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PROGRAM DOCUMENTATION
SURFACE HEATING RATE OF THIN SKIN MODELS (THNSKN)
Program Q614
Job Order 83-157

(This revision supersedes 07000 dated November 1969)

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
PROGRAM DOCUMENTATION

SURFACE HEATING RATE OF THIN SKIN MODELS (THNSKN)

Program Q614
Job Order 83-157

PREPARED BY

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

April 1975

LEC-5523
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 EHIS03.
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</tr>
</tbody>
</table>
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 \( \overline{q} \) is computed by

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

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.
- \( T_{1,i,j}, T_{i,j}, T_{N-1,i,j}, T_{N,i,j} \) = the first, second, next to the last, and last temperatures of the thermocouple in row i and column j.
- \( \rho \) = mass density in \text{lb/ft}^3.
- \( C_p \) = specific heat in \text{BTU/lb}^\circ\text{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 $q^X$ is computed by

$$
q^X_{i,j} = \frac{24Kd}{X_{i+1} - X_{i-1}} \left( \frac{T_{i,j} - T_{i-1,j}}{X_{i} - X_{i-1}} - \frac{T_{i+1,j} - T_{i,j}}{X_{i+1} - X_{i}} \right)
$$

(3)

where

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

$d = d_1$ 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 $q^Y$ 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 $q^Y$ when the material has one thickness or where it has two and all three thermocouples are the same side of the junction.

$$
q^Y_{i,j} = \frac{24Kd}{Y_{j+1} - Y_{j-1}} \left( \frac{T_{i,j} - T_{i,j-1}}{Y_{j} - Y_{j-1}} - \frac{T_{i,j+1} - T_{i,j}}{Y_{j+1} - Y_{j}} \right)
$$

(4)
where
\[ d = \begin{cases} d_1 & \text{when } j + 1 \leq k, \\ d_2 & \text{when } j - 1 > k. \end{cases} \]

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

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

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

where
\[ Y_d = \text{the } Y\text{-coordinate of the function at row } i \] (see the figure).

**Case 3:** The variable $\bar{q}^Y$ when the material has two thicknesses and $j = k + 1$.

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

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

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

$$q_{i,j} = \overline{q_{i,j}} + \overline{q_{x}} + \overline{q_{y}}$$  \hspace{1cm} (7)

3. Special Treatment When the Array Contains Bad Thermocouples:

The variables $\overline{q}$, $\overline{q_{x}}$, $\overline{q_{y}}$ 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
The slope \( M \) is computed by

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

where

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

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

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

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

\[
\sigma_n(T) = \frac{1}{n}
\]

\[
\left\{ n \sum T_i^2 - (\sum T_i)^2 - \frac{(n \sum t_i T_i - \sum t_i \sum T_i)^2}{n \sum t_i^2 - (\sum t_i)^2} \right\}^{1/2}
\]  

\[
\text{(12)}
\]
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.
ATTACHMENT 1

LEAD CARD SETUP
### LEAD CARD SETUP

**CARD NO.** 1  
**JOB**  
**NAME** THNSKN  
**PROGRAMMER** McBryde  
**DATE** 12/74  
**PAGE 1 OF 10**

<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>1-72</td>
<td>12A6</td>
<td>TITLE1</td>
<td>First title card.</td>
</tr>
</tbody>
</table>

1-1
<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>1-72</td>
<td>12A6</td>
<td>TITLE2</td>
<td>Second title card.</td>
</tr>
</tbody>
</table>
## CONSTANTS

### 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>RHO</td>
<td>Mass density $p$ of test material in $\text{lbm/ft}^3$.</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 $\text{BTU/lbm °F}$.</td>
</tr>
<tr>
<td>3</td>
<td>21-30</td>
<td>F10.3</td>
<td>BDK</td>
<td>Thermal conductivity $K$ of test material in $\text{BTU/ft sec °F}$.</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. 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 $(d_2)$. 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: $1 \leq NV \leq 50$.</td>
</tr>
<tr>
<td>7</td>
<td>54-56</td>
<td>I3</td>
<td>NY</td>
<td>Number* of y-coordinates: $1 \leq NY \leq 50$.</td>
</tr>
</tbody>
</table>

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

---

1-3
## MISCELLANEOUS RUN PARAMETERS

### LEAD CARD SETUP

**CARD NO.** 4  
**JOB** THNSKN  
**NAME** THNSKN  
**PROGRAMMER** McBryde  
**DATE** 12/74  
**PAGE** 4 OF 10

<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

<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></td>
<td></td>
<td></td>
<td></td>
<td>NOTE: This card will appear in the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>deck only if DD(2) on card 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>is used.</td>
</tr>
<tr>
<td>1</td>
<td>1-10</td>
<td>F10.3</td>
<td>YDD(1)</td>
<td>The y-coordinate of the junction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>between test material thicknesses when</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>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 | THNSKN |
| NAME | | 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 \( \leq 50 \)).
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>PROGRAMMER</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
<td>McBryde</td>
<td>12/74</td>
</tr>
<tr>
<td>NAME</td>
<td>THNSKN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FIELD ID | CARD COLUMNS | FORMAT | SYMBOLIC NAME | IDENTIFICATION |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></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. No data will be processed outside of the interval from TSTRT to TSTOP.</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. If NTME ( \leq 2 ), no curve fitting will be done.</td>
</tr>
</tbody>
</table>

**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

**CARD NO.** 9A  
**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>F10.0</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>
</tbody>
</table>
| 3        | 21-30         | F10.3  | STATME         | Start time for least squares curve fit.  
|          |               |        |                | No curve fit computations will be done prior to CESTRT or after CESTOP. |
| 4        | 31-35         | I5     | NTME           | The number of points to be curve fit.  
|          |               |        |                | If NTME ≤ 2, no curve fitting will be done. |

**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
THNSKN CARDS 1 – 4

7
8XQT .THNSKN/ABS

7
8MAP,S .THNSKN,THNSKN/ABS

7
8PREP

7
8COPIN PGMT,TPF$

7
8ASG,T 8,8C,XXXXX (Input tape number)

7
8ASG,T PGMT,8C,V02679

7
8MSG,N TWO TAPE DRIVES

7
8RUN

(Back of deck)

2-1
## INSTRUCTIONS FOR CENTRAL COMPUTER COMPLEX COMPUTER RUNS

### EXEC VIII

<table>
<thead>
<tr>
<th>OPERATING SYSTEM</th>
<th>TYPE OF RUN</th>
<th>NO. TAPES</th>
<th>NO. FASTR FILES</th>
<th>NO. DRUM FILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1108 EXEC II</td>
<td>PROD TEST</td>
<td>2</td>
<td>0</td>
<td>0</td>
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<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

- **A PROGRAM TAPE**
  - **FILE**
  - **NAME**

- **F XXXXXXX**
  - **FILE**
  - **NAME**

### OUTPUT TAPES

- **PERMANENT FAST/AND FILES**
  - **FILE**
  - **NAME**
  - **SAVE**

### CAL COMP PLOTS

- **PLOTTED OUTPUT**
  - **FILE**
  - **NAME**
  - **ACTUAL TIME USAGE**

### NOTATION SYMBOLS

- **S**
- **P**
- **L**
- **T**
- **I**
- **H**
ATTACHMENT 4

FLOW CHART
COMPUTE AVERAGE THERMOCOUPLE TEMPERATURES

PRINT REPORT

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

PRINT REPORTS

A
ATTACHMENT 5

PROGRAM LISTING
### MAIN PROGRAM

**STORAGE USED**: CODE(I) 003717; DATA(0) 073316; BLANK COMMON(2) 000000

#### EXTERNAL REFERENCES (BLOCK, NAME)

<table>
<thead>
<tr>
<th>Block</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>00150</td>
</tr>
<tr>
<td>0002</td>
<td>01714</td>
</tr>
<tr>
<td>0003</td>
<td>00140</td>
</tr>
<tr>
<td>0004</td>
<td>00015</td>
</tr>
<tr>
<td>0005</td>
<td>02407</td>
</tr>
<tr>
<td>0006</td>
<td>00301</td>
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<tr>
<td>0007</td>
<td>00315</td>
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<td>00172</td>
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<td>0019</td>
<td>00235</td>
</tr>
<tr>
<td>0020</td>
<td>00247</td>
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</tbody>
</table>

#### 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>10L</td>
<td>072336 1000F</td>
</tr>
<tr>
<td>0002</td>
<td>01714</td>
<td>1022G</td>
<td>072346 1005F</td>
</tr>
<tr>
<td>0003</td>
<td>00140</td>
<td>110L</td>
<td>072350 1007F</td>
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<tr>
<td>0004</td>
<td>00015</td>
<td>2134G</td>
<td>072352 1008F</td>
</tr>
<tr>
<td>0005</td>
<td>02407</td>
<td>1248G</td>
<td>072360 2001F</td>
</tr>
<tr>
<td>0006</td>
<td>00301</td>
<td>1377G</td>
<td>072364 2004F</td>
</tr>
<tr>
<td>0007</td>
<td>00315</td>
<td>1453G</td>
<td>072704 2011F</td>
</tr>
<tr>
<td>0008</td>
<td>00333</td>
<td>1504G</td>
<td>072770 2017F</td>
</tr>
<tr>
<td>0009</td>
<td>00344</td>
<td>1552G</td>
<td>073066 2021F</td>
</tr>
<tr>
<td>0010</td>
<td>00355</td>
<td>1677G</td>
<td>073067 2022F</td>
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<td>0011</td>
<td>00363</td>
<td>200L</td>
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<td>0012</td>
<td>00363</td>
<td>2004F</td>
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<td>00727</td>
<td>2014F</td>
<td>000000 117G</td>
</tr>
<tr>
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<td>07303</td>
<td>2019F</td>
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<td>0015</td>
<td>00156</td>
<td>220L</td>
<td>001052 512G</td>
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<tr>
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<td>00172</td>
<td>240L</td>
<td>001056 524G</td>
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<td>0017</td>
<td>00170</td>
<td>300L</td>
<td>000156 528G</td>
</tr>
<tr>
<td>0018</td>
<td>00133</td>
<td>345L</td>
<td>000149 530L</td>
</tr>
<tr>
<td>0019</td>
<td>00235</td>
<td>400L</td>
<td>000142 532G</td>
</tr>
<tr>
<td>0020</td>
<td>00247</td>
<td>500L</td>
<td>000166 533G</td>
</tr>
<tr>
<td>0021</td>
<td>00255</td>
<td>575L</td>
<td>000224 534G</td>
</tr>
</tbody>
</table>

---

**FOR TSX-122074-041391 (T)**
PROGRAM THNSKN

IDENTIFICATION

TITLE - SURFACE HEATING RATE OF THIN SKIN MODELS

PROGRAMMER - JACK D. MCKAYE, LOCKHEED ELECTRONICS CO.

DATE - OCTOBER 1969, REWRITTEN DECEMBER 1974

DESCRIPTION

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 ABEIL TAPE OUTPUT OF THE ENTSOS DATA REDUCTION COMPUTER.

PROGRAM - THE PROGRAM OUTPUT CONSISTS OF TIME HISTORY TABULATIONS IN AN ARRAY BY THERMOCOUPLE LOCATIONS.

DATA

BIGK - THERMAL CONDUCTIVITY (K) OF TEST MATERIAL (BTU/FT.SEC.F)

CESTOP - COMMAND EVENT CHANNEL STOP LEVEL INPUT (FLOATING POINT)

CESTRT - COMMAND EVENT CHANNEL START LEVEL INPUT (FLOATING POINT)

CON12 - RHO * CP / 12.

CON24 - 24 * BIGK

CONA4 - RHO * CP / 6.

CP - SPECIFIC HEAT OF TEST MATERIAL (BTU/FT.^2.F/SEC)

DD(1) - SKIN THICKNESS OF TEST MATERIAL (INCHES)

DOT27 - THE SECOND THICKNESS WHEN THE TEST MATERIAL HAS TWO

FAC - PERCENT ERROR IN THE SLOPE

ID - USED TO DESIGNATE COORDINATE IN X-DIRECTION

IDD - INDEX USED TO SPECIFY WHICH THICKNESS (DD) APPLIES

IEOF - END OF FILE INDICATOR

IESTOP - COMMAND EVENT CHANNEL STOP LEVEL (FIXED POINT)

IESTRT - COMMAND EVENT CHANNEL START LEVEL (FIXED POINT)
| 00100 | 3   | C | IEVT  | CURRENT COMMAND EVENT CHANNEL VALUE | 000000 |
| 00100 | 35  | C | IGOND | IGOND = 1 INDICATES WHEN THE FIRST SET OF 3 GOOD THERMOCOUPLES ON A ROW OR COLUMN HAS BEEN FOUND IN LOGIC FOR | 000000 |
| 00100 | 36  | C | NCC   | NUMBER OF COMMAND CHANNELS | 000000 |
| 00100 | 37  | C | CO    | COMPUTING DX OR DY | 000000 |
| 00100 | 38  | C | IOPT  | RUN CONTROLLED BY 0 - START-STOP TIMES 1 - COMMAND CHANNEL EVENTS | 000000 |
| 00100 | 39  | C | IOPT1 | IOPT = 1 | 000000 |
| 00100 | 40  | C | IPAR  | PARITY ERROR RECORD COUNTER | 000000 |
| 00100 | 41  | C | IX    | X-COORDINATE OF THERMOCOUPLE BEING DEFINED BY CHANNEL NO. | 000000 |
| 00100 | 42  | C | IY    | Y-COORDINATE OF THERMOCOUPLE BEING DEFINED BY CHANNEL NO. | 000000 |
| 00100 | 43  | C | IYDD  | THE Y COORDINATE INDEX JUST PRIOR TO THE CHANGE IN X-DIRECTION | 000000 |
| 00100 | 44  | C | LTEMP | NUMBER OF LINES REQUIRED FOR ONE NX X NY ARRAY | 000000 |
| 00100 | 45  | C | LUIN  | LOGICAL UNIT FOR INPUT TAPE | 000000 |
| 00100 | 46  | C | NCC   | NUMBER OF CHANNELS ON TAPE | 000000 |
| 00100 | 47  | C | NCHS  | NUMBER OF CHANNELS ON TAPE | 000000 |
| 00100 | 48  | C | NCTC  | TOTAL NUMBER OF THERMOCOUPLE LOCATIONS (NX X NY) | 000000 |
| 00100 | 49  | C | NTCH  | ARRAY OF THERMOCOUPLE CHANNEL NUMBERS | 000000 |
| 00100 | 50  | C | NTCLOC | TOTAL NUMBER OF THERMOCOUPLE LOCATIONS (NX X NY) | 000000 |
| 00100 | 51  | C | ND   | THE MAXIMUM NUMBER OF SCANS FOR WHICH LEAST SQUARES COMPUTATIONS MAY BE DONE | 000000 |
| 00100 | 52  | C | NN    | NUMBER OF THERMOCOUPLE BEING PROCESSED | 000000 |
| 00100 | 53  | C | NNH1,NNH2,NNH3 | CHANNEL NUMBERS OF THREE SUCCESSIVE GOOD THERMOCOUPLES (OX OR OY COMPUTATIONS) | 000000 |
| 00100 | 54  | C | NOTH | THE HISTORY TAB OPTION. IF NOTH = 0, EACH SCAN OF DATA FROM THE INPUT TAPE IN THE TIME INTERVAL WILL BE PRINTED. | 000000 |
| 00100 | 55  | C | NPAR | MAXIMUM PERMISSIBLE NUMBER OF PARITY ERRORS PER TIME | 000000 |
| 00100 | 56  | C | NPS   | NUMBER OF POINTS REQUESTED FOR CURVE FIT | 000000 |
| 00100 | 57  | C | NTSL  | NUMBER OF TIME SLICES PROCESSED | 000000 |
| 00100 | 58  | C | NX    | NUMBER OF X-COORDINATE LOCATIONS | 000000 |
| 00100 | 59  | C | NY    | NUMBER OF Y-COORDINATE LOCATIONS | 000000 |
| 00100 | 60  | C | QDOT  | USED FOR MEAN HEATING RATE AND LEAST SQUARES HEATING RATE AT DIFFERENT TIMES | 000000 |
| 00100 | 61  | C | QDOTMH | THE SUMS (OR AVERAGES) OF THE QDOT VALUES FOR NTSL TIME | 000000 |
| 00100 | 62  | C | RHO   | MASS DENSITY (LB/MM**3) | 000000 |
| 00100 | 63  | C | SIGMA | STANDARD ERROR OF THE SLOPE | 000000 |
| 00100 | 64  | C | SLICE | SLICE | 000000 |
| 00100 | 65  | C | NSC   | NUMBER OF SCANS OF DATA PROCESSED IN THE CURRENT TIME | 000000 |
| 00100 | 66  | C | NPT   | NUMBER OF POINTS USED IN THE CURVE FIT | 000000 |
| 00100 | 67  | C | NCT   | SLICE | 000000 |
| 00100 | 68  | C | NTC   | SLICE | 000000 |
| 00100 | 69  | C | NTS   | SLICE | 000000 |
| 00100 | 70  | C | QT    | SLICE | 000000 |
| 00100 | 71  | C | QYZ   | SLICE | 000000 |
| 00100 | 72  | C | S0L0M | STANDARD ERROR (LBM) | 000000 |
| 00100 | 73  | C | SLOPE | LEAST SQUARE SLOPE OR HEATING RATE | 000000 |
| 00100 | 74  | C | STIME | START TIME FOR CURVE FIT | 000000 |
| 00100 | 75  | C | SUM   | SUM X(1)*Y(1) | 000000 |
| 00100 | 76  | C | SUM2  | SUM X(L) | 000000 |
| 00100 | 77  | C | SUM3  | SUM Y(I) | 000000 |
| 00100 | 78  | C | SUM4  | SUM (X(1)**2) | 000000 |
00174 1484 IF(IOP\(1\),NE\(=\)0) IOP\(1\) \(=\) 1
00174 1485 WRITE(6,2002) NCHS NCC IOP\(1\),IPAR NOTH
00205 1501 IF (NCHS=\(=\)NC) 20,20
00210 1502 LCDERR = 0
00213 1533 WRITE (6,4003)
00219 1543 CONTINUE
00224 1544 IF (DD(2)) 30,30
00227 1553 CONTINUE
00233 1574 C READ X AND Y COORDINATE LOCATIONS
00234 1575 READ (5,1005)IYDD(IJ),J=1,NY
00242 1605 WRITE (6,2007) IYDD(IJ),I=1,NX
00256 1625 WRITE (6,2006)XDD(IJ),I=1,NX
00256 1635 WRITE (6,2005)XDD(IJ),J=1,NY
00257 1645 C READ THE THERMOCOUPLE CHANNEL NUMBER AND
00265 1665 C CORRESPONDING X-Y COORDINATES
00269 1675 READ (5,1007)IX,IY,NTCH(IJ),J=1,NY
00274 1695 WRITE (6,2022) NTCH(IJ),I=1,NX
00305 1706 DO 40 IM=1,NX
00310 1707 WRITE (6,2008)IM,NTCH(IJ),J=1,NY
00317 1708 CONTINUE
00321 1726 IOP\(1\) \(=\) IOP\(1\)+1
00322 1736 GO TO (50,60),IOP\(1\)
00323 1746 READ (5,1003)END=690TSTR,STOP,STATE,NTHE
00331 1756 IF(INTL=GT\(=\)0) WRITE(6,2021)
00333 1766 WRITE(6,2003)TSTR,STOP,STATE,NTHE
00342 1776 GO TO 70
00343 1786 READ (5,1004)CESTRT,CESTOP,STEP,STIMATE,NTHE
00354 1796 WRITE (6,2003)CESTRT,CESTOP,STIMATE,NTHE
00362 1806 IF (NTHE.GT.LNSL) GO TO 80
00364 1816 I = NLS
00365 1826 WRITE (6,4002) I
00369 1836 LCDERR = 0
00371 1846 CONTINUE
00372 1856 IF (LCDERR) \(=\) 730
00377 1866 C INITIALIZE AND DEFINE CONSTANTS
00378 1886 C
00379 1896 CONA = KNO \(\cdot\) CP \(\cdot\) \(\frac{24}{25}\)
00380 1906 CON2 = RHO \(\cdot\) CP \(\cdot\) \(\frac{12}{75}\)
00387 1916 CON24 = RIGK \(\cdot\) \(\frac{24}{25}\)
00400 1936 IPAR = '0'
00401 1946 NSCN = 0
00402 1956 LTEMP = \(\left(\frac{NY+9}{100}\right) \cdot NX + 5\)
00403 1966 DO 90 I=1,NCHS
00404 1976 DO 90 J=1,N
00411 1986 DO 90 TDD(IJ) = 0
00414 1996 TSTR = CESTR
00415 2006 TSTOP = CESTOP
00416 2016 NPT = 0
00417 2026 LINES = 1000
00420 2036 IYDD = NY \(=\) 1
00421 2046 IF (N\(\text{DD}(2)) \(=\) 110,110,
1 = NY - 1

DO 100 J = 1, I

IF (YY(J) .LE. YDD(J+1) .AND. YY(J+1) .GT. YDD(J)) IYDD = J

100 CONTINUE

TIME(1) = TIME(3)

IF (NTSL-1) .GT. 150, 150

C READ INPUT TAPE

120 READ (LUN, ERR=130, END=140) TIME(1), TEMP(1,1), I=1, NCHS)

GO TO 150

130 WRITE (6,40009)

GO TO 120

140 WRITE (6,40005)LUN

IEOF = 1

GO TO 400

150 CONTINUE

GO TO (140,170),10PT

160 IF (TIME(J) .LT. START) 120, 190, 190

170 IEVT = TEMPC(6) + 5

180 IF (IEVT .LT. IEVT(J-2)) 220, 220, 220

STARTING TIME FOUND

190 DO 200 I=1,NCHS

200 TEMP(J+1) = TEMP(J,1)

210 TIME(1) = TIME(J)

220 NSCN = 1

IF (TIME .LE. ZOR .LT. START) GO TO 330

230 NPT = NPT + 1

240 TIM(NPT) = TIME(J)

250 DO 210 I=1,NCHS

260 TEMP(I,4) = TEMP(I,2)

270 TEMP(I,3) = TEMP(I,1)

280 TEMP(I,2) = TEMP(I,3)

290 IEVT = TEMPC(6) + 5

300 IF (IEVT .LT. IEVT(J-2)) 220, 220, 220

310 IF (IEVT .LT. IEVT(J-2)) 220, 220, 220

GO TO 330

WRITE (6,40009)

IF (IPAR-NPAR) 220, 220, 220

GO TO (250,260),10PT

220 CONTINUE

READ (LUN, ERR=230, END=140) TIME (3), (TEMP(J,1), I=1, NCHS)

GO TO 240

230 IPAR = IPAR + 1

WRITE (6,40009)

IF (IPAR-NPAR) 220, 220, 730

240 CONTINUE

GO TO (250,260),10PT

250 IF (TIME(J) > STOP) 280, 280, 400

260 IEVT = TEMPC(6) + 5

270 IF (IEVT(J) .LT. IEVT(J-2)) 280, 280, 400

280 TIME(2) = TIME(J)

290 NSCN = NSCN + 1

IF (NSCN .LT. 2) 300, 300

DO 290 I=1,NCHS

300 TEMP(J,3) = TEMP(J,1)

310 TEMP(J,1) = TEMP(J,3) + TEMP(J,6)
IF (NTIME .LE. 2 .OR. TIME(2) .LT. STATME) GO TO 330
NPT = NPT + 1
DO 270 I = 1, NCMS
265 IF (TIMP(I,NPT) = TEMPF(I,4))  
266 TIMP(I,NPT) = TIME(2)
267 CONTINUE
00404
268 IF (N10TH) .LT. 360
269 IF ((LINES+TEMP-59) .EQ. J1) NPT = 340, 340,
270 WRITE (6,20000) TITLE1, TITLE2
271 LINES = 3
272 CONTINUE
00420
273 WRITE (6,2013) TIME(2)
274 WRITE (6,2023) (JEQ(J,J=1,NY)
275 LINES = LINES + LTEMP
00434
276 DO 340 I = 1, NX
277 DO 350 J = 1, NY
278 NN = NN + 1
00443
279 IF (WORD(I,J) = TEMPF(HN,K))  
280 WRITE (6,2010) (WORD(I,J),J=1,NY)
281 CONTINUE
00483
282 CONTINUE
00457
287 C  DO ERROR ANALYSIS IF *NTME* POINTS HAVE BEEN SAVED
00467
286 C
00476
285 C IF (NTIME .LE. 2 .OR. NPT .LT. LTIME) GO TO 220
00486
287 C IF (LINES+TEMP-59) .EQ. J1
00497
288 LINES = 3
00504
289 WRITE (6,20000) TITLE1, TITLE2
00514
290 WRITE (6,2015) NPT, TIM(1), TIM(NPT)
00527
291 LINES = LINES + 2 * LTEMP - 3
00547
292 CALL ERRFIT(395)
00557
293 C
00567
294 C OUTPUT HEATING RATE - QDOT AND PERCENT ERROR - ERR
00587
295 C
00597
296 C WRITE(6,212)
00607
297 C WRITE(6,2023) (JEQ(J,J=1,NY)
00617
298 DO 380 I = 1, NX
00624
299 WRITE (6,20101), (QDOT(I,J),J=1,NY)
00634
300 CONTINUE
00644
301 C
00654
302 C WRITE (6,216)
00664
303 C WRITE (6,223) (JEQ(J,J=1,NY)
00674
304 DO 390 I = 1, NX
00684
305 WRITE (6,20101), (ERR(I,J),J=1,NY)
00694
306 CONTINUE
00704
307 C
00714
308 C THE TIME SLICE HAS BEEN COMPLETED OR AN END OF FILE ENCOUNTERED
00724
309 C
00734
310 C
00744
311 C GO TO 220
00754
312 C
00764
313 C
00774
314 C 400 CONTINUE
00784
315 C IF (NTIME .LE. 2 .OR. NPT .LT. 3) GO TO 440
00794
317 C IF (LINES+TEMP-59) .EQ. J1
00804
318 WRITE (6,20000) TITLE1, TITLE2
CONTINUE

WRITE (*,15) NPT, NTIME
IF (NPT.LT. NTIME) WRITE (*,12)
WRITE (*,23) (JEQ, J=1, NY)
DO 420 I=1, NX
WRITE (*,23) (JEQ, J=1, NY)
WRITE (*,15) 430 CONTINUE

IF (INSCN .LT. 68C, GS)
LINES = 1000
WRITE (*,12) TFILES(TITLE1, TITLE2)
WRITE (*,23) (JEQ, J=1, NY)
DO 420 I=1, NX
WRITE (*,12) 430 CONTINUE

PROCESS LATERAL HEAT LOSS IN X-DIRECTION (EQUATION 3)

DO 470 I=1, NX
WRITE (*,12) 480 CONTINUE

IF (NX=3) 690 J=2
DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE

DO 470 J=1, NY
WRITE (*,12) 480 CONTINUE
01204 376* IF (13-NX) < 510 002251
01207 377* NN3 = NTCH(13,J) 002254
01210 377* IF (NN3) 500,550; 002262
01213 379* 16000 = 16000 + 1 002264
01214 380* QX(12,J) = CONZ4 + OD(D) / (XX(13) - XX(11)) - (TEMP(NN2,1) - 002264
01214 381* - (TEMP(NN1,1)) / (XX(12) - XX(11)) - (TEMP(NN3,1) - 002267
01215 385* QX(XX(13)) = QX(11,J) 002267
01215 386* IF (16000_eq_1) QX(11,J) * QX(12,J) 002322
01220 386* IF (13-NX) > 510,510 002323
01223 386* NN1 = NN2 002337
01224 387* NN2 = NN3 002343
01225 388* J = 12 002345
01226 389* J2 = 13 002347
01227 390* GO TO 500 002351
01230 391* 510 CONTINUE 002363
01233 392* WRITE (6,2004) 002364
01234 393* WRITE(6,2023) (JEQ.J+1,MY) 002365
01234 394* DO 520 I=1,NX 002366
01236 395* WRITE (6,201)I,(QX(T,J)+J1,MY) 002407
01236 396* 520 CONTINUE 002427
01237 397* 520 CONTINUE 002427
01237 398* C PROCESS LATERAL HEAT LOSS IN Y-DIRECTION 002427
01237 399* C 002427
01240 404* IF (MY-1) > 630,630, 002427
01240 405* DO 410 I=1,NX 002427
01244 406* 16004 = 0 002446
01244 407* JJ = 1 002446
01247 408* 100 = 1 002447
01251 409* J1 = 0 002447
01257 412* 540 J1 = 1 002451
01257 413* IF (J1+2-NY) > 410 002453
01257 414* NN1 = NTCH(11,J1) 002455
01257 415* IF (NN1) > 540,540; 002461
01257 416* J2 = J1 002464
01257 417* J2 = J1 + 1 002470
01260 418* 550 J2 = J1 * 1 002473
01260 419* IF (J2-1-NY) > 410 002473
01260 420* NN2 = NTCH(11,J2) 002475
01260 421* 550 IF (NN2) > 550,550; 002501
01260 422* J3 = J2 002504
01260 423* J3 = J2 + 1 002510
01263 424* J3 = J2 * 1 002513
01263 425* IF (J3-NY) > 410 002515
01263 426* NN3 = NTCH(11,J3) 002515
01263 427* IF (NN3) > 560,560; 002515
01263 428* 560 IF (J3-1-NY) > 410 002525
01263 429* IF (NN3) > 560,560; 002525
01266 430* 16000 = 16000 + 1 002527
01266 431* IF (J3-1-NY) > 410 002527
01266 432* IF (J2-TYDD) < 575,575,580 002532
01266 433* 570 IF (J2-TYDD) < 575,575,580 002536
01266 434* IF (J1-TYDD) < 575,575,580 002544
01267 435* 16000 = 16000 + 1 002550
01267 436* 16000 = 16000 + 1 002550
01267 437* 16000 = 16000 + 1 002550
01270 440* QY(11,J2) = CONZ4 + OD(D) / (YY(J3) - YY(J1)) - (TEMP(NN2,1) - 002557
01270 441* - (TEMP(NN1,1)) / (YY(J2) - YY(J1)) - (TEMP(NN3,1) - 002557
01270 442* - (TEMP(NN1,1)) / (YY(J2) - YY(J1)) - (TEMP(NN3,1) - 002557
01270 443* - (TEMP(NN1,1)) / (YY(J2) - YY(J1)) - (TEMP(NN3,1) - 002557
01270 444* - (TEMP(NN1,1)) / (YY(J2) - YY(J1)) - (TEMP(NN3,1) - 002557
TEMP(NN2,1) / (DD(2)*(YYD - YY(J2)) + DD(1)*(YY(J3) - YY(J1)))

QX(I,J) = ERR(I,J) + QX(I,J) + QY(I,J)

QDOT(I,J) = ERR(I,J) + QX(I,J) + QY(I,J)

QDOTHR(I,J) = QDOTHR(I,J) + QDOT(I,J)

CONTINUE

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)

WRITE(6,2021) (JEQ,J=1,NT)

WRITE(6,2022) (JEQ,J=1,NT)

WRITE(6,2023) (JEQ,J=1,NT)

WRITE(6,2011) (JEQ,J=1,NT)
WRITE (6,2001) TITLE1,TITLE2
WRITE (6,2002) INTSL
WRITE (6,2003) (JEQ, J=1,NY)
IF (NTSL) 730,730,0
WRITE (6,2004) (JEQ, J=1,NX)
DO 700 J=1,NY
WRITE (6,2010) I, (QDQTMH(I,J),J=1,NY)
DO 710 J=1,NX
710 CONTINUE
720 CALL EXIT
FORMAT (1HO910XO MEAN HEATING RATE 
  MEAN HEAT FLUX 
  T'S 
  TIME INTERVAL OR EVENT CODE (10PT1) 
  NUMBER OF Y-COORDINATES IN Y) 
  NUMBER OF Y-COORDINATES 
  NUMBER OF X-COORDINATES 
  NUMBER OF X-COORDINATES 
  NUMBER OF PARITIES (MPAR) 
  NUMBER OF PARITIES (MPAR) 
  NUMBER OF PARITIES (MPAR) 
  NUMBER OF PARITIES (MPAR) 
  NUMBER OF PARITIES (MPAR) 
  NUMBER OF CHANNELS ON TAPE (NCHS) 
  COMMAND CHANNEL NUMBER (NCM) 
  TIME INTERVAL OR EVENT CODE (10PT1) 
  ACCEPTABLE NO. OF PARITIES (MPAR) 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL 
  COMMAND EVERY START LEVEL =F12,4,5X,STOP LEVEL
730 CALL CMERR
SUBROUTINE ERRFIT(N)

C******************************************************************************

C SUBROUTINE TO COMPUTE THE HEATING RATE BY FITTING A GIVEN TIME
C INTERVAL OF DATA TO A FIRST DEGREE POLYNOMIAL AND TO COMPUTE
C THE STANDARD AND PERCENT ERROR OF THIS HEATING RATE.

C******************************************************************************

C IF (NPT.LE.2) GO TO 999

C SUM = 0.0

C DO 125 M = 1,NPT

C SUM = SUM2 + TIMX

C END DO

C 125 CONTINUE

C SUM = SUM2 + SUM3 + SUM4*2

C SUM = SUM3 + SUM4*2

C SUM = SUM5 + SUM2*2

C SUM = SUM5 + SUM2 + SUM3 + SUM4 + SUM6

C DO 120 I = 1,NX

C DO 200 J = 1,NY

C IOD = I + 1

C IF (IOD.NE.1) IOD = 2

C NN = NCHT(I,J)

C IF (NN.LE.0) GO TO 175

C SUM = DSD

C SUMJ = DSD

C SUMI = 0.0

C SUM = SUMI + TIM(M) + TMP(NN,M)

C 175 CONTINUE

C 200 CONTINUE

C 120 CONTINUE

C END
01701 60** C SUM Y(I) 003545
01702 605* C SUM3 * SUM3 * TMP(NN,H) 003552
01702 616* C SUM (Y(I)**2) 003552
01703 607* C SUMS * SUMS * TP(MN,H)**2 003555
01704 608* 150 CONTINUE 003562
01704 609* C SUM X(I) * SUM Y(I) 003562
01704 610* C SUM7 = SUM2 + SUM3 003562
01705 611* C SLOPE 003562
01707 612* C SLOPE = (NPT * SUM1 - SUM7) / SUM8 003562
01707 613* C SIGMA 003564
01710 614* C SIGMA = 1.0 / NPT * SORT(NPT * SUMS - SUM3**2) 003573
01710 615* C L = (NPT * SUM1 - SUM7)**2 / SUM8 003573
01710 616* C STANDARD ERROR 003573
01711 617* C SERR = NPT * SIGMA / SORT(NPT-2) * SUM8 003612
01711 618* C PERCENT ERROR 003612
01712 619* C ERR(I,J) = SERR / SLOPE * 100.0 003618
01712 620* C HEATING RATE 003619
01713 621* C QDOT(I,J) = CON12 * DD(IDD) * SLOPE 003621
01714 622* C GO TO 2ND 003624
01715 623* C ERR(I,J) = 0.0 003630
01716 624* C QDOT(I,J) = 0.0 003630
01717 625* 200 CONTINUE 003634
01722 626* RETURN 003646
01722 627* C ERR: 9999.9999 003646
01723 628* 175 ERR(I,J) = 0.0 003646
01725 629* 9999 PRETTY (THD, 10X, 700 FEW POINTS AVAILABLE FOR CURVE FIT) 003646
01726 630* RETURN 003646
01726 631* C END 003716

END OF COMPILATION: NO DIAGNOSTICS.
ATTACHMENT 6

SAMPLE INPUT
(TO BE SUPPLIED LATER)
ATTACHMENT 7

SAMPLE OUTPUT
(TO BE SUPPLIED LATER)
ATTACHMENT 8

CORRESPONDENCE
**JSC COMPUTER PROGRAM ABSTRACT**

**01 20 TITLE OF PROGRAM** (60 CHARACTERS MAXIMUM)
SURFACE HEATING RATE OF THIN SKIN MODELS

**01 72 SYMBOLIC NAME** (60 CHARACTERS MAXIMUM)
THNSKN

**02 14 CATEGORY**
FOR V

**02 27 LANGUAGE NO. 1**
Arc Jet, Heat Rate, Thin Skin, Thermocouples

**02 26 CATEGORY**

**02 32 LANGUAGE NO. 2**

**02 37 KEY WORDS (8 MAXIMUM SEPARATED BY COMMAS)**

**WHOM TO CONTACT ABOUT THE PROGRAM**

**05 14 CONTACT (LAST NAME)**
Stephenson

**05 24 SITE**
JSC

**05 35 PROJECT NO**
FD57

**05 49 NASA CENTER**

**05 48 STATUS**
A. UNDER DEVELOPMENT
B. OPERATIONAL
C. COMPLETED

**05 49**

**DATES**

**05 50 INITIATED**
11-74

**05 54 COMPLETED**
12-74

**05 58 REVISION CODE**

**05 59 MAN-MONTHS**
8

**05 64 MACHINE HOURS**
2

**05 69 COMPUTER TYPE**
1100

**05 74 TOTAL COST (DOLLARS)**
1108

**05 50**

**ABSTRACT**

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 83-15-30/McBryde)
TO: LEC/Manager, Test Data Reduction Department, 672-10  
FROM: ED5/Acting Chief, Data Processing Branch  
DATE: October 27, 1969  

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: E. J. Lapenberk 10-24
(LEC Requirements & Analysis)

Concurrence by: E. O. Grice 10/1/81
(CAD Requirements & Analysis)

Concurrence by: Carl D. Scott 10/22/81
(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 digitised 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.
Figure 1
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 EHTSO3 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 EHTSO3 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 programmer.

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.
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.

TABLE 1

<table>
<thead>
<tr>
<th>THERMOCOUPLE ARRAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-9</td>
</tr>
</tbody>
</table>
IV  COMPUTATIONS

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:

\[
\dot{q}_{ij} = \left( \frac{\rho d C_p}{12} \right) \left( \frac{\partial T_{ij}}{\partial t} \right) + \left( \dot{q}_{x,ij} \right) + \left( \dot{q}_{y,ij} \right)
\]

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

\( \left( \frac{\partial T_{ij}}{\partial t} \right) \): 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 preceding 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:

\[
q_{ij}^x = 24 \text{kd} \left[ \left( \frac{1}{X_{i+1} - X_{i-1}} \right) \left( \frac{T_{ij} - T_{i-1,j}}{X_{i} - X_{i-1}} + \frac{T_{i+1,j} - T_{ij}}{X_{i+1} - X_{i}} \right) \right]
\]

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:

\[
q_{ij}^y = 24 \text{kd} \left[ \left( \frac{1}{Y_{j+1} - Y_{j-1}} \right) \left( \frac{T_{ij} - T_{i,j-1}}{Y_{j} - Y_{j-1}} + \frac{T_{i,j+1} - T_{ij}}{Y_{j+1} - Y_{j}} \right) \right]
\]
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:

\[ q_{ij} = 24 \cdot kd \left( \frac{2}{x_2 - x_1} \right) \left( \frac{T_{2j} - T_{1j}}{x_2 - x_1} \right) \]

For test points located in the lower side of the array, equation 7 will be used in lieu of equation 4.
Equation 7:
\[ q_{i,j} = 24 k d \left( \frac{2}{x_i - x_{i-1}} \right) \left( \frac{T_{i,j} - T_{i-1,j}}{x_i - x_{i-1}} \right) \]

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:
\[ q_{i,1} = 24 k d \left( \frac{2}{y_2 - y_1} \right) \left( \frac{T_{i,2} - T_{i,1}}{y_2 - y_1} \right) \]

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

Equation 9:
\[ q_{i,J} = 24 k d \left( \frac{2}{y_J - y_{J-1}} \right) \left( \frac{T_{i,J} - T_{i,J-1}}{y_J - y_{J-1}} \right) \]

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 and 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 ($q_{ijx}$ and $q_{ijy}$) 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.

Doyle L. Johnson

Distribution: J. Fisher/ED57
E. Grice/ED57
J. Randall/C18
Y. Chempinski/B11
L. Martin/B11
D. Garrett/B11

DLJ:JDG:pm
Memorandum

TO: LEC/Manager, Test Data Reduction Department, 672-10

FROM: ED5/Chief, Data Processing Branch

DATE: November 18, 1969

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: EOGrice(LEC:JMRandal):ddc 11-18-69

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan
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:
\[ \dot{q}_{ij} = 24kd \left[ \frac{1}{X_{i+1} - X_{i-1}} \left( \frac{T_{i+1,i} - T_{i-1,i}}{X_{i+1} - X_{i-1}} - \frac{T_{i+1,i} - T_{i,i}}{X_{i+1} - X_{i}} \right) \right] \]

Equation 5:
\[ \dot{q}_{ij} = 24kd \left[ \frac{1}{Y_{j+1} - Y_{j-1}} \left( \frac{T_{i,i+1} - T_{i,i-1}}{Y_{j+1} - Y_{j-1}} - \frac{T_{i,i+1} - T_{i,i}}{Y_{j+1} - Y_{j}} \right) \right] \]

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: JMRandal); bc 11-20-69
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
(Q514)

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 modifications 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.
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 one 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

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

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

Please incorporate these corrections into the program.

C. D. Scott
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

WF:JM:jlbb
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. Broso/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
SOFTWARE CHANGE REQUEST

Date: Oct. 23, 1974

Requester/Organization: E. 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

ESTIMATED RESOURCES:
- Man-Hours: 120
- Computer Hours: 2.0

APPROVALS BY:
- Task Manager: Date
- Technical Monitor: Date
- Branch Chief: Date

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, CUR-PUR
  - Overlay production CUR/PUR with transmittal CUR/PUR
  - 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

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

Date Oct. 23, 1974
Requester/ Organization: E. 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>
</thead>
<tbody>
<tr>
<td>Mon-Hours 120</td>
<td>Task Manager</td>
</tr>
<tr>
<td>Computer Hours 2.0</td>
<td>Technical Monitor</td>
</tr>
<tr>
<td></td>
<td>Branch Chief</td>
</tr>
</tbody>
</table>

TRANSMITTAL TO PRODUCTION:
Submitted by:          Operating system
Validation approved by: New program decks have been submitted to production
System Integration Coordinator: Transmittal tape replaces current system CUR/PCR
                                 Overlay production CUR/PCR with transmittal 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:
THIN SKIN PROGRAM MODIFICATION

Code modifications are required to improve the accuracy and automation of the computer program THINSKN 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., \( q_{v}^{y} = q_{v+1}^{y} \)

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

\[
\overline{q}_{ij} = \overline{q}_{ij}^0 + \overline{q}_{ij}^x + \overline{q}_{ij}^y
\]

where:

\[
\overline{q}_{ij}^0 = \frac{\nu_c \rho c_p d}{k_i - k_j} \left( \frac{T_{ij}^H + T_{ij}^{L-1}}{N} - T_{ij}^1 - T_{ij}^2 \right)
\]

\[
\overline{q}_{ij}^x = \frac{24 K d}{x_{i+1,j} - x_{i-1,j}} \left( \frac{T_{ij} - T_{i-1,j}}{x_i - x_{i-1}} - \frac{T_{i+1,j} - T_{ij}}{x_{i+1} - x_i} \right)
\]

\[
\overline{q}_{ij}^y = \frac{24 K d}{y_{j+1,i} - y_{j-1,i}} \left( \frac{T_{ij} - T_{i,j-1}}{y_j - y_{j-1}} - \frac{T_{ij} - T_{ij+1}}{y_{j+1} - y_j} \right)
\]

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

\[
\overline{q}_{i,j+1}^y = \frac{24 K d_d}{y_{j+1} - y_j} \left( \frac{d_1(\frac{T_{ij} - T_{ij+1}}{y_j - y_{j+1}})}{(y_d - y_j) d_1 + (y_{j+1} - y_d) d_1} + \frac{T_{i,j+1} - T_{ij+1}}{y_{j+1} - y_d} \right)
\]

\[
\overline{q}_{i,j}^y = \frac{24 K d_d}{y_{j+1} - y_j} \left( \frac{d_1(\frac{T_{ij} - T_{ij+1}}{y_j - y_{j+1}})}{(y_d - y_j) d_1 + (y_{j+1} - y_d) d_1} + \frac{T_{i,j+1} - T_{ij+1}}{y_{j+1} - y_d} \right)
\]
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 tH. 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 tni and temperatures Tni 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): \( \bar{q}_{i,j} \quad \bar{q}_{i,j}^x \quad \bar{q}_{i,j}^y \)

and the net heat flux \( \bar{q}_{i,j} \). Continue to compute and print the linear least squares heat flux in the revised program. Finally, print the mean of \( \bar{q}_{i,j} \) 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 | NV |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>Valid</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Valid</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Invalid</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<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.