      IF(IPLOT(3).NE.1) GO TO 350
      I1=1
      I2=0
      YMAX=0
      DO 300 I=1,120
      IF(YTA(I).EQ.0.) GO TO 300
      IF(I2.EQ.0) I1=I
      I2=I
      IF(YTA(I).GT.YMAX) YMAX=YTA(I)
 300    CONTINUE
      IYMAX=YMAX/5.
      YMAX=IYMAX*10
      XMIN=XTA(I1)
      XMAX=XTA(I2)
      N=XMAX-XMIN +1
      TITLE(1)=TTITLE(10)
      TITLE(2)=TTITLE(11)
      TITLE(3)=TTITLE(12)
      TITLE(4)=TTITLE(13)
      TITLE(5)=TTITLE(26)
      TITLE(6)=TTITLE(26)
      CALL PPLOT(TITLE,XTA(I1),YTA(I1),N,YLIST,XMIN,XMAX,
     1 YMIN,YMAX,MPAGES)
 350  CONTINUE
```

```
      IF(IPLOT(4).NE.1) GO TO 450
      I1=1
      I2=0
      YMAX=0
      DO 400 I=1,100
      IF(YRH(I).EQ.0.) GO TO 400
      IF(I2.EQ.0) I1=I
      I2=I
      IF(YRH(I).GT.YMAX) YMAX=YRH(I)
400     CONTINUE
      IYMAX=YMAX/5.
      YMAX=IYMAX*10
      XMIN=XRH(I1)
      XMAX=XRH(I2)
       N=XMAX-XMIN +1
      TITLE(1)=TTITLE(14)
      TITLE(2)=TTITLE(15)
       TITLE(3)=TTITLE(16)
      TITLE(4)=TTITLE(17)
      TITLE(5)=TTITLE(18)
      TITLE(6)=TTITLE(26)
      CALL PPLOT(TITLE,XRH(I1),YRH(I1),N,YLIST,XMIN,XMAX,
     1 YMIN,YMAX,MPAGES)
450   CONTINUE
      IF (IPLOT(5).NE.1) GO TO 550
      I1=1
      I2=0
      YMAX=0
      DO 500 I=1,11
      IF(YCC(I).EQ.0.) GO TO 500
      I2=I
      IF(YCC(I).GT.YMAX) YMAX=YCC(I)
500     CONTINUE
      IYMAX=YMAX/5.
      YMAX=IYMAX*10
      XMIN=XCC(I1)
      XMAX=XCC(I2)
       N=XMAX-XMIN +1
      TITLE(1)=TTITLE(19)
       TITLE(2)=TTITLE(20)
      TITLE(3)=TTITLE(21)
      TITLE(4)=TTITLE(26)
      TITLE(5)=TTITLE(26)
      TITLE(6)=TTITLE(26)
      CALL PPLOT(TITLE, XCC(I1),YCC(I1),N,YLIST,XMIN,XMAX,
     1 YMIN,YMAX,MPAGES)
550   CONTINUE
      IF(IPLOT(6).NE.1) GO TO 650
      I1=1
      I2=0
      YMAX=0
      DO 600 I=1,200
      IF(YHS(I).EQ.0.) GO TO 600
      IF(I2.EQ.0) I1=I
```

```
      I2=I
      IF(YHS(I).GT.YMAX) YMAX=YHS(I)
  600   CONTINUE
      IYMAX=YMAX/5.
      YMAX=IYMAX*10
      XMIN=XHS(I1)
      XMAX=XHS(I2)
       N=XMAX-XMIN +1
      TITLE(1)=TTITLE(22)
      TITLE(2)=TTITLE(23)
      TITLE(3)=TTITLE(24)
      TITLE(4)=TTITLE(25)
       TITLE(5)=TTITLE(26)
      TITLE(6)=TTITLE(26)
      CALL PPLOT(TITLE,XHS(I1),YHS(I1),N,YLIST,XMIN,XMAX,
     1 YMIN,YMAX,MPAGES)
  650 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PPLOT (HEADNG,XX,YY,M,VARY,XMIN,XMAX,YMIN,YMAX,MPAGES)
      REAL LINE,BLANK/' '/,DOT/'.'/,X/'X'/,O/'O'/,Y/'Y'/,PLUS/'+'/
      REAL AST/'*'/
      DIMENSION LINE(112),XX(100),YY(100),YAXIS(20),XAXIS(101)
      DIMENSION VARY(101), HEADNG(20)
      WRITE (6,9) HEADNG
   10 DYMXMN = YMAX - YMIN
      YAXIS(1) = YMIN
      GO TO (12,14), MPAGES
   12 XSPACE = 50.0
      MSPACE = 51
      GO TO 16
   14 XSPACE = 100.0
      MSPACE = 101
   16 DO 20  K=2,11
   20 YAXIS(K) = YAXIS(K-1) + 0.1*DYMXMN
   30 IF (DYMXMN - 1000.0) 40,100,100
   40 IF (YMAX - 1000.0) 50,100,100
   50 IF (YMIN + 100.0) 100,100,60
   60 IF (ABS(YMIN) - (1.0E-02)) 70,70,80
   70 IF (YMIN) 100,80,100
   80 IF (ABS(YMAX) - (1.0E-02)) 90,90,110
   90 IF (YMAX) 100,110,100
  100 WRITE (6,1) (YAXIS(K), K=2,11)
      GO TO 120
  110 WRITE (6,2) (YAXIS(K), K=2,11)
  120 DO 130 J=1,112
  130 LINE(J) = BLANK
      WRITE (6,3) LINE
      KOUNT = 0
      IF (XMIN) 140,170,170
  140 IF (XMAX) 170,170,150
  150 DO 160  J=10,112
  160 LINE(J) = BLANK
      GO TO 200
  170 DO 180  J=10,110
  180 LINE(J) = DOT
      DO 190  J=10,110,10
  190 LINE(J) = PLUS
      LINE(111) = BLANK
      LINE(112) = Y
  200 DXMXMN = XMAX - XMIN
      XAXIS(1) = XMIN
      DO 210  KK=11,MSPACE,10
  210 XAXIS(KK) = XAXIS(KK-10) + (10.0/XSPACE)*DXMXMN
      KK = 1
      XINVL = DXMXMN/XSPACE
      VARX = XMIN
  220 DO 770  L=1,MSPACE
      IF (YMIN) 230,260,260
  230 JY = (100.0/DYMXMN)*ABS(YMIN) + 9.5
      IF (JY-110) 250,240,240
  240 JY = 9
  250 LINE(JY+1) = DOT
```

```
      GO TO 270
  260 LINE(10) = DOT
      JY = 9
  270 IF (L-1) 280,330,280
  280 IF (L-11) 290,340,290
  290 IF (L-21) 300,340,300
  300 IF (L-31) 310,340,310
  310 IF (L-41) 320,340,320
  320 IF (L-51) 321,340,321
  321 GO TO (430,322),MPAGES
  322 IF (L-61) 323,340,323
  323 IF (L-71) 324,340,324
  324 IF (L-81) 325,340,325
  325 IF (L-91) 326,340,326
  326 IF (L-101) 430,340,430
  330 LINE(JY+1) = X
      GO TO 430
  340 LINE(JY+1) = PLUS
      KK = L
      IF (DXMXMN - 1000.0) 350,410,410
  350 IF (XMAX -1000.0) 360,410,410
  360 IF (XMIN + 100.0) 410,410,370
  370 IF (ABS(XMIN) - (1.0E-02)) 380,380,390
  380 IF (XMIN) 410,390,410
  390 IF (ABS(XMAX) - (1.0E-02)) 400,400,420
  400 IF (XMAX) 410,420,410
  410 WRITE(6,4) XAXIS(KK)
      GO TO 430
  420 WRITE (6,5) XAXIS(KK)
  430 IF ((VARX + XINVL/2.0) - ABS(VARX)) 480,440,440
  440 KOUNT = KOUNT + 1
      IF (KOUNT - 1) 480,450,480
  450 DO 460  J=10,110
  460 LINE(J) = DOT
      DO 470  J=20,110,10
  470 LINE(J) = PLUS
      LINE(111) = BLANK
      LINE(112) = Y
  480 K = 0
      KMAX = 0
      DO 530  I=1,M
      TRY = XX(I) - VARX
      TTRY = TRY - (XINVL/2.0)
      IF (TTRY) 490,530,530
  490 IF (TTRY + XINVL) 500,510,510
  500 GO TO 530
  510 K = (YY(I) - YMIN)*100.0/DYMXMN + 9.5
      IF (K-111) 512,525,525
  512 IF (8-K) 515,525,525
  515 LINE(K+1) = O
      IF (KMAX - K) 520,530,530
  520 KMAX = K
      GO TO 530
  525 K = 0
```

```
530 CONTINUE
    J = (VARY(L) - YMIN)*100.0/DYMXMN + 9.5
    IF (J-111) 540,580,580
540 IF (8-J) 550,580,580
550 IF (LINE(J+1) - O) 570,560,570
560 LINE(J+1) = O
    GO TO  590
570 LINE(J+1) = AST
    GO TO 590
580 J = 0
590 J1 = J + 1
    K1 = KMAX + 1
    JY1 = JY + 1
    IF (LINE(112) - Y) 600,720,600
600 IF (JY - J) 620,610,610
610 IF (JY - K) 660,630,630
620 IF (J - K) 660,690,690
630 IF (L - KK) 640,650,640
640 WRITE (6,3) (LINE(JJ), JJ=10,JY1)
    GO TO 750
650 WRITE (6,6) (LINE(JJ), JJ=10,JY1)
    GO TO 750
660 IF (L - KK) 670,680,670
670 WRITE (6,3) (LINE(JJ), JJ=10,K1)
    GO TO 750
680 WRITE (6,6) (LINE(JJ), JJ=10,K1)
    GO TO 750
690 IF (L - KK) 700,710,700
700 WRITE (6,3) (LINE(JJ), JJ=10,J1)
    GO TO 750
710 WRITE (6,6) (LINE(JJ), JJ=10,J1)
    GO TO 750
720 IF (L - KK) 740,730,740
730 WRITE (6,6) (LINE(JJ), JJ=10,112)
    GO TO 750
740 WRITE (6,3) (LINE(JJ), JJ=10,112)
750 DO 760  J=10,112
760 LINE(J) = BLANK
    VARX = VARX + XINVL
770 CONTINUE
    IF (DXMXMN - 1000.0) 780,870,870
780 IF (XMAX - 1000.0) 790,870,870
790 IF (DYMXMN - 1000.0) 800,870,870
800 IF (YMAX - 1000.0) 810,870,870
810 IF (YMIN + 100.0) 870,870,820
820 IF (ABS(YMIN) - (1.0E-02)) 870,870,830
830 IF (ABS(YMAX) - (1.0E-02)) 870,870,840
840 IF (XMIN + 100.0) 870,870,850
850 IF (ABS(XMIN) - (1.0E-02)) 870,870,860
860 IF (ABS(XMAX) - (1.0E-02)) 870,870,880
870 WRITE (6,7) XMIN,XMAX,YMIN,YMAX
    GO TO 900
880 WRITE (6,8) XMIN,XMAX,YMIN,YMAX
  1 FORMAT (/,16X,1PE9.2,9(1X,1PE9.2))
```

```
  2 FORMAT (/,17X,F7.3,9(3X,F7.3))
  3 FORMAT (1H ,9X,103A1)
  4 FORMAT (' ',1PE9.2)
  5 FORMAT (' ',F9.4)
  6 FORMAT ('+',9X,103A1)
  7 FORMAT (/,14X,'XMIN = ',1PE12.5,5X,'XMAX = ',1PE12.5,
   1 /,14X,'YMIN = ',1PE12.5,5X,'YMAX = ',1PE12.5)
  8 FORMAT (/,14X,'XMIN = ',F10.6,5X,'XMAX = ',F10.6,
   1 /,14X,'YMIN = ',F10.6,5X,'YMAX = ',F10.6)
  9 FORMAT ('1',20A4)
900 RETURN
    END
```

```
      SUBROUTINE HIST(ND)
C
C     COMPUTE AND OUTPUT MEANS, CONDITIONAL MEANS AND NORMALIZED
C        MATRICES ALL BASED ON FIRST VARIABLE SELECTED.
C     OTHER ROUTINES TO PROCESS   IHIST CAN BE WRITTEN
C     THIS SUBROUTINE COMPUTES AND OUTPUTS IN TERMS OF CLASSES
C
      COMMON    IHIST,NHIST,MHIST,MBASE,IND
      DIMENSION      NHIST(5),MHIST(4),MBASE(4),IND(4)
      INTEGER*2 IHIST(10,10,10,10)
      EQUIVALENCE   (IND(1),I1),  (IND(2),I2), (IND(3),I3), (IND(4),I4)
C
C
      COMMON  /PCOM/ IPT(150),APT(100),IS(20)
      DIMENSION      ISV(10),PMS(10),FACT(10),APUT(10,10)
      INTEGER*2 IPUT(10,10,3),IADD
      EQUIVALENCE  (IPUT(1,1,1),IPT)
     1,               (IS(1),ISV(1)),      (APT(1),APUT(1,1))
C
      DATA ZR/0./
      DO 20 I=1,10
      PMS(I)=0.
 20   ISV(I)=0
      DO  50  I = 1,150
 50   IPT(I)=0
      MAX=0
C     BREAK UP INTO THREE SEPARATE MATRICES
      DO 200  K1=1,I1
      DO 200  K2=1,I2
      DO 200  K3=1,I3
      DO 200  K4=1,I4
      IADD = IHIST(K1,K2,K3,K4)
C     FIND MAXIMUM FREQUENCY FOR SAMPLE OUTPUT
      IF(IADD .GT. MAX) MAX = IADD
      ISV(K1)= ISV(K1)+IADD
      IPUT(K1,K2,1)= IPUT(K1,K2,1)+IADD
      IPUT(K1,K3,2)= IPUT(K1,K3,2)+IADD
      IPUT(K1,K4,3)= IPUT(K1,K4,3)+IADD
 200  CONTINUE
      WRITE(6,702)
      MS=0
C
C     COMPUTE  MEAN FOR FIRST PARAMETER
C
      M=0
      DO  250  I=1,9
      M=M+ISV(I)*I
 250  MS=MS+ISV(I)
      EM=M
      EMS=MS
      EMEAN = EM/EMS
      WRITE (6,700)  NHIST(1),EMEAN,ISV
C
C     DO CALCULATIONS FOR PAIRS OF (K1,KI)
```

```
C
      DO  400  I=1,3
      IF( IND(I+1) .EQ. 1) GO TO 405
      DO 325   K1=1,I1
      IF( ISV(K1) .EQ. 0) GO TO 325
      M=0
      DO  300 KK=1,9
      IADD=IPUT(K1,KK,I)
  300 M= M+ IADD*KK
      EM=M
      EMS= ISV(K1)
      PMS(K1) = EM/EMS
  325 CONTINUE
C
C     NORMALIZE AND OUTPUT MATRICES
C
      DO 350   KK=1,9
      M=0
      DO 340 K1=1,9
  340 M= M+IPUT(K1,KK,I)
      IF(M .NE. 0) GO TO 343
      DO 342 K1=1,9
  342 APUT(K1,KK) =0.
      EM=0.
      GO TO 346
  343 EM=M
      EM=EM/100.
      DO  345  K1=1,9
  345 APUT(K1,KK)  =IPUT(K1,KK,I)/EM
  346 CONTINUE
      FACT(KK)=EM
C     RECORD INVALID DATA BY CLASS
      DO  349 K1=1,I1
  349 APUT(10,K1) =IPUT(10,K1,I)
  350 CONTINUE
      J=NHIST(I+1)
      WRITE(6,701)  J, ((APUT(K1,KK),K1=1,9),FACT(KK),KK=1,9),PMS
  400 CONTINUE
  405 CONTINUE
C
C     WRITE SUBSET OF IHIST FOR CHECK OF DISTRIBUTION
C
C     OUTPUT ALL POINTS OF FREQUENCY .GE. MAX/2
      MAX=MAX/2
      WRITE(6,714)
      DO 500 K1=1,I1
      DO 500 K2=1,I2
      DO 500 K3=1,I3
      DO 500 K4=1,I4
      IADD = IHIST(K1,K2,K3,K4)
      IF(IADD .GE. MAX) WRITE (6,715) K1,K2,K3,K4,IADD
  500 CONTINUE
      RETURN
  700 FORMAT('0 MEAN CLASS NUMBER FOR PARAMETER NUMBER ',I3,' IS ',
```

```
   1 F6.2/' FREQUENCIES OF DATA IN EACH CLASS ARE '/1X,10I10//
   2' NORMALIZED DATA BY CLASS FOR EACH PAIR FOLLOWS. COLUMN 10 IS NOR
   3MALIZING FACTOR'/' ROW 10 IS MEAN (BY CLASS) FOR EACH COLUMN'/)
701 FORMAT('0',I3/(9F10.2,10X,F10.2))
702 FORMAT('1 FREQUENCY TABLES OF DATA BY PAIRS'/' FIRST PARAMETER SPE
   1CIFIED IS ALWAYS FIRST PARAMETER OF EACH PAIR, AND EACH CLASS IS A
   2 COLUMN'///)
703 FORMAT('0'/(10I10))
714 FORMAT('1  SUBSET OF EMPIRICAL DISTRIBUTIONS ')
715 FORMAT( 5I10)
    END
```

```
      SUBROUTINE  INDTST(KD,ND)
C
C
C     TEST INDEPENDENCE OF ALL DATA PAIRS USING SPEARMAN RANK
C         CORRELATION COEFFICIENT, AND OF ALL DATA TOGETHER USING
C         KENDALL COEFFICIENT OF CONCORDANCE
C
C
C     THIS SUBROUTINE DESTROYS THE INPUT DATA
C
      COMMON    X(1000,5)
     1         ,     NHIST(5)
      DIMENSION      XR(1000,5),WORK(2000),XX(5000)
      EQUIVALENCE    (XX(1),X(1,1))
C
      WRITE (6,700) KD
      DO 100 I=1,ND
      CALL RANK(X(1,I),XR(1,I),KD)
  100 CONTINUE
      I2=ND-1
      DO  150 I=1,I2
      I3=I+1
      DO  150  IJ=I3,ND
      CALL SRANK(XR(1,I),XR(1,IJ),X,KD,TAU,SD,NDF,1)
      WRITE(6,705)  NHIST(I),NHIST(IJ),TAU,SD
  150 CONTINUE
      IF( ND .EQ. 2) GO TO 200
      I2=1
      DO 180 K=1,KD
      DO 175 I=1,ND
      XX(I2) =XR(K,I)
  175 I2=I2+1
  180 CONTINUE
      CALL WTEST (X,XR,ND,KD,WORK,TAU,SD,NDF,1)
      WRITE(6,706) TAU,SD
  200 RETURN
  700 FORMAT(' INDEPENDENCE TESTS. NUMBER OF DATA POINTS IS ',I6/
     1'0',10X,'VARIABLE NUMBER',6X,'VS. VARIABLE NUMBER',6X,'RANK CORR.
     2COEF',8X,'SIGNIFICANCE PARAMETER' /)
  705 FORMAT(25X,I2,23X,I2,2E20.8)
  706 FORMAT('0 ALL VARIABLES',42X,2E20.8)
      END
```

```
      SUBROUTINE DIST(ND)
C
C     OPTION CODES INPUT IN IDPT ARE
C             0    STOP
C             1    NORMAL
C             2    EXPONENTIAL
C             5    USEDST (USER CODED -DUMMY AT PRESENT)
C
C
C
C
C     THIS PROGRAM USES A NON STANDARD VERSION OF THE SSP SUBROUTINE
C          KOLMO WHICH ALLOWS SPECIFICATION OF SUBROUTINE USEDST THROUGH
C          THE CALLING SEQUENCE
C
      EXTERNAL USEDST
      COMMON   X(1000,5),NHIST(5),MHIST(4),MBASE(4),IND(4)
      COMMON   /DSTCM/KMN(5),MEAN(5),MSD(5),KD(5),IDPT(3),IINT
      DO  200  I=1,ND
      KP=KD(I)
      IF( KP .EQ. 0) GO TO 200
      DK =KMN(I)
      DKM= DK-1.
      ISRT=0
      SMD= MSD(I)
      SMEAN = MEAN(I)
      SMEAN = SMEAN/DK
      SDEV =(SMD-DK*SMEAN*SMEAN)/DKM
      SDEV = SQRT(ABS(SDEV))
      WRITE(6,700) NHIST(I),KMN(I),KP,SMEAN,SDEV
      DO 150 IT=1,3
      IF( IDPT(IT) .EQ. 0) GO TO 200
      CALL KOLMO  (X(1,I),KP,Z,PROB,IDPT(IT),SMEAN,SDEV,IER,ISRT,USEDST)
      ISRT = 1
      WRITE( 6,701) IDPT(IT),Z,PROB,IER
  150 CONTINUE
  200 CONTINUE
      RETURN
  700 FORMAT('0 DISTRIBUTION TESTS FOR VARIABLE NUMBER ',I2/10X,I6,
     1' POINTS USED FOR MEAN ',I6,' POINTS USED FOR TEST ' /10X, E15.4
     2,' SAMPLE MEAN ',10X,E15.4,' SAMPLE STANDARD DEVIATION ')
  701 FORMAT(10X,'KOLMO OPTION ',I2,' Z ', E15.4,' PROB ',E15.4,' IER'
     1, I2)
      END
```

```
      SUBROUTINE  KOLMO(X,N,Z,PROB,IFCOD,U,S,IER,ISRT,USEDST)
      DIMENSION X(1)
C
C            NON DECREASING ORDERING OF X(I)'S  (DUBY METHOD)
C
      IER=0
      IF(ISRT .NE. 0)  GO TO 100
      DO 5 I=2,N
      IF(X(I)-X(I-1))1,5,5
    1 TEMP=X(I)
      IM=I-1
      DO 3 J=1,IM
      L=I-J
      IF(TEMP-X(L))2,4,4
    2 X(L+1)=X(L)
    3 CONTINUE
      X(1)=TEMP
      GO TO 5
    4 X(L+1)=TEMP
    5 CONTINUE
C
C             COMPUTES MAXIMUM DEVIATION DN IN ABSOLUTE VALUE BETWEEN
C             EMPIRICAL AND THEORETICAL DISTRIBUTIONS
C
  100 CONTINUE
      NM1=N-1
      XN=N
      DN=0.0
      FS=0.0
      IL=1
    6 DO 7  I=IL,NM1
      J=I
      IF(X(J)-X(J+1))9,7,9
    7 CONTINUE
    8 J=N
    9 IL=J+1
      FI=FS
      FS=FLOAT(J)/XN
      IF(IFCOD-2)10,13,17
   10 IF(S)11,11,12
   11 IER=1
      GO TO 29
   12 Z =(X(J)-U)/S
      CALL NDTR(Z,Y,D)
      GO TO 27
   13 IF(S)11,11,14
   14 Z=(X(J)-U)/S+1.0
      IF(Z)15,15,16
   15 Y=0.0
      GO TO 27
   16 Y=1.-EXP(-Z)
      GO TO 27
   17 IF(IFCOD-4)18,20,26
   18 IF(S)19,11,19
```

```
   19 Y=ATAN((X(J)-U)/S)*0.3183099+0.5
      GO TO 27
   20 IF(S-U)11,11,21
   21 IF(X(J)-U)22,22,23
   22 Y=0.0
      GO TO 27
   23 IF(X(J)-S)25,25,24
   24 Y=1.0
      GO TO 27
   25 Y=(X(J)-U)/(S-U)
      GO TO 27
 26   Y= USEDST(X(J),U,S)
   27 EI=ABS(Y-FI)
      ES=ABS(Y-FS)
      DN=AMAX1(DN,EI,ES)
      IF(IL-N)6,8,28
C
C             COMPUTES Z=DN*SQRT(N)  AND  PROBABILITY
C
   28 Z=DN*SQRT(XN)
      CALL SMIRN(Z,PROB)
      PROB=1.0-PROB
   29 RETURN
      END

      FUNCTION USEDST(X,U,S)
      USEDST=0.
      RETURN
      END
```

```
C
C     PROGRAM TO PROCESS ONE YEAR (PORTLAND) TAPE
C        THIS IS A SUBSET,WITH FORMAT CHANGES, OF THE THERMOS PROGRAM
C
C     ENVIRONMENTAL SYSTEMS LABORATORY   -L.PATMORE-(408) 734-2244
C
C        THIS PROGRAM PRODUCES JOINT DISTRIBUTIONS(BY CLASS),PERFORMS
C        INDEPENDENCE TESTS AND FITS TO DISTRIBUTIONS (ON OPTION FLAG).
C
C        PROGRAMS INCLUDED WITH THIS PACKAGE ARE HIST,INDTST,DIST, AND
C        THEIR SUBPROGRAMS.
C
C          THE IBM SCIENTIFIC SUBROUTINE PACKAGE IS USED.
C
C
C
C
C     COMMON FOR ALL OPTIONS
      COMMON   IHIST,NHIST,MHIST,MBASE,IND
      INTEGER *2    IHIST(10,10,10,10)
      DIMENSION     NHIST(5),MHIST(4),MBASE(4),IND(4)
     1,             JHIST(5),IDATA(10),ISV(7),IZR(5000),ILOC(4)
     2,             HEX(10,3),X(1000,5)
      EQUIVALENCE   (ITT,ATT)
     1,  (JHIST(1),J1), (JHIST(2),J2),(JHIST(3),J3),(JHIST(4),J4)
     2,  (IHIST(1,1,1,1),IZR(1))
     3,             (ITST,TST),  (IHIST(1,1,1,1),X(1,1))
C
C
C     COMMON FOR  DISTRIBUTION FIT
C
      COMMON    /DSTCM/KMN(5),MEAN(5),MSD(5),KD(5),IDPT(3),IINT
C
C
      DATA      AST/'*   '/,BL/'    '/,ILOC/5,7,9,10/,IOUT/0/,NDELT/1/
     1, IYAR/0/,IYEAR/2/,MNTH1/6/,MNTH2/8/,MHOUR/11/,NHOUR/14/,HEX/
     4 ZC0404040,   ZC1404040,ZC2404040,ZC3404040,ZC4404040,ZC5404040,
     5 ZC6404040,   ZC7404040,ZC8404040,ZC9404040,ZD0404040,ZD1404040,
     6 ZD2404040,   ZD3404040,ZD4404040,ZD5404040,ZD6404040,ZD7404040,
     7 ZD8404040,   ZD9404040,ZF0404040,ZF1404040,ZF2404040,ZF3404040,
     8 ZF4404040,   ZF5404040,ZF6404040,ZF7404040,ZF8404040,ZF9404040/
     9,XHEX/Z60404040/
C
C
C
      NAMELIST /TEMPS/  IOUT,NMREC,NDELT,IYAR,MNTH,IYEAR,MNTH1,MNTH2
     1,        MHOUR,NHOUR,NHIST,MHIST,MBASE,HEAD
     2,        ISURF,ISLST,IPTN,IINT,IDPT
C
C     READ      OUTPUT OPTION (OUTPUT EVERY IOUT RECORDS)
C               START YEAR MONTH     (IF ZERO USE FIRST ON TAPE)
C                 PROCEED FOR DELTA YEARS,DATA IN MNTH1 TO MNTH2
C     PROCESS DATA IN WINDOW HOUR TO HOUR2, HISTOGRAMS CHOSEN IN NHIST
C       IPTN =  RUN OPTION
```

```
C               =1   NOT AVAILABLE FOR THIS TYPE OF INPUT TAPE
C                MISSING DATA
C
C
C           =2 COMPUTE CONDITIONAL DISTRIBUTIONS,MEANS,ETC.
C              SECTION 10 IN THIS VERSION IS SAVED FOR INVALID OR
C                   CHOOSE 1-4 PARAMETERS IN NHIST
C
C
C           =3 INDEPENDENCE TESTS
C                      CHOOSE  2-4 PARAMETERS IN NHIST
C           =4 DISTRIBUTION FITS
C                      CHOOSE  1-4 PARAMETERS,ALSO IDPT AND IINT.BE SURE
C                    THAT IINT DOES NOT RESULT IN ONLY A SUBSET OF THE
C                    HOURS BEING USED TO COMPUTE THE SAMPLE STATISTICS.
C
C
C     START  RUN WITH EVERYTHING ZERO  BUT DO NOT RETURN HERE, NEXT CASE
C     TO ALLOW MINIMUM OF CHANGES WITH NAMELIST.
      DO 1 I=1,4
      NHIST(I)=0
      MHIST(I)=0
 1    MBASE(I)=0
      NHIST(5)=0
 10     IFLAG=0
      READ(5,TEMPS,END=999)
C
C     INITIALIZE  ALL  OPTIONS
C
      IKD=0
      IF (MNTH1 .EQ. 0) MNTH1 = 1
      IF (MNTH2 .EQ. 0) MNTH2 = 12
      IF(NDELT .EQ. 0) NDELT=1
      IDELT = NDELT
      ICMP=IOUT
      IF(ICMP .EQ. 0) ICMP=1
      ND=0
      ISOL =0
      IF(IPTN  .EQ. 1)  IPTN=2
C
C     INITIALIZE HISTOGRAMS,INDEPENDENCE TESTS,DISTRIBUTION FITS
C
 11   CONTINUE
      DO  15 I=1,4
      IF(NHIST(I) .EQ. 0) GO  TO  17
      ND=ND+1
 15   CONTINUE
C
 17   GO TO (19,16 ,19,18),IPTN
C
C     HISTOGRAM OPTION ONLY
 16   DO 12 I=1,4
      JHIST(I)=1
 12   IND(I)=1
```

```
      DO 13 I=1,ND
 13   IND(I)=10
      DO 14 J=1,5000
 14   IZR(J)=0
      GO  TO 19
C
C     DISTRIBUTION FITS ONLY
C
 18   CONTINUE
      DO 185 I=1,5
      KD(I)=0
      KMN(I)=0
      MEAN(I)=0
      MSD(I)=0
 185  CONTINUE
      ITSD=IINT
C     NOW HAVE COUNTED NUMBER OF HISTOGRAMS TO DO AND CLEARED SPACE
 19   CONTINUE
      WRITE(6,699)
      WRITE(6,700)  NDELT,IYAR,IYEAR,MNTH1,MNTH2,MHOUR,
     1  NHOUR,NHIST,MHIST,MBASE,IOUT
C
C     INITIALIZATION OF INPUT FINISHED
C
 40   IYUR = IYAR +IYEAR-1
 45   CONTINUE
 50   READ(12,801,END=550) IDATA
      IF(IYAR .NE. 0)  GO TO 55
      IYAR=IDATA(1)
      IYUR=IYUR+IYAR
 55   CONTINUE
      IF( IDATA(1)-IYUR) 75,70,550
 70   IF( IDATA (2).GT.  MNTH2)  GO TO 550
C                                       REJECT RECORD
 75   IF(IDATA(2) .LT.MNTH1  .OR. IDATA(2) .GT. MNTH2) GO TO 45
      IF( IDATA(4)  .LT. MHOUR  .OR. IDATA(4) .GT. NHOUR) GO TO 45
 121  CONTINUE
      IF(ICMP .NE. IOUT) GO TO 125
      WRITE(6,701) IDATA
       ICMP=0
 125  ICMP=ICMP+1
C
C     ACCEPTED RECORD
C
C
C     USE EVERY IDELT DATA POINTS(NECESSARY FOR OPTIONS WHERE DATA IS
C       BEING SAVED)
C
      IF(IDELT .EQ. NDELT ) GO TO 130
      IDELT= IDELT+1
      GO TO 175
 130  DO  150  I=1,ND
C
C     DEFAULT VALUES
```

```
C     NO DATA
      ISV(I)=-1
      JHIST(I)=10
C     COMBINE NUMERIC AND ALPHA PART OF DATA
C
 139  CONTINUE
      L=  ILOC(NHIST(I))
      ITST= IDATA(L)
      IF( L.EQ. 9)  GO TO 148
      IF( TST .EQ. AST  .OR.  TST  .EQ. BL)  GO TO 142
C
C     CHECK FOR CLOUD COVER MEASUREMENT EQUAL TO X -OVERCAST
C
      IF( L .NE. 10  .OR. TST .NE. XHEX) GO TO 1395
      ITST=10
      GO TO 148
 1395 CONTINUE
      DO  140  K2=1,3
      DO  140  K3=1,10
      IF(TST .NE. HEX(K3,K2)) GO TO 140
      ITST=K3-1
      GO TO 145
 140  CONTINUE
 142  GO TO (175,150,175,150),IPTN
 145  IF( L.EQ. 10)  GO TO 148
      ITST = ITST*10 + IDATA(L+1)
      IF( K2 .EQ. 2)  ITST= -ITST
C     SAVE ALL DATA IF EQUIL OPTION
 148  IF(IPTN .EQ. 2) GO TO 149
      ISV(I)=ITST
      GO TO 150
 149  CONTINUE
      J= ITST-MBASE(I)
      IF(J .LT. 0) J=0
      JHIST(I)= J/MHIST(I) +1
      IF(JHIST(I) .GT. 9) JHIST(I)=9
 150  CONTINUE
      IKD = IKD+1
      IDELT=1
      GO TO (155,170,165,160),IPTN
 155  CONTINUE
      GO TO 175
C     DISTRIBUTIONS - NOT FULL DATA SETS
 160  CONTINUE
C     EACH POINT IS EITHER SAVED OR USED IN SAMPLE STATISTIC.
C
      IF(IINT .NE. ITSD) GO TO 163
      DO 162 I=1,ND
      IJ=ISV(I)
      IF(IJ .LT. 0) GO TO 162
      KMN(I)=KMN(I)+1
      MEAN(I)= MEAN(I)+IJ
      MSD(I) = MSD(I) +IJ*IJ
 162  CONTINUE
```

```
      ITSD=1
      GO TO 175
 163  ITSD = ITSD +1
      DO 164 I=1,ND
      IF(ISV(I) .LT. 0) GO TO 164
      IF (KD(I) .EQ. 1000) GO TO 168
      KD(I)=KD(I)+1
      X(KD(I),I)=ISV(I)
 164  CONTINUE
      GO TO 175
C     INDEPENDENCE TESTS - FULL DATA SETS
 165  DO 167 I=1,ND
 167  X(IKD,I)=ISV(I)
C
C     CHECK X STORAGE NOT EXCEEDED
C
      IF (IKD  .LT. 1000) GO TO 175
 168  CONTINUE
      WRITE (6,754)
      GO TO 550
 170  CONTINUE
      IHIST(J1,J2,J3,J4)=IHIST(J1,J2,J3,J4)+1
 175  CONTINUE
      GO TO 45
C
C
C
C     FINISHED GATHERING DATA TOGETHER AND SORTING
C
 550  CONTINUE
      GO TO (560,570,580,590),IPTN
C
C     EQ. TEMP  AND OTHER PLOTS
C
C     THIS OPTION NOT IN THIS PROGRAM
 560  GO TO 600
C
C     HISTOGRAMS, CONDITIONAL PROBABILITIES,ETC.
C
 570  CONTINUE
      CALL HIST(ND)
      GO TO 600
C     INDEPENDENCE TESTS
 580  CONTINUE
      CALL INDTST(IKD,ND)
      GO TO 600
C
C     TEST OF FIT TO DISTRIBUTION
C
 590  CONTINUE
      CALL DIST(ND)
 600  CONTINUE
      REWIND 12
      GO TO 10
```

```
C
 999  STOP
C
C
C
C     REFERENCE  -  WBAN HOURLY SURFACE OBSERVATIONS DECK 144
 801  FORMAT(5X,4I2,27X,A1,I1,4X,A1,I2,3X,I3,A1)
 699  FORMAT('1PROGRAM FOR TAPES FROM W.B. CARD DECK 144 ')
 700  FORMAT('0 PROCESS EVERY ', I4,' RECORDS, FROM BASE YEAR ',I2,
     1' FOR ',I3,' YEARS'/'0 TIME WINDOW IS FROM
     3MONTH',I6,'TO MONTH',I6,'HOUR',I6,'TO HOUR',I6/
     4  5I5,' CODE NUMBERS OF PARAMETERS'/
     5  4I5,5X,' INTERVAL SIZE FOR CLASSES'/
     6  4I5,5X,' BASE (ZERO POINT) FOR CLASSES'/
     7  '0 OUTPUT IS EVERY',I5,' RECORDS IN WINDOW'//)
 701  FORMAT('0',4I5,3X,A1,I2,3X,A1,I3,3X,I4,3X,A1)
 753  FORMAT (4I6, (21I5/))
 754  FORMAT('0DATA COLLECTION STOPPED AT 1000 POINTS *************'//)
 799  FORMAT('0',20A4/'0 NOTE - TENTH HISTOGRAM DIVISION REPRESENTS INVA
     1LID OR MISSING DATA'/)
      END
```

```
C
C       L.PATMORE       MAY  1972
C
C       CONVERT, COMPACT, REORDER TEN YEAR SOLAR RADIATION TAPES
C       THESE TAPES HAVE MISSING DAYS, BEGINNING BLANK RECORDS
C       AND BEGINNING PORTIONS OF RECORDS BLANK
C
C
        DEFINE FILE    14(132,2109,U,IFND)
        DIMENSION      ISLR(10,16),ASLR(10,16),IPUT(2108),ISV(2),HEX(10,3)
       1, IWROTE(132)
        DATA HEX/
       4 ZC0404040,    ZC1404040,ZC2404040,ZC3404040,ZC4404040,ZC5404040,
       5 ZC6404040,    ZC7404040,ZC8404040,ZC9404040,ZD0404040,ZD1404040,
       6 ZD2404040,    ZD3404040,ZD4404040,ZD5404040,ZD6404040,ZD7404040,
       7 ZD8404040,    ZD9404040,ZF0404040,ZF1404040,ZF2404040,ZF3404040,
       8 ZF4404040,    ZF5404040,ZF6404040,ZF7404040,ZF8404040,ZF9404040/
       1,BLNK/'    '/
        EQUIVALENCE    (ISLR(1,1),ASLR(1,1)),   (ITT,ATT)
        DO 2 I=1,132
  2     IWROTE(I) = 0
        KST=0
        KMX=1
  1     K=1
        IDAY=1
  10    READ (13,803,END=600) ISLR
C
C       TAKE CARE OF POSSIBLE OVERPUNCHES IN DAY-
C         ACCEPT ONLY VALID DAYS
        DO 113 M=1,16
        L=M
C       FIND FIRST NON-BLANK YEAR,MONTH,DAY
        IF(ISLR(2,L) .EQ. 0 .OR. ISLR(3,L) .EQ. 0) GO TO 113
        DO    100 I=1,2
        TST = ASLR(I+3,L)
        IF(TST .EQ. BLNK) GO TO 113
        DO     75  I2=2,3
        DO     75  I3=1,10
        IF(  TST .NE. HEX(I3,I2)) GO  TO 75
        ISV(I)=I3-1
        GO TO 100
  75    CONTINUE
        GO TO 113
C
C       READ TO  A VALID DAY
C
  100   CONTINUE
        GO TO 115
  113   CONTINUE
        GO TO 500
  115   DO 120 I=1,3
        IPUT(K)= ISLR(I,L)
  120   K=K+1
        IPUT(K)= ISV(1)*10+ISV(2)
```

```
C      TAKE POSSIBLE MISSING DAYS INTO ACCOUNT
C
C      IPUT SHOULD NEVER BE LESS THAN IDAY
       IF(IPUT(K) - IDAY) 900,140,130
 130   IDAY = IPUT(K)
 140   CONTINUE
C
C      NOW CONVERT RADIATIONS AND LOAD FULL DAY INTO IPUT
C      MAY INCLUDE INITIAL ZERO RECORDS
C
       K=K+1
       DO 400 I=1,16
       IPUT(K)= ISLR(6,I)
       K=K+1
       IT=0
       ITT= ISLR(7,I)
C      FLAG BLANK RECORDS
       IF (ATT .NE. BLNK) GO TO 190
       IT=-9999
       GO TO 210
 190   DO  200 I2=2,3
       DO  200 I3=1,10
       IF(ATT .NE. HEX(I3,I2)) GO TO 200
       IT = (I3-1)*1000
       GO TO 210
 200   CONTINUE
C
C      ASSUME INVALID CHARACTER IS ZERO (X/BLANK)
C
 210   CONTINUE
       IPUT(K)=ISLR(8,I)+IT
       IPUT(K+1)=ISLR(9,I)
       IPUT(K+2)=ISLR(10,I)
 400   K=K+3
 500   CONTINUE
       IDAY = IDAY+1
       IF(IDAY .LE. 31) GO TO 10
C
C      PUT ONE MONTH ON DISK
C
 525   KPL=K-1
       IF(KPL .EQ. 0) GO TO 530
       KYR=(IPUT(2)-52)*12
       KM = (IPUT(3)-6)
       IF(KM .LE. 0) KM = IPUT(3)+6 -12
C      RECORD NUMBER FOR OUTPUT
       IV= KYR+KM
       IF(KPL.LT.IWROTE(IV)) GO TO 530
       IWROTE(IV) = KPL
C      FIND NUMBER OF RECORDS WRITTEN FOR REREAD
       IF(IV .GT. KMX) KMX=IV
       WRITE(14'IV)  IPUT
 530   IF (KST  .EQ. 0)  GO TO 1
C      FINISHED READING AND SORTING
```

```
 550  CONTINUE
      WRITE(6,720) IWROTE
      DO 650 I=1, KMX
      KPL=IWROTE(I)
      IF(KPL .EQ. 0) GO TO 650
      READ(14'I) IPUT
      IF(I .EQ. KMX) GO TO 615
      K=I+1
      FIND(14'K)
 615  DO 625 L=1,KPL,68
      L2=L+67
      WRITE(12) (IPUT(J),J=L,L2)
 625  CONTINUE
      JW=KPL-67
      WRITE(6,700)  (IPUT(J),J=1,68),(IPUT(J),J=JW,KPL)
 650  CONTINUE
      ENDFILE 12
      REWIND 12
      REWIND 13
      STOP
C
C     END OF INPUT  FILE
C
 600  IF(K .EQ. 1)  GO TO  550
      KST=1
C     FINISH PARTIAL (LAST) MONTH
      GO TO  525
 900  WRITE(6,720)  IPUT(1),IPUT(2),IPUT(3),IDAY,IPUT(K)
      STOP
 700  FORMAT(I6,2I5,25I4/15X,25I4/15X,15I4)
 720  FORMAT(20I6)
 803  FORMAT(16(I5,2I2,2A1,I2,A1,I3,I2,I3,44X))
      END
```

Programs to Calculate Equilibrium Temperature and Its Sensitivity to Meteorological Parameters

One computer program was written that calculates equilibrium temperature over a range of meteorological conditions and outputs the results in tabular form. This program, called EQUIL, calculates equilibrium temperature using the same equations as subroutine EQSUB, i.e., equations 4-2 through 4-12 of Appendix A. A flowchart of EQUIL is shown in Figure 4-28. The listing of program EQUIL follows the flowcharts.

Table A-7 lists the input and other important variables. Figure A-29 shows a sample set of input, and Figure A-30 shows the corresponding output.

Another program (EQUILS) was written that calculates equilibrium temperature and its sensitivity to a change in air temperature, solar radiation, relative humidity, cloud cover, and wind speed. The equations used to calculate the sensitivities are listed in Section IV, equations 4-14 through 4-58. A flowchart of EQUILS is shown in Figure A-31. The listings of EQUILS and its associated block data follows the flowchart.

This program was designed in a modular form so that if any equation was changed, its partials could be updated and the rest of the program would not need to be changed. For example, if the equation for long wave solar radiation, (HA), is changed the subroutine that calculates this value, (subroutine XHA), must be altered by replacing the equation for HA and the equation defining the partials with respect to the meteorological parameters.

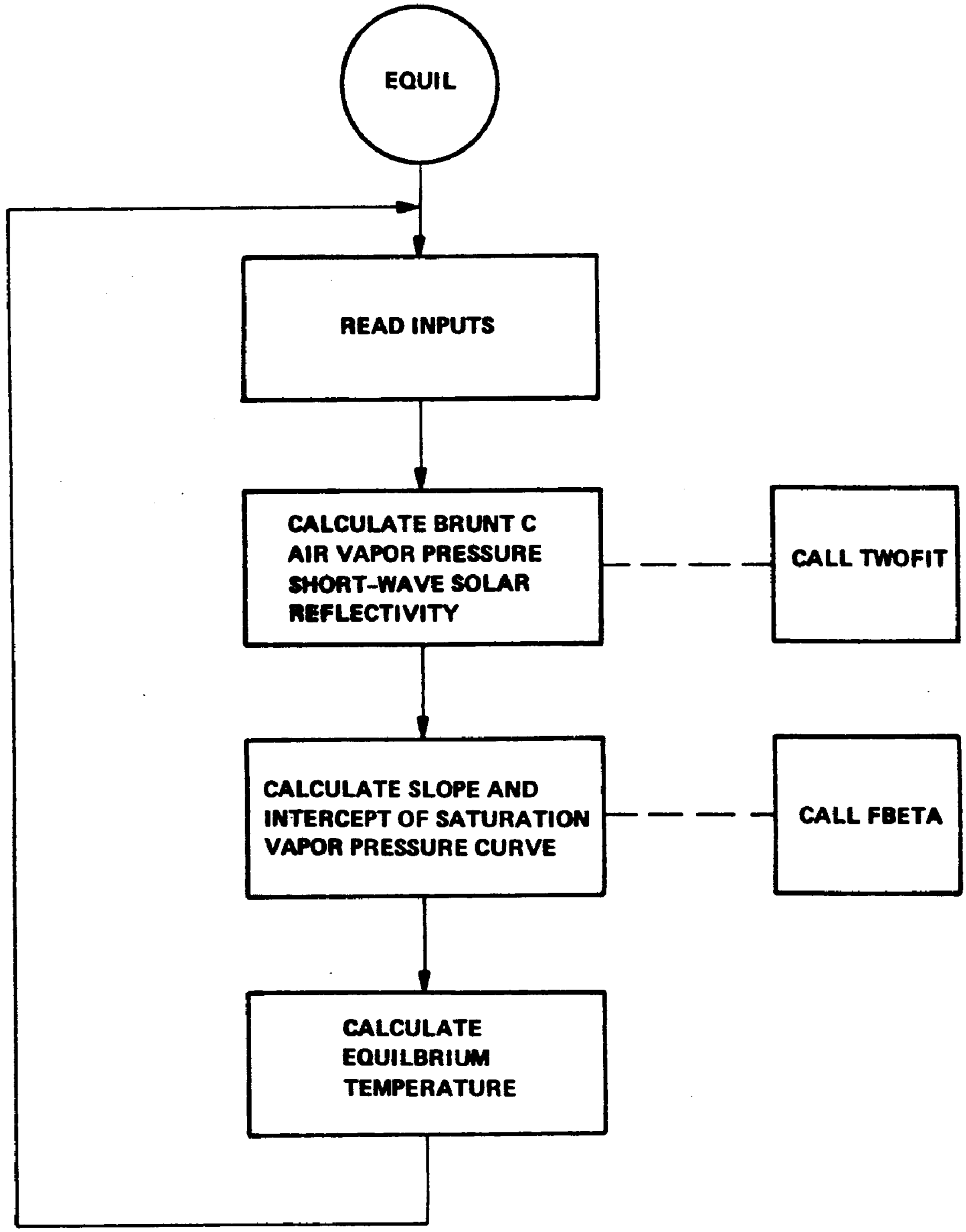


Figure A-28. Flow Chart and Listings of Program EQUIL

```
C
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,TM,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      NAMELIST/IN/ TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,
     1  CC1,DCC,CC2,W1,DW,W2,HSC,SA,A,B,HEADER,
     2 TMERR,WMULT,IFLAG,HSMULT
     3,A1PRME,A2PRME,RG,DA,DS
C
C        READ INPUTS
1     CONTINUE
 4    FORMAT(///' ',20 A4)
3     FORMAT('        TA                  HS                  RH        ',
     1'        CC                  W                   E         ')
      WRITE(6,2)
 2    FORMAT(' *')
      READ(5,IN,END=9999)
      IF(IFLAG.EQ.1)GO TO 11
      WRITE(6,IN)
11    WRITE(6,4) HEADER
      WRITE(6,3)
C     SET UP LOOPS FOR TA,HS,RH,W,AND C
      IF(DTA.NE.0.) GO TO 20
      ITA=1
      GO TO 25
 20   ITA=(TA2-TA1)/DTA +1
 25   DO 5005 IND1=1,ITA
      TA=TA1+(IND1-1)*DTA
      TM=TA
C
      IF (DHS.NE.0.) GO TO 30
      IHS=1
      GO TO 35
 30   IHS=(HS2-HS1)/DHS +1
 35   DO 5004 IND2=1,IHS
      HS=HS1+(IND2-1)*DHS
      HS=HS*HSMULT
      HSMUL2=(A2PRME+.5*(1.-A1PRME*DS)-DA)/(1.-.5*RG*(1.-A1PRME+DS))
      HSC1=HSC*HSMULT*HSMUL2
C
```

Figure A-28. -- Continued

```
      IF (DRH.NE.0.)GO TO 40
      IRH=1
      GO TO 45
40    IRH=(RH2-RH1)/DRH +1
45    DO 5003 IND3=1,IRH
      RH=RH1+(IND3-1)*DRH
C
      IF(DCC.NE.0.) GO TO 50
      ICC=1
      GO TO 55
50    ICC=(CC2-CC1)/DCC+1
55    DO 5002 IND4=1,ICC
      CC=CC1+(IND4-1)*DCC
C
      IF(DW.NE.0.)GO TO 60
      IW=1
      GO TO 65
60    IW=(W2-W1)/DW+1
65    DO 5001 IND5=1,IW
      W=W1+(IND5-1)*DW
      W=W*WMULT
      DO 5000 IND6=1,25
      RATSR=HS/HSC1
C
C        CALCULATE HA, FIRST GET VALUE OF BC AND EA
C
      CALL TWOFIT(BC,RATBC,DRATBC,10,TABC,DTABC,17,RATSR,TA,BC1)
      CALL TWOFIT(EA,RHEA,DRHEA,10,TAEA,DTAEA,7,RH,TA,EA1)
      HA=4.15E-8*(TA+460.)**4*(BC1+.031*SQRT(EA1))
C
      HAR = .03*HA
C
C        CALCULATE HSR, FIRST GET VALUE OF RSR
C
      CALL TWOFIT(RSR,SARSR,DSARSR,9,CCRSR,DCCRSR,3,SA,CC,RSR1)
      HSR=RSR1*HS
C
      HR=HA-HAR+HS-HSR
C
C        CALCULATE EXCHANGE COEFFICIENT , FIRST CALCULATE BETA AND C(B)
C
      CALL FBETA(TM,BETA1,CBETA1)
      K= 15.7 +(.26+BETA1)*(A+B*W)
C
      CAPA= .051/K
      CAPB= -((HR-1801.)/K + ((K-15.7)/K)*((EA1-CBETA1+.26*TA)/
     1 (.26+BETA1)))
      CAPD = SQRT(1.-4.*CAPA*CAPB)
```

Figure A-28. -- Continued

```
C
C      CALCULATE  EQUILIBRIUM TEMPERATURE
C
       EQUIL = (-1.+CAPD)/(2.*CAPA)
C
500    FORMAT (F10.2,6F15.2)
       IF(ABS(EQUIL-TM).LE.(TMERR*TM)) GO TO 5001
       TM=EQUIL
 5000  CONTINUE
5001   WRITE(6,500) TA,HS,RH,CC,W,EQUIL
 5002  CONTINUE
 5003  CONTINUE
 5004  CONTINUE
 5005  CONTINUE
       GO TO 1
 9999  STOP
       END
```

Figure A-28. -- Continued

```
      BLOCK DATA
      COMMON /BRUNTC/ BC(10,17),RATBC(10),TABC(17),DRATBC,DTABC
      DATA RATBC/.50,.55,.60,.65,.70,.75,.80,.85,.90,.95/,
     1     TABC/28.,32.,36.,40.,44.,48.,52.,56.,60.,64.,68.,72.,76.,80.,
     2        84.,88.,92./,
     3     BC/.71,.705,.70,.69,.675,.655,.62,.59,.535,.45,
     4        .72,.715,.71,.70,.685,.665,.64,.605,.555,.48,
     5        .725,.72,.715,.705,.69,.675,.65,.62,.575,.51,
     6      .73,.725,.72,.71,.70,.685,.66,.635,.595,.54,
     7      .735,.73,.725,.715,.705,.695,.67,.65,.615,.56,
     8      .74,.735,.73,.72,.71,.70,.68,.66,.63,.5825,
     9      .74,.74,.735,.725,.715,.71,.69,.67,.6425,.6025,
     *      .74,.74,.74,.73,.72,.715,.70,.6825,.66,.6225,
     1      .74,.74,.74,.735,.725,.72,.705,.69,.67,.64,
     2      .74,.74,.74,.7375,.73,.7225,.71,.70,.68,.655,
     3        .74,.74,.74,.74,.735,.725,.715,.705,.69,.67,
     4        .74,.74,.74,.74,.7375,.73,.72,.71,.70,.6825,
     5      .74,.74,.74,.74,.74,.7325,.725,.715,.71,.70,
     6        .74,.74,.74,.74,.74,.735,.73,.72,.7175,.7075,
     7       .74,.74,.74,.74,.74,.7375,.735,.725,.72,.7125,
     8       .74,.74,.74,.74,.74,.74,.735,.73,.7275,.72,
     9       .74,.74,.74,.74,.74,.74,.735,.735,.735,.73/
      DATA DRATBC/.05/,DTABC/4./
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),DRHEA,DTAEA
      DATA RHEA/10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
      DATA TAEA/40.,50.,60.,70.,80.,90.,100./
      DATA EA/
     1   .50  ,1.10 ,2.00 ,2.50 ,3.00 ,3.80 ,4.50 ,5.00 ,5.50 ,6.00,
     2   1.00 ,2.00 ,2.80 ,3.90 ,4.80 ,5.50 ,6.50 ,7.50 ,8.20 ,9.10,
     3   1.50 ,2.80 ,4.00 ,5.10 ,6.80 ,8.00 ,9.20 ,10.60,12.00,13.10,
     4   2.00 ,4.00 ,5.50 ,7.50 ,9.30 ,11.20,13.00,15.00,17.00,18.80,
     5   2.50 ,5.20 ,8.00 ,10.50,13.00,15.90,18.10,21.00,23.40,26.00,
     6   3.50 ,7.00 ,10.90,14.00,17.90,21.60,25.00,28.80,32.00,36.00,
     7   5.00,10.00,14.90,19.80,24.50,29.30,34.20,39.10,44.00,49.00/
      DATA DRHEA/10./,DTAEA/10./
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),DSARSR,DCCRSR
      DATA SARSR/0.,10.,20.,30.,40.,50.,60.,70.,80./
      DATA CCRSR/3.,6.5,10./
      DATA RSR/.55,.25,.125,.08,.06,.05,.045,.04,.035,
     1         .45,.18,.10,.07,.06,.05,.045,.04,.035,
     2         .25,.14,.09,.075,.06,.055,.05,.045,.04/
      DATA DSARSR/10./,DCCRSR/3.5/
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,TM,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
      DATA TA1,DTA,TA2/60.,0.,60./,
     1     HS1,DHS,HS2/1500.,0.,1500./,
     2     RH1,DRH,RH2/50.,0.,50./,
```

```
     3      CC1,DCC,CC2/5.,0.,5./,
     4      W1,DW,W2/10.,0.,10./,
     5      HSC,SA,A,B/3000.,60.,0.,11.4/,
     6 HEADER/20*4H    /,
     7 TMERR,WMULT,IFLAG,HSMULT/.01,1.,1,1./
     8,A1PRME,A2PRME,FG,DA,DS/.810,.708,.20,.07,0./
      END
```

Table A-7. Variables Used in EQUIL

Functional Area	Name (Dimension)	Program Value	Description
EQUIL	TA1	60	First Temperature used
	TA2	60	Last temperature used
	DTA	0	Step size*
	HS1	1500	First value of solar radiation used
	HS2	1500	Last value of solar radiation used
	DHS	0	Step size*
	RH1	50	First relative humidity used
	RH2	50	Last relative humidity used
	DRH	0	Step size*
	CC1	5	First value of cloud cover used
	CC2	5	Last value of cloud cover used
	DCC	0	Step size*
	W1	10	First wind speed used
	W2	10	Last wind speed used
	DW	0	Step size
	HSC	3000 (BTU Ft^{-2} Day^{-1})	Extraterrestrial solar radiation (units must be consistant with HS1, HS2.

Table A-7. -- Continued.

Functional Area	Name(Dimension)	Program Value	Description
	SA	60	Solar Angle
	A, B	0, 11.4	Characteristics of evaporation formula
	A1PRME, A2PRME	.81, .708	Transmission coefficients, functions of optical air mass in and water content of the atmosphere
	DA, DS	.07, 0	Total dust depletion
	RG	.20	Total reflectivity of the ground
	HEADER (20)	(blank)	heading to be printed at top of output
	TMERR	.01	The equilibrium temperature is calculated using an iterative method that terminates when the change is less than TMERR* equilibrium temperature.
	WMULT	1	Value used to change the units of the wind speed. If wind speed (W1, W2) is in miles/hour WMULT=1. If wind speed is in knots WMULT=1.15
	HSMULT	1	Value used to change the units of the solar radiation. If solar radiation (HS1, HS2) is in BTU Ft^{-2} Day^{-1} then HSMULT=1. If solar radiation is in Langleys hr^{-1} the HSMULT=88.47.

Table A-7. -- Continued.

Functional Area	Name(Dimension)	Program Value	Description
	IFLAG	1	If IFLAG is equal to zero the inputs are printed; if IFLAG is equal to one they are not.
	TA	-	Current value of air temperature
	HS		Current value of solar radiation
	RH		Current value of relative humidity
	CC		Current value of cloud cover
	W		Current value of wind speed
	BC1, EA1, RSR1, HA, HAR, HSR HR, K, CADA, CAPB, CAPD, EQUIL		As in Table A-5

*A step size of zero indicates that only the first value is to be used.

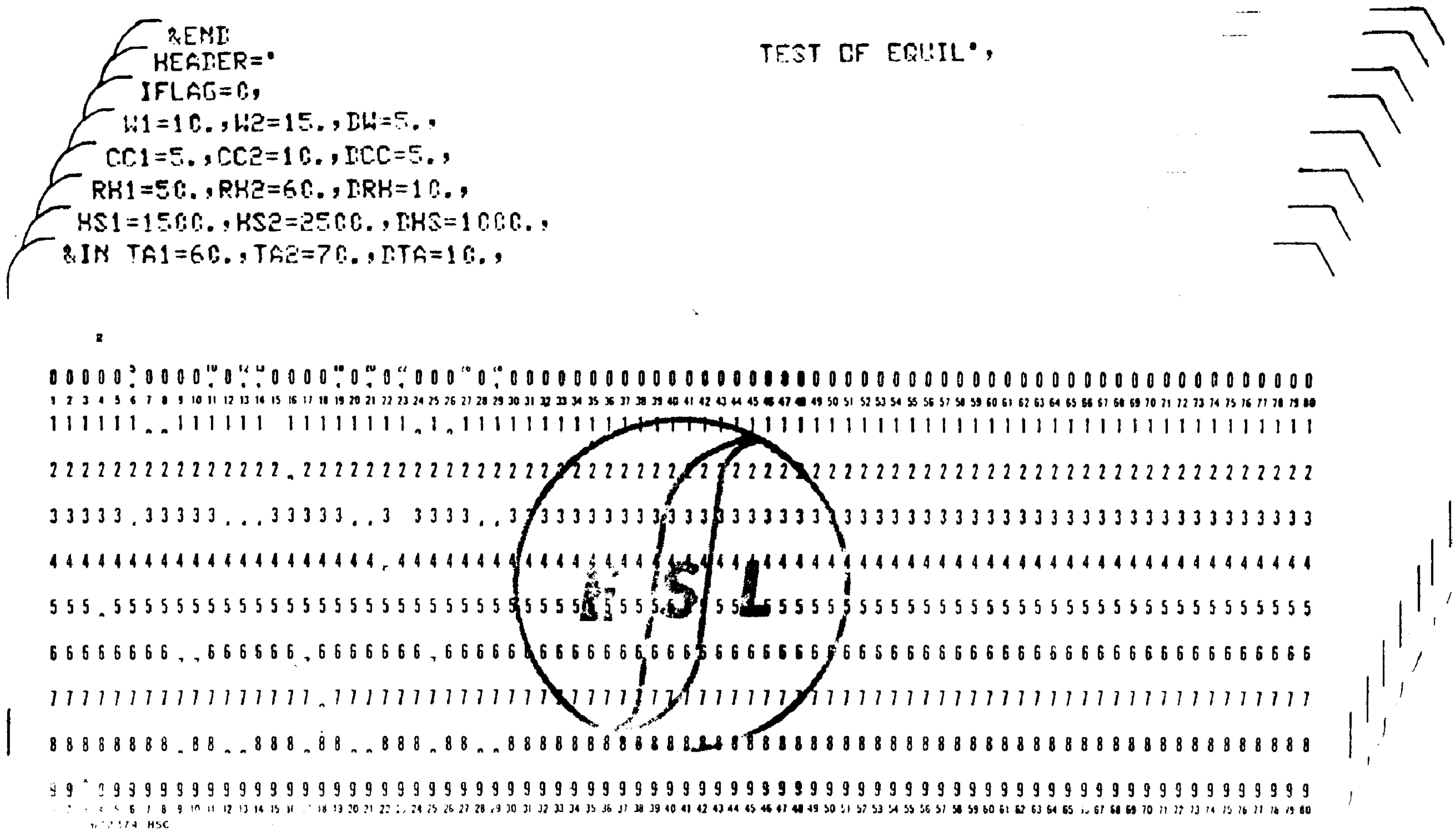


Figure A-29. Input Example for EQUIL

```
TA1=  60.000000    ,DTA=  10.000000    ,TA2=  70.000000     ,HS1=  1500.0000     ,DHS=  1000.0000    ,HS2=  2500.0000    ,RH1=
 50.000000    ,DRH=  10.000000    ,RH2=  60.000000     ,CC1=  5.0000000    ,DCC=  5.0000000    ,CC2=  10.000000    ,W1=
 10.000000    ,DW=  5.0000000    ,W2=  15.000000    ,HSC=  3000.0000    ,SA=  60.000000    ,A= 0.0          ,B=  11.400000    ,
WEIDER= 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.88973820    ,
-0.35301627E 42, 0.77284074    ,-0.56707252E 11, 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    ,
 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    ,TMERR= 0.99999979E-02,WMULT=  1.0000000    ,IFLAG=
          0,HSMULT=  1.0000000    ,A1PRME= 0.80999994    ,A2PRME= 0.70799994    ,RG= 0.19999999    ,DA= 0.69999993E-01,DS=
 0.0
&END
```

TEST OF EQUIL

TA	HS	RH	CC	W	E
60.00	1500.00	50.00	5.00	10.00	61.76
60.00	1500.00	50.00	5.00	15.00	58.75
60.00	1500.00	50.00	10.00	10.00	61.69
60.00	1500.00	50.00	10.00	15.00	58.70
60.00	1500.00	60.00	5.00	10.00	63.20
60.00	1500.00	60.00	5.00	15.00	60.31
60.00	1500.00	60.00	10.00	10.00	63.14
60.00	1500.00	60.00	10.00	15.00	60.26
60.00	2500.00	50.00	5.00	10.00	69.61
60.00	2500.00	50.00	5.00	15.00	64.76
60.00	2500.00	50.00	10.00	10.00	69.51
60.00	2500.00	50.00	10.00	15.00	64.68
60.00	2500.00	60.00	5.00	10.00	70.86
60.00	2500.00	60.00	5.00	15.00	66.16
60.00	2500.00	60.00	10.00	10.00	70.76
60.00	2500.00	60.00	10.00	15.00	66.08
70.00	1500.00	50.00	5.00	10.00	68.88
70.00	1500.00	50.00	5.00	15.00	66.01
70.00	1500.00	50.00	10.00	10.00	68.82
70.00	1500.00	50.00	10.00	15.00	65.97
70.00	1500.00	60.00	5.00	10.00	70.86
70.00	1500.00	60.00	5.00	15.00	68.15
70.00	1500.00	60.00	10.00	10.00	70.80
70.00	1500.00	60.00	10.00	15.00	68.10
70.00	2500.00	50.00	5.00	10.00	76.04
70.00	2500.00	50.00	5.00	15.00	71.46
70.00	2500.00	50.00	10.00	10.00	75.94
70.00	2500.00	50.00	10.00	15.00	71.39
70.00	2500.00	60.00	5.00	10.00	77.77
70.00	2500.00	60.00	5.00	15.00	73.38
70.00	2500.00	60.00	10.00	10.00	77.68
70.00	2500.00	60.00	10.00	15.00	73.32

Figure A-30. Output Example for EQUIL

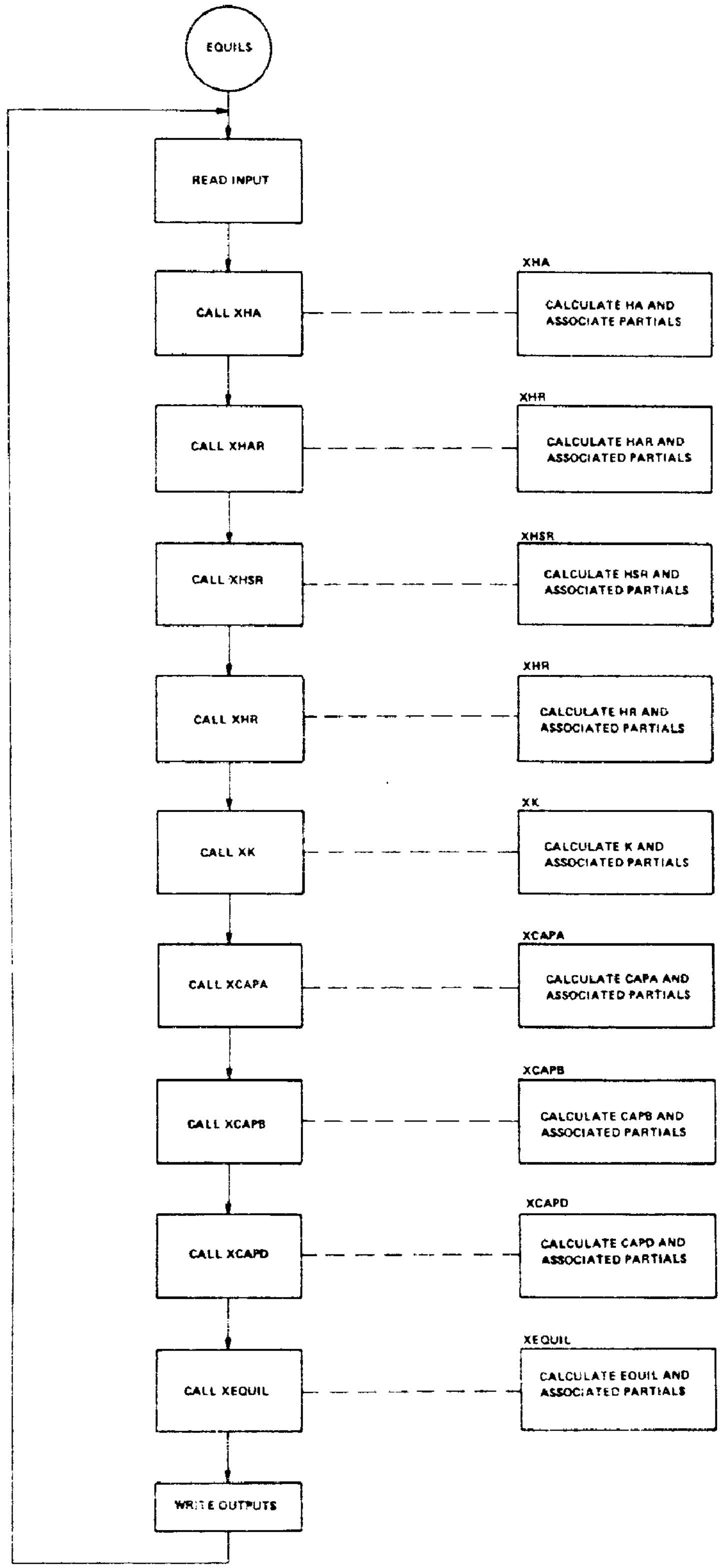


Figure A-31. Flow Chart and Listings of EQUILS

```
C
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
      NAMELIST/IN/ TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,
     1  CC1,DCC,CC2,W1,DW,W2,HSC,SA,A,B,
     2 HEADER,TMERR,WMULT,IFLAG,HSMULT
     3,A1PRME,A2PRME,RG,DA,DS
C
C        READ INPUTS
 4    FORMAT(///' ',20 A4)
 3    FORMAT('         TA                   HS                   RH         ',
     1'        CC                   W                    E          ')
 1    CONTINUE
      WRITE(6,2)
 2    FORMAT(' *')
      READ(5,IN,END=9999)
      IF(IFLAG.EQ.1) GO TO 11
      WRITE(6,IN)
 11   WRITE(6,4) HEADER
      WRITE(6,3)
C
      IF(DTA.NE.0.) GO TO 20
      ITA=1
      GC TO 25
 20   ITA=(TA2-TA1)/DTA +1
 25   DO 5005 IND1=1,ITA
```

Figure A-31. -- Continued

```
      TA=TA1+(IND1-1)*DTA
      TM=TA
C
      IF (DHS.NE.0.) GO TO 30
      IHS=1
      GO TO 35
 30   IHS=(HS2-HS1)/DHS +1
 35   DO 5004 IND2=1,IHS
      HS=HS1+(IND2-1)*DHS
      HS=HS*HSMULT
      HSMUL2=(A2PRME+.5*(1.-A1PRME*DS)-DA)/(1.-.5*RG*(1.-A1PRME+DS))
      HSC1=HSC*HSMULT*HSMUL2
C
      IF (DRH.NE.0.)GO TO 40
      IRH=1
      GO TO 45
 40   IRH=(RH2-RH1)/DRH +1
 45   DO 5003 IND3=1,IRH
      RH=RH1+(IND3-1)*DRH
C
      IF(DCC.NE.0.) GO TO 50
      ICC=1
      GO TO 55
 50   ICC=(CC2-CC1)/DCC+1
 55   DO 5002 IND4=1,ICC
      CC=CC1+(IND4-1)*DCC
C
      IF(DW.NE.0.)GO TO 60
      IW=1
      GO TO 65
 60   IW=(W2-W1)/DW+1
 65   DO 5001 IND5=1,IW
      W=W1+(IND5-1)*DW
      W=W*WMULT
      DO 5000 IND6=1,5
      RATSR =HS/HSC1
      CALL XHA
      CALL XHAR
      CALL XHSR
      CALL XHR
      CALL XK
      CALL XCAPA
      CALL XCAPB
      CALL XCAPD
      CALL XEQUIL
C
 500  FORMAT(F10.2,6F15.2)
      IF(ABS(EQUIL-TM).LE.(TMERR*TM)) GO TO 4999
```

Figure A-31. -- Continued

```
      TM=EQUIL
 5000 CONTINUE
4999  WRITE(6,500) TA,HS,RH,CC,W,EQUIL
      WRITE(6,502)PETA,PEHS,PERH,PECC,PEW
 502  FORMAT(F17.4,4F15.4)
5001  CONTINUE
 5002 CONTINUE
 5003 CONTINUE
 5004 CONTINUE
 5005 CONTINUE
      GO TO 1
9999  STOP
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XHA
      REAL*4 K
      COMMCN/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMCN /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C
C        CALCULATE HA, FIRST GET VALUE OF BC AND EA
C
      TA460=TA+460.
      TA4603=TA460**3
      TA4604=TA4603*TA460
      CALL TWOFIT(BC,RATBC,DRATBC,10,TABC,DTABC,17,RATSR,TA,BC1)
      CALL TWOFIT(EA,RHEA,DRHEA,10,TAEA,DTAEA,7,RH,TA,EA1)
      HA=4.15E-8*TA4604*(BC1+.031*SQRT(EA1))
C
C     CALCULATE PARTIALS
C
      CALL TOLOOK(PBCT,TABC,DTABC,17,RATBC,DRATBC,10,TA,RATSR,PBCT1)
      CALL TOLOOK(PBCR,RATBC,DRATBC,10,TABC,DTABC,17,RATSR,TA,PBCR1)
      CALL TOLOOK(PEARH,RHEA,DRHEA,10,TAEA,DTAEA,7,RH,TA,PEARH1)
      CALL TOLOOK(PEATA,TAEA,DTAEA,7,RHEA,DRHEA,10,TA,RH,PEATA1)
      PHAHS= 4.15E-8*TA4604*(PBCR1/HSC1)
      PHATA= 4.15E-8*(4.*TA4603*(BC1+.031*SQRT(EA1))+TA4604*
     1(PBCT1 +((.031*.5)/SQRT(EA1))*PEATA1))
      PHAW = 0.
      PHACC= 0.
      PHARH= 4.15E-8*TA4604*((.031*.5)/SQRT(EA1))*PEARH1
C
```

Figure A-31. -- Continued

```
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XHAR
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C
      HAR = .03*HA
C
C
C     CALCULATE PARTIALS
C
      PHARHS = .03*PHAHS
      PHARTA = .03*PHATA
      PHARW  = .03*PHAW
      PHARCC = .03*PHACC
      PHARRH = .03*PHARH
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XHSR
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C        CALCULATE HSR, FIRST GET VALUE OF RSR
C
      CALL TWOFIT(RSR,SARSR,DSARSR,9,CCRSR,DCCRSR,3,SA,CC,RSR1)
      CALL TOLOCK(PRSRCC,CCRSR,DCCRSR,3,SARSR,DSARSR,9,CC,SA,PRSRC1)
      HSR=RSR1*HS
C
C     CALCULATE PARTIALS
C
      PHSRHS = RSR1
      PHSRTA = 0.
      PHSRW  = 0.
      PHSRCC = HS*PRSRC1
      PHSRRH = 0.
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XHR
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C
      HR=HA-HAR+HS-HSR
C
C
C     CALCULATE PARTIALS
C
      PHRHS= PHAHS-PHARHS+1.-PHSRHS
      PHRTA= PHATA-PHARTA-PHSRTA
      PHRW = PHAW -PHARW -PHSRW
      PHRCC = PHACC-PHARCC-PHSRCC
      PHRRH= PHARH-PHARRH-PHSRRH
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XK
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C        CALCULATE EXCHANGE COEFFICIENT , FIRST CALCULATE BETA AND C(B)
C
      CALL FBETA(TM,BETA1,CBETA1)
      K= 15.7 +(.26+BETA1)*(A+B*W)
C
C     CALCULATE PARTIALS
C
      PKHS = 0.
      PKTA =0.
      PKW  = (.26+BETA1)*B
      PKCC =0.
      PKRH =0.
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROLTINF XCAPA
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
      SQK=K*K
C
      CAPA= .051/K
C
C     CALCULATE PARTIALS
C
      PCAHS = (-.051*PKHS)/(SQK)
      PCATA = (-.051*PKTA)/(SQK)
      PCAW  = (-.051*PKW )/(SQK)
      PCACC = (-.051*PKCC)/(SQK)
      PCARH = (-.051*PKRH)/(SQK)
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XCAPB
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
      HR18=HR-1801.
      SQK=K*K
      TA26=.26*TA
      BET26=.26+BETA1
      CAPB= -((HR18)/K + ((K-15.7)/K)*((EA1-CBETA1+TA26)/
     1 (BET26)))
C
C     CALCULATE PARTIALS
C
      PCBHS = -((K*PHRHS-(HR18)*PKHS)/(SQK) + ((K*PKHS-(K-15.7)*
     1PKHS)/(SQK))*((EA1-CBETA1)+(TA26))/(BET26))
C
      PCBTA = -((K*PHRTA-(HR18)*PKTA)/(SQK) +(((K-15.7)/K)*
     1(PEATA1+ .26)/(BET26)  + ((K*PKTA - (K-15.7)*PKTA)/(SQK))*
     2((EA1-CBETA1+TA26)/(BET26))))
C
      PCBW  = -((K*PHRW -(HR18)*PKW )/(SQK) + ((K*PKW-(K-15.7)*PKW)/
     1(SQK))*((EA1-CBETA1+TA26)/(BET26)))
C
      PCBCC = -((K*PHRCC-(HR18)*PKCC)/(SQK) + ((K*PKCC-(K-15.7)*
     1PKCC)/(SQK))*((EA1-CBETA1+TA26)/(BET26)))
C
      PCBRH = -((K*PHRRH-(HR18)*PKRH)/(SQK) + ((K*PKRH-(K-15.7)*
```

Figure A-31. -- Continued

```
     1PKRH)/(SQK))*((EA1-CBETA1+TA26)/(BET26))+((K-15.7)/K)*(PEARH1
     2 /BET26))
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XCAPD
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
      CAPD = SQRT(1.-4.*CAPA*CAPB)
C
C     CALCULATE PARTIALS
C
      PREMUL =((.5)/SQRT(1.-4.*CAPA*CAPB))*(-4.)
C
      PCDHS = PREMUL*(PCAHS*CAPB + PCBHS*CAPA)
      PCDTA = PREMUL*(PCATA*CAPB + PCBTA*CAPA)
      PCDW  = PREMUL*(PCAW *CAPB + PCBW *CAPA)
      PCDCC = PREMUL*(PCACC*CAPB + PCBCC*CAPA)
      PCDRH = PREMUL*(PCARH*CAPB + PCBRH*CAPA)
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      SUBROUTINE XEQUIL
      REAL*4 K
      COMMON/BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(10,17),
     1 PBCR(10,17),DRATBC,DTABC
C
      COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(10,7),
     1 DRHEA,DTAEA
C
      COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(9,3),DSARSR,DCCRSR
C
      COMMON /INPUT/TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,CC1,DCC,CC2,
     1W1,DW,W2,HSC,SA,A,B,HEADER(20),TMERR,WMULT,IFLAG,HSMULT
     2,A1PRME,A2PRME,RG,DA,DS
C
      COMMON /DATA/ HS,TA,W,RH,CC,RATSR,HSC1,TM,
     1 HA,PHAHS,PHATA,PHAW,PHARH,PHACC,
     2 HAR,PHARHS,PHARTA,PHARW,PHARRH,PHARCC,
     3 HSR,PHSRHS,PHSRTA,PHSRW,PHSRRH,PHSRCC,
     4 HR,PHRHS,PHRTA,PHRW,PHRRH,PHRCC,
     5 K,PKHS,PKTA,PKW,PKRH,PKCC,
     6 CAPA,PCAHS,PCATA,PCAW,PCARH,PCACC,
     7 CAPB,PCBHS,PCBTA,PCBW,PCBRH,PCBCC,
     8 CAPD,PCDHS,PCDTA,PCDW,PCDRH,PCDCC,
     9 EQUIL,PEHS,PETA,PEW,PERH,PECC,
     * BC1,EA1,RSR1,BETA1,CBETA1,PBCR1,PBCT1,PEARH1,PEATA1,PRSRC1
C
C     CALCULATE  EQUILIBRIUM TEMPERATURE
C
      EQUIL = (-1.+CAPD)/(2.*CAPA)
C
C     CALCULATE PARTIALS
C
      CONST1 =2.*CAPA*CAPA
      CONST2 = (-1.+CAPD)
      PEHS =(CAPA*PCDHS - CONST2 *PCAHS)/CONST1
      PETA =(CAPA*PCDTA - CONST2 *PCATA) /CONST1
      PEW  =(CAPA*PCDW  - CONST2 *PCAW)  /CONST1
      PECC =(CAPA*PCDCC - CONST2 *PCACC) /CONST1
      PERH =(CAPA*PCDRH - CONST2 *PCARH) /CONST1
C
      RETURN
      END
```

Figure A-31. -- Continued

```
      BLOCK DATA
      CCMMON /BRUNTC/ BC(10,17),RATBC(10),TABC(17),PBCT(17,10),
     1 PBCR(10,17),DRATBC,DTABC
      DATA RATBC/.50,.55,.60,.65,.70,.75,.80,.85,.90,.95/,
     1      TABC/28.,32.,36.,40.,44.,48.,52.,56.,60.,64.,68.,72.,76.,80.,
     2         E4.,88.,92./,
     3      BC/.71,.705,.70,.69,.675,.655,.62,.59,.535,.45,
     4         .72,.715,.71,.70,.685,.665,.64,.605,.555,.48,
     5         .725,.72,.715,.705,.69,.675,.65,.62,.575,.51,
     6       .73,.725,.72,.71,.70,.685,.66,.635,.595,.54,
     7       .735,.73,.725,.715,.705,.695,.67,.65,.615,.56,
     8       .74,.735,.73,.72,.71,.70,.68,.66,.63,.5825,
     9       .74,.74,.735,.725,.715,.71,.69,.67,.6425,.6025,
     *       .74,.74,.74,.73,.72,.715,.70,.6825,.66,.6225,
     1       .74,.74,.74,.735,.725,.72,.705,.69,.67,.64,
     2       .74,.74,.74,.7375,.73,.7225,.71,.70,.68,.655,
     3         .74,.74,.74,.74,.735,.725,.715,.705,.69,.67,
     4         .74,.74,.74,.74,.7375,.73,.72,.71,.70,.6825,
     5       .74,.74,.74,.74,.74,.7325,.725,.715,.71,.70,
     6         .74,.74,.74,.74,.74,.735,.73,.72,.7175,.7075,
     7        .74,.74,.74,.74,.74,.7375,.735,.725,.72,.7125,
     8        .74,.74,.74,.74,.74,.74,.735,.73,.7275,.72,
     9        .74,.74,.74,.74,.74,.74,.735,.735,.735,.73/
      CATA CRATBC/.05/,DTABC/4./
      CATA PBCT/
     1 .0025,.00125,.0C125,.00125,.00125,12*0.,
     2.0025,.00125,.00125,.00125,.00125,.00125,0.,0.,0.,0.,0.,0.,0.,
     2 C.,0.,0.,0.,
     3 .0025,.00125,.0C125,.00125,.00125,.00125,.00125,0.,0.,C.,0.,
     3 C.,0.,0.,0.,0.,0.,
     4 .0025,.00125,.00125,.00125,.C0125,.00125,.00125,.00125,.0006,
     4 .0006,0.,C.,0.,0.,0.,0.,0.,
     5 .0025,.00125,.0C25,.00125,.0C125,.00125,.00125,.00125,.00125,
     5 .00125,.0006,.0006,0.,0.,0.,0.,0.,
     6 .0025,.0025,.0025,.0025,.00125,.0025,.00125,.00125,.0006,.0006,
     6 .00125,.C006,.0006,.0006,.0006,0.,0.,
     7 .0050,.0025,.0025,.0C25,.0025,.C025,.0025,.00125,.00125,.00125,
     7 .00125,.00125,.00125,.00125,0.,0.,0.,
     8 .00375,.00375,.C0375,.00375,.0C25,.0025,.00306,.0019,.0025,
     8 .00125,.0C125,.00125,.00125,.00125,.00125,.C0125,0.,
     9 .0050,.C050,.0050,.0050,.00375,.00306,.0044,.0025,.0025,.0025,
     9 .0025,.0050,.0019,.C006,.0019,.0019,0.,
     * .0C75,.0075,.0075,.0050,.C06,.005,.005,.0044,.004,.004,.0031,
     * .0044,.0019,.00125,.0019,.0025,0./
      CATA PBCR
     1/-.100,-.10C,-.200,-.300,-.400,-.700,-.600,-1.10,-1.80,-2.00,
     2 -.100,-.100,-.200,-.300,-.400,-.500,-.700,-1.00,-1.50,-1.75,
     3 -.100,-.100,-.200,-.300,-.300,-.500,-.600,-.900,-1.30,-1.50,
```

```
 DATA CCRSR/3.,6.5,10./
 DATA RSR/.55,.25,.125,.08,.06,.05,.045,.04,.035,
1          .45,.18,.10,.07,.06,.05,.045,.04,.035,
2          .25,.14,.09,.075,.06,.055,.05,.045,.04/
 DATA PRSRCC/
1 -.028,-.056,-.057,
2 -.020,-.011,-.011,
3 -.007,-.003,-.003,
4 -.003,.0014,.0014,
5 0.    ,0.    ,0.    ,
6 0.    ,.0014,.0014,
7 0.    ,.0014,.0014,
8 0.    ,.0014,.0014,
9 0.    ,.0014,.0014/
 DATA DSARSR/10./,DCCRSR/3.5/
 COMMON /INPUT/ TA1,DTA,TA2,HS1,DHS,HS2,RH1,DRH,RH2,
1 CC1,DCC,CC2,W1,DW,W2,HSC,SA,A,B,HEADER(20),
2 TMEFR,WMULT,IFLAG,HSMULT
3,A1PRME,A2PRME,RG,DA,DS
 DATA TA1,DTA,TA2/60.,0.,60./,
1      HS1,DHS,HS2/1500.,0.,1500./,
2      RH1,DRH,RH2/50.,0.,50./,
3      CC1,DCC,CC2/5.,0.,5./,
4      W1,DW,W2/10.,0.,10./,
5      HSC,SA,A,B/3000.,60.,0.,11.4/,
6 HEADER/20*4H    /,
7 TMEFR,WMULT,IFLAG,HSMULT/.01,1.,1,1./
8,A1PRME,A2PRME,RG,DA,DS/.810,.708,.20,.07,0./
 END
```

```
4 -.100,-.100,-.200,-.200,-.300,-.500,-.500,-.800,-1.10,-1.25,
5 -.100,-.100,-.200,-.200,-.200,-.500,-.400,-.700,-1.10,-1.20,
6 -.100,-.100,-.200,-.200,-.200,-.400,-.400,-.600,-.950,-1.125,
7 0.    ,-.100,-.200,-.200,-.100,-.400,-.400,-.550,-.800,-.925,
8 0.    ,0.    ,-.200,-.200,-.100,-.300,-.350,-.450,-.750,-.900,
9 0.    ,0.    ,-.100,-.200,-.100,-.300,-.300,-.400,-.600,-.700,
* 0.    ,0.    ,-.050,-.150,-.150,-.250,-.200,-.400,-.500,-.550,
1 0.    ,0.    ,0.    ,-.100,-.200,-.200,-.200,-.300,-.400,-.450,
2 0.    ,0.    ,0.    ,-.050,-.150,-.200,-.200,-.200,-.350,-.425,
3 0.    ,0.    ,0.    ,0.    ,-.150,-.150,-.200,-.100,-.200,-.250,
4 0.    ,0.    ,0.    ,0.    ,-.100,-.100,-.200,-.050,-.200,-.275,
5 0.    ,0.    ,0.    ,0.    ,-.050,-.050,-.200,-.100,-.150,-.175,
6 0.    ,0.    ,0.    ,0.    ,0.    ,-.100,-.100,-.050,-.150,-.200,
7 0.    ,0.    ,0.    ,0.    ,0.    ,-.100,0.    ,0.    ,-.100,-.150/
 COMMON /EA/ EA(10,7),RHEA(10),TAEA(7),PEARH(10,7),PEATA(7,10),
1DRHEA,DTAEA
 DATA RHEA/10.,20.,30.,40.,50.,60.,70.,80.,90.,100./
 DATA TAEA/40.,50.,60.,70.,80.,90.,100./
 DATA EA/
1    .50  ,1.10 ,2.00 ,2.50 ,3.00 ,3.80 ,4.50 ,5.00 ,5.50 ,6.00,
2    1.00 ,2.00 ,2.80 ,3.90 ,4.80 ,5.50 ,6.50 ,7.50 ,8.20 ,9.10,
3    1.50 ,2.80 ,4.00 ,5.10 ,6.80 ,8.00 ,9.20 ,10.60,12.00,13.10,
4    2.00 ,4.00 ,5.50 ,7.50 ,9.30 ,11.20,13.00,15.00,17.00,18.80,
5    2.50 ,5.20 ,8.00 ,10.50,13.00,15.90,18.10,21.00,23.40,26.00,
6    3.50 ,7.00 ,10.90,14.00,17.90,21.60,25.00,28.80,32.00,36.00,
7    5.00,10.00,14.90,19.80,24.50,29.30,34.20,39.10,44.00,49.00/
 DATA PEATA/
1 .050,.050,.050,.050,.100,.150,.175,
2 .090,.080,.120,.120,.180,.300,.360,
3 .080,.120,.150,.250,.290,.400,.455,
4 .140,.120,.240,.300,.350,.580,.695,
5 .180,.200,.250,.370,.490,.660,.745,
6 .170,.250,.320,.470,.570,.770,.870,
7 .200,.270,.380,.510,.690,.880,1.035,
8 .250,.310,.440,.600,.780,1.030,1.155,
9 .270,.380,.550,.640,.860,1.20,1.370,
* .290,.400,.570,.720,1.00,1.30,1.45/
 DATA PEARH/
1 .060,.090,.050,.050,.080,.070,.050,.050,.050,.050,
2 .100,.080,.110,.090,.070,.100,.100,.070,.090,.100,
3 .130,.120,.110,.170,.120,.120,.140,.140,.110,.095,
4 .200,.150,.200,.180,.190,.180,.200,.200,.180,.170,
5 .270,.280,.250,.250,.290,.220,.290,.240,.260,.270,
6 .350,.390,.310,.390,.370,.340,.380,.320,.400,.440,
7 .500,.490,.490,.470,.480,.490,.510,.490,.500,.505/
 DATA DRHEA/10./,DTAEA/10./
 COMMON /RSR/ RSR(9,3),SARSR(9),CCRSR(3),PRSRCC(3,9),DSARSR,DCCRSR
 DATA SARSR/0.,10.,20.,30.,40.,50.,60.,70.,80./
```

Table A-8 lists the variables used in the EQUILS program. Figure A-32 lists a set of input and Figure A-33 lists the corresponding outputs. Note that the input values for the meteorological parameters are listed below the headings while the sensitivity of the equilibrium temperature with respect to that parameter is printed below and to the right of the value of the parameter.

Table A-8. Variables in EQUILS

Functional Area	Name (Dimension)	Description
EQUILS	TA1, TA2, DTA, HS1, HS2, DHS, RH1, RH2, DRH, CC1, CC2, DCC, W1, W2, DW, HSC, SA, A, B, A1PRME, A2PRME, DA, DS, RG HEADER(20), TMERR, WMULT, HSMULT, IFLAG, TA, HS, RH, CC, W, BC1, EA1, RSR1, HA, HAR, HSR, HR, K, CAPA, CAPB, CAPD, EQUIL	Same as Table A-7
XHA	HA	Long Wave Atmospheric Radiation
	PBCT1	∂BC1/∂TA
	PBCR1	∂BC1/∂RH
	PEARH2	∂EA1/∂RH
	PEATA1	∂EA1/∂TA
	PHAHS	∂HA/∂HS
	PHATA	∂HA/∂TA
	PHAW	∂HA/∂W
	PHACC	∂HA/∂CC
	PHARH	∂HA/∂RH
XHAR	HAR	Reflected Atmospheric Radiation
	PHARHS	∂HAR/∂HS
	PHARTA	∂HAR/∂TA
	PHARW	∂HAR/∂W

Table A-8. -- Continued.

Functional Area	Name (Dimension)	Description
	PHARCC	∂HAR/∂CC
	PHARRH	∂HAR/∂RH
XHSR	HSR	Reflected Solar Radiation
	PHSRHS	∂HSR/∂HS
	PHARTA	∂HSR/∂TA
	PHARW	∂HSR/∂W
	PHARCC	∂HSR/∂CC
	PHARRH	∂HSR/∂RH
XHR	HR	Net Radiation Input
	PHRHS	∂HR/∂HS
	PHRTA	∂HR/∂TA
	PHRW	∂HR/∂W
	PHRCC	∂HR/∂CC
	PHRRH	∂HR/∂RH
XK	K	Exchange Coefficient
	PKHS	∂K/∂HS
	PKTA	∂K/∂TA
	PKW	∂K/∂W
	PKCC	∂K/∂CC
	PKRH	∂K/∂RH

Table A-8. -- Continued.

Functional Area	Name (Dimension)	Description
XCAPA	CAPA	Intermediate variable see equation 4-9.
	PCAHS	∂CAPA/∂HS
	PCATA	∂CAPA/∂TA
	PCAW	∂CAPA/∂W
	PCACC	∂CAPA/∂CC
	PCARH	∂CAPA/∂RH
XCAPB	CAPB	Intermediate variable see equation 4-10.
	PCBHS	∂CAPB/∂HS
	PCBTA	∂CAPB/∂TA
	PCBW	∂CAPB/∂W
	PCBCC	∂CAPB/∂CC
	PCBRH	∂CAPB/∂RH
XCAPD	CAPD	Intermediate variable see equation 4-11.
	PCDHS	∂CAPD/∂HS
	PCDTA	∂CAPD/∂TA
	PCDW	∂CAPD/∂W
	PCDCC	∂CAPD/∂CC
	PCDRH	∂CAPD/∂RH

Table A-8. -- Continued.

Functional Area	Name (Dimension)	Description
XEQUIL	EQUIL	Equilibrium temperature
	PEHS	∂EQUIL/∂HS
	PETA	∂EQUIL/∂TA
	PEW	∂EQUIL/∂W
	PECC	∂EQUIL/∂CC
	PERH	∂EQUIL/∂RH

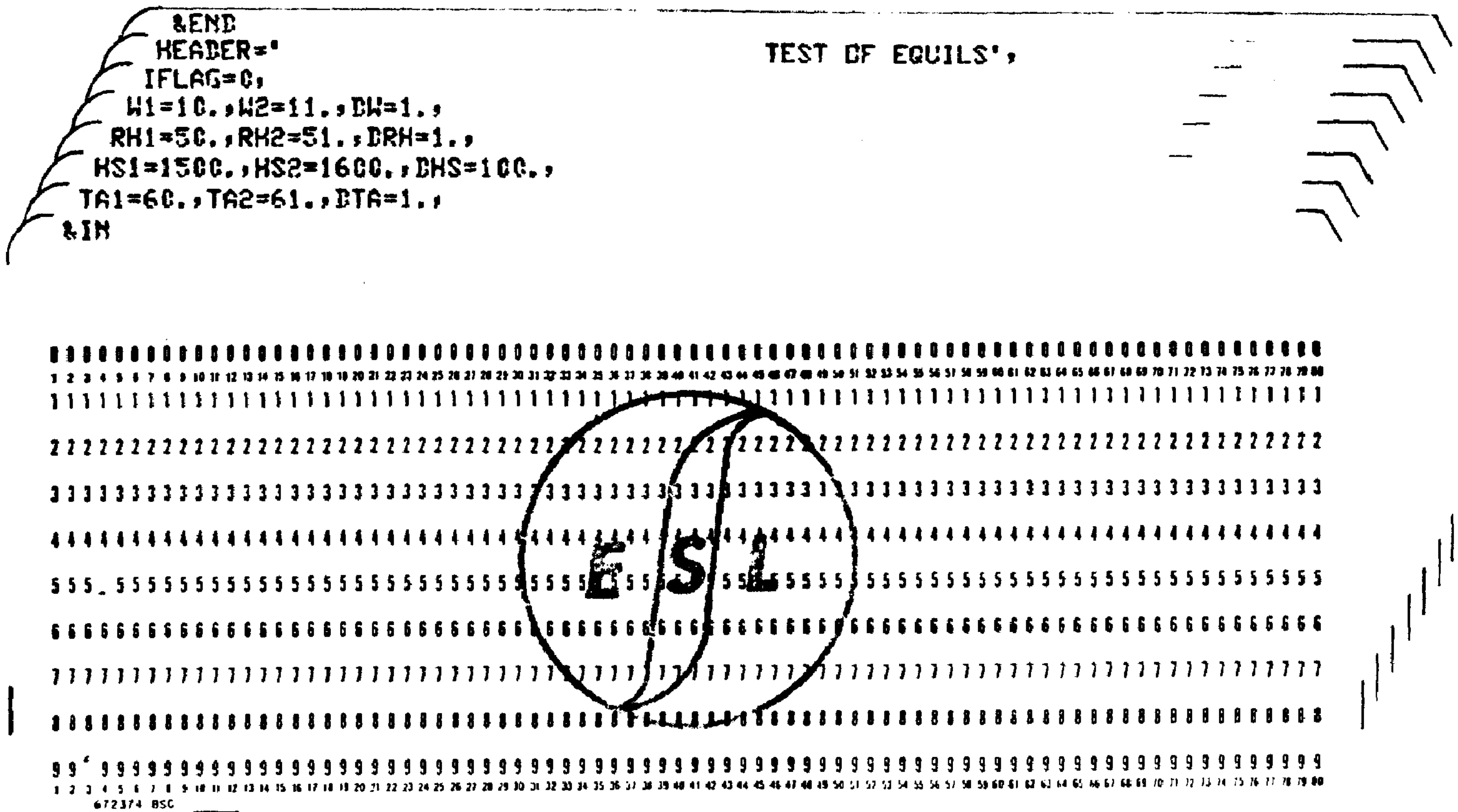


Figure A-32. Input Example for EQUILS

```
*
&IN
TA1=  60.000000    ,DTA=  1.0000000    ,TA2=  61.000000    ,HS1=  1500.0000    ,DHS=  100.00000    ,HS2=  1600.0000    ,RH1=
 50.000000    ,DRH=  1.0000000    ,RH2=  51.000000    ,CC1=  5.0000000    ,DCC= 0.0                ,CC2=  5.0000000    ,W1=
 10.000000    ,DW=  1.0000000    ,W2=  11.000000    ,HSC=  3000.0000    ,SA=  60.000000    ,A= 0.0             ,B=  11.400000    ,
HEADER= 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.88973820    ,
-0.35301687E 42, 0.77284074    ,-0.56877122E 11, 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    ,
 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    , 0.25098038    ,TMERR= 0.99999979E-02,WMULT=  1.0000000    ,IFLAG=
         0,HSMULT=  1.0000000    ,A1PRME= 0.80999994    ,A2PRME= 0.70799994    ,RG= 0.19999999    ,DA= 0.69999993E-01,DS=
 0.0
&END
```

INPUT DATA PRINTED IF IFLAG = 0

T OF EQUILS

TA	$\partial EQUIL/\partial TA$	HS	$\partial EQUIL/\partial HS$	RH	$\partial EQUIL/\partial RH$	CC	$\partial EQUIL/\partial CC$	W	$\partial EQUIL/\partial W$	E
60.00	0.7527	1500.00	0.0089	50.00	0.1465	5.00	0.0	10.00	-0.8198	61.76
60.00	0.7574	1500.00	0.0083	50.00	0.1494	5.00	0.0	11.00	-0.7131	61.00
60.00	0.7594	1500.00	0.0088	51.00	0.1460	5.00	0.0	10.00	-0.8169	61.91
60.00	0.7640	1500.00	0.0083	51.00	0.1489	5.00	0.0	11.00	-0.7103	61.15
60.00	0.7415	1600.00	0.0087	50.00	0.1443	5.00	0.0	10.00	-0.8772	62.64
60.00	0.7467	1600.00	0.0082	50.00	0.1473	5.00	0.0	11.00	-0.7634	61.83
60.00	0.7480	1600.00	0.0087	51.00	0.1438	5.00	0.0	10.00	-0.8742	62.79
60.00	0.7532	1600.00	0.0082	51.00	0.1468	5.00	0.0	11.00	-0.7605	61.97
61.00	0.7441	1500.00	0.0088	50.00	0.1528	5.00	0.0	10.00	-0.8154	62.51
61.00	0.7495	1500.00	0.0082	50.00	0.1559	5.00	0.0	11.00	-0.7089	61.75
61.00	0.7505	1500.00	0.0087	51.00	0.1523	5.00	0.0	10.00	-0.8124	62.66
61.00	0.7548	1500.00	0.0082	51.00	0.1553	5.00	0.0	11.00	-0.7061	61.91
61.00	0.7330	1600.00	0.0086	50.00	0.1506	5.00	0.0	10.00	-0.8721	63.38
61.00	0.7379	1600.00	0.0081	50.00	0.1537	5.00	0.0	11.00	-0.7587	62.57
61.00	0.7393	1600.00	0.0086	51.00	0.1500	5.00	0.0	10.00	-0.8689	63.53
61.00	0.7442	1600.00	0.0081	51.00	0.1531	5.00	0.0	11.00	-0.7557	62.72

Figure A-33.   Output Example For EQUILS

*U.S. GOVERNMENT PRINTING OFFICE: 1973 546-311/119 1-3

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

2.

3. Accession No. **W**

4. Title Statistical Prediction of Equilibrium Temperature From Standard Meteorological Data Bases

5. Report Date

6.

8. Performing Organization Report No.

7. Author(s) C. Michael Hogan
Leda C. Patmore
Harry Seidman

10. Project No. 16130 GSD

9. Organization

ESL INCORPORATED
495 Java Drive
Sunnyvale, California 94083

11. Contract/Grant No. 68-01-0167

13. Type of Report and Period Covered

12. Sponsoring Organization U. S. Environmental Protection Agency

15. Supplementary Notes U. S. Environmental Protection Agency report number EPA-660/2-73-003, August 1973.

16. Abstract

A computer program has been written and applied to investigate the stochastic distribution of equilibrium temperature as determined from a standard meteorological data base. The equilibrium temperature at an air-water interface is the temperature which would be attained by the surface if the net heat flow through it were zero. Since it is a basic factor in the prediction of actual water temperatures, the distribution of equilibrium temperature, and hence of water temperature, is an important statistic.

In the process, data from three cities (Fresno, California; Boston, Massachusetts; and Portland, Oregon) and for several time periods were compared through use of U.S. Weather Bureau hourly observations of surface and solar weather data, collected over 10 years. The conclusions arrived at concern both the use of the data and the computation of the distribution of equilibrium temperature.

17a. Descriptors

Water temperature*, stochastic processes*, statistical models, mathematical models, energy budget*, heat budget, meteorology*

17b. Identifiers

Equilibrium water temperature*, water temperature prediction

17c. COWRR Field & Group OSA, O2D

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

Abstractor C. Michael Hogan *Institution* ESL Incorporated