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STANFORD REMOTE SENSING LABORATORY

TECHNICAL REPORT 76-3

Final Report For

The National Aeronautics and Space Administration

Research Grant NASG-5050

FIELD MAPPING FOR HEAT CAPACITY MAPPING DETERMINATIONS: Ground Support For Airborne Thermal Surveys

June 1976

REMOTE SENSING LABORATORY
SCHOOL OF EARTH SCIENCES

STANFORD UNIVERSITY • STANFORD, CALIFORNIA

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KEY TO SYMBOLS EMPLOYED

Symbol	Explanation	Source/Worker	(Page used)
γ (or T.I)	Thermal inertia	Watson	(3) Table 2
F_n	Average flux into ground nth interval	Jaeger	(3)
T_p	Period of flux F_n	Jaeger	(3)
V_s	Surface temperature as periodic step function	Jaeger/ Watson	(3)(16)
FS_n	Solar heating flux component	Jaeger	
FA_n	Atmospheric heating flux component	Jaeger	(3)
FG_n	Ground radiation flux component	Jaeger	(3)
S.	Solar constant	Watson	(3)
Z	Solar zentih angle	Watson	(3)
m(Z)	Atmospheric transmission factor (air mass)	Watson	(3)
Σ	Emissivity	standard	(3)
λ	Latitude	Watson	(4)
ϕ'	Latitude	Rosema	Table 2
A	Albedo	Lyon/Watson	(3)
α	Albedo Jaeger/Watson (3)	Outcalf	(7)
a	Albedo	Rosema	Table 2
σ	Stefan-Boltzmann constant	standard	(3)
δ	Solar declination	Lyon/Watson	(4)
DEC	Solar declination	Outcalt	Table 2
$\acute{o}'$	Solar declination	Rosema	Table 2
d	Dip	Watson	(4)
ϕ	Strike azimuth from north	Watson	(4)
f (or fS.)	Cloud cover factor (or solar input)	Watson	Table 2;(3)(4)
w	Diurnal angular frequency	DeVries/ Watson	(4)
D	Damping depth	DeVries	
t	Local time from noon	Watson	(4)
T_N, T_D or T_{AN},T_{AD}	Sky temperature (night, day)	Watson	(3)
T_{sky}	Sky radiant temperature	Outcalt	(7), Table 2
R	Radius vector of sun	Outcalt	(7), Table 2
D	Dust content atmosphere	Outcalt	Table 2
u	Wind speed	Outcalt	Table 2
v	Wind speed	Rosema	Table 2

KEYS TO SYMBOLS EMPLOYED CONTINUED

Symbol	Explanation	Source/Worker	(Page used)
q	Air humidity	Outcalt	Table 2
s	Air humidity	Rosema	Table 2
X_p	Soil porosity	Rosema	Table 2
w	Precipitable water (atmosphere)	Outcalt	Table 2
p	Station atmospheric pressure	Outcalt	Table 2
C	Volumetric heat capacity	DeVries	
GC	Volumetric heat capacity	Outcalt	Table 2
	Thermal diffusivity	Watson/Lyon	(3)
GD	Thermal diffusivity	Outcalt	Table 2
ρ	Density	standard	
c	Specific heat	standard	
k	Thermal conductivity	standard	
Xm	Volume fraction minerals in soil	DeVries	Table 2
Xo	Volume fraction organics in soil	DeVries	Table 2
Xw	Volume fraction water in soil	DeVries	Table 2
Zo	Surface roughness (Aerodynamic roughness)	Outcalt	(7), Table 2
Xw	Wet fraction soil	Outcalt	(7)
SHDRAT	Shadow fraction	Outcalt	Table 2
T_2	Air temperature	Outcalt	Table 2
Ta	Air temperature	Rosema	Table 2
h	Depth subsoil water level	Rosema	Table 2
$\bar{T}$	Temperature at subsoil water level	Rosema	Table 2
θ	Moisture characteristics	Rosema	Table 2
R	Net radiation balance	standard	(7)
H	Vertical transfer sensible heat to or from air column	standard	(7)
LE	Evaporation	standard	(7)
G	Net flux sensible heat into or out of soil	standard	(7)
ΔT	Change in temperature		
Z_2,K,r,σ	Fixed constants	Outcalt	(7)
(Q+q)		Outcalt	(7)
U_2		Outcalt	(7)
Z_s		Outcalt	(7)
K_s		Outcalt	(7)

ABSTRACT

Thermal models from 3 sources (Watson, Outcalt and Rosema) were compared using similar input data and found to yield very different results. Watson-type models are very sensitive to albedo variations and to back-radiation from the sky.

Field data with which to check the validity of models are rare and usually insufficient parameters were measured. Our Pisgah Crater-Lavic Lake data, for March 29-30, 1975, have been re-examined to indicate the serious discrepancy between results for thermal inertia, between JPL calculations (Kahle et al. 1976) and ours, when made using the same original data sets.

Roof-top modelling experiments are underway to explore the practicality of determining thermal parameters of a known standardized material (Ottawa sand), when using remotely sensed data.

I. INTRODUCTION

The Stanford Remote Sensing Laboratory has maintained a long and close relationship with thermal infrared mapping experiments. The often difficult acquisition of this experience has made us uniquely aware of both the advantages and problems of thermal mapping employing modelling techniques of thermal parameters with repeated diu al aircraft and/or satellite coverage. This same expertise with field measurement programs has made it painfully apparent to us that great difficulties exist in the determination of thermal parameters at the ground-air interface in an absolute sense.

The work performed under this grant attempts to assess these determinations. This assessment includes a comparison of thermal mapping schemes, and the JPL/Stanford field effort at Pisgah Crater, California which indicated estimates of these "body-parameters" of the surficial materials may be in error as much as 100%. In light of these indications a study of a material with laboratory-determined thermal conductivity and diffusivity was begun to attempt to fix confidence limits on attempts to make absolute measurements of soil/rock thermal inertia.

Adequate technology and reasonable software exists to create thermal inertia images from twice daily aircraft-satellite coverage, however, the accuracy of these determinations in terms of absolute measure remains to be established (Kahle, et.al., 1976).

II. COMPARISON OF THERMAL MODELS

The prediction of diurnal surface temperatures, given the thermal parameters of a material, is of considerable significance to any thermal study. The contemporary principles of one-dimensional heat flow on the earth's surface can be converted into mathematical models to resolve surface temperatures, and have been programmed by a number of scientists. The mathematical model is an extremely valuable technique, and infrared studies are improved by understanding the modelling results and using them to help recognize variations in thermal properties and anomalous geothermal sites.

In order to study and perhaps analyze the significance of thermal modelling the components of four competitive models that compute the diurnal surface temperature will be analyzed. These models represent advances in our understanding of heat flow over the past five years. All four models were written for digital computations since they are based on rather complicated mathematical solutions. By comparing results of the models the significance of various thermal parameters will be made clear, and the applicability of their results to delineation of surface materials will be apparent.

A. Description of Thermal Models

MODEL 1. Watson (1971a and 1971b) developed the first computer program of thermal modelling for interpretation of infrared images. A mathematical model for the diurnal surface temperature variation of the earth's surface was derived from the one-dimensionsl heat-conduction equation of Jaeger (1953) by applying the Laplace transform;

$$F_n = \frac{\gamma}{\pi T_p} \sum_{s=1}^{m} V_s \phi n\text{-}s\text{+}1. \qquad (1)$$

where F_n is the average flux into the ground in the nth interval, (γ) is thermal inertia, T_p is the period of the flux, V_s is the surface temperature as a periodic step function, and ϕn-s+1 is a set of coefficients determined solely by the number of incremental steps m, in the period T_p. The flux into the ground, F_n, is considered to be the result of solar heating, FS_n; atmospheric heating, FA_n; and radiation from the ground, FG_n.

$$F_n = FS_n + FA_n - FG_n. \qquad (2)$$

where

$$FS_n = fS.\ (1-A)M(Z)\ \mathrm{Cos}\ Z + \sigma T_{AD}{}^4 = \Sigma\sigma V_n{}^4.\ \text{day}$$

$$= \sigma T_{AN}{}^4 - \Sigma\sigma V_n = 0. \qquad \text{night} \quad (3)$$

and f is cloud cover, S. is the colar constant, A is albedo, M(Z) is air mass or an atmospheric transmission (M(Z) = 1-0.2 sec Z), Z is the zenith angle. σ is the Stefan-Boltzmann constant, T_{AN} is the effective nighttime sky temperature, T_{AD} is the effective day time sky temperature, and Σ is the mean emmissivity.

TABLE 1

THERMAL PARAMETERS

Typical Values of Thermal Conductivity
(cal $cm^{-1} sec^{-1}$ $°C^{-1}$)

Material	Value	Source
Quartz	0.021	Sellers
Clay Minerals	0.007	Sellers
Organic Matter	0.0006	Sellers
Water	0.00137	Sellers
Ice	0.0052	Sellers
Air	·0.00006	Sellers
Granite	0.0065	Ingersoll et al.
Limestone	0.0048	Ingersoll et al.
Sandstone	0.0062	Ingersoll et al.
Quartz sand, dry, medium-fine	0.00063	Ingersoll et al.
Soil, very dry	0.0004-0.0008	Ingersoll et al.
Soil, wet	0.003-0.008	Ingersoll et al.

Typical Values of Volumetric Heat Capacity
(cal cm^{-3} $°C^{-1}$)

Quartz	0.46	Van Wijk & De Vries
Organic Matter	0.60	Van Wijk & De Vries
Water	1.00	Van Wijk & De Vries
Air	0.00029	Van Wijk & De Vries
Granite	0.513	Ingersoll et al.
Limestone	0.594	Ingersoll et al.
Sandstone	0.546	Ingersoll et al.
Quartz sand, dry, medium- fine	0.314	Ingersoll et al.
Quartz sand, 8.3% moisture, medium fine	0.420	Ingersoll et al.

Typical Values of Thermal Diffusivity
($cm^2 sec^{-1}$)

Material	Value	Source
Quartz	0.044	Sellers
Clay Minerals	0.015	Sellers
Organic Matter	0.0010	Sellers
Ice	0.0114	Sellers
Air	0.202	Sellers
Water	0.0014	Sellers
Granite	0.0127	Ingersoll et al.
Limestone	0.0081	Ingersoll et al.
Sandstone	0.0113	Ingersoll et al.
Quartz sand, dry, medium-fine	0.0020	Ingersoll et al.
Quartz sand, 8.3% moisture medium-fine	0.0033	Ingersoll et al.
Soil, very dry	0.002-0.003	Ingersoll et al.
Soil, wet	0.004-0.010	Ingersoll et al.

Typical Values of Thermal Inertia
(cal cm^{-2} $°C^{-1}$ $sec^{-1/2}$)

Quartz	0.098	Sellers
Organic Matter	0.019	Sellers
Water	0.037	Sellers
Air	0.0001	Sellers
Granite	0.058	Ingersoll et al.
Limestone	0.053	Ingersoll et al.
Sandstone	0.058	Ingersoll et al.
Quartz sand dry, medium-fine	0.014	Ingersoll et al.
Silts	0.020	Friedman
Pumice sand	0.009	Friedman
Tuff	0.040	Friedman
Quartz monzonite	0.060	Friedman
Carbonates	0.011-0.038	Friedman

Typical Values of Emissivity
(%)

Material	Value	Source
Water	92-96	Sellers
Fresh Snow	82-99.5	Sellers
Ice	96	Sellers
Sand, dry light	89-90	Sellers
Sand, wet	95	Sellers
Gravel, coarse	91-92	Sellers
Limestone, light gray	91-92	Sellers
Ground, moist bare	95-98	Sellers
Desert	90-91	Sellers
Grass,high dry	90	Sellers
Oak Woodland	90	Sellers
Pine Forest	90	Sellers
Oak Leaves	91-95	Sellers
Fields and Shrubs	90	Sellers
Silts	95.7	Friedman
Pumice Sand	95.8	Friedman
Tuff	94.7	Friedman
Carbonates	97.4-96.5	Friedman
Quartz Monzonite	93.1	Friedman

Typical Values of Albedo
(% wavelength varies)

Water	6-21	Sellers
Fresh Snow	75-95	Sellers
Sand dune, dry	35-45	Sellers
Sand dune, wet	20-30	Sellers
Soil, dark	5-15	Sellers
Soil, moist gray	10-20	Sellers
Soil, dry light sand	25-45	Sellers
Desert	25-30	Sellers
Chaparral	15-20	Sellers
Meadows, green	10-20	Sellers
Forest, deciduous	10-20	Sellers
Forest, coniferous	5-15	Sellers
Silts	40	Friedman
Pumice Sand	80	Friedman
Tuff	40	Friedman
Quartz monzonite	40	Friedman

The model to this point assumes the ground is flat, therefore, to improve the model a topographic correction was introduced. Assuming that a change in surface slope will only alter significantly the incident solar flux.

$$FS_n = fS.\ (1-A)M(Z)\ \mathrm{Cos}\ Z'. \qquad (4)$$

where Cos Z' is the zenith angle modified for local slope of dip angle d and strike azimuth from north ϕ.

$$\mathrm{Cos}\ Z' = \cos(\lambda - d\sin\phi)\ \cos\delta(\cos(wt + d\cos\phi) + \tan(\lambda - d\sin\phi)\tan\delta).$$

And λ is Σh local latitude, δ is sun's declination, t is local time from noon, w the diurnal angular frequency. Significanc topographic variation would therefore produce, for a single site, a large variation in surface temperature that would be at a maximum near noon and at a minimum near dawn.**

Atmospheric effects are treated in terms of the cloud cover factors and transmission as a function of zenith angle. The model accounts for variations in convection, evaporation, and condensation in the night and day sky temperature terms.

$$FA_n = \Sigma\sigma T_{AD}^{4}. \qquad \text{day}$$

$$= \Sigma\sigma T_{AN}^{4}. \qquad \text{night} \qquad (5)$$

** Recent work by Watson (1975) has uncovered an error in the equation for zenith angle modified for local slope variations. Watson now expresses the relation:

$$\cos Z' = \cos d \cos Z - \sin d(\sin\phi\cos\delta \ \sin wt - \cos\phi\sin\delta\cos\lambda - \sin\delta \ \sin\lambda \cos wt).$$

However, because we have taken strike and dip in the model comparisons that follow to be zero the results are completely unaffected. Either the relation for cos Z' originally contained in Watson's model or the correct relation will reduce (when strike and dip are both zero) to the normal zenith angle relation,

$$\cos Z - \cos\lambda\ \cos\delta\ \cos wt + \sin\lambda\sin\delta$$

which is correctly formulated in the model.

From analysis of computer runs Watson (1971a) concluded that daytime variations of the sky temperature have a small effect on the ground temperature changes because insulation is the major source of surface heating; while at night, however, it has a marked effect on surface temperature because it is the major source of heating.

The radiation from the ground, FG_n is affected by a number of surface state effects.

$$FG_n = \Sigma\sigma V_s^4 \tag{6}$$

Equation (1) is solved subject to equations (2) through (6) by making an initial estimate of V_s and iteratively improving the solution. The surface parameters of thermal inertia, albedo, and emissivity help formulate the initial guess. The properties of thermal inertia and albedo also strongly affect the amplitude of diurnal temperature variations and therefore significantly affect the accuracies of the model calculations.

Watson et al. (1971b), has employed the WATEMP model in the study of an area near Mill Creek, Oklahoma. Model results agred with thermal contrasts exhibited by thermal infrared images from altitudes of 150m to 17 km.

MODEL 2. Subsequent to the development of the Watson thermal model a similar program was developed, also based on a sinusoidal input for solar flux, at the Stanford Remote Sensing Lab. The Stanford temperature model program, SURTEMP, was independently written early in 1972 by Andrew Green for fully interactive use on IBM 360/67 and subsequently adapted for use on the PDP-10 computer by Frank Honey. The program is intentionally similar to that of Watson in that input consists of cloud cover factor, albedo, emissivity, thermal inertia, latitude and sun's declination, orientation, and inclination of the surface, and the day and night sky temperatures. However, differences exist in the computations using thermal inertia and emissivity, and in establishing the initial estimate of surface temperature. The Watson program iteratively solves the equation for ϕ values until ΔT between the last two iterations is $0.1^{\circ}K$. SURTEMP solves the equation employing a maximum of 20 iterations (ϕ values). From the work of Jaeger (1953) this should yield an error in amplitude of the approximate results of about 2%.

MODEL 3. A digital surface-climate simulator was developed by Outcalt (1972) following an analog solution for the diurnal surface thermal, and energy transfer, regimes based upon equilibrium temperature solutions by Myrup (1969). Though the model was developed for climatological studies, it is nevertheless applicable to surface thermal infrared studies in that it computes the diurnal variation of temperature from the surface to a depth of 25 cm. The basic equation of energy transfer or radiation balance,

$$R = H + LE + G. \qquad (7)$$

set equal to zero, is the basis of the Myrup solution. Where H is the vertical transfer of sensible heat to or from the air column, Le is the evaporation, and G is the net rate or flux of sensible heat into or out of the soil. By characterizing these terms by measurable parameters the Outcalt model takes the form:

$$(1-\alpha)(Q+q) + \Sigma\sigma T_{sky}^{4} - \Sigma\sigma T_{o}^{4} + \frac{\rho k^{2} U_{2}}{(\ln)Z_{2}/Z_{o}))^{2}} \times$$

$$C(T_{2}-rZ_{2}-T_{o}) + L\, q_{2}-(X_{w}/L)\ f(T_{o}) \quad +$$

$$\frac{K_{s}}{(Z_{s}/2)}\,(T_{n} - T_{o}) = 0. \qquad (8)$$

where Z_2, k, r, ρ, are fixed constants: $(Q+q)$, T_{sky}, U_2, q_2, T_2, are meteorological variables; and α, Σ, Z_o, X_w, Z_s, K_s, are terrain variables.

The number of boundary conditions of the Outcalt model greatly exceed the Watson or SURTEMP models. However, the model results contain estimates of climatological and soil conditions useful to the climatologist (see Table 2).

MODEL 4. A most recent thermal model was developed by Rosema (1974) to calculate the diurnal variation of surface temperature. The program solves the heat transport equations numerically using parabolic differential equations. It initially calculates soil conductivities and heat capacities, followed by calculations of matrix potential and temperatures, and heat and water balance. Input of the Rosema model like that of Outcalt is of greater relevance to the climatologist or soil scientists.

B. Comparison of Thermal Models

In an attempt to understand the implications of the differences in input parameters and mathematical solutions between these four models, data sets and output temperatures were compared. The SURTEMP program was already established on the Stanford PDP-10 system and therefore available. Watson's (1971a) program had been published, and after modifications to achieve compatability with the Stanford IBM 360/67 system by this author, it too became available. (Cost of the Watson thermal model (WATEMP) program on the Stanford IBM 360/67 far exceeded SURTEMP runs; each input set required approximately 0.75 minute CPU Time or roughly \$6.00). Although the Outcalt and Rosema modeling programs themselves were not available at that time, test run results had been published and these results could therefore be compared to either program available at Stanford.

R.J.P. Lyon (1974) over the past several years has run comparisons of the Friedman (1968) field data to the SURTEMP model.

Carefully documented and measured field data relating the model input parameters to surface temperatures are quite rare. The only significant, geologically relevant, study to date is that of Friedman (1968), but though this study did relate surface temperatures to albedo, emissivity and thermal inertia, sky temperatures were not measured, and no calculations of thermal models appear. By assuming the soil parameters are correct and knowing that the cloud cover factor for those days was zero, the SURTEMP program was run, varying slope orientation and inclination and sky temperatures until model temperatures matched observed temperatures.

By comparing ΔT between maximum and minimum temperatures Lyon was able to conclude that surface dip slope changes of 15 to 50% and surface strike changes of 10 to 33%, will produce a $1^{\circ}C$ change in maximum or minimum target temperature. Watson (1974a) compared the differential change in property values which produced a $1^{\circ}C$ change in predawn temperature and arrived at similar results. Other parametric variations, which will produce a $1^{\circ}C$ change in target temperature are listed below:

TABLE 2

INPUT PARAMETERS OF THE THERMAL MODELS

WATSON-SURTEMP	OUTCALT	ROSEMA
Cloud Cover (f)	Solar Declination (DEC)	Albedo (a)
Albedo (A)	Radius Vector of Sun (R)	Emissivity (Σ)
Emissivity (Σ)	Sky Radiant Temperature (T_{sky})	Porosity (X_p)
Thermal Inertia (γ)	Dust Content (D)	Vol. Qtz. Content (X_m)
Latitude (λ)	Air Temperature (T_2)	Vol. Clay + Feldspar Content (X_m)
Suns Declination (δ)	Wind Velocity (u)	Vol. Organics Content (Xo)
Strike (ϕ)	Air Humidity (q)	Latitude (ϕ')
Dip (d)	Precipitable Water (w)	Day (Suns Declination) (δ')
Day and Night Sky Temperature (T_N) (T_D)	Station Pressure (p)	Aerodynamic Roughness (Zo)
	Soil Vol. Heat Capacity (GC)	Windspeed (v)
	Soil Thermal Diffusivity (GD)	Air Temperature (Ta)
	Surface Roughness (Zo)	Air Humidity (s)
	Albedo (α)	Depth of Subsoil Water Level (h)
	Wet Fraction (Xw)	Temp at Subsoil Water Level ($\bar{T}$)
	Shadow Fraction (SHDRAT)	Moisture Characteristics (θ)

Parameter	Percent Variability for 1^{o} Change: Lyon	Watson
Albedo (A)	1.5-3	17
Emissivity (Σ)	25	2
Thermal Inertia (γ)	12-15	10
Sky Temperature T_N or T_D	1-2	--

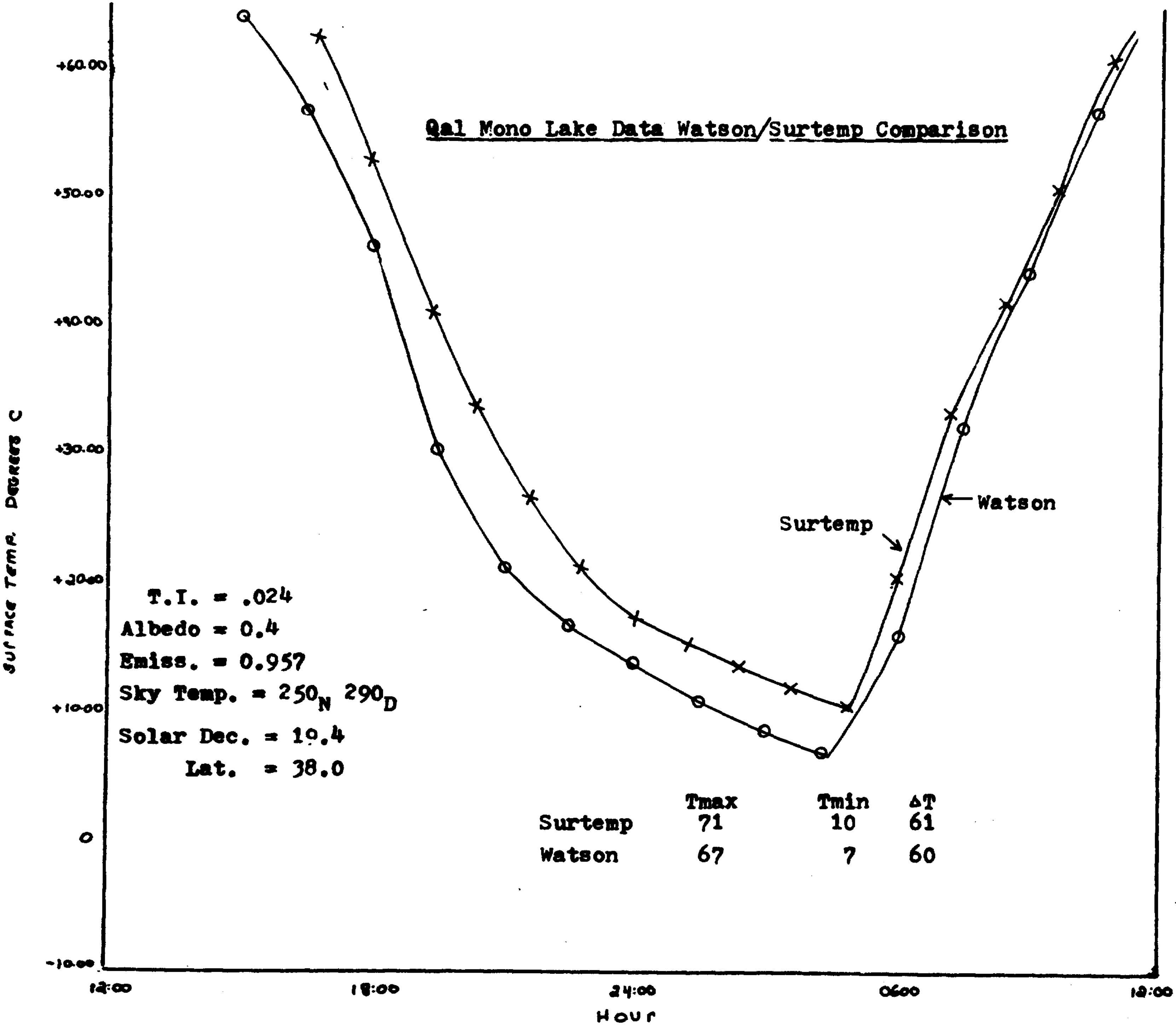
It is apparent that a considerable discrepancy exists between the calculated results of Watson and Lyon, for albedo and emissivity while the thermal inertia values are quite similar. Watson (1974a) did not calculate a percent change for sky temperature variation. In an attempt to resolve these discrepancies, the Watson model was run using the same Mono Lake data (Friedman 1968) used by Lyon to form his conclusions. These comparisons are plotted on the following figures, input parameters and comparison of maximum, minimum, and temperature differences appear on each graph.

Initial comparison involved using two different rock types. Figures 1 and 2 compare the programs for olivine basalt lapilli (Qvb) and silty playa and deltaic deposits (Qal). Inspection of the variations indicates that the nature of the diurnal surface temperature curves are quite similar. Maximum and minimum temperatures depart from one another by only one degree for Qvb, and the ΔT for both runs are within $1^{o}C$. Comparison runs of sky temperatures, (Figures 3-4), using the same input data for lacustrine carbonate (Qm), were made. The shape of the curves are again similar and variations in ΔT are less than $1^{o}C$.

Variation between the two programs appears to be unrelated to the sky temperature chosen.

Comparison runs of albedo and emissivity are compared on Figures 5-6. The curves are again quite similar in shape, and ΔT is again within $1^{o}C$.

A number of preliminary conclusions can be made concerning these two models. As one would expect the programs are quite similar, and the



Qal Mono Lake Data Watson/Surtemp Comparison
Surface Temp. Degrees C
+60.00
+50.00
+40.00
+30.00
+20.00
+10.00
0
-10.00
12:00
18:00
24:00
0600
12:00
Hour
Surtemp
Watson
T.I. = .024
Albedo = 0.4
Emiss. = 0.957
Sky Temp. = 250N 290D
Solar Dec. = 19.4
Lat. = 38.0
Tmax Tmin ΔT
Surtemp 71 10 61
Watson 67 7 60

Figure 1

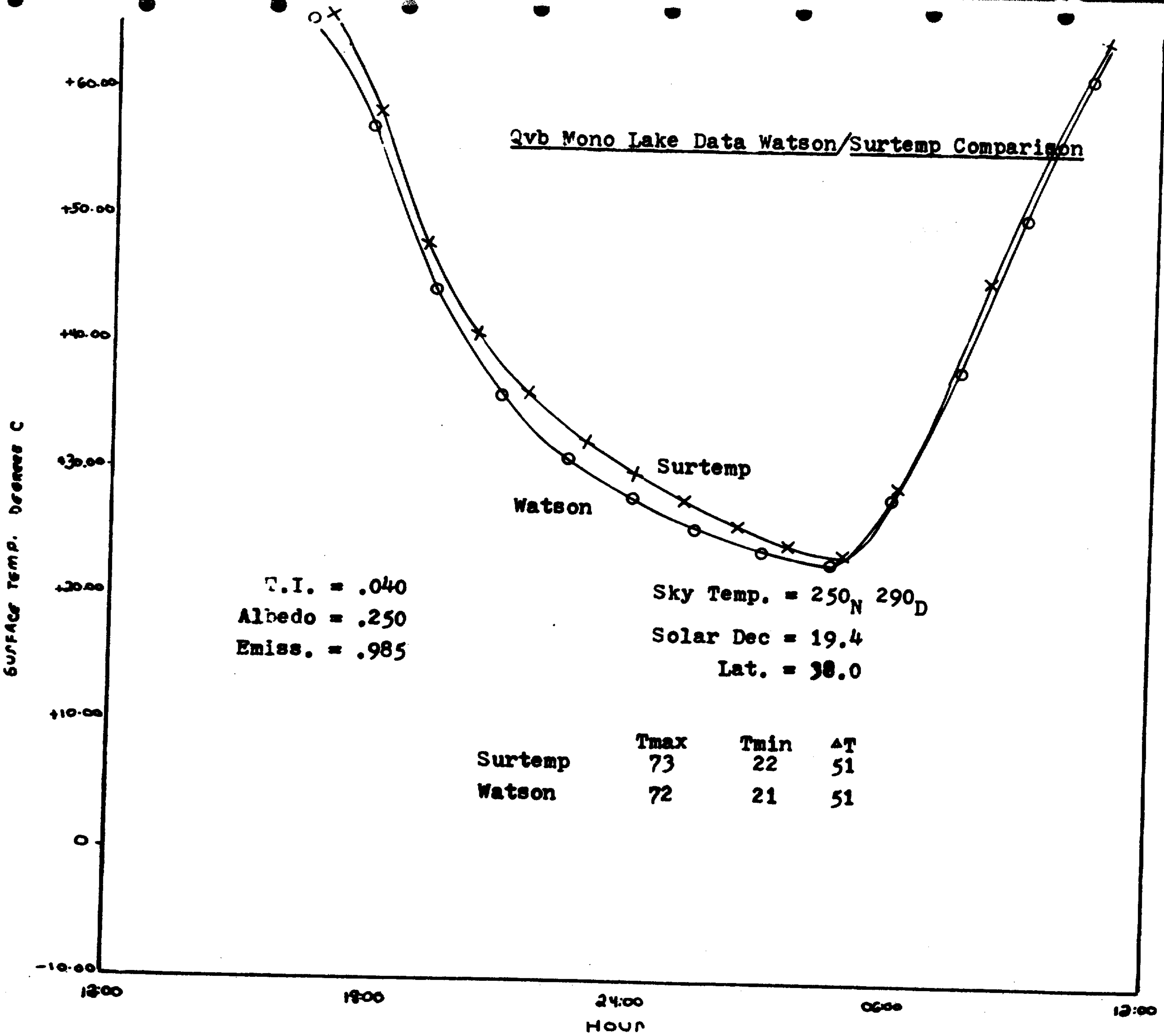

Qvb Mono Lake Data Watson/Surtemp Comparison
Surtemp
Watson
T.I. = .040
Albedo = .250
Emiss. = .985
Sky Temp. = 250N 290D
Solar Dec = 19.4
Lat. = 38.0
Tmax Tmin ΔT
Surtemp 73 22 51
Watson 72 21 51
Surface Temp. Degrees C
+60.00
+50.00
+40.00
+30.00
+20.00
+10.00
0
-10.00
12:00
18:00
24:00
06:00
12:00
Hour

Figure 2

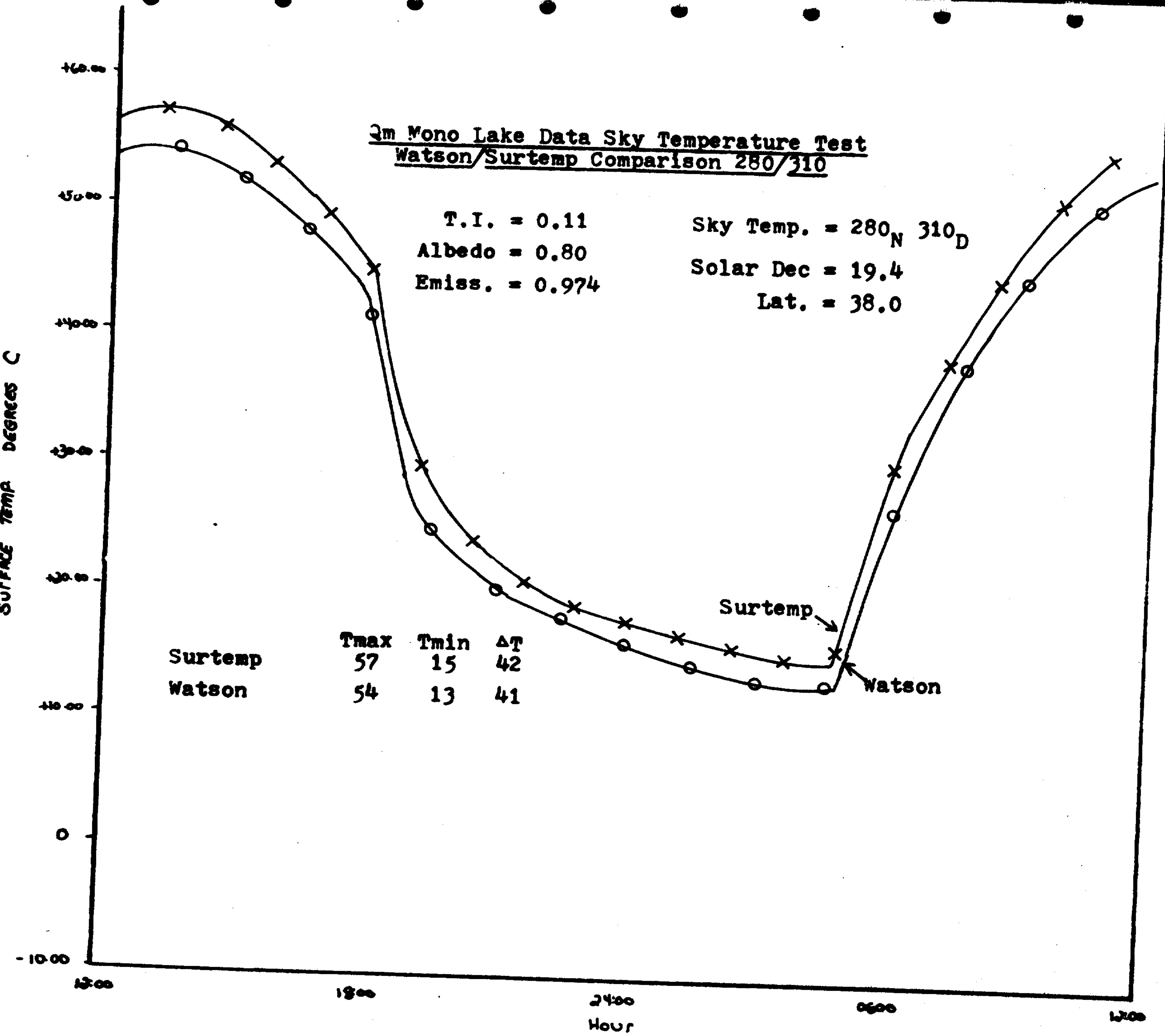

2m Mono Lake Data Sky Temperature Test
Watson/Surtemp Comparison 280/310
T.I. = 0.11
Albedo = 0.80
Emiss. = 0.974
Sky Temp. = 280N 310D
Solar Dec = 19.4
Lat. = 38.0
Surtemp
Watson
Tmax Tmin ΔT
Surtemp 57 15 42
Watson 54 13 41
SURFACE TEMP DEGREES C
+40.00
+30.00
+10.00
0
-10.00
18:00
24:00
06:00
Hour

Figure 3

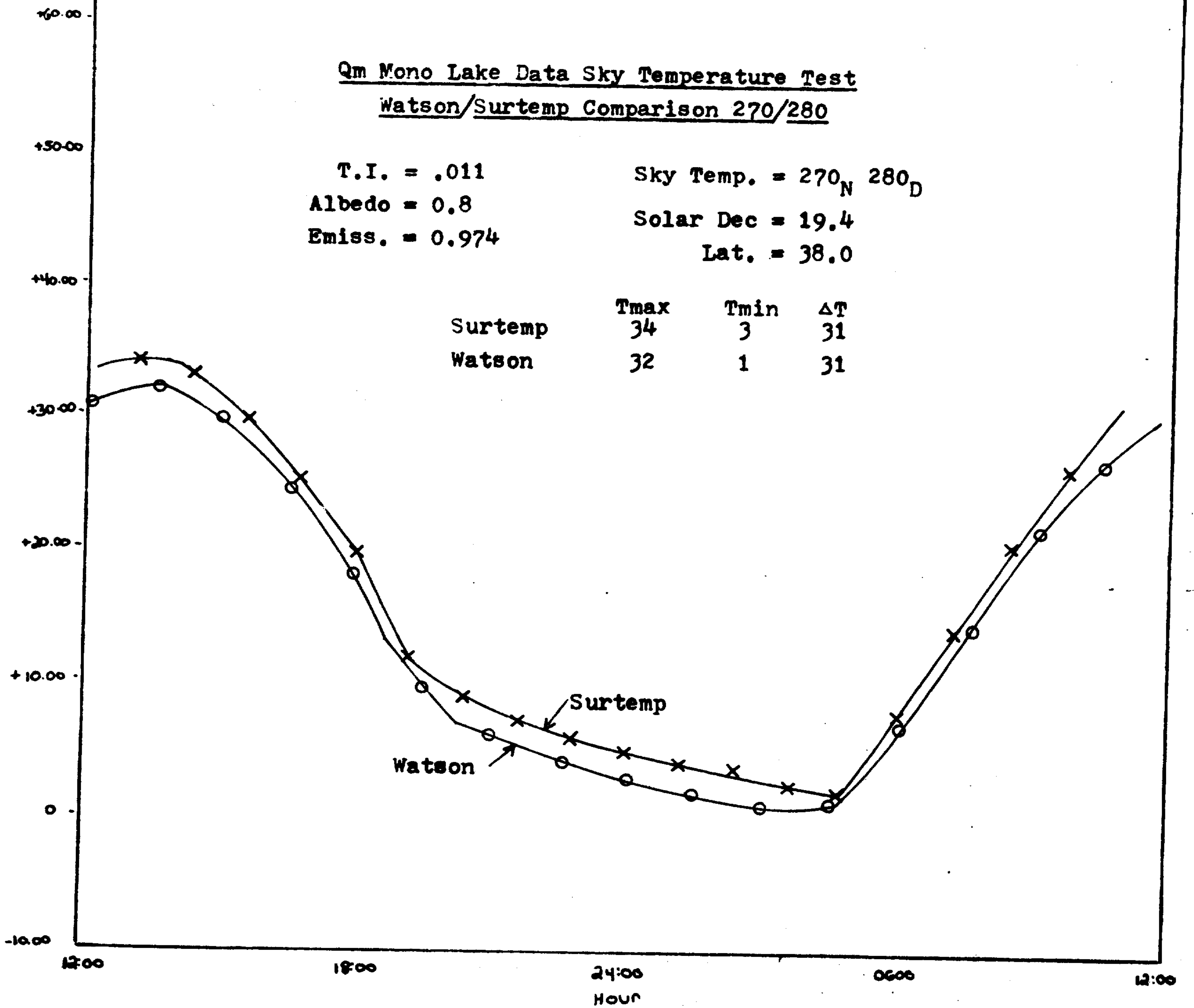

Qm Mono Lake Data Sky Temperature Test
Watson/Surtemp Comparison 270/280
T.I. = .011
Albedo = 0.8
Emiss. = 0.974
Sky Temp. = 270_N 280_D
Solar Dec = 19.4
Lat. = 38.0
Tmax Tmin ΔT
Surtemp 34 3 31
Watson 32 1 31
Surtemp
Watson
+60.00
+50.00
+40.00
+30.00
+20.00
+10.00
0
-10.00
SURFACE TEMP DEGREES C
12:00
18:00
24:00
0600
12:00
Hour

Figure 4

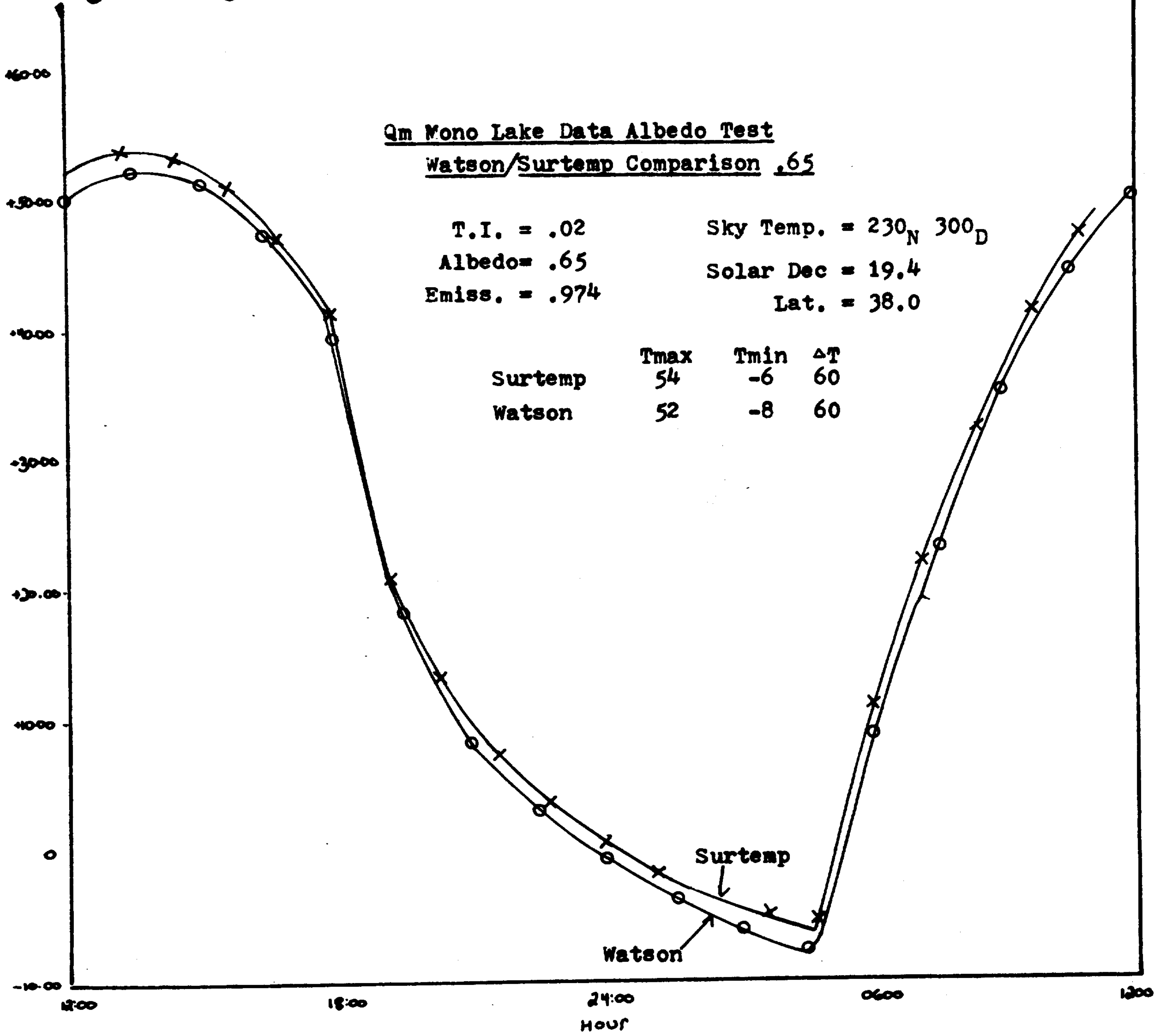

Qm Mono Lake Data Albedo Test
Watson/Surtemp Comparison .65
T.I. = .02
Albedo= .65
Emiss. = .974
Sky Temp. = 230N 300D
Solar Dec = 19.4
Lat. = 38.0
Tmax Tmin ΔT
Surtemp 54 -6 60
Watson 52 -8 60
Surtemp
Watson
Surface Temp Degrees C
Hour
12:00
18:00
24:00
0600
1200

Figure 5

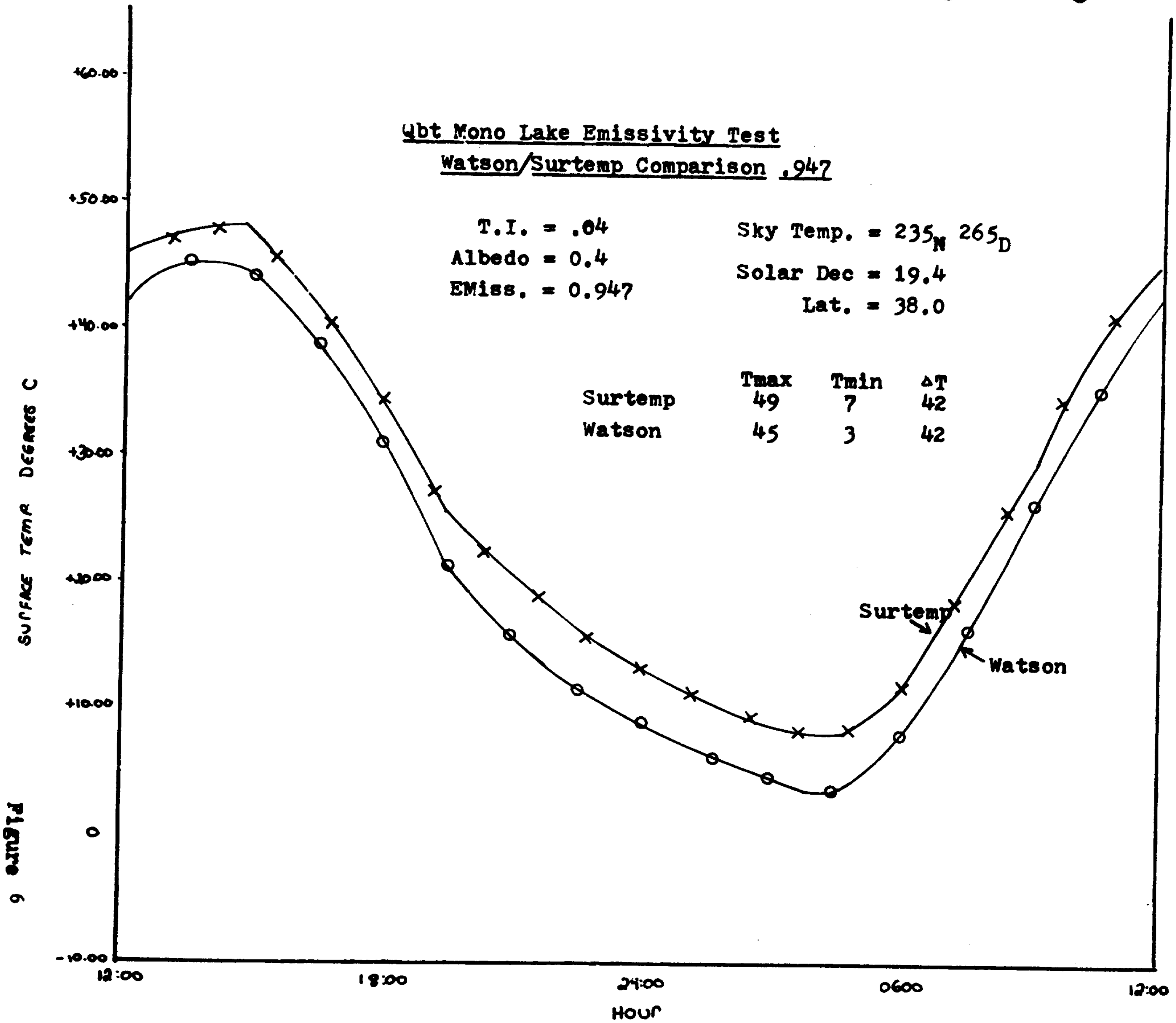

Qbt Mono Lake Emissivity Test
Watson/Surtemp Comparison .947
T.I. = .04
Albedo = 0.4
EMiss. = 0.947
Sky Temp. = 235N 265D
Solar Dec = 19.4
Lat. = 38.0
Tmax Tmin ΔT
Surtemp 49 7 42
Watson 45 3 42
Surtemp
Watson
+60.00
+50.00
+40.00
+30.00
+20.00
+10.00
0
-10.00
Surface Temp. Degrees C
12:00
18:00
24:00
0600
12:00
Hour

Figure 6

similarity in the shape of the diurnal variation curves would tend to confirm this. Inspection of the sky temperature change comparisons would indicate that within both models a $1^{o}C$ change in target would arise from a small change in sky temperature, (<5%). Inspection of all the graphs indicates the largest discrepancy between the two programs occurs between the post sunset (2000 hours) and predawn (0400 hours). Differences in maximum and minimum temperatures however are only between one and four degrees (C). The fact that the largest variations occur in the predawn hours and that Watson's (1974a) estimate of differential change in property values is taken at the predawn temperature does not necessarily provide an explanation for the discrepancies, because the shape of the curves appear similar for varying input parameter values. It is unclear what number of runs were made by Watson; to reach this conclusion, however, from the amount of data published by Watson it may be assumed his data base exceeded the two to six runs made by Lyon for each of his parameter change comparisons. This may have induced the discrepancies, nevertheless there is no strong evidence for this conclusion and could only be resolved through further runs of WATEMP and SURTEMP. An additional factor that undoubtably would vary the program results concerns the site location. The percent change discrepancies may in fact be due to the range of input variables used. Changes in emissivity, for example, that would produce a $1^{o}C$ change in surface temperature in the 0.94 to 0.95 range may be different in a lower or high range of values (i.e. 0.91 to 0.93 or 0.96 to 0.98). There is no explanation of the ranges used in Watson's (1974a) analysis, so a definitive conclusion concerning this effect can not be made; Lyon's data however are for real rock materials and parametric variations measured in the field (using Friedman, 1968, values).

It is surprising that estimates of percent change by the two researchers should vary considerably for albedo and emissivity and not for thermal inertia, and particularly so, after noting in the previous discussion of thermal parameters the significance of thermal inertia to target temperature variations. To resolve this, further comparisons would have to be made. It is concluded that the difference between the two program results are probably caused by variations in the initial temperature approximation and the number of iterations for each solution. The Watson program consistently gives lower temperature estimates for any particular hour. The shape of the curves are quite similar and temperature differences are minor except during the late evening to predawn hours.

A comparison of the Outcalt (1972) thermal model to the Watson (1971a) and SURTEMP models was made using published input and model results of a test run inserted both into the Stanford IBM 360 WATEMP program, and the PDP-10 SURTEMP program. Input parameters given by Outcalt (and corresponding to the WATEMP-SURTEMP model) are:

Latitude	= 49.3°
Solar decl.	= -14.9°
Albedo	= 0.15
Sky radiant T.	= $235^{\circ}K$
Soil thermal diffus.	= .0056 (cgs)
Soil vol. heat capac.	= 0.500 (cgs)
Shadow ratio	= 0.0

From the diffusivity (α) and volumetric heat capacity (C) it is possible to compute conductivity (k) and thermal inertia (Υ) from the relation:

$$\alpha = \frac{k}{\rho c} \qquad \Upsilon = (kC)^{1/2}$$

$$0.0056 = k/0.500 \qquad \Upsilon = (0.0028 \times 0.500)^{1/2}$$

$$k = 0.0028 \text{ cal cm}^{-2} \text{ sec}^{-1}\ {}^{o}C^{-1} \qquad \Upsilon = 3.74 \times 10^{-2} \text{cal cm}^{-2} \text{ sec}^{-1}\ {}^{o}C^{-1}$$

An emissivity of 0.98 was assumed from the description of the site-"Needle-Ice Event", and the slope orientation and inclination are assumed to be zero from the shadow ratio. Additional input for the Outcalt model included values for air column and soil conditions.

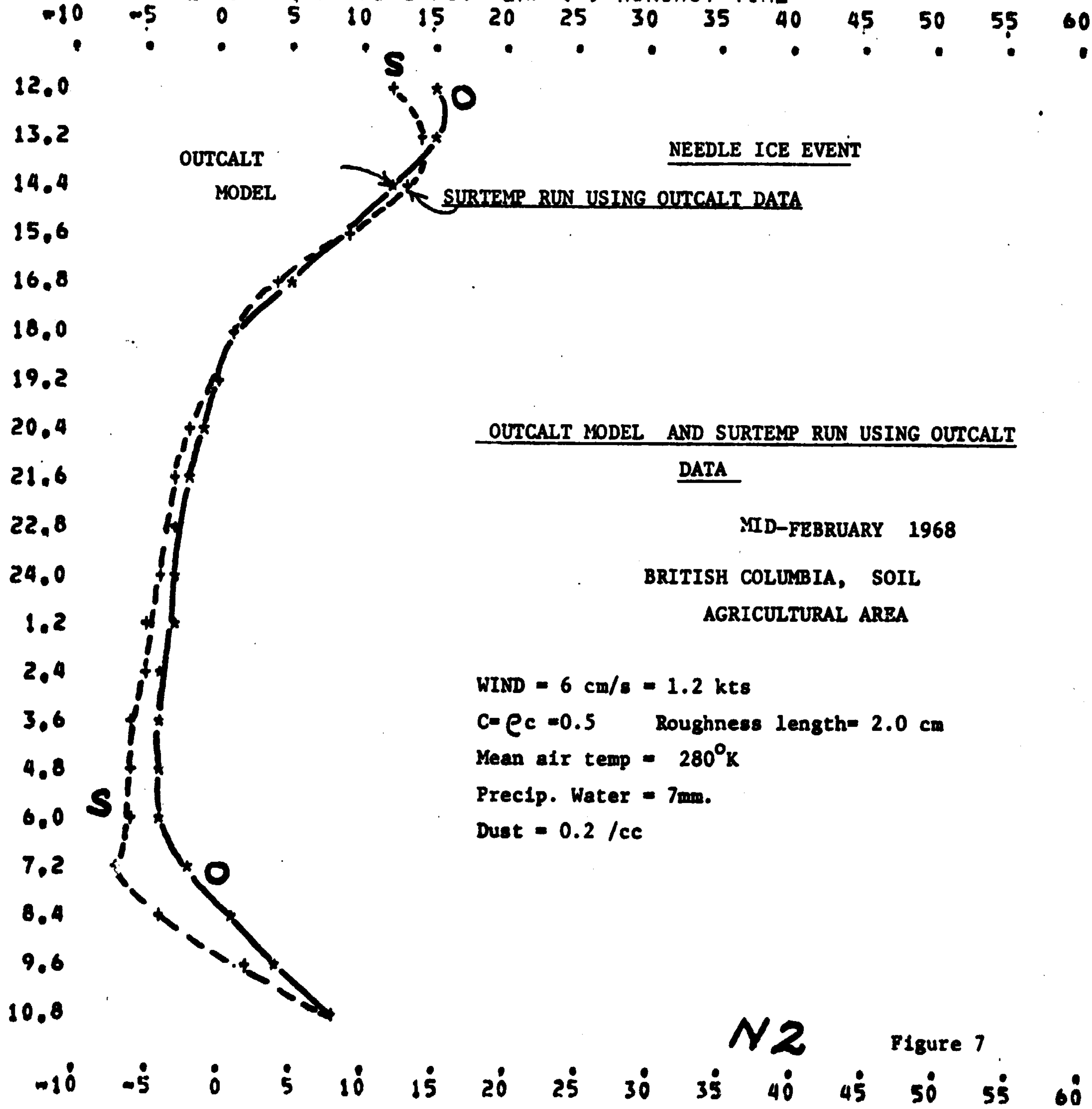
Results of the comparison run are illustrated on Figures 7 and 8. The shape of both curves are similar, and maximum temperature varies by only $1^{o}C$, minimum by $4^{o}C$, and ΔT by $3^{o}C$. Interestingly, again the largest discrepancy

```
0000000000
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 12.2 14.6 13.2 14.1 14.7 14.4 13.1 12.0 15.6  9.0  8.5 16.8  3.9  4.6
18.0  1.3  0.6 19.2 -0.4 -0.4 20.4 -1.7 -1.3 21.6 -2.7 -1.9 22.8 -3.4 -2.6
24.0 -4.1 -3.0  1.2 -4.7 -3.2  2.4 -5.2 -3.8  3.6 -5.6 -3.9  4.8 -6.0 -4.0
 6.0 -6.4 -4.1  7.2 -6.7 -2.0  8.4 -3.5  1.0  9.6  2.1  4.1 10.8  7.9  8.4

T MAX   14.1   T MIN   -6.7   AVERAGE TEMP   0.67

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD    0.0 (6) ALB  0.150 (7) EMS 0.9800 (8) T IN 0.037 (9) LAT   49.3
(10) DEC  -15.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  253.0 (14) TD  253.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
```



N2

Figure 7

```
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 12.2 11.5 13.2 14.1 13.0 14.4 13.1 14.4 15.6  9.0  5.7 16.8  3.9  2.0
18.0  1.3 -1.0 19.2 -0.4 -2.2 20.4 -1.7 -3.5 21.6 -2.7 -4.4 22.8 -3.4 -5.3
24.0 -4.1 -6.0  1.2 -4.7 -6.8  2.4 -5.2 -7.2  3.6 -5.6 -7.8  4.8 -6.0 -8.0
 6.0 -6.4 -8.1  7.2 -6.7 -6.9  8.4 -3.5 -4.4  9.6  2.1 -0.9 10.8  7.9  5.0

T MAX   14.1    T MIN   -6.7    AVERAGE TEMP   0.67

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.0 (6) ALB  0.150 (7) EMS 0.9800 (8) T IN 0.037 (9) LAT   49.3
(10) DEC  -15.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  253.0 (14) TD  253.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
```

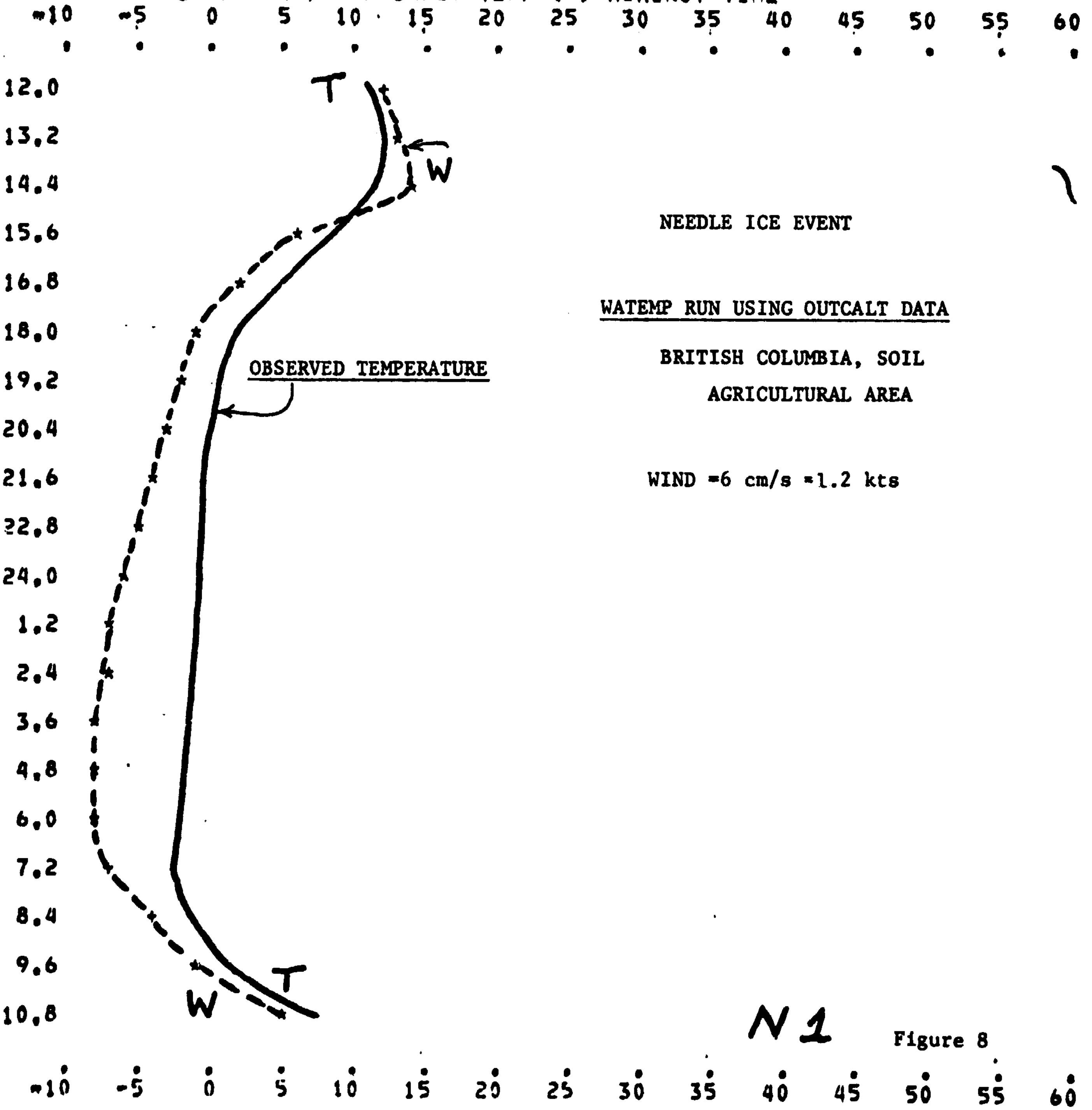


Figure 8

between the two models exists in the predawn hours. From the comparison it appears we can tentatively conclude that both programs yield similar temperature estimates ($\pm 4^{o}C$). The additional complexity of Outcalt's program however does not necessarily make its results more accurate. Uncertainty of parameters must still exist and added parameters may increase total uncertainties. To ensure the usefulness of a model the additional parameters that are of value only to the climatologist should be disregarded by the geologist or geophysicist. This would make the job of collecting field data simpler and the model less cumbersome to use.

Two comparisons of the ROSEMA/WATEMP/SURTEMP models were made using the input parameters published by Rosema (1974) for coarse sand and Basin clay at sites in Holland ($52^{o}N$), that he does not describe in detail. Input values given by Rosema applicable to the Watson program are:

		Coarse Sand	Basin Clay
Albedo		0.30	0.15
Emissivity		0.92	0.94
Vol. Qtz. Content	X_m	0.60	0.00
Vol. Clay + Feldspar	X_m	0.00	0.46
Vol. organics (X_o)		0.00	0.00
Latitude		52.0^{o}	52.0^{o}
Day		April 12	April 12

Values of sky temperature and thermal inertia had to be estimated. The selection of sky temperature for the location and season of the test, at a ground temperature of $280^{o}K$ was fixed somewhat arbitrarily at $260^{o}K$ night and $270^{o}K$ day.*** Selection of thermal inertia was somewhat less arbitrary. Employing the De Vries (1933) equation for soil heat capacity:

$$C = 0.46X_m + 0.60X_o + X_w \text{ cal cm}^{-3}\ {}^{o}C^{-1} \qquad (9)$$

the coarse sand with a moisture content of 0.20, would have a heat capacity of:

$$C = 0.46(0.60) + 0.60\ (0.0) + (0.20) = 0.476 \qquad (10)$$

***Humidity at the site should produce close night and day temperatures (Lyon, personal communication 1975).

with a moisture content of 0.20; the Basin clay would have a heat capacity of:

$$C = 0.46\ (0.46) + 0.60\ (0.0) + (0.30) = 0.512 \qquad (11)$$

Estimates of conductivities given by Sellers (1965) and De Vries (1963) at moisture contents of 0.20 are 4.2×10^{-3} and 5.3×10^{-3} cal cm^{-1}sec^{-1} $^{o}C^{-1}$ for coarse sand; and 3.5×10^{-3} and 2.8×10^{-3}cal cm^{-1}sec^{-1} $^{o}C^{-1}$ for Basin clay. Taking the mean of these values with the calculation of estimated volumetric heat capacities calculated, values of thermal inertia (γ) can be estimated:

$$\gamma = \rho\ (kC)^{1/2}$$

$$\text{Coarse sand} = (4.8 \times 10^{-3} \times 0.48)^{1/2} = 0.048. \qquad (12)$$

$$\text{Basin clay} = (3.2 \times 10^{-3} \times 0.51)^{1/2} = 0.040. \qquad (13)$$

Results from the comparisons (figure 9) indicate a large discrepancy of surface temperature. The comparison, nevertheless, was a useful exercise in showing the difficulty of obtaining thermal parameters for any given test. The large uncertainty in our estimation of appropriate sky temperature and thermal inertia illustrate their significant effects on modeling of the diurnal temperature variation.

Certain added ambiguities exist in the Watson-Rosema Comparison: Within the description of the parameters of the sample materials, by Rosema (1974), it is difficult to imagine an absolute zero quartz content in the Basin clay. Also somewhat surprising are the results given by WATEMP. It is unusual that surface temperatures in early April at a north latitude of 52^{o} could reach $50^{o}C$.

C. Discussion

The value of thermal models seems apparent from the previous discussion. The thermal models of Watson and SURTEMP appear quite similar, and hold an advantage over those of Outcalt and Rosema in their simplicity of input parameters. When used to differentiate rock and soil types as on infrared

DDDDDDDDDD

TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES

12.0	53.5	0.0	13.2	56.1	0.0	14.4	55.8	20.2	15.6	52.7	18.1	16.8	47.0	14.0
18.0	39.6	10.9	19.2	33.1	8.4	20.4	29.3	6.3	21.6	26.6	4.9	22.8	24.5	4.1
24.0	22.9	3.3	1.2	21.5	2.9	2.4	20.3	2.4	3.6	19.3	2.0	4.8	18.3	1.8
6.0	20.3	2.4	7.2	26.0	5.8	8.4	33.5	9.2	9.6	41.4	13.0	10.8	48.4	17.0

T MAX 56.1 T MIN 18.3 AVERAGE TEMP 34.50

HOLLAND
BASIN CLAY

PROGRAM PARAMETERS CURRENT VALUES

(5) CLOUD 0.0 (6) ALB 0.150 (7) EMS 0.9400 (8) T IN 0.040 (9) LAT 52.0
(10) DEC 8.3 (11) DIP 0.0 (12) STR 0.0 (13) TN 260.0 (14) TD 270.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME

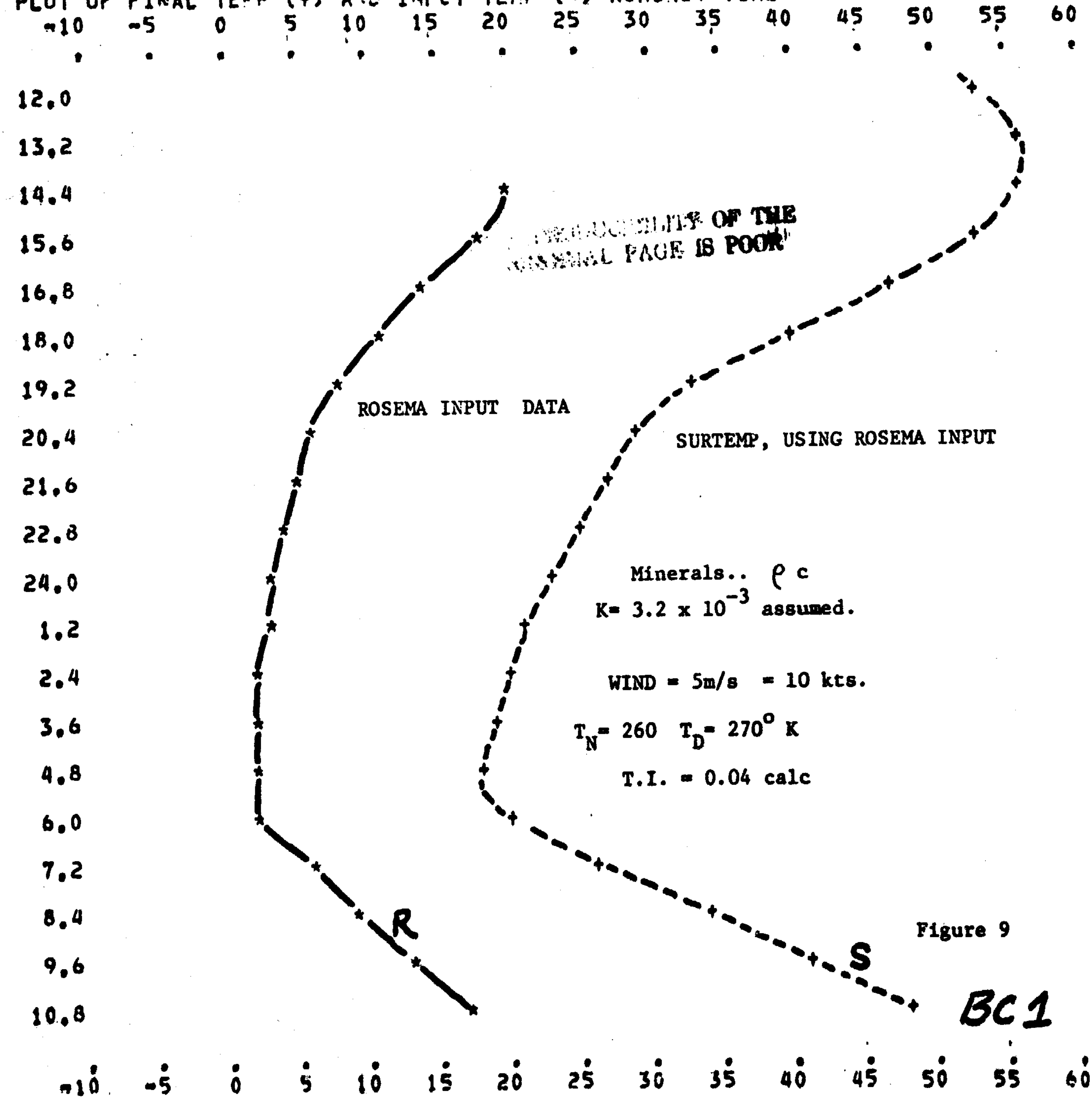


Figure 9

BC1

imagery, the model indicates that thermal inertia is a good discriminator of materials, and the effects of thermal inertia on surface temperatures are maximized near dawn. Thus dawn represents the optimum time to observe thermal contrasts due to thermal property differences.

III. PISGAH-LAVIC LAKE STUDY (March 29-30, 1975)

A. Site Description

The Pisgah Crater-Lavic Lake area is located in the Mohave Desert, San Bernadino County, California. It is approximately 38 miles east-southeast of the town of Barstow. Pisgah Crater and its associated flow is nearly 14 miles long and 4 miles across. At the southeastward end of the flow is Lavic Dry Lake approximately 2 miles in diameter. Other details of the area appear in Kahle, et.al., 1976.

The Pisgah Crater flow is composed of numerous thin olivine basalt flows. The top of this flow sequence is made up of both pahoehoe (ropy) and aa (jagged-clinkery) lava. The aa lava is dark gray, or more usually, black in color and has an extremely rough surface. The pahoehoe lava is a "medium" dark gray in color and has a smoother undulatory surface. Both types of surface can accumulate windblown sand or silt. Pisgah Crater is made of cinders (that range in color from black to grayish red), and small bombs. The crater floor is pahoehoe basalt.

Lavic Dry Lake is a very flat playa composed of a very pale, yellowish-brown silty clay. Neal (1965) determined the playa is made up of 79% clay (essentially montmorillonite and illite) 20.7% granular components, and 0.2% accessories with a bulk density of 1.67. The playa had an approximate maximum relief of 2 1/2 feet. Numerous areas on the playa are mantled by pebbles or cobbles of basalt or alluvial fan material. These mantling materials are somewhat anomalous as they are found some distance from their obvious source. Gawarecki (1964) reports they are believed to be ice rafted to their current position when sufficient lake levels existed.

Alluvial fan material is found along the borders of Lavic Lake. This material is a heterogeneous conglomerate derived from present topographic highs. It is a yellowish gray color with a sparse vegetation cover.

Measurement sites at the crater, designated, "Crater outeredge" and "Crater station" consisted of cinders, clinkers and bombs; site "Crater outside Basalt" consisted of aa and pahoehoe basalt east of the cone viewed from a distance. Site "Crater center" was measured from a distance and consisted of solidified pahoehoe lava; Site "Crater Red Cinder" consisted of an area of predominantly Red cinder on the inner lip of the crater; and site "Crater Road"consisted of compacted cinders and dirt.

Lavic Lake sites 1-1, 1-2, 1-3, 1-4, 2-2, 2-3, consist of the pale yellowish-brown silty clay. Site 2-1 was on alluvium (Figure Map 1).

B. Albedo Measurements and Analysis

Measurements of albedo were made at the test sites on Lavic Lake and at the crater employing an ISCO spectral radiometer and an EXOTECH radiometer by Stanford Remote Sensing Lab personnel. These measurements were necessary to better understand the site locations and to provide the necessary input data for our thermal model. The procedure involved making a number (5-25) of readings at each site attempting to include the greatest diversity in surficial conditions, with concurrent readings of white reflectance standards of $BaSO_4$ and Fiberfrax. ISCO readings (see Appendix 2) were made from 0.400 to 1.55 micrometers with a bandpass interval of .025 micrometers in the visible and a bandpass interval of .050 micrometers in the near-IR. Exotech readings were collected in detail at the Lavic Lake sites. The instrument sensed in the same channels as the LANDSAT MSS sensor (0.5-.6, .6-.7, .7-.8, .8-1.1 micrometers). Twenty-five readings at Stations 2-1 (alluvium), 1-1 and Base camp (playa) were made, and five readings at Stations 1-2, 1-3, 2-2A, 2-2B, 2-2A (playa) were made (Figure Map 1). Appendix 1 catalogues these measurements and yields values of bandpass, reflectance, and "pseudo-CIE" color coordinates for each channel and calculates an albedo for each site.

The albedo values from the Exotech measurement sites are compiled in Table 3 along with means and standard deviations for each location. The 75 playa measurements yielded a mean of 0.375 and a standard deviation of 0.027 (7% variation) while the 25 alluvium sites (2-1) yielded a mean of .295 and a standard deviation of .018 (6% variations). These statistical checks indicate

indicate that complete discrimination is possible between playa and alluvium within (1σ) one standard deviation interval. However, a slight overlap exists at the two standard (2σ) deviation interval. The seven distinct playa stations (1-1, 1-2, 1-3, 2-2A, 2-2B, 2-2, BC) cannot be separately delineated by the albedo values except for station 2-2 which can be discriminated by albedo within a two standard deviation interval. A contour map of the site albedos (figure 10) visually expresses this discriminatory ability of albedo.

To determine the most favorable spectral information for discrimination of the playa sites the complete data set (Appendix 1) was input to the BMD07M (stepwise discriminant analysis) program developed by the UCLA Health Sciences Computing Facility (April 10, 1972). The results showed that the simple bandpass of channel BP5* (.6-.7 µm) had the greatest success (55%) at discrimination by itself. This was followed by R5 reflectance .6-.7 µm (82%), R4 reflectance .5-.6 µm (83%), BP4 bandpass .5-.6 µm (85%), and R74 ratio of reflectances .8-1.1 by .5-.6 µm), for the pair, trio, quartet, quintet as used, respectively. This is graphically displayed in Figure 11. Of the 25 sites measured at station 1-1,17 were correctly classified and of the 25 at station base camp 18 were correctly classified, using the quintet, with 84% success level. At this level, the program employing the input quintet, all measured sites were correctly classified at stations 1-2, 1-3, 2-2, 2-2A, 2-2B. Station 2-1 within alluvium is readily distinguishable from the playa and of the 25 sites measured 24 were correctly classified.

It seems reasonable to conclude then that though total albedo is a necessary measurement for thermal modelling it is not entirely successful at spectral discrimination. Greater spectral discriminatory ability is available employing individual spectral bands and ratios of bands using a simple ratiometer of the EXOTECH type. Thus LANDSAT satellite data could have been used to discriminate between sites of this degree of spectral albedo differences.

C. <u>Surface Temperature Measurements and Analysis</u> - Pisgah Crater and Lavic Lake

Stanford Remote Sensing Lab personnel were able to provide much needed expertise in the collection of field thermal measurements. We made use of several Barnes (PRT) Radiation thermometers and thermistor probes. Appendix 3 catalogues these measurements and Appendix 6 graphically display the probe

* BP 4, 5, and 7 are bandpass radiances and R4, 5, 6, and 7 are bi-directional reflectances using LANDSAT type bandpass filters (EXOTECH).

SITE LOCATIONS LAVIC LAKE

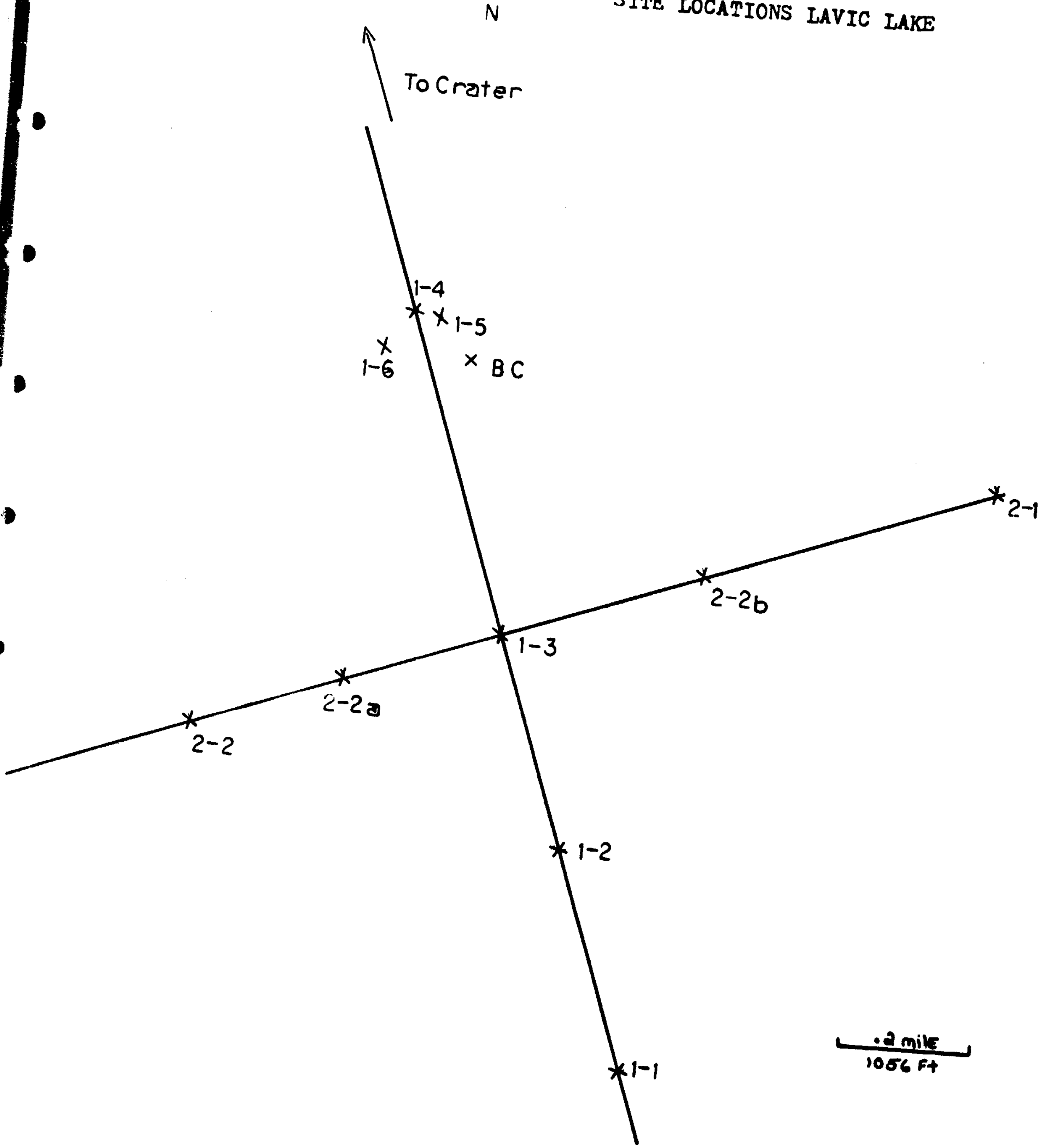


Figure Map 1

TABLE 3

Albedo Determinations:

PLAYA

Site:	1-1	1-1N	1-1E	1-1S	1-1W
	.352	.378	.340	.364	.367
	.359	.378	.348	.344	.387
	.348	.377	.349	.398	.372
	.354	.401	.354	.369	.368
	.363	.367	.355	.377	.363
$\bar{X}$=	.355	.380	.349	.370	.371
s=	.006	.013	.006	.020	.009

$\bar{X}_{total}$ = .365

n=25

s_{total} = .016

Site:	1-2	1-3	2-2A	2-2B	2-2
	.368	.404	.365	.385	.461
	.365	.369	.347	.386	.469
	.373	.375	.348	.388	.457
	.391	.372	.377	.375	.450
	.392	.370	.353	.384	.448
$\bar{X}$=	.378	.378	.358	.384	.457
s=	.013	.015	.013	.005	.009

Site:	BC	BCN	BCS	BCE	BCW
	.364	.370	.355	.353	.368
	.366	.416	.388	.360	.368
	.377	.393	.360	.362	.365
	.410	.353	.359	.360	.365
	.372	.366	.369	.364	.370
$\bar{X}$=	.378	.380	.366	.360	.367
s=	.019	.025	.013	.004	.002

$\bar{X}_{total}$ = .370

n=25

s_{total} = .016

$\bar{X}_{playa}$ = .375

n=75

s_{playa} = .027

Table 3 continued

ALLUVIUM

Site:	2-1	2-1N	2-1E	2-1S	2-1W
	.293	.299	.288	.305	.298
	.287	.273	.358	.290	.298
	.293	.282	.278	.300	.272
	.290	.291	.311	.303	.271
	.286	.288	.298	.311	.312
$\overline{X}=$	.290	.287	.307	.302	.290
s=	.003	.010	.031	.008	.018

$\overline{X}_{total} = .295$ n=25

$s_{total} = .018$

Emissivity for the playa was assumed, at each site, to be .985.

CONTOUR OF SITE ALBEDO VALUES

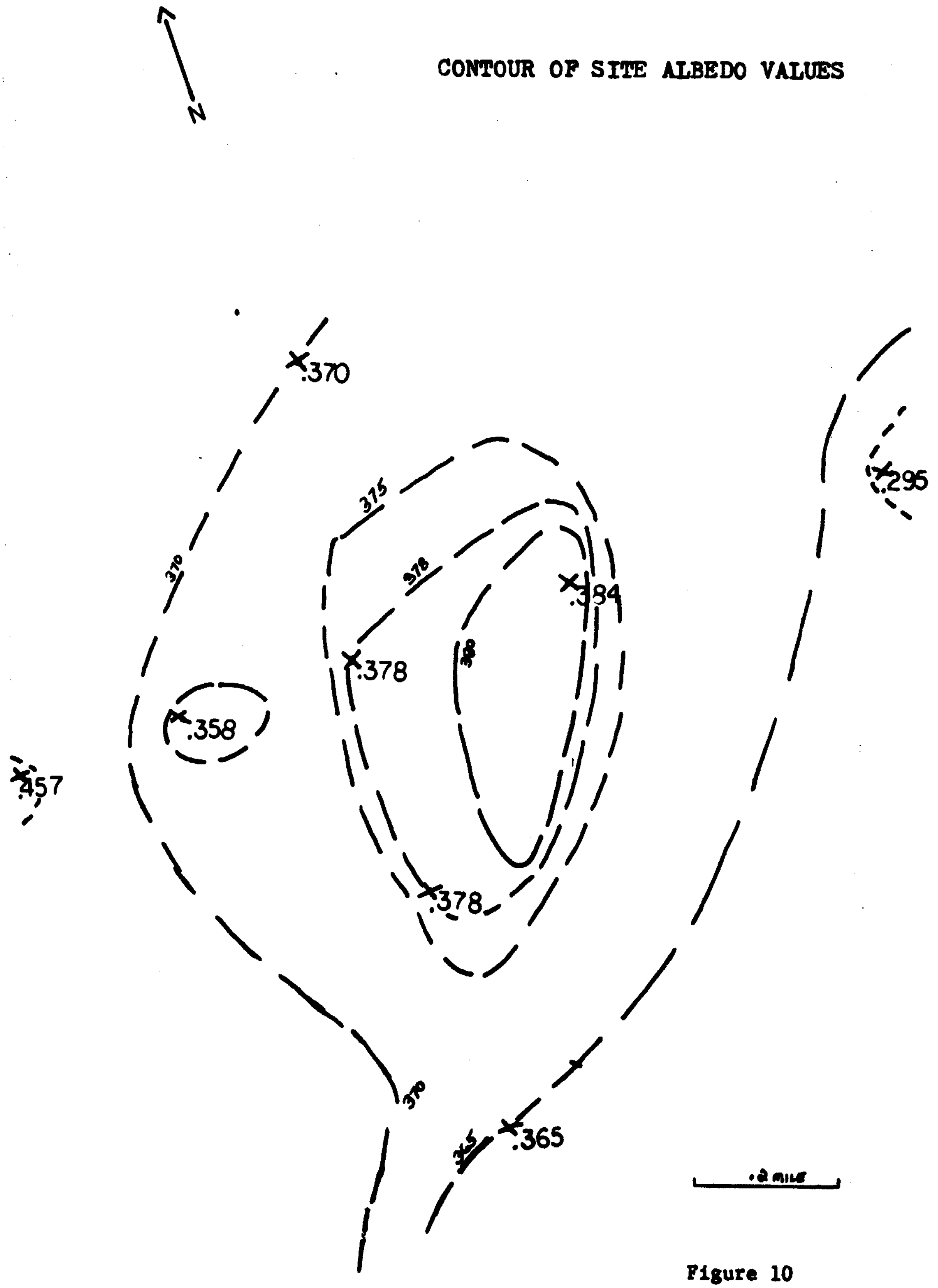
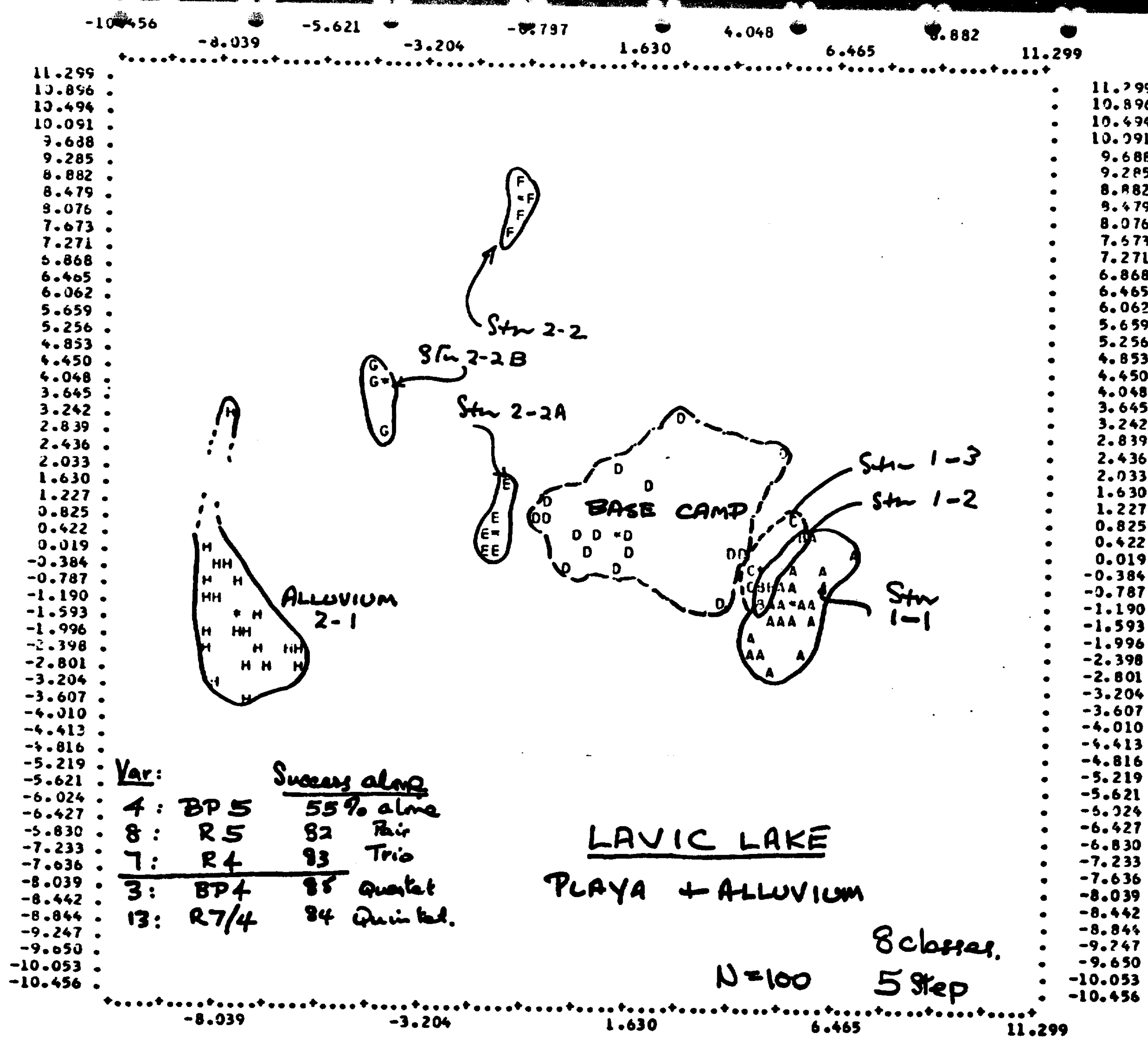


Figure 10

FIGURE 11



D.19CPU

11

measurements for the playa sites, as tautochrones ,or depth-temperature plots. The scale of the tautochrones permit positioning to within .5°C and .5 cm depth, and therefore should be considered accurate representations. Appendix 4 shows the measured (average of the 5 readings) surface temperatures (solid line) compared with runs of the SURTEMP and WATEMP programs.

The major concern in the determination of input parameters entails the selection of a thermal inertia value (Υ) to accurately match the measured surface temperatures. Various methods were employed to arrive at a value that can be considered reliable. Input parameters that are evident for the dry lake sites, are;

Latitude:	34.66°
Dip :	0.0
Strike :	0.0
Sun's Declination:	03°02.9'.

The work of Neal (1965) provided pertinent data on the bulk density and composition of the Lavic Lake playa; soil moisture samples were taken during the mission and provided data yielding weight % water at .09% (vol. fraction .20%). With this data it is possible to apply the DeVries (1963) formula for volumetric heat capacity (C) of the playa material,

$$C = 0.46\ X_m + 0.60\ X_o + X_w, \tag{14}$$

where X_m = vol. fract. minerals X_o = vol. fract. organic, and X_w = vol. fract. water. DeVries also determined a formula for the damping depth of a soil related to thermal diffusivity (α),

$$(2\ \alpha/w)^{1/2} = D \tag{15}$$

where D = Damping depth, and w = angular period of the diurnal wave (7.276×10^{-5} rad sec^{-1}). The damping depth is that depth where the surface temperature considered at a sinusoidal wave, is reduced by 1/e (.37). From inspection of the tautochrones at the playa sites the damping depth occurs at 10 cm.

Employing this knowledge we can solve for thermal diffusivity and arrive at a value of 3.64×10^{-3} cm^{2}sec^{-1}. If we consider this value and that for volumetric heat capacity (C=.568) to be valid then the thermal inertia of the playa can be calculated after first determining thermal conductivity (K).

Now,

$$\alpha = k/C \qquad 3.64 \times 10^{-3} = k/.568$$

$$k = 2.07 \times 10^{-3} \text{ cal cm}^{-1}\text{sec}^{-1}\ {}^{o}C^{-1} \qquad (16)$$

$$\gamma = (kC)^{1/2} \qquad = (2.07 \times 10^{-3} \times .568)^{1/2}$$

$$= .034 \text{ cal cm}^{-2}\ {}^{o}C^{-1}\text{sec}^{-1}. \qquad (17)$$

Additional information needed for the SURTEMP thermal model included a cloud cover factor assumed initially to be zero, a hemispherical net sky radiation term (sky temperature) for the day and night, and the emissivity of the surface approximated from measurements of similar surfaces at 0.985. From previous work (see Section II) of Lyon (1975) we note that an inaccuracy in the emissivity of 25% will produce only a $1^{o}C$ change in surface temperature, employing the SURTEMP program. However, as we have noted, the thermal model is quite sensitive to sky temperature. Unfortunately a net radiometer, necessary for these measurements, was not available and thus sky temperature could be only approximated from the known meteorological conditions. These calculations and approximations along with the albedo measurements were performed for each of the playa sites and closestfits to the observed data were plotted (Appendix 4). As can be seen, fairly close fits can be achieved with day and night sky temperatures of 240^{o}, $230^{o}K$ respectively and employing the calculate thermal inertia (γ) of .034 cal $cm^{-2}\ {}^{o}C^{-1}sec^{-1}$.

Discussion of these results with the JPL investigators, whom we were assisting, indicated that they believed a more accurate thermal inertia value for the playa fell between .01-.03 cal $cm^{-2}\ {}^{o}C^{-1}$. The thermal model developed by Kahle (1976) compensates for wind at the site and they felt this meteorological variable (not directly included in the SURTEMP model) invalidated our results. To further explore this discussion additional SURTEMP runs were made analyzing station 1-1, (Appendix 5). It was determined by using the cloud cover factor to simulate a moderate wind speed (i.e. loss of input heating) and by altering the sky temperature the results could be made to approximately conform to a thermal inertia of .02 cal $cm^{-2}\ {}^{o}C^{-1}sec^{-1}$.

Unfortunately, we have not convincingly proven, <u>even in the simple case of the playa material</u>, what is the true value for the thermal inertia! Though admittedly the SURTEMP program does not include a compensating factor for strong windspeeds, it must also be pointed out that the JPL results were based on an assumption that the playa moisture content was zero! It can be shown that this assumption can reduce a final thermal inertia value by more than 30%. Scientific integrity would therefore force us to conclude that an exact measure of thermal inertia was not determined by either group. If it is to be accurately estimated, precise measures of net sky radiation, emissivity, soil moisture, and wind speed must be made and included in thermal modeling.

It is abundantly clear that solution of thermal models using real data is not a simple problem, and much remains to be done. The problem is especially complex if the measurements are made from a remote vehicle.

IV. SANDBOX STUDY

A. Objectives

In an attempt to determine the accuracy of thermal inertia determinations by remote sensing techniques a study was begun at the Remote Sensing Lab. Though many workers are now reporting thermal inertia values using various computer model deviations of the heat conduction equation, it is difficult to fix confidence limits to these determinations. Therefore, after a considerable search, a standard material was found for which both thermal conductivity and diffusivity had been determined by direct laboratory techniques at varying moisture contents. A heat transfer study by Moench (1969) had determined these parameters for 20/30 mesh Ottawa sand (quartz, 0.5 to 0.8 mm size).

The sand could thus be placed under simulated natural conditions and attempts made to correctly determine its thermal properties. If successful further impetus would be gained for heat capacity mapping. If, however, a thorough experiment proved completely unsuccessful, we would be forced to examine the total validity of thermal inertia determinations and their discrimination by remote sensing techniques.

We have only begun preliminary experimentations, but these results and tentative assessments will be reported.

B. Measurements

In order to simulate natural soil conditions the sand was placed within a square box, constructed of Douglas Fir and sealed with water-safe glue, nails, and screws. The thickness of the walls is uniformly 6.3 cm, and it is 30.5 cm deep and 45.7 cm long and wide. The sand and thermistor probes placed within the sand were allowed to equilibrate for over one week.

For this preliminary work the same information was collected as was collected during the Pisgah-Lavic Lake mission. This procedure was adopted in order to assess the importance of accurate, in situ, net sky radiation and emissivity measurements. All other parameters were accurately measured, including albedo (.5-1.1μm) which was determined to be 0.54. The thermal measurements are compiled in Table 4 and the tautochrone of the data is depicted in figure 12. The emissivity of the sand was considered to be about 0.95, and the sky temperature (day and night) were both estimated at 263^{o}K. Partly cloudly conditions existed sporadically during the day and evening and seemed to indicate a slight cloud cover factor.

C. <u>Results</u>

The water content of the sand was kept as close to zero as possible, yielding, from Moench's work, an expected thermal inertia of 0.0166 cal cm^{-2} ^{o}C^{-1}sec^{-1}. Figure 13 represents the best fit for the observed data with these input parameters. The 5^{o}C discrepancy between the measured and modeled final temperatures, when the thermal inertia is known, succinctly states the need for more accurate measurements of net sky radiation, emissivity, and cloud cover-windspeed.

During this NASA grant a "look-up table" program for thermal inertia, based upon SURTEMP, was developed. The program allows for the construction of a 3-dimensional matrix, developed from the standard (or fixed) input data sets and with variable albedo and day and night temperature as the sand ordinates. Thus for any particular time of day and or night, a similar table, as seen in figure 14, can be generated. In this instance, the program yields a thermal inertia value of 0.0195 cal cm^{-2} ^{o}C^{-1}sec^{-1}. The input is identical to that of figure 13. Comparison of these techniques allows us therefore to conclude the inaccuracies in our input parameters has produced a discrepancy of .003 in the thermal inertia.

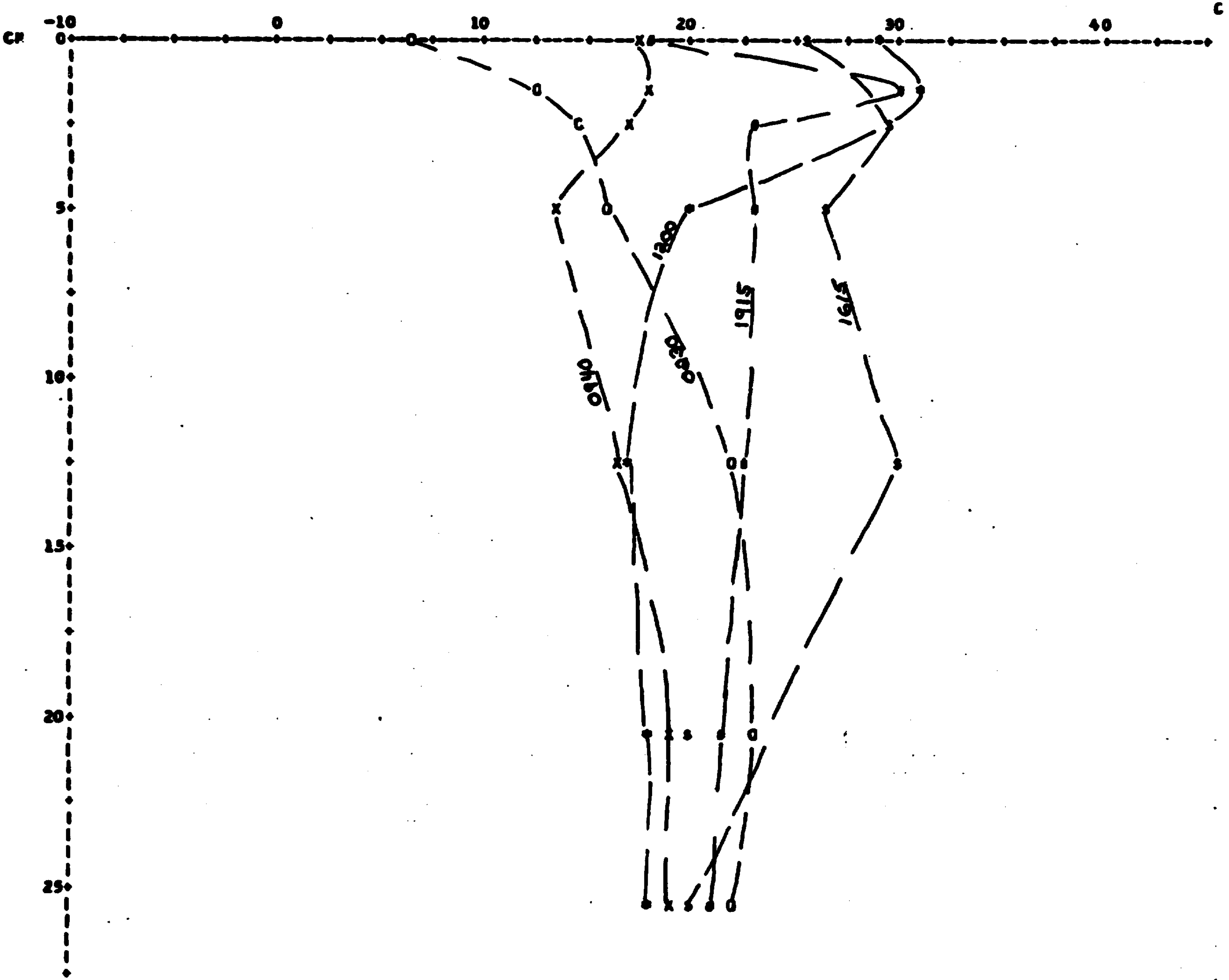
These efforts are continuing and will be expanded with renewed funding for the HCMM program.

V. CONCLUSIONS

A. Little agreement exists today between results from several thermal models using the same input data sets.

B. Each model has a varying degree of sensitivity to any specified parameter, site [redacted]

FIGURE 12



```
12:35 SAT 4 OCT 75
                                                                        <FWBUDI>SEM.;1
UNNBUNNNNN
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 35.7 29.2 13.2 37.4 31.0 14.4 35.8 30.4 15.6 31.0100.0 16.8 23.4 25.7
18.0 14.3 21.5 19.2 10.1 17.8 20.4  7.6100.0 21.6  5.8100.0 22.8  4.5100.0
24.0  3.4100.0  1.2  2.6100.0  2.4  1.9  7.0  3.6  1.3100.0  4.8  0.8100.0
 6.0  0.3  6.0  7.2  6.2100.0  8.4 14.8100.0  9.6 23.6 17.7 10.8 30.9 25.4

T MAX   37.4   T MIN    0.3   AVERAGE TEMP  14.57

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD    0.1 (6) ALF  0.540 (7) EMS 0.9500 (8) T IN 0.017 (9) LAT   37.5
(10) DFC     3.8 (11) DIP   0.0 (12) STR    0.0 (13) TN  263.0 (14) TD  263.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
```

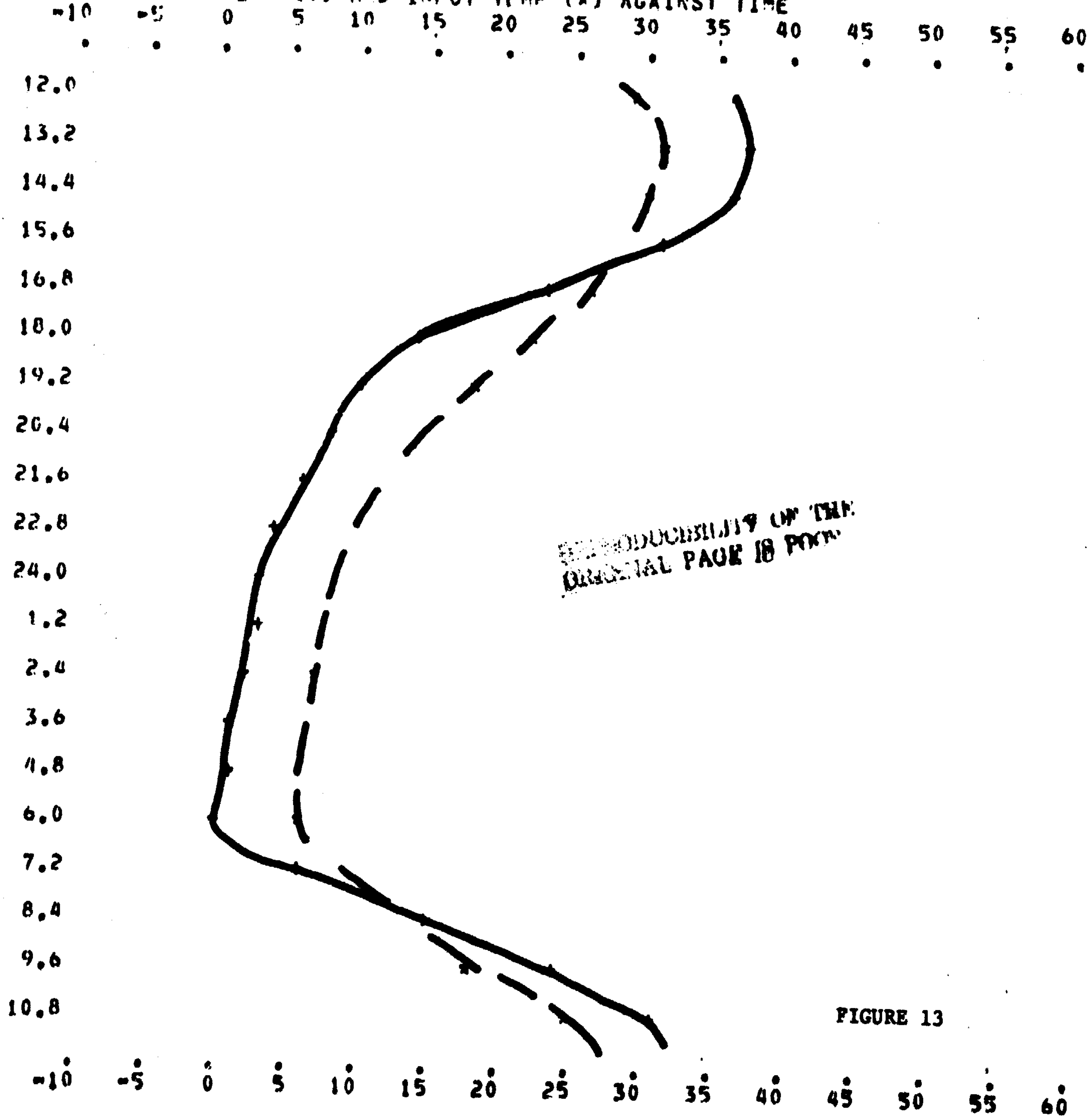


FIGURE 13

TABLE 4

"SANDBOX" EXPERIMENT TEMPERATURES

Date/Time	DEPTH PROBE (cm) 1.27	2.54	5.08	12.70	20.32	25.40	AIR SURFACE	AIR(10cm) ABOVE SURFACE	WIND mph	PRT-5 SURFACE					MEAN
10/3/75	(°C)						(°C)	(°C)		(°C)					
0936	17.8	17.2	13.7	16.7	18.9	18.8	23.5	21.2	2	18.0	17.5	18.2	17.5	17.5	17.7
1048	24.6	23.4	16.5	16.5	18.4	18.4	28.8	25.5	0	26.0	25.0	25.5	25.2	25.5	25.4
1205	30.8	29.4	20.2	16.9	18.1	18.2	29.5	29.5	0	29.2	29.1	28.9	29.4	29.6	29.2
1312	30.5	29.4	22.0	17.4	18.1	18.3	26.8	23.6	0-5	28.0	28.4	28.5	27.9	28.1	28.2
1425	32.8	31.3	24.2	18.6	18.5	18.7	32.7	26.6	3-5	29.8	30.4	30.4	30.9	30.4	30.4
1650	30.0	29.4	26.5	20.9	19.9	19.8	29.7	26.2	0-3	25.5	25.6	25.9	25.9	25.4	25.7
1800	25.4	26.3	25.3	21.9	20.7	20.4	29.1	23.2	0-2	21.0	21.5	22.5	21.9	20.4	21.5
1830	23.8	25.2	24.7	22.1	21.0	20.6	22.7	22.4	0	19.5	19.4	19.9	20.5	19.4	19.7
1915	20.9	22.8	23.2	22.7	21.5	21.0	19.0	19.3	0-1	17.4	17.5	18.5	17.8	17.9	17.8
0224	12.4	14.7	15.8	22.0	22.8	22.2	17.0	12.2	0	6.0	6.5	6.5	7.0	7.5	6.7
0600	11.0	12.8	13.4	19.9	21.5	21.4	11.5	12.1	0	5.8	6.2	6.2	6.0	6.1	6.0

PLANE OF THERMAL INERTIA TABLE FOR ALBEDO INDEX 3 (ALBEDO= .5333)

DAY TEMPERATURE

NIGHT:	10.0	13.0	16.0	19.0	22.0	25.0	28.0	31.0	34.0	37.0	40.0
.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0190	.0185	.0185
3.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
6.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
9.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
12.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
15.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
18.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
21.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
24.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
27.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195
30.0	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195	.0195

FIGURE 14

mostly to sky temperature.

C. A net radiometer appears to be a vital part of any ground installation, and the net-radiation balances as a function of time of day and weather, are necessary.

D. Fitting remotely-sensed data to spot locations around weather station sites, on flat ground, may be possible, but extrapolation to outlying areas is unlikely.

E. Relative determinations of thermal properties may be possible using remote sensing, but absolute value determinations appear most unlikely.

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APPENDIX I

STATISTICAL COMPILATION BI-DIRECTIONAL

SUMMARY SHEETS

REFLECTANCE DATA - PISGAH MISSION #2

OUTPUT KEY

901	121000	1.0	1.190	1.720	1.0	1.640	1.870	0.000	15	LL 1-1
CODE	TIME	GAIN	VOLTS CH 4	VOLTS CH 5	GAIN	VOLTS CH 6	VOLTS CH 7	SOLRMIR	FIELD OF VIEW	SITE

0.336 0.393

Pseudo-CIE color coordinates, a measure of "color" of the target

2.447	3.713	3.225	4.378	0.283	0.339	0.386	0.400	0.352
BP 4	BP 5	BP 6	BP 7	R 4	R 5	R 6	R 7	Albedo

(Radiances w. cm^{-2}) (Reflectances) (averaged)

1.036	1.181	1.413	1.139	1.364	1.197
R 76	R 75	R 74	R 65	R 64	R 54

(reflectance ratios)

```
STATISTICAL DATA FROM PISGAH TRIP # 2.ALBEDO CALCULATED ALSO***
901 121000    1.0    1.150    1.720    1.0    1.640    1.870    0.000    15.   LL 1-1
         0.336       0.393
         2.447 3.715 3.225 4.378 0.283 0.339 0.386 0.400 0.352
   1.036 1.181 1.413 1.139 1.364 1.197
   -------------------------------------------------
902 121100    1.0    1.150    1.740    1.0    1.700    1.950    0.000    15.   LL 1-1
         0.323       0.396
         2.366 3.756 3.346 4.562 0.274 0.343 0.401 0.417 0.359
   1.041 1.216 1.523 1.169 1.403 1.252
   -------------------------------------------------
903 121200    1.0    1.130    1.670    1.0    1.620    1.930    0.000    15.   LL 1-1
         0.326       0.390
         2.325 3.607 3.134 4.516 0.269 0.329 0.382 0.413 0.348
   1.083 1.254 1.534 1.158 1.417 1.223
   -------------------------------------------------
904 121300    1.0    1.150    1.760    1.0    1.650    1.900    0.000    15.   LL 1-1
         0.324       0.402
         2.365 3.795 3.245 4.447 0.274 0.347 0.389 0.407 0.354
   1.046 1.173 1.484 1.121 1.419 1.256
   -------------------------------------------------
905 121400    1.0    1.240    1.820    1.0    1.670    1.680    0.000    15.   LL 1-1
         0.337       0.401
         2.546 3.926 3.285 4.401 0.295 0.359 0.394 0.403 0.363
   1.022 1.123 1.364 1.098 1.334 1.215
   -------------------------------------------------
906 123000    1.0    1.270    1.780    1.0    1.770    2.040    0.000    15.   LL 1-1N
         0.338       0.384
         2.608 3.641 3.486 4.769 0.301 0.352 0.420 0.438 0.378
   1.044 1.243 1.455 1.190 1.393 1.171
   -------------------------------------------------
907 123100    1.0    1.250    1.850    1.0    1.760    2.020    0.000    15.   LL 1-1N
         0.351       0.396
         2.566 3.389 3.458 4.723 0.296 0.366 0.417 0.434 0.378
   1.040 1.185 1.464 1.139 1.407 1.235
   -------------------------------------------------
908 123200    1.0    1.220    1.770    1.0    1.810    2.040    0.000    15.   LL 1-1N
         0.330       0.388
         2.597 3.820 3.569 4.769 0.289 0.351 0.429 0.438 0.377
   1.021 1.250 1.514 1.225 1.403 1.211
   -------------------------------------------------
909 123300    1.0    1.320    1.880    1.0    1.940    2.130    0.000    15.   LL 1-1N
         0.336       0.367
         2.709 4.053 3.833 4.977 0.313 0.372 0.461 0.457 0.401
   0.992 1.229 1.462 1.239 1.474 1.189
   -------------------------------------------------
910 123400    1.0    1.200    1.800    1.0    1.670    1.940    0.000    15.   LL 1-1N
         0.323       0.409
         2.467 4.053 3.285 4.539 0.285 0.372 0.395 0.417 0.367
   1.055 1.121 1.464 1.062 1.388 1.306
   -------------------------------------------------
911 124000    1.0    1.130    1.700    1.0    1.570    1.800    0.000    15.   LL 1-1E
         0.333       0.401
         2.325 3.671 3.083 4.216 0.273 0.333 0.372 0.381 0.340
   1.026 1.146 1.397 1.117 1.302 1.219
   -------------------------------------------------
912 124100    1.0    1.180    1.570    1.0    1.650    1.840    0.000    15.   LL 1-1E
         0.340       0.389
         2.426 3.607 3.245 4.308 0.285 0.327 0.391 0.390 0.348
```

```
0.996 1.192 1.368 1.197 1.374 1.148
------------------------------------------------
913  124200   1.0   1.140   1.760   1.0   1.610   1.870   0.000   15.  LL 1-1E
     0.324      0.404
     2.346 3.798 3.164 4.378 0.275 0.344 0.381 0.396 0.349
 1.038 1.150 1.436 1.103 1.386 1.251
------------------------------------------------
914  124300   1.0   1.170   1.750   1.0   1.670   1.870   0.000   15.  LL 1-1E
     0.330      0.400
     2.406 3.777 3.235 4.378 0.282 0.342 0.396 0.396 0.354
 0.999 1.156 1.402 1.157 1.403 1.212
------------------------------------------------
915  124400   1.0   1.190   1.780   1.0   1.620   1.890   0.000   15.  LL 1-1E
     0.331      0.400
     2.447 3.841 3.134 4.424 0.287 0.348 0.384 0.400 0.355
 1.042 1.149 1.393 1.103 1.337 1.213
------------------------------------------------
916  124500   1.0   1.230   1.860   1.0   1.660   1.990   0.000   15.  LL 1-1S
     0.328      0.401
     2.527 4.011 3.265 4.654 0.288 0.362 0.385 0.419 0.363
 1.088 1.157 1.457 1.064 1.339 1.259
------------------------------------------------
917  124600   1.0   1.140   1.710   1.0   1.640   1.880   0.000   15.  LL 1-1S
     0.327      0.397
     2.346 3.692 3.225 4.401 0.267 0.333 0.380 0.396 0.344
 1.042 1.189 1.434 1.141 1.425 1.249
------------------------------------------------
918  124700   1.0   1.330   2.010   1.0   1.850   2.120   0.000   15.  LL 1-1S
     0.339      0.397
     2.551 4.329 3.550 4.954 0.325 0.391 0.431 0.446 0.398
 1.036 1.141 1.375 1.102 1.327 1.204
------------------------------------------------
919  124800   1.0   1.290   1.830   1.0   1.750   1.960   0.000   15.  LL 1-1S
     0.342      0.392
     2.649 3.947 3.448 4.585 0.301 0.356 0.407 0.413 0.369
 1.015 1.159 1.369 1.141 1.349 1.182
------------------------------------------------
920  124900   1.0   1.250   1.850   1.0   1.830   2.040   0.000   15.  LL 1-1S
     0.333      0.395
     2.568 3.959 3.610 4.769 0.292 0.360 0.426 0.429 0.377
 1.009 1.192 1.469 1.182 1.457 1.232
------------------------------------------------
921  125000   1.0   1.190   1.820   1.0   1.690   1.970   0.000   15.  LL 1-1W
     0.324      0.401
     2.447 3.926 3.326 4.608 0.285 0.360 0.400 0.423 0.367
 1.037 1.177 1.483 1.114 1.403 1.260
------------------------------------------------
922  125100   1.0   1.290   1.920   1.0   1.770   2.050   0.000   15.  LL 1-1W
     0.331      0.399
     2.649 4.138 3.488 4.792 0.309 0.379 0.420 0.440 0.387
 1.048 1.161 1 425 1.108 1.359 1.227
------------------------------------------------
923  125200   1.0   1.220   1.810   1.0   1.720   1.990   0.000   15.  LL 1-1W
     0.329      0.396
     2.507 3.904 3.387 4.654 0.292 0.358 0.408 0.428 0.371
 1.048 1.195 1.462 1.140 1.394 1.223
------------------------------------------------
924  125300   1.0   1.200   1.840   1.0   1.660   1.970   0.000   15.  LL 1-1W
     0.325      0.403
     2.467 3.968 3.306 4.608 0.288 0.363 0.398 0.423 0.368
```

```
1.063 1.165 1.471 1.335 1.383 1.263
--------------------------------------------------
925  125400   1.0   1.160   1.770   1.0   1.690   1.970   0.000   15.  LL 1-1W
      0.322      0.398
      2.346 3.620 3.328 4.606 0.278 0.350 0.400 0.423 0.363
 1.057 1.210 1.521 1.145 1.439 1.257
--------------------------------------------------
926  133500   1.0   1.170   1.770   1.0   1.720   1.960   0.000   15.  LL 1-2
      0.325      0.397
      2.405 3.820 3.337 4.585 0.283 0.356 0.410 0.423 0.368
 1.032 1.189 1.496 1.152 1.450 1.259
--------------------------------------------------
927  133800   1.0   1.160   1.810   1.0   1.660   1.940   0.000   15.  LL 1-2
      0.321      0.405
      2.386 3.904 3.265 4.539 0.280 0.364 0.395 0.419 0.364
 1.060 1.151 1.494 1.087 1.410 1.297
--------------------------------------------------
928  134000   1.0   1.160   1.790   1.0   1.740   2.020   0.000   15.  LL 1-2
      0.319      0.398
      2.386 3.802 3.427 4.723 0.280 0.360 0.415 0.436 0.373
 1.031 1.211 1.555 1.153 1.480 1.283
--------------------------------------------------
929  134200   1.0   1.240   1.900   1.0   1.810   2.090   0.000   15.  LL 1-2
      0.322      0.400
      2.548 4.095 3.569 4.884 0.299 0.381 0.432 0.451 0.391
 1.043 1.181 1.506 1.132 1.443 1.274
--------------------------------------------------
930  134300   1.0   1.240   1.890   1.0   1.830   2.100   0.000   15.  LL 1-2
      0.323      0.398
      2.546 4.074 3.610 4.908 0.299 0.379 0.437 0.453 0.392
 1.036 1.193 1.513 1.151 1.459 1.258
--------------------------------------------------
932  135300   1.0   1.220   1.770   1.0   1.680   1.920   0.000   15.  LL 1-3
      0.335      0.394
      2.507 3.820 3.306 4.493 0.300 0.359 0.403 0.414 0.369
 1.027 1.155 1.382 1.124 1.345 1.197
--------------------------------------------------
933  135400   1.0   1.240   1.820   1.0   1.700   1.950   0.000   15.  LL 1-3
      0.334      0.397
      2.543 3.926 3.346 4.562 0.304 0.369 0.408 0.420 0.375
 1.031 1.141 1.361 1.107 1.340 1.211
--------------------------------------------------
934  135500   1.0   1.220   1.830   1.0   1.690   1.910   0.000   15.  LL 1-3
      0.332      0.403
      2.537 3.947 3.326 4.470 0.300 0.371 0.405 0.412 0.372
 1.016 1.112 1.375 1.094 1.354 1.237
--------------------------------------------------
935  135600   1.0   1.210   1.790   1.0   1.700   1.900   0.000   15.  LL 1-3
      0.333      0.399
      2.487 3.662 3.346 4.447 0.297 0.363 0.408 0.410 0.369
 1.005 1.130 1.379 1.125 1.373 1.220
--------------------------------------------------
936  140800   1.0   1.100   1.650   1.0   1.710   1.910   0.000   15.  LL BC
      0.322      0.391
      2.265 3.565 3.366 4.470 0.275 0.341 0.419 0.421 0.364
 1.005 1.236 1.533 1.230 1.525 1.240
--------------------------------------------------
937  140900   1.0   1.070   1.730   1.0   1.670   1.950   0.000   15.  LL BC
      0.309      0.404
      2.204 3.735 3.285 4.562 0.267 0.357 0.409 0.430 0.366
```

```
1.051 1.204 1.607 1.146 1.529 1.335
--------------------------------------------------
938  141000   1.0   1.210   1.810   1.0   1.700   1.890   0.000   15.  LL BC
     0.332      0.402
       2.487 3.904 3.346 4.424 0.302 0.373 0.417 0.417 0.377
 1.001 1.117 1.381 1.116 1.380 1.236
--------------------------------------------------
939  141100   1.0   1.220   1.940   1.0   1.860   2.170   0.000   15.  LL BC
     0.313      0.402
       2.507 4.180 3.671 5.069 0.304 0.400 0.457 0.478 0.410
 1.045 1.196 1.570 1.144 1.502 1.313
--------------------------------------------------
940  141200   1.0   1.140   1.750   1.0   1.690   1.940   0.000   15.  LL BC
     0.321      0.399
       2.346 3.777 3.326 4.539 0.285 0.361 0.414 0.428 0.372
 1.033 1.185 1.503 1.147 1.455 1.268
--------------------------------------------------
941  143400   1.0   1.010   1.600   1.0   1.590   1.790   0.000   15.  LL BCN
     0.314      0.402
       2.063 3.459 3.123 4.193 0.273 0.360 0.421 0.426 0.370
 1.012 1.183 1.558 1.169 1.540 1.317
--------------------------------------------------
942  143500   1.0   1.160   1.830   1.0   1.720   2.040   0.000   15.  LL BCN
     0.315      0.402
       2.380 3.947 3.387 4.769 0.313 0.411 0.456 0.484 0.416
 1.061 1.179 1.547 1.111 1.458 1.312
--------------------------------------------------
943  143600   1.0   1.120   1.700   1.0   1.640   1.910   0.000   15.  LL BCN
     0.323      0.396
       2.305 3.671 3.225 4.470 0.302 0.382 0.434 0.454 0.393
 1.045 1.188 1.501 1.138 1.437 1.263
--------------------------------------------------
944  143700   1.0   0.970   1.560   1.0   1.470   1.720   0.000   15.  LL BCN
     0.312      0.405
       2.002 3.374 2.850 4.032 0.263 0.351 0.388 0.409 0.353
 1.055 1.166 1.559 1.105 1.477 1.337
--------------------------------------------------
945  143800   1.0   1.000   1.620   1.0   1.520   1.790   0.000   15.  LL BCN
     0.310      0.406
       2.062 3.501 2.931 4.193 0.271 0.364 0.402 0.426 0.366
 1.060 1.169 1.574 1.103 1.484 1.346
--------------------------------------------------
946  144500   1.0   0.920   1.550   1.0   1.470   1.660   0.000   15.  LL BCS
     0.305      0.414
       1.931 3.353 2.880 3.894 0.256 0.358 0.399 0.407 0.355
 1.021 1.137 1.592 1.113 1.559 1.401
--------------------------------------------------
947  144600   1.0   1.090   1.630   1.0   1.540   1.860   0.000   15.  LL BCS
     0.324      0.393
       2.244 3.523 3.022 4.355 0.302 0.376 0.419 0.455 0.388
 1.088 1.210 1.508 1.112 1.386 1.246
--------------------------------------------------
948  144700   1.0   0.980   1.530   1.0   1.480   1.680   0.000   15.  LL BCS
     0.319      0.402
       2.022 3.310 2.900 3.940 0.272 0.354 0.402 0.412 0.360
 1.026 1.165 1.514 1.136 1.476 1.309
--------------------------------------------------
949  144600   1.0   0.960   1.550   1.0   1.470   1.650   0.000   15.  LL BCS
     0.318      0.407
       2.022 3.353 2.880 3.671 0.272 0.358 0.399 0.405 0.359
```

```
 1.015 1.130 1.468 1.113 1.465 1.317
 ---------------------------------------------------
950  144500   1.0   1.010   1.580   1.0   1.510   1.710   0.000   15.  LL BCS
     0.317     0.404
     2.083 3.410 2.951 4.009 0.280 0.365 0.410 0.419 0.368
 1.022 1.143 1.495 1.123 1.463 1.303
 ---------------------------------------------------
951  145000   1.0   0.950   1.470   1.0   1.420   1.620   0.000   15.  LL BCE
     0.320     0.401
     1.961 3.183 2.778 3.802 0.269 0.345 0.392 0.405 0.353
 1.034 1.176 1.505 1.137 1.455 1.280
 ---------------------------------------------------
952  145100   1.0   0.980   1.480   1.0   1.420   1.690   0.000   15.  LL BCE
     0.322     0.394
     2.022 3.204 2.778 3.963 0.278 0.347 0.392 0.423 0.360
 1.076 1.217 1.521 1.129 1.411 1.250
 ---------------------------------------------------
953  145200   1.0   0.970   1.480   1.0   1.470   1.680   0.000   15.  LL BCE
     0.321     0.396
     2.002 3.204 2.830 3.940 0.275 0.347 0.406 0.420 0.362
 1.034 1.210 1.528 1.170 1.477 1.262
 ---------------------------------------------------
954  145300   1.0   0.920   1.500   1.0   1.460   1.690   0.000   15.  LL BCE
     0.307     0.405
     1.901 3.247 2.659 3.963 0.261 0.352 0.403 0.423 0.360
 1.048 1.202 1.618 1.147 1.545 1.347
 ---------------------------------------------------
955  145400   1.0   0.940   1.460   1.0   1.510   1.710   0.000   15.  LL BCE
     0.314     0.394
     1.941 3.162 2.961 4.009 0.267 0.343 0.418 0.428 0.364
 1.023 1.248 1.603 1.220 1.567 1.234
 ---------------------------------------------------
956  150500   1.0   0.950   1.500   1.0   1.440   1.670   0.000   15.  LL BCW
     0.315     0.402
     1.961 3.247 2.819 3.917 0.278 0.362 0.406 0.426 0.368
 1.048 1.178 1.533 1.124 1.462 1.301
 ---------------------------------------------------
957  150600   1.0   0.930   1.470   1.0   1.490   1.630   0.000   15.  LL BCW
     0.320     0.400
     1.951 3.193 2.920 3.825 0.278 0.355 0.421 0.416 0.367
 0.988 1.173 1.497 1.187 1.515 1.276
 ---------------------------------------------------
958  150700   1.0   0.940   1.460   1.0   1.440   1.670   0.000   15.  LL BCW
     0.316     0.397
     1.941 3.162 2.619 3.917 0.275 0.352 0.406 0.426 0.365
 1.048 1.210 1.549 1.154 1.478 1.231
 ---------------------------------------------------
959  150800   1.0   0.930   1.490   1.0   1.450   1.640   0.000   15.  LL BCW
     0.313     0.405
     1.921 3.225 2.839 3.848 0.272 0.359 0.409 0.419 0.365
 1.022 1.165 1.538 1.139 1.504 1.320
 ---------------------------------------------------
960  150900   1.0   0.960   1.470   1.0   1.490   1.650   0.000   15.  LL BCW
     0.321     0.397
     1.982 3.183 2.920 3.871 0.281 0.355 0.421 0.421 [illegible]369
 1.000 1.187 1.499 1.187 1.499 1.263
 ---------------------------------------------------
961  151500   1.0   0.930   1.450   1.0   1.390   1.560   0.000   15.  LL 2-2A
     0.320     0.403
     1.921 3.141 2.718 3.709 0.281 0.365 0.402 0.412 0.365
```

```
1.023 1.130 1.463 1.104 1.430 1.295
----------------------------------------------------
962  151600   1.0   0.870   1.370   1.0   1.300   1.550   0.000   15.  LL 2-2A
      0.314      0.400
      1.400 2.971 2.535 3.640 0.264 0.345 0.375 0.404 0.347
 1.077 1.172 1.532 1.089 1.423 1.308
----------------------------------------------------
963  151700   1.0   0.890   1.350   1.0   1.350   1.500   0.000   15.  LL 2-2A
      0.324      0.397
      1.540 2.928 2.636 3.525 0.270 0.340 0.390 0.391 0.348
 1.002 1.151 1.451 1.149 1.448 1.261
----------------------------------------------------
964  151800   1.0   0.980   1.450   1.0   1.450   1.640   0.000   15.  LL 2-2A
      0.327      0.392
      2.022 3.141 2.839 3.848 0.296 0.365 0.420 0.427 0.377
 1.016 1.172 1.441 1.153 1.419 1.230
----------------------------------------------------
965  152000   1.0   0.910   1.370   1.0   1.350   1.520   0.000   15.  LL 2-2A
      0.325      0.396
      1.680 2.971 2.630 3.594 0.276 0.345 0.390 0.399 0.352
 1.022 1.157 1.448 1.132 1.417 1.251
----------------------------------------------------
966  152600   1.0   1.190   1.760   1.0   1.650   1.910   0.000   15.  LL 2-2
      0.331      0.397
      2.447 3.793 3.245 4.470 0.374 0.454 0.500 0.517 0.461
 1.033 1.137 1.381 1.101 1.337 1.215
----------------------------------------------------
967  152900   1.0   1.120   1.770   1.0   1.730   2.010   0.000   15.  LL 2-2
      0.313      0.400
      2.505 3.620 3.407 4.700 0.352 0.457 0.525 0.543 0.469
 1.035 1.169 1.542 1.149 1.490 1.296
----------------------------------------------------
968  153000   1.0   1.170   1.740   1.0   1.650   1.890   0.000   15.  LL 2-2
      0.330      0.397
      2.436 3.756 3.245 4.424 0.368 0.449 0.500 0.511 0.457
 1.023 1.136 1.390 1.113 1.359 1.221
----------------------------------------------------
969  153100   1.0   1.140   1.720   1.0   1.610   1.880   0.000   15.  LL 2-2
      0.326      0.398
      2.346 3.713 3.164 4.401 0.359 0.444 0.487 0.509 0.450
 1.045 1.145 1.419 1.096 1.360 1.239
----------------------------------------------------
970  153200   1.0   1.170   1.650   1.0   1.630   1.820   0.000   15.  LL 2-2
      0.337      0.394
      2.406 3.650 3.204 4.262 0.368 0.437 0.494 0.493 0.448
 0.998 1.129 1.339 1.131 1.342 1.187
----------------------------------------------------
971  154000   1.0   0.890   1.330   1.0   1.300   1.460   0.000   15.  LL 2-2B
      0.328      0.397
      1.840 2.686 2.555 3.433 0.307 0.377 0.425 0.431 0.385
 1.013 1.142 1.401 1.127 1.383 1.227
----------------------------------------------------
972  154100   1.0   0.900   1.330   1.0   1.310   1.450   0.000   15.  LL 2-2B
      0.331      0.396
      1.860 2.686 2.555 3.410 0.311 0.377 0.429 0.428 0.386
 0.996 1.134 1.376 1.136 1.379 1.214
----------------------------------------------------
973  154200   1.0   0.880   1.305   1.0   1.330   1.500   0.000   15.  LL 2-2B
      0.326      0.391
      1.820 2.833 2.596 3.525 0.304 0.370 0.435 0.442 0.388
```

```
       1.016 1.194 1.454 1.176 1.432 1.218
       -------------------------------------------------
     974  154500    1.0    0.830    1.300    1.0    1.260    1.440    0.000    15.   LL 2-2B
            0.317       0.402
            1.719 2.622 2.494 3.387 0.287 0.369 0.418 0.425 0.375
       1.016 1.152 1.479 1.134 1.457 1.235
       -------------------------------------------------
     975  154400    1.0    0.890    1.320    1.0    1.300    1.450    0.000    15.   LL 2-2B
            0.330       0.396
            1.840 2.865 2.535 3.410 0.307 0.374 0.425 0.428 0.383
       1.006 1.142 1.391 1.135 1.383 1.218
       -------------------------------------------------
     976  155500    5.0    3.020    4.640    5.0    4.410    5.240    0.000    15.   LL 2-1
            0.319       0.397
            1.228 1.980 1.945 2.424 0.222 0.278 0.347 0.324 0.293
       0.932 1.166 1.460 1.251 1.567 1.253
       -------------------------------------------------
     977  155600    5.0    2.970    4.570    5.0    4.290    5.170    0.000    15.   LL 2-1
            0.319       0.397
            1.208 1.950 1.891 2.392 0.218 0.274 0.338 0.319 0.287
       0.946 1.168 1.465 1.235 1.550 1.255
       -------------------------------------------------
     978  155700    5.0    3.050    4.780    5.0    4.380    5.150    0.000    15.   LL 2-1
            0.319       0.405
            1.240 2.039 1.931 2.383 0.224 0.286 0.345 0.318 0.293
       0.922 1.112 1.421 1.206 1.541 1.278
       -------------------------------------------------
     979  155800    5.0    2.990    4.620    5.0    4.310    5.220    0.000    15.   LL 2-1
            0.318       0.398
            1.216 1.972 1.900 2.415 0.219 0.277 0.339 0.323 0.289
       0.950 1.166 1.469 1.228 1.547 1.260
       -------------------------------------------------
     980  155900    5.0    2.960    4.540    5.0    4.320    5.100    0.000    15.   LL 2-1
            0.320       0.397
            1.204 1.938 1.904 2.360 0.217 0.272 0.340 0.315 0.286
       0.926 1.160 1.450 1.252 1.566 1.231
       -------------------------------------------------
     981  160400    5.0    2.910    4.450    5.0    4.290    5.020    0.000    15.   LL 2-1N
            0.320       0.397
            1.184 1.900 1.891 2.323 0.227 0.282 0.357 0.328 0.298
       0.919 1.163 1.447 1.265 1.575 1.244
       -------------------------------------------------
     982  160500    5.0    2.710    4.070    5.0    3.920    4.510    0.000    15.   LL 2-1N
            0.326       0.396
            1.103 1.736 1.726 2.088 0.211 0.258 0.326 0.295 0.272
       0.905 1.142 1.397 1.262 1.542 1.222
       -------------------------------------------------
     983  160600    5.0    2.740    4.140    5.0    4.020    4.840    0.000    15.   LL 2-1N
            0.320       0.391
            1.115 1.708 1.771 2.240 0.214 0.263 0.335 0.317 0.282
       0.947 1.205 1.482 1.273 1.565 1.230
       -------------------------------------------------
     984  160700    5.0    2.900    4.340    5.0    4.160    4.820    0.000    15.   LL 2-1N
            0.327       0.396
            1.180 1.853 1.833 2.231 0.226 0.275 0.346 0.315 0.290
       0.911 1.145 1.395 1.257 1.531 1.218
       -------------------------------------------------
     985  160700    5.0    2.810    4.350    5.0    4.100    4.800    0.000    15.   LL 2-1N
            0.320       0.401
            1.143 1.857 1.806 2.222 0.219 0.276 0.341 0.314 0.287
```

```
     0.920 1.136 1.433 1.236 1.557 1.260
     ----------------------------------------------------------
    986  160600   5.0   2.800   4.210   5.0   4.060   4.700   0.000   15.  LL 2-1E
           0.325        0.396
           1.139 1.798 1.788 2.176 0.224 0.274 0.338 0.315 0.288
     0.932 1.148 1.402 1.232 1.505 1.221
     ----------------------------------------------------------
    987  160900   5.0   3.500   5.430   5.0   4.750   5.990   0.000   15.  LL 2-1E
           0.319        0.401
           1.422 2.315 2.096 2.769 0.280 0.353 0.396 0.401 0.357
     1.012 1.135 1.430 1.122 1.413 1.260
     ----------------------------------------------------------
    988  161000   5.0   2.590   4.060   5.0   3.910   4.710   0.000   15.  LL 2-1E
           0.313        0.397
           1.054 1.734 1.722 2.180 0.208 0.264 0.325 0.315 0.278
     0.970 1.193 1.518 1.230 1.565 1.273
     ----------------------------------------------------------
    989  161100   5.0   3.040   4.610   5.0   4.340   5.060   0.000   15.  LL 2-1E
           0.325        0.399
           1.236 1.967 1.913 2.341 0.244 0.300 0.361 0.339 0.311
     0.937 1.129 1.391 1.205 1.484 1.232
     ----------------------------------------------------------
    990  161200   5.0   2.940   4.400   5.0   4.110   4.900   0.000   15.  LL 2-1E
           0.326        0.395
           1.196 1.878 1.811 2.268 0.236 0.286 0.342 0.328 0.298
     0.959 1.145 1.392 1.194 1.452 1.216
     ----------------------------------------------------------
    991  161300   5.0   2.850   4.340   5.0   4.130   4.710   0.000   15.  LL 2-1S
           0.325        0.400
           1.159 1.853 1.820 2.160 0.236 0.293 0.365 0.326 0.305
     0.895 1.114 1.383 1.245 1.546 1.242
     ----------------------------------------------------------
    992  161300   5.0   2.710   4.160   5.0   3.840   4.530   0.000   15.  LL 2-1S
           0.323        0.401
           1.103 1.777 1.690 2.098 0.224 0.281 0.339 0.314 0.289
     0.927 1.117 1.399 1.206 1.509 1.252
     ----------------------------------------------------------
    993  161400   5.0   2.760   4.180   5.0   4.070   4.730   0.000   15.  LL 2-1S
           0.322        0.395
           1.123 1.765 1.793 2.190 0.229 0.282 0.359 0.328 0.299
     0.912 1.161 1.434 1.273 1.572 1.235
     ----------------------------------------------------------
    994  161400   5.0   2.750   4.280   5.0   4.050   4.850   0.000   15.  LL 2-1S
           0.316        0.398
           1.119 1.827 1.784 2.245 0.228 0.289 0.358 0.336 0.303
     0.940 1.163 1.475 1.237 1.570 1.260
     ----------------------------------------------------------
    995  161400   5.0   2.850   4.400   5.0   4.180   4.950   0.000   15.  LL 2-1S
           0.319        0.398
           1.159 1.878 1.842 2.291 0.236 0.297 0.369 0.343 0.311
     0.929 1.154 1.453 1.243 1.565 1.259
     ----------------------------------------------------------
      1  161500   5.0   2.710   4.120   5.0   3.940   4.710   0.000   15.  LL 2-1W
           0.321        0.394
           1.103 1.760 1.735 2.180 0.228 0.282 0.352 0.331 0.298
     0.940 1.173 1.450 1.248 1.543 1.236
     ----------------------------------------------------------
      2  161600   5.0   2.690   4.150   5.0   3.970   4.620   0.000   15.  LL 2-1W
           0.320        0.399
           1.095 1.772 1.746 2.139 0.227 0.284 0.355 0.325 0.298
```

```
0.915 1.143 1.433 1.249 1.566 1.254
------------------------------------------------
 3  161700   5.0   2.460   3.650   5.0   3.700   4.270   0.000   15.  LL 2-1W
    0.324       0.389
    1.002 1.560 1.628 1.978 0.207 0.250 0.330 0.300 0.272
0.909 1.200 1.448 1.321 1.593 1.206
------------------------------------------------
 4  161800   5.0   2.590   4.010   5.0   3.150   4.400   0.000   15.  LL 2-1W
    0.320       0.401
    1.054 1.713 1.393 2.036 0.218 0.275 0.281 0.309 0.271
1.102 1.126 1.417 1.022 1.286 1.258
------------------------------------------------
 5  161900   5.0   2.830   4.200   5.0   4.190   4.880   0.000   15.  LL 2-1W
    0.324       0.390
    1.151 1.794 1.846 2.259 0.238 0.287 0.375 0.343 0.314
 0.915 1.192 1.439 1.505 1.573 1.207
------------------------------------------------
/*
```

APPENDIX 2

ISCO Bi-DIRECTIONAL REFLECTANCE MEASUREMENTS

DATE: March 28, 1975 TIME: 1205 LOCATION: Lavic Lake

STANDARD: $BaSO_4$ OBSERVER: Gary Ballew/ Stuart Marsh

TARGETS: #1 - 1-1B #2 - Base Camp #3 - Alluvium

	Time: 1131-1210		1416-1431	1433-1459	1555-	1635-
Wavelength (μm)	STD	#1	STD	#2	STD	#3
.400	3.25	1.52	3.5	1.25	1.75	0.62
.425	5.61	4.10	18.0	3.5	10.0	1.25
.450	60.0	13.2	57.0	11.0	38	6.0
.475	87.0	21.2	85	17.5	55	9.4
.500	90.0	23.3	87	18.9	57	10.0
.525	88.0	24.0	86	19.4	56	10.5
.550	88.0	24.7	81	19.8	52	10.0
.575	74.0	24.0	70	19.5	47	9.5
.600	99.0	36.5	97	31.0	66	15.0
.625	100	38.0	98	33.0	66	16.5
.650	100	39.0	98	33.5	67	17.0
.675	94.0	35.7	90	31.0	60.5	15.8
.700	81.5	34.0	82	29.0	55.5	15.0
.725	76.5	31.5	74	28.0	49.5	13.8
.750	64.5	27.5	61	23.5	41	11.6
.75	77.0	34.0	74	30.0	53	16
.80	77.0	33.0	73	30	52	16.5
.85	66.0	30.0	63	26	45	13.3
.90	48.0	22.0	45	19.5	33	10.0
.95	37.0	18.2	35	13	23.5	77.7
1.00	40.0	19.6	31.5	15.7	27.0	88.8
1.05	36.5	18.0	34.0	15.0	24.5	8.33
1.10	31.0	16.0	30	13.0	21.0	7.5
1.15	15.0	7.6	13.3	6.2	9.5	3.2
1.20	14.0	7.3	12.4	5.8	9.2	3.5
1.25	26.0	13.0	23.5	12.5	16.5	5.6
1.30	29.0	14.7	27	12.0	18.5	6.5
1.35	14.8	8.15	16	7.0	9.5	3.1
1.40	34.0	5.30	3.4	1.20	2.5	0.6
1.45	7.3	4.50	2.3	0.94	1.4	0.44
1.50	6.2	3.33	5.7	2.70	3.8	1.35
1.55	9.3	15.0	8.6	4.00	6.0	2.2

DATE: March 29, 1975 LOCATION: Pisgah Crater

ISCO HEAD: Probe OBSERVER: G. Ballew

TARGETS: #1 - Cinders Near W. Cone

#2 - Red Cinders, 20' West of #1

Wavelength (μm)	TIME: 1036-1054 BaSo4	1555-110 Fiberfrax SA = 51°	118-1133 SA = 53°	1347-1400 SA = 54.3°	1310-1335 BaSO4
.400	1.80	4.90	0.24	0.30	1.55
.425	8.0	10.5	0.67	0.80	8.10
.450	29.0	34.0	2.45	2.65	27.5
.475	42.0	50.0	3.50	3.80	38.0
.500	43.0	50.0	3.60	4.10	40.0
.525	41.0	48.0	3.90	4.30	39.0
.550	40.0	45.0	3.95	4.25	31.5
.575	34.0	38.0	3.80	4.20	33.0
.600	51.0	56.0	5.95	7.00	47.0
.625	52.0	56.0	6.10	7.50	48.0
.650	51.0	55.0	6.10	7.85	47.5
.675	45.0	49.5	5.65	7.40	42.5
.700	42.0	45.5	5.40	7.25	39.0
.725	37.5	40.5	4.85	6.70	35.0
.750	31.5	34.0	4.10	5.90	29.0
.75	51.0	55.0	6.30	8.20	43.0
.80	50.0	52.0	6.10	8.50	37.0
.85	41.0	46.0	5.30	2.25	21.0
.90	32.0	35.0	4.00	5.70	21.5
.95	24.5	26.5	2.95	4.30	23.5
1.00	26.5	29.5	3.10	4.90	22.0
1.05	24.5	27.0	2.90	4.75	20.0
1.10	22.5	23.5	2.65	4.50	17.3
1.15	9.0	10.5	1.20	2.00	7.2
1.20	9.0	9.5	1.15	2.15	7.6
1.25	16.5	18.5	2.15	4.20	14.0
1.30	18.5	21.5	2.45	4.90	15.5
1.35	10.5	12.0	1.25	2.35	8.0
1.40	2.25	2.50	0.29	0.30	1.70
1.45	1.50	1.80	0.21	0.40	1.15
1.50	4.10	4.70	0.55	1.20	3.4
1.55	6.00	7.10	0.83	1.75	5.0

APPENDIX 3

MEASURED SURFACE AND PROBE TEMPERATURES

Output Key

-- PROBE

OCC	29	2400		1.0	2.0	3.0	4.0	5.0	6.0
CODE	DAY	TIME	DEPTH	1/2"	2"	5"	10"	15"	20"

-- SURFACE

1-1	29	2400	L.	.100	.200	.300	.400	.500	1.0	2.0	3.0	4.0	5.0	05NW	S-5
CODE	DAY	TIME	SETTING	DIGITAL OUTPUT					TEMP. OUTPUT °C					WIND	RADIOMETER

```
C CRATER STATION          PROBE
 OCC29 0520  1.4  5.6  9.2 12.5
 OCC29 0514  0.9  5.4  9.1 12.3
 OCC29 0527  0.5  5.4  9.0 12.1
 OCC29 0810  4.6  5.3  8.7 12.0
 OCC29 1020 18.4  5.1  9.1 11.8
 OCC29 1213 25.6 14.0 10.7 11.7
 OCC29 1406 28.0 18.1 13.0 12.0
 OCC29 1426 27.3 18.6 13.4 12.1
 OCC29 1453 26.7 19.1 13.9 12.2
 OCC29 1714 16.8 19.2 15.9 13.1
 OCC29 1910 11.5 16.1 15.8 13.7
 OCC29 2110  8.2 13.1 14.8 14.2
 OCC29 2312  6.5 11.0 13.6 14.3
 OCC30 0123  5.4  9.7 12.4 14.1
 OCC30 0321  4.3  8.7 11.7 13.8
 OCC30 0524  3.6  7.8 11.0 13.5
 OCC30 1435 35.9 23.1 16.5 13.2
C CRATER CENTER
  CC29 0528L.722 .715 .715 .728 .699 -0.4 -0.3 -0.5 -0.1 -1.0 35.0 29.0 14SW
  CC29 0630L.708 .708 .692 .710 .695 -0.9 -0.9 -1.6 -1.0 -1.6 37.0 28.5 10SW
  CC29 0813M.265 .326 .244 .470 .212  9.0 10.6  6.0 15.4  7.0 36.5 28.0 14N
  CC29 1013                          58.0 67.0 72.0 73.0 75.0 46.0 33.0 10N  +4
  CC29 1206                          76.0 81.0 83.0 86.0 82.0 49.0 35.0 09NW
  CC29 1401                          78.0 79.0 82.0 70.0 82.0 47.5 34.0 07N
  CC29 1420                          72.0 74.0 78.0 82.0 78.0
  CC29 1448                          65.0 69.0 73.0 77.0 77.0
  CC29 1708                          56.0 63.0 62.0 60.0 58.0 52.0 36.5 05N
  CC29 1903                          47.0 48.0 48.0 48.0 47.0 53.0 39.5 00N
  CC29 2104                          36.0 36.0 36.0 40.0 40.0 51.5 42.0 04W
  CC29 2307                          38.0 36.0 39.0 40.0 39.0 48.0 36.0 03N
  CC30 0119                          35.0 33.0 34.0 34.0 32.0 47.0 35.0 04N
  CC30 0316                          33.0 33.0 34.0 34.0 34.0 45.0 34.0 02N
  CC30 0519                          28.0 28.0 29.0 30.0 30.0 54.0 38.0 02N
  CC30 1429                          86.0 88.0 90.0 88.0 91.0 68.0 37.0 05N
C CRATER RED CINDER
  RC29 0531L.730 .751 .757 .771 .738  0.2  1.0  1.0  1.5  0.5
  RC29 0631L.726 .736 .737 .739 .733 -0.3  0.4  0.4  0.5  0.2
  RC29 0815M.146 .059 .127 .075 .100  4.6  1.6  4.0  2.3  3.0
  RC29 1015                          64.0 61.0 60.0 65.0 64.0
  RC29 1207                          87.0 88.0 84.0 82.0 78.0
  RC29 1402                          96.0 96.0 96.0 92.0 96.0
  RC29 1421                          97.0 96.0 94.0 97.0 92.0
  RC29 1449                          95.0 96.0 96.0 97.0 93.0
  RC29 1710                          81.0 81.0 82.0 79.0 82.0
  RC29 1905                          52.0 52.0 52.0 52.0 52.0
  RC29 2106                          41.0 42.0 41.0 41.0 41.0
  RC29 2308                               41.0 42.0 41.0 42.0 41.0
  RC30 0119                          38.0 39.0 39.0 39.0 38.0
  RC30 0317                          37.0 37.0 37.0 38.0 39.0
  RC30 0520                          35.0 35.0 35.0 34.0 35.0
  RC30 1430                         104.0 102. 104. 105. 107.
C CRATER ROAD
  RR29 0534L.714 .721 .718 .725 .726 -0.5 -0.5 -0.5  0.0 -0.2
  RR29 0632L.720 .718 .717 .722 .739 -0.1 -0.2 -0.4  0.2  0.5
  RR29 0816M.226 .209 .220 .215 .165  7.4  6.9  7.3  7.1  5.5
  RR29 1016                          72.0 70.0 69.0 67.0 66.0
  RR29 1209                          92.0 95.0 89.0 87.0 85.0
  RR29 1404                          95.0 96.0 94.0 92.0 90.0
  RR29 1423                          95.0 93.0 95.0 93.0 92.0
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     PR29 1450                                88.0 92.0 91.0 89.0 95.0
     PR29 1711                                77.0 77.0 77.0 73.0 79.0
     RR29 1906                                50.0 51.0 50.0 49.0 48.0
     RR29 2108                                44.0 43.0 44.0 43.0 45.0
     SS29 2309                                42.0 42.0 43.0 43.0 42.0
     RR30 0120                                38.0 36.0 37.0 38.0 38.0
     FR30 0318                                36.0 35.0 36.0 37.0 38.0
     RR30 0521                                32.0 32.0 33.0 34.0 35.0
     RF30 1431                               105.0 109. 104. 104. 103.
   C CRATER CLTERECCE
     CE29 0535L.742 .747 .746 .752 .753   0.5  1.0  0.6  1.0  1.0
     CE29 0634L.732 .749 .732 .735 .740   0.4  0.6  0.2  0.2  0.4
     CE29 0819M.311 .344 .286 .264 .243  10.5 11.4  8.6  8.8  8.8
     CE29 1018                                68.0 69.0 66.0 68.0 69.0
     CE29 1210                                78.0 85.0 75.0 80.0 82.0
     CE29 1406                                78.0 72.0 82.0 75.0 83.0
     CE29 1424                                78.0 79.0 80.0 77.0 81.0
     CE29 1451                                77.0 79.0 78.0 78.0 76.0
     CE29 1712                                59.0 56.0 59.0 56.0 60.0
     CE29 1908                                44.0 45.0 45.0 44.0 44.0
     CE29 2110                                42.0 42.0 42.0 41.0 41.0
     DE29 2310                                42.0 43.0 43.0 42.0 42.0
     CE30 0121                                39.0 39.0 40.0 40.0 39.0
     CE30 0219                                36.0 37.0 37.0 37.0 37.0
     CE30 0522                                34.0 34.0 35.0 33.0 34.0
     CE30 1432                                95.0 96.0 98.0 94.0 89.0
   C CRATER CUTSIDE BASALT
       B29 0536L.737 .733 .732 .734 .730   0.2  0.0  +.2  0.5 -0.5
       B29 0635L.722 .724 .725 .738 .730  -0.1 -0.3 -0.4  0.2 -0.2
       B29 0820M.156 .134 .112 .150 .125   5.2  4.4  3.5  4.9  4.2
       B29 1019                                60.0 56.0 56.0 52.0 46.0
       B29 1211                                74.0 72.0 64.0 62.0 60.0
       B29 1407                                82.0 81.0 78.0 78.0 76.0
       B29 1425                                77.0 79.0 78.0 78.0 81.0
       B29 1452                                67.0 67.0 65.0 74.0 73.0
       B29 1713                                63.0 66.0 73.0 71.0 74.0
       B29 1909                                48.0 50.0 50.0 51.0 52.0
       B29 2112                                44.0 45.0 46.0 46.0 46.0
       B29 2311                                43.0 43.0 44.0 44.0 43.0
       B30 0122                                40.0 40.0 40.0 39.0 39.0
       B30 0320                                35.0 35.0 36.0 36.0 36.0
       B30 0523                                32.0 33.0 33.0 33.0 33.0
       B30 1433                                98.0 92.0 93.0 92.0 88.0
   CC LAVIC LAKE 1-1            PROBE
    1-129 0442 -3.2   1.0   8.0 11.0
    1-129 0610  2.3   0.0   7.2 10.9
    1-129 0728  0.0   0.5   7.5 10.5
    1-129 0955 12.0   5.7   6.9 10.2
    1-129 1207 20.0 15.9   7.5 10.0
    1-129 1415 24.0 18.1   9.2 10.0
    1-129 1557 21.2 19.1  11.0 10.0
    1-129 1605 15.0 16.9  12.2 10.1
    1-129 2050  3.9 10.0  12.5 11.0
    1-129 2738  0.8   7.0  11.5 11.0
    1-130 0100 -2.0   3.4  10.6 11.8
    1-130 0315 -4.0   1.5   9.0 11.0
    1-130 0610 -6.2  -1.0   7.9 11.0
    1-130 0912 12.7   5.0   7.2 11.0
    1-130 1058 26.1 14.1   7.8 10.8
    1-130 1316 32.0 22.0   9.0  9.6
    1-130 1425 23.5 24.0  10.5 10.0
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C LAVIC LAKE 1-2                     PROBE
  1-229 0430 -2.0  1.5  9.0 12.9
  1-229 0615 -1.5  1.5  6.8 11.0
  1-229 0730 -1.5  1.5  6.0 10.9
  1-229 1000 10.0  5.1  6.1 11.0
  1-229 1215 19.1 11.7  7.5 10.5
  1-229 1220 19.9 13.5  8.4 10.1
  1-229 1420 23.0 16.5  9.8 11.0
  1-229 1602 20.5 19.4 12.0 10.1          13.6
  1-229 1907 15.0 17.0 13.0 10.1
  1-229 2155  5.0 10.0 11.7  9.5
  1-229 2245  2.0  8.0 11.5 11.0
  1-230 0105 -1.0  5.0 10.0 11.1
  1-230 0320 -2.0  3.6  9.1 12.0
  1-230 0611 -7.2  1.0  6.0  9.2
  1-230 0909  9.7  3.7  6.5 11.5
  1-230 1100 23.2 11.3  7.3 11.3
  1-230 1320 30.0 15.2  9.9 10.1
  1-230 1427 31.5 21.2 11.5 10.1
C LAVIC LAKE 1-3                     PROBE
  1-329 0459 -1.5  2.1  8.1 11.0
  1-329 0725 -1.0  2.0  7.3 11.0
  1-329 1006 10.9  6.0  7.2 10.5
  1-329 1425 24.0 17.1 10.0 10.1
  1-329 1606 21.0 18.2 11.6 10.1
  1-329 1810 16.0 16.6 13.5 10.9
  1-329 2100  6.0 10.5 12.5 11.0
  1-329 2250  3.2  8.4 12.0 13.5
  1-330 0110 -0.5  5.0 10.0 11.1
  1-330 0330 -2.0  3.2  9.8 11.5
  1-330 0616 -4.9  1.0  7.9 11.0
  1-330 0907 10.2  4.8  7.6 11.3
  1-330 1102 24.2 12.5  8.2 11.0
  1-330 1335 31.0 20.0 10.1 10.1
  1-330 1432 32.4 22.0 11.1 10.0
C LAVIC LAKE ALLUVIUM 2-1PROBE
  2-129 0515  1.0  4.5  8.3 13.0
  2-129 0655  0.0  2.1  7.1 10.8
  2-129 1015 10.2  6.1  7.0 11.0  9.2
  2-129 1240 22.9 13.1  8.9 11.0
  2-129 1435 25.5 17.5 11.0 11.0
  2-129 1615 22.0 18.0 12.5 10.9
  2-129 1820 16.5 17.0 14.0 11.5
  2-129 2030  8.0 13.9 13.5 12.0
  2-129 2300  3.7  8.9 11.2 11.9
  2-130 0120  1.0  6.6 11.0 12.0
  2-130 0345 -1.0  4.2  9.7 12.0
  2-130 0600 -2.8  2.8  7.7 11.9
  2-130 0900  9.2  5.0  7.9 12.3
  2-130 1105 24.6 12.8  8.6 12.0
  2-130 1340 33.4 20.1 11.1 11.0
  2-130 1500 34.4 22.5 13.1 11.0
C LAVIC LAKE 2-2                     PROBE
  2-229 0502 -1.5  2.0  8.1 11.9        13.1
  2-229 0715 -1.2  1.8  7.4 11.5        13.0
  2-229 1009 12.7  6.8 10.9 11.3        13.1
  2-229 1222 23.5 13.5  8.8 11.3        13.4
  2-229 1430 25.5 18.0 10.1 11.0        13.0
  2-229 1610 22.0 18.9 11.6 10.4
  2-229 1815 15.0 17.0 13.0 11.0 13.5
  2-229 2105  4.2 10.8 13.0 11.5        12.9
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183.    2-229 2251  1.3  7.8 12.1 11.9       12.7
184.    2-230 0115 -1.7  4.5 10.5 11.7       12.7
185.    2-230 0335 -3.0  1.9  9.0 11.4       11.6
186.    2-230 0620 -6.0  0.0  7.9 11.1       12.5
187.    2-230 0918 10.5  5.2  7.3 11.9       13.3
188.    2-230 1052 22.9 12.3  7.6 11.8       13.2
189.    2-230 1330 32.5 20.1 10.0 10.8       13.5
190.    2-230 1435 33.9 22.1 11.1 10.5       13.1
191.   C LAVIC LAKE 2-3          PROBE
192.    2-329 0504 -2.0  3.1  8.2 11.9
193.    2-329 0720 -3.0  1.5  7.0 10.4
194.    2-329 1012 16.0  9.0  8.9 11.8
195.    2-329 1225 24.0 12.1  8.4 11.0
196.    2-329 1433 25.9 16.4  9.9 10.7
197.    2-329 1613 21.2 17.5 11.2  9.1
198.    2-329 1818 13.2 16.1 12.1 10.2
199.    2-329 2106  2.0 10.5 12.0 11.0
200.    2-329 2255 -1.0  8.0 11.8 11.2
201.    2-330 0116 -4.3  5.0 10.2 11.0
202.    2-330 0336 -5.5  4.5  9.0 11.0
203.    2-330 0621 -8.0  1.0  7.8 11.0
204.    2-330 0917 15.8  4.8  7.5 11.6
205.    2-330 1055 21.4 11.0  8.0 11.4
206.    2-330 1331 33.2 19.0 10.1 10.8
207.    2-330 1436 35.0 20.5 11.0 10.1
208.   C LAVIC LAKE 1-4          PROBE
209.    1-429 0623 -4.0  0.0  6.0 11.4
210.    1-429 0737  2.0  3.0 11.9 12.0
211.    1-429 1025 15.5  8.5  8.1 12.1
212.    1-429 1253 24.0 15.1  9.5 11.0
213.    1-429 1445 25.8 19.0 12.0 11.0
214.    1-429 1625 25.0 21.5 14.5 12.0
215.    1-429 1823 16.9 17.7 14.5 11.1
216.    1-429 2113  6.3 10.7 13.5 11.6
217.    1-429 2304  3.0  8.0 12.0 12.0
218.    1-430 0125 -0.1  5.0 10.4 11.9
219.    1-430 0351 -2.3  2.7  9.2 11.8
220.    1-430 0627 -4.0  1.2  8.0 11.9
221.    1-430 0920 13.4  6.0  7.4 12.0
222.    1-430 1110 27.4 14.1  9.0 11.8
223.    1-430 1346 33.0 21.5 12.0 11.0
224.    1-430 1446 34.2 23.1 13.7 11.0
225.   C LAVIC LAKE 1-5          PROBE
226.    1-529 0620  0.0  2.8  6.0 10.0 11.5
227.    1-529 0740  0.9  2.1  5.0  8.5 10.1
228.    1-529 1020 11.0  6.8  5.2  7.6
229.    1-529 1250 24.5 15.8  9.5  6.2  9.1
230.    1-529 1440 29.0 20.9 13.0  9.9  9.5
231.    1-529 1620 30.0 23.9 15.9 11.0  9.8
232.    1-529 1922 22.2 21.2 18.2 12.7 10.2
233.    1-529 2112  9.0 12.8 15.0 13.5 12.5
234.    1-529 2303  4.9  9.5 13.4 13.9 12.2
235.    1-530 0121  2.2  6.5 10.5 12.2 12.0
236.    1-530 0350  1.0  4.0  8.5 11.7 11.8
237.    1-530 0626 -1.5  2.0  7.7 11.2 12.4
238.    1-530 0923  8.3  6.0  6.6  9.8 11.6
239.    1-530 1111 23.0 14.5  8.8  9.6 11.3
240.    1-530 1345 35.0 23.0 14.0 10.0 10.0
241.    1-530 1445 38.0 25.8 11.1 11.0 10.1
242.   C LAVIC LAKE 1-6          PROBE
243.    1-629 0625  0.0  2.1  7.5 13.0                 0.0
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1-629 0743 -1.0  0.0  4.6 10.0                          0.0
1-629 1027 12.6  9.4  8.9 13.1                          5.0
1-629 1252 21.2 16.0 11.0 12.5                          8.5
1-629 1443 22.2 19.9 15.5 12.4                         11.1
1-629 1630 22.0 20.8 15.8 12.9                         13.3
1-629 1825 18.1 19.0 16.2 13.1                         12.6
1-629 2114 11.9 14.0 13.2 12.5                          4.4
1-629 2309  7.0 10.1 13.2 13.5                          1.7
1-630 0127  4.8  6.2 13.6 16.0                         -1.1
1-630 0352  1.8  5.4 10.2 14.0                         -3.3
1-630 0628  0.0  3.9  9.0 15.6                         -6.7
1-630 0925 10.8  7.9  8.9 14.0                          8.5
1-630 1112 21.1 15.0 10.7 13.7                         17.6
1-630 1348 29.0 27.0 14.0 12.5                         20.0
1-630 1450 31.0 24.1 15.6 12.5                         21.7
C LAVIC LAKE 1-1
1-129 0442L.360 .287 .388 .384 .329 -5.8 -4.7 -4.7 -5.0 -6.8                L-5
1-129 0610L.373 .335 .387 .390 .355 -5.4 -6.5 -5.7 -4.5 -7.5 33.0 29.5
1-129 0728                          29.0 29.0 31.0 28.0 30.0
1-129 0955M.471 .413 .385 .406 .490 15.5 13.8 12.8 13.4 16.4                S-5
1-129 1207M.775 .801 .799 .810 .798 24.5 25.2 25.2 25.7 25.3
1-129 1415M.872 .942 .892 .913 .924 27.2 28.7 28.8 28.8 28.4
1-129 1557M.723 .736 .690 .694 .705 22.9 23.4 22.1 22.2 20.6
1-129 1805M.421 .416 .480 .400 .410 14.2 13.6 16.2 13.4 13.8
1-129 2050L.786 .782 .757 .806 .759  4.5  2.5  1.5  3.4  1.6
1-129 2236L.732 .728 .736 .706 .692  0.4  0.2  0.5 -0.7 -1.5                S-5
1-130 0100L.675 .670 .690 .690 .662 -2.2 -2.3 -2.0 -1.5 -2.7                S-5
1-130 0315L.676 .636 .637 .617 .658  1.5 -3.3 -3.8 -4.8 -3.0                S-5
1-130 0610L.592 .604 .625 .598 .563 -5.6 -4.8 -4.2 -5.5 -7.2                S-5
1-130 1316H.279 .291 .309 .299 .274 37.6 38.1 38.9 39.1 37.4                S-5
1-130 1425H.290 .285 .271 .278 .251 39.3 38.0 37.4 37.4 36.6                S-5
C LAVIC LAKE 1-2
1-229 0450L.362 .357 .366 .337 .343 -5.5 -5.7 -6.5 -6.5 -5.5
1-229 0615L.372 .391 .305 .367 .350 -5.0 -4.5 -5.0 -5.4 -5.5
1-229 0730                          34.0 34.0 33.0 32.0 33.0
1-229 1000M.475 .432 .426 .462 .487 15.6 14.8 14.2 15.6 16.2                S-5
1-229 1215M.774 .742 .860 .722 .838 24.3 23.7 20.8 23.0 26.4
1-229 1220M.826 .839 .830 .886 .890 25.8 20.6 26.3 27.6 27.4
1-229 1430M.905 .967 .870 .870 .882 27.8 29.5 27.2 26.8 27.3
1-229 1602M.685 .762 .670 .725 .635 22.0 24.0 21.6 24.2 20.6
1-229 1837M.421 .385 .393 .396 .400 14.1 13.0 13.0 13.1 13.6
1-229 2035L.791 .776 .782 .768 .768  2.8  2.2  2.6  1.9  1.8
1-229 2245L.734 .725 .721 .721 .712  0.4  0.0 -0.2 -0.2 -0.4                S-5
1-230 0105L.707 .661 .680 .678 .652 -1.0 -2.5 -1.7 -2.0 -3.1                S-5
1-230 0320L.655 .652 .646 .652 .655 -2.6 -3.0 -3.3 -3.0 -3.0                S-5
1-230 0511L.611 .605 .598 .604 .569 -5.0 -5.2 -5.6 -5.3 -6.0                S-5
1-230 1320H.272 .243 .247 .214 .244 37.6 35.6 35.2 34.8 36.4                S-5
1-230 1427H.247 .232 .269 .258 .235 36.1 35.6 37.5 37.0 35.6                S-5
C LAVIC LAKE ROAD
RD29 0455L.370 .380 .366 .355 .378 -5.5 -5.0 -5.0 -6.0 -5.2
RD29 0618L.394 .390 .363 .377 .394 -4.2 -4.1 -4.0 -4.5 -5.0
RD29 0735                          33.0 34.0 34.0 36.0 35.0
RD29 1004M.417 .449 .526 .456 .508 13.6 14.8 17.4 15.2 15.8
RD29 1217M.945 .766 .840 .809 .920 26.6 24.2 26.4 25.4 28.5
RD29 1422M.870 .902H.152 .062 .052 27.4 28.2H32.2 28.0 27.2
RD29 1604M.682 .741 .728 .712 .652 22.0 23.6 23.2 23.0 24.2
RD29 1809M.456 .439 .409 .414 .402 15.2 14.6 14.1 13.6 13.4
C LAVIC LAKE 1-3
1-329 0458L.390 .337 .372 .379 .366 -5.1 -4.8 -5.5 -5.0 -4.9
1-329 0725                          34.0 34.0 34.0 34.0 34.0
1-329 1006M.422 .471 .447 .484 .410 13.6 15.3 14.7 15.8 13.6
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1-329 1425M.093 .085 .038 .044 .073 26.5 28.8 26.5 26.7 28.3
1-329 1606M.748 .728 .727 .674 .715 24.0 23.2 23.2 21.8 22.8
1-329 1810M.394 .410 .397 .399 .374 13.2 13.6 13.2 13.4 12.7
1-329 2100L.812 .815 .924 .619 .815  3.6  3.7  4.0  4.0  3.9        S-5
1-329 2250L.752 .755 .750 .755 .734  1.5  1.4  1.0  1.3  0.7        S-5
1-330 0110L.713 .695 .697 .672 .682 -0.5 -1.0 -1.2 -2.2 -1.7        S-5
1-330 0331L.680 .673 .672 .650 .643 -2.0 -2.2 -2.3 -3.2 -3.2        S-5
1-330 0616L.622 .621 .614 .609 .625 -4.5 -4.2 -4.9 -5.1 -4.4        S-5
1-330 1335H.181 .225 .215 .139 .176 33.6 35.2 34.9 31.4 33.2        S-5
1-330 1432H.235 .273 .281 .235 .281 35.6 37.4 37.7 35.5 37.7    6S  S-5
C LAVIC LAKE ALLUVIUM 2-1
2-129 0515L.416 .398 .390 .411 .381 -3.8 -4.2 -4.8 -3.0 -4.6
2-129 0655                          22.0                           Q-4
2-129 1015M.580 .530 .530 .560 .580 18.6 17.2 17.4 18.2 18.7
2-129 1240M.981 .898 .912 .878 .836 29.7 26.2 27.5 28.2 26.3
2-129 1435H.161 .135 .140 .128 .139 32.2 31.2 31.4 30.6 31.3
2-129 1615M.754 .722 .721 .739 .710 24.2 23.2 23.1 23.6 23.0
2-129 1820M.425 .432 .455 .402 .434 14.2 14.4 15.2 15.4 14.4
2-129 2045M.174 .157 .161 .142 .129  5.6  5.2  5.4  4.9  4.3
2-129 2300L.780 .775 .755 .782 .754  2.5  2.0  1.6  1.8  2.4    2S  S-5
2-130 0120L.717 .713 .703 .692 .695 -0.3 -0.5 -0.6 -1.5 -1.2        S-5
2-130 0345L.691 .682 .669 .659 .687 -1.4 -2.0 -2.2 -2.6 -1.8        S-5
2-130 0600L.663 .654 .646 .670 .656 -2.5 -3.0 -2.5 -2.1 -2.5        S-5
2-130 1340H.303 .324 .328 .314 .294 39.0 39.6 39.6 39.2 38.2        S-5
2-130 1500H.329 .284 .247 .314 .256 39.3 37.8 36.2 39.2 36.6        S-5
C LAVIC LAKE 2-2
2-229 0502L.417 .367 .385 .391 .353 -3.8 -5.2 -5.9 -4.8 -5.6
2-229 0715                          27.0 32.0 30.0 32.0 30.0
2-229 1009M.457 .408 .500 .390 .414 15.2 13.8 16.4 13.1 13.7
2-229 1222M.793 .777 .790 .864 .770 24.8 24.7 24.8 26.3 24.4
2-229 1427M.047 .032 .010M.819 .875 27.0 25.2 25.2M25.7 27.4
2-229 1610M.707 .638 .643  650 .649 22.7 20.7 20.8 21.0 21.0
2-229 1915M.311 .324 .256 .306 .291 10.3 11.0  9.8 10.7  8.8
2-229 2105L.804 .799 .804 .742 .765  3.3  3.0  3.5  0.7  1.6        S-5
2-229 2251L.711 .724 .725 .768 .756 -0.5  0.0  0.2  1.7  1.4        S-5
2-230 0115L.645 .680 .672 .680 .641 -3.3 -2.2 -2.1 -2.0 -3.6        S-5
2-230 0335L.637 .652 .631 .636 .608 -3.7 -3.0 -4.0 -4.0 -5.2        S-5
2-230 0620L.598 .608 .626 .610 .586 -5.6 -5.2 -4.3 -4.9 -6.0        S-5
2-230 1330H.238 .228 .191 .244 .216 35.8 35.4 33.7 36.1 35.0        S-5
2-230 1435H.260 .245 .197 .232 .246 36.8 36.2 34.2 35.2 35.8        S-5
C LAVIC LAKE 2-3
2-329 0504L.420 .388 .356 .322 .362 -3.5 -4.6 -5.4 -6.5 -4.5
2-329 0720                          34.0 32.0 35.0 33.0 33.0
2-329 1012M.404 .461 .460 .485 .478 15.2 15.2 15.2 16.0 15.8
2-329 1225M.945 .831 .842 .803 .816 28.2 25.8 26.2 25.4 25.4
2-329 1430H.050 .079 .097H.125 .112 27.1 27.8 26.0 30.5 30.2
2-329 1612M.695 .735 .641 .666 .573 22.5 23.7 21.0 21.4 21.5
2-329 1818M.358 .309 .275 .370 .392 12.0 10.2  9.2 10.4 13.0
2-329 2106L.794 .765 .756 .754 .758  3.0  1.3  1.7  2.0  1.8        S-5
2-329 2255L.736 .731 .732 .691 .715  0.6  0.5  0.4 -1.2 -0.3        S-5
2-330 0116L.679 .678 .665 .626 .652 -2.0 -2.2 -2.5 -4.2 -3.2        S-5
2-330 0336L.631 .614 .612 .575 .612 -4.0 -4.6 -4.6 -6.7 -5.2        S-5
2-330 0621L.604 .605 .574 .608 .619 -5.2 -5.3 -6.8 -5.2 -4.5        S-5
2-330 1331H.225 .259 .195 .277 .276 34.9 36.7 34.0 37.4 37.3        S-5
2-330 1436H.221 .245 .236 .197 .200 34.8 36.0 35.2 34.2 34.2        S-5
C LAVIC LAKE 1-4
1-429 0623L.400 .414 .419 .410 .422 -4.0 -3.8 -3.2 -4.0 -3.6
1-429 0737                          36.0 36.0 37.0 37.0 36.0
1-429 1025M.502 .602 .554 .574 .563 16.4 19.6 18.2 18.4 18.4
1-429 1253H.069 .091 .062 .086 .058 27.6 28.6 27.6 28.6 27.3
1-429 1445M.120 .127 .110 .070 .085 30.2 30.6 30.2 28.4 28.7
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1-429 1621M.675 .665 .692 .643 .663 21.8 21.2 22.2 21.0 21.4            10S
1-429 1835M.377 .402 .400 .385 .386 10.7 13.5 10.2 12.8 12.8
1-429 2113H.852 .871 .826 .816 .834  5.2  5.0  4.2  4.0  4.5                S-5
1-429 2304L.906 .798 .787 .775 .781  3.5  3.0  2.7  2.0  2.3                S-5
1-430 0125L.730 .744 .729 .739 .722  1.0  0.6  0.2  0.6 -0.2                S-5
1-430 0351L.713 .690 .685 .702 .632 -0.5 -1.5 -1.5 -1.0 -1.6                S-5
1-430 0627L.657 .675 .669 .664 .655 -1.3 -2.0 -2.4 -2.6 -2.7                S-5
1-430 1348H.149 .126 .151 .103 .100 32.0 30.7 31.6 29.6 32.8                S-5
1-430 1446H.239 .240 .218 .215 .200 36.0 35.6 34.8 35.0 34.0                S-5
C LAVIC LAKE 1-5
1-529 0620L.475 .453 .462 .480 .504 -1.7 -2.1 -1.5 -1.4 -2.1
1-529 0740                          36.0 37.0 35.0 36.0 36.0
1-529 1020M.295 .358 .242 .275 .286 10.2  9.1  8.6  9.4  9.8
1-529 1250M.777 .745 .712 .635 .773 24.7 23.7 22.4 26.2 24.3
1-529 1437H.142 .127 .103 .060 .045 31.4 30.6 30.0 27.4 27.0
1-529 1620H.177 .181 .144 .097 .033 33.0 33.2 31.7 29.9 26.0
1-529 1822M.850 .805 .812 .837 .820 24.0 25.2 25.4 26.3 25.8
1-529 2112M.328 .235 .300 .296 .280 11.0  9.1 10.  10.1  9.5                S-5
1-529 2303L.909 .841 .888 .894 .902  7.5  4.9  6.7  6.8  7.4                S-5
1-530 0121L.807 .802 .832 .840 .825  3.6  3.3  4.5  4.8  4.0                S-5
1-530 0350L.606 .756 .772 .798 .788  3.5  1.4  2.0  3.2  2.7                S-5
1-530 0626L.718 .724 .739 .719 .745  2.5  0.2  0.6  0.0  0.8                S-5
1-530 1345H.266 .211 .154 .185 .185 37.6 34.6 32.1 33.4 33.5                S-5
1-530 1445H.335 .312 .280 .275 .308 40.1 39.1 37.7 37.0 39.2                S-5
C LAVIC LAKE 1-6
1-629 0625L.449 .480 .455 .441 .450 -2.5 -1.5 -2.1 -2.6 -2.3            10S
1-629 0743                          38.0 38.0 39.0 38.0 40.0 41.0 35.5 8S
1-629 1027M.372 .670 .603 .627 .669 21.7 21.5 19.7 20.4 21.6 49.0 46.5 10S
1-629 1231H.159 .165 .136 .160 .127 32.8 31.7 30.8 32.2 31.5            10S
1-629 1440H.102 .072 .124 .129 .135 30.2 28.2 30.5 30.8 31.3             9S
1-629 1632M.328 .780 .802 .865 .815 25.8 24.8 24.2 27.0 25.7
1-629 2114M.153 .149 .139 .148 .142 15.2  5.1  4.7  5.0  4.7             4S S-5
1-629 2305L.930 .733 .781 .794 .786  3.0  2.4  2.0  3.0  2.3             2S S-5
1-630 0127L.752 .738 .743 .742 .745  1.3  0.7  0.8  0.6  0.9             2S S-5
1-630 0352L.710 .709 .704 .695 .715 -0.5 -0.7 -0.8 -1.0 -0.4 32.0 32.0 1S S-5
1-630 0628L.694 .686 .688 .670 .672 -1.0 -1.6 -1.6 -2.3 -2.1             1S S-5
1-630 1348H.269 .350 .305 .281 .352 37.4 41.4 38.6 38.0 41.0             7S S-5
1-630 1450H.337 .322 .275 .250 .355 39.8 39.4 37.2 36.5 40.8             6S S-5
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PRI-5 SPECIAL (Spectral Passband, 8 - 14μ)

S-5

LO RANGE Meter (°C)	LO RANGE Recorder (MV D-C)	MED RANGE Meter (°C)	MED RANGE Recorder (MV D-C)	HI RANGE Meter (°C)	HI RANGE Recorder (MV D-C)
-40.0	0.0	0.0	0.0	25.0	0.0
-39.0	14.0	1.0	28.6	26.0	21.3
-38.0	28.3	2.0	57.6	27.0	42.7
-37.0	42.8	3.0	86.9	28.0	64.3
-36.0	57.5	4.0	116.5	29.0	86.2
-35.0	72.4	5.0	146.4	30.0	108.2
-34.0	87.6	6.0	176.6	31.0	130.4
-33.0	103.0	7.0	207.2	32.0	152.8
-32.0	118.7	8.0	238.1	33.0	175.4
-31.0	134.5	9.0	269.3	34.0	198.2
-30.0	150.6	10.0	300.8	35.0	221.2
-29.0	167.0	11.0	332.7	36.0	244.3
-28.0	183.6	12.0	364.8	37.0	267.7
-27.0	200.4	13.0	397.3	38.0	291.2
-26.0	217.5	14.0	430.2	39.0	315.0
-25.0	234.8	15.0	463.3	40.0	338.9
-24.0	252.3	16.0	496.8	41.0	363.1
-23.0	270.1	17.0	530.6	42.0	387.4
-22.0	288.1	18.0	564.7	43.0	411.9
-21.0	306.4	19.0	599.2	44.0	436.6
-20.0	324.9	20.0	634.0	45.0	461.5
-19.0	343.7	21.0	669.1	46.0	486.6
-18.0	362.7	22.0	704.6	47.0	511.9
-17.0	382.0	23.0	740.3	48.0	537.4
-16.0	401.5	24.0	776.4	49.0	563.1
-15.0	421.3	25.0	812.9	50.0	588.9
-14.0	441.3	26.0	849.6	51.0	615.0
-13.0	461.6	27.0	886.7	52.0	641.2
-12.0	482.2	28.0	924.2	53.0	667.7
-11.0	503.0	29.0	961.9	54.0	694.3
-10.0	524.0	30.0	1000.0	55.0	721.2
-9.0	545.3			56.0	748.2
-8.0	566.9			57.0	775.4
-7.0	588.7			58.0	802.8
-6.0	610.8			59.0	830.4
-5.0	633.1			60.0	858.2
-4.0	655.7			61.0	886.2
-3.0	678.6			62.0	914.3
-2.0	701.7			63.0	942.7
-1.0	725.1			64.0	971.3
0.0	748.8			65.0	1000.0
1.0	772.7				
2.0	796.9				
3.0	821.3				
4.0	846.1				
5.0	871.0				
6.0	896.3				
7.0	921.8				
8.0	947.6				
9.0	973.7				
10.0	1000.0				

* High-level output. Low level output is 1/20th of listed value.

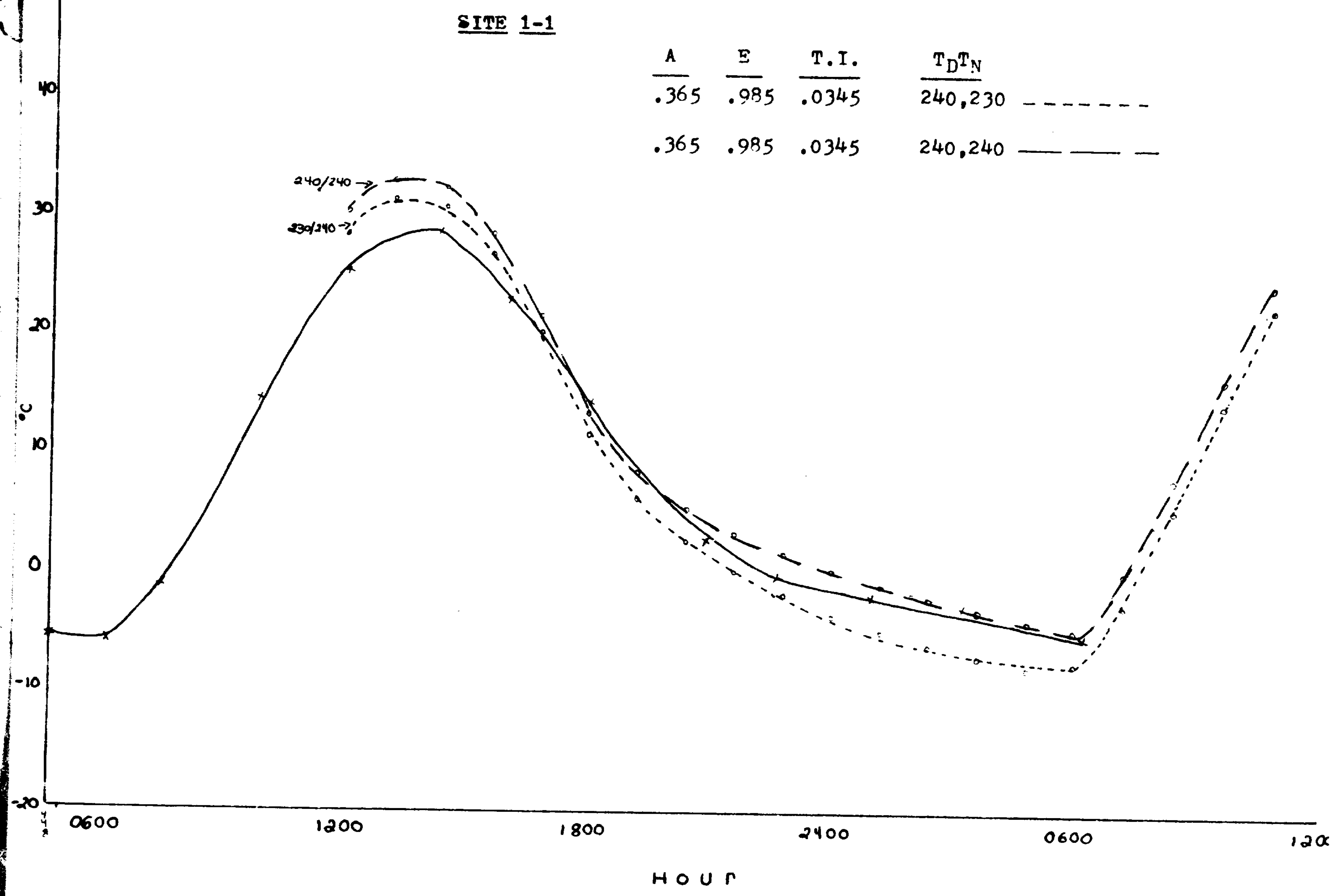
Figure 2-2 RECORDER-OUTPUT CALIBRATION*
(Standard Spectral Passband, 8 to 14μ)

LOW RANGE		MEDIUM RANGE		HIGH RANGE	
Meter (°C)	Recorder (mv d-c)	Meter (°C)	Recorder (mv d-c)	Meter (°C)	Recorder (mv d-c)
-20	0.0	10	0.0	40	0.0
-19	24.0	11	24.5	41	25.3
-18	48.4	12	49.4	42	51.1
-17	73.1	13	74.9	43	77.3
-16	98.2	14	100.9	44	104.0
-15	123.5	15	127.3	45	131.2
-14	149.1	16	154.3	46	158.8
-13	175.0	17	181.7	47	186.9
-12	201.4	18	209.8	48	215.5
-11	228.0	19	237.1	49	243.4
-10	255.0	20	264.8	50	271.4
- 9	282.3	21	292.7	51	299.7
- 8	319.9	22	320.8	52	328.2
- 7	337.9	23	352.0	53	356.9
- 6	366.1	24	377.8	54	385.7
- 5	394.7	25	406.8	55	414.8
- 4	423.5	26	436.0	56	441.1
- 3	452.9	27	465.5	57	473.7
- 2	482.4	28	495.1	58	503.5
- 1	512.4	29	525.0	59	535.3
0	542.6	30	554.8	60	562.4
+ 1	573.1	31	584.7	61	592.1
2	604.1	32	614.2	62	622.0
3	643.7	33	644.5	63	651.3
4	665.3	34	674.2	64	680.8
5	695.2	35	704.8	65	711.0
6	727.1	36	735.0	66	742.1
7	758.7	37	765.2	67	771.1
8	790.5	38	795.7	68	801.0
9	822.6	39	829.0	69	830.0
10	841.7	40	855.0	70	857.6
11	880.3	41	883.5	71	885.7
12	909.8	42	912.7	72	914.9
13	939.8	43	941.1	73	943.0
14	969.2	44	970.1	74	971.0
15	1000.0	45	1000.0	75	1000.0

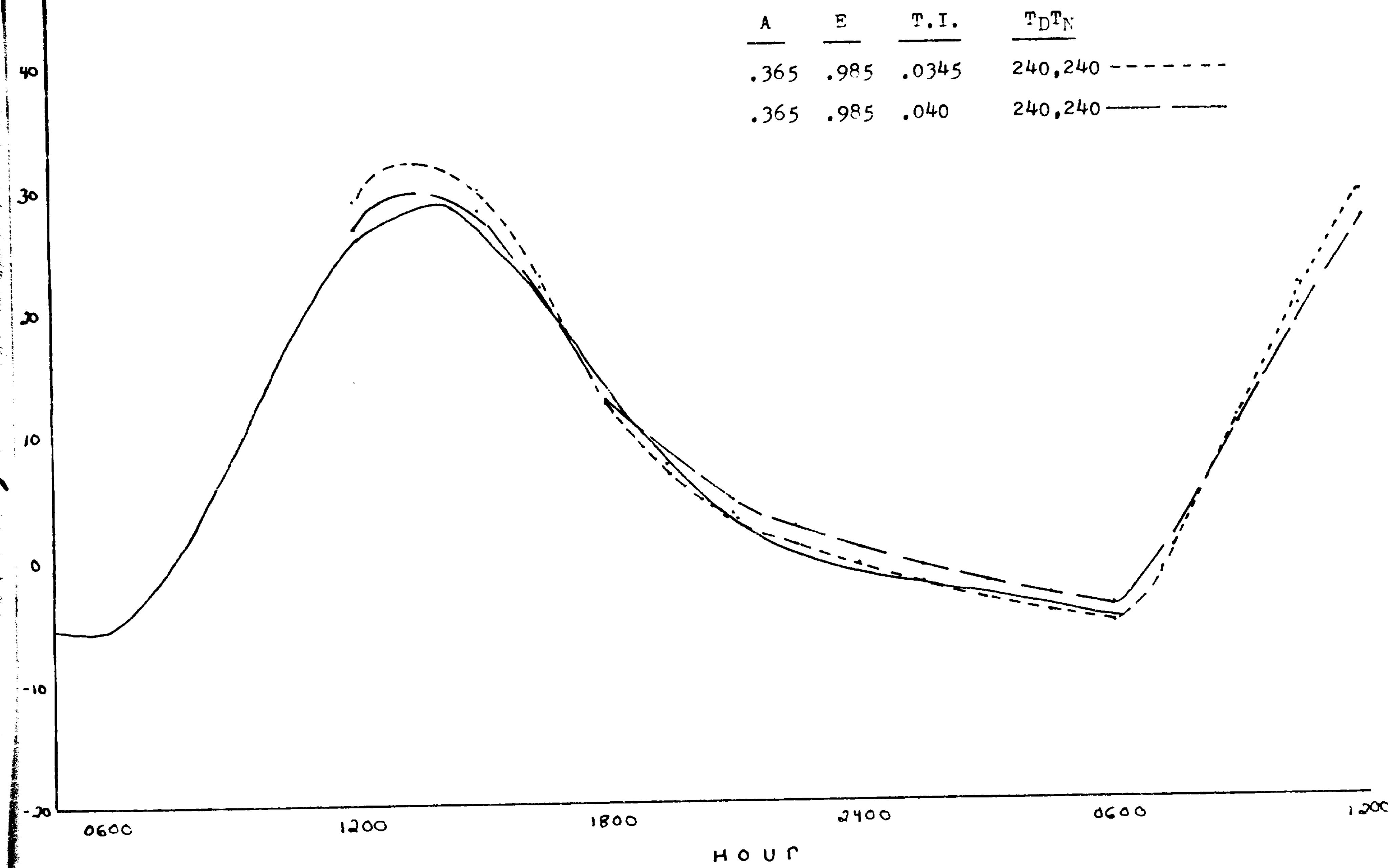
Note: High-level output is listed. Low-level output is 5% of value listed for each temperature.

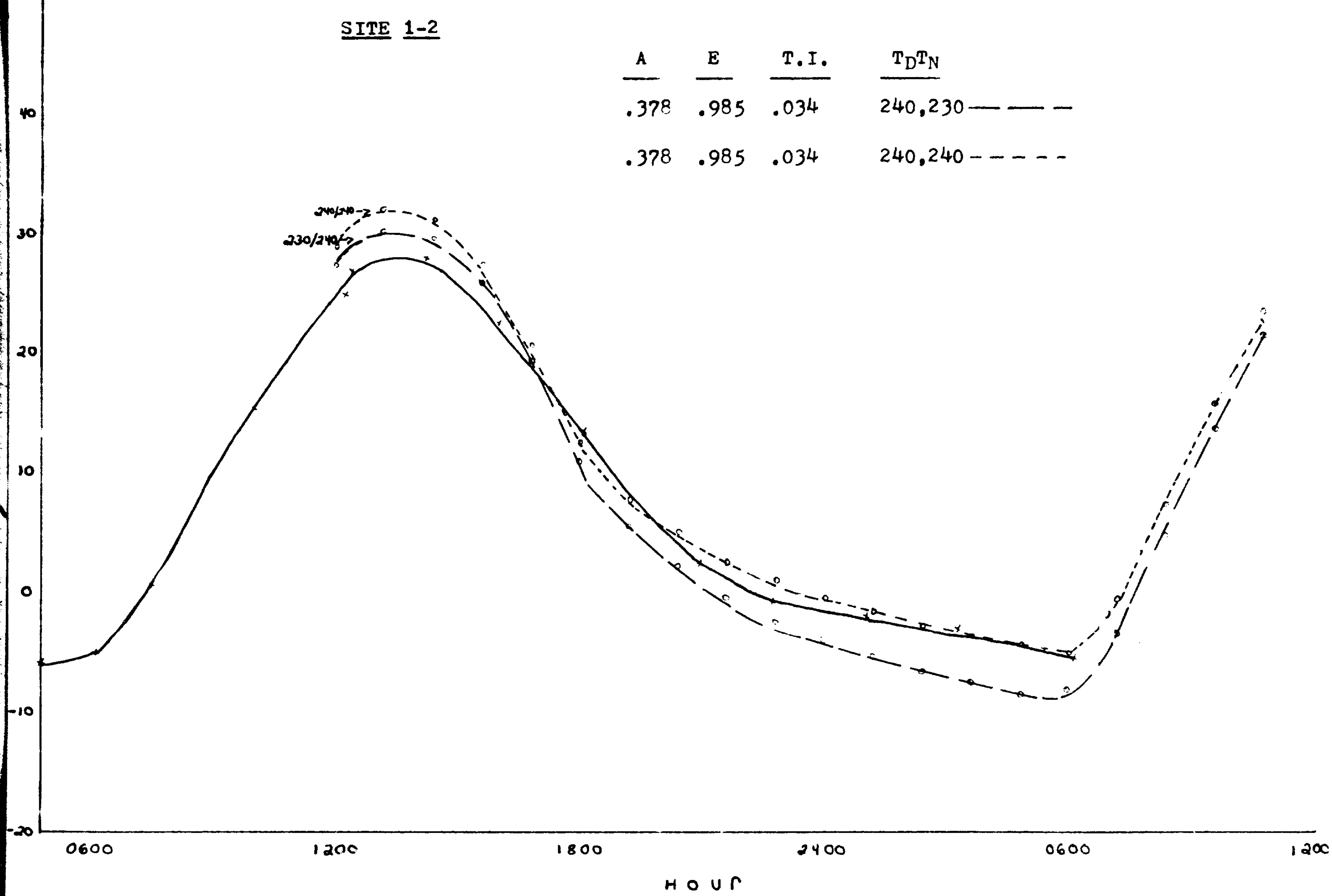
APPENDIX 4

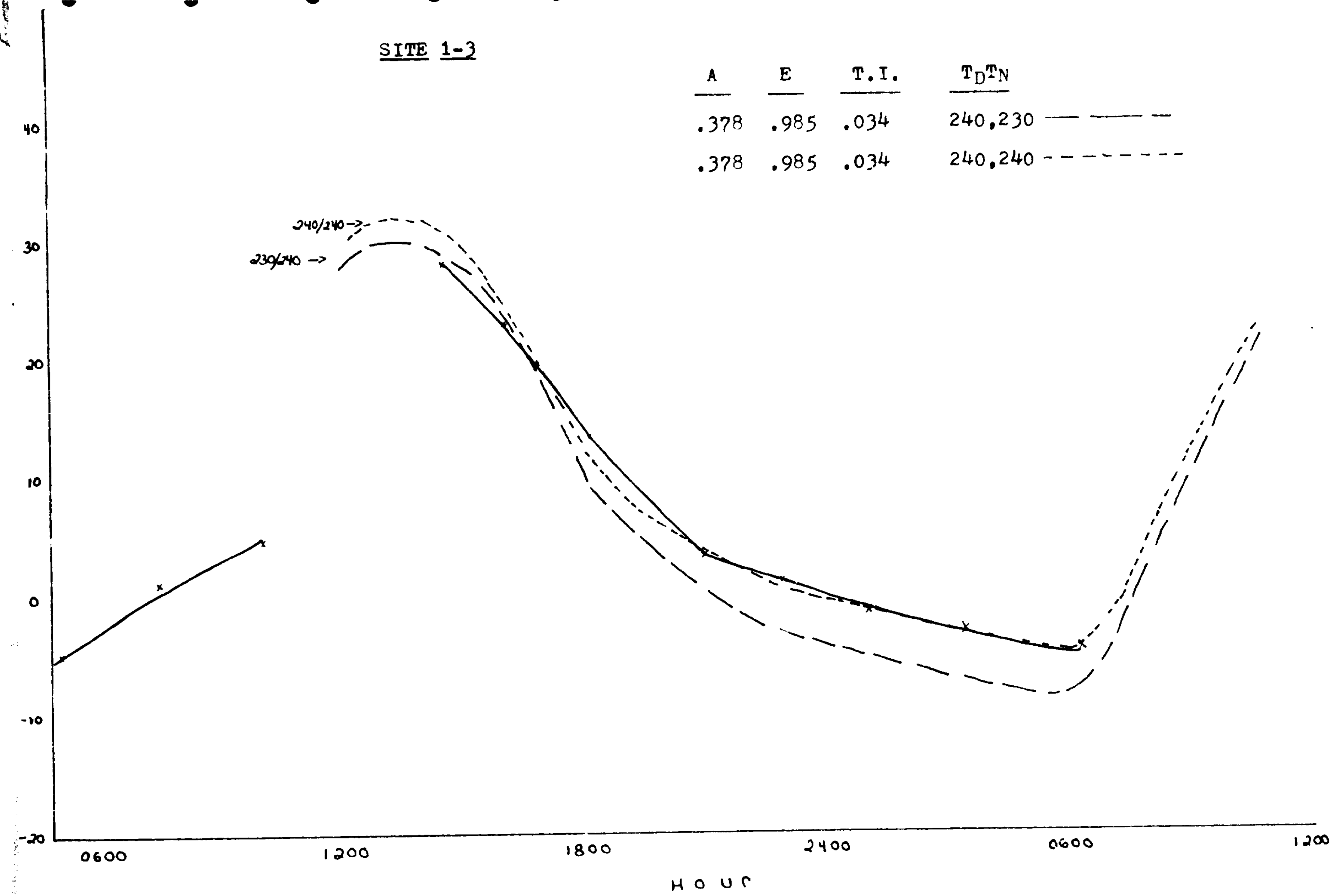
GRAPHICAL REPRESENTATION OF MEASURED DIURNAL SURFACE TEMPERATURES v. THERMAL MODEL RUNS


SITE 1-1
A E T.I. T_DT_N
.365 .985 .0345 240,230
.365 .985 .0345 240,240
240/240
230/240
°C
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR

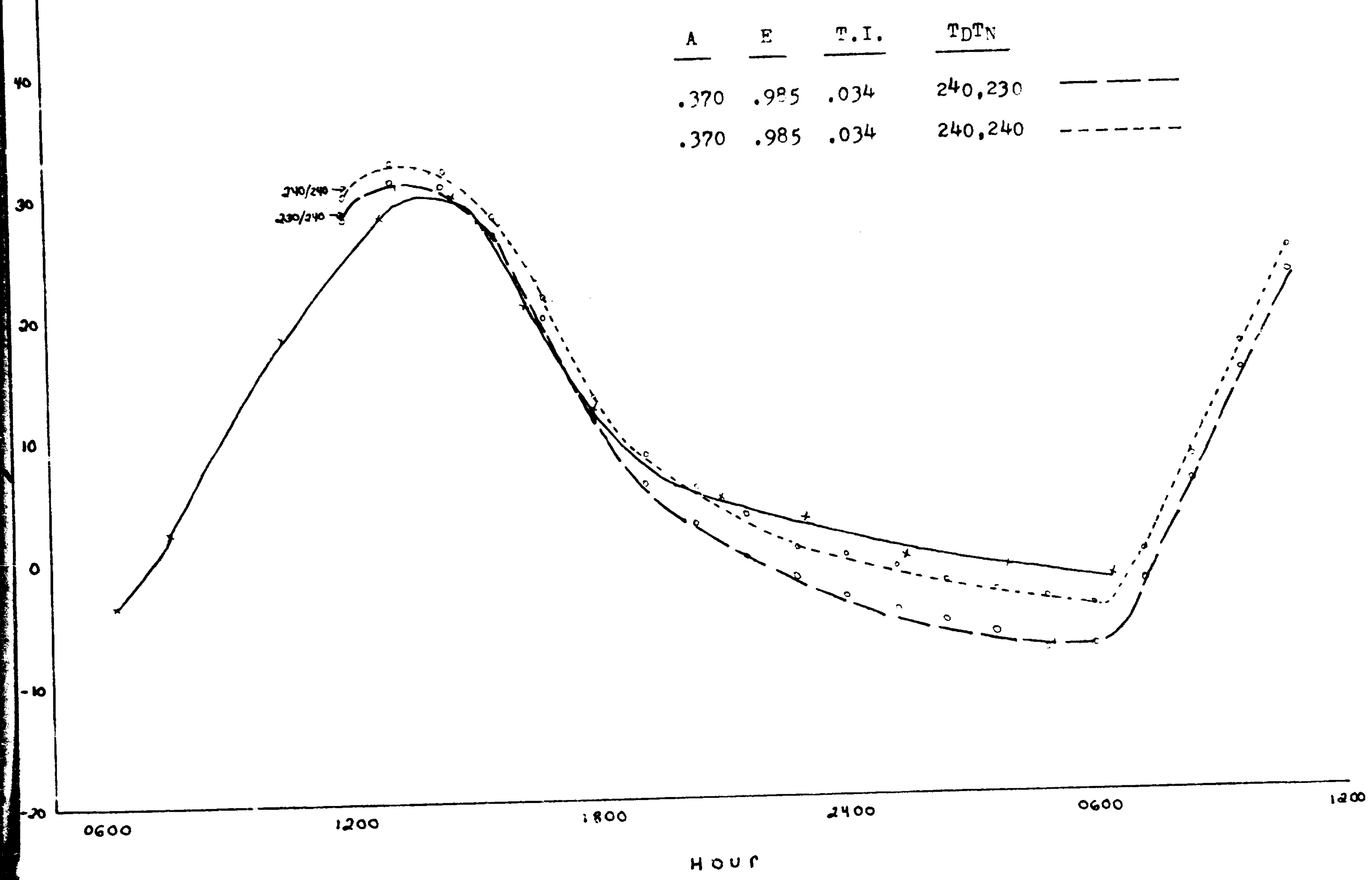
Site 1-1 WATEMP Program

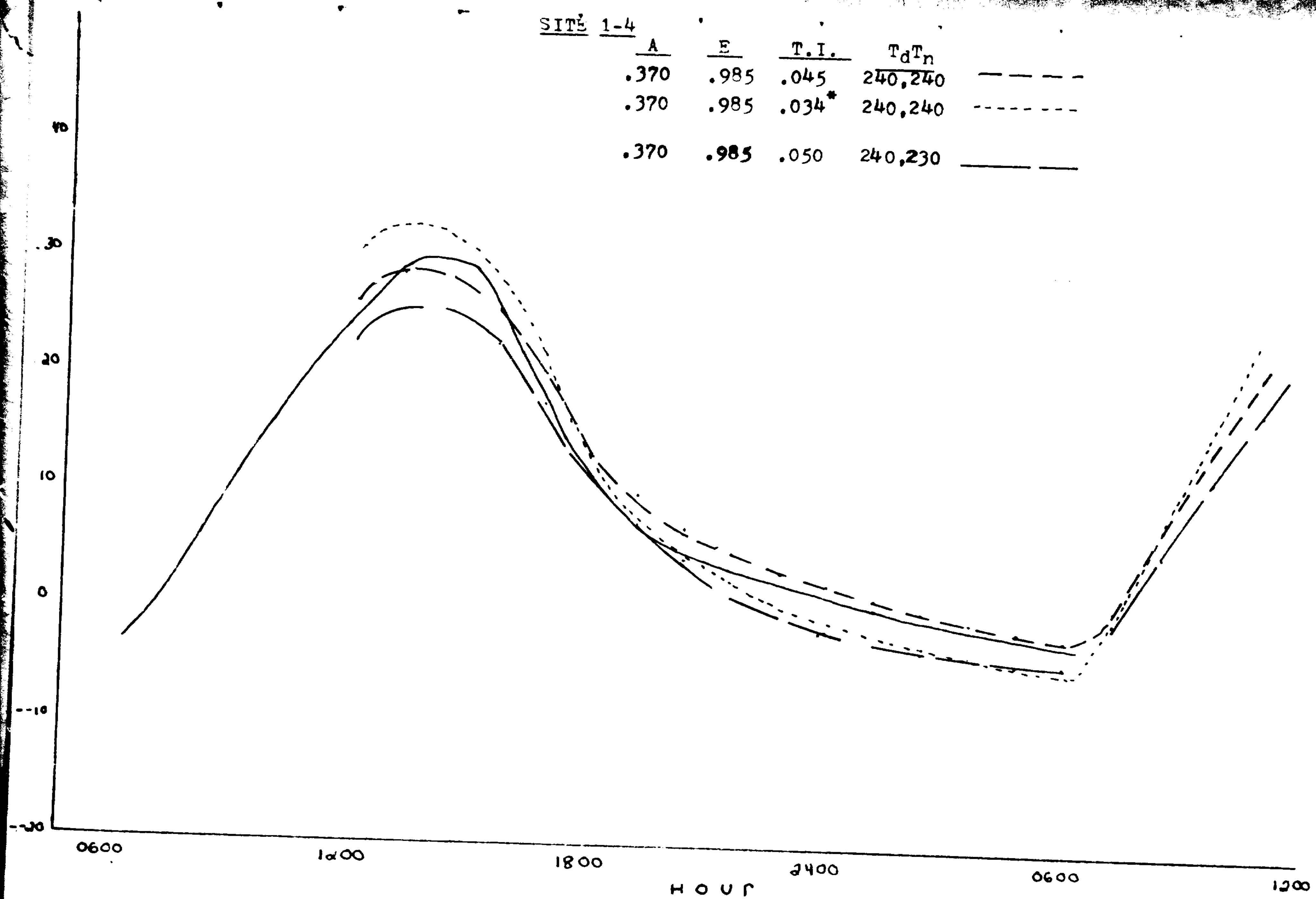


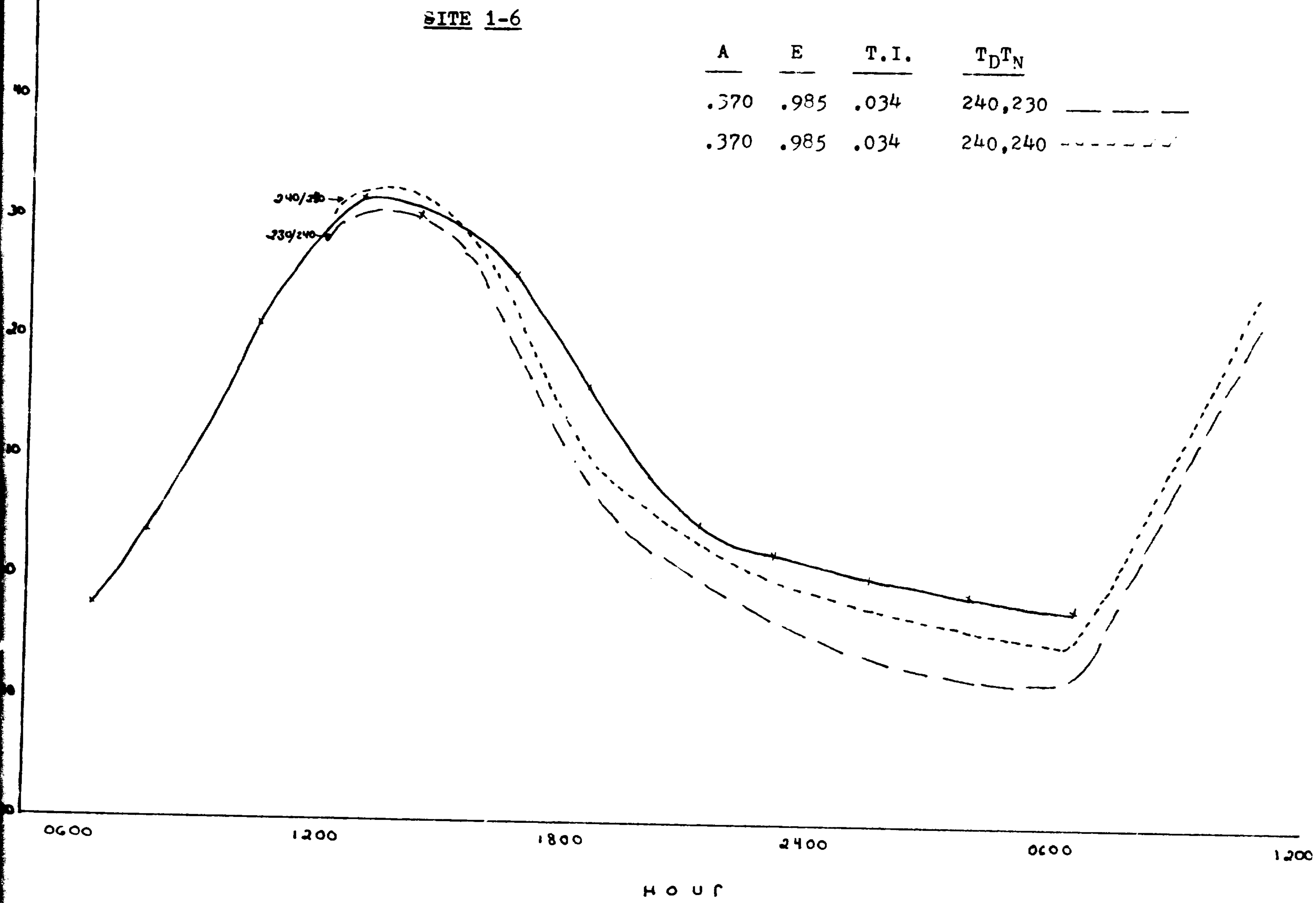

SITE 1-2
A E T.I. $T_D T_N$
.378 .985 .034 240,230
.378 .985 .034 240,240
240/240-2
230/240-2
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR

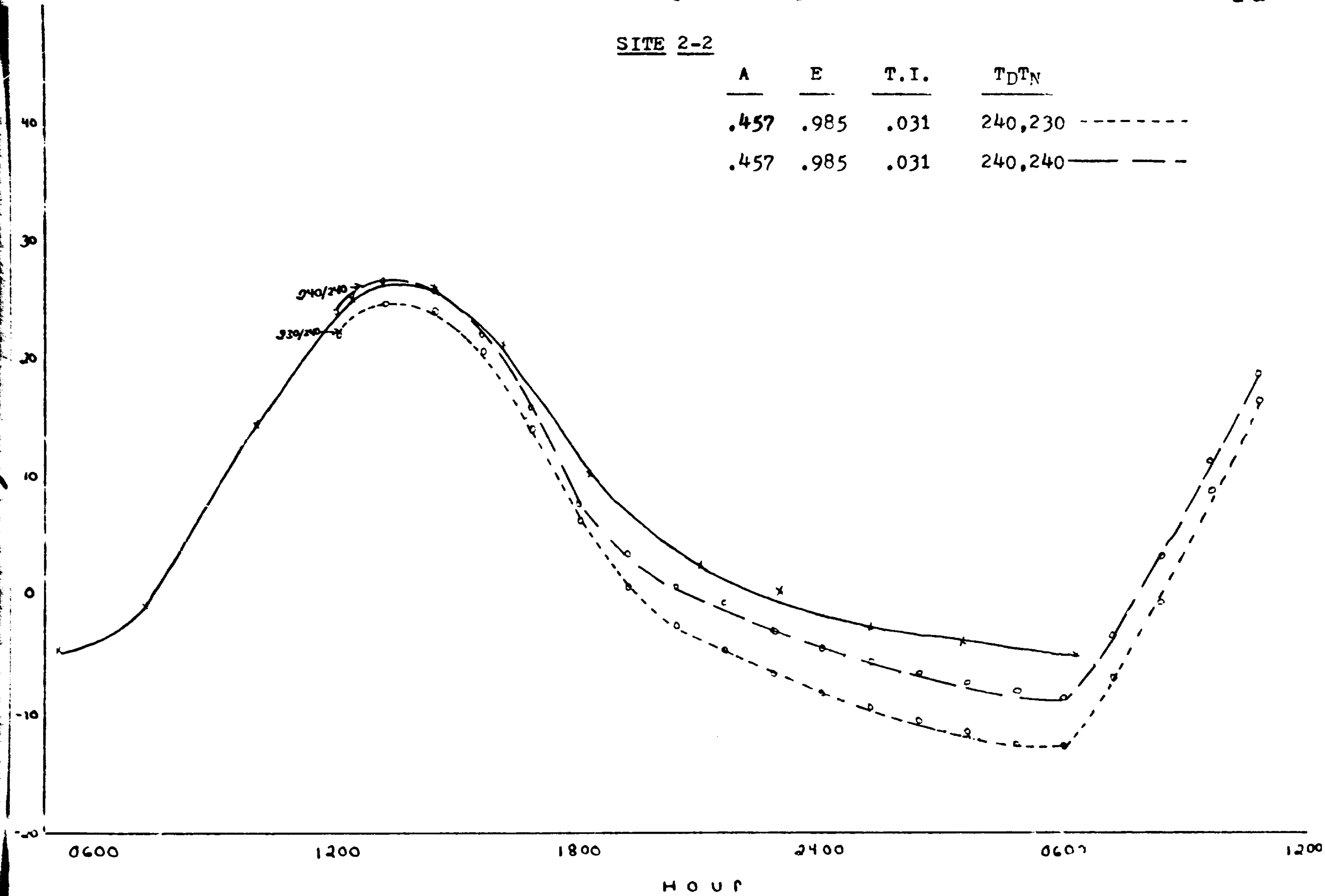

SITE 1-3
A E T.I. $T_D T_N$
.378 .985 .034 240,230
.378 .985 .034 240,240
240/240 ->
230/240 ->
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR

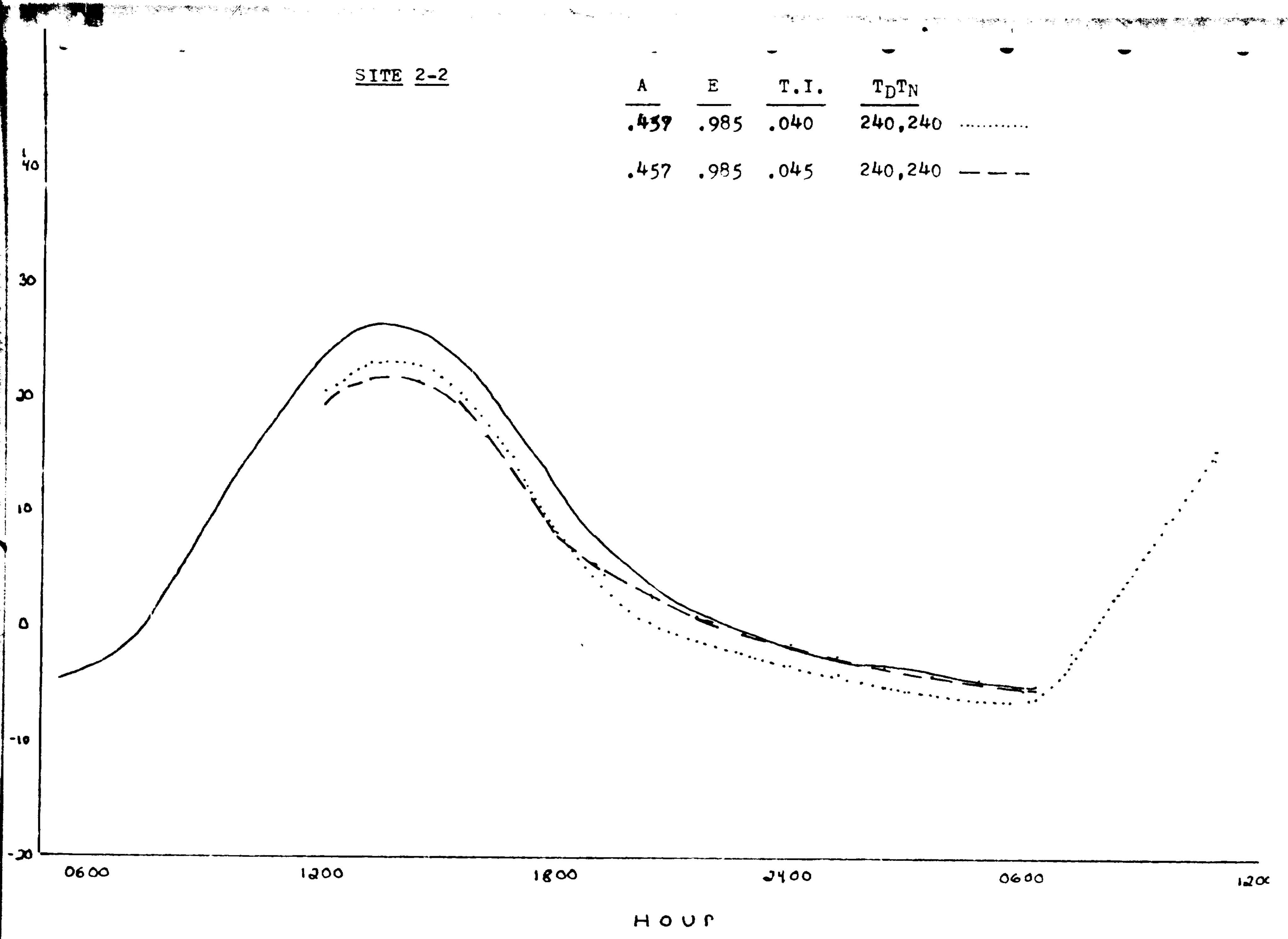
SITE 1-4


A E T.I. TDTN
.370 .985 .034 240,230
.370 .985 .034 240,240
240/240
230/240
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR


SITE 1-4
A
E
T.I.
T_dT_n
.370
.985
.045
240,240
.370
.985
.034*
240,240
.370
.985
.050
240,230
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR


SITE 1-6
A E T.I. T_DT_N
.370 .985 .034 240,230
.370 .985 .034 240,240
240/230
230/240
40
30
20
10
0600
1200
1800
2400
0600
1200
HOUR

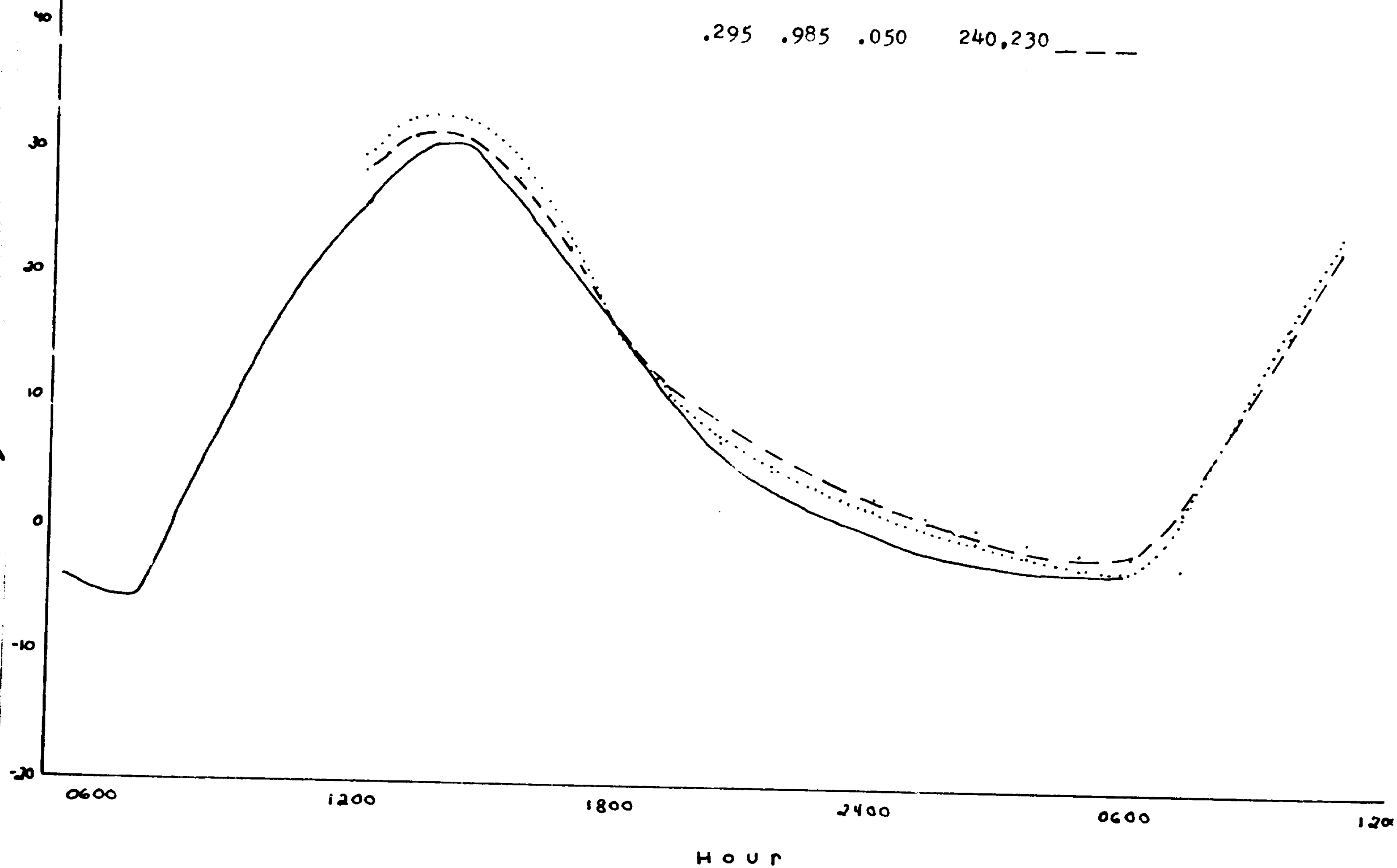

SITE 2-2
A E T.I. T_DT_N
.457 .985 .031 240,230
.457 .985 .031 240,240
240/240
230/240
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
1200
HOUR



SITE 2-2
A E T.I. $T_D T_N$
.459 .985 .040 240,240
.457 .985 .045 240,240
40
30
20
10
0
-10
-20
0600
1200
1800
2400
0600
HOUr

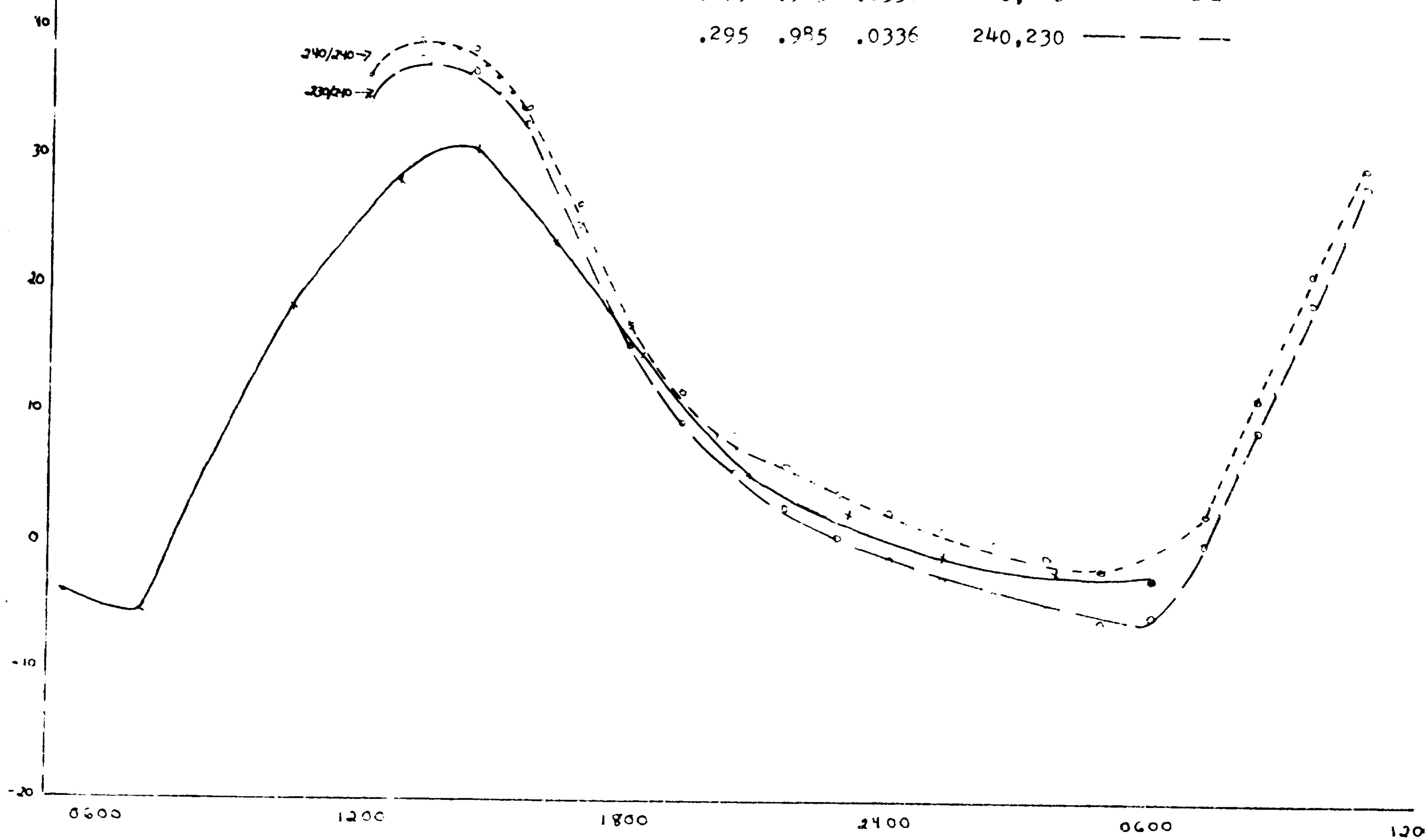
SITE 2-1

A	E	T.I.	$T_D T_N$	
.295	.985	.045	240,230	....
.295	.985	.050	240,230	_ _ _



SITE 21

A	E	T.I.	$T_D T_N$	
.295	.985	.0336	240,240	- - - - - - -
.295	.985	.0336	240,230	— — —



APPENDIX 5

DETAILED ANALYSIS OF STATION 1-1 EMPLOYING SURTEMP THERMAL MODEL - "INPUT TEMP" MEASURED AT SITE

MARCH 29-30, 1975

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TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 24.5 25.1 13.2 27.1 28.1 14.4 27.0 27.7 15.6 24.1 24.5 16.8 18.7 20.1
18.0 12.0 14.3 19.2  7.5  8.0 20.4  4.6  3.7 21.6  2.4  1.3 22.8  0.7 -1.0
24.0 -0.8 -2.0  1.2 -2.0 -2.3  2.4 -3.0 -2.6  3.6 -4.0 -3.7  4.8 -4.8 -4.4
 6.0 -4.8 -5.4  7.2 -0.8 -2.8  8.4  5.7  4.0  9.6 12.9 11.4 10.8 19.5 20.3

T MAX   27.1   T MIN   -4.8   AVERAGE TEMP   8.32

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD    0.0 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.045 (9) LAT   34.7
(10) DEC     3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  230.0 (14) TD  240.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
  -10   -5    0    5   10   15   20   25   30   35   40   45   50   55   60
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
12.0                                     +*
13.2                                        +*
14.4                                        +*
15.6                                     +*
16.8                                +*
18.0                         +  *
19.2                    +*
20.4                 *+
21.6              *+
22.8            *  +
24.0           *+
 1.2           +
 2.           +
 :           *
 4.8        * *
 6.0        +
 7.2          *  +
 8.4                *  +
 9.6                      *  +
10.8                                +*
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
  -10   -5    0    5   10   15   20   25   30   35   40   45   50   55   60
```

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□□□□□□□□□□□
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 22.9 25.1 13.2 25.0 28.1 14.4 24.8 27.7 15.6 22.4 24.5 16.8 18.1 20.1
18.0 12.6 14.3 19.2  9.6  8.0 20.4  7.6  3.7 21.6  6.0  1.3 22.8  4.8 -1.0
24.0  3.8 -2.0  1.2  2.9 -2.3  2.4  2.2 -2.6  3.6  1.5 -3.7  4.8  0.9 -4.4
 6.0  0.4 -5.4  7.2  3.3 -2.8  8.4  8.2  4.0  9.6 13.8 11.4 10.8 19.0 20.3

T MAX   25.0   T MIN    0.4   AVERAGE TEMP  10.50

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.2 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.045 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  250.0 (14) TD  250.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
   -10   -5    0    5   10   15   20   25   30   35   40   45   50   55   60
     .    .    .    .    .    .    .    .    .    .    .    .    .    .    .

12.0                                  + *

13.2                                    +  *

14.4                                    +  *

15.6                                 +  *

16.8                             + *

18.0                            +*

19.2                       * +

20.4                   *   +

21.6                *    +

22.8              *     +

24.0             *     +

 1.2             *    +

 2.4            *    +

 3.6           *     +

 4.8           *    +

 6.0          *    +

 7.2            *     +

 8.4                   *   +

 9.6                          *  +

10.8                              +*

     .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
   -10   -5    0    5   10   15   20   25   30   35   40   45   50   55   60
```

ooooooooooo

TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES

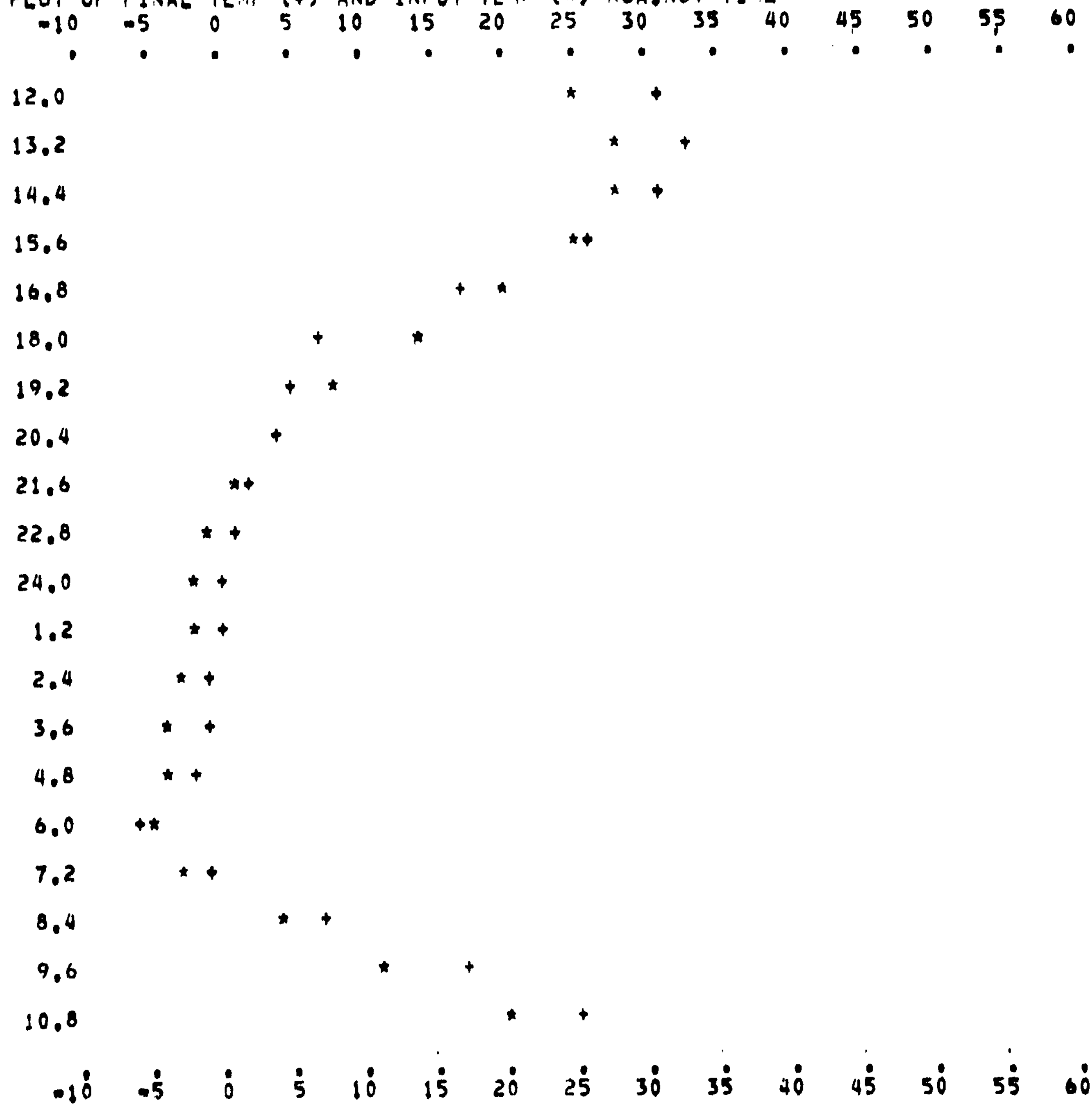
```
12.0 30.8 25.1 13.2 32.8 28.1 14.4 31.1 27.7 15.6 25.7 24.5 16.8 17.0 20.1
18.0  6.8 14.3 19.2  5.3  8.0 20.4  3.7  3.7 21.6  2.4  1.3 22.8  1.3 -1.0
24.0  0.5 -2.0  1.2 -0.3 -2.3  2.4 -0.9 -2.6  3.6 -1.4 -3.7  4.8 -1.9 -4.4
 6.0 -6.1 -5.4  7.2 -1.4 -2.8  8.4  7.4  4.0  9.6 16.9 11.4 10.8 25.2 20.3
```

T MAX 32.8 T MIN -6.1 AVERAGE TEMP 9.75

PROGRAM PARAMETERS CURRENT VALUES

```
(5) CLOUD   0.2 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.020 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  260.0 (14) TD  240.0
```

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME



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oooooooooo
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 37.6 25.1 13.2 40.5 28.1 14.4 38.6 27.7 15.6 32.2 24.5 16.8 21.8 20.1
18.0  9.4 14.3 19.2  1.8  8.0 20.4 -2.7  3.7 21.6 -5.8  1.3 22.8 -8.2 -4.0
24.0-10.1 -2.0  1.2-11.7 -2.3  2.4-13.0 -2.6  3.6-14.2 -3.7  4.8-15.2 -4.4
 6.0-14.5 -5.4  7.2 -6.0 -2.8  8.4  6.5  4.0  9.6 19.5 11.4 10.8 30.4 20.3

T MAX   40.5   T MIN  -15.2   AVERAGE TEMP   6.84

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.0 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.020 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  230.0 (14) TD  240.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
     .    .    .    .    .    .    .    .    .    .    .    .    .    .    .

12.0                                    *            +

13.2                                       *           +

14.4                                       *          +

15.6                                    *      +

16.8                               * +

18.0                    +    *

19.2             +     *

20.4        +      *

21.6     +      *

22.8   +   *

24.0+        *

 1.2+        *

 2.4+       *

 3.6+      *

 4.8+      *

 6.0+     *

 7.2     +  *

 8.4               *  +

 9.6                      *        +

10.8                               *         +

     .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
```
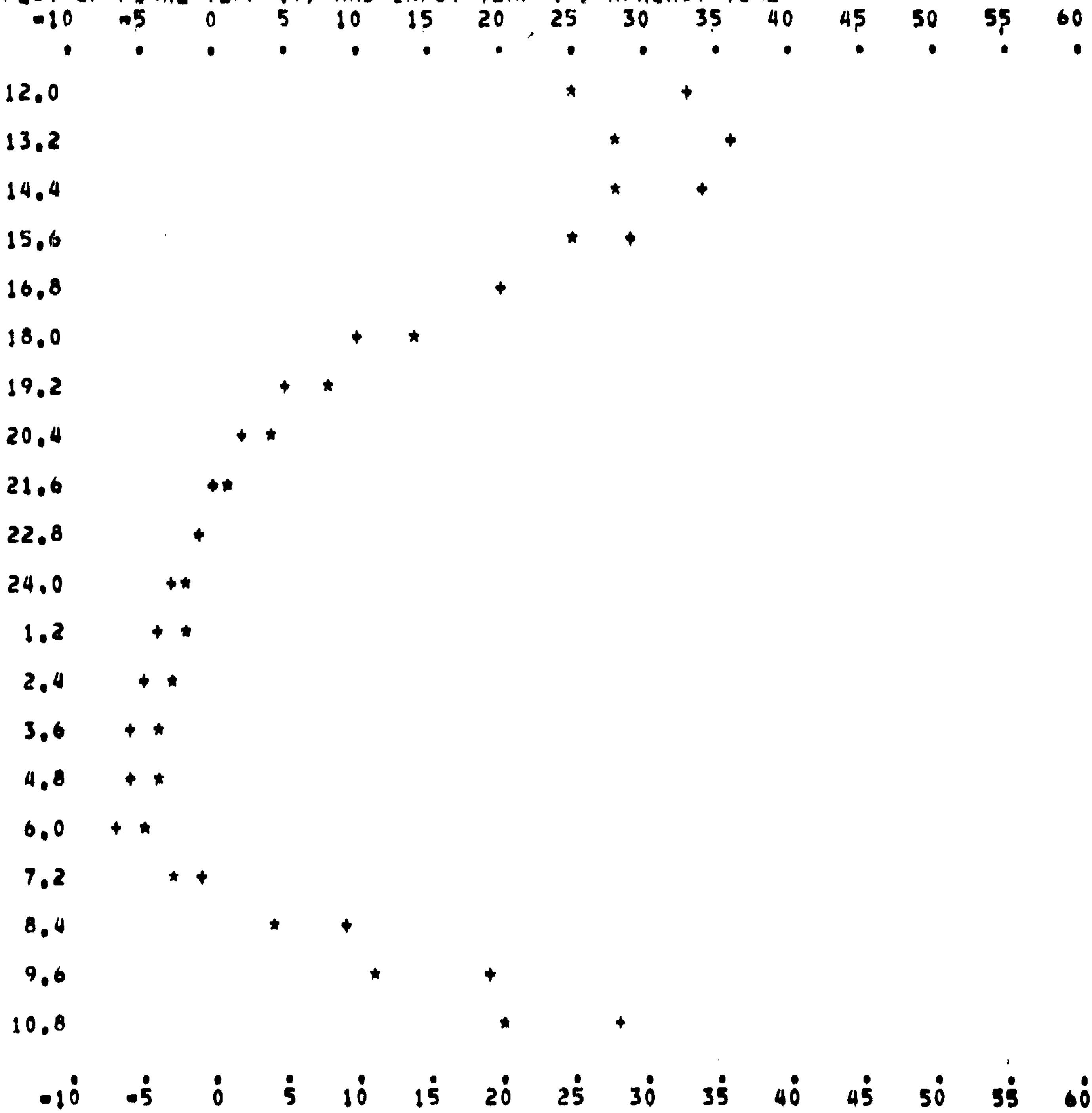

```
0000000000
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 33.4 25.1 13.2 35.6 28.1 14.4 34.1 27.7 15.6 28.8 24.5 16.8 20.3 20.1
18.0 10.3 14.3 19.2  5.5  8.0 20.4  2.4  3.7 21.6  0.2  1.3 22.8 -1.4 -1.0
24.0 -2.8 -2.0  1.2 -3.9 -2.3  2.4 -4.8 -2.6  3.6 -5.6 -3.7  4.8 -6.3 -4.4
 6.0 -6.9 -5.4  7.2 -0.7 -2.8  8.4  8.9  4.0  9.6 19.0 11.4 10.8 27.6 20.3

T MAX   35.6   T MIN   -6.9   AVERAGE TEMP   9.69

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.2 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.020 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  250.0 (14) TD  250.0
```

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME



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□□□□□□□□□□
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 24.8 25.1 13.2 27.0 28.1 14.4 25.4 27.7 15.6 19.9 24.5 16.8 11.1 20.1
18.0  0.7 14.3 19.2 -1.3  8.0 20.4 -3.1  3.7 21.6 -4.7  1.3 22.8 -5.9 -1.0
24.0 -6.9 -2.0  1.2 -7.7 -2.3  2.4 -8.4 -2.6  3.6 -9.0 -3.7  4.8 -9.6 -4.4
 6.0-13.4 -5.4  7.2 -8.6 -2.8  8.4  0.5  4.0  9.6 10.4 11.4 10.8 18.9 20.3

T MAX   27.0   T MIN  -13.4   AVERAGE TEMP   3.01

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.2 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.020 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  250.0 (14) TD  230.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
     .    .    .    .    .    .    .    .    .    .    .    .    .    .    .

12.0                                    +

13.2                                      +*

14.4                                    +  *

15.6                               +    *

16.8                      +        *

18.0            +            *

19.2          +        *

20.4        +      *

21.6      +     *

22.8     +    *

24.0    +    *

 1.2   +     *

 2.4   +    *

 3.6 +    *

 4.8+     *

 6.0+    *

 7.2 +     *

 8.4            +  *

 9.6                     +*

10.8                              +*

   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
```

...IBILITY OF THE ... PAGE IS POOR

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0000000000
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 28.9 25.1 13.2 31.1 28.1 14.4 29.5 27.7 15.6 24.2 24.5 16.8 15.5 20.1
18.0  5.3 14.3 19.2  2.0  8.0 20.4 -0.5  3.7 21.6 -2.3  1.3 22.8 -3.7 -1.0
24.0 -4.9 -2.0  1.2 -5.8 -2.3  2.4 -6.7 -2.6  3.6 -7.4 -3.7  4.8 -8.0 -4.4
 6.0-10.3 -5.4  7.2 -4.8 -2.8  8.4  4.5  4.0  9.6 14.5 11.4 10.8 23.1 20.3

T MAX   31.1   T MIN  -10.3   AVERAGE TEMP   6.21

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD   0.2 (6) ALB  0.365 (7) EMS 0.9850 (8) T IN 0.020 (9) LAT   34.7
(10) DEC    3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  250.0 (14) TD  240.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .

12.0                                   *   +

13.2                                      *  +

14.4                                      * +

15.6                                  +*

16.8                          +   *

18.0               +        *

19.2            +     *

20.4          +   *

21.6        +   *

22.8       +  *

24.0      +  *

 1.2     +   *

 2.4    +   *

 3.6    +  *

 4.8   +   *

 6.0+    *

 7.2      + *

 8.4               +

 9.6                      *  +

10.8                               *  +

    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
   -10  -5    0    5   10   15   20   25   30   35   40   45   50   55   60
```
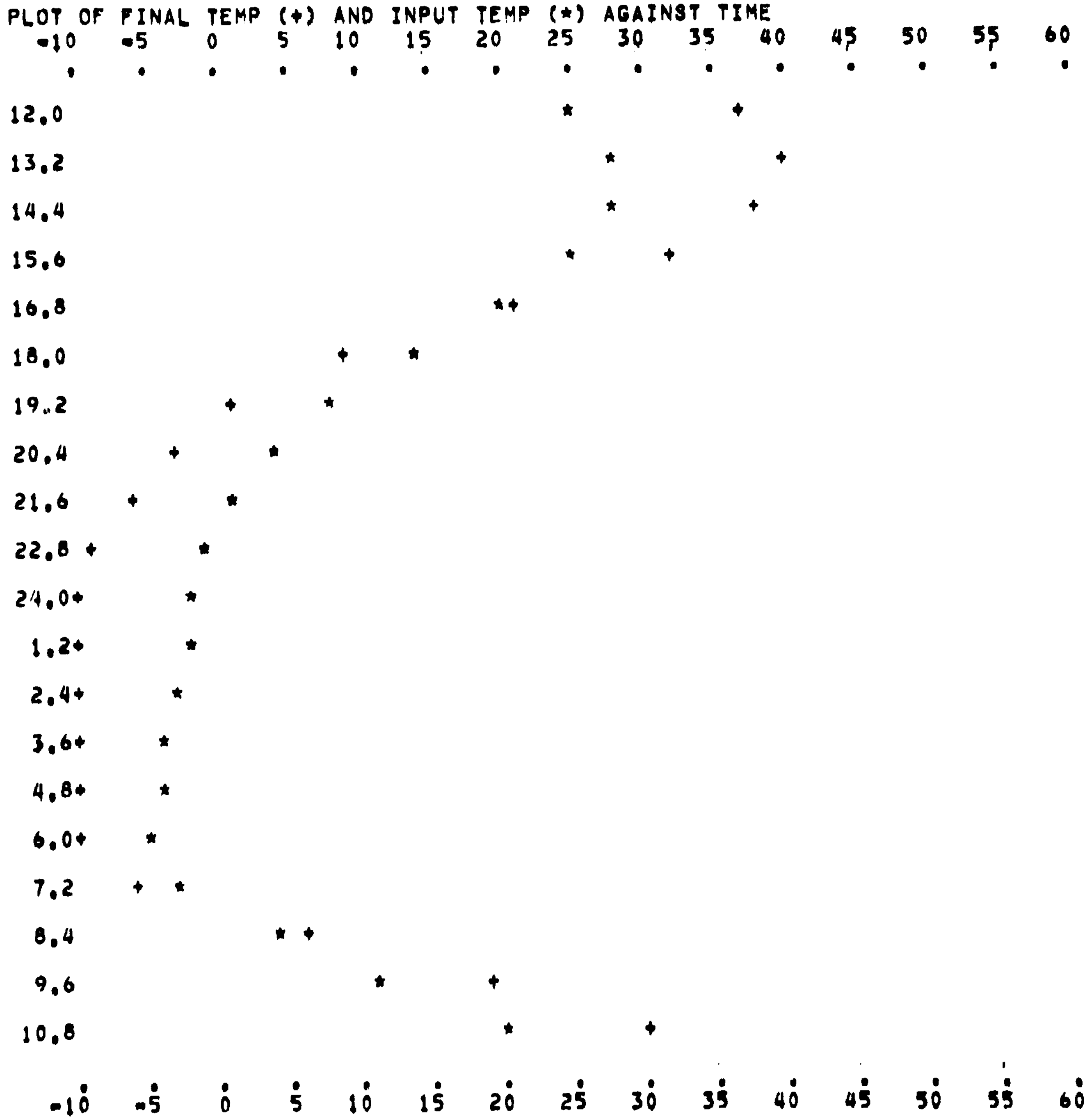
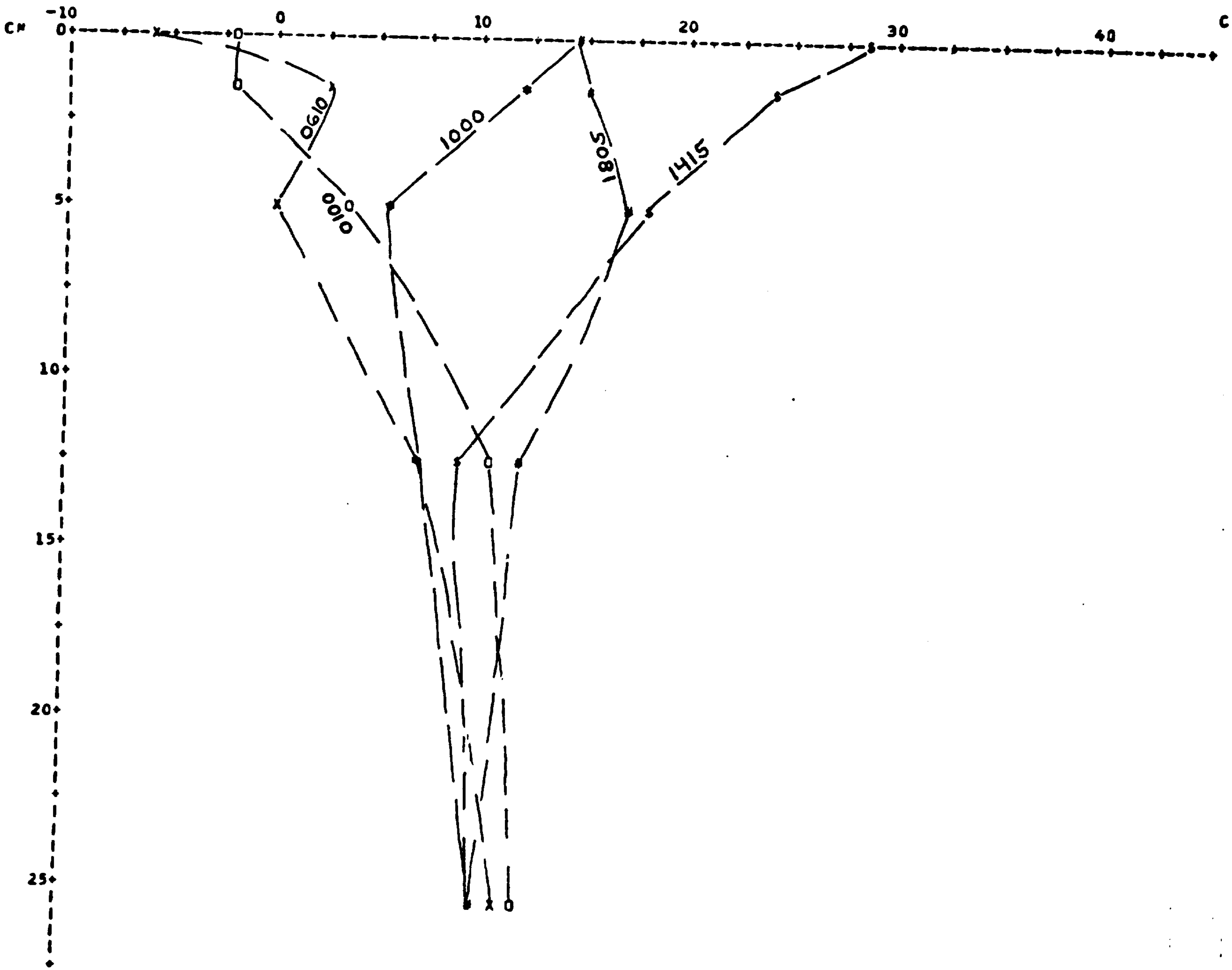

```
0000000000
TIMES, FINAL SURFACE TEMPERATURES, AND INPUT TEMPERATURES
12.0 37.0 25.1 13.2 39.9 28.1 14.4 38.0 27.7 15.6 31.6 24.5 16.8 21.2 20.1
18.0  8.8 14.3 19.2  1.3  8.0 20.4 -3.2  3.7 21.6 -6.3  1.3 22.8 -8.7 -1.0
24.0-10.6 -2.0  1.2-12.2 -2.3  2.4-13.5 -2.6  3.6-14.7 -3.7  4.8-15.7 -4.4
 6.0-14.9 -5.4  7.2 -6.5 -2.8  8.4  6.1  4.0  9.6 19.0 11.4 10.8 29.8 20.3

T MAX   39.9   T MIN  -15.7   AVERAGE TEMP   6.31

PROGRAM PARAMETERS CURRENT VALUES
(5) CLOUD    0.0 (6) ALB  0.365 (7) EMS 1.0000 (8) T IN 0.020 (9) LAT   34.7
(10) DEC     3.0 (11) DIP   0.0 (12) STR   0.0 (13) TN  230.0 (14) TD  240.0

PLOT OF FINAL TEMP (+) AND INPUT TEMP (*) AGAINST TIME
```



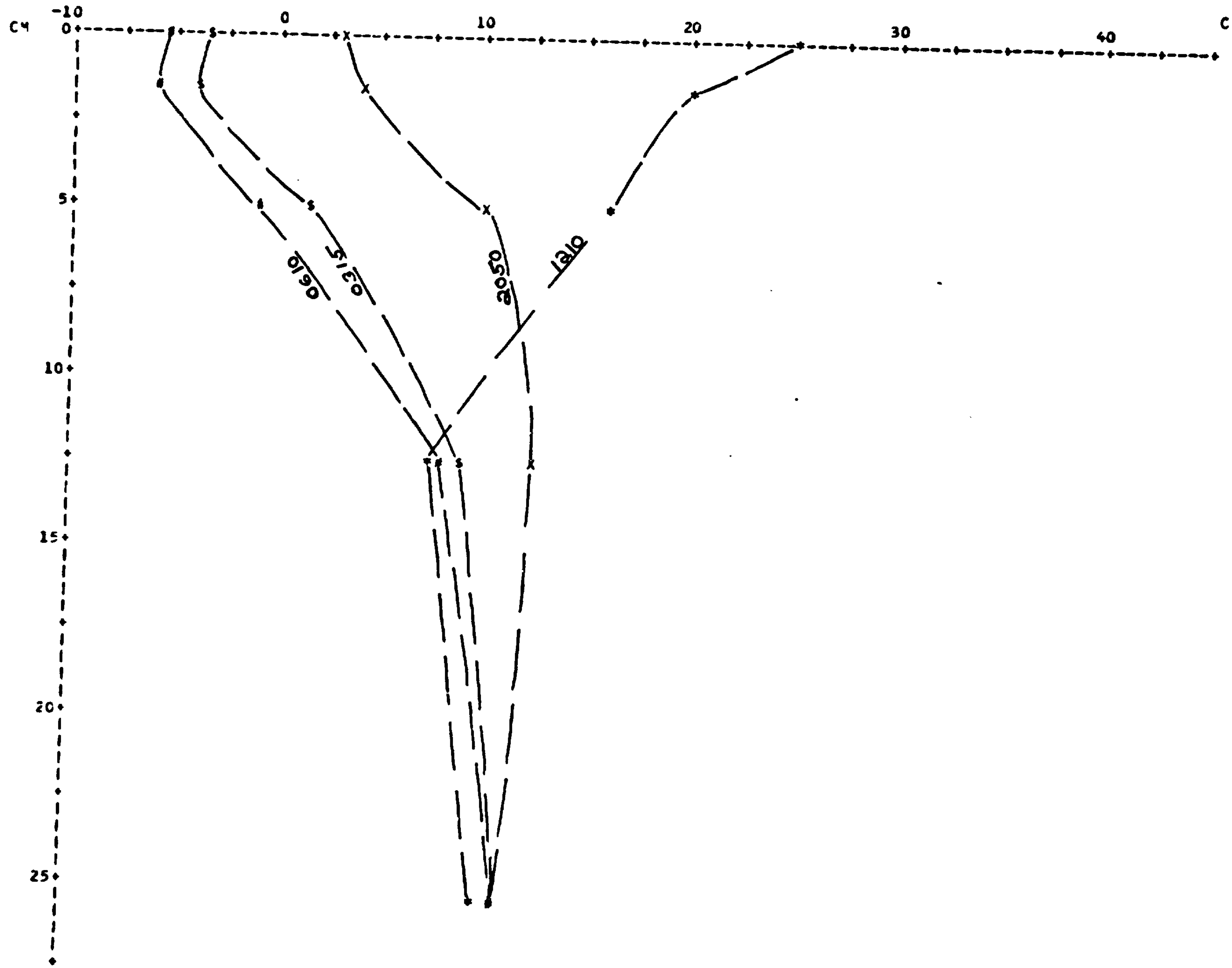
APPENDIX 6

TAUTOCHRONES FROM PLAYA PROBE MEASUREMENTS

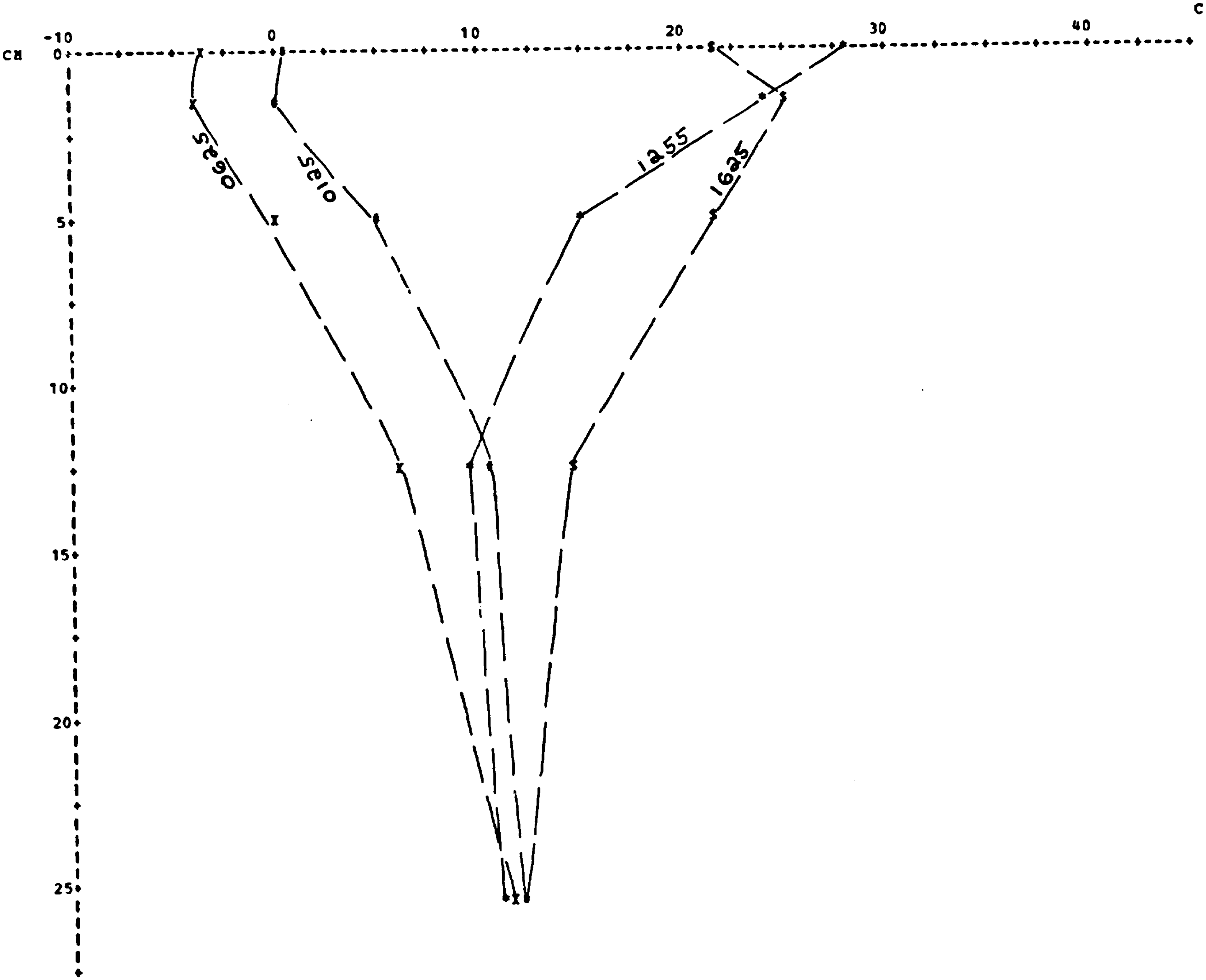
site I-I



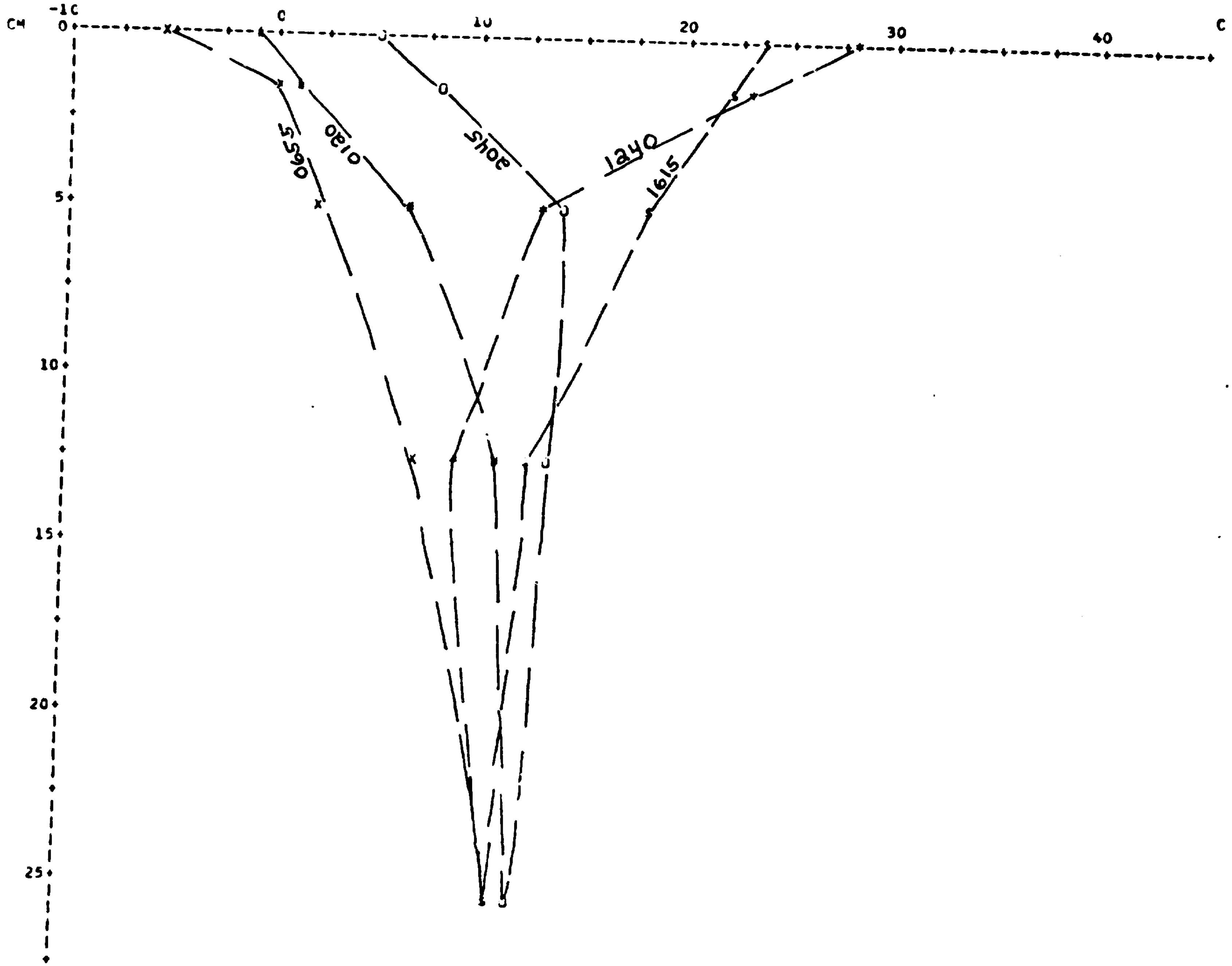
site H



site I-4



site 21



site 2-2