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Produced by the NASA Center for Aerospace Information (CASI)
SURFACE HEATING RATE OF THIN SKIN MODELS (THNSKN)

Program Q614

Job Order 83-157

(This revision supersedes 07000 dated November 1969)

Prepared By
Lockheed Electronics Company, Inc.
Aerospace Systems Division
Houston, Texas
Contract NAS 9-12200
For
INSTITUTIONAL DATA SYSTEMS DIVISION

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas
April 1975

LEC-5523
PROGRAM DOCUMENTATION
SURFACE HEATING RATE OF THIN SKIN MODELS (THNSKN)

Program Q614
Job Order 83-157

PREPARED BY

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Lockheed Electronics Company, Inc.

For

Institutional Data Systems Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

April 1975
**TECHNICAL REPORT INDEX/ABSTRACT**

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<td>JSC-09434</td>
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<td>J. E. Wakeland</td>
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<td>Jack D. McBryde</td>
</tr>
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<tr>
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<td>SUBSYSTEM</td>
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<td>DRL NO. AND REVISION</td>
<td>MAJOR EQUIPMENT GROUP</td>
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**13. ABSTRACT**

THNSKN computes the mean heating rate at a maximum of 100 locations on the surface of thin skin transient heating rate models. Output is printed in tabular form and consists of time history tabulation of temperatures, average temperatures, heat loss without conduction correction, mean heating rate, least squares heating rate, and the percent standard error of the least squares heating rates. The input tape used is produced by the program EHTS03.

**14. SUBJECT TERMS**

ARC JET  THERMOCOUPLES

HEATING RATE  THIN SKIN
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UNIT I
PROGRAM ABSTRACT AND HISTORY OF USE

A. ABSTRACT

Program THNSKN computes the mean heating rate at a number of thermocouple locations on the surface of thin skin transient heating rate models. Experimental data, calibrated in engineering units, is obtained from ABEL tape output of the EHTS03 data reduction computer program. The program output consists of time history tabulations in an array by thermocouple locations for each time sample.

B. PROGRAM HISTORY

The original THNSKN program was written in 1969. The current version was written in December 1974 as requested by SCR83-15-30.
UNIT II
PROGRAM USERS INFORMATION

A. IDENTIFICATION

Title: Surface Heating Rate of Thin Skin Models (THNSKN)
Author: Jack D. McBryde
Date: December 1974
Installation: JSC, Houston, Texas
Authorization: Contract NAS 9-12200
Source Language: FORTRAN V
Computer Configuration: UNIVAC 1108 or 1110, EXEC 8

B. DESCRIPTION OF PROGRAM REQUEST

See attachment 8.

C. USAGE

1. Input Requirements and Data Descriptions:

The THNSKN input tape is produced by the program EHTS03. It is a FORTRAN-written binary tape containing time in floating-point seconds followed by data in floating point for N channels. The number of channels (N) is fixed for a given tape (N ≤ 259).

See attachment 6 for sample input.

2. Lead Card Setup:

See attachment 1.
3. Deck Setup:  
   See attachment 2.

4. Tape Assignments:  
   See attachment 3.

5. Restrictions:  
   The following list is a summary of the restrictions:  
   - The input tape must have the format specified in section C.1.
   - The array of thermocouples must have no more than 50 rows or columns, and one row or column must contain at least three thermocouples.
   - Each specified time slice must contain at least three input records.
   - The maximum number of points for thermocouples, which may be used for least squares heat loss computations, is 50.

6. Diagnostic, Normal-Console, and Standard-Output Messages:  
   See attachment 9.

7. Labels, Save-Tapes, and Output Disposition:  
   There is printer output only.

8. Output Formats:  
   See attachment 7.
9. Nonstandard System Requirements:
There are none.

10. Running Time:
THNSKN processes nine thermocouples for 40 time points in less than 1/2 minute.

D. ANALYSIS

1. Description of the Relationship of Variables to the Test Item:
The test item may be considered to be a rectangular plate having, at most, two thicknesses as shown:

- The origin of the x-, y-coordinate system is the upper left corner.
• The variables $d_1$ and $d_2$ are the two thicknesses. If the test item has only one thickness, it is represented by $d$.

• The variable $T_{i,j}$ is the temperature at a thermocouple in degrees Fahrenheit.

• The variables $T_{i,k}$ and $T_{i,k+1}$ are temperatures adjacent to the thickness difference junction.

• The variable $Y_{i,d}$ is the $y$-coordinate of the junction at row $i$ in inches.

• Each row or column is colinear in the $X$-, $Y$-plane so that the coordinates of all the thermocouples $(X, Y)$ can be expressed using $i$-values of $X$ and $j$-values of $Y$. Both $X$ and $Y$ are in inches.

2. Equations:

2.1 Mean temperatures:

The mean temperature $\bar{T}$ for each thermocouple is computed by

$$\bar{T} = \frac{1}{N} \sum_{\ell=1}^{N} T_{\ell}$$

(1)

where $N$ is the number of temperatures read in the time interval processed.
2.2 Mean heat flux without conduction correction:

The mean heat flux without conduction correction \( \bar{q} \) is computed by

\[
\bar{q}_{i,j} = \frac{\rho C_p d}{24(t_N - t_1)} \frac{N - 1}{N - 2} \left( \frac{T_{i,j}^N + T_{i,j}^{N-1} - T_{i,j}^1 - T_{i,j}^2}{N - 2} \right)
\]

(2)

where

- \( t_1 \) = the time for the first scan of data in the interval in seconds.
- \( t_N \) = the time for the last scan of data in the interval in seconds.
- \( T_{i,j}^1, T_{i,j}^2, T_{i,j}^{N-1}, T_{i,j}^N \) = the first, second, next to the last, and last temperatures of the thermocouple in row i and column j.
- \( \rho \) = mass density in lb/ft\(^3\).
- \( C_p \) = specific heat in BTU/lb\(^\circ\)F.
- \( d \) = thickness of test material in inches.

If the test item has two thicknesses, then \( d = d_1 \) for \( j \leq k \) (see the figure) and \( d = d_2 \) for \( j > k \).
2.3 Mean lateral heat loss in the X-direction:

The mean lateral heat loss in the X-direction $\overline{q^X}$ is computed by

$$
\overline{q^X}_{i,j} = \frac{24Kd}{x_{i+1} - x_{i-1}} \left( \frac{T_{i,j} - T_{i-1,j}}{x_i - x_{i-1}} - \frac{T_{i+1,j} - T_{i,j}}{x_{i+1} - x_i} \right)
$$

(3)

where

$K = $ thermal conductivity in BTU/ft sec°C.

d = $ $d_1$ for $j \leq k$ (see the figure).

d = $d_2$ for $j > k$.

2.4 Mean lateral heat loss in the Y-direction:

The mean lateral heat loss in the Y-direction $\overline{q^Y}$ may be computed by one of three equations, depending on whether the test material has one or two thicknesses and the position of the thermocouple relative to the junction between the thicknesses.

Case 1: The variable $\overline{q^Y}$ when the material has one thickness or where it has two and all three thermocouples are the same side of the junction.

$$
\overline{q^Y}_{i,j} = \frac{24Kd}{y_{j+1} - y_{j-1}} \left( \frac{T_{i,j} - T_{i,j-1}}{y_j - y_{j-1}} - \frac{T_{i,j+1} - T_{i,j}}{y_{j+1} - y_j} \right)
$$

(4)
where

\[ \begin{align*}
    &d = d_1 \quad \text{when } j + 1 \leq k, \\
    &d = d_2 \quad \text{when } j - 1 > k.
\end{align*} \]

**Case 2:** The variable \( q^y \) when the material has two thicknesses and \( j = k \) (see the figure).

\[
\overline{q^y}_{i,j} = \frac{24Kd_1}{Y_{k+1} - Y_{k-1}}
\]

\[
\left( \frac{T_{i,k} - T_{i,k-1}}{Y_k - Y_{k-1}} - \frac{d_2(T_{i,k+1} - T_{i,k})}{(Y_d - Y_k)d_2 + (Y_{k+1} - Y_d)d_1} \right)
\]

(5)

where

\( Y_d = \) the \( Y \)-coordinate of the function at row \( i \) (see the figure).

**Case 3:** The variable \( q^y \) when the material has two thicknesses and \( j = k + 1 \).

\[
\overline{q^y}_{i,j} = \frac{24Kd_2}{Y_{k+2} - Y_k}
\]

\[
\left( \frac{d_1(T_{i,k+1} - T_{i,k})}{(Y_d - Y_k)d_2 + (Y_{k+1} - Y_d)d_1} - \frac{T_{i,k+2} - T_{i,k+1}}{Y_{k+2} - Y_{k+1}} \right)
\]

(6)
2.5 Mean heating rate:

The mean heating rate $\overline{q}$ is computed from equations 2, 3, and 4, 5, or 6.

$$\overline{q}_{i,j} = \overline{q}_{i,j} + \overline{q}_{i,j}^x + \overline{q}_{i,j}^y$$ (7)

3. Special Treatment When the Array Contains Bad Thermocouples:

The variables $\overline{q}$, $\overline{q}$, $\overline{q}^x$, and $\overline{q}^y$ are not computed for bad thermocouples. These values are set to zero.

In computing $\overline{q}^x$ for a column containing one or more bad thermocouples, temperatures and x-coordinates of three successive good (but not necessarily adjacent) thermocouples are used.

The same procedure is used in computing $\overline{q}^y$.

4. The Variables $\overline{q}^x$ and $\overline{q}^y$ at Row or Column End Points:

The conduction correction ($\overline{q}^x$ or $\overline{q}^y$) used at the end points (first or last good thermocouple) are the same as those computed for the adjacent thermocouple in the row or column.

5. Linear Least Squares Heating Rate and Percent Standard Error:

The heating rate at each thermocouple $\overline{Q}$ is computed from the slope $M$ by
\[ Q = \frac{\rho C_p d}{12} M \]  

(8)

The slope \( M \) is computed by

\[
M = \frac{n \sum t_i T_i - \sum t_i \sum T_i}{n \sum t_i^2 - (\sum t_i)^2}
\]  

(9)

where

\( n = \) the number of scans.
\( t = \) time.
\( T = \) temperature.

The percent standard error \( E \) is computed by

\[
E = \frac{S_n(M)}{M} \times 100
\]  

(10)

\[
S_n(M) = n \sigma_n(T) \left\{ \frac{(n - 2) \left[ n \sum t_i^2 - (\sum t_i)^2 \right]}{n \sum t_i^2 - (\sum t_i)^2} \right\}^{1/2}
\]  

(11)

\[
\sigma_n(T) = \frac{1}{n}
\]
If the time slice specified contains more than \( n \) scans, the last time and corresponding temperatures are used as the first time and temperatures for the next \( n \) scans.

E. **FLOW CHART**

See attachment 4.

F. **STORAGE REQUIREMENTS**

Forty-three thousand decimal locations are required.

G. **LIST OF SUBROUTINES**

None.

H. **LOCATION OF SOURCE AND BINARY DECKS**

The Data Processing Systems Department of Lockheed Electronics Company, Inc., maintains all source and binary decks for this program.

I. **PROGRAM LISTING**

See attachment 5.

J. **CORRESPONDENCE**

See attachment 8.
# LEAD CARD SETUP

**CARD NO.** 1  
**JOB**  
**NAME** THNSKN  
**PROGRAMMER** McBryde  
**DATE** 12/74  

<table>
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<th>FIELD ID</th>
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<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
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</thead>
<tbody>
<tr>
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<td>1-72</td>
<td>12A6</td>
<td>TITLE1</td>
<td>First title card.</td>
</tr>
<tr>
<td>FIELD ID</td>
<td>CARD COLUMNS</td>
<td>FORMAT</td>
<td>SYMBOLIC NAME</td>
<td>IDENTIFICATION</td>
</tr>
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<td>----------</td>
<td>---------------</td>
<td>--------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
<td>1-72</td>
<td>12A6</td>
<td>TITLE2</td>
<td>Second title card.</td>
</tr>
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NAME: THNSKN  
PROGRAMMER: McBryde  
DATE: 12/74
<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>RHO</td>
<td>Mass density ((p)) of test material in (1\text{bm/ft}^3).</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.3</td>
<td>CP</td>
<td>Specific heat ((C_p)) of test material in (\text{BTU/lbm ^\circ F}).</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>BIGK</td>
<td>Thermal conductivity ((K)) of test material in (\text{BTU/ft sec ^\circ F}).</td>
</tr>
<tr>
<td>4</td>
<td>31-40</td>
<td>F10.3</td>
<td>DD(1)</td>
<td>Test material thickness ((d_1)) in inches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If there is only one thickness in the sample, the next field will be left blank.</td>
</tr>
<tr>
<td>5</td>
<td>41-50</td>
<td>F10.3</td>
<td>DD(2)</td>
<td>The second test material thickness ((d_2)).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>If a second thickness is supplied, card 5 must appear in the deck.</td>
</tr>
<tr>
<td>6</td>
<td>51-53</td>
<td>I3</td>
<td>NX</td>
<td>Number* of x-coordinates:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1 \leq NV \leq 50).</td>
</tr>
<tr>
<td>7</td>
<td>54-56</td>
<td>I3</td>
<td>NY</td>
<td>Number* of y-coordinates:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1 \leq NY \leq 50).</td>
</tr>
</tbody>
</table>

Comment: *A minimum of a 1\times3 or 3\times1 array of x, y-coordinates is required.
MISCELLANEOUS RUN PARAMETERS

LEAD CARD SETUP

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-5</td>
<td>I5</td>
<td>NCHS</td>
<td>Number of data channels on input tape*.</td>
</tr>
<tr>
<td>2</td>
<td>6-10</td>
<td>I5</td>
<td>NCC</td>
<td>Command channel number*.</td>
</tr>
<tr>
<td>3</td>
<td>11-15</td>
<td>I5</td>
<td>IOPT1</td>
<td>0 – Use card 9 to specify start-stop times.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 – Use card 9A to specify start-stop command event levels.</td>
</tr>
<tr>
<td>4</td>
<td>16-20</td>
<td>I5</td>
<td>NPAR</td>
<td>The maximum number of parity error records per time slice which will be permitted. If blank, 2 will be used. Parity error records are skipped.</td>
</tr>
<tr>
<td>5</td>
<td>21-25</td>
<td>I5</td>
<td>NOTH</td>
<td>If NOTH is blank or zero time, temperature data for each scan in the time slice will be printed.</td>
</tr>
</tbody>
</table>

Comment: *The input tape record has a time word preceding the data channels. These numbers do not include the time word.
Y-COORDINATES OF THICKNESS DIFFERENCE JUNCTION

LEAD CARD SETUP

CARD NO. 5

JOB THNSKN

NAME THNSKN

PROGRAMMER McBryde

DATE 12/74

NOTE: This card will appear in the deck only if DD(2) on card 3 is used.

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>YDD(1)</td>
<td>The y-coordinate of the junction between test material thicknesses when the x-coordinate is xx(1) (see card 6).</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.3</td>
<td>YDD(2)</td>
<td>Same for XX(2).</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>YDD(3)</td>
<td>Same for XX(3).</td>
</tr>
<tr>
<td>4</td>
<td>31-40</td>
<td>F10.3</td>
<td>YDD(4)</td>
<td>Same for XX(4).</td>
</tr>
<tr>
<td>5</td>
<td>41-50</td>
<td>F10.3</td>
<td>YDD(5)</td>
<td>Same for XX(5).</td>
</tr>
</tbody>
</table>

Comment: Use as many cards as required to define NX values.
## X-COORDINATES

### LEAD CARD SETUP

**CARD NO.** 6  
**JOB**  
**NAME** THNSKN  
**PROGRAMMER** McBryde  
**DATE** 12/74

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>XX(1)</td>
<td>X-axis location of first thermocouple row in inches.</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.3</td>
<td>XX(2)</td>
<td>X-axis location of second thermocouple row.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>XX(3)</td>
<td>X-axis location of third thermocouple row.</td>
</tr>
<tr>
<td>4</td>
<td>31-40</td>
<td>F10.3</td>
<td>XX(4)</td>
<td>X-axis location of fourth thermocouple row.</td>
</tr>
<tr>
<td>5</td>
<td>41-50</td>
<td>F10.3</td>
<td>XX(5)</td>
<td>X-axis location of fifth thermocouple row.</td>
</tr>
</tbody>
</table>

**Comment:** Enter as many cards as needed to define NX locations (NX ≤ 50).
Y-COORDINATES

LEAD CARD SETUP

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>YY(1)</td>
<td>Y-axis location of first thermocouple column in inches.</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.3</td>
<td>YY(2)</td>
<td>Y-axis location of second thermocouple column.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>YY(3)</td>
<td>Y-axis location of third thermocouple column.</td>
</tr>
<tr>
<td>4</td>
<td>31-40</td>
<td>F10.3</td>
<td>YY(4)</td>
<td>Y-axis location of fourth thermocouple column.</td>
</tr>
<tr>
<td>5</td>
<td>41-50</td>
<td>F10.3</td>
<td>YY(5)</td>
<td>Y-axis location of fifth thermocouple column.</td>
</tr>
</tbody>
</table>

Comment: Enter as many cards as required to define NY locations (NY ≤ 50).
## THERMOCOUPLE CHANNEL NUMBERS

### LEAD CARD SETUP

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-3</td>
<td>I3</td>
<td>IX</td>
<td>Row number (X-direction) of thermocouple.</td>
</tr>
<tr>
<td>2</td>
<td>4-6</td>
<td>I3</td>
<td>IY</td>
<td>Column number (Y-direction) of thermocouple.</td>
</tr>
<tr>
<td>3</td>
<td>7-10</td>
<td>I4</td>
<td>NTCH (IX,IY)</td>
<td>Channel number for temperature of thermocouple located at IX, IY.</td>
</tr>
<tr>
<td>4</td>
<td>11-13</td>
<td>I3</td>
<td>IX</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>14-16</td>
<td>I3</td>
<td>IY</td>
<td>Second thermocouple.</td>
</tr>
<tr>
<td>6</td>
<td>17-20</td>
<td>I4</td>
<td>NTCH (IX,IY)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>21-23</td>
<td>I3</td>
<td>IX</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>24-26</td>
<td>I3</td>
<td>IY</td>
<td>Third thermocouple.</td>
</tr>
<tr>
<td>9</td>
<td>27-30</td>
<td>I4</td>
<td>NTCH (IX,IY)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>31-33</td>
<td>I3</td>
<td>IX</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>34-36</td>
<td>I3</td>
<td>IY</td>
<td>Fourth thermocouple.</td>
</tr>
<tr>
<td>12</td>
<td>37-40</td>
<td>I4</td>
<td>NTCH (IX,IY)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>41-43</td>
<td>I3</td>
<td>IX</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>44-46</td>
<td>I3</td>
<td>IY</td>
<td>Fifth thermocouple.</td>
</tr>
<tr>
<td>15</td>
<td>47-50</td>
<td>I4</td>
<td>NTCH (IX,IY)</td>
<td></td>
</tr>
</tbody>
</table>

**Comment:** Enter as many cards as needed to define NX * NY thermocouple locations. Bad thermocouples should be indicated with NTCH (IX, IY) = 0.
## START-STOP TIMES

### LEAD CARD SETUP

<table>
<thead>
<tr>
<th>CARD NO.</th>
<th>JOB</th>
<th>NAME</th>
<th>PROGRAMMER</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
<td>THNSKN</td>
<td>McBryde</td>
<td>12/74</td>
</tr>
</tbody>
</table>

### IDENTIFICATION

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD COLUMNS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>TSTRT</td>
<td>Computation start time.</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.3</td>
<td>TSTOP</td>
<td>Computation stop time.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>STATME</td>
<td>Start time for least squares curve fit.</td>
</tr>
</tbody>
</table>

   - No data will be processed outside of the interval from TSTRT to TSTOP.

   - If NTME \( \leq 2 \), no curve fitting will be done.

### NOTE:

This card will be used if IOPT1 on card 4 is zero or blank. Card 9A will not be used and must not appear in the deck. As many start-stop time cards may be used as desired but the time slices must not overlap; i.e., the start time for the current time slice must be \( \geq \) the stop time for the previous time slice.
## COMMAND EVENT START-STOP

## LEAD CARD SETUP

<table>
<thead>
<tr>
<th>FIELD ID</th>
<th>CARD NUMBERS</th>
<th>FORMAT</th>
<th>SYMBOLIC NAME</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.0</td>
<td>CESTRT</td>
<td>Command event start level.</td>
</tr>
<tr>
<td>2</td>
<td>11-20</td>
<td>F10.0</td>
<td>CESTOP</td>
<td>Command event stop level.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>STATME</td>
<td>Start time for least squares curve fit.</td>
</tr>
<tr>
<td>4</td>
<td>31-35</td>
<td>I5</td>
<td>NTME</td>
<td>The number of points to be curve fit.</td>
</tr>
</tbody>
</table>

NOTE: Card 9A will appear in the deck only if IOPT1 on card 4 is 1. Card 9 must not appear in the decks. As many event start-stop cards may be used as required, but intervals requested must not overlap.
ATTACHMENT 2

DECK SETUP
DECK SETUP FOR PROGRAM THNSKN (EXEC VIII)  PAGE NO. 1 OF 1

(Back of deck)

8 PMD, E

One or more card 9A's if IOPT1
on card 4 is 1.

One or more card 9's if IOPT1
on card 4 is 0.

CARDS 6 - 8

CARD 5 [Only if DD(2) on card 3 > 0]

THNSKN CARDS 1 - 4

7

8XQT  .THNSKN/ABS

8MAP,S  .THNSKN,THNSKN/ABS

7

8PREP

7

8COPIN PGMTP,TPF$

7

8ASG,T 8,8C,XXXXXX (Input tape number)

7

8ASG,T PGMTP,8C,V02679

7

8MSG,N TWO TAPE DRIVES

7

8RUN

(Front of deck)
ATTACHMENT 3

RUN REQUEST FORM
## INSTRUCTIONS FOR CENTRAL COMPUTER COMPLEX COMPUTER RUNS

### EXEC VIII

<table>
<thead>
<tr>
<th>PROGRAMMER</th>
<th>BRIDGE NO.</th>
<th>BOX NO.</th>
<th>PHONE NO.</th>
<th>DATE</th>
<th>PRIORITY &amp; INITIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDXX</td>
<td>Q614</td>
<td>XXXX</td>
<td>XX</td>
<td>XX</td>
<td>XXX</td>
</tr>
</tbody>
</table>

### OPERATING SYSTEM

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>TYPE OF RUN</th>
<th>NO. TAPES</th>
<th>NO. FAST VS. FILES</th>
<th>NO. DRUM FILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1108 EXEC II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1108 EXEC III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1108 COBOL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### INPUT TAPES

<table>
<thead>
<tr>
<th>UNIT</th>
<th>REEL NO.</th>
<th>FILE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>XXXX</td>
<td>PROGRAM TAPE</td>
</tr>
<tr>
<td>F</td>
<td>XXXX</td>
<td>XXXX</td>
</tr>
</tbody>
</table>

### PERMANENT FAST VS. AND DRUM FILES

### OUTPUT TAPES

<table>
<thead>
<tr>
<th>UNIT</th>
<th>REEL NO.</th>
<th>FILE NAME</th>
<th>SAVE</th>
<th>PUNCH OUT</th>
<th>PEEL NO.</th>
<th>NO. CARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
</tr>
</tbody>
</table>

### CAL. COMP.

<table>
<thead>
<tr>
<th>UNIT</th>
<th>REEL NO.</th>
<th>FILE NO.</th>
<th>PUNCH OUT</th>
<th>PEEL NO.</th>
<th>NO. CARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 MM</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
<td>XXXX</td>
</tr>
</tbody>
</table>

### ACTUAL TIME USAGE

- **CAL. COMP.**
- **PUNCH OUTPUT**
- **PEEL NO.**
- **NO. CARDS**

### SYSTEM MESSAGES

- **INPUT MESSAGES**
- **OUTPUT MESSAGES**
ATTACHMENT 4

FLOW CHART
BEGIN

THNSKN

READ AND PRINT LEAD CARD VALUES APPLICABLE TO WHOLE RUN

READ AND PRINT LEAD CARD VALUES FOR THIS TIME SLICE

STOP TIME FOUND

NO

PROCESSING COMPLETED

NO

START TIME FOUND

YES

START TIME FOUND

NO

READ TAPE RECORD

YES

STOP

READ TAPE RECORD

COMPUTE SUMS FOR EACH THERMOCOUPLE

STORE DATA FOR LEAST SQUARES HEAT FLOW COMPUTATIONS

NO

NPT = NTIME

YES

STOP

COMPUTE LEAST SQUARES HEATING RATE AND ERROR

PRINT REPORT

EXECUTE

COMPUTE LEAST SQUARES HEATING RATE AND ERROR

PRINT REPORT

END
COMPUTE AVERAGE THERMOCOUPLE TEMPERATURES

PRINT REPORT

COMPUTE HEAT LOSS IN X ANY DIRECTIONS, UNCORRECTED HEAT LOSS AND CORRECTED HEAT LOSS

PRINT REPORTS

A

B
ATTACHMENT 5

PROGRAM LISTING
**Main Program**

**Storage Used:**
- Code (1) 000717
- Data (0) 073316
- Blank Common (2) 000000

**External References (Block, Name):**
- 0003 EXIT
- 0004 CHERR
- 0005 NINTS
- 0006 NWDUS
- 0007 NI039
- 0010 NI029
- 0011 NWDUS
- 0012 NI019
- 0013 NIERRS
- 0015 NSTOPS
- 0016 DSRT
- 0017 NERRS
- 0020 HERRS

**Storage Assignment (Block, Type, Relative Location, Name):**

<table>
<thead>
<tr>
<th>Block</th>
<th>Type</th>
<th>Relative Location</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>00150</td>
<td>1OL</td>
<td></td>
</tr>
<tr>
<td>0002</td>
<td>072344</td>
<td>1004F</td>
<td></td>
</tr>
<tr>
<td>0003</td>
<td>001741</td>
<td>1022G</td>
<td></td>
</tr>
<tr>
<td>0004</td>
<td>000070</td>
<td>1100L</td>
<td></td>
</tr>
<tr>
<td>0005</td>
<td>001554</td>
<td>2104G</td>
<td></td>
</tr>
<tr>
<td>0006</td>
<td>02407</td>
<td>1294G</td>
<td></td>
</tr>
<tr>
<td>0007</td>
<td>03017</td>
<td>1377G</td>
<td></td>
</tr>
<tr>
<td>0008</td>
<td>03157</td>
<td>1453G</td>
<td></td>
</tr>
<tr>
<td>0009</td>
<td>03334</td>
<td>1504G</td>
<td></td>
</tr>
<tr>
<td>0010</td>
<td>03644</td>
<td>1562G</td>
<td></td>
</tr>
<tr>
<td>0011</td>
<td>03845</td>
<td>1677G</td>
<td></td>
</tr>
<tr>
<td>0012</td>
<td>03632</td>
<td>200L</td>
<td></td>
</tr>
<tr>
<td>0013</td>
<td>072643</td>
<td>2004F</td>
<td></td>
</tr>
<tr>
<td>0014</td>
<td>072734</td>
<td>2014F</td>
<td></td>
</tr>
<tr>
<td>0015</td>
<td>073034</td>
<td>2019F</td>
<td></td>
</tr>
<tr>
<td>0016</td>
<td>00156</td>
<td>220L</td>
<td></td>
</tr>
<tr>
<td>0017</td>
<td>00172</td>
<td>240L</td>
<td></td>
</tr>
<tr>
<td>0018</td>
<td>00126</td>
<td>260L</td>
<td></td>
</tr>
<tr>
<td>0019</td>
<td>00170</td>
<td>300L</td>
<td></td>
</tr>
<tr>
<td>0020</td>
<td>00136</td>
<td>345L</td>
<td></td>
</tr>
<tr>
<td>0021</td>
<td>073155</td>
<td>4002F</td>
<td></td>
</tr>
<tr>
<td>0022</td>
<td>00110</td>
<td>476G</td>
<td></td>
</tr>
<tr>
<td>0023</td>
<td>002356</td>
<td>510L</td>
<td></td>
</tr>
<tr>
<td>0024</td>
<td>002473</td>
<td>550L</td>
<td></td>
</tr>
<tr>
<td>0025</td>
<td>002557</td>
<td>575L</td>
<td></td>
</tr>
<tr>
<td>0026</td>
<td>003131</td>
<td>640L</td>
<td></td>
</tr>
</tbody>
</table>
THE PROGRAM COMPUTES THE HEATING RATE AT A NUMBER OF LOCATIONS ON THE SURFACE OF THIN SKIN TRANSIENT HEATING RATE MODELS. EXPERIMENTAL DATA, CALIBRATED IN ENGINEERING UNITS, IS OBTAINED FROM THE ABEEL TAPE OUTPUT OF THE ENTSOS DATA REDUCTION COMPUTER. THE PROGRAM OUTPUT CONSISTS OF TIME HISTORY TABULATIONS IN AN ARRAY BY THERMOCOUPLE LOCATIONS.
<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00100</td>
<td>IEVT - CURRENT COMMAND EVENT CHANNEL VALUE</td>
</tr>
<tr>
<td>00100</td>
<td>IGOOD - IGOOD = 1 INDICATES WHEN THE FIRST SET OF 3 GOOD THERMOCOUPLES ON A ROW OR COLUMN HAS BEEN FOUND IN LOGIC FOR COMPUTING GX OR GY</td>
</tr>
<tr>
<td>00100</td>
<td>IOPT - RUN CONTROLLED BY 0 = START-STOP TIMES 1 = COMMAND CHANNEL EVENTS</td>
</tr>
<tr>
<td>00100</td>
<td>IOPT1 - IOPT = 1</td>
</tr>
<tr>
<td>00100</td>
<td>IDPAR - PARTITION ERROR RECORD COUNTER</td>
</tr>
<tr>
<td>00100</td>
<td>IX - X-COORDINATE OF THERMOCOUPLE BEING DEFINED BY CHANNEL NO.</td>
</tr>
<tr>
<td>00100</td>
<td>IY - Y-COORDINATE OF THERMOCOUPLE BEING DEFINED BY CHANNEL NO.</td>
</tr>
<tr>
<td>00100</td>
<td>IYDD - THE Y COORDINATE INDEX JUST PRIOR TO THE CHANGE IN ADJACENT LOCATIONS OF GOOD THERMOCOUPLES IN THE X-DIRECTION</td>
</tr>
<tr>
<td>00100</td>
<td>J - USED TO DESIGNATE COORDINATES IN Y-DIRECTION</td>
</tr>
<tr>
<td>00100</td>
<td>J1, J2, J3 - SAME AS J, J1, J2, J3 NOT IN Y DIRECTION</td>
</tr>
<tr>
<td>00100</td>
<td>LINES - LINE COUNTER FOR PAGE EJECT CONTROL</td>
</tr>
<tr>
<td>00100</td>
<td>LTEMP - NUMBER OF LINES REQUIRED FOR ONE NX X NY ARRAY</td>
</tr>
<tr>
<td>00100</td>
<td>LUIN - LOGICAL UNIT FOR INPUT TAPE</td>
</tr>
<tr>
<td>00100</td>
<td>N - THE MAXIMUM NUMBER OF CHANNELS THE INPUT TAPE MAY HAVE</td>
</tr>
<tr>
<td>00100</td>
<td>NCC - NUMBER OF COMMAND CHANNELS</td>
</tr>
<tr>
<td>00100</td>
<td>NCHS - NUMBER OF CHANNELS ON TAPE</td>
</tr>
<tr>
<td>00100</td>
<td>NLBS - THE MAXIMUM NUMBER OF SCANS FOR WHICH LEAST SQUARES COMPUTATIONS MAY BE DONE</td>
</tr>
<tr>
<td>00100</td>
<td>NPAR - MAXIMUM PERMISSIBLE NUMBER OF PARITY ERRORS PER TIME</td>
</tr>
<tr>
<td>00100</td>
<td>NN - CHANNEL NUMBER OF THERMOCOUPLE BEING PROCESSED</td>
</tr>
<tr>
<td>00100</td>
<td>NN1, NN2, NN3 - CHANNEL NUMBERS OF THREE SUCCESSIVE GOOD THERMOCOUPLES (GX OR GY COMPUTATIONS)</td>
</tr>
<tr>
<td>00100</td>
<td>NOTH - THE HISTORY TAB OPTION: IF NOTH = 0, EACH SCAN OF DATA FROM THE INPUT TAPE IN THE TIME INTERVAL WILL BE PRINTED.</td>
</tr>
<tr>
<td>00100</td>
<td>NPFT - MAXIMUM PERMISSIBLE NUMBER OF POINTS PER TIME</td>
</tr>
<tr>
<td>00100</td>
<td>NSCN - NUMBER OF SCANS OF DATA PROCESSED IN THE CURRENT TIME</td>
</tr>
<tr>
<td>00100</td>
<td>NTCH - ARRAY OF THERMOCOUPLE CHANNEL NUMBERS</td>
</tr>
<tr>
<td>00100</td>
<td>NTCC - TOTAL NUMBER OF THERMOCOUPLE LOCATIONS (NX X NY)</td>
</tr>
<tr>
<td>00100</td>
<td>NTLC - NUMBER OF POINTS REQUESTED FOR CURVE FIT</td>
</tr>
<tr>
<td>00100</td>
<td>NTME - NUMBER OF Y-COORDINATE LOCATIONS</td>
</tr>
<tr>
<td>00100</td>
<td>NTSL - NUMBER OF TIME SLICES PROCESSED</td>
</tr>
<tr>
<td>00100</td>
<td>NXY - NUMBER OF X-COORDINATE LOCATIONS</td>
</tr>
<tr>
<td>00100</td>
<td>NY - NUMBER OF Y-COORDINATE LOCATIONS</td>
</tr>
<tr>
<td>00100</td>
<td>QDOT - USED FOR MEAN HEATING RATE AND LEAST SQUARES HEATING RATE AT DIFFERENT TIMES</td>
</tr>
<tr>
<td>00100</td>
<td>QDOTTH - THE SUTS (OR AVERAGES) OF THE QDOT VALUES FOR NTSL TIME</td>
</tr>
<tr>
<td>00100</td>
<td>QDOTTH - THE SUTS (OR AVERAGES) OF THE QDOT VALUES FOR NTSL TIME</td>
</tr>
<tr>
<td>00100</td>
<td>QSLICE - LEAST SQUARE SLOPE OR HEATING RATE</td>
</tr>
<tr>
<td>00100</td>
<td>QSTATME - START TIME FOR CURVE FIT</td>
</tr>
<tr>
<td>00100</td>
<td>QSUM - SUM (X(I)*Y(I))</td>
</tr>
<tr>
<td>00100</td>
<td>QSUM2 - SUM (X(I))</td>
</tr>
<tr>
<td>00100</td>
<td>QSUM3 - SUM (Y(I))</td>
</tr>
<tr>
<td>00100</td>
<td>QSUM4 - SUM (X(I)**2)</td>
</tr>
</tbody>
</table>
PARAMETER NC=260, NL9=50
DIMENSION TITLE(12), TITLE2(12), XX(50), YY(50), NTCH(50,50)
DIMENSION TEMPINC(4), WORD(150), Q(50,50), QT(50,50), QDOT(50,50)
DIMENSION GDP(600), TEMPINC(NLS), ERR(50,50), DOT(12)
DIMENSION TIME(3), YDOT(50)
DOUBLE PRECISION SUM1, SUM2, SUM3, SUM4, SUM5, SUM6, SUM7, SUM8

READ TITLE CARDS
READ (5,1000) TITLE2
WRITE (6,2000) TITLE1, TITLE2, TITLE3
READ CONSTANTS
READ (5,1001) RHO, CP, BSK, DD, NX, NY
WRITE (6,2001) RHO, CP, BSK, DD, NX, NY
NTCLOC = NX * NY
IF (NTCLOC.LT.3) THEN
  WRITE (A,4001)
  GO TO 10
END IF
READ TAPE INFORMATION
10 READ (5,1002) NCHS, NCC, IPO, NPAR, NOTH
00175 148-  IF (IOP1, NEQ 0) IOP1 = 1
00176 149-  WRITE (6, 2002) NCHS, NCC, IOP1, NPAR, NOTH
00177 150-  IF (NCHS/(NC-1) 20, 20,
00178 151-  LCODE = I
00179 152-  WRITE (6, 4003)
00180 153-  20 CONTINUE
00181 154-  IF (DD(2)) 30, 30,
00182 155-  READ (5, 1005) YDD(1), J = 1, NX
00183 156-  WRITE (6, 2019) YDD(I), I = 1, NX
00184 157-  30 CONTINUE
00185 158-  C  READ X AND Y COORDINATE LOCATIONS
00186 159-  READ (5, 1005) X(1), I, NCH, NPAR, NOTH
00187 160-  WRITE (6, 2006) X(I), I = 1, NX
00188 161-  WRITE (6, 2006) Y(1), J = 1, NY
00189 162-  WRITE (6, 2006) Y(J), J = 1, NY
00190 163-  C  READ THERMOCOUPLE CHANNEL NUMBER AND
00191 164-  CORRESPONDING X-Y COORDINATES
00192 165-  READ (5, 1007) (X, I, NCH(I), J, I, NY)
00193 166-  WRITE (6, 2007)
00194 167-  WRITE (6, 2006) (JEOY(J), J = 1, NY)
00195 168-  DO 40 I = 1, NX
00196 169-  WRITE (6, 2008) (1, NCH(I), J, J = 1, NY)
00197 170-  40 CONTINUE
00198 171-  C  READ START STOP TIMES OR EVENT LEVELS
00199 172-  IOP1 = IOP1 + 1
00200 173-  GO TO (50, 60), IOP1
00201 174-  50 READ (5, 1003) END, 01ST, TSTOP,STATME, NTME
00202 175-  IF (INTL < GT 0) WRITE (6, 2021)
00203 176-  WRITE (6, 2003) INTL, TSTOP, STATME, NTME
00204 177-  GO TO 70
00205 178-  60 READ (5, 1004) CESTRT, CESTOP, STATME, NTME
00206 179-  IF (INTL < GT 0) WRITE (4, 2021)
00207 180-  WRITE (6, 2003) CESTRT, CESTOP, STATME, NTME
00208 181-  70 IF (NTME .LE. NLS) GO TO 80
00209 182-  1 = NLS
00210 183-  WRITE (6, 4002)
00211 184-  LCODE = 1
00212 185-  80 CONTINUE
00213 186-  IF (LCODE) 1, 730
00214 187-  C  INITIALIZE AND DEFINE CONSTANTS
00215 188-  CONA = RHO . CP / 24.
00216 189-  CON12 = RHO . CP / 12.
00217 190-  CON24 = SIGK . 24.
00218 191-  IPAR = 0
00219 192-  NSCN = 0
00220 193-  LTEMP = (NTM * 9) / 101 + NX + 5
00221 194-  DO 90 I = 1, NCHS
00222 195-  DO 90 J = 1, NY
00223 196-  IF (LD(2)) 110, 110,
00224 197-  DO 100 I = 1, NCHS
00225 198-  100 CONTINUE
00226 199-  110 TCESTRT = CESTRT
00227 200-  IESTOP = CESTOP
00228 201-  NPT = 0
00229 202-  LINES = 1000
00230 203-  ITOD = NY + 1
00231 204-  IF (DD(2)) 110, 110,
STARTING TIME FOUND

GO TO 330

READ (LUIN, ERR=130, END=140) TIME(1), TEMP(1,6), NCHS

GO TO 150

WRITE (6, 4005)

GO TO 120

WRITE (6, 4005) LUIN

IF (IPAR = NPAR)

DO 290 IC = 1, NPAR

READ (LUIN, ERR=230, END=140) TIME(3), TEMP(1,6), NCHS

GO TO 240

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

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WRITE (6, 4009)

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WRITE (6, 4009)

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IF (IPAR = NPAR)

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WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)

IF (IPAR = NPAR)

DO 230 IC = 1, NPAR

WRITE (6, 4009)
00574   262* IF (NTME .LE. 2 OR TIME(2) .LT. STATME) GO TO 330
00576   263* NPT = NPT + 1
00577   264* DO 270 I = 1, NCHS
00579   266* CONTINUE
00580   268* IF (NPD(N)' .LT. 360) GO TO 270
00582   270* WRITE (4,20000) TITLE1,TITLE2
00584   271* LINES = 3
00585   272* CONTINUE
00586   273* WRITE (4,2013) TIME(2)
00587   274* LINES = LINES + LTEMP
00588   275* TIM(NPT) = TIME(2)
00589   276* CONTINUE
00590   278* IF (LINES .GT. 340) GO TO 270
00592   279* WRITE (4,20010) WORD(J), J = 1, NTME
00593   280* CONTINUE
00594   281* CONTINUE
00595   282* CONTINUE
00596   283* C DO ERROR ANALYSIS IF *NTME POINTS HAVE BEEN SAVED
00597   284* C IF (NTME .LE. 2 OR NPT .LT. NTME) GO TO 220
00598   285* IF (LINES + LTEMP - NPT) .GT. 370 GO TO 270
00599   286* LINES = 3
00600   287* WRITE (4,20000) TITLE1,TITLE2
00601   288* WRITE (4,2015) NPT, TIM(NPT)
00602   289* LINES = LINES + 2* LTEMP - 3
00603  290* CALL ERRFIT(53951)
00604  291* C OUTPUT HEATING RATE - QDOT AND PERCENT ERROR - ERR
00605  292* C WRITE(6,212)
00606  293* WRITE(6,223) (JEQ(J), J = 1, NTME)
00607  294* DO 300 I = 1, NCHS
00608  295* WRITE (4,20101) (QDOT(I), I = 1, NTME)
00609  296* CONTINUE
00610  297* WRITE (6,216)
00611  298* WRITE(6,223) (JEQ(J), J = 1, NTME)
00612  299* DO 300 I = 1, NCHS
00613  300* WRITE (4,20101) (ERR(I), I = 1, NTME)
00614  301* CONTINUE
00615  302* TIM(I) = TIM(NPT)
00616  303* DO 304 I = 1, NCHS
00617  304* TMP(I) = TMP(I, NPT)
00618  305* CONTINUE
00619  306* CONTINUE
00620  307* CONTINUE
00621  308* CONTINUE
00622  309* CONTINUE
00623  310* NPT = I
00624  311* GO TO 220
00625  312* C THE TRUE SLICE HAS BEEN COMPLETED OR AN END OF FILE ENCOUNTERED
00626  313* C
00627  314* C 440 CONTINUE
00628  315* IF (NTME .LE. 2 OR NPT .LT. 3) GO TO 440
00629  316* IF (LINES .GT. LTEMP - 59) GO TO 270
00630  317* WRITE (4,20000) TITLE1,TITLE2
00631  318* WRITE (4,2015) NPT, TIM(NPT)
*00776 319* CONTINUE
*00777 320* WRITE (6,2015) NPT, TIM(TI), TIM(NPT)
*00778 321* IF (NPT.LT.NTME) WRITE (6,2017)
*00779 322* WRITE(6,2015) NPT, TIM(TI), TIM(NPT)
*00780 323* WRITE (6,2023) (JEG, J=1, NX)
*00781 324* DO 420 I=1, NX
*00782 325* WRITE (6,2010) (QO(I), J=1, NY)
*00783 326* 420 CONTINUE
*00784 327* WRITE (6,2016)
*00785 328* WRITE (6,2023) (JEG, J=1, NY)
*00786 329* DO 430 J=1, NY
*00787 330* WRITE (6,2010) (QO(I), J=1, NY)
*00788 331* 430 CONTINUE
*00789 332* IF (NSCN) 680, 9
*00790 333* NTSL = NTSL + 1
*00791 334* LINES = LINES + 1
*00792 335* WRITE (6,2000) TITLE1, TITLE2
*00793 336* WRITE (6,2023) (JEG, J=1, NY)
*00794 337* DO 450 I=1, NY
*00795 338* J = J + 1
*00796 339* IF (J.GT.IYDD) IDD = 2
*00797 340* IF (NX - J) 490, 490
*00798 341* TEMP(J) = TEMP(J) / NSCN
*00799 342* WRITE (6,2010) (WORD(I), J=1, NY)
*00800 343* 450 CONTINUE
*00801 344* IF (NSCN) 680, 9
*00802 345* NTSL = NTSL + 1
*00803 346* LINES = LINES + 1
*00804 347* WRITE (6,2000) TITLE1, TITLE2
*00805 348* WRITE (6,2023) (JEG, J=1, NY)
*00806 349* DO 450 J=1, NY
*00807 350* J = J + 1
*00808 351* IF (J.GT.IYDD) IDD = 2
*00809 352* IF (NX - J) 490, 490
*00810 353* TEMP(J) = TEMP(J) / NSCN
*00811 354* WRITE (6,2010) (WORD(I), J=1, NY)
*00812 355* 450 CONTINUE
*00813 356* C PROCESS LATERAL HEAT LOSS IN X-DIRECTION (EQUATION 3)
*00814 357* DO 470 I=1, NX
*00815 358* Q(X(I), J) = 0
*00816 359* 470 QDOT(I,J) = 0
*00817 360* IF (NX - J) 530, 530
*00818 361* IODD = 1
*00819 362* DO 510 J=1, NY
*00820 363* IGOOD = 0
*00821 364* IF (J+GT, IYDD) IODD = 2
*00822 365* II = 0
*00823 366* 480 II = II + 1
*00824 367* IF (II = NX) 510, 510
*00825 368* WRITE (6,2016)
*00826 369* I = I + 1
*00827 370* IF (I = 12) 510, 510
*00828 371* NN2 = NTCX(12, J)
*00829 372* IF (NN2) 990, 990
*00830 373* I = I + 1
*00831 374* 500 II = II + 1
*00832 375* 500 II = II + 1
*00833 376* 500 II = II + 1
*00834 377* 500 II = II + 1
*00835 378* 500 II = II + 1
*00836 379* 500 II = II + 1
*00837 380* 500 II = II + 1
*00838 381* 500 II = II + 1
*00839 382* 500 II = II + 1
*00840 383* 500 II = II + 1
*00841 384* 500 II = II + 1
*00842 385* 500 II = II + 1
*00843 386* 500 II = II + 1
*00844 387* 500 II = II + 1
*00845 388* 500 II = II + 1
*00846 389* 500 II = II + 1
*00847 390* 500 II = II + 1
*00848 391* 500 II = II + 1
*00849 392* 500 II = II + 1
*00850 393* 500 II = II + 1
*00851 394* 500 II = II + 1
*00852 395* 500 II = II + 1
*00853 396* 500 II = II + 1
*00854 397* 500 II = II + 1
*00855 398* 500 II = II + 1
*00856 399* 500 II = II + 1
*00860 400* 500 II = II + 1
1204  376*  IF (13-NX) #510
1207  377*  NX = NTCH(13:J)
1210  377*  IF (NN3) 500,500
1213  379*  IG00D = IG00D + 1
1214  380*  QX(J2:J) = CON24 * DD(IDD) / (XX(J1) = XX(J1)) * (TEMP(NN2:1)
1216  382*      TEMP(NN1:1) / (XX(J2) = XX(J1)) = (TEMP(NN3,1) -
1218  383*      TEMP(NN2:1) / (XX(J1) = XX(J2))
1219  385*  QX(J1:J) = QX(J1:J) * qx(J1:J)
1220  384*  IF (IG00D-EG-1) QX(J1:J) = QX(J1:J)
1222  385*  IF (13-NX) #510,#510
1223  386*  NN1 = NN2
1224  387*  NN2 = NN3
1225  388*  J = J1
1226  389*  JZ = J1
1227  389*  GO TO 500
1230  391*  510 CONTINUE
1232  392*  WRITE (6,2009)
1234  393*  WRITE (6,2023) (JEQ,J=1,1,MY)
1236  394*  DO 520 =1,1,NX
1238  395*  WRITE (6,2010) (QX(J1:J) = J1,J=1,1,MY)
1239  396*  520 CONTINUE
1240  397*  530 CONTINUE
1242  398*  C  PROCESS LATERAL HEAT LOSS IN Y-DIRECTION
1244  399*  C
1246  400*  IF (NY=1) 630,630
1248  402*  DO 610 =1,1,NX
1250  403*  IG00D = 0
1252  404*  IDD = 1
1254  405*  J1 = 0
1256  406*  540 J1 = 1
1258  407*  IF (J1=#MY) #610
1260  408*  NN1 = NTCH(J1:J)
1262  409*  IF (NN1) 540#540
1264  410*  J2 = J1
1266  412*  JZ = J2
1268  413*  550 JZ = 1
1270  414*  IF (JZ=#MY) #610
1272  415*  NN2 = NTCH(J2:J)
1274  416*  IF (NN2) 550#550
1276  417*  J3 = J2
1278  418*  560 J3 = 1
1280  419*  IF (J3=#MY) #610
1282  420*  NN3 = NTCH(J3:J)
1284  421*  IF (NN3) 560#560
1286  422*  J4 = J3
1288  424*  570 J4 = 1
1290  425*  IF (J4=#MY) #610
1292  426*  QY(J1:J2) = CON24 * DD(IDD) / (YY(J3) - YY(J1)) * (TEMP(NN2:1)
1294  428*      TEMP(NN1:1) / (YY(J2) - YY(J1)) = (TEMP(NN3:1) -
1296  430*      TEMP(NN2:1) / (YY(J3) - YY(J2))
1298  432*  575 QY(J1:J2) = CON24 * DD(IDD) / (YY(J3) - YY(J1)) * (TEMP(NN2:1)
1300  434*      TEMP(NN1:1) / (YY(J2) - YY(J1)) = (TEMP(NN3:1) -
1302  436*      TEMP(NN2:1) / (YY(J3) - YY(J2))
01701  60**  C  SUM Y(i)
01702  605*  C  SUM3 * SUM3 + TMP(N,1)
01702  606*  C  SUM (Y(i)**2)
01703  607*  C  SUM * SUM5 * TMP(N,1)**2
01704  608*  C  SUM3 * SUM5 * TMP(N,1)**2
01704  609*  C  SUM X(i) * SUM Y(i)
01705  610*  C  SUM7 = SUM2 * SUM3
01706  611*  C  SLOPE
01707  612*  C  SLOPE = (NPT * SUM1 - SUM7) / SUM8
01707  613*  C  SIGMA
01708  614*  C  SIGMA = 1.0 / NPT * SORT(NPT) * SUMS - SUM3**2
01710  615*  C  1.0 = (NPT * SUM1 - SUM7)**2 / SUM8
01710  616*  C  STANDARD ERROR
01711  617*  C  SERR = NPT * SIGMA / SORT(NPT-2) * SUMB
01711  618*  C  PERCENT ERROR
01712  619*  C  HEATING RATE
01712  620*  C  ERR(I,J) = SERR / SLOPE * 100.0
01713  621*  C  QDOT(I+J) = CON12 * DD(I+J) * SLOPE
01714  622*  C  GO TO 200
01715  623*  C  175 ERR(I,J) = 0.0
01716  624*  C  QDOT(I+J) = 0.0
01717  625*  C  200 CONTINUE
01722  626*  C  RETURN
01722  627*  C  ERR(I,J) * ERR(I,J)
01723  628*  C  ERR(I,J) * ERR(I,J)
01725  629*  C  PRENT(I+J) * PRENT(I+J)
01725  630*  C  PRENT(I+J) * PRENT(I+J)
01726  631*  C  RETURN !
01727  632*  C  END

END OF COMPILED:  NO DIAGNOSTICS.

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5-13
ATTACHMENT 8

CORRESPONDENCE
THNSKN computes the mean heating rate at up to 100 locations on the surface of thin skin transient heating rate models. Output is printed in tabular form and consists of time history tabulation of temperatures, average temperatures, heat loss, without conduction correction, mean heating rate, least squares heating rate, and the percent standard error of the least squares heating rates. The input tape used is produced by the program EHTS03. (SCR 85-15-50/McBryde)
TO: LEC/Manager, Test Data Reduction Department, 672-10
FROM: ED5/Acting Chief, Data Processing Branch

SUBJECT: Requirements for a Thin Skin Transient Heating Rate Model Program

Programing support is required to develop a program to compute heating rates of thin skin transient heating rate models. This program will be developed for the Experimental Heat Transfer Section of the Structures and Mechanics Division. The program will be used to support definition of the aerothermodynamic design of the MSC space shuttle vehicle.

It is necessary that the program, specified by the attached requirements document, be operation by October 31, 1969. Preliminary requirements have been reviewed by Dr. Carl D. Scott, project engineer, and forwarded to Mrs. Yvonne Chempinski. Work on this task should be charged to project number 4556. For further information, please contact Mr. E. O. Grice, extension 5533.

Enclosure

cc:
ES56/Dr. C. D. Scott
ED57:EOGrice(LEC:JMRandal):ddc 10-27-69
DATA PROCESSING REQUIREMENTS
for a
THIN SKIN TRANSIENT HEATING RATE MODEL PROGRAM

Prepared by: J. M. Randal 22 Oct 69
(LEC Requirements & Analysis)

Approved by: K. J. Lapenborg 10-24
(LEC Requirements & Analysis)

Concurrence by: E. O. Grice 10/73
(CAD Requirements & Analysis)

Concurrence by: Carl D. Scott 10/22/63
(Experimental Heat Transfer Section)
I

PROJECT DISCUSSION

The Experimental Heat Transfer Section of the Structures and Mechanics Division has requirements for a digital computer program to compute heating rates of thin skin transient heating rate models. These models will be tested in either the 1.5 Megawatt or the 10 Megawatt Arc-Heater facility. The tests in which such models will be used will be directly related to current MSC space shuttle vehicle activities. The program outputs will be used to support definition of the aerothermodynamic design of the MSC space shuttle vehicle configuration.

II

TEST CONFIGURATION

The thin skin transient heating rate models will be constructed with a thin metal skin. Thermocouple instrumentation will be attached to the back side of the skin in rectangular arrays and used to measure temperature. When these models are subjected to a non-uniform constant heat flux by the arc-heater equipment, the surface temperature of the skin will increase according to the laws of heat conduction and capacitance. The skin will be sufficiently thin so that the temperature gradient normal to the skin will be negligible. Therefore, it will be assumed that the thermocouples attached to the back surface actually measure the temperature of the skin at each location.

The analog signals output by the thermocouple array will be digitized by use of either the 160 channel data acquisition system located in Building 222 or the 50 channel data acquisition located in Building 262. The digital data tape output by either of these systems will be compatible with the CAD UNIVAC 1108 digital computer system. The existing EHTS03 (Q566) program will be used to calibrate the experimental data in engineering units and output a data tape for input to the required thin skin transient heating rate model program. See Figure 1 for a diagram of the data flow and test configuration.
III DATA PROCESSING REQUIREMENTS

The hardware required to accomplish the data processing task will be the UNIVAC 1108 digital computer. The software required will be the existing EHTS03 (Q566) program and the Thin Skin Transient Heating Rate Model Program specified in Appendix A.

The data processing procedure will consist of the steps listed below:

1. The project engineer will have the data tape and the lead card input for the EHTS03 program delivered to the test data coordinator in Room 228 of Building 12.

2. The data coordinator will issue instructions for computer processing and notify the project engineer when the processing is complete.

3. The project engineer will review the EHTS03 data and provide lead card setups for the thin skin transient heating rate model program.

4. The data coordinator will issue instructions for computer processing and notify the project engineer when the processing is complete.

IV TECHNICAL REFERENCES

1. Memo: ES5/9-24(9)/249M, Memorandum to: ED/Chief, Computation and Analysis Division; from: ES/Chief, Structures and Mechanics Division; Subject: Requirements for a computer program to calculate heating rates using thin skin models.

2. Program Documentation, Experimental Heat Transfer Data Reduction Package #3 (EHTS03), Program Q566, Project 4556, August 1969.
APPENDIX A
PROGRAMING SPECIFICATION
for
THIN SKIN TRANSIENT HEATING RATE MODEL PROGRAM

I
PURPOSE

The purpose of this program will be to compute the heating rate at each of a number of locations on the surface of thin skin transient heating rate models. Experimental data, calibrated in engineering units, will be obtained from the ABEL tape output by the EHTS03 computer program. The program output will consist of time history tabulations of computed data with options for input and intermediate computation tabulations.

II
INPUT

The program inputs will be the ABEL time history data tape output by the EHTS03 program and the lead card inputs necessary to specify computational constants, input data channels, command channels, options, and command event levels. The magnetic input data tape will consist of FORTRAN written data records in a single data file. The first data word in each record will be the time word. The remaining words will be the data channel words ordered by channel number. The tape will be written with 800 bit per inch density and odd parity using the UNIVAC 1108 computer.

The lead card inputs will include, but not be limited to, the following items. The exact card formats will be determined by the programer.

1. Two cards, each containing at least sixty column alphanumeric entries will be used to identify the data contained in the output tabulation. This input will appear in the title of each page of the tabulation.
2. Coordinate positions for each thermocouple with a maximum array of 50x50 positions. The upper left hand position will be designated $T_{xy} = T_{11}$ as shown by Table 1 in Section III.

3. Input tape data channel number for each thermocouple in $T_{xy}$ array.

4. Physical locations of each row and column. All locations will be determined from the row and column containing $T_{xy} = T_{11}$ in inches.

5. Input tape data channel number for the command channel.

6. Command channel signal level used to start computations. Millivolt level.

7. Command channel signal level used to terminate computations. Millivolt level.

8. Input tape data channel number for the time channel. Normally channel 1.


10. Stop computation time.

11. Coordinate positions of known erroneous thermocouple data.

12. Option to tabulate tape input temperatures.

13. Option to tabulate intermediate computation results.
14. Computational constants:
   a. Mass density ($\rho$) of the test material in pounds mass per cubic foot. (lbm/ft$^3$)
   b. Specific heat ($c_p$) of the test material in Btu/lbm °F
   c. Material thickness (d) in inches
   d. Thermal conductivity (K) in Btu/ft sec°F

III TABLES

The thermocouple instrumentation used to measure the temperatures on the thin skin transient heating model will be arrayed in the rectangular coordinate system shown by Table 1. The maximum size of the array will be 50x50. The minimum array will be 3x1 or 1x3. Only line, rectangular or square arrays will be defined. Other array configurations may be computed if dummy data is input to fill out the array. Even though the thermocouple array will generally be rectangular, the spacing between rows and columns will not normally be the same. Therefore, the distance of each row and column from $T_{11}$ will be a separate card input. The array will be computed as for a planar surface regardless of the actual configuration of the model. That is, the last row will not be adjacent to the first row as in the case of a cylindrical surface, etc. Spherical and conical surfaces will not be defined other than as rectangular arrays.

```
0,0                      Y
 X

T_{1,1}  T_{1,2}  T_{1,3}  \ldots  T_{1,max}
T_{2,1}  \ldots
T_{3,1}  \ldots
\vdots
T_{max,1}  \ldots  T_{1,j}
```

TABLE 1

THERMOCOUPLE ARRAY

8-9
Equation 1 will be the energy balance equation used to describe the heating applied to the model surface at each coordinate \((x_i, y_j)\) for each data time sample \((t_k)\).

Equation 1:

\[
\dot{q}_{ij} = \left( \frac{\rho d C_p}{12} \right) \left( \frac{T_{ij}}{t} \right) + (\dot{q}_{x_{ij}}) + (\dot{q}_{y_{ij}})
\]

where:

\(\dot{q}_{ij}\): Heating rate to the model surface \(X_i, Y_j\)

\(\rho\): Mass density of surface material

\(d\): Material thickness of surface material

\(C_p\): Specific heat of surface material

\(\frac{\partial T_{ij}}{\partial t}\): Derivative computed by the use of equation 2

\(\dot{q}_{x_{ij}}\): Derivative computed by the use of equation 4

\(\dot{q}_{y_{ij}}\): Derivative computed by the use of equation 5
Equation 2 will be used to compute the partial derivative of temperature with respect to time for the thermal mass around the thermocouple test point for each data time sample \((t_k)\).

Equation 2:

\[
\frac{\partial T_{ij}}{\partial t} = b_k + 2C_k t_k
\]

Where:

- \(b_k\): Determined by solution of equations 3a, 3b, and 3c
- \(C_k\): Determined by solution of equations 3a, 3b and 3c

Equations 3a, 3b and 3c will be solved for \(b_k\) and \(C_k\) by the use of the Gauss-Jordan or other appropriate method for the solution of simultaneous equations.

\[
T_{ij}(t_{k-1}) = a_k + b_k t_{k-1} + C_k (t_{k-1})^2
\]

\[
T_{ij}(t_k) = a_k + b_k t_k + C_k (t_k)^2
\]

\[
T_{ij}(t_{k+1}) = a_k + b_k t_{k+1} + C_k (t_{k+1})^2
\]

Where:

- \(a_k, b_k, c_k\): Coefficients of a second degree polynomial
- \(t_{k-1}\): Time of preceeding data sample from ABEL input tape
- \(t_k\): Time of current data sample
- \(t_{k+1}\): Time of succeeding data sample
Equation 4 will be used to compute the lateral heat loss in the X direction for input to equation 1 for each time sample \( t_k \).

**Equation 4:**

\[
q_{1j}^X = 2\delta \ k \ d \ \left( \frac{1}{X_{i+1} - X_{i-1}} \right) \left( \frac{T_{ij} - T_{i-1,j}}{X_{i} - X_{i-1}} + \frac{T_{i+1,j} - T_{ij}}{X_{i+1} - X_{i}} \right)
\]

Where:

- \( k \): Thermal conductivity (card input)
- \( d \): Material thickness (card input)
- \( X_{i+1} - X_{i-1} \): Distance between thermocouples located on either side of \( X_i \) thermocouple, etc.
- \( T_{ij} - T_{i-1,j} \): Input data temperature difference between thermocouples.

Equation 5 will be used in the same manner as equation 4 to determine the lateral heat loss in the Y direction for each data time sample.

**Equation 5:**

\[
q_{1j}^Y = 2\delta \ k \ d \ \left( \frac{1}{Y_{j+1} - Y_{j-1}} \right) \left( \frac{T_{ij} - T_{i,j-1}}{Y_{j} - Y_{j-1}} + \frac{T_{i,j+1} - T_{ij}}{Y_{j+1} - Y_{j}} \right)
\]
Equation 1 will be set to zero for the two end points in a test array consisting of a single line of thermocouples. Further, equation 1 will be set to zero for the four corner transducers in a square or rectangular array. That is:

\[ 2 \leq i \leq I-1, \]
\[ 2 \leq j \leq J-1 \]

where: I and J are defined as the greatest i and j limits, respectively, of the transducer array.

Equation 1 will be computed for the test points in the transducer array that lie on the four sides of 3x2, 2x3 or larger arrays. Either equation 4 or equation 5 will be modified as required to prevent erroneous results due to lack of valid inputs for the transducers located on the sides of the test array. For test points located on the upper side of the test point array, equation 6 will be used instead of equation 4.

Equation 6:

\[ q_{ij} = 24 \, kd \left( \frac{2}{x_2 - x_1} \right) \left( \frac{T_{2j} - T_{ij}}{x_2 - x_1} \right) \]

For test points located in the lower side of the array, equation 7 will be used in lieu of equation 4.
Equation 7:

\[ q_{1j}^* = 24 \ k d \left( \frac{2}{x_j - x_{j-1}} \right) \left( \frac{T_{1j} - T_{1j-1}}{x_j - x_{j-1}} \right) \]

Equation 5 will be valid regardless of whether equations 6 or 7 are used for upper and lower limit test points.

For test points located on the left side of the array shown in Table 1, equation 8 will be used in lieu of equation 5.

Equation 8:

\[ q_{11} = 24 \ k d \left( \frac{2}{y_2 - y_1} \right) \left( \frac{T_{12} - T_{11}}{y_2 - y_1} \right) \]

For test points located on the right side of the array, equation 9 will be used in lieu of equation 5.

Equation 9:

\[ q_{1j} = 24 \ k d \left( \frac{2}{y_j - y_{j-1}} \right) \left( \frac{T_{1j} - T_{1j-1}}{y_j - y_{j-1}} \right) \]

Equation 4 will be valid regardless of whether equations 8 or 9 are used for left or right test points. Note that the end points of a linear array and corner points of a rectangular array will not be computed, as previously stated.
Card input will be used to specify which if any, of the input test points have invalid tape data input due to hardware malfunction in the test hardware or the data acquisition system. Computations for the test points on the four sides of the invalid points will be made by using the input temperature from and the distance to the thermocouple on the opposite side of the faulty point. For example, if \( T_{2,2} \) were faulty (see Table 1), \( q_{2,1} \) would be computed using \( T_{2,3} \) for the temperature input and \( Y_3 - Y_1 \) for the distance input to equation 5. Note that the program will be designed to salvage data only for points within the array. A bad point at any edge or corner of the array will be eliminated by deleting that row or column from the program input. Substitution of data from a similar point may also be done by card input. No provision will be made for computing data around specified bad input points that are separated by at least one row or column of good input data.

Computations will be controlled by card input start-stop times or by card input command channel levels. Either one or the other may be used, but not both. Start-stop times will be input in seconds and milliseconds. Command Channel start and stop levels will be input at the same levels used in the ETHS03 program. These levels will be 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90 and 95 millivolts plus or minus 2.5 millivolts.
PROGRAM OUTPUT

The program output will consist of tabulations of the input lead cards, thermocouple array format, computed and input data. No data tape will be output. Each page of the tabulated output will be identified by the card input identification title L, addition to any other identification, column headings, etc. The tabulations will include:

1. Tabulation of all input card data.
2. Row by row tabulation of input tape data channels: This tabulation will start with the channel number for \( T_{xy} = T_{11} \) and list the input data channels in 10 columns across the page. See Table 1 for a typical format. Channel numbers assigned will be set to zero for those channels specified as erroneous by card input.
3. Row by row tabulation of computed heating rate \( q_{ij} \) for each time history slice. The time of each sample will precede each beginning row of computed data. Time will be output in seconds and milliseconds.
4. Optional row by row tabulation of tape input data temperatures for each time history slice as tabulated in 3, above.
5. Optional row by row tabulation of computed X and Y heat losses \( q_{ix}^X \) and \( q_{iy}^Y \) as in 3, above.

Note that tabulated data outputs for non-computed end points, corner points and bad data points will set to zero.
October 31, 1969

TO: ED5/Chief, Data Processing Branch
FROM: LEC/Manager, Test Data Reduction Department
SUBJECT: Technical Memorandum 11-69-622, October 27, 1969, Requirements for a Thin Skin Transient Heating Rate Model Program

Subject Technical Memorandum was received by the Test Data Reduction Department on October 29, 1969.

Responsibility for the requested programming support has been assigned to Mrs. Yvonne Chempinski. Mrs. Chempinski has been working from preliminary requirements documents. The program has been completed on schedule with test output delivered to Doctor Scott. Two minor additions were requested by Doctor Scott and will be completed shortly.

Please direct any additional communications regarding this project to Mrs. Chempinski at HU8-0080, extension 345 or Mr. Len Martin, ext. 336.

Unless otherwise directed, all effort expended on this task will continue to be charged to Project Number 4556.
TO: LEC/Manager, Test Data Reduction Department, 672-10  
DATE: November 18, 1969

FROM: ED5/Chief, Data Processing Branch  
In reply refer to: 11-69-634

SUBJECT: Requirements for modification of the THNSKN (Q614) program

Programming support is required to modify the Thin Skin Transient Heating Rate Model Program. The modifications requested by Dr. C. D. Scott of the Experimental Heat Transfer Section of the Structures and Mechanics Division are listed below:

a. Change the card input format for X and Y coordinates from F 5.1 to F 10.3.

b. Change the data output print format to F 10.3.

c. Make the tabulation of tape input data temperatures, X and Y lateral heat losses as standard output rather than optional.

d. Compute end point and corner point data for the thermocouple array rather than setting this data to zero.

It is understood that Mrs. Yvonne Chempinski has started work on these modifications in response to a verbal request from Dr. Scott. Work on this task should be a continuing charge to project number 4556. For further information, please contact E. O. Grice, extension 5533.

cc:
ES56/Dr. C. D. Scott  
ED57/J. L. Fisher

ED57:E0Grice(LEC:JMRandal):ddc 11-18-69
November 25, 1969

TO: ED5/Chief, Data Processing Branch
FROM: LEC/Manager, Test Data Reduction Department
SUBJECT: Technical Memorandum 11-69-634, November 18, 1969

Requirements for Modification of the THNSKN (Q614) Program

Subject Technical Memorandum was received by the Test Data Reduction Department on November 21, 1969.

Responsibility for maintenance of the THNSKN program has been assigned to Mrs. Yvonne Chempinski. The program modifications specified in the subject Technical Memorandum have been completed, and the modified program has been validated.

Please direct any further communications regarding this task to Mrs. Chempinski, HU8-0080, extension 345.

As directed, all effort expended on this task will continue to be charged to Project Number 4556.

Doyle L. Johnson

DLJ:JDG:pm
Distribution: J. L. Fisher/ED57
E. O. Grice/ED57
J. M. Randal/C18
Y. Chempinski/B11
J. D. Garrett/B11
TO: LEC/Manager, Test Data Reduction Department 672-10

FROM: ED5/Chief, Data Processing Branch

SUBJECT: Requirements for modification of the THNSKN (Q614) program

Programming support is required to modify the Thin Skin Transient Heating Rate Model Program. Equations 4 and 5 are to be changed to the form shown below:

Equation 4:

\[
\frac{dX}{dt} = 24kd \left[ \frac{1}{(X_{i+1} - X_{i-1})} \left( \frac{T_{i,i} - T_{i-1,i}}{X_{i} - X_{i-1}} - \frac{T_{i+1,i} - T_{i,i}}{X_{i+1} - X_{i}} \right) \right]
\]

Equation 5:

\[
\frac{dX}{dt} = 24kd \left[ \frac{1}{(Y_{j+1} - Y_{j-1})} \left( \frac{T_{i,i} - T_{i,i-1}}{Y_{j} - Y_{j-1}} - \frac{T_{i,i+1} - T_{i,i}}{Y_{j+1} - Y_{j}} \right) \right]
\]

Mrs. Yvonne Chempinski has started work on these changes in response to a verbal request from Dr. Scott. Work on this task should be a continuing charge to project number 4556. For further information, please contact E. O. Grice, extension 5533.

cc: ES56: Dr. C. D. Scott

ED57/EOGrice(LEC:JM Randall); bc 11-20-69

Fred Fulton
December 1, 1969

TO:       ED5/Chief, Data Processing Branch
FROM:  LEC/Manager, Test Data Reduction Department
SUBJECT:  Technical Memorandum 11-69-636, November 24, 1969
          Requirements for Modification of the THNSKN Program
          (Q614)

Subject Technical Memorandum was received by the Test Data Reduction
Department on November 28, 1969.

Programming support for the subject program has been assigned to
Mrs. Yvonne Chempinski of the Data Acquisition Systems programming
group. Mrs. Chempinski has completed the requested program modifi-
cations having worked from a verbal request from Doctor Carl Scott.

Please direct any additional communications regarding this project
to Mrs. Chempinski, HU8-0080, extension 345, or to Mr. Len Martin,
the Engineering Applications Programming team leader, at extension
336.

As directed, all work expended on this task will continue to be
charged to Project Number 4556.

[Signature]

Doyle L. Johnson

DLJ:JDG:pm
Distribution:  J. L. Fisher/ED57
              E. O. Grice/ED57
              J. M. Randal/C18
              Y. Chempinski/B11
              L. Martin/B11
              J. D. Garrett/B11
December 23, 1974

Lockheed Electronics Co. Inc.
Attn: Mr. James Brose
Mail Stop C-30
16311 El Camino Real
Houston, TX 77058

Dear Mr. Brose:

A software change request was issued by Mr. E. J. Jung and me on October 23, 1974, to incorporate changes into the thin skin heating rate data reduction computer program (THINSKIN). Equation (2) of that document should be

\[ q = \frac{1}{24} \rho c_p d N^{-1} \left( \frac{t_{ij} - t_{ij}^{N-1} - t_{ij}^{N-2}}{t_{N-1} - t_{ij}^{N-2}} \right) \]

The expressions in equations (5) and (6) should be carrying a negative sign.

Please incorporate these corrections into the program.

C. D. Scott
December 31, 1974

TO: FD5/Chief, Data Processing Branch
FROM: LEC/Manager, Data Processing Systems Department
SUBJECT: Transmittal of EXEC VIII Version of the THNSKN Program

Transmitted herewith is the EXEC VIII version of THNSKN program for the Structures and Mechanics System. This version replaces the EXEC II version.

Results from the validation runs, after being checked for correctness with the use of LEC generated test data, were submitted to the customer, Dr. Carl Scott. Upon his acceptance, the Software Change Request was signed by the SIC and NASA Project Leader. The Software Change Request form is attached giving the descriptive reason for program modification.

W. N. Fitzpatrick

Attachments
cc: H. Stephenson/FD53
    D. L. McCormick/FD52
    C. Scott/ES3
    E. J. Jung/ES3
    C. E. Hutchinson/C30
    C. F. Iven/C11
    J. Brose/C30
    J. E. McFarland/C30
    J. O. File
December 31, 1974

TO:        FD5/Chief, Data Processing Branch
FROM:      LEC/Manager, Data Processing Systems Department
SUBJECT:   Transmittal of EXEC VIII Version of the THNSKN Program

Transmitted herewith is the EXEC VIII version of THNSKN program for the Structures and Mechanics System. This version replaces the EXEC II version.

Results from the validation runs, after being checked for correctness with the use of LEC generated test data, were submitted to the customer, Dr. Carl Scott. Upon his acceptance, the Software Change Request was signed by the SIC and NASA Project Leader. The Software Change Request form is attached giving the descriptive reason for program modification.

WF: JEM: jlb
Attachments

cc: H. Stephenson/FD53
D. L. McCormick/FD52
C. Scott/ES3
E. J. Jung/ES3
C. E. Hutchinson/C30
C. F. Iven/C11
J. Brosc/C30
J. E. McFarland/C30
J. O. File

A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION
SOFTWARE CHANGE REQUEST

Date: Oct. 23, 1974

Requester/Organization: J. Jung/C. Scott/JSC-ES

Need Date: Dec. 31, 1974

REASON FOR CHANGE:
To improve the accuracy and automation of the computer program THNSKN used to calculate heat fluxes from temperature time histories measured on thin skin heat transfer models tested in JSC arc tunnel facilities.

CHANGE DESCRIPTION (attach extra sheet if necessary):
See the attached description.

TO BE COMPLETED BY RESPONSIBLE ORGANIZATION

<table>
<thead>
<tr>
<th>ESTIMATED RESOURCES:</th>
<th>APPROVALS BY:</th>
</tr>
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<td>Man-Hours 120</td>
<td></td>
</tr>
<tr>
<td>Computer Hours 2.0</td>
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TRANSMITTAL TO PRODUCTION:
Submitted by:
Programmer
Validation approved by:
System integration Coordinator

Operating system
New program decks have been submitted to production
Transmittal tape replaces current system CUR/PUR
Overlay production CUR/PUR with transmitted CUR/F
Symbolic elements are contained in file number
Relocatable elements are contained in file number
No changes are required in execution deck setup
Changes in run instructions are attached
Transmitted program tape number

ACCEPTANCE BY PRODUCTION:
Date test run completed 8-24
Project Leader Date
SOFTWARE CHANGE REQUEST

Date: Oct. 23, 1974

To Be Completed By Responsible Organization

Job Order: 83-15
SCR No.: 83-15-30

Program Name: THNSKN
Program No.: Q614
Project No.: 4300
Project Code: 4300

Need Date: Dec. 31, 1974
Target Date: 12/31/74

REASON FOR CHANGE:
To improve the accuracy and automation of the computer program THNSKN used to calculate heat fluxes from temperature time histories measured on thin skin heat transfer models tested in JSC arc tunnel facilities.

CHANGE DESCRIPTION (attach extra sheet if necessary):
See the attached description.

TO BE COMPLETED BY RESPONSIBLE ORGANIZATION

ESTIMATED RESOURCES:

<table>
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<th>Man-Hours</th>
<th>Computer Hours</th>
</tr>
</thead>
<tbody>
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<td>120</td>
<td>2.0</td>
</tr>
</tbody>
</table>

APPROVALS BY:

Task Manager: [Signature] 11/28/74
Technical Monitor: [Signature] 11/12/74
Branch Chief: [Signature] 11/14/74

TRANSMISSION TO PRODUCTION:

Submitted by: [Signature] Date

Validation approved by: [Signature] Date

Operating system: New program decks have been submitted to production
Transmittal tape replaces current system CUR/PCR
Overlay production CUR/PCR with transmittal CUR/P
Symbolic elements are contained in file number
Relocatable elements are contained in file number
No changes are required in execution deck setup
Changes in run instructions are attached
Transmitted program tape number

ACCEPTANCE BY PRODUCTION:

Data test run completed: 8-24

Project Leader: Date
THIN SKIN PROGRAM MODIFICATION

Code modifications are required to improve the accuracy and automation of the computer program THINSKIN used to calculate heat fluxes from temperature time histories measured on thin skin heat transfer models tested in the JSC arc tunnel facilities. The modification described here will also allow one discontinuity in the skin thickness (in one direction only) and uses finite difference expressions which are approximately second order accurate (except at end points) in both the space and time derivatives of the heat conduction equation.

The following modifications are required:

1) At present the computer program calculates heat fluxes only during one time period. Modify the program so that the number of time periods that heat fluxes are calculated during a run may be specified in the input.

2) Compute the average heat fluxes for each time period and print the average for each location.

3) Remove the restriction that if bad thermocouples are at end points of rows or columns of thermocouples, the computation is absorbed. Use the next good thermocouple on the end point.

4) Compute the conduction correction at end points (last good thermocouple) using the same conduction correction as at points adjacent to the end point. e.g., $q_{c1} = q_{c2} = q_{c3}$

5) Allowance for discontinuity in skin thickness. In the input two skin thicknesses, $d_1$ and $d_2$, are to be specified along with
the position $y_d$ of the junction between the two thicknesses
\( d = d_1 \) for \( y < y_d \) and \( d = d_2 \) for \( y > y_d \)
Use the appropriate thickness \( d \) for each location.

6) Compute the mean heat flux for each time interval using the
formula
\[
\bar{q}_{b_{ij}} = \bar{q}_{b_{ij}}^x + \bar{q}_{b_{ij}}^y
\]
where:
\[
\bar{q}_{b_{ij}} = \frac{1}{C_v d_1} \left( \frac{N}{2} \left( T_{ij}^{\text{H}} + T_{ij}^{\text{U}} - T_{ij}^{\text{L}} - T_{ij}^{\text{R}} \right) \right)
\]
\[
\bar{q}_{b_{ij}}^x = \frac{2A_k d_1}{X_{i+1,j} - X_{i-1,j}} \left( \frac{T_{ij}^{\text{L}} - \bar{T}_{i-1,j}}{X_i - X_{i-1}} \right)
\]
\[
\bar{q}_{b_{ij}}^y = \frac{2A_k d_1}{Y_{i+1,j} - Y_{i-1,j}} \left( \frac{T_{ij}^{\text{L}} - \bar{T}_{i,j}}{Y_j - Y_{i-1}} \right)
\]

To compute \( \bar{q}_{b_{ij}}^y \) at thermocouple locations adjacent to the skin
thickness jump \( (y_d) \) use the following formulas for \( y_k < y_d < y_{k+1} \)
instead of \( \bar{q}_{b_{ij}}^y \) (4).

\[
\bar{q}_{b_{ik}} = \frac{2A_k d_1}{y_{k+1} - y_{k-1}} \left( \frac{T_{i-1,k} - \bar{T}_{k}}{y_{k-1} - y_k} + \frac{d_2 \left( \bar{T}_{k+1} - \bar{T}_{k} \right)}{(y_d - y_k)d_2 - (y_{k+1} - y_d)d_1} \right)
\]
\[
\bar{q}_{b_{ik+1}} = \frac{2A_k d_2}{y_{k+2} - y_k} \left( \frac{d_1 \left( \bar{T}_{k} - \bar{T}_{k+1} \right)}{(y_d - y_k)d_1 + (y_{k+2} - y_d)d_1} + \frac{\bar{T}_{k+1} - \bar{T}_{k+2}}{y_{k+2} - y_{k+1}} \right)
\]
The bars over the T's denote time average of the temperatures throughout a given interval. The superscripts on the T's in the first term denote the first, second, last, and next to last temperatures in the time interval. The number of samples in a time interval is N. The first time in the interval is t, and the last is tF. The latter two terms in equations (3) and (4) are the lateral heat loss terms as used previously except now they are averages over the time interval. This procedure will replace the one currently used in the code.

7) Output - Print the start and stop times for each time interval. Print out the number of times N in each interval, the times t, and temperatures T^, at each time. No longer print the heat flux terms at each time since these are no longer calculated. Print each of the terms in equation (1): $\overline{q_{ij}}$, $\overline{q_{ij}^X}$, $\overline{q_{ij}^Y}$

and the net heat flux $\overline{q_{ij}}$. Continue to compute and print the linear least squares heat flux in the revised program. Finally, print the mean of $\overline{q_{ij}}$, averaged over the number of time intervals specified in the input.

8) Amend program documentation to reflect these and any previous changes.
ATTACHMENT 9

DIAGNOSTIC MESSAGES
DIAGNOSTIC MESSAGES

***FEWER POINTS THAN REQUESTED***

This message occurs at the end of a time slice when the number of points accumulated for least squares heat flux computations is less than the requested (NTME). This is not necessarily abnormal.

***PARITY ERROR RECORD DELETED***

An input record has been skipped because of parity errors.

END OF FILE ENCOUNTERED ON UNIT 8. PROCESSING OF ACCUMULATED DATA WILL BE ATTEMPTED.

Normally, stop times or stop event levels should be chosen so that the end-of-file is never encountered. If at least three scans of data have been accumulated, processing will be done.

TOO FEW POINTS AVAILABLE FOR CURVE FIT

Fewer than three data points have been stored so no least squares heat flux computations can be done.

***ERROR - NX OR NY IS BAD

Either one or both of NX and NY are too large or too small. Currently, the maximum size for either is 50. Either NX or NY must have a minimum value of 3.
Examples:  | NX | NY |  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>Valid</td>
</tr>
<tr>
<td>51</td>
<td>51</td>
<td>Invalid</td>
</tr>
</tbody>
</table>

***ERROR - NTME IS LARGER THAN NN

The requested number of points to be used for least squares heat flow computations exceeds array dimensions (NN). Currently NN is 50.

***ERROR - TOO MANY CHANNELS

The number of channels specified for the input tape is too large for the array dimensions. Currently, the maximum number of channels which can be processed is 260.