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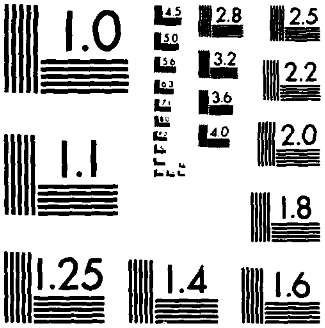
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HEATING PARAMETER ESTIMATION USING COAXIAL THERMOCOUPLE GAGES IN WIND TUNNEL TEST ARTICLES

THESIS

Neil T. Cahoon
Captain, USAF

AFIT/GAE/AA/84D-3

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Aeronautical Engineering

Neil T. Cahoon, B.S.E.
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Also to my wife, Shirley, for the sacrifices she made during the course of this academic experience, I would like to say thanks. She provided immeasurable support and encouragement during my long hours of study.

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List of Symbols

A, A', b, d	Coefficient Matrices (i x i)
c	Specific Heat
E	Residual Error Vector (m)
G	Kalman Gain Vector (i)
H	Thermocouple Location Matrix (m x i)
h_0	Magnitude of Heat Transfer Coefficient Ratio
h_s	Heat Transfer Coefficient Derivitive
h_{bar}	Heat Transfer Coefficient Ratio
h_{ref}	Reference Heat Transfer Coefficient at Zero State
I	Identity Matrix
J_k	Conditional Information Matrix
k	Thermal Conductivity
L	Total Number of Spatial Node Points
P	Covariance Matrix (i x i)
Q	Model Error Covariance Matrix (i x i)
q	Heating Rate
R_m	Covariance for mth measurement
S	Score Vector (k)
$S_{i,k}$	Sensitivity Vectors (i) for the kth Parameter
T_{aw}	Adiabatic Wall Temperature
t	Time
U	Temperature Vector (i)

x	Spatial Coordinate
Y	Thermocouple Measurement Vector
α	Angle of Attack
ε	Emissivity
θ	Parameter Vector
μ_n	Measurement Vector at nth Time Point
ρ	Density
σ	Stefan-Boltzmann Constant
ϕ	Transition Matrix
ϕ_c	Scaling Parameter for Specific Heat
ϕ_k	Scaling Parameter for Thermal Conductivity

Superscripts

$-$	a priori Propogation
$+$	a posteriori Propogation
$*$	Parameter Estimate
n	Time Level
s	Iteration Level
T	Transpose

Subscripts

i	Spatial Node Point
k	Number of Model Parameter
m	Number of Thermocouples
o	Freestream Conditions

Abstract

A heat energy balance is applied to a coaxial thermocouple gage for parameter estimation in wind tunnel test articles. This method can significantly reduce wind tunnel test costs and time. Modifications to the data reduction technique HEATEST (HEATing ESTimation) are made. The program allows for transient test techniques to be used as well as assuming an isothermal wall. A non-linear convective heat transfer coefficient model may also be used. Data is generated to test the new program. Temperature profiles throughout the thermocouple gage were good and were compared with changes in time step, thermocouple length, and number of discrete node points. The estimation of the convective heat transfer coefficient and thermal conductivity were excellent.

HEATING PARAMETER ESTIMATION USING COAXIAL THERMOCOUPLE GAUGES IN WIND TUNNEL TEST ARTICLES

I. INTRODUCTION

1.1 Background

The determination of heat transfer rates on hypersonic configurations upon reentry is important for the survival of the vehicle. The problem is that the heat rate is not a quantity which may be directly scaled from model tests in wind tunnels. However, the parameters which make up the heat rate equation (thermal conductivity and specific heat, for example) can be scaled from which the heat rate may then be calculated. Wind tunnel heat transfer measurements have traditionally used a thin walled test model fabricated with thermocouples mounted on the inside skin surface. The "thermal model" then yields a heat rate based on temperature measurement from the thermocouple. Another technique uses a coaxial thermocouple gage mounted in a thick skin model. A discussion of the two methods follows.

The Traditional Thin Skin Model

The "thermal model" of a traditional wind tunnel thin skin model assumes that all of the heat penetrates the thin skin via conduction to a standard thermocouple gage mounted on the back face. No lateral conduction is assumed and since the emittance of the steel model is low, radiation is assumed negligible. A typical heat rate measurement data point is aquired by injecting the cooled model into the wind tunnel at a known temperature and time and by measuring the temperature at later times. The model is then removed from the tunnel, cooled, and a change in configuration is made in preparation for the next injection and subsequent dat point. There are three very severe limitations associated with this technique (Ref 1).The first is the inability to acquire more than one data point during any one injection. The thermal model simply does not allow for the type of change in configuration or model attitude which can be accomplished using dynamic testing techniques (to be discussed later). Associated with this limitation is the long cooling time between each test which significantly increases the cost per data point for the overall test. A second limitation is the special thin skin model which must be fabricated, further contributing to increased test cost. Finally, the assumption of no lateral conduction through the model may in fact be a poor assumption at some critical locations with large curvature. An alternate type of gage, the coaxial thermocouple, can eliminate these limitations with an overall effect of reducing time and cost.

A New Application For An Old Thermocouple

The coaxial thermocouple gage is shown in Fig. 1.1. It consists of a constantan (a metal alloy) jacket surrounding a chromel core with a thin layer of insulation separating the two metals. The coaxial gage is mounted in a steel model thick enough so that the thermal pulse is not sensed on the backface (ie. the model wall is considered a semi-infinite slab). The thermocouple surface is formed when the gage is lightly sanded to match the contour of the model. Some gages are available with backface temperature monitoring to assure that the thermal pulse does not reach the backface in any given run so that an analytical integration of the heat equation can be used to determine the heating rate history. The backface temperature information prior to this investigation is not factored into the data reduction process, however.

Operation of the coax gage is based on uniform conduction along the gage length which would necessitate the model be made of a material with similar thermal properties (Ref 3). The thermal properties of stainless steel match very closely with the gage properties, therefore, the presence of the gage is negligible. The matching of thermal properties also enhances accuracy. A coaxial gage which is matched thermally with the model allows an isothermal wall assumption, whereas other gauges such as calorimeters and thin film gages are not thermally matched, and cause a non-isothermal wall. Measured heat transfer can be in error by

$$\{\dot{U}\} = [A]\{U\} + \{b\} + W(t)$$
$$\{\dot{S}_k\} = [A]\{S_k\} + \{d_k\} \qquad (3\text{-}1)$$

These equations are solved using a tridiagonal algorithm in subroutine TPS3 for the temperature states, and subroutine SENS for the sensitivity of the temperature to the kth parameter. Propogation of the covariance, P, of the temperature state at each node is accomplished by the approximate difference equation,

$$P(t_n^-) = \phi(\Delta t)P(t_{n-1}^+)\phi^T(\Delta t) + \int_{t_{n-1}}^{t_n} \phi(t_n-\lambda)Q\phi^T(t_n-\lambda)d\lambda \qquad (3\text{-}2)$$

where ϕ is the transition matrix and where the - and + superscripts are used to denote the expected values before an update (or a priori) and updated (or a posteriori) values, respectively. This calculation is made in subroutine TPSOSP2.

A model of the temperature measurement process must be used for the Kalman filter equations. The measurement equation to identify thermocouple location is,

$$Y(t_n) = H\ \{U(t_n)\} + \{\mu_n\} \qquad (3\text{-}3)$$

The updated temperature is calculated by,

$$U(t_n^+) = U(t_n^-) + GE(t_n) \qquad (3\text{-}4)$$

time. They are found by employing a Kalman filter - a set of recursive equations that optimally combine the propogation of the model equations with measurement updates at each sample time. After the entire temperature - time (state) history has been calculated, a gradient algorithm is used to solve for best estimates of the parameters according to a maximum likelihood criterion.

The second type of estimate consists of the parameters defined in the parameter vector,$\{\Theta\}$, as given in Equation 2-10. These parameters remain essentially constant throughout a transient maneuver profile such as a pitch sweep and are estimated based on data from the entire maneuver history. The process of estimating states and parameters is then iterated for convergence to some optimal estimate.

The method used to estimate the states and parameters is formulated from stochastic estimation theory and is known as adaptive estimation. A detailed development of the estimation equations is beyond the scope of this thesis and the reader is referred to References 7 and 8 for more detail.

The thermal model equations for temperature and sensitivity have already been written in the matrix stochastic estimation form of Equation 2-12 as,

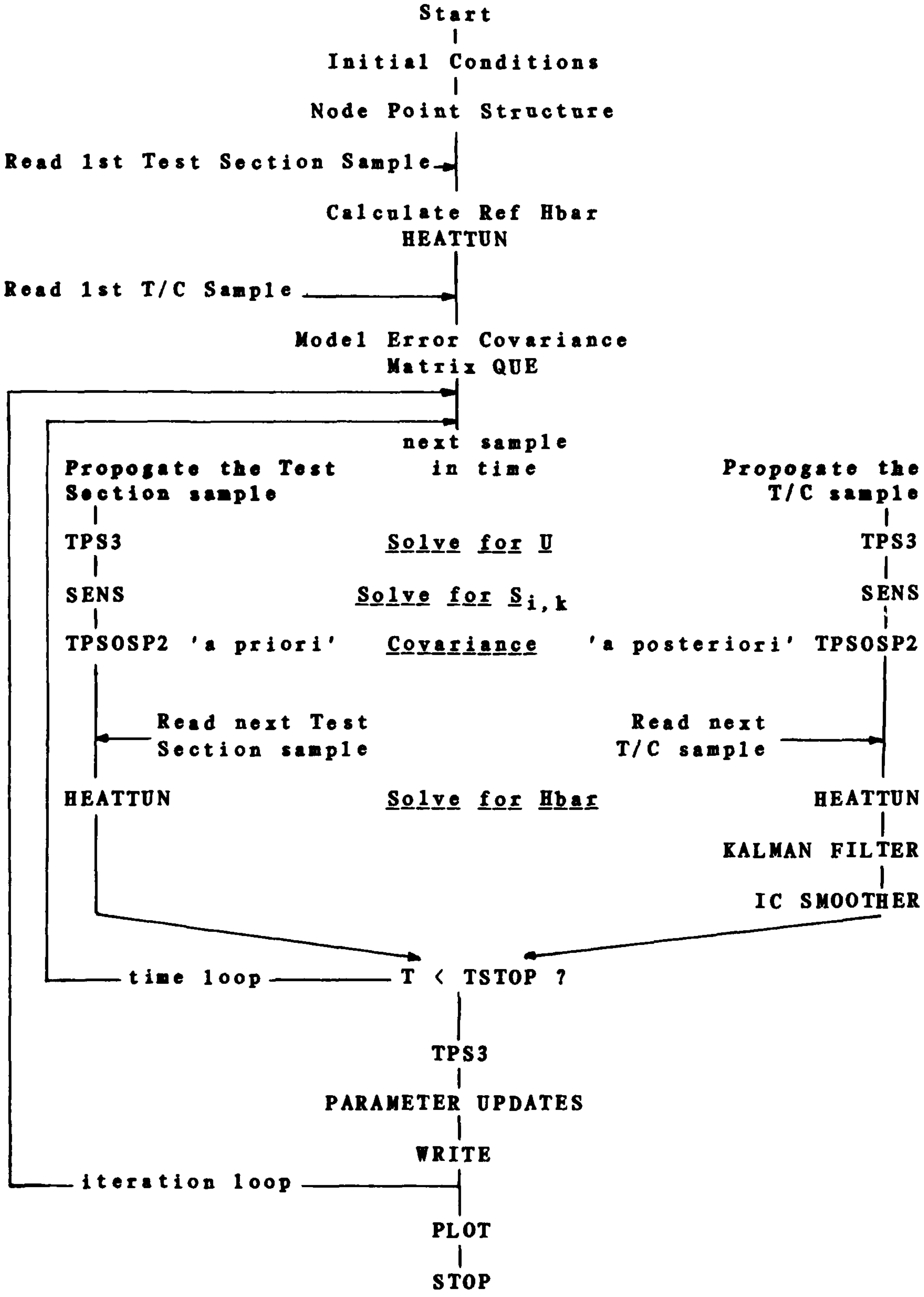


Figure 3.1 HEATEST Algorithm Summary

III. HEATEST OVERVIEW

The HEATEST program was originally developed to determine and model heat rates from the Space Shuttle Orbiter thermocouple data, hence most of its nomenclature references flight data samples and trajectory samples. The wind tunnel equivalence of the trajectory sample would be the test section conditions at the time of the sample (ie. density, velocity, pressure, etc.). The flight data are the thermocouple measurements from the coaxial gages.

An algorithm summary of the HEATEST program is given in Figure 3.1. The initial conditions for the temperature profile, U(t), and the initial covariance, P(t), are specified at the start of the wind tunnel test run. Heating model initial parameters, and the initial reference values for the heating model are read in as inputs to the program. Initial sensitivities of the state are specified to be zero. The node point structure throughout the depth of the thermocouple is then calculated from the input of the length of the gage and the number of node points.

Two types of estimates must be made in order to describe the thermodynamic environment in the wind tunnel. The first type are the state estimates, which are defined by each node temperature. These state estimates are not constant since the temperature varies throughout the maneuver, and hence, must be estimated at each node point in

The {b} vector is not used directly for the covariance equation, but is approximated by an error model given by,

$$Q_{error} = [h_{bar} h_{ref} (T_{aw} - U_1) \Delta x / \phi_k k]^2 \qquad (2\text{-}15)$$

where S is the sensitivity. The i subscript identifies the node point and the second subscript identifies the particular parameter number. The sensitivity equations may also be written in the familiar form,

$$[A']\{S_{i,k}{}^{n}\} + \{d\} = 0 \tag{2-12}$$

The sensitivity equations are developed and summarized in Appendix B.

2.3 Covariance Equation

Propogation of the covariance of the temperature state at each node requires the equations to be of the form

$$\begin{aligned} \{\dot{U}\} &= [A]\{U\} + \{b\} \\ \text{and} \quad \{\dot{S}_{i,k}\} &= [A]\{S_k\} + \{d_k\} \end{aligned} \tag{2-13}$$

Substituting the definitions of Equations (A-14) into Equations (2-7) and (2-8) and rearranging yields a common tridiagonal [A] matrix for the above equations which is shown presently,

$$[A] = \begin{bmatrix} \dfrac{-[RM_1+RP_1+4\varepsilon\sigma(U_1{}^{n,s})^3+h_{bar}h_{ref}]}{RCX_1} & \dfrac{RP_1}{RCX_1} & 0 \\ \ddots & \ddots & \ddots \\ \dfrac{RM_i}{RCX_i} & \dfrac{-(RM_i+RP_i)}{RCX_i} & \dfrac{RP_i}{RCX_i} \\ & \ddots & \ddots \\ 0 & & \end{bmatrix} \tag{2-14}$$

$$[A']\{U_i^n\} + \{b\} = 0 \qquad (2\text{-}9)$$

where $[A']$ is an n x n tridiagonal matrix of material properties and $\{U_i^n\}$ is the n-dimensional column vector of unknown temperature at each node point for each time.

In general, the unknown parameters in this model formulation are the heat transfer coefficient intercept, h_0, the slopes $h_{\alpha 1}$ and $h_{\alpha 2}$, and the scaling parameters for specific heat and thermal conductivity, ϕ_c and ϕ_k, respectively. These parameters may be defined as a vector, , of unknown parameters for use in the system identification scheme as,

$$\vartheta = \{h_0, h_{\alpha 1}, h_{\alpha 2}, \phi_c, \phi_k\}^T \qquad (2\text{-}10)$$

The primary purpose of the heating estimation program is to obtain best estimates of these parameters during transient test maneuvers. To estimate these parameters it is necessary to calculate the model sensitivity to each unknown parameter.

2.2 Sensitivity Equations

The derivative of Equation (2-7) with respect to each parameter yields equations of the same form as Equation (2-9) from which the HEATEST program propogates the sensitivity. For example, the sensitivity of the temperature with respect to h_0 would be written as follows,

$$\frac{\partial U}{\partial \theta_1} = \frac{\partial U}{\partial h_0} = S_{h0} = S_{i,1} \qquad (2\text{-}11)$$

level defined by the superscript n,

$$(U_1^{n,s+1})^4 = (U_1^{n,s})^4 + 4(U_1^{n,s})^3[U_1^{n,s+1} - U_1^{n,s}]$$

$$= -3(U_1^{n,s})^4 + 4(U_1^{n,s})^3 U_1^{n,s+1} \qquad (2\text{-}6)$$

Substituting Equation (2-6) into (2-5) yields,

$$\frac{\rho\phi_c c\Delta x}{2}\,\frac{U_1^n - U_1^{n-1}}{\Delta t} = \frac{-\phi_k k_{1+1/2}}{\Delta x} U_1^n + \frac{\phi_k k_{1+1/2}}{\Delta x} U_2^n$$

$$- \varepsilon\sigma[-3(U_1^{n,s})^4 + 4(U_1^{n,s})^3 U_1^{n,s+1} - (U_\infty^n)^4]$$

$$+ [h_0 + h_{\alpha 1}(\alpha - \alpha_1) + h_{\alpha 2}(\alpha - \alpha_2)]\,h_{ref}(T_{aw} - U_1^{n,s+1})$$

$$(2\text{-}7)$$

The model equation for the interior node points, (i=2,imax), yields,

$$\rho\phi 1_c c\Delta x\,\frac{U_i^n - U_i^{n-1}}{\Delta t} = \frac{\phi_k k_{i-1/2}}{\Delta x} U_{i-1}$$

$$- \frac{\phi_k (k_{i-1/2} + k_{i+1/2})}{\Delta x} U_i$$

$$+ \frac{\phi_k k_{i+1/2}}{\Delta x} U_{i+1}$$

$$(2\text{-}8)$$

Equations (2-7) and (2-8) can be rearranged into the familiar matrix form, parameters other than those included in the reference heat transfer coefficient are summarized by the static transfer relation or heat transfer coefficient ratio, $h_{bar} = h/h_{ref}$. Here, the ratio is assumed to be piecewise linear with respect to angle of attack as derived from Lagrange Interpolation Theory (Ref 6 and Ref therin).

$$h_{bar} = [h_0 + h_{\alpha 1}(\alpha - \alpha_1) + h_{\alpha 2}(\alpha - \alpha_2)] \qquad (2\text{-}4)$$

where h_0 is the magnitude of the heat transfer coefficient, h at the reference conditions ,α_1 , specified by the one subscript. The heating parameters h_0 , $h_{\alpha 1}$, and $h_{\alpha 2}$ are considered to be unknown and constant over a prescribed time period, and will be estimated by the HEATEST program. The parameters correspond to a derivative with respect to deflection angle of the model. Thus, for constant step size, the model equation at the surface node, (i=1), becomes,

$$\frac{\rho \phi_c c \Delta x}{2} \frac{U_1{}^n - U_1{}^{n-1}}{\Delta t} = \frac{-\phi_k k_{1+1/2}}{\Delta x} U_1{}^n$$
$$+ \frac{\phi_k k_{1+1/2}}{\Delta x} U_2{}^n - \varepsilon\sigma[(U_1{}^n)^4 - (U_\infty{}^n)^4]$$
$$+ [h_0 + h_{\alpha 1}(\alpha - \alpha_1) + h_{\alpha 2}(\alpha - \alpha_2)] h_{ref}(T_{aw} - U_1{}^n) \qquad (2\text{-}5)$$

The non-linear radiation term is quasi-linearized on an iteration level defined by the superscript s and by the time

where	ε	radiative emissivity
	σ	StefanBoltzmann constant
	c	material Specific Heat
	ρ	material density
	k	Thermal Conductivity
	ϕ_c	Specific Heat scaling parameter
	ϕ_k	Thermal Conductivity scaling parameter

The material specific heat and thermal conductivity are both scaled by the two factors ϕ_c and ϕ_k, respectively, hence the value for c and k will remain unchanged. The parameters ϕ_c and ϕ_k will be estimated by the HEATEST program. Coefficients with subscripts which are less than one or greater than n are zero. The radiation and heat rate terms are also zero except at the surface node. Equation 2-1 includes terms due to conduction from adjacent node points $k_{i-1/2}/\Delta x_{i-1}$, surface radiation $\varepsilon\sigma U_i^4$, and the convective transfer of energy as obtained from the heating model. The resulting system of implicit difference equations must be solved simultaneously.

The heating model for the convective transfer of energy is based on Newton's Law of Cooling,

$$q = h(T_{aw} - T) \tag{2-2}$$

Non-dimensionalizing by a reference heat transfer coefficient, h_{ref} yields,

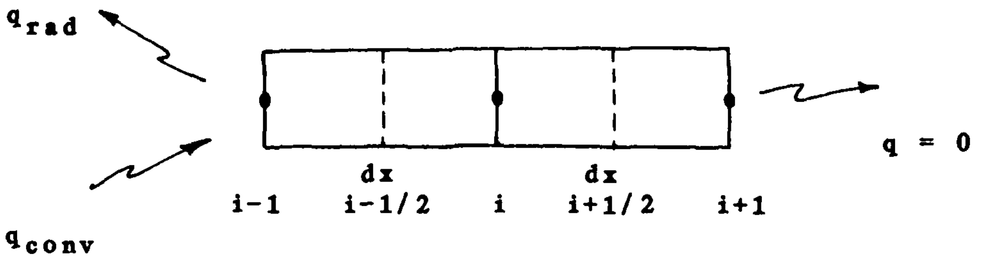
$$q = h_{bar}h_{ref}(T_{aw} - U_i) \tag{2-3}$$

The dependance of the heat transfer coefficient on

II.THE THERMAL MODEL

2.1 Temperature Equations

A cross section of the one-dimensional model is given in Figure 1.1 and below as a typical coaxial thermocouple gage.



An energy balance is performed on each element. The thermal conductivity, k, is taken as an average between each node. Fourier's Law of Heat Conduction throughout the gage, the Stefan-Boltzmann Law for radiation and Newton's Law of Cooling for convection on the surface face yield a system of n nonlinear differential equations of the form:

$$
\begin{aligned}
&[(\rho_i \phi_c c_i \Delta x_i + \rho_{i-1} \phi_c c_{i-1} \Delta x_{i-1})/2][(U_i^{n} - U_i^{n-1})\Delta t] \\
&\quad = \phi_k [k_{i-1/2}/\Delta x_{i-1}] U_{i-1}^{n} \\
&\qquad - \phi_k [k_{i-1/2}/\Delta x_{i-1} + k_{i+1/2}/\Delta x_{i+1}] U_i^{n} \\
&\qquad + \phi_k [k_{i+1/2}/\Delta x_{i+1}] U_{i+1}^{n} \\
&\qquad - \varepsilon\sigma(U_i^{4} - U_{i-1}^{4}) + h_{bar} h_{ref} (T_{aw} - U_i) \qquad (2\text{-}1)
\end{aligned}
$$

gage using a Kalman filter(Ref 2). The purpose of this investigation is to incorporate the appropriate thermal model equations into the HEATEST program for application to coaxial thermocouple gages as used in the wind tunnel. Two reasons for doing this are, 1) replace the analytical with the semi-infinite assumption, ie. extend the run time or shorten the gage, and, 2) estimate thermal properties. Testing and verification of the modified program is necessary for verification of the validity of the results. Simulated data are generated by an analytical solution, and are processed for testing purposes for which the results are known.

1.3 Overview

A development of the pertinent temperature, sensitivity, and covariance equations will be developed for introduction into the HEATEST program in Chapter II. Details in format for programming may be found in Appendix A & B. Chapter III is an overview of the HEATEST algorithm and shows how the equations developed in Chapter II are utilized. Chapter IV outlines the method for testing the program and offers a discussion of the test cases made and results. Finally, conclusions about the validity of the modifications, and suggestions for further improvement are included in Chapter V.

up to 40% because of the non-isothermal (Ref 2). The same rugged model built for pressure measurements can be used for temperature measurements as well, which would further reduce the wind tunnel costs. The data reduction technique, which uses the temperature time history, eliminates the requirement to fix the model configuration or attitude during any one run, hence dynamic testing techniques may be used similar to the flight test technique used for the Space Shuttle Orbiter (Ref 4). The model may be swept in angle of attack, for example, to determine heat rates as a function of angle of attack. All of these attributes along with a short response time and no required calibration (ref Knox) combine to yield the wind tunnel engineer a tool of marked improvement over previous methods.

1.2 OBJECTIVES

A method of analysis to identify the aerothermodynamic flight environment and update the thermal model of the engineering simulation of the Space Shuttle Orbiter was designed by the Air Force Flight Test Center. This method is in the form of a digital computer program called HEATEST (HEATing ESTimation). The program provides a correlation of the heating as well as a heat rate time history. The program integrates numerically instead of relying on some analytical assumption. It satisfies a maximum likelihood criteria for each parameter and obtains best estimates for the temperature at discrete nodes throughout the length of the

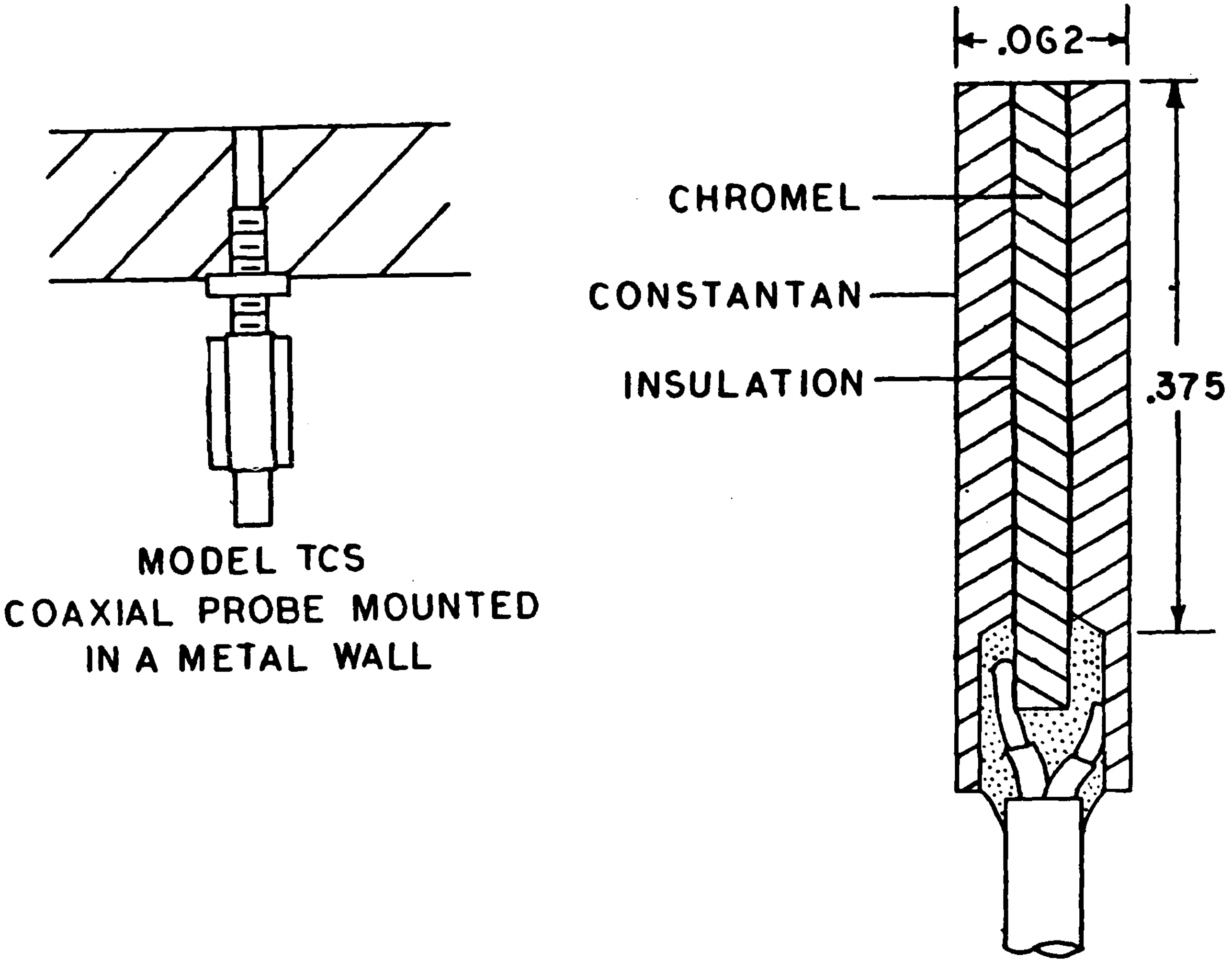


FIGURE 1.1 COAXIAL THERMOCOUPLE GAGE

where

$$G = P(t_n^-)H^T[HP(t_n^{-1})H^T + R_m]^{-1}$$

$$E = Y(t_n) - HU(t_n^-)$$

The updated sensitivities are calculated by,

$$S_k(t_n^+) = [I-GH]P(t_n^-)[I-GH]^T + GR_mG^T \qquad (3-5)$$

The updated covariance is calculated by,

$$P(t_n^+) = [I-GH]P(t_n^-)[I-GH]^T + GR_mG^T \qquad (3-6)$$

To alleviate the problem of imprecise initial conditions, a fixed point smoothing algorithm has been added to the HEATEST program. Details of the smoother and its effects in the adaptive estimation scheme may be found in Reference 6.

Finally, the best estimates of the parameters are then estimated at the end of a specified time segment by the gradient algorithm,

$$\theta^* = \theta - [\partial^2F/\partial 0^2]^{-1}\partial F/\partial\theta = \theta + J^{-1}S \qquad (3-7)$$

where,

$$J_{i,j} = \sum_{n=1}^{N} S_{i,k}(t_n^-)H^T[HP(t_n^-)H^T+Rm]HS_{i,k}(t_n^-)$$

$$S_k = \sum_{n=1}^{N} S_{i,k}(t_n^-)H^T+Rm]^{-1}[Y(t_n)-HU(t_n^-)]$$

The matrix J is an approximation for the Jacobian or conditional information matrix and is given in component form by $J_{i,k}$. The score vector, S_k, is used to approximate the gradient of the likelihood function for a large number of time samples.

Using these equations, best estimates for the temperature time history (states) at each node can be found, as well as the deviation in temperature as provided by the covariance matrix. Also, an estimate of the parameter uncertainty is provided by the Cramer-Rao bound. The Cramer-Rao bound relates the conditional information matrix to the covariance of the parameter estimate.

IV. RESULTS

4.1 Test Procedure

To test the validity of the program modifications, a set of contrived data was generated. It's development assumes that the heat rate due to convection at the surface node is constant and equal to the heat rate due to conduction at the surface. The heat rate due to convection is given by,

$$q = h(T_{aw} - T_w)$$

or

$$q = h_{bar}h_{ref}(T_{aw} - T_w) \qquad (4-1)$$

where h_{bar} is defined as in Equation A-12. The equation for the heat rate due to conduction assuming a one-dimensional, homogenous, semi-infinite solid is as follows (Ref 9),

$$q = \frac{(\rho ck)^{1/2}}{\pi} \int_{o}^{t} \frac{dT_w(\tau)}{d\tau} \frac{d\tau}{(t-\tau)^{1/2}} \qquad (4-2)$$

where t = time from start of heating
$T(t)$ = surface temperature rise
τ = dummy variable of integration

Equating Equations 4-1 and 4-2 yields,

$$q = h_{bar}h_{ref}(T_{aw}-T_w) = \frac{(\rho c k)^{1/2}}{\mu} \int \frac{dT_w(\tau)}{d\tau} \frac{d\tau}{(t-\tau)^{1/2}} \tag{4-3}$$

Two different expressions for the derivative of the wall temperature with respect to time were used. The first implied a linear change in temperature with respect to time yielding a constant for dT_w/dt and the second expression assumes that temperature was a quadratic function of time as shown,

<u>Linear</u>	<u>Quadratic</u>
$T_w = bt + c$	$T_w = at^2 + bt + c$
$\frac{dT_w}{dt} = b$	$\frac{dT_w}{dt} = 2at + b$

Solving Equation 4-3 for T_{aw} so that h and q are constant and after making the indicated substitutions and integrating yields,

<u>Linear assumption</u>

$$T_{aw} = T_w + \frac{2b}{h_{bar}h_{ref}}\sqrt{\frac{\rho c k t}{\pi}} \tag{4-4}$$

<u>Quadratic assumption</u>

$$T_{aw} = T_w + \frac{2}{h_{bar}h_{ref}}\sqrt{\frac{\rho c k t}{\pi}}\left(b + \frac{4at}{3}\right) \tag{4-5}$$

A short computer program was written to produce a temperature-time history in the data tape format for the HEATEST program. For the above equations, h_{ref} and h_{bar} (the estimated parameter) were set equal to 1 and the coefficients a, b, and c, were selected to yield reasonable values for T_w.

4.2 Test Cases

The reference test case was taken to be a 10 sec. simulated wind tunnel test run using the linear data provided from the previous section. Thermocouple samples and test section samples were provided at the rate of one sample per second. The objective was to examine the rate of convergence of the temperature states and to estimate the first parameter, h_0. Recall from Section 4.1 that the data was generated to yield a value of one for h_0. Also of interest, was the validity of the model to the semi-infinite solid assumption (ie. no change in the temperature at the back face node throughout any specified time segment).

The input data is shown in Figure 4.1 and is generated digitally depending upon a desired time step (del t). The initial temperature throughout each gage is assigned a value of 60^{o}F. Figure 4.2 shows the input temperature values for a del t = 1 sec. as used in the reference test case.

Figure 4.3 identifies the temperature state at the 2 sec.(lowest curve), 6 sec.(middle curve), and 10 sec.(top curve) times following the first iteration through the updated HEATEST program. It clearly shows that at the back face node, the semi-infinite solid assumption used to derive the data is violated. This is indicated by the change in backface (node 6) temperature with time. Note also, however, that the temperature gradient at the back nodes (between nodes 5 and 6) is zero due to the adiabatic wall assumption. It should also be pointed out that surface node temperature response to the given input was immediate with no time lag.

Figure 4.4 is similar to Figure 4.3 except the temperature states and parameter estimates have been iterated to convergence, in this case, three times. Overlaying the two figures shows no perceptible difference between them, and the data shows no variations in values until after the second decimal point. In spite of the response of the back face node which would ordinarily invalidate the test, the estimated value for h_0 was .99598, within .4% of the desired value of 1! Several test cases will be compared to this reference by examining changes in time step, thermocouple length, and the number of node points. Also, an examination of the ability of the program to estimate the other parameters, follows.

4.2.1 Changes in Time Step

Figures 4.4, 4.5, and 4.6 show temperature states at 2, 6, and 10 sec. for del t equal to 1, .5, and .25 sec., respectively. All three curves required three iterations for convergence. The curves are all similar in shape with almost no perceptible differences. However, if the 10 sec. curves from del t = 1 sec. and del t = .25 sec. are overlayed as in Figure 4.7, a small difference may be noted at the backface nodes indicating that, indeed, a decrease in time step will yield a profile which will more closely approximate the model.

4.2.2 Changes in Thermocouple Length

Changes in thermocouple length offered the most dramatic changes in temperature state as can be seen in Figures 4.8, 4.9, and 4.10 where the lengths range from .1 ft., .05ft., and .025 ft., respectively. The two longer lengths converged within three iterations while the short thermocouple length took four iterations to converge. The extra iteration is most likely due to the large deviation from the model and the large differences in temperature state from one time step to the next. Figure 4.11 compares the temperature state of each thermocouple length after the 10 sec. run. The lowest curve is associated with the longest thermocouple, and the upper curve is associated with the short gage.

4.2.3 Changes in Number of Node Points

For this comparison, a 10 sec. run with 6 node points and a 3 sec. run with 6 node points (Figures 4.12 and 4.13) will be compared with a 10 sec. run with 12 node points and a 3 sec. run with 12 node points (Figures 4.14 and 4.15). Each of the test runs were converged by the third iteration. At both of the different run times, increasing the number of nodes yielded a solution which more closely approximates the model (ie. the semi-infinite solid at the back face node) and gave correspondingly better estimates for h_0. The comparison of temperature states is better represented by Figures 4.16 and 4.17 which directly compares 6 nodes and 12 nodes interspersed evenly throughout the .05 ft. long thermocouple for 10 sec. and 3 sec. run times, respectively.

4.2.4 Parameter Estimation

The ability of the algorithm to estimate h_0 has already been discussed. To summarize, even when the output temperature states clearly violate the semi-infinite solid assumption used in generating the data, the estimated values of h_0 remain within 15%. The 15% is a worst case number derived from the short thermocouple using a course grid for a long run time. An average deviation which considers all of the test cases evaluated is closer to 3%.

To estimate ϕ_k, an erroneous data value was given for K_{data}, wherin the program iterated to a value for ϕ_k which, when multiplied by the erroneous K_{data}, would yield the correct value, ie. $\phi_k K_{data} = K_{correct}$. The erroneous K_{data} which was input into the program was 14% in error of the $K_{correct}$ value. The value provided by the program for ϕ_k when multiplied by K_{data} yielded a value within .9% of the $K_{correct}$ value!

The estimate of ϕ_c was not as successful, however. After 6 iterations, the solution was diverging from the expected value. A suspected sign error in the ϕ_c sensitivity calculation is the most likely cause.

The quadratic input data was used as a comparison to the linear data to challenge the algorithm, ie. the more complicated the input the more difficult the estimation process. No direct comparison may be made of temperature, however, since the input data is different. The parameter estimation of h_ϕ using the quadratic input data was still excellent yielding .1%, while the estimate using linear data was somewhat better at .05%.

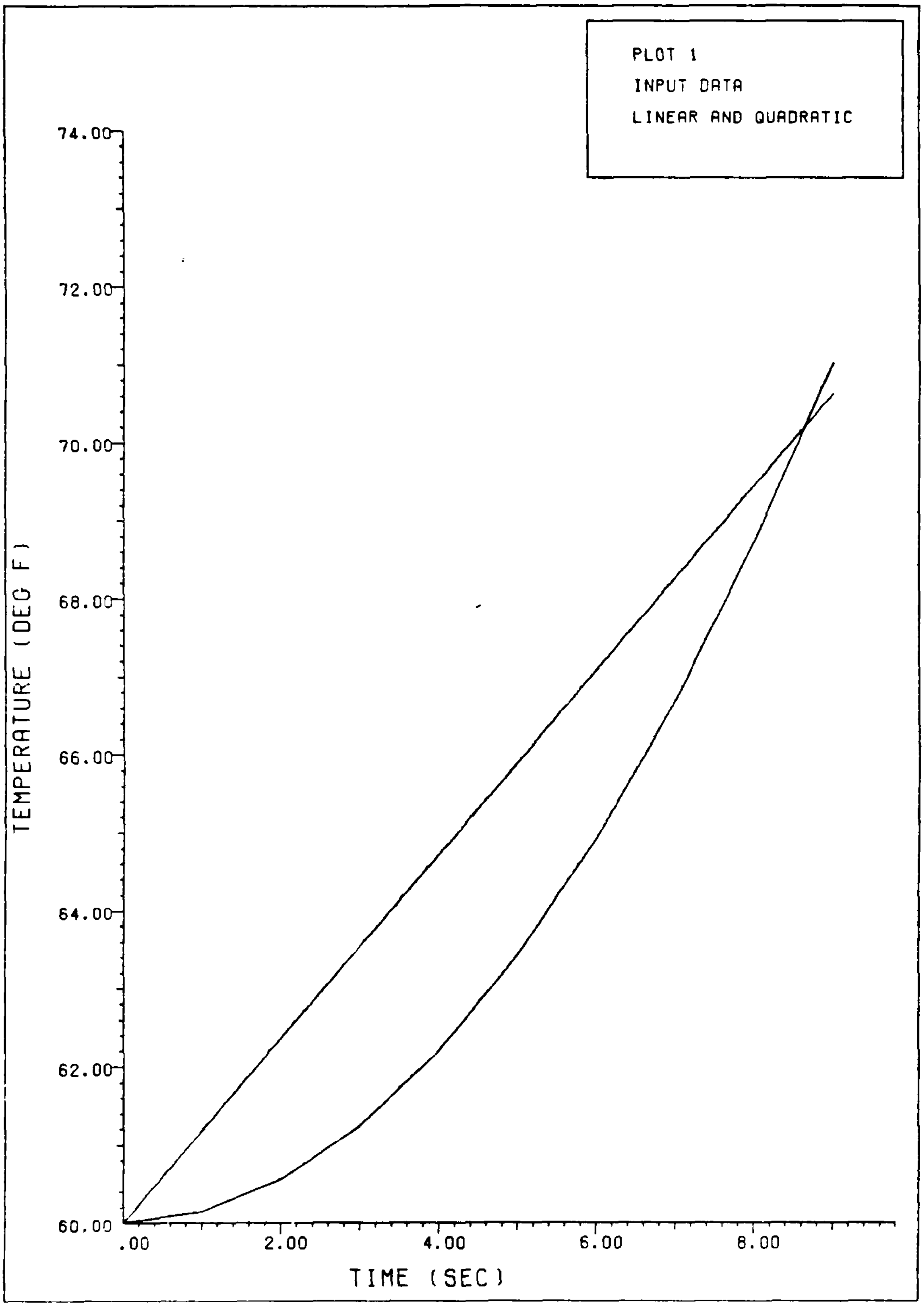

PLOT 1
INPUT DATA
LINEAR AND QUADRATIC
74.00
72.00
70.00
68.00
66.00
64.00
62.00
60.00
TEMPERATURE (DEG F)
.00
2.00
4.00
6.00
8.00
TIME (SEC)

FIGURE 4.1

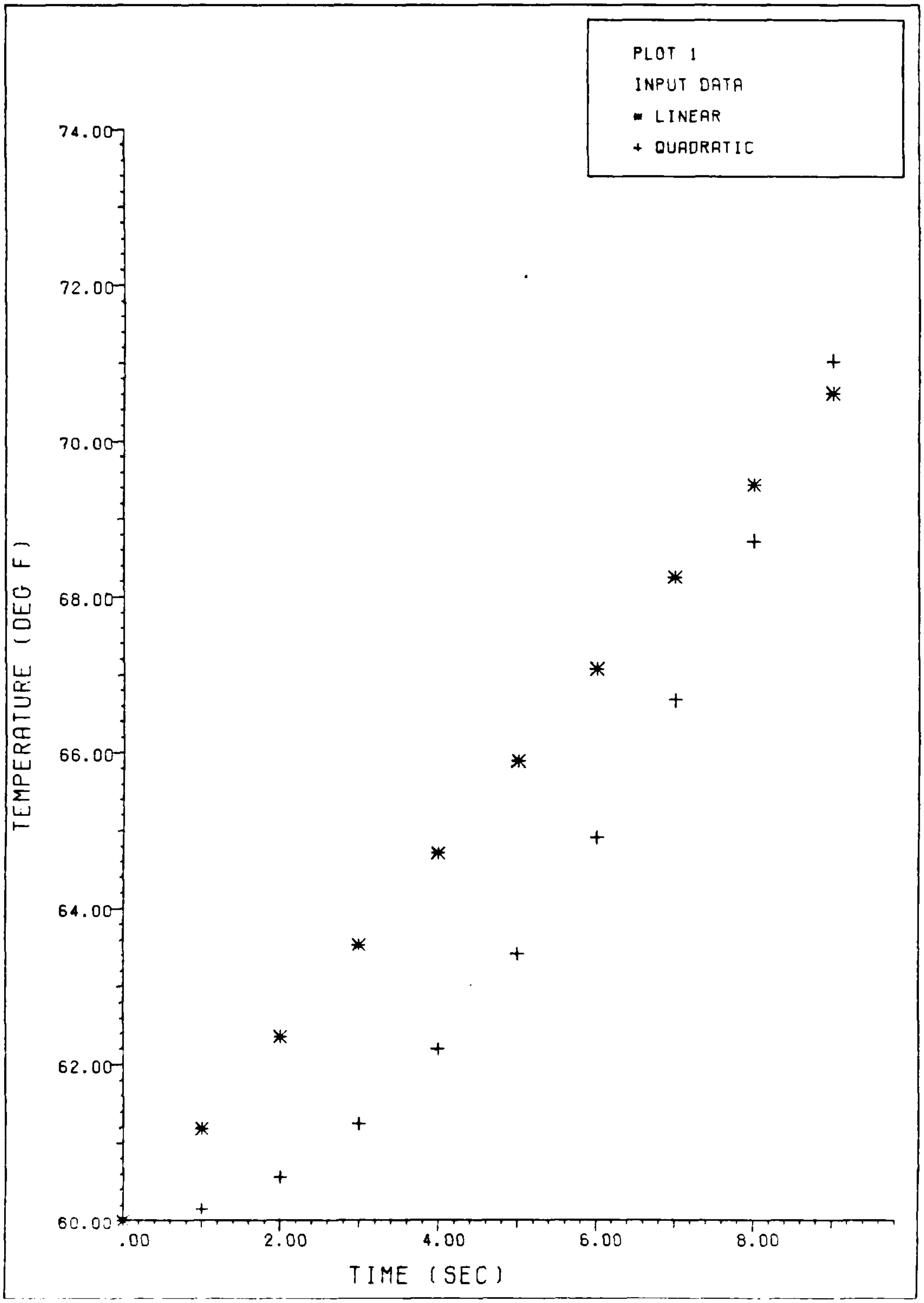

PLOT 1
INPUT DATA
* LINEAR
+ QUADRATIC
74.00
72.00
70.00
68.00
66.00
64.00
62.00
60.00
TEMPERATURE (DEG F)
.00
2.00
4.00
6.00
8.00
TIME (SEC)

FIGURE 4.2

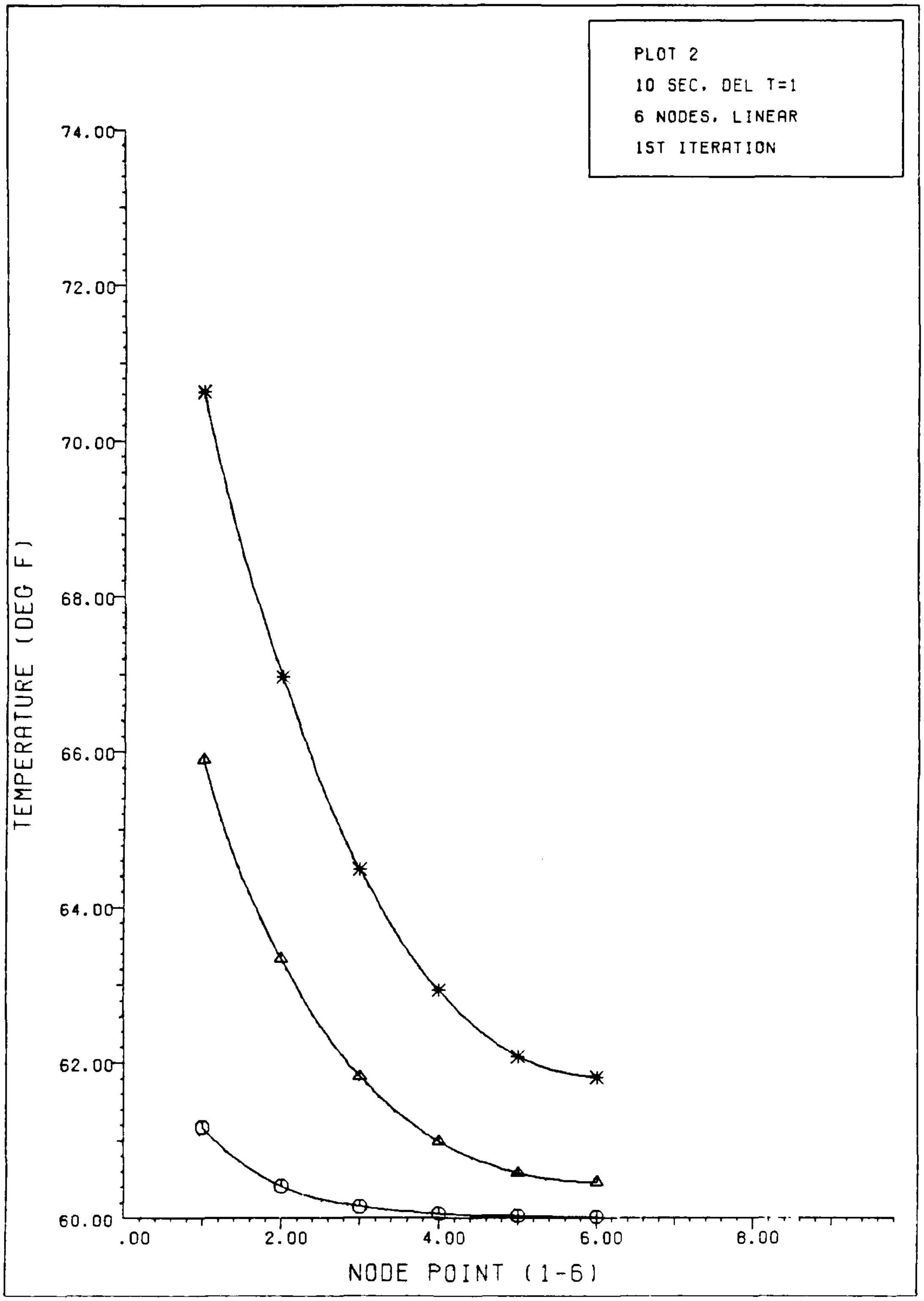


FIGURE 4.3 TEMP VS NODE POINT HISTORY (2.6.10 SEC)

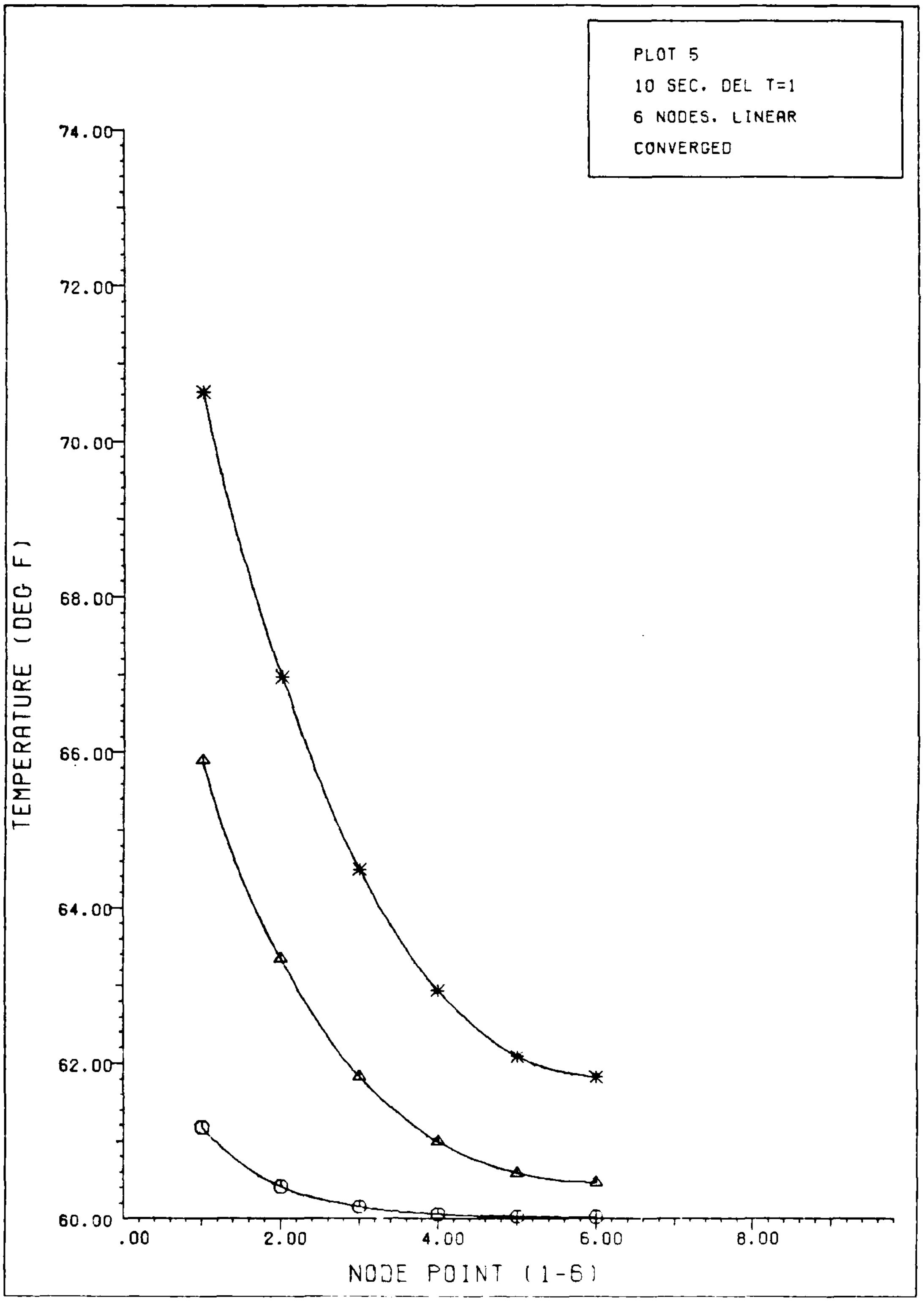


FIGURE 4.4 TEMP VS NODE POINT HISTORY (2.5.10 SEC)

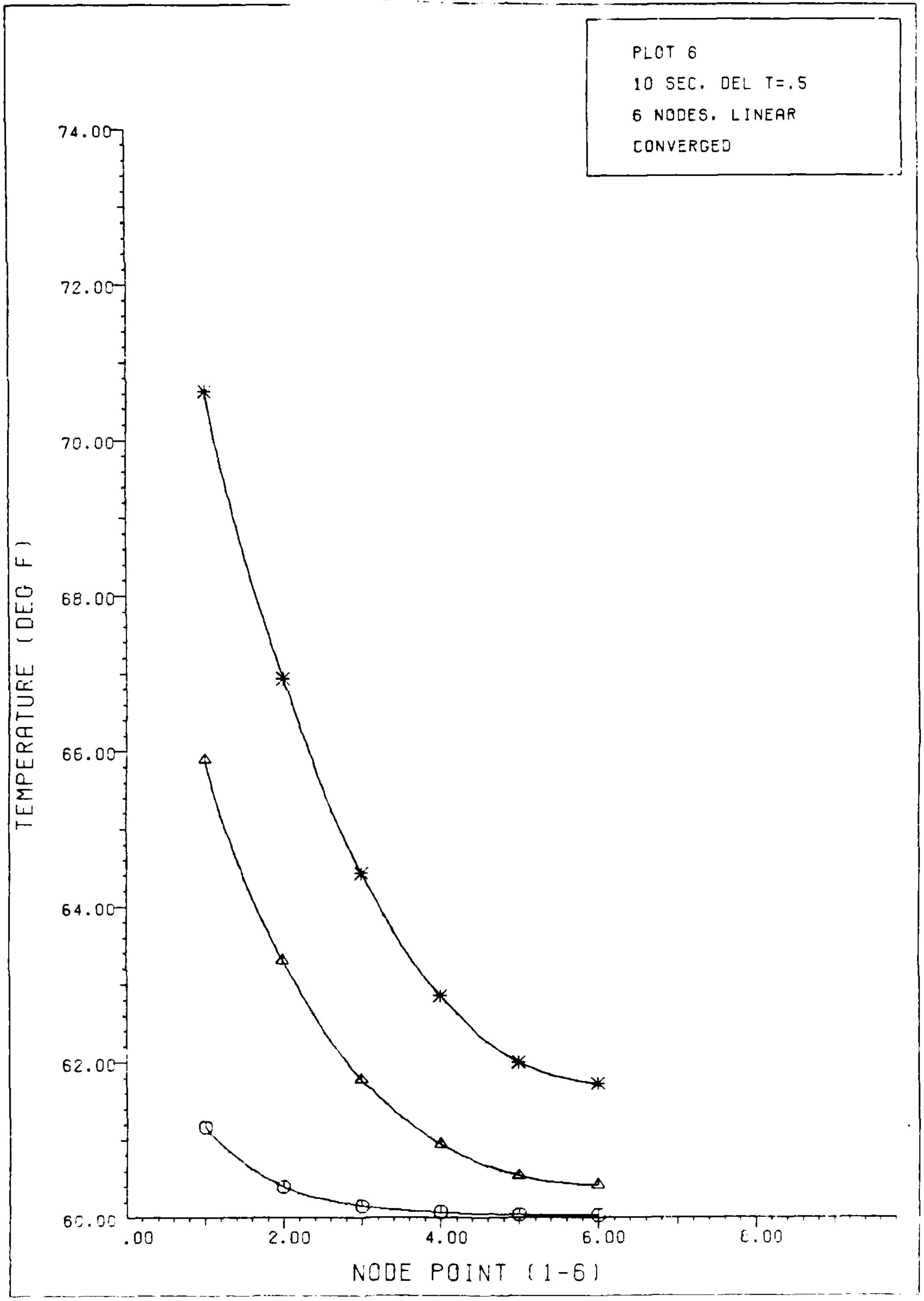


FIGURE 4.5 TEMP VS NODE POINT HISTORY (2,6,10 SEC)

the utility of the program to be used in wind tunnel runs of much longer duration.

5.2 Recommendations

Actual wind tunnel test data from coaxial gages needs to be analyzed by the program to instill more confidence in the results. This would require that the data tape format be modified to be compatible with the program inputs.

Also, a prescribed model for h_{bar} as a function of angle of attack needs to be input to determine the ability of the program to estimate the piecewise linear derivitives, $h_{\alpha 1}$ and $h_{\alpha 2}$. The additional input data would then be the wind tunnel model angle of attack at each thermocouple sample time.

Another potential modification to the program would be to use a second order time derivitive approximation as opposed to the current first order approximation. It is suspected that the increased accuracy would improve the state estimates particularly for large time gaps in thermocouple data.

The temperature state estimates might be improved by incorporating a variable grid. An exponential grid generation scheme would concentrate node points near the surface where the largest temperature gradients exist.

A final recommendation, would be to make the program more 'user friendly' and to publish documentation much like a users manual.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The program works for this simplified test case of known parameters and number of node points. The ability of the program to determine the temperature state appeared very good but definite conclusions cannot be drawn without comparing this data to actual thermcouple data. The ability of the program to estimate the parameters, h_0 and ϕ_k was demonstrated extremely well. Re-examination of the ϕ_c equations must be made before further conclusions may be made about the ability of the program to estimate this parameter. It is theoretically possible, however.

The objective, to validate the use of the modified HEATEST program for use of coaxial thermocouple gages on wind tunnel test articles, has been met for the special case of this analytical model. The program is capable of determining temperature states and estimating parameters with a high degree of accuracy. A note concerning the semi-infinite slab assumption needs to be emphasized. This assumption was made only for the data generation program to yield data for which the analytical solution was known. As mentioned in Chapter 1, some coaxial gages are available with backface temperature monitoring which would also provide another temperature measurement to enhance estimation of ϕ_k and ϕ_c. This feature would greatly enhance

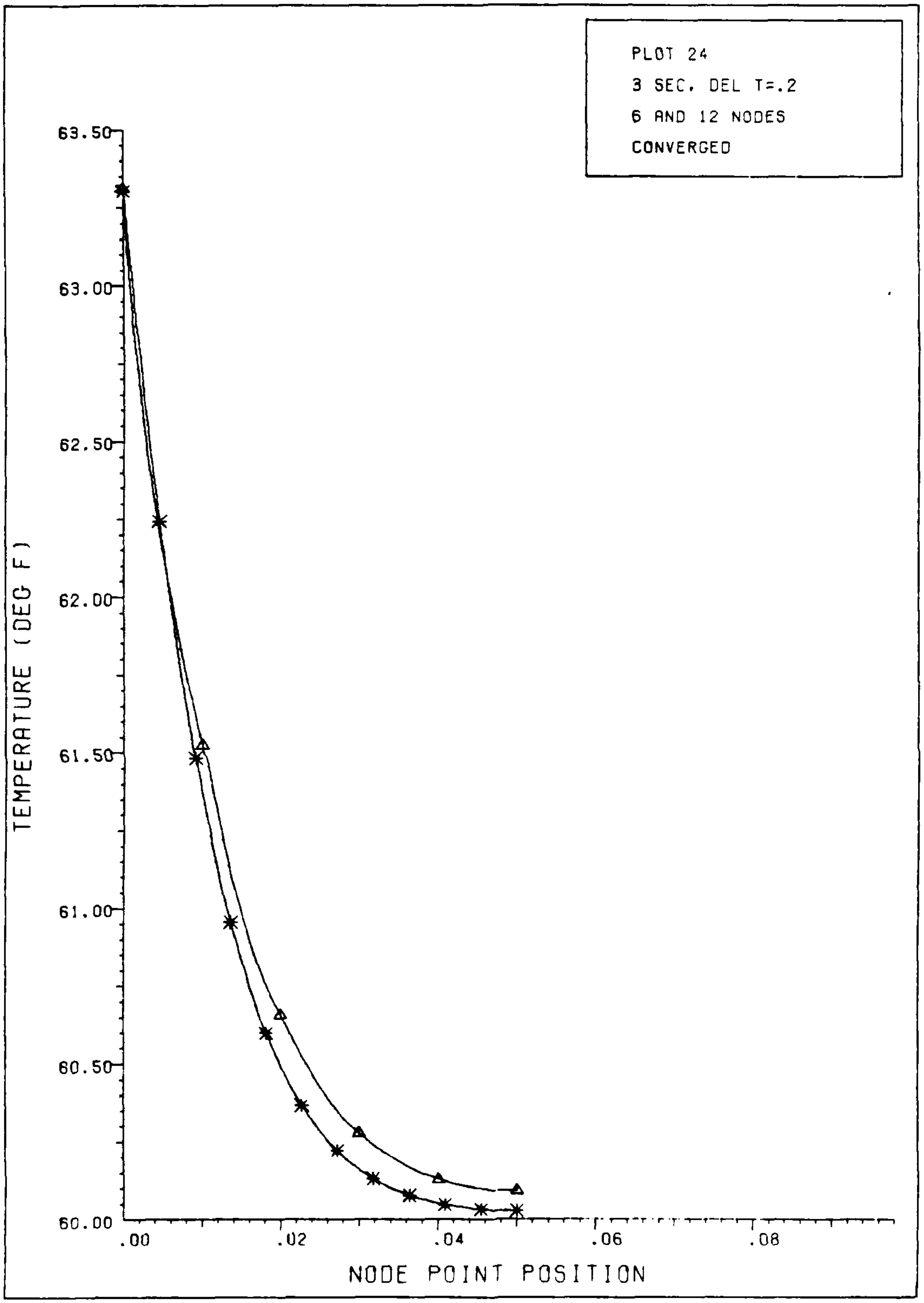


FIGURE 4.17 TEMP VS NODE POS.(6 NODES VS 12 NODES)

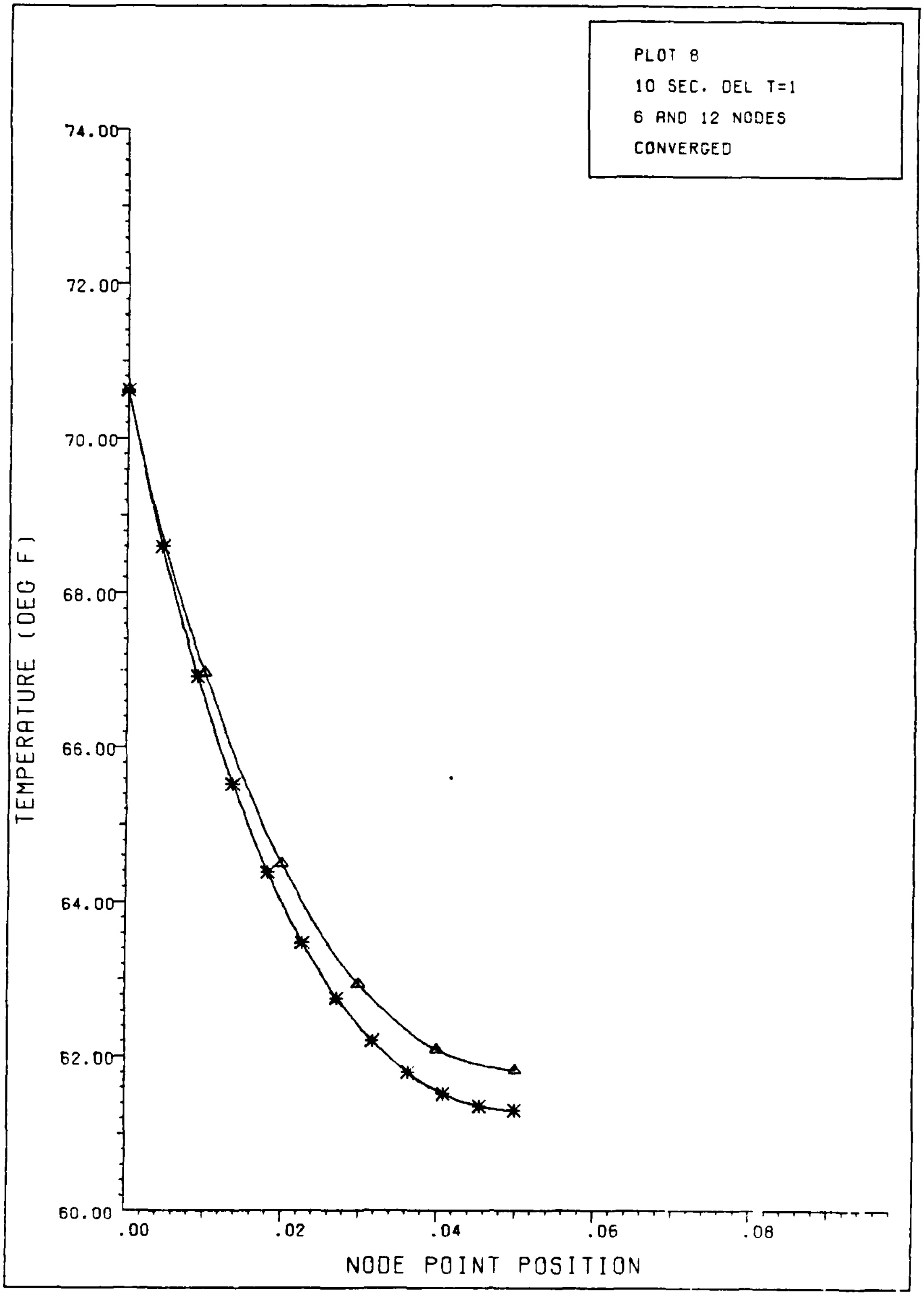


FIGURE 4.16 TEMP VS NODE POS.(6 NODES VS 12 NODES)

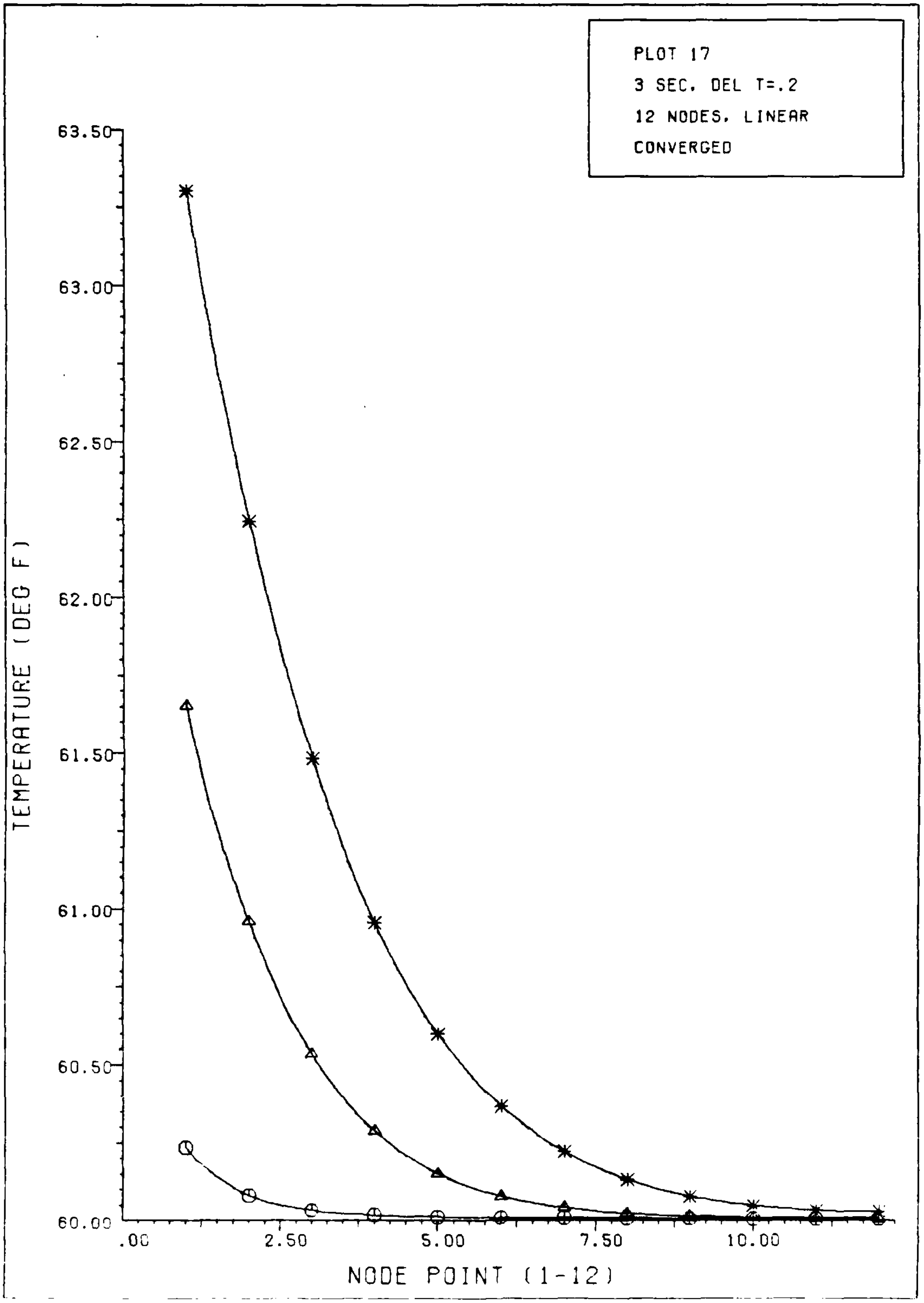


FIGURE 4.15 TEMP VS NODE POINT (.4, 1.6, 3.0 SEC.)

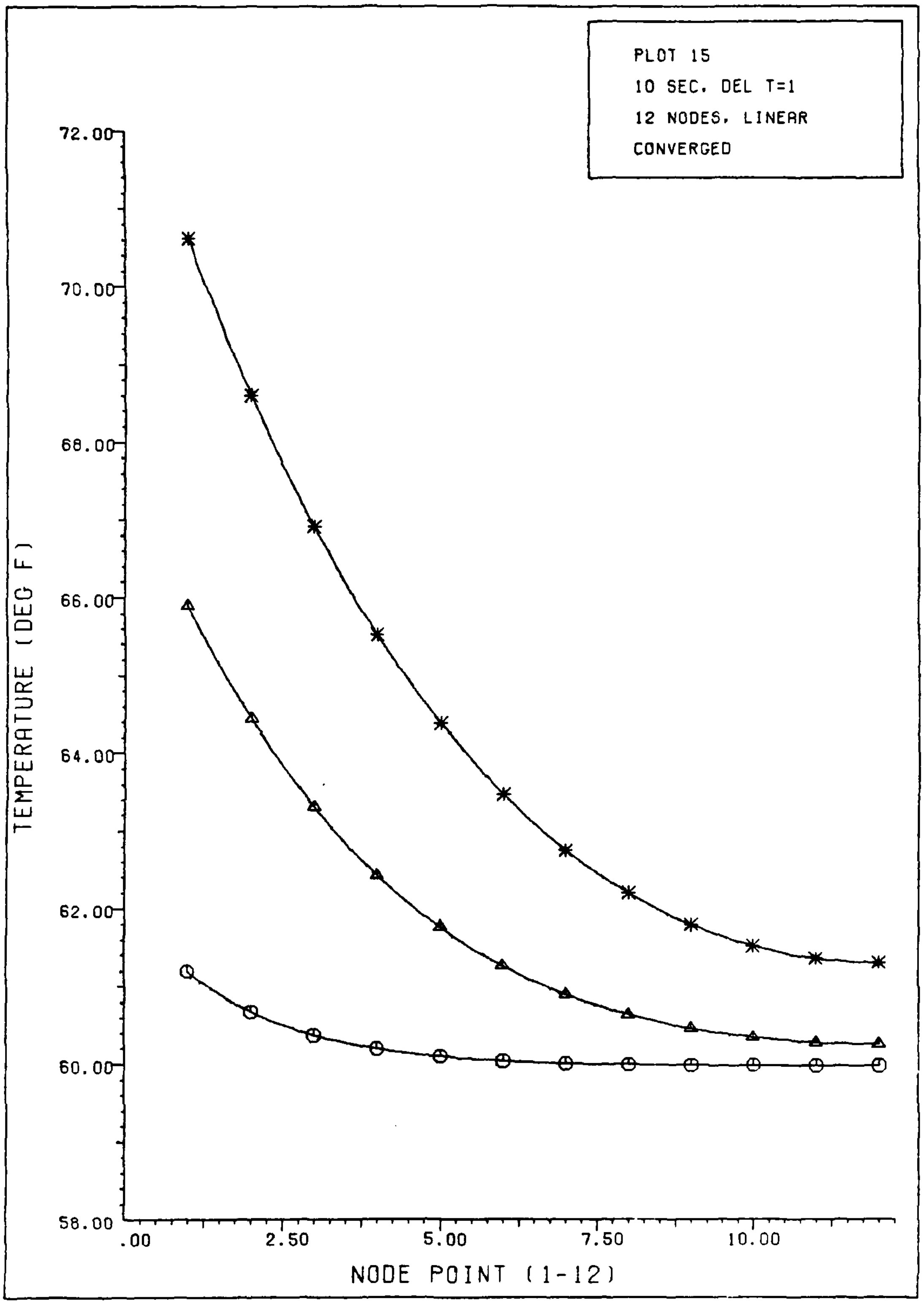


FIGURE 4.14 TEMP VS NODE POINT HISTORY(2,6,10 SEC)

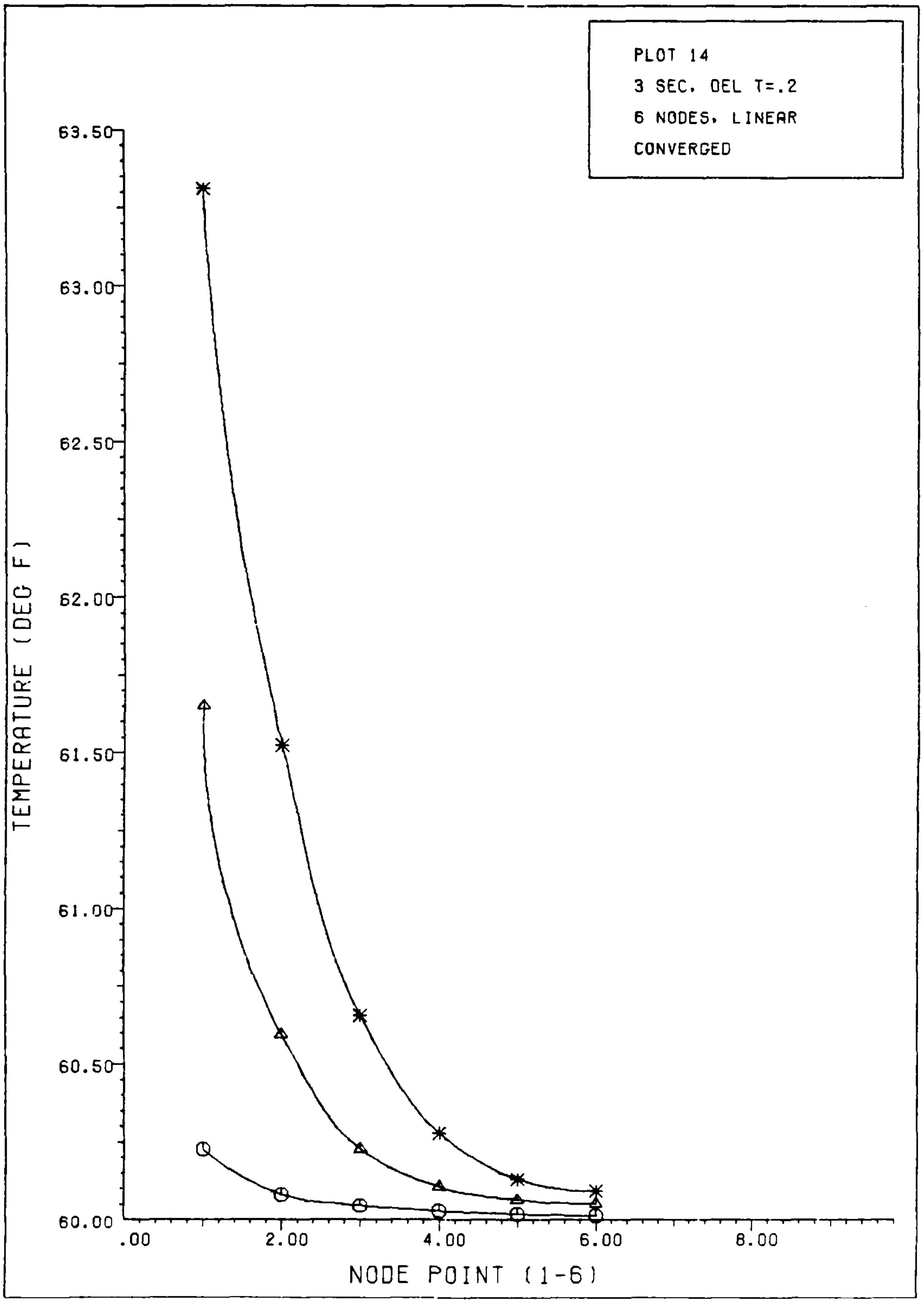


FIGURE 4.13 TEMP VS NODE POINT (.4, 1.6, 3.0 SEC)

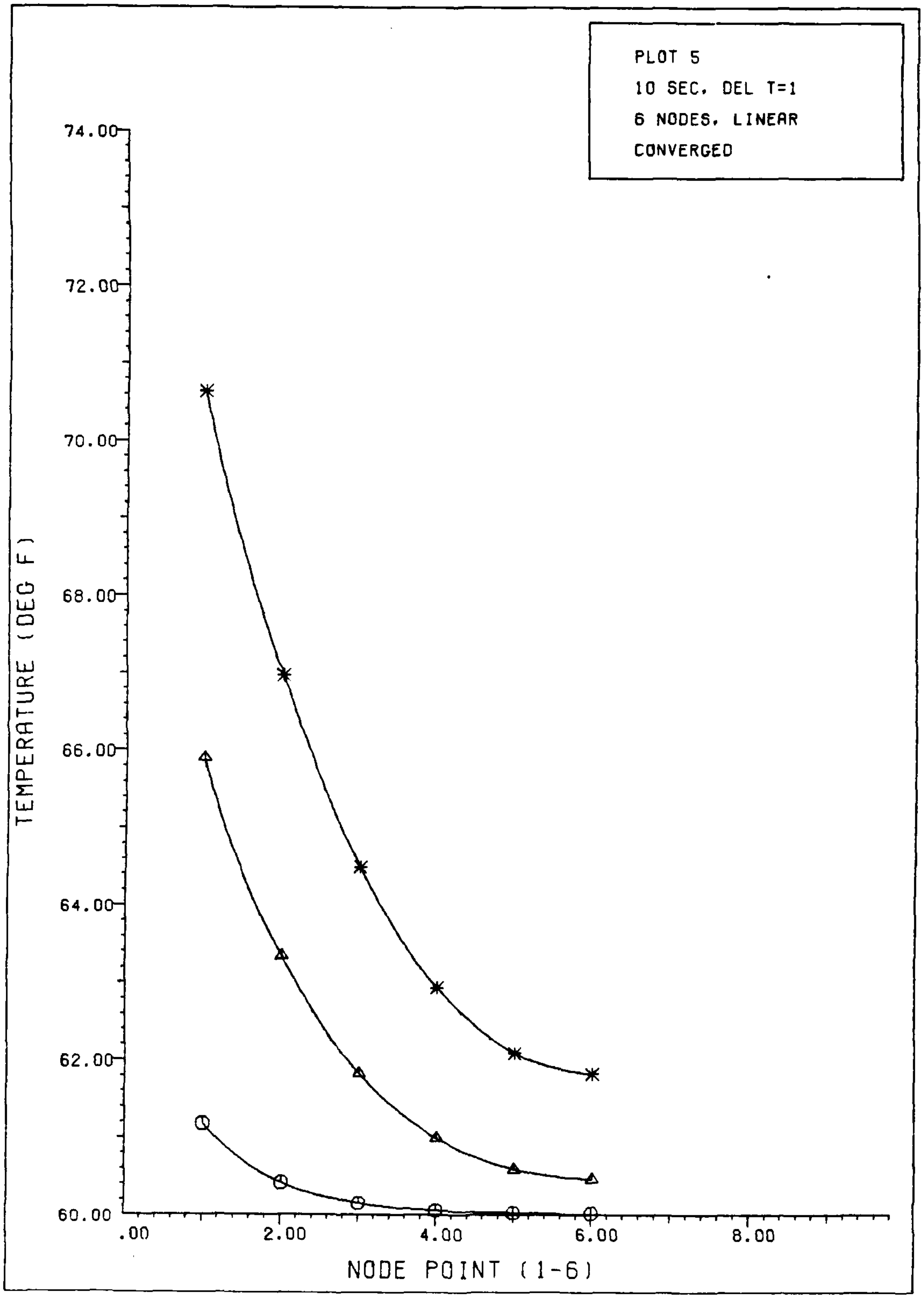


FIGURE 4.12 TEMP VS NODE POINT HISTORY(2.6.10 SEC)

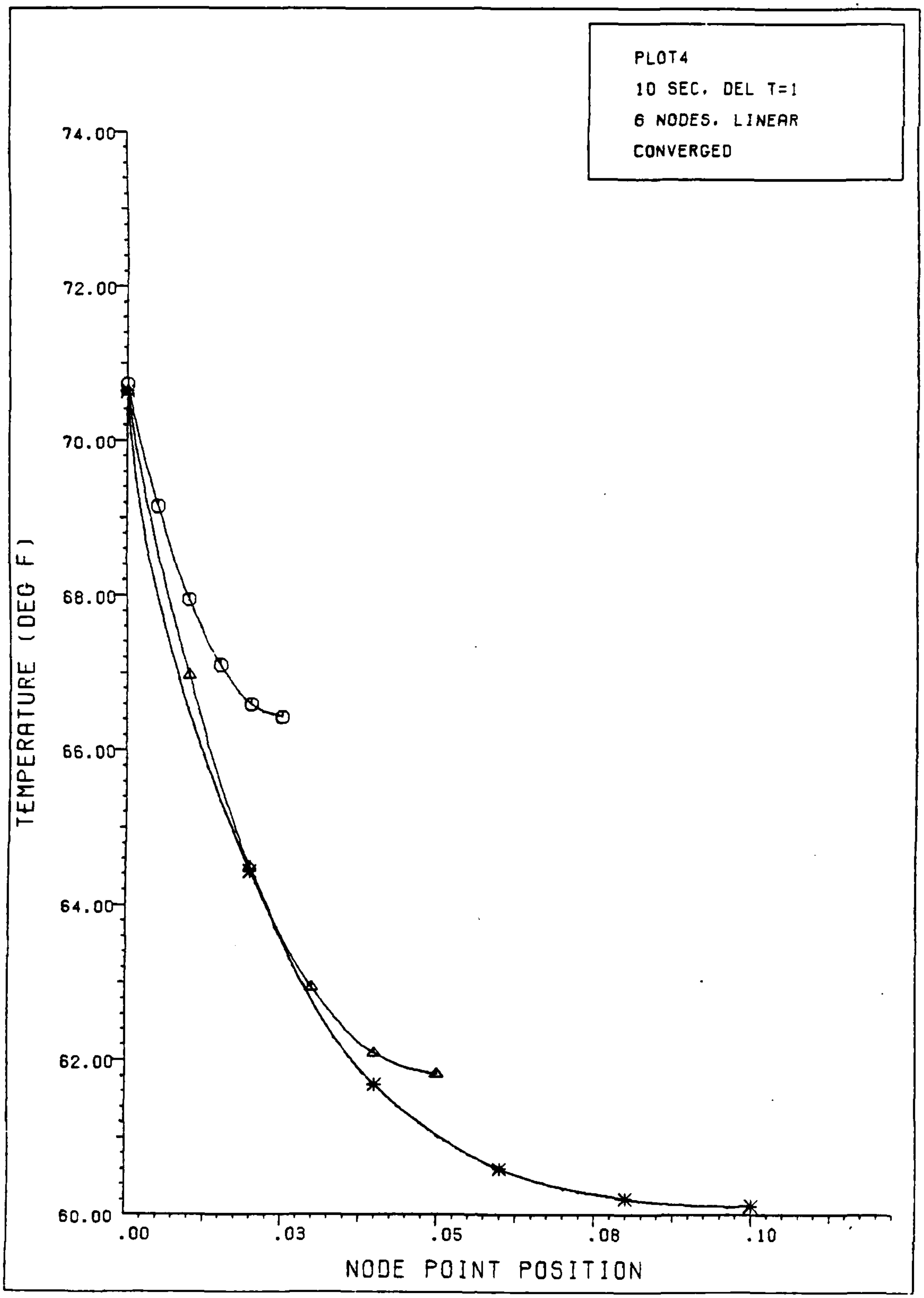


FIGURE 4.11 TEMP VS POS.(T/C LENGTH=.1,.05,.025FT)

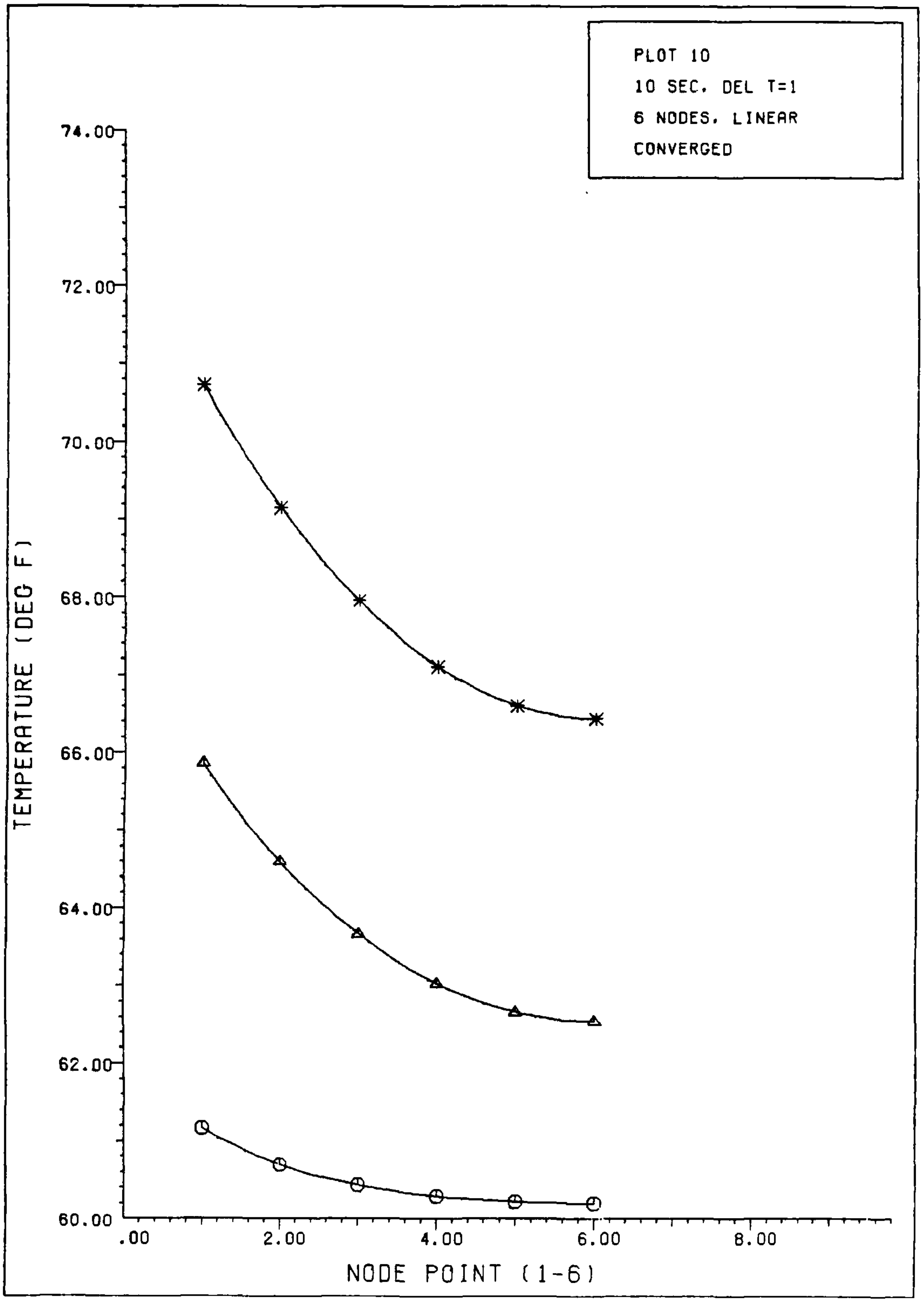


FIGURE 4.10 TEMP VS NODE POINT (T/C LENGTH=.025FT)

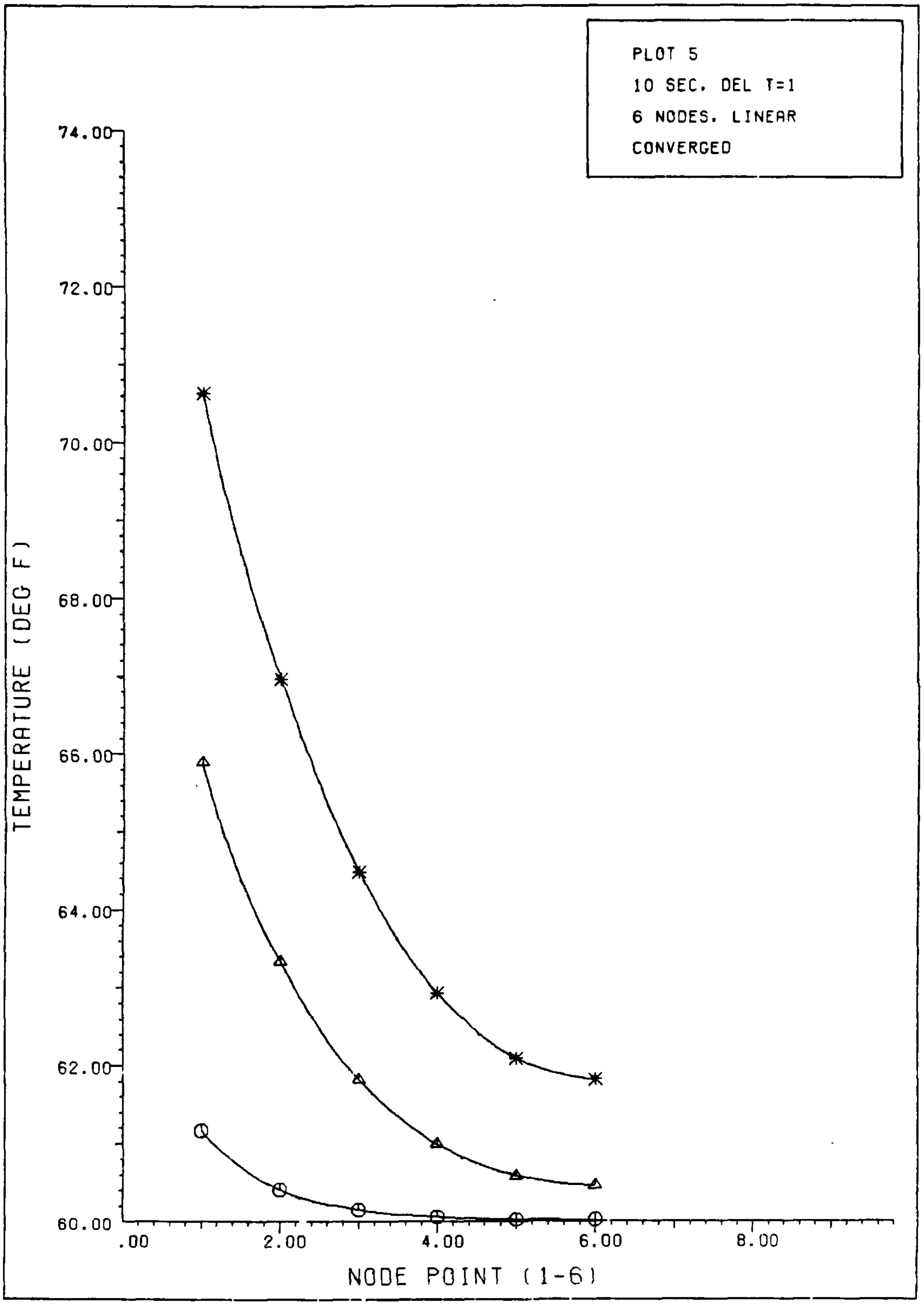


FIGURE 4.9 TEMP VS NODE POINT (T/C LENGTH= .05 FT)

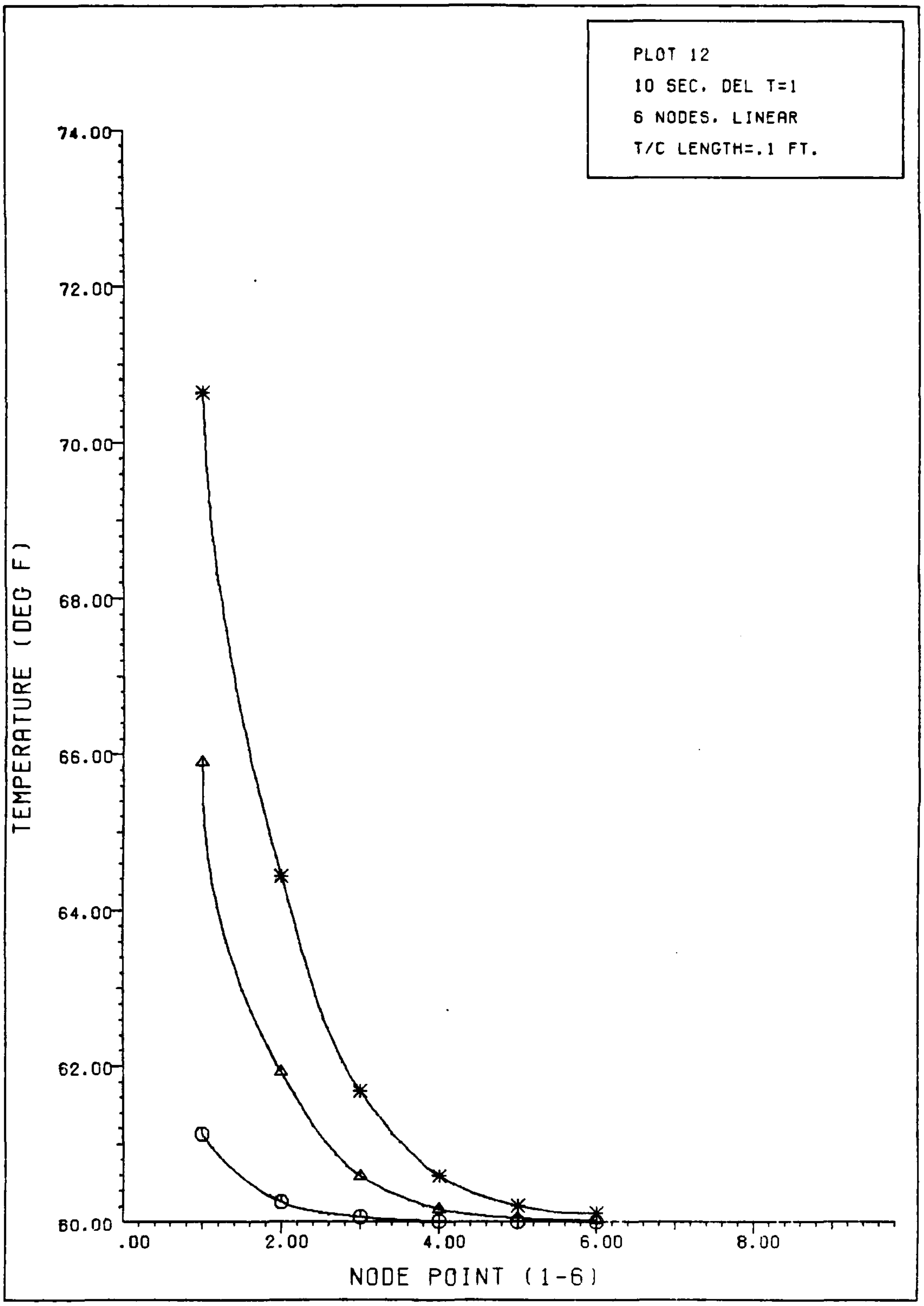


FIGURE 4.8 TEMP VS NODE POINT (T/C LENGTH= .1 FT.)

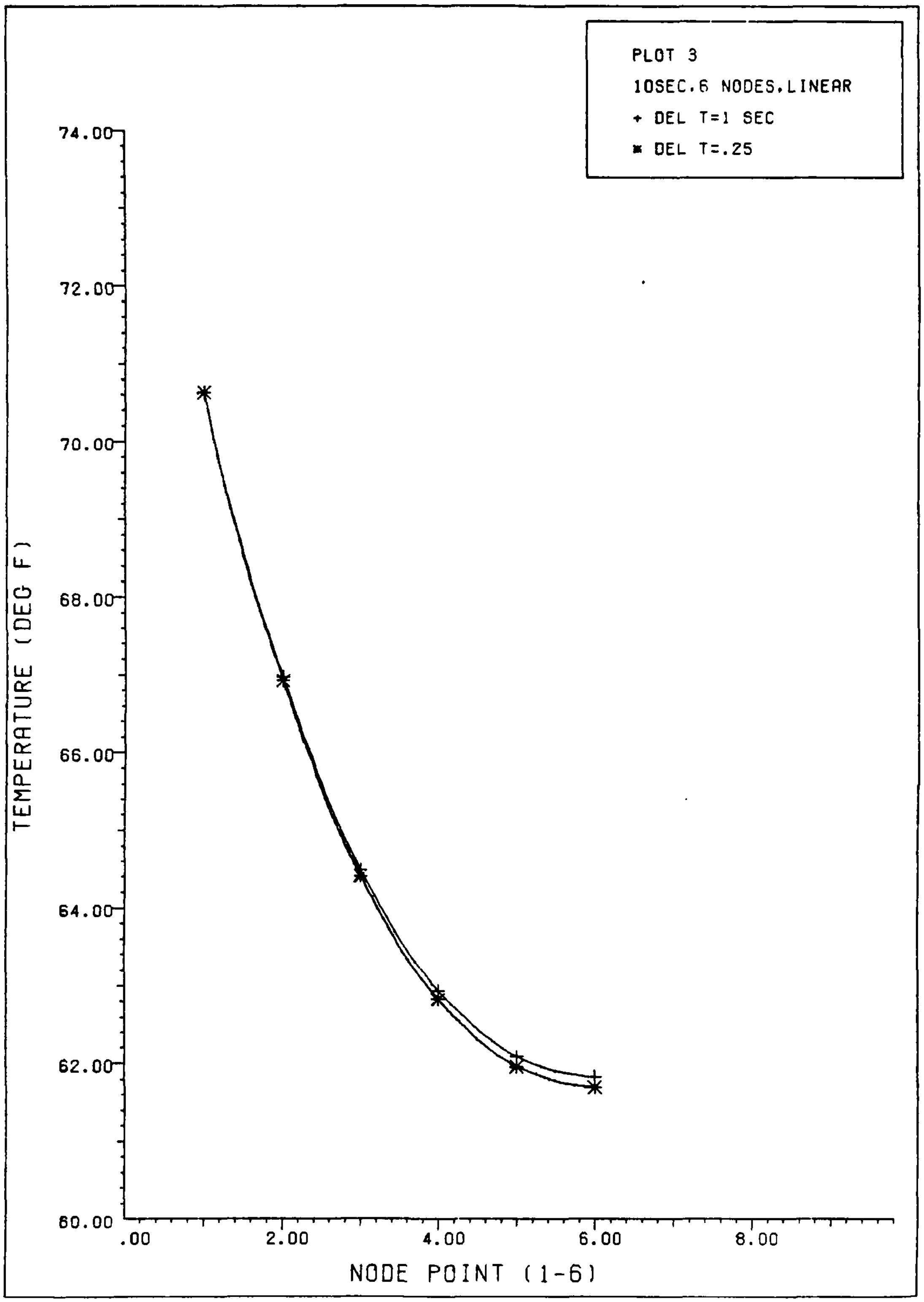


FIGURE 4.7 TEMP VS NODE POINT(DEL T=1 AND .25 SEC)

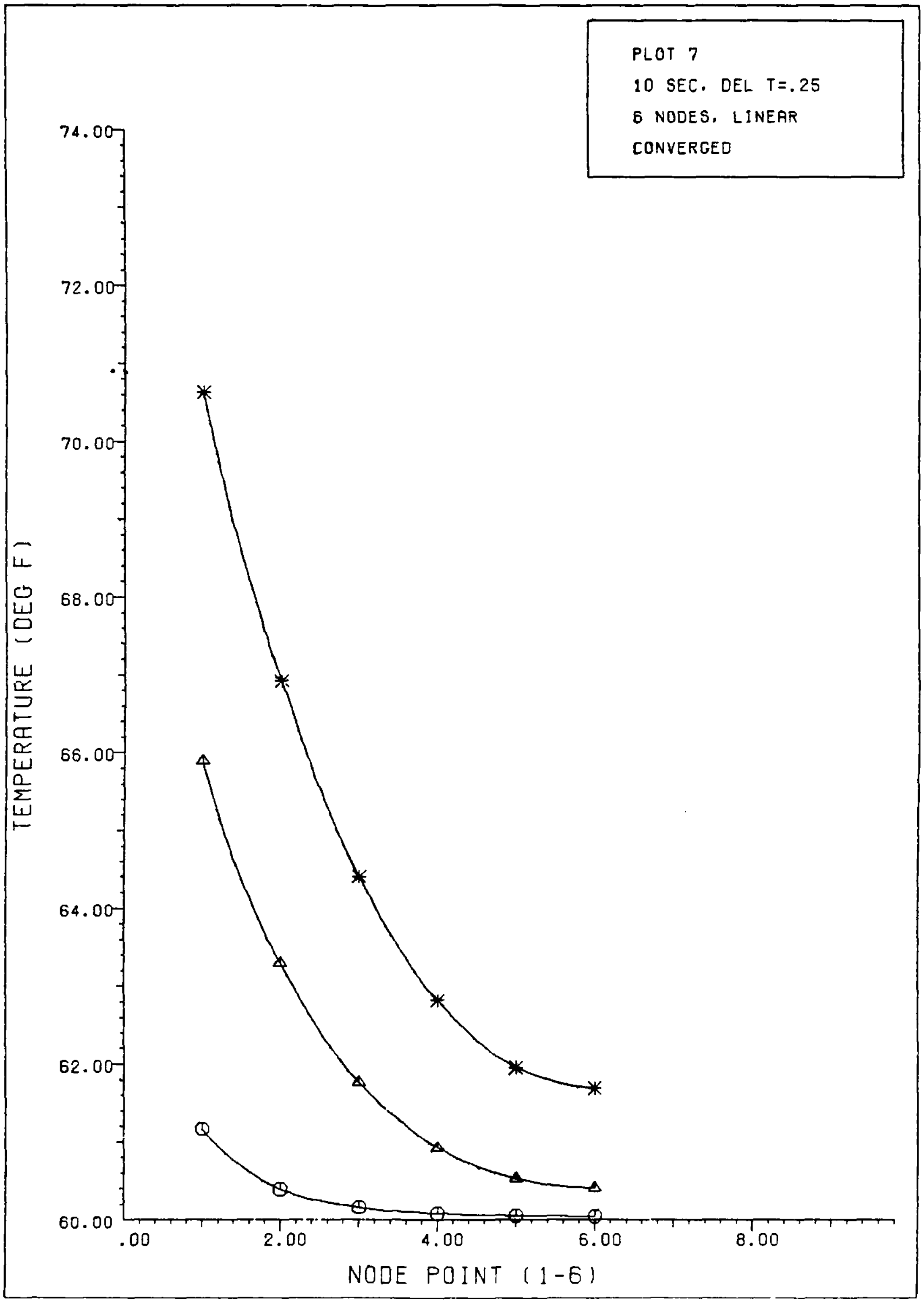
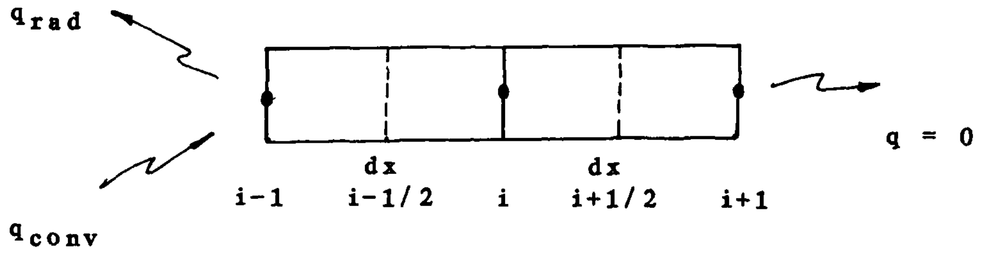


FIGURE 4.6 TEMP VS NODE POINT HISTORY (2,6,10 SEC)

APPENDIX A

Derivation of equations using a one-dimensional energy balance formulation are given as follows,



Energy in the left face $= -k\partial T/\partial x = q_1$

Energy generated within the element $= q\ dx = 0$

Change in internal energy $= \rho c(\partial T/\partial \tau)dx$

Energy out of right face $= -k(\partial T/\partial x)_{x+dx}$

$$= -\left[k\frac{\partial T}{\partial x} + \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)dx\right]$$

Then, combining the above and using Fourier's Law of Heat Conduction, ie,

energy in left face + energy within the element = change in internal energy + energy out right face

yields,

$$-k\frac{\partial T}{\partial x} + q\,dx = \rho c\frac{\partial T}{\partial \tau}dx - \left[k\frac{\partial T}{\partial x} + \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)dx\right] \tag{A-1}$$

or,

$$\rho c\frac{\partial T}{\partial \tau} = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) \tag{A-2}$$

or, replacing T by U,

$$\rho c U_t = (kU_x)_x \tag{A-3}$$

or,

$$\rho c U_t = \left[\frac{k_{i-1/2}}{\Delta x_{i-1/2}}(U_{i-1}{}^n - U_i{}^n) - \frac{k_{i+1/2}}{\Delta x_{i+1/2}}(U_i{}^n - U_{i+1}{}^n)\right]\frac{1}{\Delta x} \tag{A-4}$$

where ΔX may be written as,

$$\Delta x = \frac{\Delta x_{i+1/2} + \Delta x_{i-1/2}}{2}$$

then, writing the time gradient in first order backward difference form and expanding yields,

$$\begin{aligned}\rho c\frac{U_i{}^n - U_{i-1}{}^n}{\Delta t} = {} & \frac{2k_{i-1/2}}{\Delta x_{i-1/2}(\Delta x_{i+1/2}+\Delta x_{i-1/2})}U_{i-1}{}^n \\ & - \frac{2k_{i-1/2}}{\Delta x_{i-1/2}(\Delta x_{i+1/2}+\Delta x_{i-1/2})}U_i{}^n \\ & - \frac{2k_{i+1/2}}{\Delta x_{i+1/2}(\Delta x_{i+1/2}+\Delta x_{i-1/2})}U_i{}^n \\ & + \frac{2k_{i+1/2}}{\Delta x_{i+1/2}(\Delta x_{i+1/2}+\Delta x_{i-1/2})}U_{i+1}{}^n\end{aligned} \tag{A-5}$$

then, specifying equal spacing for each node point,

$$\Delta x_{i+1/2} = \Delta x_{i-1/2}$$

and the equation becomes,

$$\rho c \frac{U_i^{\,n} - U_i^{\,n-1}}{\Delta t} = \frac{k_{i-1/2}}{\Delta x^2} U_{i-1}^{\,n} - \left(\frac{k_{i-1/2}}{\Delta x^2} + \frac{k_{i+1/2}}{\Delta x^2} \right) U_i^{\,n} + \frac{k_{i+1/2}}{\Delta x^2} U_{i+1}^{\,n} \tag{A-6}$$

Now, instead of estimating c and k directly, define two scaling parameters ϕ_c and ϕ_k such that c and k will remain constant. These two parameters are estimated by the HEATEST program.

$$\rho \phi_c c \Delta x \frac{U_i^{\,n} - U_i^{\,n-1}}{\Delta t} = \phi_k \frac{k_{i-1/2}}{\Delta x} U_{i-1}^{\,n} - \phi_k \left(\frac{k_{i-1/2}}{\Delta x} + \frac{k_{i+1/2}}{\Delta x} \right) U_i^{\,n} + \phi_k \frac{k_{i+1/2}}{\Delta x} U_{i+1}^{\,n} \tag{A-7}$$

This equation is applicable at all interior ($i \neq 1, i \neq i_{max}$) points.

For the back face, assuming a semi-infinite solid, $i = i_{max}$ and the equation becomes,

$$\frac{\rho \phi_c c \Delta x}{2} \frac{U_L^{\,n} - U_L^{\,n-1}}{\Delta t} = \frac{\phi_k k_{L-1/2}}{\Delta x} U_{L-1}^{\,n} - \frac{\phi_k k_{L-1/2}}{\Delta x} U_L^{\,n} \tag{A-8}$$

For the front face, $(i = 1)$, the effects of radiation away from and convection toward the solid surface must be accounted for.

The radiation is modeled using the Stefan-Boltzmann Law,

$$q = \varepsilon\sigma(U_1{}^4 - U_\infty{}^4) \tag{A-9}$$

where	ε	radiative emissivity
	σ	Stefan-Boltzmann constant
	U	Temperature (°R)

The convective transfer of energy is modeled using Newton's Law of Cooling,

$$q = h(T_{aw} - T_w) \tag{A-10}$$

Non-dimensionalizing by a reference heat transfer coefficient, h_{ref} yields,

$$q = h_{bar}h_{ref}(T_{aw} - U_1) \tag{A-11}$$

where, h_{bar} = convective heat transfer coefficient ratio
T_{aw} = adiabatic wall temp of test article

The dependance of the heat transfer coefficient on parameters other than those included in the reference heat transfer coefficient are summarized by the static transfer relation or heat transfer coefficient ratio, h/h_{ref}. Here, the ratio is assumed to be piecewise linear with respect to angle of attack as derived from Lagrange Interpolation Theory (Ref 6),

$$h_{bar} = h/h_{ref} = [h_0+h_{\alpha 1}(\alpha-\alpha_1)+h_{\alpha 2}(\alpha-\alpha_2)] \qquad \text{(A-12)}$$

where h_0 is the magnitude of the heat transfer coefficient, h , at the reference condition specified at α_1. Combining Equations A-7, A-9, A-11, and A-12 and evaluating at node one yields,

$$\frac{\rho\phi_c c\Delta x}{2}\,\frac{U_1{}^n - U_1{}^{n-1}}{\Delta t} = \frac{-\phi_k k_{k+1/2}}{\Delta x}\,U_1{}^n$$
$$+ \frac{\phi_k k_{1+1/2}}{\Delta x}\,U_2{}^n - \varepsilon\sigma[(U_1{}^n)^4 - (U_\infty{}^n)^4]$$
$$+ [h_0+h_{\alpha 1}(\alpha-\alpha_1)+h_{\alpha 2}(\alpha-\alpha_2)]h_{ref}(T_{aw}-U_1{}^n)$$

(A-13)

Using the quasi-linearization as developed in Equation 2-6, the resultant form for determining the temperature time history at each node point is given in Equations 2-7 and 2-8.

The matrix form for the equations may be found after defining the following,

$$RCX_i = \rho\phi_c c\Delta x \qquad RCX_1 = \frac{RCX_1}{2} \qquad RCX_L = \frac{RCX_L}{2}$$

$$RM_i = \frac{\phi_k k_{i-1/2}}{\Delta x} \qquad RM_1 = 0$$

$$RP_i = \frac{\phi_k k_{i+1/2}}{\Delta x} \qquad RP_L = 0$$

$$BBB_1 = \frac{RCX_1}{\Delta t} + RM_1 + RP_1 + 4\varepsilon\sigma(U_1^{n,s})^3 + h_{bar}h_{ref}$$

$$BBB_i = \frac{RCX_i}{\Delta t} + RM_i + RP_i \tag{A-14}$$

Then, using Equations A-14 in Equations 2-7 and 2-8 yields the matrix form of Equation 2-9,

$$[A]\{U_i^n\} + \{b\} = 0 \tag{2-9}$$

where,

$$[A] = \begin{bmatrix} -1 & RP_i/BBB_i & & 0 \\ RM_i/BBB_i & \ddots & \ddots & \\ & \ddots & \ddots & RP_i/BBB_i \\ 0 & & RM_i/BBB_i & -1 \end{bmatrix} \tag{A-15}$$

and,

$$\{b\} = \left\{ \begin{array}{l} \dfrac{\varepsilon\sigma[(3U_1^{n,s})^4 + U_\infty^4] + h_{bar}h_{ref}T_{aw} + \frac{RCX_1}{\Delta t}U_1^{n-1}}{BBB_1} \\ \\ \dfrac{RCX_i}{\Delta t}U_i^{n-1} \Big/ BBB_i \\ \\ \\ \dfrac{RCX_L}{\Delta t}U_L^{n-1} \Big/ BBB_L \end{array} \right\} \tag{A-16}$$

APPENDIX B

The derivation of the sensitivity equations. The derivative of Equation 2-7 with respect to each parameter yields equations from which the HEATEST program propogates the sensitivity. A vector of parameters is formed and the sensitivity notation is as shown,

$$\theta = [h_0,\ h_{\alpha 1},\ h_{\alpha 2},\ \phi_c,\ \phi_k)]^T \qquad S_{i,k} = \frac{\partial U}{\partial \theta_k}$$

parameter no
node point

Defining, $h_{bar} = [h_0 + h_{\alpha 1}(\alpha - \alpha 1) + (h_{\alpha 2}(\alpha - \alpha 2))]$, the sensitivity equations at node one are,

$$\theta_1: \quad \frac{\rho \phi_c c \Delta x}{2} \frac{S_{1,1}{}^{n} - S_{1,1}{}^{n-1}}{\Delta t} = \frac{-\phi_k (k_{i+1/2})}{\Delta x} S_{1,1}{}^{n}$$

$$+ \frac{\phi_k (k_{i+1/2})}{\Delta x} S_{2,1}{}^{n} - 4 \varepsilon \sigma (U_1{}^{n})^3\ S_{1,1}{}^{n} + h_{ref}(T_{aw} - U_1{}^{n})$$

$$- S_{1,1}{}^{n} h_{ref} h_{bar} \tag{B-1}$$

$$\theta_2: \quad \frac{\rho \phi_c c \Delta x}{2} \frac{S_{1,2}{}^{n} - S_{1,2}{}^{n-1}}{\Delta t} = \frac{-\phi_k (k_{i+1/2})}{\Delta x} S_{1,2}{}^{n}$$

$$+ \frac{\phi_k (k_{i+1/2})}{\Delta x} S_{2,2}{}^{n} - 4 \varepsilon \sigma (U_1{}^{n})^3\ S_{1,2}{}^{n}$$

$$+ (\alpha - \alpha 1) h_{ref}(T_{aw} - U_1{}^{n}) - S_{1,2}{}^{n} h_{ref} h_{bar} \tag{B-2}$$

$$\theta_3: \quad \frac{\rho\phi_c c\Delta x}{2}\,\frac{S_{1,3}{}^{n}-S_{1,3}{}^{n-1}}{\Delta t} = \frac{-\phi_k(k_{i+1/2})}{\Delta x}\,S_{1,3}{}^{n}$$

$$+ \frac{\phi_k(k_{i+1/2})}{\Delta x}\,S_{2,3}{}^{n} - 4\varepsilon\sigma(U_1{}^{n})^3\,S_{1,3}{}^{n}$$

$$+ (\alpha-\alpha 2)h_{ref}(T_{aw}-U_1{}^{n}) - S_{1,3}{}^{n}h_{ref}h_{bar}$$

(B-3)

$$\theta_4: \quad \frac{S_{1,4}{}^{n}-S_{1,4}{}^{n-1}}{\Delta t} = \frac{-2\phi_k k_{i+1/2}}{\rho\phi_c c\Delta x^2}\,S_{1,4}{}^{n} + \frac{2\phi_k k_{1+1/2}}{\rho\phi_c{}^2 c\Delta x^2}\,U_1{}^{n}$$

$$+ \frac{2\phi_k k_{1+1/2}}{\rho\phi_c c\Delta x^2}\,S_{1,4}{}^{n} - \frac{2\phi_k k_{1+1/2}}{\rho\phi_c{}^2 c\Delta x^2}\,U_2{}^{n}$$

$$- \frac{8\varepsilon\sigma(U_1{}^{n})^3}{\rho\phi_c c\Delta x}\,S_{1,4}{}^{n} + \frac{2\varepsilon\sigma(U_1{}^{4}-U_\phi{}^{4})}{\rho\phi_c{}^2 c\Delta x}$$

$$- \frac{2h_{bar}h_{ref}}{\rho\phi_c c\Delta x}\,S_{1,4}{}^{n} - \frac{2h_{bar}h_{ref}}{\rho\phi_c{}^2 c\Delta x}(T_{aw}-U_1)$$

(B-4)

$$\theta_5: \quad \frac{\rho\phi_c c\Delta x}{2}\,\frac{S_{1,5}{}^{n}-S_{1,5}{}^{n-1}}{\Delta t} = \frac{-\phi_k k_{1+1/2}}{\Delta x}\,S_{1,5}{}^{n}$$

$$- \frac{k_{1+1/2}}{\Delta x}\,U_1{}^{n} + \frac{\phi_k k_{1+1/2}}{\Delta x}\,S_{2,5}{}^{n} + \frac{k_{1+1/2}}{\Delta x}\,U_2{}^{n}$$

$$- 4\varepsilon\sigma U_1{}^{3}S_{1,5} - S_{1,5}h_{ref}h_{bar}$$

(B-5)

The sensitivity equations at the interior node points are as follows,

Θ_i , i = 1, 2, 3

$$\rho\phi_c c\Delta x \frac{S_{i,k}{}^{n}-S_{i,k}{}^{n-1}}{\Delta t} = \frac{\phi_k k_{i-1/2}}{\Delta x} S_{i-1,k}$$

$$- \frac{\phi_k (k_{i-1/2}+k_{i+1/2})}{\Delta x} S_{i,k}$$

$$+ \frac{\phi_k k_{i+1/2}}{\Delta x} S_{i+1,k}$$

(B-6)

Θ_4:

$$\frac{S_{i,4}{}^{n}-S_{i,4}{}^{n-1}}{\Delta t} = \frac{\phi_k k_{i-1/2}}{\rho\phi_c c\Delta x^2} S_{i-1,4}{}^{n} - \frac{\phi_k k_{i-1/2}}{\rho\phi_c{}^2 c\Delta x^2} U_{i-1}{}^{n}$$

$$- \frac{\phi_k}{\rho\phi_c c\Delta x} \frac{(k_{i-1/2}+k_{i+1/2})}{\Delta x} S_{i,4}{}^{n}$$

$$+ \frac{\phi_k}{\rho\phi_c{}^2 c\Delta x} \frac{(k_{i-1/2}+k_{i+1/2})}{\Delta x} U_i{}^{n} + \frac{\phi_k k_{i+1/2}}{\rho\phi_c c\Delta x^2} S_{i+1,4}{}^{n}$$

$$- \frac{\phi_k k_{i+1/2}}{\rho\phi_c{}^2 c\Delta x^2} U_{i+1}{}^{n}$$

(B-7)

Θ_5:

$$\rho\phi_c c\Delta x \frac{S_{i,5}{}^{n}-S_{i,5}{}^{n-1}}{\Delta t} = \frac{\phi_k k_{i-1/2}}{\Delta x} S_{i-1,5}$$

$$- \frac{\phi_k (k_{i-1/2}+k_{i+1/2})}{\Delta x} S_{i,5}$$

$$+ \frac{\phi_k k_{i+1/2}}{\Delta x} S_{i+1,5} + \frac{k_{i-1/2}}{\Delta x} U_{i-1}$$

$$- \frac{(k_{i-1/2} + k_{i+1/2})}{\Delta x} U_i + \frac{k_{i+1/2}}{\Delta x} U_{i+1} \qquad \text{(B-8)}$$

The backface equations are of the same form as the node 1 equations without the convection and radiation terms.

If Equations A-14 are used to reduce the equations to the form of Equation 2-9, the sensitivity equations become,

$$[A'] \{S_{i,k}\} + \{d_k\} = 0 \qquad \text{(B-9)}$$

where tha [A] matrix for the sensitivity equations is the same as the [A] matrix for the temperature equations, A-15. The {d} vectors for each parameter are listed as follows,

$$\{d\}1 = \left\{ \begin{matrix} \left(h_{ref}(T_{aw} - U_1) + \frac{RCX_1}{\Delta t} S_{1,1}{}^{n-1}\right) / BBB_1 \\ \left(\frac{RCX_i}{\Delta t} S_{i,1}{}^{n-1}\right) / BBB_i \\ \\ \end{matrix} \right\}$$

$$\{d\}2 = \left\{ \begin{matrix} \left((\alpha - \alpha 1) h_{ref}(T_{aw} - U_1) + \frac{RCX_1}{\Delta t} S_{1,2}{}^{n-1}\right) / BBB_1 \\ \left(\frac{RCX_i}{\Delta t} S_{i,2}{}^{n-1}\right) / BBB_i \\ \\ \end{matrix} \right\}$$

$$\{d\}3 = \left\{ \begin{array}{l} \left((\alpha-\alpha 2) h_{ref} (T_{aw} - U_1) + \frac{RCX}{\Delta t}_1 \; S_{1,3}{}^{n-1} \right) \Big/ BBB_1 \\ \\ \left(\frac{RCX}{\Delta t}_i \; S_{i,3}{}^{n-1} \right) \Big/ BBB_i \\ \\ \end{array} \right\}$$

$$\{d\}4 = \left\{ \begin{array}{l} \left(-RP_1 \frac{(U_2 - U_1)}{\phi_c} + \varepsilon\sigma \frac{(U_1{}^4 - U_{\infty}{}^4)}{\phi_c} - \frac{h_{bar} h_{ref} (T_{aw} - U_1)}{\phi_c} \right. \\ \qquad\qquad\qquad\qquad \left. + \frac{RCX}{\Delta t}_1 S_{i,4}{}^{n-1} \right) \Big/ BBB_1 \\ \\ \left(-\frac{RM}{\phi_c}_i (U_{i-1} - U_i) + \frac{RP}{\phi_c}_i (U_i - U_{i+1}) + \frac{RCX}{\Delta t}_i S_{i,4} \right) \Big/ BBB_i \\ \\ \end{array} \right\}$$

$$\{d\}5 = \left\{ \begin{array}{l} \left(\frac{RP_1}{\phi_k} (U_2 - U_1) + \frac{RCX}{\Delta t}_1 S_{i,5}{}^{n-1} \right) \Big/ BBB_1 \\ \\ \left(\frac{RM}{\phi_k}_i U_{i-1} - \frac{(RM_i + RP_i)}{\phi_k} U_i + \frac{RP}{\phi_k}_i U_{i+1} + \frac{RCX}{\Delta t}_i S_{i,5}{}^{n-1} \right) \Big/ BBB_i \\ \\ \end{array} \right\}$$

(B-10)

APPENDIX C

The HEATEST program follows.

```
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

 1            PROGRAM HEATEST (INPUT,OUTPUT,TAPE2,TAPE3,TAPE4,TAPE5,TAPE6=        OCT10       6
 2           *OUTPUT,TAPE9,TAPE10,TAPE12,TAPE13,TAPE21,TAPE30)                    OCT10       7
 3      C                                                                         FHEATEST2   4
 4      C  TAPE2 = CALCOMP PLOT FILE                                              FHEATEST2   5
 5      C  TAPE3 = TEMP ICS                                                       FHEATEST2   6
 6      C  TAPE4 = MANEUVER (BET) FILE                                            FHEATEST2   7
 7      C  TAPE9 = TEMP IC OUTPUT FILE FROM ADAPTIVE FILTER MODE                  FHEATEST2   8
 8      C  TAPE10 = ADDAPTIVE TEMPERATURE/STATE ESTIMATE TIME SERIES              FHEATEST2   9
 9      C  TAPE12 = FORMATTED TIME SERIES FOR PLOT                                FHEATEST2  10
10      C  TAPE13 = THERMOCOUPLE MEASUREMENTS                                     FHEATEST2  11
11      C                                                                         FHEATEST2  12
12            REAL M1                                                             FHEATEST2  13
13            REAL TW1                                                            UPOCT09    10
14            LOGICAL IFICENT,IFPLOT,IFPRINT,IFXFLG                               FHEATEST2  14
15            COMMON /CFLAG/IFICENT,IFPLOT,IFPRINT                                UPOCT09    11
16            COMMON/CTCMMT/NTCT                                                  UPAUG16     9
17            COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                   UPAUG16     6
18           &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)                 UPOCT09     5
19            COMMON/CSENS/SUSI(6,5),UM1(6)                                       UPAUG16     7
20            LOGICAL FREAD(13)                                                   FHEATEST2  21
21            DIMENSION CI(5)                                                     UPAUG16    10
22            LOGICAL FAUTO                                                       CPARAM      2
23            DIMENSION FAUTO(7)                                                  OCT10       2
24            DIMENSION QP(5)                                                     UPAUG16     1
25            COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),            UPAUG16     2
26           &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                     UPAUG16     3
27            EQUIVALENCE (HO,QP(1))                                              UPAUG16     4
28            COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,              OCT10       3
29           &TO,TSINK,XFT,DEL,PDEL                                               COMTUN      3
30            COMMON/CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                         UPAUG16    12
31            COMMON/ICTPS2/TINIT(1),ERALOW,E                                     UPAUG16    13
32            COMMON/CTIME/TSTART,TSTOP,DTPENT,NRPITER,ITPRAM                     FHEATEST2  30
33            COMMON/CDX/DX(1)                                                    UPAUG16    14
34             COMMON /CONST/ XP1(13)                                             HAROLD      1
35            COMMON/CPARAM2/AVERROR,EQUI,UMEAS                                   UPOCT09    12
36            COMMON /CFPLOT/IPLOT,TSCALE,TMIN,TAXL,YSCALE,YMIN,YAXL,ASCALE,AMIN FHEATEST2  34
37           *,AAXL                                                               FHEATEST2  35
38            COMMON /CSMTH/ UICSM(6),PICSM(6,6),UAP(6),PAP(6,6),                 UPOCT09     1
39           &SMIC,TSMTH,W(6,6)                                                   UPOCT09     2
40            LOGICAL SMIC                                                        FCSMTH      4
41            COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT                  UPAUG16     8
42            REAL K,J1                                                           FDKF        3
43            COMMON/CPC/NPTPC                                                    FHEATEST2  37
44            DIMENSION FLT1(2),FLT2(1)                                           UPAUG16    15
45            EQUIVALENCE (TAW1,FLT1(1))                                          UPAUG16    16
46            EQUIVALENCE (REF,ALPH)                                              UPAUG16    17
47            EQUIVALENCE (TW1,TC(1))                                             UPAUG16    18
48            DIMENSION TITLE(10)                                                 FHEATEST2  41
49            DIMENSION REMARK(10)                                                FHEATEST2  42
50            DIMENSION PLAB1(12),PLAB2(12),NUM(12)                               FHEATEST2  43
51            DIMENSION VAR(13)                                                   HAROLD      2
52            DIMENSION PU(2),PE(2),PUF(2),PEF(2)                                 UPAUG16    19
53            DIMENSION READ(13)                                                  FHEATEST2  45
54            DATA NPAR /5/                                                       UPAUG16    20
55            DATA CLAB /1HC/                                                     FHEATEST2  47
```

```
      56               DATA LABELX/5HLABEL/                                          FHEATEST2  48
      57               DATA DTP/0/                                                   FHEATEST2  49
      58               DATA ERALOW/.5/                                               FHEATEST2  50
      59               DATA KA,KAF,IPE/1,1,1/                                        FHEATEST2  52
      60               DATA THDEP/.05/                                               OCT30       1
      61               DATA NPTSS/6/                                                 UPSEP19     2
      62               DATA TRAD/0./                                                 UPSEP19     3
      63         C                                                                   FHEATEST2  54
      64         C  READ INPUT DECK DATA                                             FHEATEST2  55
      65         C                                                                   FHEATEST2  56
      66               CALL INPUT                                                    FHEATEST2  57
      67         C                                                                   FHEATEST2  58
      68         C  NODE POINT STRUCTURE                                             FHEATEST2  59
      69         C                                                                   FHEATEST2  60
      70               DX(1)=THDEP/NPTSS                                             UPSEP19     4
      71               NODES(1)=1                                                    OCT24       1
      72               NODES(2)=NPTSS                                                OCT24       2
      73         C                                                                   FHEATEST2 120
      74         C                                                                   FHEATEST2 121
      75         C  ENTER OUTER/PARAMETER ESTIMATION ITERATION LOOP                  FHEATEST2 122
      76         C                                                                   FHEATEST2 123
      77               READ(5,3990)ITRJSK,ITCSK,NPTPC,IIC                            FHEATEST2 124
      78          3990 FORMAT(8(8X,I2))                                              FHEATEST2 125
      79               READ(5,4001)INTERV,IFXFLG                                     FHEATEST2 126
      80          4001 FORMAT(6X,I4,9X,L1,10X,7L1)                                   FHEATEST2 127
      81               DELS=(TSTOP-TSTART)/INTERV                                    FHEATEST2 128
      82               TSTOPF=TSTOP                                                  FHEATEST2 129
      83          4      TSTOP=TSTART+DELS                                           FHEATEST2 130
      84               IF(IFXFLG)THEN                                                FHEATEST2 131
 1    85               READ(5,4011,END=4034)NRPITER,IFX,FAUTO,TSTOP,KFOPT,NPTPC      FHEATEST2 132
 1    86          4011 FORMAT(4X,I1,5X,16I1,10X,7L1/8X,F10.5,5X,I1,8X,I2)            FHEATEST2 133
 1    87               READ(5,4012,END=4034)FREAD,READ                               FHEATEST2 134
 1    88          4012 FORMAT(3X,13L1,13F8.4)                                        FHEATEST2 135
 1    89               DO 4016 II=1,5                                                UPSEP24     1
 1    90         4016  IF(FREAD(II))QP(II)=READ(II)                                  UPSEP24     2
 1    91               READ(5,4013,END=4034)FREAD,READ                               FHEATEST2 138
 1    92               DO 4017 II=1,2                                                UPSEP19     5
 1    93          4017 IF(FREAD(II))ALPH(II)=READ(II)                                UPSEP19     6
 1    94          4013 FORMAT(3X,7L1,7F10.5)                                         FHEATEST2 141
 1    95               GO TO 4033                                                    FHEATEST2 142
 1    96          4034 IFXFLG=.FALSE.                                                FHEATEST2 143
 1    97               TSTOP=TSTOPF                                                  FHEATEST2 144
 1    98          4033 CONTINUE                                                      FHEATEST2 145
 1    99               END IF                                                        FHEATEST2 146
     100               IF(TSTOP.GT.TSTOPF)TSTOP=TSTOPF                               FHEATEST2 147
     101               IFXSUM=0                                                      FHEATEST2 149
     102               DO 30 I=1,NPAR                                                FHEATEST2 150
     103          30   IFXSUM=IFXSUM+IFX(I)                                          FHEATEST2 151
     104               NRPIT=NRPITER+1                                               FHEATEST2 152
     105               DO 198 ITPRAM=1,NRPIT                                         FHEATEST2 153
     106               KA=1                                                          FHEATEST2 154
     107               KAF=1                                                         FHEATEST2 155
     108               REWIND 3                                                      FHEATEST2 156
     109               REWIND 4                                                      FHEATEST2 157
     110               REWIND 10                                                     FHEATEST2 158
     111               REWIND 13                                                     FHEATEST2 159
     112               CALL ZERO(S,NPAR,1)                                           FHEATEST2 160
```

```
            SUBROUTINE TPS3(DTT)                                              UPAUG1     11
            COMMON /CTCMMT/NTCT                                               UPAUG1     12
            COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,            OCT10       3
           &TO,TSINK,XFT,DEL,PDEL                                             COMTUN      3
            COMMON /CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                      UPAUG1     14
            COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                 UPAUG16     6
           &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)               UPOCT09     5
            COMMON/CSENS/SUSI(6,5),UM1(6)                                     UPAUG16     7
            COMMON /ICTPS2/TINIT(1),ERALOW,E                                  UPAUG1     15
            COMMON /CDX/DX(1)                                                 UPAUG15     3
            REAL M1                                                           FTPS3      16
            DIMENSION AAAA(6),CCCC(6),DDDD(6),G(6),W(6)                       UPOCT09     8
            EQUIVALENCE (QD(1,1),AAAA(1)),(QD(1,2),CCCC(1)),(QD(1,3),DDDD(1)),  FTPS3    19
           &(QD(1,5),G(1)),(QDT(1,1),W(1))                                    FTPS3      20
            DATA SIG/4.761E-13/                                               UPAUG1     16
            DATA MIT/2/                                                       UPAUG1     17
      C SHIFT STORAGE                                                         FTPS3      38
            DO 460 I=1,NPTSS                                                  FTPS3      39
        460 UM1(I)=USI(I)                                                     FTPS3      40
      C                                                                       FTPS3      46
      C  FORM TRIDIAGONAL MATRIX                                              FTPS3      47
      C                                                                       FTPS3      48
            DO 511 I=2,NPTSS                                                  FTPS3      49
      C                                                                       FTPS3      57
            BBB=RCX(I)/DTT+RP(I)+RM(I)                                        FTPS3      58
            AAAA(I)=RM(I)/BBB                                                 FTPS3      59
            CCCC(I)=RP(I)/BBB                                                 FTPS3      60
            DDDD(I)=RCX(I)*UM1(I)/DTT/BBB                                     UPSEP12     1
        511 CONTINUE                                                          FTPS3      72
      C  TRIDIAGONAL SOLUTION                                                 FTPS3      73
            DO 540 M=1,MIT                                                    FTPS3      74
      C  I=1                                                                  FTPS3      79
            BBB=RCX(1)/DTT+RP(1)+RM(1)+4.*E*SIG*(USI(1)+460.)**3.+            UPAUG1     18
           @HBAR*HREF                                                         UPAUG1     19
            AAAA(1)=RM(1)/BBB                                                 UPAUG1     20
            CCCC(1)=RP(1)/BBB                                                 UPAUG1     21
            DDDD(1)=(RCX(1)*UM1(1)/DTT+E*SIG*(3*USI(1)**4+TRAD**4)+HBAR*HREF* UPAUG1     22
           &TAW1)/BBB                                                         UPAUG1     23
             G(1)=DDDD(1)                                                     UPAUG1     24
             W(1)=-CCCC(1)                                                    UPAUG1     25
            DO 520 I=2,NPTSS                                                  FTPS3     114
        510 W(I)=-CCCC(I)/(1.+AAAA(I)*W(I-1))                                 FTPS3     115
        520 G(I)=(DDDD(I)+AAAA(I)*G(I-1))/(1.+AAAA(I)*W(I-1))                 FTPS3     116
            UNEW =G(NPTSS)                                                    FTPS3     118
            UERMX=ABS(UNEW-USI(NPTSS))                                        FTPS3     119
            USI(NPTSS)=UNEW                                                   FTPS3     120
            DO 530 L=2,NPTSS                                                  FTPS3     121
            I=NPTSS-L+1                                                       FTPS3     122
            UNEW=G(I)-W(I)*USI(I+1)                                           FTPS3     123
            UERR=ABS(UNEW-USI(I))                                             FTPS3     124
            UERMX=AMAX1(UERMX,UERR)                                           FTPS3     125
            USI(I)=UNEW                                                       FTPS3     126
        530 CONTINUE                                                          FTPS3     127
            IF(UERMX.LT.ERALOW.AND.M.GE.5)GO TO 550                           FTPS3     128
        540 CONTINUE                                                          FTPS3     129
```

```
 1    56               RCX(I)=RHOG*PHIC*ZP*DX(1)*.5                                     UPAUG1       8
 1    57               RP(I)=PHIK*Z/DX(1)                                               UPAUG1       9
 1    58               RM(I)=0.                                                         FMAKEA2    181
 1    59               A(1,1)=-RP(I)/RCX(I)                                             FMAKEA2    182
 1    60               A(1,2)=RP(I)/RCX(I)                                              FMAKEA2    183
 1    61               ALIN1=-(4.*E*SIG*(USI(1)+460.)**3.+HBAR*HREF)/RCX(I)             OCT30       14
 1    62               END IF                                                           FMAKEA2    185
      63           511 CONTINUE                                                         FMAKEA2    186
      64               A(1,1) = A(1,1)+ALIN1                                            FMAKEA2    187
      65         C                                                                      FMAKEA2    193
      66         C  SYSTEM MATRIX COMPLETED                                             FMAKEA2    194
      67         C                                                                      FMAKEA2    195
      68               RETURN                                                           FMAKEA2    196
      69               END                                                              FMAKEA2    197
```

```
      SUBROUTINE MAKEA       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29        PAGE      1
      DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
      FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

        1                 SUBROUTINE MAKEA                                                      FMAKEA2      2
        2                 COMMON /CPLCL/IPT,PFRAC                                               FMAKEA2      3
        3                 COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,                OCT10        3
        4                &TO,TSINK,XFT,DEL,PDEL                                                 COMTUN       3
        5                 COMMON /CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                          UPAUG16     40
        6                 COMMON /ICTPS2/TINIT(1),ERALOW,E                                      UPAUG16     41
        7                 COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                     UPAUG16      6
        8                &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)                   UPOCT09      5
        9                 COMMON/CPC/NPTPC                                                      FMAKEA2     13
       10                 LOGICAL FAUTO                                                         CPARAM       2
       11                 DIMENSION FAUTO(7)                                                    OCT10        2
       12                 DIMENSION QP(5)                                                       UPAUG16      1
       13                 COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),              UPAUG16      2
       14                &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                       UPAUG16      3
       15                 EQUIVALENCE (HO,QP(1))                                                UPAUG16      4
       16                 COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT                    UPAUG16      8
       17                 REAL K,J1                                                             FDKF         3
       18                 COMMON /CDX/DX(1)                                                     UPAUG15      2
       19                 REAL M1                                                               FMAKEA2     18
       20                 COMMON /CTCMMT/NTCT                                                   UPAUG16     42
       21                 DATA SIG/4.761E-13/                                                   UPAUG16     43
       22                 DATA E/.3/                                                            UPAUG16     44
       23                 DATA HREF/1./                                                         UPAUG20      4
       24                 DATA RHOG/17.10603937/                                                OCT30       11
       25                 DATA ZP/3.233477/                                                     OCT30       12
       26                 DATA Z/3.054E-3/                                                      OCT30       13
       27            C  SET UP LINEARIZED SYSTEM MATRIX, A                                      FMAKEA2     44
       28            C                                                                          FMAKEA2     45
       29                 CALL ZERO (A(1,1),NPTSS,NPTSS)                                        FMAKEA2     46
       30                 DO 511 I=1,NPTSS                                                      FMAKEA2     47
       31            C  CURRENT PASS TEMPERATURES                                               FMAKEA2     48
       32            C                                                                          FMAKEA2     57
       33            C  FORM MATRIX                                                             FMAKEA2     58
       34            C                                                                          FMAKEA2     59
       35            C                                                                          FMAKEA2     94
       36            C  I=NPTS                                                                  FMAKEA2     95
       37                 IF (I.EQ.NPTSS) THEN                                                  UPAUG1       1
   1   38                 RCX(I)=RHOG*PHIC*ZP*DX(1)*.5                                          UPAUG1       2
   1   39                 RM(I)=PHIK*Z/DX(1)                                                    UPAUG1       3
   1   40                 RP(I)=0.                                                              FMAKEA2    104
   1   41                 A(I,I-1)=RM(I)/RCX(I)                                                 FMAKEA2    105
   1   42                 A(I,I)=-RM(I)/RCX(I)                                                  FMAKEA2    106
   1   43            C                                                                          FMAKEA2    125
   1   44            C  BLOCK B  INTERIOR POINTS                                                FMAKEA2    126
   1   45            C                                                                          FMAKEA2    128
   1   46                  ELSE IF((I.GT.1).AND.(I.LT.NPTSS))THEN                               UPAUG1       4
   1   47                 RCX(I)=RHOG*PHIC*ZP*DX(1)                                             UPAUG1       5
   1   48                 RP(I)=PHIK*Z/DX(1)                                                    UPAUG1       6
   1   49                 RM(I)=PHIK*Z/DX(1)                                                    UPAUG1       7
   1   50                 A(I,I-1)=RM(I)/RCX(I)                                                 FMAKEA2    170
   1   51                 A(I,I+1)=RP(I)/RCX(I)                                                 FMAKEA2    171
   1   52                 A(I,I)=-A(I,I-1)-A(I,I+1)                                             FMAKEA2    172
   1   53            C                                                                          FMAKEA2    173
   1   54            C SURFACE NODE I=1                                                         FMAKEA2    174
   1   55                 ELSE IF (I.EQ.1) THEN                                                 FMAKEA2    175
```

```
       56          C  WHILE I.EQ.1 ADD BOUNDARY NOISE DUE TO HEAT TERMS                       FQUE      54
       57                IF (I.EQ.1) THEN                                                     FQUE      55
 1     58                QUE(I,J) = QER*QER*SDME*SQRT(SDBN**2+SDME**2)*R(I,J)                 FQUE      56
 1     59                ELSE                                                                 FQUE      57
 1     60                QUE(I,J) = QER*QER*SDME**2.*R(I,J)                                   FQUE      58
 1     61                END IF                                                               FQUE      59
 1     62          C  END WHILE                                                               FQUE      60
 1     63          C                                                                          FQUE      61
       64             221 QUE(J,I) = QUE(I,J)                                                 FQUE      62
       65             222 CONTINUE                                                            FQUE      63
       66          C                                                                          FQUE      64
       67                RETURN                                                               FQUE      65
       68                END                                                                  FQUE      66
```

```
SUBROUTINE QUEMAT      74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29         PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

     1          SUBROUTINE QUEMAT                                                 FQUE        2
     2           COMMON /CONST/ XP1(13)                                           HAROLD     28
     3          LOGICAL IFICENT,IFPLOT,IFPRINT                                    UPOCT09    23
     4          COMMON /CFLAG/IFICENT,IFPLOT,IFPRINT                              UPOCT09    24
     5          COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,            OCT10       3
     6         &TO,TSINK,XFT,DEL,PDEL                                             COMTUN      3
     7          COMMON /CTCMMT/NTCT                                               UPAUG16    35
     8          COMMON /CDX/DX(1)                                                 UPAUG16    36
     9          COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                 UPAUG16     6
    10         &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)               UPOCT09     5
    11          COMMON /ICTPS2/TINIT(1),ERALOW,E                                  UPAUG16    37
    12          COMMON/CSENS/SUSI(6,5),UM1(6)                                     UPAUG16     7
    13          COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT                UPAUG16     8
    14          REAL K,J1                                                         FDKF        3
    15          COMMON /CICSTAT/TR,SDIC,SDME,SDMEA,SDBN                           FQUE       15
    16          COMMON /CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                      UPAUG16    38
    17          REAL M1                                                           FQUE       17
    18          DIMENSION R(6,6)                                                  UPOCT09     7
    19          EQUIVALENCE (QD(1,1),R(1,1))                                      FQUE       19
    20    C                                                                       FQUE       20
    21          RR = SDMEA                                                        FQUE       21
    22    C                                                                       FQUE       22
    23    C  MATRIX OF SPACIAL CORRELATIONS, R                                    FQUE       23
    24    C  SPACIAL CORRELATIONS IN RSI MUST ALLOW FOR VARIABLE NODE STRUCTURE   FQUE       24
    25          DO 200 I=1,NPTSS                                                  FQUE       25
    26          SUMR=0.                                                           FQUE       26
    27          DO 200 J=I,NPTSS                                                  FQUE       27
    28          XP=SUMR/TR                                                        OCT30       9
    29          XP=ABS(XP)                                                        FQUE       29
    30          IF(I .EQ. 1)XP1(J)=XP*TR                                          HAROLD     29
    31          IF(XP.GT.100.)XP=100.                                             FQUE       30
    32          R(I,J)=EXP(-XP)                                                   FQUE       31
    33          IF(ABS(RP(J)).LT.1.E-8)GO TO 200                                  FQUE       32
    34          SUMR=SUMR+RCX(J)/RP(J)                                            FQUE       33
    35     200  R(J,I)=R(I,J)                                                     FQUE       34
    36          PRINT*,'XP1= ',(XP1(I),I=1,NPTSS)                                 HAROLD     30
    37    C                                                                       FQUE       35
    38    C  MODEL ERROR MATRIX, QUE                                              FQUE       36
    39    C                                                                       FQUE       37
    40          RC=SQRT(ABS((RCX(1)+RCX(2))*.5))                                  FQUE       38
    41          QER=(HBAR*HREF*(TAW1-USI(1))/(RM(1)+RP(1))/2)**2                  OCT10      10
    42          DO 221 I = 1,NPTSS                                                FQUE       40
    43    C                                                                       FQUE       41
    44    C  WHILE I.EQ.1 ADD BOUNDARY NOISE DUE TO HEAT TERMS                    FQUE       42
    45          IF (I.EQ.1) THEN                                                  FQUE       43
 1  46          QUE(I,I)=((SDBN*QER)**2+(SDME*QER)**2)/2                          OCT30      10
 1  47          ELSE                                                              FQUE       45
 1  48          QUE(I,I) = (SDME*QER)**2.                                         FQUE       46
 1  49          END IF                                                            FQUE       47
 1  50    C  END WHILE                                                            FQUE       48
 1  51    C                                                                       FQUE       49
    52          IF (I.EQ.NPTSS) GO TO 222                                         FQUE       50
    53          IP1 = I+1                                                         FQUE       51
    54          DO 221 J = IP1,NPTSS                                              FQUE       52
    55    C                                                                       FQUE       53
```

```
      C                                                                 FINPUT     129
      C  READ CALCOMP PLOT SPECIFICATIONS                               FINPUT     130
      C                                                                 FINPUT     131
            READ(5,1000)IPLOT                                           FINPUT     132
            READ(5,2000)TSCALE,TMIN,TAXL                                FINPUT     133
            READ(5,2000)YSCALE,YMIN,YAXL                                FINPUT     134
            READ(5,2000)ASCALE,AMIN,AAXL                                FINPUT     135
       1000 FORMAT(10X,I2,7(3X,I2))                                     FINPUT     140
      C                                                                 FINPUT     142
      C  READ TIMES                                                     FINPUT     143
      C                                                                 FINPUT     144
      C START-STOP TIMES / PRINT TIME STEP                               FINPUT     145
            READ(5,2000)TSTART,TSTOP,DTPENT                             FINPUT     146
      C  DATA FOR I.C. SMOOTHER                                         CHUCK       34
            READ(5,100)SMIC,TSMTH                                       UPSEP24      3
       100  FORMAT(6X,L1,8X,F10.5)                                      CHUCK       36
      C # OF ITERATIONS/FIX=0 FIXES  PARAMETER/AUTO FLAG FOR REFERENCE  FINPUT     147
            READ(5,2010)NRPITER,IFX,FAUTO,KFOPT                         FINPUT     148
      C NEWTON-RAPHSON ACCELERATION PARAMETERS(0)ACC)2)                 FINPUT     149
            READ(5,2015)ACC                                             FINPUT     150
      C HEATING MODEL INITIAL PARAMETERS                                FINPUT     151
            READ(5,2020)(QP(II),II=1,NPAR)                              UPSEP24      4
      C INITIAL REFERENCE VALUES FOR HEATING MODEL                      FINPUT     153
            READ(5,2030)ALPH                                            UPSEP24      5
       2010 FORMAT(5X,I2,3X,5I1,5X,7L1,8X,I1)                           OCT10        8
       2015 FORMAT(5X,8F5.2/5X,8F5.2)                                   FINPUT     156
       2020 FORMAT(10X,8F8.4/26X,5F8.4)                                 FINPUT     157
       2030 FORMAT(10X,7F8.4)                                           FINPUT     158
            RETURN                                                      FINPUT     159
            END                                                         FINPUT     160
```

```
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      SUBROUTINE IC                                                     FIC         2
      LOGICAL IFICENT,IFPLOT,IFPRINT                                    UPOCT09    21
      COMMON /CFLAG/IFICENT,IFPLOT,IFPRINT                              UPOCT09    22
      COMMON /CTCMMT/NTCT                                               UPAUG16    31
      COMMON /CDX/DX(1)                                                 UPAUG16    32
      COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                 UPAUG16     6
     &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)               UPOCT09     5
      COMMON /ICTPS2/TINIT(1),ERALOW,E                                  UPAUG16    33
      COMMON/CSENS/SUSI(6,5),UM1(6)                                     UPAUG16     7
      COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT                UPAUG16     8
      REAL K,J1                                                         FDKF        3
      COMMON /CICSTAT/TR,SDIC,SDME,SDMEA,SDBN                           FIC        15
      COMMON /CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                      UPAUG16    34
      REAL M1                                                           FIC        17
      DIMENSION R(6,6)                                                  UPOCT09     7
      EQUIVALENCE (QD(1,1),R(1,1))                                      FIC        19
C                                                                       FIC        20
C  INITIAL SENSITIVITIES                                                FIC        21
C                                                                       FIC        22
      RR = SDMEA                                                        FIC        23
C                                                                       FIC        24
C  MATRIX OF SPACIAL CORRELATIONS, R                                    FIC        25
C                                                                       FIC        26
C  SPACIAL CORRELATIONS IN RSI MUST ALLOW FOR VARIABLE NODE STRUCTURE   FIC        27
      DO 200 I=1,NPTSS                                                  FIC        28
      SUMR=0.                                                           FIC        29
      DO 200 J=I,NPTSS                                                  FIC        30
      XP=SUMR/TR                                                        OCT30       8
      XP=ABS(XP)                                                        FIC        32
      IF(XP.GT.100.)XP=100.                                             FIC        33
      R(I,J)=EXP(-XP)                                                   FIC        34
      IF(ABS(RP(J)).LT.1.E-8)GO TO 200                                  FIC        35
      SUMR=SUMR+RCX(J)/RP(J)                                            FIC        36
  200 R(J,I)=R(I,J)                                                     FIC        37
C                                                                       FIC        38
C  COVARIANCE MATRIX OF TEMP ICS, PC                                    FIC        39
C                                                                       FIC        40
      DO 210 I = 1,NPTSS                                                FIC        41
      PC(I,I) = (SDIC*USI(I))**2.                                       FIC        42
      IF (I.EQ.NPTSS) GO TO 211                                         FIC        43
      IP1 = I+1                                                         FIC        44
      DO 210 J = IP1,NPTSS                                              FIC        45
      PC(I,J) = USI(I)*USI(J)*SDIC**2.*R(I,J)                           FIC        46
  210 PC(J,I) = PC(I,J)                                                 FIC        47
  211 CONTINUE                                                          FIC        48
      RETURN                                                            FIC        49
      END                                                               FIC        50
```

```
      C                                                                FINPUT     129
      C  READ CALCOMP PLOT SPECIFICATIONS                              FINPUT     130
      C                                                                FINPUT     131
            READ(5,1000)IPLOT                                          FINPUT     132
            READ(5,2000)TSCALE,TMIN,TAXL                               FINPUT     133
            READ(5,2000)YSCALE,YMIN,YAXL                               FINPUT     134
            READ(5,2000)ASCALE,AMIN,AAXL                               FINPUT     135
       1000 FORMAT(10X,I2,7(3X,I2))                                    FINPUT     140
      C                                                                FINPUT     142
      C  READ TIMES                                                    FINPUT     143
      C                                                                FINPUT     144
      C START-STOP TIMES / PRINT TIME STEP                              FINPUT     145
            READ(5,2000)TSTART,TSTOP,DTPENT                            FINPUT     146
      C  DATA FOR I.C. SMOOTHER                                        CHUCK       34
            READ(5,100)SMIC,TSMTH                                      UPSEP24      3
       100  FORMAT(6X,L1,8X,F10.5)                                     CHUCK       36
      C # OF ITERATIONS/FIX=0 FIXES  PARAMETER/AUTO FLAG FOR REFERENCE FINPUT     147
            READ(5,2010)NRPITER,IFX,FAUTO,KFOPT                        FINPUT     148
      C NEWTON-RAPHSON ACCELERATION PARAMETERS(0)ACC)2)                FINPUT     149
            READ(5,2015)ACC                                            FINPUT     150
      C HEATING MODEL INITIAL PARAMETERS                               FINPUT     151
            READ(5,2020)(QP(II),II=1,NPAR)                             UPSEP24      4
      C INITIAL REFERENCE VALUES FOR HEATING MODEL                     FINPUT     153
            READ(5,2030)ALPH                                           UPSEP24      5
       2010 FORMAT(5X,I2,3X,5I1,5X,7L1,8X,I1)                          OCT10        8
       2015 FORMAT(5X,8F5.2/5X,8F5.2)                                  FINPUT     156
       2020 FORMAT(10X,8F8.4/26X,5F8.4)                                FINPUT     157
       2030 FORMAT(10X,7F8.4)                                          FINPUT     158
            RETURN                                                     FINPUT     159
            END                                                        FINPUT     160
```

```
SUBROUTINE INPUT       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587          84/11/19. 13.14.29          PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      SUBROUTINE INPUT                                                   FINPUT        2
      LOGICAL IFICENT,IFPLOT,IFPRINT                                     FINPUT        3
      CHARACTER *30 VEH,FLTDT,TMANV,CTPT                                 FINPUT        5
      COMMON /CFLAG/IFICENT,IFPLOT,IFPRINT                               UPOCT09      20
      COMMON/CTCMMT/NTCT                                                 UPAUG16      26
      COMMON/CTIME/TSTART,TSTOP,DTPENT,NRPITER,ITPRAM                    FINPUT        9
      COMMON/ICTPS2/TINIT(1),ERALOW,E                                    UPAUG16      27
      COMMON/CDX/DX(1)                                                   UPAUG16      28
      LOGICAL FAUTO                                                      CPARAM        2
      DIMENSION FAUTO(7)                                                 OCT10         2
      DIMENSION QP(5)                                                    UPAUG16       1
      COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),           UPAUG16       2
     &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                    UPAUG16       3
      EQUIVALENCE (HO,QP(1))                                             UPAUG16       4
      COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT                 UPAUG16       8
      REAL K,J1                                                          FDKF          3
      COMMON /CSMTH/ UICSM(6),PICSM(6,6),UAP(6),PAP(6,6),                UPOCT09       1
     &SMIC,TSMTH,W(6,6)                                                  UPOCT09       2
      LOGICAL SMIC                                                       FCSMTH        4
      COMMON /CCOM/VEH,FLTDT,TMANV,CTPT                                  FINPUT       16
      COMMON /CICSTAT/TR,SDIC,SDME,SDMEA,SDBN                            FINPUT       17
      COMMON /CFPLOT/IPLOT,TSCALE,TMIN,TAXL,YSCALE,YMIN,YAXL,ASCALE,AMIN FINPUT       18
     *,AAXL                                                              FINPUT       19
C                                                                        FINPUT       22
C  READ VEHICLE/MANEUVER UNIQUES                                         FINPUT       23
C                                                                        FINPUT       24
      READ(5,3000)VEH                                                    FINPUT       25
 3000 FORMAT(A30)                                                        FINPUT       26
      READ(5,3000)FLTDT                                                  FINPUT       27
      READ(5,3000)TMANV                                                  FINPUT       28
      READ(5,3000)CTPT                                                   FINPUT       29
C                                                                        FINPUT       30
C                                                                        FINPUT       49
      READ(5,1000)NTCT                                                   UPAUG24       2
C                                                                        FINPUT       64
C  IFICENT = T  ICS FROM DISK       / F  CONSTANT ICS FROM CARDS         FINPUT       65
C  IFPLOT  = T  CREATE CALCOMP      / F  NO PLOT FILE                    FINPUT       66
C  IFPRINT = T  PRINT TIME SERIES   / F  NO TEMP TIME SERIES OUTPUT      FINPUT       67
C                                                                        FINPUT       68
      READ(5,4000)IFICENT                                                FINPUT       69
 4000 FORMAT(8(9X,L1))                                                   FINPUT       70
      READ(5,4000)IFPLOT                                                 FINPUT       71
      READ(5,4000)IFPRINT                                                FINPUT       72
 2000 FORMAT(10X,F10.5,3(5X,F10.5)/10X,F10.5,3(5X,F10.5))                FINPUT       73
C                                                                        FINPUT       74
C  READ IN INITIAL TEMPERATURES  (USED IF IFICENT = F)                   FINPUT       75
C                                                                        FINPUT       76
      READ(5,2000)TINIT                                                  FINPUT       77
C                                                                        FINPUT       78
C                                                                        FINPUT      122
C  INITIAL COVARIANCE AND ERROR STATISTICS                               FINPUT      123
C                                                                        FINPUT      124
      READ(5,2001)TR,SDIC,SDME,SDMEA                                     FINPUT      125
      READ(5,2001)SDBN                                                   FINPUT      126
 2001 FORMAT(10X,F10.5,3(5X,F10.5))                                      FINPUT      127
```

```
1   341             PRINT *,'T,USI=',TLEST,(USI(II),II=1,NPTSS)                  FHEATEST2 450
1   342             REWIND 3                                                     FHEATEST2 451
1   343                TSTART=TSTOP                                              FHEATEST2 452
1   344                GO TO 4                                                   FHEATEST2 453
1   345                END IF                                                    FHEATEST2 454
    346             REWIND 3                                                     FHEATEST2 455
    347             WRITE(3) USI,PC,SUSI                                         FHEATEST2 456
    348             PRINT *,'T,USI=',TLEST,(USI(II),II=1,NPTSS)                  FHEATEST2 457
    349         998 IF(IFPLOT) CALL FPLOT                                        CHUCK      32
    350       C                                                                  FHEATEST2 459
    351       C  PLOT CALCOMP FILE FROM TAPE12                                   FHEATEST2 460
    352       C                                                                  FHEATEST2 461
    353             STOP                                                         FHEATEST2 462
    354         999 STOP 'END-OF-FILE ENCOUNTERED ON INPUT TAPE IN HEATEST'      FHEATEST2 463
    355             END                                                          FHEATEST2 464
```

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1   284              IF(NLAB.EQ.0)GO TO 120                              FHEATEST2 342
1   285           24 CONTINUE                                            FHEATEST2 343
1   286                 GO TO 100                                        FHEATEST2 344
1   287              END IF                                              FHEATEST2 345
1   288         C                                                        FHEATEST2 346
1   289         C PROPAGATION TO TSTOP                                   FHEATEST2 347
1   290         C                                                        FHEATEST2 348
    291          120  DELT=TSTOP-TLEST                                   FHEATEST2 349
    292              CALL TPS3(DELT)                                     FHEATEST2 350
    293              TLEST=TSTOP                                         FHEATEST2 351
    294         C  WRITE SMOOTHED I.CS TO TAPE3                          CHUCK      23
    295              IF(SMIC)THEN                                        CHUCK      24
1   296                REWIND (3)                                        CHUCK      27
1   297                WRITE(3) UICSM,PICSM,SUSI                         CHUCK      28
1   298                REWIND (3)                                        CHUCK      29
1   299               IIC=1                                              HAROLD     26
1   300              ENDIF                                               CHUCK      30
1   301         C                                                        FHEATEST2 352
1   302         C  EXIT TEMPERATURE/STATE ESTIMATION LOOP                FHEATEST2 353
1   303         C                                                        FHEATEST2 354
    304              IF(ITPRAM.LE.NRPITER.OR.NRPITER.EQ.0) THEN          FHEATEST2 355
    305         C                                                        FHEATEST2 356
    306         C  UPDATE PARAMETER ESTIMATES - LIST RESULTS             FHEATEST2 357
    307         C                                                        FHEATEST2 358
1   308              CALL PAREST                                         FHEATEST2 359
1   309              IT=1                                                FHEATEST2 360
1   310              DO 197 II=1,NPAR                                    FHEATEST2 361
1   311              IF(IFX(II).EQ.0)THEN                                FHEATEST2 362
2   312              CI(II)=0.                                           FHEATEST2 363
2   313              GO TO 197                                           FHEATEST2 364
2   314              END  IF                                             FHEATEST2 365
1   315              CI(II)=SQRT(ABS(CIF(IT,IT)))                        FHEATEST2 366
1   316              IT=IT+1                                             FHEATEST2 367
1   317          197  CONTINUE                                           FHEATEST2 368
1   318              IF(ITPRAM.EQ.1)WRITE(6,3079)                        FHEATEST2 371
1   319          3079 FORMAT(//1X,'ITER',T18,'HALPH1',T30,'HALPH2',T42,'PHIC',   OCT30       6
1   320             &T54,'PHIK',T66,'ZP',T76,'Z',T88,'ALPHA1',T100,      OCT30       7
1   321             &'ALPHA2',T112,'ALPHA3'/T6,'QBETA',T18,'QLOGRE',T30,'QDELE',T42   FHEATEST2 374
1   322             &,'QDELBF',T54,'QMACH',T66,'PHIKB'/1X,'(CRAMER-RAO BOUND)')       FHEATEST2 375
1   323              WRITE(6,3080)ITPRAM,(QP(I),I=1,10),(CI(I),I=1,10),  FHEATEST2 376
1   324             &(QP(I),I=11,16),(CI(I),I=11,16)                     FHEATEST2 377
1   325          3080 FORMAT(1X,I2,2X,10(F8.5,4X)/5X,10(1X,'(',E8.2,')',1X)/      FHEATEST2 378
1   326             &/5X,6(F8.5,4X)/5X,6(1X,'(',E8.2,')',1X))            FHEATEST2 379
1   327              WRITE(6,3081)AVERROR                                FHEATEST2 380
1   328          3081 FORMAT(1X,'AVERAGE ERROR=',E12.5/)                 FHEATEST2 381
1   329         C                                                        FHEATEST2 382
1   330              END IF                                              FHEATEST2 383
    331           198 CONTINUE                                           FHEATEST2 384
    332              IIC=1                                               FHEATEST2 385
    333         C                                                        FHEATEST2 397
    334         C                                                        FHEATEST2 444
    335              IF(SMIC) GO TO 998                                  CHUCK1      1
    336              IF(TSTOP.LT.TSTOPF-1.E-6)THEN                       FHEATEST2 445
    337         C  RESET INITIAL CONDITIONS WITH FOLLOWING DATA TO DISK  FHEATEST2 446
    338         C                                                        FHEATEST2 447
1   339              REWIND 3                                            FHEATEST2 448
1   340              WRITE(3)USI,PC,SUSI                                 FHEATEST2 449
```

```
2    227         C  SAVE A PRIORI VALUES                                                CHUCK       11
1    228                DO 27 I=1,NPTSS                                                 CHUCK       12
1    229                 UAP(I)=USI(I)                                                  CHUCK       13
1    230                DO 27 J=1,NPTSS                                                 CHUCK       14
1    231         27     PAP(I,J)=PC(I,J)                                                CHUCK       15
1    232         C                                                                      CHUCK       16
1    233                DO 25 I=1,NTCT                                                  FHEATEST2 312
1    234                PU(I)=USI(NODES(I))                                             FHEATEST2 313
1    235          25            PE(I)=SQRT(ABS(PC(NODES(I),NODES(I))))                  FHEATEST2 314
1    236                CALL KF                                                         FHEATEST2 315
1    237                E1 = SQRT(ABS(PC(1,1)))                                         FHEATEST2 316
1    238                DO 26 I=1,NTCT                                                  FHEATEST2 317
1    239                PUF(I)=USI(NODES(I))                                            FHEATEST2 318
1    240          26    PEF(I)=SQRT(ABS(PC(NODES(I),NODES(I))))                         FHEATEST2 319
1    241                WRITE(6,99)T,PU(1),PE(1),PUF(1),PEF(1),TC(1)                    OCT30        2
1    242          99    FORMAT(1X,F5.2,3X,2(3X,F9.5,3X,'(',E8.2,')'),5X,F9.5)           OCT30        3
1    243                WRITE(6,98)(USI(I),I=1,NPTSS)                                   OCT30        4
1    244          98    FORMAT(T11,6(F8.5,3X))                                          OCT30        5
1    245         C INITIALIZE SMOOTHER                                                  HAROLD      10
1    246                IF(ICOUNT .EQ. 0)THEN                                           HAROLD      11
2    247                 DO 1000 I=1,NPTSS                                              HAROLD      12
2    248                  UICSM(I)=USI(I)                                               HAROLD      13
2    249                 DO 1000 J=1,NPTSS                                              HAROLD      14
2    250                  PICSM(I,J)=PC(I,J)                                            HAROLD      15
2    251          1000   W(I,J)=PC(I,J)                                                 HAROLD      16
2    252                ENDIF                                                           HAROLD      17
1    253                 TSMTH=TLEST                                                    HAROLD      18
1    254         C  SMOOTH I.C.'S                                                       CHUCK       17
1    255                IF(SMIC)THEN                                                    CHUCK       18
2    256                 IF(ICOUNT .NE. 0)THEN                                          HAROLD      19
3    257                 CALL FPSM(TSTART)                                              HAROLD      20
3    258                DO 510 IM=1,NPTSS                                               HAROLD      21
3    259          510    VAR(IM)=SQRT(ABS(PICSM(IM,IM)))                                HAROLD      22
3    260                 ENDIF                                                          CHUCK       21
2    261                ENDIF                                                           CHUCK       22
2    262         C                                                                      FHEATEST2 320
2    263         C  WRITE APOSTERIORI STATE ESTIMATE TO TAPE10/TAPE12                   FHEATEST2 321
2    264         C                                                                      FHEATEST2 322
1    265                IF (ITPRAM.GT.NRPITER) THEN                                     FHEATEST2 323
2    266                  IF(IFPRINT)WRITE(10)1,TLEST,USI(1),E1,EQUI,PU,PE,PUF,PEF,TC,  FHEATEST2 324
2    267               &      Q,QREF,ALPHA,BETA,RENS,DELE,DELBF,M1                      UPOCT09     16
2    268               &,M1                                                             FHEATEST2 326
2    269                IF(IFPLOT)WRITE(12,3055)TLEST,USI(1),EQUI,PU(1),TC(1),          FHEATEST2 328
2    270               &ALPHA,BETA,RENS,DELE,DELBF,M1,QN                                FHEATEST2 329
2    271                     TRITE=TLEST                                                FHEATEST2 330
2    272                END IF                                                          FHEATEST2 331
1    273                DTP = 0.                                                        FHEATEST2 332
1    274         C                                                                      FHEATEST2 333
1    275                 ICOUNT= 1                                                      HAROLD      25
1    276         C  KF UPDATE COMPLETE - SET UP FOR NEXT PROPAGATION INTERVAL           FHEATEST2 334
1    277         C                                                                      FHEATEST2 335
1    278         C UPDATE THERMAL PROPERTIES/A MATRIX BASED ON UPDATED STATES           FHEATEST2 336
1    279         C NOTE! PROPERTIES MAY NEED UPDATED MORE OFTEN IF TC SAMPLE RATE IS LOW  FHEATEST2 337
1    280                   CALL MAKEA                                                   FHEATEST2 338
1    281         C          READ NEXT THERMOCOUPLE SAMPLE                               FHEATEST2 339
1    282                DO 24 II=1,ITCSK                                                FHEATEST2 340
1    283                  READ(13,END=999)NLAB,TUPDT,(TC(I),I=1,NTCT)                   UPAUG24      1
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     170                DO 500 IM=1,NPTSS                                       HAROLD       4
     171                 UICSM(IM)=USI(IM)                                      HAROLD       5
     172          500    VAR(IM)=SQRT(ABS(PC(IM,IM)))                           HAROLD       6
     173                PRINT*,'UIC= ',(UICSM(IM),IM=1,NPTSS)                   HAROLD       7
     174                PRINT*,'VAR= ',(VAR(IM),IM=1,NPTSS)                     HAROLD       8
     175                ICOUNT=0                                                HAROLD       9
     176         C PROPAGATION TO TRAJECTORY SAMPLE TIME/TIMES                  FHEATEST2 262
     177         C                                                              FHEATEST2 263
     178          100  IF(T.LT.TUPDT.AND.T.LT.TSTOP)THEN                        FHEATEST2 264
 1   179                  DELT=T-TLEST                                          FHEATEST2 265
 1   180                  CALL TPS3(DELT)                                       FHEATEST2 266
 1   181                  CALL SENS(DELT)                                       FHEATEST2 267
 1   182               CALL TPSOSP2(DELT)                                       FHEATEST2 268
 1   183                  TLEST=T                                               FHEATEST2 269
 1   184               DTP=DTP+DELT                                             FHEATEST2 270
 1   185         C                                                              FHEATEST2 271
 1   186         C  WHEN DTP.GE.DTPENT THEN WRITE TEMP/STATE ESTIMATES TO TAPE10/TAPE12   FHEATEST2 272
 1   187         C                                                              FHEATEST2 273
 1   188               IF ((DTP.GE.DTPENT).AND.(ITPRAM.GT.NRPITER)) THEN        FHEATEST2 274
 2   189                    DTP = 0.                                            FHEATEST2 275
 2   190                    IF(IFPRINT)WRITE(6)0,TLEST,USI(1),TC(1),HBAR,HREF,ALPHA,TO   UPOCT09     13
 2   191                    IF(IFPRINT)WRITE(10)0,TLEST,USI(1),EQUI,USI(NODES(1)),Q,     UPOCT09     14
 2   192              &QREF,ALPHA,BETA,RENS,DELE,DELBF,M1                       FHEATEST2 277
 2   193                   IF(IFPLOT)WRITE(12,3055)TLEST,USI(1),EQUI,USI(NODES(1)),TC(1),  FHEATEST2 279
 2   194              &     ALPHA,BETA,RENS,DELE,DELBF,M1,QN                    FHEATEST2 280
 2   195          3055      FORMAT(6E13.7)                                      FHEATEST2 281
 2   196                    TRITE=TLEST                                         FHEATEST2 282
 2   197               END IF                                                   FHEATEST2 283
 2   198         C                                                              FHEATEST2 284
 2   199         C        READ NEXT TRAJECTORY SAMPLE                           FHEATEST2 285
 1   200               DO 22 II=1,ITRJSK                                        FHEATEST2 286
 1   201                  READ(4,END=999)NLAB,T,(FLT1(I),I=1,NLAB)              FHEATEST2 287
 1   202                  IF(NLAB.EQ.0)T=TSTOP                                  FHEATEST2 288
 1   203           22  CONTINUE                                                 FHEATEST2 289
 1   204               CALL HEATTUN                                             UPAUG16     24
 1   205                  GO TO 100                                             FHEATEST2 291
 1   206               END IF                                                   FHEATEST2 292
 1   207         C          PROPAGATION TO THERMOCOUPLE SAMPLE TIME/TIMES       FHEATEST2 293
 1   208         C                                                              FHEATEST2 294
     209               IF(TUPDT.LE.TSTOP)THEN                                   FHEATEST2 295
 1   210                  DELT=TUPDT-TLEST                                      FHEATEST2 296
 1   211                  CALL TPS3(DELT)                                       FHEATEST2 297
 1   212                  CALL SENS(DELT)                                       FHEATEST2 298
 1   213                  CALL TPSOSP2(DELT)                                    FHEATEST2 299
 1   214                  TLEST=TUPDT                                           FHEATEST2 300
 1   215               DTP=DTP+DELT                                             FHEATEST2 301
 1   216               IF(TUPDT.GE.T)THEN                                       FHEATEST2 302
 2   217               DO 23 II=1,ITRJSK                                        FHEATEST2 303
 2   218                  READ(4,END=999)NLAB,T,(FLT1(I),I=1,NLAB)              FHEATEST2 304
 2   219                  IF(NLAB.EQ.0)T=TSTOP                                  FHEATEST2 305
 2   220            23 CONTINUE                                                 FHEATEST2 306
 2   221               CALL HEATTUN                                             UPAUG16     25
 2   222               END IF                                                   FHEATEST2 308
 2   223         C                                                              FHEATEST2 309
 2   224         C KALMAN UPDATES                                               FHEATEST2 310
 2   225         C                                                              FHEATEST2 311
 2   226         C                                                              CHUCK       10
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     113            CALL ZERO(CIF,NPAR,NPAR)                                   FHEATEST2 161
     114            IF(IIC.EQ.0)CALL ZERO(SUSI,NPTSS,NPAR)                     FHEATEST2 162
     115      C                                                                FHEATEST2 163
     116      C  READ C & B FILE LABEL ON TRAJ TAPE                            FHEATEST2 164
     117      C                                                                FHEATEST2 165
     118            READ(4)C,LIC,ITAIL,TITLE,ITEST,FLT,DFLT,DREQ,DCOM          FHEATEST2 166
     119         33 IF(EOF(4) .NE. 0.) CALL EXIT                               FHEATEST2 167
     120            IF (C .NE. CLAB) CALL EXIT                                 FHEATEST2 168
     121            READ(4) LABEL,NRSECT,NREM,(REMARK(I),I=1,NREM),NLAB,       FHEATEST2 169
     122           *(PLAB1(I),PLAB2(I),NUM(I),I=1,NLAB)                        FHEATEST2 170
     123            IF (LABEL .NE. LABELX) CALL EXIT                           FHEATEST2 171
     124      C                                                                FHEATEST2 172
     125      C  READ C & B FILE LABEL ON THE T/C MEAS TAPE                    FHEATEST2 173
     126      C                                                                FHEATEST2 174
     127          7 READ(13)C,LIC,ITAIL,TITLE,ITEST,FLT,DFLT,DREQ,DCOM         FHEATEST2 175
     128         44 IF (EOF(13) .NE. 0.) CALL EXIT                             FHEATEST2 176
     129            IF(C .NE.CLAB) CALL EXIT                                   FHEATEST2 177
     130            READ(13)LABEL,NRSECT,NREM,(REMARK(I),I=1,NREM),NLAB,       FHEATEST2 178
     131           *(PLAB1(I),PLAB2(I),NUM(I),I=1,NLAB)                        FHEATEST2 179
     132            IF(LABEL .NE. LABELX) CALL EXIT                            FHEATEST2 180
     133      C                                                                FHEATEST2 181
     134      C  SET TEMPERATURE INITIAL CONDITIONS                            FHEATEST2 182
     135      C                                                                FHEATEST2 183
     136            IF(IIC.EQ.0)THEN                                           FHEATEST2 184
     137      C  INITIAL TEMPERATURES                                          FHEATEST2 185
     138      C                                                                FHEATEST2 186
 1   139            DO 403 I=1,NPTSS                                           FHEATEST2 187
 1   140       403  USI(I)=TINIT(1)                                            UPAUG16    21
 1   141            IF(IFICENT) THEN                                           FHEATEST2 189
 2   142            READ (3) USI                                               FHEATEST2 190
 2   143            END IF                                                     FHEATEST2 191
 1   144            END IF                                                     FHEATEST2 192
     145            IF(IIC.NE.0)THEN                                           FHEATEST2 193
 1   146               REWIND 3                                                FHEATEST2 194
 1   147            READ(3)USI,PC,SUSI                                         FHEATEST2 195
 1   148               REWIND 3                                                FHEATEST2 196
 1   149            END IF                                                     FHEATEST2 197
     150            EQUI=USI(1)                                                FHEATEST2 198
     151      C  INITIALIZE SMOOTHER                                           CHUCK       2
     152      C INITIALIZE PARAMETERS AT TSTART                                FHEATEST2 199
     153            DTP=0.                                                     FHEATEST2 200
     154            TLEST=TSTART                                               FHEATEST2 201
     155      C READ FIRST TRAJECTORY SAMPLE                                   FHEATEST2 202
     156       10   READ(4,END=999)NLAB,T,(FLT1(I),I=1,NLAB)                   FHEATEST2 203
     157            IF(NLAB.EQ.0)GO TO 999                                     FHEATEST2 204
     158            IF(T.LT.TSTART)GO TO 10                                    FHEATEST2 205
     159      C CALCULATE REFERENCE HEATING                                    FHEATEST2 206
     160            CALL HEATTUN                                               UPAUG16    22
     161      C READ FIRST THERMOCOUPLE SAMPLES AND LOCAL PRESSURE             FHEATEST2 208
     162       20   READ(13,END=999)NLAB,TUPDT,(TC(I),I=1,NTCT)                UPAUG16    23
     163            IF(NLAB.EQ.0)GO TO 999                                     FHEATEST2 210
     164            IF(TUPDT.LT.TSTART)GO TO 20                                FHEATEST2 211
     165      C INITIALIZE THERMAL PROPERTIES/A MATRIX                         FHEATEST2 212
     166            CALL MAKEA                                                 FHEATEST2 213
     167             IF(IIC .EQ. 0)CALL IC                                     HAROLD      3
     168            CALL QUEMAT                                                FHEATEST2 215
     169      C                                                                FHEATEST2 261
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               IF(UERMX.GT.ERALOW)WRITE(6,1000)ERALOW,N,T,UERMX,USI(1)               FTPS3     130
          1000 FORMAT(1X,15HMAX ERROR TEMP~,E12.6,2X,I2,2X,4(E12.6,1X))              FTPS3     131
          550  CONTINUE                                                              FTPS3     132
          570  RETURN                                                                FTPS3     133
               END                                                                   FTPS3     134
```

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DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


       SUBROUTINE SENS(DTT)                                                UPAUG1     26
      COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,               OCT10       3
     &TD,TSINK,XFT,DEL,PDEL                                                COMTUN      3
      COMMON /CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                         UPAUG16    45
      COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                    UPAUG16     6
     &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)                  UPOCT09     5
      COMMON /ICTPS2/TINIT(1),ERALOW,E                                     UPAUG16    46
      COMMON /CDX/DX(1)                                                    UPAUG15     4
      COMMON/CSENS/SUSI(6,5),UM1(6)                                        UPAUG16     7
      LOGICAL FAUTO                                                        CPARAM      2
      DIMENSION FAUTO(7)                                                   OCT10       2
      DIMENSION QP(5)                                                      UPAUG16     1
      COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),             UPAUG16     2
     &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                      UPAUG16     3
      EQUIVALENCE (HO,QP(1))                                               UPAUG16     4
      REAL M1                                                              FSENS3     16
      DIMENSION AA(6),BB(6),CC(6),DD(6),AAA(6),CCC(6),DDD(6),W(6),G(6)     UPOCT09     9
      EQUIVALENCE (QD(1,1),AA(1)),(QD(1,2),BB(1)),(QD(1,3),CC(1)),         FSENS3     18
     &(QD(1,4),DD(1)),(QD(1,5),AAA(1))                                     FSENS3     19
      EQUIVALENCE (QDT(1,1),CCC(1)),(QDT(1,2),DDD(1)),(QDT(1,3),W(1)),     FSENS3     20
     &(QDT(1,4),G(1))                                                      FSENS3     21
      DATA SIG/4.761E-13/                                                  UPAUG16    47
      DATA E/.3/                                                           UPAUG16    48
      DATA NPTS/40/                                                        FSENS3     23
C                                                                          FSENS3     25
       IF (DTT.EQ.0.0) GO TO 999                                           UPAUG1     28
C                                                                          FSENS3     28
C  BACKWARD-DIFFERENCE FORMULATION OF DIFF. EQS.                           FSENS3     29
C                                                                          FSENS3     30
C                                                                          FSENS3     35
C  I=1                                                                     FSENS3     36
      RCX(1)=RHOG*PHIC*ZP*DX(1)*.5                                         UPAUG1     29
      RP(1)=PHIK*Z/DX(1)                                                   UPAUG1     30
      RM(1)=0.                                                             FSENS3     43
C SET UP TRIDIAGONAL MATRIX (COMMON TERMS ONLY)                            FSENS3     49
      DO 520 I=1,NPTSS                                                     FSENS3     50
      BB(I)=RCX(I)/DTT+RM(I)+RP(I)                                         FSENS3     51
      AA(I)=RM(I)                                                          FSENS3     52
      CC(I)=RP(I)                                                          FSENS3     53
      DD(I)=RCX(I)/DTT                                                     FSENS3     54
 520  CONTINUE                                                             FSENS3     55
    . BB(1)=BB(1)+4.*E*SIG*(USI(1)+460.)**3+  HBAR  *HREF                  UPAUG1     31
C                                                                          FSENS3     66
C  I=1 SENSITIVITY FOR EACH PARAMETER                                      FSENS3     67
      DO 530 IP=1,NPAR                                                     FSENS3     68
      IF(IFX(IP).EQ.0)GO TO 530                                            FSENS3     69
      DO 531 I=1,NPTSS                                                     FSENS3     70
 531  DDD(I)=DD(I)*SUSI(I,IP)                                              FSENS3     71
C                                                                          FSENS3     72
C  SENSITIVITY FOR UNIT SURFACE CONDUCTANCE NAUT (THETA ONE)               UPAUG1     32
      IF(IP.EQ.1) DDD(1)=DDD(1)+HREF*(TAW1-USI(1))                         UPAUG1     33
C SENSITIVITIES FOR EACH HEATING MODEL PARAMETER                           FSENS3     82
      IF(IP.EQ.2) DDD(1)=DDD(1) +HREF*(TAW1-USI(1))*(ALPHA-ALPH(1))        UPAUG1     34
      IF(IP.EQ.3) DDD(1)=DDD(1) +HREF*(TAW1-USI(1))*(ALPHA-ALPH(2))        UPAUG1     35
C  SENSITIVITY FOR SPECIFIC HEAT FACTOR PHIC                               UPAUG1     36
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            IF(IP.EQ.4) THEN                                                   UPAUG1   37
1           DDD(1)=DDD(1)-RP(1)*(USI(2)-USI(1))-(HBAR*HREF*(TAW1-              OCT30    15
1          &USI(1))+E*SIG*((USI(1)+460.)**4-TRAD**4))/PHIC                     OCT30    16
1           DO 533 I=2, NPTSS-1                                                UPAUG1   40
1     533   DDD(I)=DDD(I)-(RM(I)*(USI(I-1)-USI(I))+RP(I)*(USI(I)-USI(          OCT30    17
1          &I+1)))/PHIC                                                        UPAUG1   42
1           DDD(NPTSS)=DDD(NPTSS)+RM(NPTSS)*(USI(NPTSS-1)-USI(NPTSS))/PHIC     UPAUG1   43
1           END IF                                                             UPAUG1   44
1     C  SENSITIVITY FOR CONDUCTIVITY FACTOR PHIK                             UPAUG1   45
            IF(IP.EQ.5) THEN                                                   UPAUG1   46
1           DDD(1)=DDD(1)+RP(1)*(USI(2)-USI(1))/PHIK                           UPAUG1   47
1           DO 534 I=2,NPTSS-1                                                 UPAUG1   48
1     534   DDD(I)=DDD(I)+(RM(I)*USI(I-1)-(RM(I)+RP(I))*USI(I)+RP(I)           UPAUG1   49
1          &*USI(I+1))/PHIK                                                    UPAUG1   50
1           DDD(NPTSS)=DDD(NPTSS)+RM(NPTSS)*(USI(NPTSS-1)-USI(NPTSS))/PHIK     UPAUG1   51
1           END IF                                                             UPAUG1   52
            DO 535 I=1,NPTSS                                                   FSENS3  105
            AAA(I)=AA(I)/BB(I)                                                 FSENS3  106
            CCC(I)=CC(I)/BB(I)                                                 FSENS3  107
       535  DDD(I)=DDD(I)/BB(I)                                                FSENS3  108
      C                                                                        FSENS3  109
      C                                                                        FSENS3  110
      C TRIDIAGONAL SOLUTION                                                   FSENS3  111
      C ELIMINATION STEP                                                       FSENS3  112
            G(1)=DDD(1)                                                        FSENS3  113
            W(1)=-CCC(1)                                                       FSENS3  114
            DO 536 I=2,NPTSS                                                   FSENS3  115
            W(I)=-CCC(I)/(1.+AAA(I)*W(I-1))                                    FSENS3  116
       536  G(I)=(DDD(I)+AAA(I)*G(I-1))/(1.+AAA(I)*W(I-1))                     FSENS3  117
      C BACKWARD SUBSTITUTION                                                  FSENS3  118
            SUSI(NPTSS,IP)=G(NPTSS)                                            FSENS3  119
            DO 537 L=2,NPTSS                                                   FSENS3  120
            I=NPTSS-L+1                                                        FSENS3  121
            SUSI(I,IP)=G(I)-W(I)*SUSI(I+1,IP)                                  FSENS3  122
       537  CONTINUE                                                           FSENS3  123
       530  CONTINUE                                                           FSENS3  124
       999  RETURN                                                             FSENS3  125
            END                                                                FSENS3  126
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SUBROUTINE PAREST     74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587       84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

        1            SUBROUTINE PAREST                                                  FPAREST      2
        2            LOGICAL FAUTO                                                      CPARAM       2
        3            DIMENSION FAUTO(7)                                                 OCT10        2
        4            DIMENSION QP(5)                                                    UPAUG16      1
        5            COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),           UPAUG16      2
        6           &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                    UPAUG16      3
        7            EQUIVALENCE (HO,QP(1))                                             UPAUG16      4
        8            COMMON/ICTPS2/TINIT(1),ERALOW,E                                    UPSEP24      7
        9            COMMON/CDX/DX(1)                                                   UPSEP24      8
       10            COMMON/CTIME/TSTART,TSTOP,DTPENT,NRPITER,ITPRAM                    FPAREST      8
       11            COMMON/MAIN2/IMA2                                                  FPAREST      9
       12            DIMENSION CIFI(6,6)                                                UPSEP24      9
       13            DATA KIN,KOUT/5,6/                                                 FPAREST     12
       14            IMA2=16                                                            FPAREST     13
       15            NR=IFXSUM                                                          FPAREST     14
       16            IF(NR.EQ.1)THEN                                                    FPAREST     15
    1  17            CIF(1,1)=1./CIF(1,1)                                               FPAREST     16
    1  18            GO TO 20                                                           FPAREST     17
    1  19            END IF                                                             FPAREST     18
    1  20      C                                                                        FPAREST     19
    1  21      C INVERT CONDITIONAL INFORMATION MATRIX,CIF                              FPAREST     20
       22            CALL GMINV(NR,NR,CIF,CIFI,MR,1)                                    FPAREST     21
       23            DO 15 IR=1,NR                                                      FPAREST     22
       24            DO 15 IC=1,NR                                                      FPAREST     23
       25        15  CIF(IR,IC)=CIFI(IR,IC)                                             FPAREST     24
       26      20     IT=1                                                              UPSEP24     10
       27            DO 29 IP=1,NPAR                                                    FPAREST     28
       28            IF(IFX(IP).EQ.0)GO TO 29                                           FPAREST     29
       29            JT=1                                                               FPAREST     30
       30            DO 28 JP=1,NPAR                                                    FPAREST     31
       31            IF(IFX(JP).EQ.0)GO TO 28                                           FPAREST     32
       32            QP(IP)=QP(IP)+CIF(IT,JT)*S(JT)                                     OCT24        3
       33            JT=JT+1                                                            FPAREST     35
       34        28  CONTINUE                                                           FPAREST     36
       35            IT=IT+1                                                            FPAREST     37
       36        29  CONTINUE                                                           FPAREST     38
       37            RETURN                                                             FPAREST     41
       38            END                                                                FPAREST     42
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SUBROUTINE KF         74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29          PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

          1             SUBROUTINE KF                                                  FKFSUM      2
          2             LOGICAL IFICENT,IFPLOT,IFPRINT                                 FKFSUM      3
          3             COMMON /CSMTH/ UICSM(6),PICSM(6,6),UAP(6),PAP(6,6),            OCT10      11
          4            &SMIC,TSMTH,W(6,6)                                              OCT10      12
          5             COMMON /CFLAG/IFICENT,IFPLOT,IFPRINT                           UPOCT09    25
          6             COMMON /CTCMMT/NTCT                                            UPSEP24    12
          7             COMMON/CPC/NPTPC                                               FKFSUM      8
          8             LOGICAL FAUTO                                                  CPARAM      2
          9             DIMENSION FAUTO(7)                                             OCT10       2
         10             DIMENSION QP(5)                                                UPAUG16     1
         11             COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),       UPAUG16     2
         12            &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                UPAUG16     3
         13             EQUIVALENCE (HO,QP(1))                                         UPAUG16     4
         14             COMMON /ICTPS2/TINIT(1),ERALOW,E                               UPAUG24     3
         15             COMMON /CDX/DX(1)                                              UPAUG24     4
         16             COMMON/CSENS/SUSI(6,5),UM1(6)                                  UPAUG16     7
         17             COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,              UPAUG16     6
         18            &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)            UPOCT09     5
         19             COMMON/CTIME/TSTART,TSTOP,DTPENT,NRPITER,ITPRAM                FKFSUM     16
         20             COMMON/CPARAM2/AVERROR,EQUI,UMEAS                              UPOCT09    26
         21             COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT             UPAUG16     8
         22             REAL K,J1                                                      FDKF        3
         23             COMMON /MAIN1/INP,IPVT(6),WORK(6)                              OCT10       4
         24             INP=6                                                          OCT10       5
         25       C                                                                    FKFSUM     21
         26             SDMEA=RR                                                       FKFSUM     22
         27       C                                                                    FKFSUM     23
         28       C  THE FOLLOWING CONTROL CONSTRUCT SORTS KF UPDATE ITERATIONS        FKFSUM     24
         29       C  REQUIRED BY VECTOR UPDATES AS SPECIFIED IN THE INPUT DECK         FKFSUM     25
         30       C                                                                    FKFSUM     26
         31             DO 98 I=1,NPTSS                                                FKFSUM     29
         32             DO 5 ITT=1,NTCT                                                FKFSUM     30
         33             IF(I.EQ.NODES(ITT))THEN                                        FKFSUM     31
    1    34               NODE=NODES(ITT)                                              FKFSUM     32
    1    35               UMEAS=TC(ITT)                                                FKFSUM     33
    1    36               GO TO 10                                                     FKFSUM     34
    1    37             END IF                                                         FKFSUM     35
         38        5    CONTINUE                                                       FKFSUM     36
         39             GO TO 98                                                       FKFSUM     37
         40        10    ERROR=UMEAS-UAP(NODE)                                         HAROLD     38
         41       C                                                                    FKFSUM     39
         42             IF(KAF.EQ.1) AVERROR=ERROR                                     FKFSUM     40
         43             AVERROR=((KAF-1)*AVERROR+ERROR)/KAF                            FKFSUM     41
         44             KAF=KAF+1                                                      FKFSUM     42
         45       C                                                                    FKFSUM     43
         46       C  SCORE RUNNING SUMS FOR JACOBIAN OF LIKELIHOOD FN. S,              FKFSUM     44
         47       C  AND CONDITIONAL INFORMATION MATRIX, CIF                           FKFSUM     45
         48       C                                                                    FKFSUM     46
         49             R=(SDMEA*UMEAS)**2.                                            FKFSUM     47
         50       C                                                                    FKFSUM     48
         51             DO 26 KO=1,NPAR                                                FKFSUM     49
         52             S1(KO)=SUSI(NODE,KO)*IFX(KO)*ERROR/(PC(NODE,NODE)+R)           FKFSUM     50
         53             DO 25 L=1,NPAR                                                 FKFSUM     51
         54        25   J1(KO,L)=SUSI(NODE,KO)*IFX(KO)*IFX(L)*SUSI(NODE,L)/(PC(NODE,NODE)+ FKFSUM  52
         55            *R)                                                             FKFSUM     53
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   26 CONTINUE                                                            FKFSUM    54
      IT=1                                                                FKFSUM    55
      DO 29 IP=1,NPAR                                                     FKFSUM    56
      IF(IFX(IP).EQ.0)GO TO 29                                            FKFSUM    57
      S(IT)=S1(IP)+S(IT)                                                  FKFSUM    58
      JT=1                                                                FKFSUM    59
      DO 28 JP=1,NPAR                                                     FKFSUM    60
      IF(IFX(JP).EQ.0)GO TO 28                                            FKFSUM    61
      CIF(IT,JT)=J1(IP,JP)+CIF(IT,JT)                                     FKFSUM    62
      JT=JT+1                                                             FKFSUM    63
   28 CONTINUE                                                            FKFSUM    64
      IT=IT+1                                                             FKFSUM    65
   29 CONTINUE                                                            FKFSUM    66
C                                                                         FKFSUM    67
C  COMPUTE KALMAN GAIN, K                                                 FKFSUM    68
C                                                                         FKFSUM    69
      DO 30 IK=1,NPTSS                                                    FKFSUM    70
   30  K(IK)=PAP(IK,NODE)/(PAP(NODE,NODE)+R)                              HAROLD    37
C IF KOPT=1 UPDATE                                                        FKFSUM    72
C IF KOPT=2 UPDATE EXCEPT ON LAST ITERATION(ITPRAM-NRPITER)               FKFSUM    73
C IF KOPT=3 DO NOT UPDATE                                                 FKFSUM    74
C IF KOPT=4 UPDATE COVARIANCE AND SENSITIVITY ONLY                        FKFSUM    75
C IF KFOPT=5 ONLY UPDATE TEMP ON LAST ITERATION                           FKFSUM    76
C IF KFOPT=6 ONLY UPDATE ON LAST ITERATION                                FKFSUM    77
      GO TO(101,102,103,104,101,101)KFOPT                                 FKFSUM    78
  102 IF(ITPRAM.GT.NRPITER)GO TO 103                                      FKFSUM    79
C                                                                         FKFSUM    80
C  STATE UPDATE                                                           FKFSUM    81
C                                                                         FKFSUM    82
  101 IF(KFOPT.GE.6.AND.ITPRAM.LE.NRPITER)GO TO 103                       FKFSUM    83
      IF(KFOPT.EQ.5.AND.ITPRAM.LE.NRPITER)GO TO 104                       FKFSUM    84
      DO 40 IO=1,NPTSS                                                    FKFSUM    85
   40  USI(IO)=USI(IO)+K(IO)*(UMEAS-UAP(NODE))                            HAROLD    38
C                                                                         FKFSUM    87
C  SENSITIVITY UPDATE                                                     FKFSUM    88
C                                                                         FKFSUM    89
  104 CONTINUE                                                            FKFSUM    90
      DO 35 IP=1,NPAR                                                     FKFSUM    91
      DO 35 L=1,NPTSS                                                     FKFSUM    92
   35 SUSI(L,IP)=SUSI(L,IP)-K(L)*SUSI(NODE,IP)                            FKFSUM    93
C                                                                         FKFSUM    94
C  COVARIANCE UPDATE, PC  -  JOSEPH FORM                                  FKFSUM    95
      NPTSS=NPTPC                                                         FKFSUM    96
C                                                                         FKFSUM    97
      CALL ZERO(QD(1,1),NPTSS,NPTSS)                                      FKFSUM    98
      DO 50 IC=1,NPTSS                                                    FKFSUM    99
      QD(IC,IC) = 1.0                                                     FKFSUM   100
   50 QD(IC,NODE) = QD(IC,NODE)-K(IC)                                     FKFSUM   101
      CALL MAT4(NPTSS,NPTSS,PC(1,1),QD(1,1),QDT(1,1))                     FKFSUM   102
      CALL MAT4(NPTSS,1,R,K(1),QD(1,1))                                   FKFSUM   103
      DO 55 IPC=1,NPTSS                                                   FKFSUM   104
      DO 55 JPC=1,NPTSS                                                   FKFSUM   105
   55 PC(IPC,JPC) = QDT(IPC,JPC)+QD(IPC,JPC)                              FKFSUM   106
      NPTSS=INP                                                           FKFSUM   107
   98 CONTINUE                                                            FKFSUM   108
  103 CONTINUE                                                            FKFSUM   109
      RETURN                                                              FKFSUM   110
```

```
                    END                                                                        FKFSUM     111
```

```
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.
```

```
       SUBROUTINE FPSM(TSTART)                                     HAROLD     39
       COMMON /CONST/ XP1(13)                                      HAROLD     40
      COMMON /CTCMMT/NTCT                                          OCT10      13
      COMMON /CSMTH/ UICSM(6),PICSM(6,6),UAP(6),PAP(6,6),          UPOCT09     1
     &SMIC,TSMTH,W(6,6)                                            UPOCT09     2
      LOGICAL SMIC                                                 FCSMTH      4
      COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,            UPAUG16     6
     &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)          UPOCT09     5
      COMMON/CKF/K(6),S1(6),J1(6,6),TC(2),NODES(2),KFOPT           UPAUG16     8
      REAL K,J1                                                    FDKF        3
      DIMENSION RINV(8,8),HTR(6,8),SFP(6,6),GAIN(6),               UPOCT09     3
     &WRK1(6,6),WRK2(6,6)                                          UPOCT09     4
      COMMON /MAIN1/INP,IPVT(6),WORK(6)                            OCT10       4
      INP=6                                                        OCT10       5
C                                                                  FPSMIC      8
C  THIS ROUTINE IS A FIXED POINT SMOOTHER ALGORITHM                FPSMIC      9
C                                                                  FPSMIC     10
      CALL ZERO(SFP,NPTSS,NPTSS)                                   HAROLD     42
      DO 10 I=1,NTCT                                               HAROLD     43
 10    SFP(NODES(I),NODES(I))=1./(RR*TC(I))**2.                    HAROLD     44
C                                                                  FPSMIC     25
C  FORM I-SP AND FIND PHIT                                         FPSMIC     26
      CALL MMUL(SFP,PC,NPTSS,NPTSS,NPTSS,WRK1)                     FPSMIC     27
      DO 30 I=1,NPTSS                                              FPSMIC     28
      DO 30 J=1,NPTSS                                              FPSMIC     29
        WRK1(I,J)=-WRK1(I,J)                                       FPSMIC     30
        IF(I .EQ. J)WRK1(I,J)=1.0+WRK1(I,J)                        FPSMIC     31
 30   WRK2(I,J)=PHI(J,I)                                           HAROLD     45
      DO 35 I=1,NPTSS                                              HAROLD     46
       DO 35 J=1,NPTSS                                             HAROLD     47
 35     PHI(I,J)=WRK2(I,J)                                         HAROLD     48
C                                                                  FPSMIC     33
C  FORM W=W*PHIT*(I-SP)                                            FPSMIC     34
      CALL MMUL(PHI,WRK1,NPTSS,NPTSS,NPTSS,WRK2)                   CHUCK1      4
      CALL MMUL(W,WRK2,NPTSS,NPTSS,NPTSS,WRK1)                     FPSMIC     36
      DO 40 I=1,NPTSS                                              FPSMIC     37
      DO 40 J=1,NPTSS                                              FPSMIC     38
 40   W(I,J)=WRK1(I,J)                                             FPSMIC     39
C                                                                  FPSMIC     40
C  SOLVE FOR COVARIANCE -- P=P-W(S*PAP*S + S)WTRAN                 FPSMIC     41
      CALL MMUL(PAP,SFP,NPTSS,NPTSS,NPTSS,WRK1)                    FPSMIC     42
      CALL MMUL(SFP,WRK1,NPTSS,NPTSS,NPTSS,WRK2)                   FPSMIC     43
      DO 50 I=1,NPTSS                                              FPSMIC     44
      DO 50 J=1,NPTSS                                              FPSMIC     45
 50    WRK1(I,J)=WRK2(I,J) +SFP(I,J)                               FPSMIC     46
       CALL TRI(NPTSS,WRK1,W,PHI,WRK2,NPTSS)                       HAROLD     49
      DO 60 I=1,NPTSS                                              FPSMIC     48
      DO 60 J=1,NPTSS                                              FPSMIC     49
 60    PICSM(I,J)=PICSM(I,J) - WRK2(I,J)                           FPSMIC     50
C                                                                  FPSMIC     51
C  SOLVE FOR SMOOTHED STATE (SCALAR UPDATES)                       FPSMIC     52
      DO 150 I=1,NPTSS                                             FPSMIC     53
       DO 110 ITT=1,NTCT                                           FPSMIC     54
        IF(I .EQ. NODES(ITT))THEN                                  FPSMIC     55
          NODE=NODES(ITT)                                          FPSMIC     56
```

```
1     56                    UMEAS=TC(ITT)                                            FPSMIC      57
1     57                    GO TO 120                                                FPSMIC      58
1     58                  ENDIF                                                      FPSMIC      59
      59           110   CONTINUE                                                    FPSMIC      60
      60                GO TO 150                                                    FPSMIC      61
      61           120  R=(RR*UMEAS)**2.                                             FPSMIC      62
      62          C                                                                  FPSMIC      63
      63          C  COMPUTE GAIN                                                    FPSMIC      64
      64                DO 121  IJ=1,NPTSS                                           FPSMIC      65
      65           121   GAIN(IJ)=W(IJ,NODE)/R                                       FPSMIC      66
      66          C                                                                  FPSMIC      67
      67          C  UPDATE                                                          FPSMIC      68
      68                DO 125 IO=1,NPTSS                                            FPSMIC      69
      69                 TCONST=TSTART+XP1(IO)                                       HAROLD      50
      70                 IF(TSMTH .GT. TCONST) GO TO 125                             HAROLD      51
      71                 UICSM(IO)=UICSM(IO)+GAIN(IO)*(UMEAS-UAP(NODE))              HAROLD      52
      72           125   CONTINUE                                                    HAROLD      53
      73           150  CONTINUE                                                     FPSMIC      71
      74                RETURN                                                       FPSMIC      72
      75                END                                                          FPSMIC      73
```

```
SUBROUTINE MULT        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587          84/11/19. 13.14.29          PAGE        1
DO--LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

1                     SUBROUTINE MULT(X,Y,N,Z,N2)                                             MULT         2
2                     DIMENSION X(N2,N2),Y(N2,N2),Z(N2,N2                                     MULT         3
3                     DO 20  I=1,N                                                            MULT         4
4                     DO 20  J=1,N                                                            MULT         5
5                     Z(I,J)=0.                                                               MULT         6
6                     DO 20  K=1,N                                                            MULT         7
7                  20 Z(I,J)=Z(I,J)+X(I,K)*Y(K,J)                                             MULT         8
8                     RETURN                                                                  MULT         9
9                     END                                                                     MULT        10
```

```
SUBROUTINE MEXP        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587          84/11/19  13.14.29          PAGE     1
DO   LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5 I ANSI=0,L=OUTS,LO=S/-A.


      SUBROUTINE MEXP(N,SUB1,TIME,SUB2,Q,QT,N2)                         MEXP2      2
      DIMENSION SUB1(N2,N2),SUB2(N2,N2)                                 MEXP2      3
      DIMENSION Q(N2,N2),QT(N2,N2)                                      MEXP2      4
C    MULTIPLY ELEMENTS OF SUB1 BY TIME                                  MEXP2      5
      DO 102  I=1,N                                                     MEXP2      6
      DO 102  J=1,N                                                     MEXP2      7
      SUB1(I,J)=SUB1(I,J)*TIME                                          MEXP2      8
  102 SUB2(I,J)=SUB1(I,J)                                               MEXP2      9
C    GENERATE IDENTITY MATRIX FOR INPUT Q, FOR HQR                      MEXP2     10
      DO 30  I=1,N                                                      MEXP2     11
      DO 30  J=1,N                                                      MEXP2     12
      Q(I,J)=0.                                                         MEXP2     13
   30 IF(I .EQ. J) Q(I,J)=1.                                            MEXP2     14
      CALL HQR(N,SUB2,Q,IERR,N2)                                        MEXP2     15
C    MATRIX SUB2 HAS BEEN DESTOYED                                      MEXP2     16
C    Q IS NOW AN ORTHOGONAL TRANSFORMATION MATRIX                       MEXP2     17
      DO 40  I=1,N                                                      MEXP2     18
      DO 40  J=1,N                                                      MEXP2     19
   40 QT(I,J)=Q(J,I)                                                    MEXP2     20
C    QT IS NOW THE TRANSPOSE,AND THE INVERSE, OF Q                      MEXP2     21
      CALL MULT(SUB1,Q,N,SUB2,N2)                                       MEXP2     22
      CALL MULT(QT,SUB2,N,SUB1,N2)                                      MEXP2     23
C    SUB1 NOW CONTAINS THE TRIANGULAR MATRIX QT*A*Q                     MEXP2     24
      DO 50  I=1,N                                                      MEXP2     25
      DO 50  J=1,N                                                      MEXP2     26
   50 SUB2(I,J)=0.                                                      MEXP2     27
      CALL FUNCT(1,N,SUB1,SUB2,N2)                                      MEXP2     28
C    SUB2 NOW HOLDS EXP(A*TIME) IN TRIANGULAR FORM                      MEXP2     29
      CALL MULT(SUB2,QT,N,SUB1,N2)                                      MEXP2     30
      CALL MULT(Q,SUB1,N,SUB2,N2)                                       MEXP2     31
C    SUB2 NOW HOLDS EXP(A*TIME) IN ORIGINAL BASIS FORM                  MEXP2     32
      RETURN                                                            MEXP2     33
      END                                                               MEXP2     34
```

```
[illegible] LONG OT ARG--COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTNS I ANSI=O,L=OUTS,LO=S/-A.

            SUBROUTINE FUNCT(R,S,T,F,MM)
            DIMENSION T(MM,MM),F(MM,MM)
            INTEGER R,S
            REAL EXP
            DO 10  I=R,S
      C THE IF-BLOCK GIVES 14-DIGIT ACCURACY WITHOUT UNDERFLOW
            IF( T(I,I) .LT. -43.) THEN
               F(I,I)=0.
            ELSE
              F(I,I)=EXP( T(I,I) )
            END IF
         10 CONTINUE
      C   PROCESS THE KTH SUPERDIAGONAL
            N=S-R+1
            NN=N-1
      C    NN = NUMBER OF SUPERDIAGONALS IN THE BLOCK
            IF(NN .EQ. 0) RETURN
            DO 13  K=1,NN
            LL=S-K
               DO 12  I=R,LL
               DIFF=T(I,I)-T(I+K,I+[illegible]
               IF(ABS(DIFF) .EQ. 0.0) GO TO 14
               G=T(I,I+K)*(F(I,I)-F(I+K,I+K))
               KK=K-1
               IF(KK .EQ. 0) GO TO 12
                  DO 11  M=1,KK
         11  G=G+(F(I,I+M)*T(I+M,I+K)-T(I,I+K-M)*F(I+K-M,I+K))
         12  F(I,I+K)=G/DIFF
         13 CONTINUE
            RETURN
         14 MM= -MM
            RETURN
            END
```

```
      TINE HQR         74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587            84/11/19  13 14 29          PAGE      1
           ARG= COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
         ANSI 0 L-OUTS LO=S/-A.

            SUBROUTINE HQR(IGH,H,Z,IERR,N2)                                               HQR        2
            INTEGER I,J,K,L,M,N,EN,II,JJ,LL,MM,NA,NM,NN,N2,                               HQR        3
     X           IGH,ITS,LOW,MP2,ENM2,IERR,MINO                                           HQR        4
            REAL H(N2,N2),Z(N2,N2)                                                        HQR        5
            REAL P,Q,R,S,T,W,X,Y,RA,SA,VI,VR,ZZ,NORM                                      HQR        6
            REAL MACHEP,SQRT,ABS,SIGN,REAL,AIMAG                                          HQR        7
            LOGICAL NOTLAS                                                                HQR        8
            COMPLEX Z3,CMPLX                                                              HQR        9
      C                                                                                   HQR       10
      C                                                                                   HQR       11
      C                                                                                   HQR       12
      C   MACHEP IS A PARAMETER THAT SPECIFIES PRECISION                                  HQR       13
            MACHEP=0.000000000001                                                         HQR       14
            NM=IGH                                                                        HQR       15
            N=IGH                                                                         HQR       16
            LOW= 1                                                                        HQR       17
            IERR= 0                                                                       HQR       18
            NORM= 0.                                                                      HQR       19
            K= 1                                                                          HQR       20
      C   COMPUTE MATRIX NORM                                                             HQR       21
            DO 50  I = 1,N                                                                HQR       22
               DO 40  J = K,N                                                             HQR       23
         40    NORM = NORM + ABS(H(I,J))                                                  HQR       24
               K = I                                                                      HQR       25
         50 CONTINUE                                                                      HQR       26
            EN = IGH                                                                      HQR       27
            T = 0.0                                                                       HQR       28
      C     *** SEARCH FOR NEXT EIGENVALUES***                                            HQR       29
         60 IF(EN .LT. LOW) GO TO 1001                                                    HQR       30
            ITS = 0                                                                       HQR       31
            NA = EN - 1                                                                   HQR       32
            ENM2 = NA - 1                                                                 HQR       33
      C     ***LOOK FOR SINGLE SMALL SUB-DIAGONAL ELEMENT                                 HQR       34
      C        FOR L=EN STEP -1 UNTIL LOW DO ***                                          HQR       35
         70 DO 80  LL = LOW, EN                                                           HQR       36
               L = EN + LOW - LL                                                          HQR       37
               IF(L .EQ. LOW) GO TO 100                                                   HQR       38
               S = ABS(H(L-1,L-1)) + ABS(H(L,L))                                          HQR       39
            IF(S .EQ. 0.0) S = NORM                                                       HQR       40
            IF(ABS(H(L,L-1)) .LE. MACHEP * S) GO TO 100                                   HQR       41
         80 CONTINUE                                                                      HQR       42
      C     *** FORM SHIFT ***                                                            HQR       43
        100 X = H(EN,EN)                                                                  HQR       44
            IF(L .EQ. EN) GO TO 270                                                       HQR       45
            Y = H(NA,NA)                                                                  HQR       46
            W = H(EN,NA) * H(NA,EN)                                                       HQR       47
            IF(L .EQ. NA) GO TO 280                                                       HQR       48
            IF(ITS .EQ. 30) GO TO 1000                                                    HQR       49
            IF(ITS .NE. 10 .AND. ITS .NE. 20) GO TO 130                                   HQR       50
      C     *** FORM EXCEPTIONAL SHIFT ***                                                HQR       51
            T = T + X                                                                     HQR       52
            DO 120  I = LOW,EN                                                            HQR       53
        120 H(I,I) = H(I,I) - X                                                           HQR       54
            S = ABS(H(EN,NA)) + ABS(H(NA,ENM2))                                           HQR       55
            X = 0.75 * S                                                                  HQR       56
```

```
            Y = X
            W = 0.4375 * S * S
      130 ITS = ITS + 1
C     *** LOOK FOR TWO CONSECUTIVE SMALL SUB-DIAGONAL ELEMENTS***
C     *** FOR M=EN-2 STEP -1 UNTIL L DO ***
          DO 140  MM = L, ENM2
             M = ENM2 + L - MM
             ZZ = H(M,M)
             R = X - ZZ
             S = Y - ZZ
             P = (R * S - W) / H(M+1,M) + H(M,M+1)
             Q = H(M+1,M+1) - ZZ - R - S
             R = H(M+2,M+1)
             S = ABS(P) + ABS(Q) + ABS(R)
             P = P/S
             Q = Q/S
             R = R/S
             IF(M .EQ. L) GO TO 150
             IF(ABS(H(M,M-1))*(ABS(Q) + ABS(R)) .LE. MACHEP*ABS(P)
     X       * (ABS(H(M-1,M-1))+ABS(ZZ)+ABS(H(M+1,M+1)))) GO TO 150
      140 CONTINUE
      150 MP2 = M + 2
          DO 160  I = MP2, EN
             H(I,I-2) = 0.0
             IF(I .EQ. MP2) GO TO 160
             H(I,I-3) = 0.0
      160 CONTINUE
C     * DOUBLE QR STEP INVOLVING ROWS L TO EN AND COLUMNS M TO EN *
          DO 260  K = M, NA
             NOTLAS = K .NE. NA
             IF (K .EQ. M) GO TO 170
             P = H(K,K-1)
             Q = H(K+1,K-1)
             R = 0.0
             IF (NOTLAS) R = H(K+2,K-1)
             X = ABS(P) + ABS(Q) + ABS(R)
             IF(X .EQ. 0.0) GO TO 260
             P = P/X
             Q = Q/X
             R = R/X
      170 S = SIGN(SQRT(P*P+Q*Q+R*R),P)
             IF(K.EQ. M) GO TO 180
             H(K,K-1) = -S * X
             GO TO 190
      180    IF(L .NE. M) H(K,K-1) = -H(K,K-1)
      190    P = P + S
             X = P/S
             Y = Q/S
             ZZ = R/S
             Q = Q/P
             R = R/P
C     *** ROW MODIFICATION ***
             DO 210  J = K, N
                P = H(K,J) +Q * H(K+1,J)
                IF(.NOT. NOTLAS) GO TO 200
                P = P + R * H(K+2,J)
                H(K+2,J) = H(K+2,J) - P * ZZ
```

AD-A153 039 HEATING PARAMETER ESTIMATION USING COAXIAL THERMOCOUPLE 2/2
GAGES IN WIND TUN..(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. N T CAHOON
UNCLASSIFIED DEC 84 AFIT/GAE/AA/84D-3 F/G 9/2 NL

END
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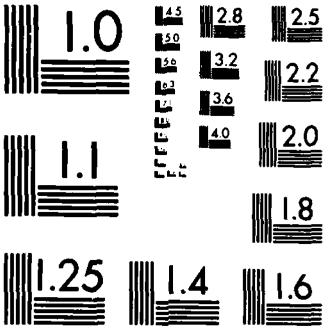

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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  200         H(K+1,J) = H(K+1,J) - P * Y                        HQR     114
              H(K,J) = H(K,J) - P * X                            HQR     115
  210      CONTINUE                                              HQR     116
           J = MINO(EN,K+3)                                      HQR     117
C     *** COLUMN MODIFICATION ***                                HQR     118
           DO 230  I = 1, J                                      HQR     119
              P = X * H(I,K) + Y * H(I,K+1)                      HQR     120
              IF( .NOT. NOTLAS) GO TO 220                        HQR     121
              P = P + ZZ * H(I,K+2)                              HQR     122
              H(I,K+2) = H(I,K+2) - P * R                        HQR     123
  220          H(I,K+1) = H(I,K+1) - P * Q                       HQR     124
              H(I,K) = H(I,K) - P                                HQR     125
  230      CONTINUE                                              HQR     126
C     *** ACCUMULATE TRANSFORMATIONS ***                         HQR     127
           DO 250  I = LOW, IGH                                  HQR     128
              P = X * Z(I,K) + Y * Z(I,K+1)                      HQR     129
              IF( .NOT. NOTLAS) GO TO 240                        HQR     130
              P = P + ZZ * Z(I,K+2)                              HQR     131
              Z(I,K+2) = Z(I,K+2) - P * R                        HQR     132
  240         Z(I,K+1) = Z(I,K+1) - P * Q                        HQR     133
              Z(I,K) = Z(I,K) - P                                HQR     134
  250      CONTINUE                                              HQR     135
  260 CONTINUE                                                   HQR     136
      GO TO 70                                                   HQR     137
C     *** ONE ROOT FOUND ***                                     HQR     138
  270 H(EN,EN) = X + T                                           HQR     139
      EN = NA                                                    HQR     140
      GO TO 60                                                   HQR     141
C     *** TWO ROOTS FOUND ***                                    HQR     142
  280 P = (Y - X)/ 2.0                                           HQR     143
      Q = P*P + W                                                HQR     144
      ZZ = SQRT(ABS(Q))                                          HQR     145
      H(EN,EN) = X + T                                           HQR     146
      X = H(EN,EN)                                               HQR     147
      H(NA,NA) = Y + T                                           HQR     148
      IF(Q .LT. 0.0) GO TO 320                                   HQR     149
C     *** REAL PAIR ***                                          HQR     150
      ZZ = P + SIGN(ZZ,P)                                        HQR     151
      X = H(EN,NA)                                               HQR     152
      S = ABS(X) + ABS(ZZ)                                       HQR     153
      P = X / S                                                  HQR     154
      Q = ZZ / S                                                 HQR     155
      R = SQRT(P*P + Q*Q)                                        HQR     156
      P = P / R                                                  HQR     157
      Q = Q / R                                                  HQR     158
C     *** ROW MODIFICATION ***                                   HQR     159
      DO 290  J = NA, N                                          HQR     160
         ZZ = H(NA,J)                                            HQR     161
         H(NA,J) = Q*ZZ + P*H(EN,J)                              HQR     162
         H(EN,J) = Q*H(EN,J) - P*ZZ                              HQR     163
  290 CONTINUE                                                   HQR     164
C     *** COLUMN MODIFICATION ***                                HQR     165
      DO 300  I = 1, EN                                          HQR     166
         ZZ = H(I,NA)                                            HQR     167
         H(I,NA) = Q*ZZ + P*H(I,EN)                              HQR     168
         H(I,EN) = Q*H(I,EN) - P*ZZ                              HQR     169
  300 CONTINUE                                                   HQR     170
```

```
170      C     *** ACCUMULATE TRANSFORMATIONS ***                               HQR      171
171            DO 310  I = LOW, IGH                                             HQR      172
172               ZZ = Z(I,NA)                                                  HQR      173
173               Z(I,NA) = Q*ZZ + P*Z(I,EN)                                    HQR      174
174               Z(I,EN) = Q*Z(I,EN) - P*ZZ                                    HQR      175
175        310 CONTINUE                                                         HQR      176
176            GO TO 330                                                        HQR      177
177      C     *** COMPLEX PAIR ***                                             HQR      178
178        320 CONTINUE                                                         HQR      179
179        330 EN = ENM2                                                        HQR      180
180            GO TO 60                                                         HQR      181
181      C   * SET ERROR - NO CONVERGENCE TO EIGENVALUE AFTER 30 ITERATIONS     HQR      182
182       1000 IERR = EN                                                        HQR      183
183       1001 RETURN                                                           HQR      184
184            END                                                              HQR      185
```

```
SUBROUTINE MULT2       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


 1                SUBROUTINE MULT2(N,X,Y,Z,N2)                                     MULT2        2
 2            C   COMPUTES Z=X*Y"                                                  MULT2        3
 3                DIMENSION X(N2,N2),Y(N2,N2),Z(N2,N2)                             MULT2        4
 4                DO 20  I=1,N                                                     MULT2        5
 5                DO 20  J=1,N                                                     MULT2        6
 6                Z(I,J)= 0.                                                       MULT2        7
 7                DO 20  K=1,N                                                     MULT2        8
 8             20 Z(I,J)= Z(I,J)+X(I,K)*Y(J,K)                                     MULT2        9
 9                RETURN                                                           MULT2       10
10                END                                                              MULT2       11
```

```
SUBROUTINE TRI        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                SUBROUTINE TRI(N,Q,X,W,Z,N2)                                 TRI         2
          C   COMPUTES Z=XQX"                                                TRI         3
                DIMENSION Q(N2,N2),X(N2,N2),W(N2,N2),Z(N2,N2)                TRI         4
                CALL MULT(X,Q,N,W,N2)                                        TRI         5
          C   X*Q IS STORED IN W                                             TRI         6
                CALL MULT2(N,W,X,Z,N2)                                       TRI         7
          C   Z=W*X"                                                         TRI         8
                RETURN                                                       TRI         9
                END                                                          TRI        10
```

```
      SUBROUTINE SGEFA(A,LDA,N,IPVT,INFO)                         SGEFA     2
      INTEGER LDA,N,IPVT(1),INFO                                  SGEFA     3
      REAL A(LDA,1)                                               SGEFA     4
C                                                                 SGEFA     5
C   SGEFA FACTORS A REAL MATRIX BY GAUSSIAN ELIMINATION.          SGEFA     6
C                                                                 SGEFA     7
C   ON ENTRY:                                                     SGEFA     8
C   A: THE MATRIX TO BE FACTORED                                  SGEFA     9
C   LDA: THE LEADING DIMENSION OF THE ARRAY A                     SGEFA    10
C   N: THE ORDER OF THE ARRAY A                                   SGEFA    11
C                                                                 SGEFA    12
C   ON RETURN                                                     SGEFA    13
C   A: AN UPPER TRIANGULAR MATRIX AND THE MULTIPLIERS             SGEFA    14
C      WHICH WERE USED TO OBTAIN IT.                              SGEFA    15
C   IPVT: AN INTEGER VECTOR OF PIVOT INDICES                      SGEFA    16
C   INFO: = 0  NORMAL VALUE.                                      SGEFA    17
C         = K  IF U(K,K).EQ. 0.0   THIS IS NOT AN ERROR           SGEFA    18
C              CONDITION FOR SGEFA, BUT INDICATES THAT            SGEFA    19
C              SGEDI WILL DIVIDE BY ZERO WHEN CALLED.             SGEFA    20
C   THIS IS FROM LINPACK USER'S GUIDE,VERSION 08/14/78            SGEFA    21
      REAL T                                                      SGEFA    22
      INTEGER ISAMAX,J,K,KP1,L,NM1                                SGEFA    23
C                                                                 SGEFA    24
C   GAUSSIAN ELIMINATION WITH PARTIAL PIVOTING                    SGEFA    25
      INFO= 0                                                     SGEFA    26
      NM1= N-1                                                    SGEFA    27
      IF(NM1 .LT. 1) GO TO 70                                     SGEFA    28
      DO 60  K=1,NM1                                              SGEFA    29
      KP1= K+1                                                    SGEFA    30
C                                                                 SGEFA    31
C   FIND L = PIVOT INDEX                                          SGEFA    32
      L= ISAMAX(N-K+1,A(K,K),1)+K-1                               SGEFA    33
      IPVT(K)= L                                                  SGEFA    34
C                                                                 SGEFA    35
C   ZERO PIVOT IMPLIES THIS COLUMN IS TRIANGULARIZED              SGEFA    36
      IF(A(L,K) .EQ. 0.0E0) GO TO 40                              SGEFA    37
C                                                                 SGEFA    38
C   INTERCHANGE IF NECESSARY                                      SGEFA    39
      IF(L .EQ. K) GO TO 10                                       SGEFA    40
      T=A(L,K)                                                    SGEFA    41
      A(L,K)= A(K,K)                                              SGEFA    42
      A(K,K)= T                                                   SGEFA    43
   10 CONTINUE                                                    SGEFA    44
C                                                                 SGEFA    45
C   COMPUTE MULTIPLIERS                                           SGEFA    46
      T= -1.0E0/A(K,K)                                            SGEFA    47
      CALL SSCAL(N-K,T,A(K+1,K),1)                                SGEFA    48
C                                                                 SGEFA    49
C   ROW ELIMINATION WITH COLUMN INDEXING                          SGEFA    50
      DO 30  J=KP1,N                                              SGEFA    51
      T= A(L,J)                                                   SGEFA    52
      IF(L .EQ. K) GO TO 20                                       SGEFA    53
      A(L,J)= A(K,J)                                              SGEFA    54
      A(K,J)= T                                                   SGEFA    55
   20 CONTINUE                                                    SGEFA    56
```

```
      CALL SAXPY(N-K,T,A(K+1,K),1,A(K+1,J),1)                       SGEFA     57
   30 CONTINUE                                                      SGEFA     58
      GO TO 50                                                      SGEFA     59
   40 CONTINUE                                                      SGEFA     60
      INFO= K                                                       SGEFA     61
   50 CONTINUE                                                      SGEFA     62
   60 CONTINUE                                                      SGEFA     63
   70 CONTINUE                                                      SGEFA     64
      IPVT(N)= N                                                    SGEFA     65
      IF(A(N,N) .EQ. 0.0E0) INFO= N                                 SGEFA     66
      RETURN                                                        SGEFA     67
      END                                                           SGEFA     68
```

```
      SUBROUTINE SGEDI(A,LDA,N,IPVT,WORK)                               SGEDI       2
      INTEGER LDA,N,IPVT(1)                                             SGEDI       3
      REAL A(LDA,1),WORK(1)                                             SGEDI       4
C                                                                       SGEDI       5
C   SGEDI COMPUTES INVERSE OF MATRIX A USING                            SGEDI       6
C    FACTORS COMPUTED BY SGEFA.                                         SGEDI       7
C                                                                       SGEDI       8
C   ON ENTRY:                                                           SGEDI       9
C   A: THE OUTPUT FROM SGEFA, REAL(LDA,N)                               SGEDI      10
C   LDA: THE LEADING DIMENSION OF ARRAY A                               SGEDI      11
C   N: THE ORDER OF MATRIX A                                            SGEDI      12
C   IPVT: THE PIVOT VECTOR FROM SGEFA,INTEGER(N)                        SGEDI      13
C   WORK: WORK VECTOR,CONTENTS DESTROYED,REAL(N)                        SGEDI      14
C                                                                       SGEDI      15
C   ON RETURN:                                                          SGEDI      16
C   A: INVERSE OF THE ORIGINAL MATRIX                                   SGEDI      17
C                                                                       SGEDI      18
C   ERROR CONDITION: A DIVISION BY ZERO WILL OCCUR IF THE               SGEDI      19
C   INPUT FACTOR CONTAINS A ZERO ON THE DIAGONAL.                       SGEDI      20
C   IT WILL NOT OCCUR IF SGEFA HAS SET INFO=0                           SGEDI      21
C                                                                       SGEDI      22
C   THIS IS FROM LINPACK USER'S GUIDE,VERSION 08/14/78                  SGEDI      23
      REAL T                                                            SGEDI      24
      INTEGER I,J,K,KB,KP1,L,NM1                                        SGEDI      25
C                                                                       SGEDI      26
C   COMPUTE INVERSE                                                     SGEDI      27
      DO 100  K=1,N                                                     SGEDI      28
      A(K,K)= 1.0E0/A(K,K)                                              SGEDI      29
      T= -A(K,K)                                                        SGEDI      30
      CALL SSCAL(K-1,T,A(1,K),1)                                        SGEDI      31
      KP1= K+1                                                          SGEDI      32
      IF(N .LT. KP1) GO TO 80                                           SGEDI      33
      DO 80  J=KP1,N                                                    SGEDI      34
      T= A(K,J)                                                         SGEDI      35
      A(K,J)= 0.0E0                                                     SGEDI      36
      CALL SAXPY(K,T,A(1,K),1,A(1,J),1)                                 SGEDI      37
   80 CONTINUE                                                          SGEDI      38
   90 CONTINUE                                                          SGEDI      39
  100 CONTINUE                                                          SGEDI      40
C                                                                       SGEDI      41
C   FORM INVERSE(U)*INVERSE(L)                                          SGEDI      42
      NM1= N-1                                                          SGEDI      43
      IF(NM1 .LT. 1) GO TO 140                                          SGEDI      44
      DO 130  KB=1,NM1                                                  SGEDI      45
      K= N-KB                                                           SGEDI      46
      KP1= K+1                                                          SGEDI      47
      DO 110  I=KP1,N                                                   SGEDI      48
      WORK(I)= A(I,K)                                                   SGEDI      49
      A(I,K)= 0.0E0                                                     SGEDI      50
  110 CONTINUE                                                          SGEDI      51
      DO 120  J=KP1,N                                                   SGEDI      52
      T= WORK(J)                                                        SGEDI      53
      CALL SAXPY(N,T,A(1,J),1,A(1,K),1)                                 SGEDI      54
  120 CONTINUE                                                          SGEDI      55
      L= IPVT(K)                                                        SGEDI      56
```

```
            IF(L .NE. K) CALL SSWAP(N,A(1,K),1,A(1,L),1)                  SGEDI      57
        130 CONTINUE                                                      SGEDI      58
        140 CONTINUE                                                      SGEDI      59
            RETURN                                                        SGEDI      60
            END                                                           SGEDI      61
```

```
 FUNCTION ISAMAX     74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587       84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      INTEGER FUNCTION ISAMAX(N,SX,INCX)                                ISAMAX 2
C   ISAMAX FINDS INDEX OF ELEMENT WITH MAX. ABSOLUTE VALUE.             ISAMAX 3
C   LINPACK USER'S GUIDE, VERSION 03/11/78                              ISAMAX 4
      REAL SX(1),SMAX                                                   ISAMAX 5
      INTEGER I,INCX,IX,N                                               ISAMAX 6
      ISAMAX= 0                                                         ISAMAX 7
      IF(N .LT. 1) RETURN                                               ISAMAX 8
      ISAMAX= 1                                                         ISAMAX 9
      IF(N .EQ. 1) RETURN                                               ISAMAX10
      IF(INCX .EQ. 1) GO TO 20                                          ISAMAX11
C                                                                       ISAMAX12
C   CODE FOR INCREMENT NOT EQUAL TO 1                                   ISAMAX13
      IX= 1                                                             ISAMAX14
      SMAX= ABS(SX(1))                                                  ISAMAX15
      IX= IX+INCX                                                       ISAMAX16
      DO 10  I=2,N                                                      ISAMAX17
      IF(ABS(SX(IX)).LE.SMAX) GO TO 5                                   ISAMAX18
      ISAMAX= I                                                         ISAMAX19
      SMAX= ABS(SX(IX))                                                 ISAMAX20
    5 IX= IX+INCX                                                       ISAMAX21
   10 CONTINUE                                                          ISAMAX22
      RETURN                                                            ISAMAX23
C                                                                       ISAMAX24
C   CODE FOR INCREMENT EQUAL TO 1                                       ISAMAX25
   20 SMAX= ABS(SX(1))                                                  ISAMAX26
      DO 30  I=2,N                                                      ISAMAX27
      IF(ABS(SX(I)).LE.SMAX) GO TO 30                                   ISAMAX28
      ISAMAX= I                                                         ISAMAX29
      SMAX= ABS(SX(I))                                                  ISAMAX30
   30 CONTINUE                                                          ISAMAX31
      RETURN                                                            ISAMAX32
      END                                                               ISAMAX33
```

```
SUBROUTINE SAXPY       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587         84/11/19. 13.14.29          PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      SUBROUTINE SAXPY(N,SA,SX,INCX,SY,INCY)                            SAXPY      2
C   CONSTANT TIMES A VECTOR PLUS A VECTOR.                              SAXPY      3
C   USES UNROLLED LOOP FOR INCREMENTS= 1.                               SAXPY      4
C   FROM LINPACK USER'S GUIDE,VERSION 03/11/78                          SAXPY      5
      REAL SX(1),SY(1),SA                                               SAXPY      6
      INTEGER I,INCX,INCY,IX,IY,M,MP1,N                                 SAXPY      7
      IF(N .LE. 0) RETURN                                               SAXPY      8
      IF(SA .EQ. 0.0) RETURN                                            SAXPY      9
      IF(INCX .EQ. 1 .AND. INCY .EQ. 1) GO TO 20                        SAXPY     10
C                                                                       SAXPY     11
C   CODE FOR UNEQUAL INCREMENTS OR FOR                                  SAXPY     12
C     EQUAL INCREMENTS NOT EQUAL TO 1                                   SAXPY     13
      IX= 1                                                             SAXPY     14
      IY= 1                                                             SAXPY     15
      IF(INCX.LT.0)  IX= (-N+1)*INCX +1                                 SAXPY     16
      IF(INCY.LT.0)  IY= (-N+1)*INCY +1                                 SAXPY     17
      DO 10  I=1,N                                                      SAXPY     18
      SY(IY)= SY(IY)+ SA*SX(IX)                                         SAXPY     19
      IX= IX+INCX                                                       SAXPY     20
      IY= IY+INCY                                                       SAXPY     21
   10 CONTINUE                                                          SAXPY     22
      RETURN                                                            SAXPY     23
C                                                                       SAXPY     24
C   CODE FOR BOTH INCREMENTS EQUAL TO 1                                 SAXPY     25
C   CLEAN-UP LOOP                                                       SAXPY     26
   20 M=MOD(N,4)                                                        SAXPY     27
      IF(M .EQ. 0) GO TO 40                                             SAXPY     28
      DO 30  I=1,M                                                      SAXPY     29
      SY(I)= SY(I)+ SA*SX(I)                                            SAXPY     30
   30 CONTINUE                                                          SAXPY     31
      IF(N .LT. 4) RETURN                                               SAXPY     32
   40 MP1= M+1                                                          SAXPY     33
      DO 50  I=MP1,N,4                                                  SAXPY     34
      SY(I)= SY(I)+ SA*SX(I)                                            SAXPY     35
      SY(I+1)= SY(I+1)+ SA*SX(I+1)                                      SAXPY     36
      SY(I+2)= SY(I+2)+ SA*SX(I+2)                                      SAXPY     37
      SY(I+3)= SY(I+3)+ SA*SX(I+3)                                      SAXPY     38
   50 CONTINUE                                                          SAXPY     39
      RETURN                                                            SAXPY     40
      END                                                               SAXPY     41
```

```
SUBROUTINE SSCAL       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587         84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      SUBROUTINE SSCAL(N,SA,SX,INCX)                                     SSCAL       2
C  SCALES A VECTOR BY A CONSTANT.                                        SSCAL       3
C  USES UNROLLED LOOPS FOR INCREMENT EQUAL TO 1.                         SSCAL       4
C  LINPACK USER'S GUIDE,VERSION 03/11/78                                 SSCAL       5
C                                                                        SSCAL       6
      REAL SA,SX(1)                                                      SSCAL       7
      INTEGER I,INCX,M,MP1,N,NINCX                                       SSCAL       8
      IF(N .LE. 0) RETURN                                                SSCAL       9
      IF(INCX .EQ. 1) GO TO 20                                           SSCAL      10
C                                                                        SSCAL      11
C  CODE FOR INCREMENT NOT EQUAL TO 1                                     SSCAL      12
      NINCX= N*INCX                                                      SSCAL      13
      DO 10  I=1,NINCX,INCX                                              SSCAL      14
      SX(I)= SA*SX(I)                                                    SSCAL      15
   10 CONTINUE                                                           SSCAL      16
      RETURN                                                             SSCAL      17
C                                                                        SSCAL      18
C  CODE FOR INCREMENT EQUAL TO 1.                                        SSCAL      19
C  CLEAN-UP LOOP                                                         SSCAL      20
   20 M= MOD(N,5)                                                        SSCAL      21
      IF(M .EQ. 0) GO TO 40                                              SSCAL      22
      DO 30  I=1,M                                                       SSCAL      23
      SX(I)= SA*SX(I)                                                    SSCAL      24
   30 CONTINUE                                                           SSCAL      25
      IF(N .LT. 5) RETURN                                                SSCAL      26
   40 MP1= M+1                                                           SSCAL      27
      DO 50  I=MP1,N,5                                                   SSCAL      28
      SX(I)= SA*SX(I)                                                    SSCAL      29
      SX(I+1)= SA*SX(I+1)                                                SSCAL      30
      SX(I+2)= SA*SX(I+2)                                                SSCAL      31
      SX(I+3)= SA*SX(I+3)                                                SSCAL      32
      SX(I+4)= SA*SX(I+4)                                                SSCAL      33
   50 CONTINUE                                                           SSCAL      34
      RETURN                                                             SSCAL      35
      END                                                                SSCAL      36
```

```
SUBROUTINE SSWAP       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

      SUBROUTINE SSWAP(N,SX,INCX,SY,INCY)                               SSWAP      2
C   INTERCHANGES TWO VECTORS.                                           SSWAP      3
C   USES UNROLLED LOOPS FOR INCREMENTS EQUAL TO 1.                      SSWAP      4
C   LINPACK USER'S GUIDE,VERSION 03/11/78                               SSWAP      5
C                                                                       SSWAP      6
      REAL SX(1),SY(1),STEMP                                            SSWAP      7
      INTEGER I,INCX,INCY,IX,IY,M,MP1,N                                 SSWAP      8
      IF(N .LE. 0) RETURN                                               SSWAP      9
      IF(INCX .EQ. 1 .AND. INCY .EQ. 1) GO TO 20                        SSWAP     10
C                                                                       SSWAP     11
C   CODE FOR UNEQUAL INCREMENTS OR EQUAL INCREMENTS NOT EQUAL TO 1      SSWAP     12
      IX= 1                                                             SSWAP     13
      IY= 1                                                             SSWAP     14
      IF(INCX .LT. 0)  IX= (-N+1)*INCX+1                                SSWAP     15
      IF(INCY .LT. 0)  IY= (-N+1)*INCY+1                                SSWAP     16
      DO 10  I=1,N                                                      SSWAP     17
      STEMP= SX(IX)                                                     SSWAP     18
      SX(IX)= SY(IY)                                                    SSWAP     19
      SY(IY)= STEMP                                                     SSWAP     20
      IX= IX+INCX                                                       SSWAP     21
      IY= IY+INCY                                                       SSWAP     22
   10 CONTINUE                                                          SSWAP     23
      RETURN                                                            SSWAP     24
C                                                                       SSWAP     25
C   CODE FOR BOTH INCREMENTS EQUAL TO 1.                                SSWAP     26
C   CLEAN-UP LOOP                                                       SSWAP     27
   20 M= MOD(N,3)                                                       SSWAP     28
      IF(M .EQ. 0) GO TO 40                                             SSWAP     29
      DO 30  I=1,M                                                      SSWAP     30
      STEMP= SX(I)                                                      SSWAP     31
      SX(I)= SY(I)                                                      SSWAP     32
      SY(I)= STEMP                                                      SSWAP     33
   30 CONTINUE                                                          SSWAP     34
      IF(N .LT. 3) RETURN                                               SSWAP     35
   40 MP1= M+1                                                          SSWAP     36
      DO 50  I=MP1,N,3                                                  SSWAP     37
      STEMP= SX(I)                                                      SSWAP     38
      SX(I)= SY(I)                                                      SSWAP     39
      SY(I)= STEMP                                                      SSWAP     40
      STEMP= SX(I+1)                                                    SSWAP     41
      SX(I+1)= SY(I+1)                                                  SSWAP     42
      SY(I+1)= STEMP                                                    SSWAP     43
      STEMP= SX(I+2)                                                    SSWAP     44
      SX(I+2)= SY(I+2)                                                  SSWAP     45
      SY(I+2)= STEMP                                                    SSWAP     46
   50 CONTINUE                                                          SSWAP     47
      RETURN                                                            SSWAP     48
      END                                                               SSWAP     49
```

```
SUBROUTINE FLINE       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5.I,ANSI=0,L=OUTS,LO=S/-A.


                  SUBROUTINE FLINE(M,TSCALE,TMIN,I,ASCALE,AMIN,AYL)                     FLINE       2
                  DIMENSION U(12)                                                       FLINE       3
                  EQUIVALENCE (T,U(1))                                                  FLINE       4
                  DATA IUNIT/12/                                                        FLINE       5
                  REWIND IUNIT                                                          FLINE       6
                  II=0                                                                  FLINE       7
             100  READ(IUNIT,1000,END=190)U                                             FLINE       8
            1000  FORMAT(6E13.7)                                                        FLINE       9
                  XO=(U(M)-TMIN)/TSCALE                                                 FLINE      10
                  YO=(U(I)-AMIN)/ASCALE+AYL                                             FLINE      11
                  II=II+1                                                               FLINE      12
                  IF(II.EQ.1)CALL PLOT(XO,YO,3)                                         FLINE      13
                  CALL PLOT(XO,YO,2)                                                    FLINE      14
                  GO TO 100                                                             FLINE      15
             190  RETURN                                                                FLINE      16
                  END                                                                   FLINE      17
```

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SUBROUTINE FLINES      74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587         84/11/19. 13.14.29         PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


                SUBROUTINE FLINES(M,TSCALE,TMIN,I,ASCALE,AMIN,AYL,HT,ISKIP,NCHAR)  FLINES       2
                DIMENSION U(12)                                                   FLINES       3
                EQUIVALENCE (T,U(1))                                              FLINES       4
                DATA IUNIT/12/                                                    FLINES       5
                REWIND IUNIT                                                      FLINES       6
                II=0                                                              FLINES       7
          100   READ(IUNIT,1000,END=190)U                                         FLINES       8
          1000  FORMAT(6E13.7)                                                    FLINES       9
                XO=(U(M)-TMIN)/TSCALE                                             FLINES      10
                YO=(U(I)-AMIN)/ASCALE+AYL                                         FLINES      11
                II=II+1                                                           FLINES      12
                III=((II/ISKIP))*ISKIP                                            FLINES      13
                IF(II.NE.III)GO TO 100                                            FLINES      14
                CALL SYMBOL(XO,YO,HT,NCHAR,0.,-1)                                 FLINES      15
                GO TO 100                                                         FLINES      16
          190   CONTINUE                                                          FLINES      17
                RETURN                                                            FLINES      18
                END                                                               FLINES      19
```

```
C  START PLOT SEQUENCE                                                  FPLOT     51
      HT=.07                                                            FPLOT     52
      CALL PLOT(4.,.5,-3)                                               FPLOT     53
C                                                                       FPLOT     54
      YLAB="T2(DEG F )"                                                 FPLOT     55
      TLAB="TIME(SEC) "                                                 FPLOT     56
      CALL AXIS(0.,0.,TLAB,-10,TAXL,0.,TMIN,TSCALE)                     FPLOT     57
      CALL AXIS(0.,0.,YLAB, 10,YAXL,90.,YMIN,YSCALE)                    FPLOT     58
C  4 IN CALL POINTS TO 4TH VARIABLE IN READ,Y                           FPLOT     59
      CALL FLINE(1,TSCALE,TMIN,4,YSCALE,YMIN,0.)                        FPLOT     60
C  5 POINTS TO Z                                                        FPLOT     61
      CALL FLINES(1,TSCALE,TMIN,5,YSCALE,YMIN,0.,HT,1,3)                FPLOT     62
C  PLOT DEPENDENT VARIABLE                                              FPLOT     63
      AYL=YAXL+1.                                                       FPLOT     64
      ALAB="ALPHA(DEG)"                                                 FPLOT     65
      CALL AXIS(0.,AYL,ALAB,10,AAXL,90.,AMIN,ASCALE)                    FPLOT     66
C 6 POINTS TO A                                                         FPLOT     67
      CALL FLINE(1,TSCALE,TMIN,6,ASCALE,AMIN,AYL)                       FPLOT     68
C                                                                       FPLOT     69
C                                                                       FPLOT     70
C  NEXT PLOT SEQUENCE                                                   FPLOT     71
      AXO=TAXL+2.                                                       FPLOT     72
      CALL PLOT(AXO,0.,-3)                                              FPLOT     73
      YLAB="   Q/QREF "                                                 FPLOT     74
      YAXL=10.                                                          FPLOT     75
      YSCALE=.1                                                         FPLOT     76
      YMIN=0.                                                           FPLOT     77
      IFOX(1)=IFX(4)                                                    HAROLD    56
      DO 32 I=2,6                                                       HAROLD    57
       IFOX(I)=IFX(I+9)                                                 HAROLD    58
  32   CONTINUE                                                         HAROLD    59
      DO 200 I=1,6                                                      FPLOT     78
      IF(IFOX(I) .EQ. 0)GO TO 200                                       HAROLD    60
      DATA XL/"ALPHA(DEG)","BETA(DEG) ","LOG(RE)   ",                   FPLOT     80
     &"DELE(DEG) ","DELBF(DEG)","  MACH    "/                           FPLOT     81
      DATA XXL/5.,6.,4.,4.,5.,5./                                       FPLOT     82
      DATA XSC/5.,1.,1.,5.,5.,5./                                       FPLOT     83
      DATA XM/20.,-3.,5.,-10.,0.,0./                                    FPLOT     84
      CALL AXIS(0.,0.,YLAB,10,YAXL,90.,YMIN,YSCALE)                     FPLOT     85
      CALL AXIS(0.,0.,XL(I),-10,XXL(I),0.,XM(I),XSC(I))                 FPLOT     86
C  I+5 POINTS TO ALPHA   /    12 POINTS TO Q/QREF                       FPLOT     87
      IPT=I+5                                                           FPLOT     88
      CALL FLINE(IPT,XSC(I),XM(I),12,YSCALE,YMIN,0.)                    FPLOT     89
      CALL PLOT(AXO,0.,-3)                                              FPLOT     90
  200 CONTINUE                                                          FPLOT     91
      CALL PLOTE(N)                                                     FPLOT     92
      RETURN                                                            FPLOT     93
      END                                                               FPLOT     94
```

```
SUBROUTINE FPLOT      74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

            SUBROUTINE FPLOT                                                  FPLOT        2
            COMMON/CFPLOT/IPLOT,TSCALE,TMIN,TAXL,YSCALE,YMIN,YAXL,            FPLOT        3
           $ASCALE,AMIN,AAXL                                                  FPLOT        4
            DIMENSION XL(6),XXL(6),XSC(6),XM(6)                               FPLOT        5
            DIMENSION IFOX(6)                                                 HAROLD      55
            DIMENSION DUM(1024)                                               FPLOT        6
            LOGICAL FAUTO                                                     CPARAM       2
            DIMENSION FAUTO(7)                                                OCT10        2
            DIMENSION QP(5)                                                   UPAUG16      1
            COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),          UPAUG16      2
           &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                   UPAUG16      3
            EQUIVALENCE (HO,QP(1))                                            UPAUG16      4
      C INITIALIZE PLOTS AND WRITE PLOT FILE TO UNIT 2                        FPLOT        8
            CALL PLOTS(DUM,1024,2)                                            FPLOT        9
            CALL FACTOR(.787402)                                              FPLOT       10
            DATA IUNIT/12/                                                    FPLOT       11
            REWIND IUNIT                                                      FPLOT       12
      C FIND MAX AND MINS FOR SCALING                                         FPLOT       13
            DATA TMN,TMX,YMN,YMX/1.E7,0.,5000.,-460./                         FPLOT       14
            DATA AMN,AMX/25.,45./                                             FPLOT       15
      C READ T,USI1,EQUI,USI2,UMEAS,ALPHA                                     FPLOT       16
       100   READ(IUNIT,1000,END=190)T,U,V,Y,Z,A,B,R,DE,DB,DM,QN              FPLOT       17
       1000 FORMAT(6E13.7)                                                    FPLOT       18
            TMN=AMIN1(TMN,T)                                                  FPLOT       19
            TMX=AMAX1(TMX,T)                                                  FPLOT       20
            YMN=AMIN1(YMN,U,V,Y,Z)                                            FPLOT       21
            YMX=AMAX1(YMX,U,V,Y,Z)                                            FPLOT       22
            AMN=AMIN1(AMN,A)                                                  FPLOT       23
            AMX=AMAX1(AMX,A)                                                  FPLOT       24
            GO TO 100                                                         FPLOT       25
       190  CONTINUE                                                          FPLOT       26
            IF(IPLOT.GT.0)GO TO 195                                           FPLOT       27
      C DEFAULT TIME AXIS LENGTH = 4 INCHES                                   FPLOT       28
            TAXL=4.                                                           FPLOT       29
            TSCALE=IFIX(((TMX-TMN)/TAXL)+.999)                                FPLOT       30
            TMIN=TMN                                                          FPLOT       31
      C DEFAULT Y AXIS LENGTH =4 INCHES                                       FPLOT       32
            YAXL=4                                                            FPLOT       33
            DYMIN=25.                                                         FPLOT       34
            YSCALE=DYMIN*IFIX((YMX-YMN)/DYMIN/YAXL+1.999)                     FPLOT       35
            YMIN=YSCALE*IFIX(YMN/YSCALE)                                      FPLOT       36
      C DEFAULT A AXIS LENGTH = 2 INCHES                                      FPLOT       37
            AAXL=2.                                                           FPLOT       38
            DAMIN=5                                                           FPLOT       39
            ASCALE=DAMIN*IFIX((AMX-AMN)/DAMIN/AAXL+1.999)                     FPLOT       40
            AMIN=ASCALE*IFIX(AMN/ASCALE)                                      FPLOT       41
       195  CONTINUE                                                          FPLOT       42
      C                                                                       FPLOT       43
      C SCALE TIME USING INPUT TSCALE ONLY                                     FPLOT       44
      C PUT IN NEGATIVE OR ZERO FOR TMIN AND TAXL                             FPLOT       45
            IF(TAXL.GT.0)GO TO 198                                            FPLOT       46
            TMIN=TMN                                                          FPLOT       47
            TAXL=IFIX((TMX-TMN)/TSCALE+.999)                                  FPLOT       48
       198  CONTINUE                                                          FPLOT       49
      C                                                                       FPLOT       50
```

```
SUBROUTINE MSCALE     74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                    SUBROUTINE MSCALE (N1,N2,A,X,B)                                     MSCALE      2
                    DIMENSION A(1), B(1)                                                MSCALE      3
                    COMMON /MAIN1/ NDIM                                                 MSCALE      4
                    DIMENSION IRAY(6)                                                   SYSTEMC     2
                    DATA IRAY/6* -0/                                                    SYSTEMC     3
                    IRAY(4)=0                                                           SYSTEMC     4
                    JEND=N2*NDIM                                                        MSCALE      5
                    DO 1 I=1,N1                                                         MSCALE      6
                    CALL SYSTEMC(144,IRAY)                                              OCT24       5
                    DO 1 IJ=I,JEND,NDIM                                                 MSCALE      7
                  1 B(IJ)=X*A(IJ)                                                       MSCALE      8
                    RETURN                                                              MSCALE      9
                    END                                                                 MSCALE     10
```

```
SUBROUTINE MMUL       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                    SUBROUTINE MMUL(X,Y,N1,N2,N3,Z)                                       MMUL        2
                    DIMENSION X(1),Y(1),Z(1)                                              MMUL        3
                    COMMON/MAIN1/NDIM                                                     MMUL        4
                    NEND3=NDIM*N3                                                         MMUL        5
                    NEND2=NDIM*N2                                                         MMUL        6
                    DO 1 I=1,N1                                                           MMUL        7
                    DO 1 J=I,NEND3,NDIM                                                   MMUL        8
                    TM=0.                                                                 MMUL        9
                    K=I                                                                   MMUL       10
                    KK=J-I                                                                MMUL       11
                  5 KK=KK+1                                                               MMUL       12
                    TM=TM+X(K)*Y(KK)                                                      MMUL       13
                    K=K+NDIM                                                              MMUL       14
                    IF(K.LE.NEND2) GO TO 5                                                MMUL       15
                  1 Z(J)=TM                                                               MMUL       16
                    RETURN                                                                MMUL       17
                    END                                                                   MMUL       18
```

```
SUBROUTINE MAT4       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587          84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

            SUBROUTINE MAT4 (N1,N2,X,Y,Z)                                MAT4        2
C           Z=YXY" X=X" IS N2XN2, Y IS N1XN2, Z IS N1XN1                 MAT4        3
            DIMENSION X(1), Y(1), Z(1)                                   MAT4        4
            COMMON /MAIN1/ NDIM                                          MAT4        5
            CALL MMUL (Y,X,N1,N2,N2,Z)                                   MAT4        6
            NN2=N2*NDIM                                                  MAT4        7
            DO 3 I=1,N1                                                  MAT4        8
            IM1=I-1                                                      MAT4        9
            II=IM1*NDIM                                                  MAT4       10
            JJ=I+II                                                      MAT4       11
            DO 2 J=I,N1                                                  MAT4       12
            TEMP=0.                                                      MAT4       13
            KK=J                                                         MAT4       14
            DO 1 K=I,NN2,NDIM                                            MAT4       15
            TEMP=TEMP+Y(K)*Z(KK)                                         MAT4       16
          1 KK=KK+NDIM                                                   MAT4       17
            Z(JJ)=TEMP                                                   MAT4       18
          2 JJ=JJ+NDIM                                                   MAT4       19
            JJ=I                                                         MAT4       20
            K=II+1                                                       MAT4       21
            KK=II+IM1                                                    MAT4       22
            DO 3 J=K,KK                                                  MAT4       23
            Z(JJ)=Z(J)                                                   MAT4       24
            JJ=JJ+NDIM                                                   MAT4       25
          3 CONTINUE                                                     MAT4       26
            RETURN                                                       MAT4       27
            END                                                          MAT4       28
```

```
     FUNCTION XNORM       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587          84/11/19. 13.14.29          PAGE       1
    DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
    FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

     1                    FUNCTION XNORM (N,A)                                              XNORM        2
     2            C           COMPUTES AN APPROXIMATION TO NORM OF A-- NOT A BOUND          XNORM        3
     3                    DIMENSION A(1)                                                    XNORM        4
     4                    COMMON /MAIN1/ NDIM                                               XNORM        5
     5                    NDIM1=NDIM+1                                                      XNORM        6
     6                    NN=N*NDIM                                                         XNORM        7
     7                    C1=0.                                                             XNORM        8
     8                    TR=A(1)                                                           XNORM        9
     9                    IF (N.EQ.1) GO TO 4                                               XNORM       10
    10                    I=2                                                               XNORM       11
    11                    DO 2 II=NDIM1,NN,NDIM                                             XNORM       12
    12                    J=II                                                              XNORM       13
    13                    DO 1 JJ=I,II,NDIM                                                 XNORM       14
    14                    C1=C1+ABS(A(J)*A(JJ))                                             XNORM       15
    15                  1 J=J+1                                                             XNORM       16
    16                    TR=TR+A(J)                                                        XNORM       17
    17                  2 I=I+1                                                             XNORM       18
    18                    TR=TR/FLOAT(N)                                                    XNORM       19
    19                    DO 3 II=1,NN,NDIM1                                                XNORM       20
    20                  3 C1=C1+(A(II)-TR)**2                                               XNORM       21
    21                  4 XNORM=ABS(TR)+SQRT(C1)                                            XNORM       22
    22                    RETURN                                                            XNORM       23
    23                    END                                                               XNORM       24
```

```
SUBROUTINE TRANS       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                     SUBROUTINE TRANS(A,N,X)                                               TRANSP       2
                     DIMENSION A(1),X(1)                                                   TRANSP       3
                     COMMON/MAIN1/NDIM                                                     TRANSP       4
                     DO 10 I=1,N                                                           TRANSP       5
                     DO 10 J=1,N                                                           TRANSP       6
                     II=I+NDIM*(J-1)                                                       TRANSP       7
                     JJ=J+NDIM*(I-1)                                                       TRANSP       8
               10    A(II)=X(JJ)                                                           TRANSP       9
                     RETURN                                                                TRANSP      10
                     END                                                                   TRANSP      11
```

```
   60 CONTINUE                                                     SGTSL      57
   70 CONTINUE                                                     SGTSL      58
   80 CONTINUE                                                     SGTSL      59
   90 CONTINUE                                                     SGTSL      60
  100 CONTINUE                                                     SGTSL      61
      RETURN                                                       SGTSL      62
      END                                                          SGTSL      63
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SUBROUTINE SGTSL       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587          84/11/19. 13.14.29         PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


     1                 SUBROUTINE SGTSL(N,C,D,E,B,INFO)                                        SGTSL        2
     2                 INTEGER N,INFO                                                          SGTSL        3
     3                 REAL C(1),E(1),B(1),D(1)                                                SGTSL        4
     4           C                                                                             SGTSL        5
     5           C  SGTSL GIVEN A GENERAL TRIDIAGONAL MATRIX AND A RIGHT HAND                  SGTSL        6
     6           C  SIDE WILL FIND THE SOLUTION  -  SEE THE LINPAC USER'S GUIDE                SGTSL        7
     7           C                                                                             SGTSL        8
     8                 INTEGER K,KB,KP1,NM1,NM2                                                SGTSL        9
     9                 REAL T                                                                  SGTSL       10
    10                 INFO=0                                                                  SGTSL       11
    11                 C(1)=D(1)                                                               SGTSL       12
    12                 NM1=N-1                                                                 SGTSL       13
    13                 IF(NM1.LT.1)GO TO 40                                                    SGTSL       14
    14                 D(1)=E(1)                                                               SGTSL       15
    15                 E(1)=0.0E0                                                              SGTSL       16
    16                 E(N)=0.0E0                                                              SGTSL       17
    17                 DO 30 K=1,NM1                                                           SGTSL       18
    18                 KP1=K+1                                                                 SGTSL       19
    19                 IF(ABS(C(KP1)).LT.ABS(C(K)))GO TO 10                                    SGTSL       20
    20                 T=C(KP1)                                                                SGTSL       21
    21                 C(KP1)=C(K)                                                             SGTSL       22
    22                 C(K)=T                                                                  SGTSL       23
    23                 T=D(KP1)                                                                SGTSL       24
    24                 D(KP1)=D(K)                                                             SGTSL       25
    25                 D(K)=T                                                                  SGTSL       26
    26                 T=E(KP1)                                                                SGTSL       27
    27                 E(KP1)=E(K)                                                             SGTSL       28
    28                 E(K)=T                                                                  SGTSL       29
    29                 T=B(KP1)                                                                SGTSL       30
    30                 B(KP1)=B(K)                                                             SGTSL       31
    31                 B(K)=T                                                                  SGTSL       32
    32              10 CONTINUE                                                                SGTSL       33
    33                 IF(C(K).NE.0.0E0)GO TO 20                                               SGTSL       34
    34                 INFO=K                                                                  SGTSL       35
    35                 GO TO 100                                                               SGTSL       36
    36              20 CONTINUE                                                                SGTSL       37
    37                 T=-C(KP1)/C(K)                                                          SGTSL       38
    38                 C(KP1)=D(KP1)+T*D(K)                                                    SGTSL       39
    39                 D(KP1)=E(KP1)+T*E(K)                                                    SGTSL       40
    40                 E(KP1)=0.0E0                                                            SGTSL       41
    41                 B(KP1)=B(KP1)+T*B(K)                                                    SGTSL       42
    42              30 CONTINUE                                                                SGTSL       43
    43              40 CONTINUE                                                                SGTSL       44
    44                 IF(C(N).NE.0.0E0)GO TO 50                                               SGTSL       45
    45                 INFO=N                                                                  SGTSL       46
    46                 GO TO 90                                                                SGTSL       47
    47              50 CONTINUE                                                                SGTSL       48
    48                 NM2=N-2                                                                 SGTSL       49
    49                 B(N)=B(N)/C(N)                                                          SGTSL       50
    50                 IF(N.EQ.1)GO TO 80                                                      SGTSL       51
    51                 B(NM1)=(B(NM1)-D(NM1)*B(N))/C(NM1)                                      SGTSL       52
    52                 IF(NM2.LT.1)GO TO 70                                                    SGTSL       53
    53                 DO 60 KB=1,NM2                                                          SGTSL       54
    54                 K=NM2-KB+1                                                              SGTSL       55
    55                 B(K)=(B(K)-D(K)*B(K+1)-E(K)*B(K+2))/C(K)                                SGTSL       56
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SUBROUTINE INTEG       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587         84/11/19. 13.14.29          PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                  SUBROUTINE INTEG(N,A,T,QUE,PHI,QD,QDT,N2)                             INTEG2        2
                  DIMENSION A(N2,N2),QUE(N2,N2),PHI(N2,N2),QD(N2,N2),QDT(N2,N2)         INTEG2        3
                  T2= -T*0.5                                                            INTEG2        4
                  CALL MEXP(N,A(1,1),T2,PHI(1,1),QD(1,1),QDT(1,1),N2)                   INTEG2        5
                  CALL TRI(N,QUE(1,1),PHI(1,1),QD(1,1),QDT(1,1),N2)                     INTEG2        6
                  CALL MSCALE(N,N,QDT(1,1),4.0,QDT(1,1))                                INTEG2        7
                  CALL MULT(PHI(1,1),PHI(1,1),N,A(1,1),N2)                              INTEG2        8
                  CALL TRI(N,QUE(1,1),A(1,1),QD(1,1),PHI(1,1),N2)                       INTEG2        9
                  DO 10 I=1,N                                                           INTEG2       10
                  DO 10 J=1,N                                                           INTEG2       11
               10 QDT(I,J)= QUE(I,J)+ QDT(I,J)+ PHI(I,J)                                INTEG2       12
                  T6=T/6.0                                                              INTEG2       13
                  CALL MSCALE(N,N,QDT(1,1),T6,QDT(1,1))                                 INTEG2       14
                  RETURN                                                                INTEG2       15
                  END                                                                   INTEG2       16
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SUBROUTINE HEATTUN    74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

       1              SUBROUTINE HEATTUN                                                 UPOCT09     28
       2              COMMON/CHEAT/Q,TS,QREF,TW,M1,RENS,HBAR,HREF                        UPOCT09     29
       3              COMMON/COMTUN/T,TAW1,ALPHA,H,V,RHO,P,TEMP,C,TRAD,RHOG,             OCT10        3
       4             &TO,TSINK,XFT,DEL,PDEL                                              COMTUN       3
       5              LOGICAL FAUTO                                                      CPARAM       2
       6              DIMENSION FAUTO(7)                                                 OCT10        2
       7              DIMENSION QP(5)                                                    UPAUG16      1
       8              COMMON/CPARAM/HO,HALF(2),PHIC,PHIK,ZP,Z,ALPH(2),KA,S(5),           UPAUG16      2
       9             &CIF(5,5),KAF,IFX(5),ACC(5),IFXSUM,NPAR,DALPH(2)                    UPAUG16      3
      10              EQUIVALENCE (HO,QP(1))                                             UPAUG16      4
      11              COMMON/ICTPS2/TINIT(1),ERALOW,E                                    UPOCT09     32
      12              COMMON/CDX/DX(1)                                                   UPOCT09     33
      13              DATA HREF/1./                                                      UPOCT09     34
      14        C                                                                        UPOCT09     35
      15        C     CHECK FOR ALPHA SEGMENT                                            UPOCT09     36
      16        C                                                                        UPOCT09     37
      17              IF(ALPHA.LT.ALPH(2)) THEN                                          OCT10       14
  1   18                 DALPH(1)=ALPHA                                                  UPOCT09     39
  1   19                 DALPH(2)=ALPH(2)                                                UPOCT09     40
  1   20              ENDIF                                                              UPOCT09     41
      21              IF(ALPHA.GE.ALPH(2)) THEN                                          UPOCT09     42
  1   22                 DALPH(1)=ALPH(1)                                                OCT10       15
  1   23                 DALPH(2)=ALPHA                                                  UPOCT09     43
  1   24              ENDIF                                                              UPOCT09     44
  1   25        C                                                                        UPOCT09     45
      26              HBAR=HO+HALF(1)*(DALPH(1)-ALPH(1))+HALF(2)*(DALPH(2)-ALPH(2))      UPOCT09     46
      27              RETURN                                                             UPOCT09     47
      28              END                                                                UPOCT09     48
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SUBROUTINE TPSOSP2    74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


  1                SUBROUTINE TPSOSP2(DT)                                                  FTPSOSP3    2
  2                COMMON/COSP/NPTSS,USI(6),PHI(6,6),NPT,PC(6,6),RR,                       UPAUG16     6
  3               &QD(6,6),QDT(6,6),QUE(6,6),A(6,6),RCX(6),RP(6),RM(6)                     UPOCT09     5
  4                COMMON/COPT/N,IOA(8),IOB(8),IOC(8),IOFACE(8),IOD(8)                     FTPSOSP3    4
  5                COMMON/CPC/NPTPC                                                        FTPSOSP3    5
  6                COMMON /MAIN1/INP,IPVT(6),WORK(6)                                       OCT10       4
  7                INP=6                                                                   OCT10       5
  8                IF(DT .LE. 0.) GO TO 999                                                FTPSOSP3    7
  9                T=DT                                                                    UPSEP24    13
 10                CALL INTEG(NPTPC,A,T,QUE,PHI,QD,QDT,NPTSS)                              FTPSOSP3    9
 11                CALL SGEFA(A(1,1),NPTSS,NPTPC,IPVT(1))                                  FTPSOSP3   10
 12                CALL SGEDI(A(1,1),NPTSS,NPTPC,IPVT(1),WORK(1))                          FTPSOSP3   11
 13                CALL MAT4(NPTPC,NPTPC,QDT(1,1),A(1,1),QD(1,1))                          FTPSOSP3   12
 14                CALL MAT4(NPTPC,NPTPC,PC(1,1),A(1,1),QDT(1,1))                          FTPSOSP3   13
 15                DO 20  I=1,NPTPC                                                        FTPSOSP3   14
 16                DO 20  J=1,NPTPC                                                        FTPSOSP3   15
 17                PHI(I,J)=A(I,J)                                                         HAROLD     54
 18             20 PC(I,J)= QDT(I,J)+ QD(I,J)                                              FTPSOSP3   16
 19            999 RETURN                                                                  FTPSOSP3   17
 20                END                                                                     FTPSOSP3   18
```

```
SUBROUTINE EQUATE      74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                    SUBROUTINE EQUATE (NR,NC,A,B)                                  EQUATE      2
                    DIMENSION A(1), B(1)                                           EQUATE      3
                    COMMON /MAIN1/ NDIM                                            FQUATE      4
                    NN=NC*NDIM                                                     EQUATE      5
                    NR1=NR-1                                                       EQUATE      6
                    DO 1 J=1,NN,NDIM                                               EQUATE      7
                    II=J+NR1                                                       EQUATE      8
                    DO 1 IJ=J,II                                                   EQUATE      9
                    A(IJ)=B(IJ)                                                    EQUATE     10
                  1 CONTINUE                                                       EQUATE     11
                    RETURN                                                         EQUATE     12
                    END                                                            EQUATE     13
```

```
SUBROUTINE GMINV       74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE      1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


     1                  SUBROUTINE GMINV (NR,NC,A,U,MR,MT)                                 FGMINV      2
     2                  DIMENSION A(1), U(1), S(30)                                        FGMINV      3
     3                  COMMON /MAIN2/ NDIM                                                FGMINV      4
     4                  COMMON /INOU/ KIN,KOUT                                             FGMINV      5
     5                  NDIM1=NDIM+1                                                       FGMINV      6
     6                  TOL=1.E-14                                                         FGMINV      7
     7                  ADV=1.E-24                                                         FGMINV      8
     8                  MR=NC                                                              FGMINV      9
     9                  NRM1=NR-1                                                          FGMINV     10
    10                  TOL1=0.                                                            FGMINV     11
    11                  JJ=1                                                               FGMINV     12
    12                  DO 1 J=1,NC                                                        FGMINV     13
    13                  S(J)=DOT(NR,A(JJ),A(JJ))                                           FGMINV     14
    14                  IF (S(J).GT.TOL1) TOL1=S(J)                                        FGMINV     15
    15                1 JJ=JJ+NDIM                                                         FGMINV     16
    16                  TOL1=ADV*TOL1                                                      FGMINV     17
    17                  ADV=TOL1                                                           FGMINV     18
    18                  JJ=1                                                               FGMINV     19
    19                  DO 14 J=1,NC                                                       FGMINV     20
    20                  FAC=S(J)                                                           FGMINV     21
    21                  JM1=J-1                                                            FGMINV     22
    22                  JRM=JJ+NRM1                                                        FGMINV     23
    23                  JCM=JJ+JM1                                                         FGMINV     24
    24                  DO 2 I=JJ,JCM                                                      FGMINV     25
    25                2 U(I)=0.                                                            FGMINV     26
    26                  U(JCM)=1.0                                                         FGMINV     27
    27                  IF (J.EQ.1) GO TO 5                                                FGMINV     28
    28                  KK=1                                                               FGMINV     29
    29                  DO 3 K=1,JM1                                                       FGMINV     30
    30                  IF (S(K).EQ.1.0) GO TO 3                                           FGMINV     31
    31                  TEMP=-DOT(NR,A(JJ),A(KK))                                          FGMINV     32
    32                  CALL VADD (K,TEMP,U(JJ),U(KK))                                     FGMINV     33
    33                3 KK=KK+NDIM                                                         FGMINV     34
    34                  DO 4 L=1,2                                                         FGMINV     35
    35                  KK=1                                                               FGMINV     36
    36                  DO 4 K=1,JM1                                                       FGMINV     37
    37                  IF (S(K).EQ.0.) GO TO 4                                            FGMINV     38
    38                  TEMP=-DOT(NR,A(JJ),A(KK))                                          FGMINV     39
    39                  CALL VADD (NR,TEMP,A(JJ),A(KK))                                    FGMINV     40
    40                  CALL VADD (K,TEMP,U(JJ),U(KK))                                     FGMINV     41
    41                4 KK=KK+NDIM                                                         FGMINV     42
    42                  TOL1=TOL*FAC+ADV                                                   FGMINV     43
    43                  FAC=DOT(NR,A(JJ),A(JJ))                                            FGMINV     44
    44                5 IF (FAC.GT.TOL1) GO TO 9                                           FGMINV     45
    45                  DO 6 I=JJ,JRM                                                      FGMINV     46
    46                6 A(I)=0.                                                            FGMINV     47
    47                  S(J)=0.                                                            FGMINV     48
    48                  KK=1                                                               FGMINV     49
    49                  IF (S(K).EQ.0.) KK=KK+NDIM                                         FGMINV     50
    50                  IF (S(K).EQ.0.) GO TO 8                                            FGMINV     51
    51                  DO 7 K=1,JM1                                                       FGMINV     52
    52                  TEMP=-DOT(K,U(KK),U(JJ))                                           FGMINV     53
    53                  CALL VADD (NR,TEMP,A(JJ),A(KK))                                    FGMINV     54
    54                7 KK=KK+NDIM                                                         FGMINV     55
    55                8 FAC=DOT(J,U(JJ),U(JJ))                                             FGMINV     56
```

```
      MR=MR-1                                                            FGMINV   57
      GO TO 11                                                           FGMINV   58
    9 S(J)=1.0                                                           FGMINV   59
      KK=1                                                               FGMINV   60
      DO 10 K=1,JM1                                                      FGMINV   61
      IF (S(K).EQ.1.) GO TO 10                                           FGMINV   62
      TEMP=-DOT(NR,A(JJ),A(KK))                                          FGMINV   63
      CALL VADD (K,TEMP,U(JJ),U(KK))                                     FGMINV   64
   10 KK=KK+NDIM                                                         FGMINV   65
   11 FAC=1./SQRT(FAC)                                                   FGMINV   66
      DO 12 I=JJ,JRM                                                     FGMINV   67
   12 A(I)=A(I)*FAC                                                      FGMINV   68
      DO 13 I=JJ,JCM                                                     FGMINV   69
   13 U(I)=U(I)*FAC                                                      FGMINV   70
   14 JJ=JJ+NDIM                                                         FGMINV   71
      IF (MR.EQ.NR.OR.MR.EQ.NC) GO TO 15                                 FGMINV   72
      IF (MT.NE.0) WRITE (KOUT,19) NR,NC,MR                              FGMINV   73
   15 NEND=NC*NDIM                                                       FGMINV   74
      JJ=1                                                               FGMINV   75
      DO 18 J=1,NC                                                       FGMINV   76
      DO 16 I=1,NR                                                       FGMINV   77
      II=I-J                                                             FGMINV   78
      S(I)=0.                                                            FGMINV   79
      DO 16 KK=JJ,NEND,NDIM                                              FGMINV   80
   16 S(I)=S(I)+A(II+KK)*U(KK)                                           FGMINV   81
      II=J                                                               FGMINV   82
      DO 17 I=1,NR                                                       FGMINV   83
      U(II)=S(I)                                                         FGMINV   84
   17 II=II+NDIM                                                         FGMINV   85
   18 JJ=JJ+NDIM1                                                        FGMINV   86
      RETURN                                                             FGMINV   87
   19 FORMAT (I3,1HX,I2,8H M: RANK,I2)                                   FGMINV   88
      END                                                                FGMINV   89
```

```
   FUNCTION DOT        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS    FTN 5.1+587       84/11/19. 13.14.29       PAGE      1
  DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
  FTN5,I,ANSI=0,L=OUTS,LO=S/-A.


1                    FUNCTION DOT (NR,A,B)                                           FDOT        2
2                    DIMENSION A(1), B(1)                                            FDOT        3
3                    DOT=0.                                                          FDOT        4
4                    DO 1 I=1,NR                                                     FDOT        5
5                  1 DOT=DOT+A(I)*B(I)                                               FDOT        6
6                    RETURN                                                          FDOT        7
7                    END                                                             FDOT        8
```

```
SUBROUTINE VADD        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587         84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                  SUBROUTINE VADD (N,C1,A,B)                                          FVADD        2
                  DIMENSION A(1), B(1)                                                FVADD        3
                  DO 1 I=1,N                                                          FVADD        4
                1 A(I)=A(I)+C1*B(I)                                                   FVADD        5
                  RETURN                                                              FVADD        6
                  END                                                                 FVADD        7
```

```
SUBROUTINE ZERO        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS      FTN 5.1+587        84/11/19. 13.14.29         PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

                  SUBROUTINE ZERO (A,NR,NC)                                             FZERO        2
                  DIMENSION A(NR,NC)                                                    FZERO        3
                  DO 1 IC=1,NC                                                          FZERO        4
                  DO 1 IR=1,NR                                                          FZERO        5
                1 A(IR,IC)=0.0                                                          FZERO        6
                  RETURN                                                                FZERO        7
                  END                                                                   FZERO        8
```

```
SUBROUTINE VADD        74/855  OPT=0,ROUND= A/ S/ M/-D,-DS     FTN 5.1+587        84/11/19. 13.14.29        PAGE     1
DO=-LONG/-OT,ARG=-COMMON/-FIXED,CS= USER/-FIXED,DB=-TB/-SB/-SL/ ER/-ID/-PMD/-ST,PL=5000
FTN5,I,ANSI=0,L=OUTS,LO=S/-A.

 1                    SUBROUTINE VADD (N,C1,A,B)                                     FVADD        2
 2                    DIMENSION A(1), B(1)                                           FVADD        3
 3                    DO 1 I=1,N                                                     FVADD        4
 4                  1 A(I)=A(I)+C1*B(I)                                              FVADD        5
 5                    RETURN                                                         FVADD        6
 6                    END                                                            FVADD        7
```

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A heat energy balance is applied to a coaxial thermocouple gage for parameter estimation in wind tunnel test articles. This method can significantly reduce wind tunnel test costs and time. Modifications to the data reduction program HEATEST (HEATing ESTimation) are made. The program allows for transient test techniques to be used as well as assuming an isothermal wall. A non-linear convective heat transfer coefficient model may also be used, Data is generated to test the new program. Temperature profiles throughout the thermocouple gage were good and were compared with changes in time step, thermocouple length, and number of discrete node points. The estimation of the convective heat transfer coefficient and thermal conductivity were excellent.

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