SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAMS USING THE GROUP TRANSFORMATION METHOD

by B. J. Lee and P. B. Burchfield

Manned Spacecraft Center
Houston, Texas

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ABSTRACT

This paper presents a method of evaluating the performance of a solid propellant rocket motor of fixed geometry and given propellant characteristics using the constant $K_N$ (ratio of propellant burning-surface area to nozzle-throat area) process and group transformation method. This method does not require a prior knowledge of the $K_N$ values, but requires only that the parameters to be evaluated be selected at constant regressed distances normal to the original propellant surface. Two computer programs utilizing this method are presented. The first performs the evaluation for general performance parameters over selected time intervals, and the second performs the evaluation for instantaneous performance versus time.
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- Second-order, least-squares curve fit of experimentally determined burning rates at the individual regressed distance of interest normal to the original propellant surface versus prefire propellant temperature
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A solid propellant rocket motor of fixed geometry and given propellant will yield different performance with various prefire propellant temperatures. This paper presents two computer programs that transform the test data from as many as three different prefire propellant temperature groups to a like number of common prefire propellant temperatures of interest. Statistical calculations are made on the test data after they have been transformed. A detailed description of these computer programs is presented.

INTRODUCTION

The internal ballistic performance of a solid propellant rocket motor is a function of geometry, propellant temperature, and propellant composition. Therefore, a solid propellant rocket motor of fixed geometry (figs. 1(a) through 1(c)) and given propellant characteristics (fig. 2) will yield different performance with various propellant temperatures (fig. 3 and refs. 1 and 2). This phenomenon is due to the variation of propellant burning rate with propellant temperature (fig. 2) and will be referred to as the thermal sensitivity of the propellant.

By using adequate experimental test data, the variation of motor performance with propellant temperature can be mathematically defined. With proper utilization of this mathematical definition the performance test data (from motor test firings conducted at different propellant temperatures) can be transformed to any common temperature of interest, within the extremities of the test data.

There is generally a limited number of motors allotted to determine the performance variations (performance versus time and product variance) of a
given motor design. The transformation of test data from different prefire propellant temperatures to given temperatures of interest is utilized in this report to obtain greater confidence in the statistical analyses performed on the test data.

This report describes two solid propellant rocket motor performance computer programs that were written at the Manned Spacecraft Center. These programs transform experimental test data from as many as three different prefire propellant temperature groups to a like number of propellant temperatures of interest. The computer program presented in appendix A performs the transformations and calculates general performance parameters over selected time intervals. The computer program presented in appendix B performs the transformation for instantaneous performance versus time.

Statistical analyses are performed on the test data after they have been transformed. The statistical analyses consist of calculating means, standard deviations, one-sided tolerance limits, and two-sided tolerance limits.

SYMBOLS

\[ A \quad \text{area} \]

\[ a \quad \text{burning-rate equation coefficient, } r = aP^n \]

\[ b \quad K_N \text{ equation coefficient, } K_N = bP^m \]

\[ e \quad \text{base of natural logarithm, } 2.71828\ldots \]

\[ F \quad \text{longitudinal thrust} \]

\[ K \quad \text{tolerance factor} \]

\[ K_N \quad \text{ratio of propellant burning-surface area to nozzle-throat area} \]

\[ \ln \quad \text{natural logarithm} \]

\[ m \quad K_N \text{ equation exponent, } K_N = bP^m \]

\[ N \quad \text{sample size} \]
n burning-rate equation exponent, $r = aP^n$

P chamber pressure; percentage of population

$P_a$ ambient pressure

r burning rate

s estimated standard deviation

T prefire propellant temperature

t motor operating time interval

u tolerance limit

w web thickness

X experimentally determined values that make up a sample

$\gamma$ probability or confidence level

$\pi_K$ temperature sensitivity coefficient of chamber pressure

$\sigma_K$ temperature sensitivity coefficient of burning rate

$\phi$ nozzle cant angle

Subscripts:

d desired

e exit

f value of the parameter that corresponds to $T_d$ as determined from a second-order least-squares curve fit of the parameter versus $T$

g prefire propellant temperature group whose data are to be transformed
value of the parameter that the explicit motor would be expected to experience if the prefire propellant temperature had been $T_d$

value of the parameter experimentally acquired from the explicit motor whose data are to be transformed

value of the parameter that corresponds to $\overline{T_g}$ as determined from a second-order least-squares curve fit of the parameter versus $T$

lower

throat

upper

vacuum

one-sided

two-sided

Operator:

— average (such as $\overline{F}$)

RELATED SOLID PROPELLANT ROCKET MOTOR THEORY

Ratio of Propellant Burning-Surface Area to Nozzle-Throat Area

Solid propellants burn in parallel layers and regress normal to the propellant surface (fig. 1(c)). Therefore, at any increasing distance normal to the original propellant surface, the exposed surface area can be predicted (fig. 4). Assuming that nozzle-throat erosion is reproducible, a geometric relationship can be determined between the ratio of propellant burning-surface area to nozzle-throat area $K_N$ and the distance regressed normal to the original propellant surface (fig. 5).

The chamber pressure of a solid propellant rocket motor, with fixed geometry and given propellant characteristics at a known propellant
temperature, is a function of \( K_N \). The relationship between \( K_N \), chamber pressure, and propellant temperature is generally determined experimentally and can, in some cases, be quite complex (fig. 2). However, the relationship between \( K_N \) and motor chamber pressure for limited chamber-pressure ranges can be approximated for a given propellant at a known propellant temperature by the following empirically determined relationship (fig. 6)

\[
K_N = bP^m
\]  

(1)

where

\[ b = K_N \text{ equation coefficient.} \]
\[ P = \text{chamber pressure.} \]
\[ m = K_N \text{ equation exponent.} \]

Burning Rate

Burning rate \( r \) is the rate at which a solid propellant is consumed. It is measured in a direction normal to the propellant surface and expressed by in./sec. The burning rate of a specific propellant is a function of chamber pressure and propellant temperature. The complex relationship between burning rate, chamber pressure, and propellant temperature (fig. 2) can be approximated for a given propellant at a known propellant temperature for limited chamber pressure ranges by the following empirically determined relationship (fig. 6)

\[
r = aP^n
\]  

(2)

where

\[ a = \text{burning-rate equation coefficient.} \]
\[ n = \text{burning-rate equation exponent.} \]
PROPELLANT THERMAL SENSITIVITY

Data obtained from test firings, conducted at different propellant temperatures, can be transformed to any common temperature of interest within the extremities of the available test data by any one of three processes. These processes are constant pressure, constant burn rate, and constant $K_N$. Compensations must be made for factors such as erosive burning and pressure losses along the length of the grain perforation during motor operation. The constant $K_N$ process presented in this report is based on a constant geometric configuration at specifically regressed distances normal to the original propellant surface that compensates for the above mentioned factors. The actual regressed distance need not be known as long as the transformations are conducted at a constant regressed distance. This transformation method is also valid for the average geometric configuration during a time interval corresponding to a specific regressed distance (such as burn time, action time, and tail-off time).

Chamber-Pressure Transformation—Equation Derivation

The chamber-pressure transformation equation can be derived by first taking the natural logarithm of equation (1) giving

$$\ln K_N = \ln b + (m) \ln P$$

(3)

Taking the partial derivative of equation (3) with respect to the propellant temperature $T$ at a constant $K_N$, and assuming $m$ is independent of temperature, yields

$$\frac{\partial}{\partial T} \ln K_N \bigg|_{K_N} = 0 = \frac{\partial}{\partial T} (\ln b)_{K_N} + (m) \frac{\partial}{\partial T} (\ln P)_{K_N}$$

(4)
Therefore,

\[
\frac{\partial}{\partial T}(\ln P)_{K_N} = -\frac{\frac{\partial}{\partial T}(\ln b)_{K_N}}{m}
\]  

(5)

The expression \( \frac{\partial}{\partial T}(\ln P)_{K_N} \) is defined as the temperature sensitivity coefficient of chamber pressure (ref. 1) and is expressed as \( \pi_K \).

Performing the indicated differentiation of equation (5) yields

\[
\pi_K = \left[ \frac{1}{P} \left( \frac{\partial P}{\partial T} \right) \right]_{K_N}
\]

(6)

Integrating equation (6) yields

\[
\int_{T_g}^{T_d} \pi_K dT = \left[ \int_{P_j}^{P_f} \frac{dP}{P} \right]_{K_N}
\]

(7)

where

\( \bar{T}_g \) = mean propellant temperature of the motors in the propellant temperature group whose data are to be transformed.

\( T_d \) = desired propellant temperature or the propellant temperature to which the experimental test data are to be transformed.

\( P_j \) = chamber pressure that corresponds to \( \bar{T}_g \) as obtained from a second-order least-squares curve fit of the experimentally
determined chamber pressures, at the specific regressed distance of interest normal to the original propellant surface, versus propellant temperature (fig. 7).

\( P_f = \) chamber pressure that corresponds to \( T_d \) as obtained from a second-order least-squares curve fit of the experimentally determined chamber pressures, at the specific regressed distance of interest normal to the original propellant surface, versus propellant temperature (fig. 7).

All least-squares curve fits are of the form \( \ln x = a + by + cy^2 \) where \( x \) is the dependent parameter, \( y \) is the independent parameter, and \( a, b, \) and \( c \) are constants.

The mean value theorem permits writing equation (7) as

\[
\pi_K^* \int_{\bar{T}_g}^{T_d} \frac{dP}{P} = \left[ \int_{\bar{T}_g}^{P_f} \frac{dP}{P} \right]_{K_N}
\]

where \( \pi_K^* \) is the average value of \( \pi_K \) over the path of constant \( K_N \) from \( \bar{T}_g \) to \( T_d \). This quantity \( \pi_K^* \) will hereafter be referred to as \( \pi_K \).

Performing the indicated integration of equation (8) yields

\[
\pi_K \left( T_d - \bar{T}_g \right) = \left[ \ln P_f - \ln P_j \right]_{K_N}
\]
Therefore,

\[
\pi_K = \left[ \frac{1}{(T_d - \bar{T}_g)} \right] \left[ \ln \frac{P_f}{P_j} \right] K_N
\] (10)

By rearranging equation (10), the chamber pressure for each motor in the prefire propellant temperature group \( T_g \) (experimentally determined at the specific regressed distance for which \( \pi_K \) was calculated) is transformed to the chamber pressure corresponding to the desired prefire propellant temperature

\[
P_h = P_i e^{\pi_K(T_d-T_i)} K_N
\] (11)

where

- \( P_h \) = expected chamber pressure (at the specific regressed distance of interest normal to the original propellant surface) of the explicit motor if the propellant temperature had been \( T_d \).
- \( P_i \) = chamber pressure experimentally determined at the specific regressed distance of interest normal to the original propellant surface of the explicit motor whose data are to be transformed.
- \( T_i \) = actual propellant temperature of the explicit motor whose data are to be transformed.
Burning-Rate Transformation—Equation Derivation

Reference 1 presents a relationship between \( m \) and \( n \), \( m = 1 - n \), thus equations (1) and (2) may be combined and rearranged to give

\[
P = \left( \frac{K_N}{b} \right)^{\frac{1}{1-n}}
\]

(12)

Then, substituting equation (12) in equation (2) yields

\[
r = a \left( \frac{K_N}{b} \right)^{\frac{n}{1-n}}
\]

(13)

Taking the natural logarithm of equation (13) gives

\[
\ln r = \ln a - \left( \frac{n}{1-n} \right) \ln b + \left( \frac{n}{1-n} \right) \ln K_N
\]

(14)

Partial differentiation of equation (14) with respect to the propellant temperature \( T \) at a constant \( K_N \), and assuming \( n \) is independent of temperature, yields

\[
\frac{\partial}{\partial T} \ln r \bigg|_{K_N} = \frac{\partial}{\partial T} \ln a \bigg|_{K_N} - \frac{n}{1-n} \frac{\partial}{\partial T} \ln b \bigg|_{K_N} + \frac{n}{1-n} \frac{\partial}{\partial T} \ln K_N \bigg|_{K_N}
\]

(15)

The expression \( \frac{\partial}{\partial T} \ln r \bigg|_{K_N} \) is defined as the temperature sensitivity coefficient of burning rate (ref. 1) and is expressed as \( \sigma_K \).
Performing the indicated differentiation of equation (15) yields

$$\sigma_K = \left( \frac{1}{r} \right) \frac{\partial r}{\partial T} K_N$$  \hspace{1cm} (16)

Integrating equation (16) yields

$$\int_{T_g}^{T_d} \sigma_K dT = \left[ \int_{r_j}^{r_f} \frac{dr}{r} \right] K_N$$  \hspace{1cm} (17)

where

- \(r_j\) = burning rate that corresponds to \(T_g\) as obtained from a second-order least-squares curve fit of the experimentally determined burning rates, at the specific regressed distance of interest normal to the original propellant surface, versus propellant temperature (fig. 8).

- \(r_f\) = burning rate corresponding to \(T_d\) as obtained from a second-order least-squares curve fit of the experimentally determined burning rates, at the specific regressed distance of interest normal to the original propellant surface, versus propellant temperature (fig. 8).

The mean value theorem permits writing equation (17) as

$$\sigma_K^* \int_{T_g}^{T_d} dt = \left[ \int_{r_j}^{r_f} \frac{dr}{r} \right] K_N$$  \hspace{1cm} (18)
where $\sigma_K^*$ is the average value of $\sigma_K$ over the path of constant $K_N$ from $\bar{T}_g$ to $T_d$. This quantity $\sigma_K^*$ will hereafter be referred to as $\sigma_K$. Performing the indicated integration of equation (18) yields

$$
\sigma_K \left[ T_d - \bar{T}_g \right] = \left[ \ln r_f - \ln r_j \right] K_N
$$

Therefore,

$$
\sigma_K = \left[ \frac{1}{(T_d - \bar{T}_g)} \right] K_N
$$

By rearranging equation (20), the burning rate for each motor in the propellant temperature group $T_g$ (experimentally determined at the specific regressed distance for which $\sigma_K$ was calculated) is transformed to the burning rate corresponding to the desired propellant temperature

$$
r_h = \left[ r_i \, e^{\sigma_K (T_d - T_i)} \right] K_N
$$

where

$r_h$ = expected burning rate (at the specific regressed distance of interest normal to the original propellant surface) of the explicit motor if the propellant temperature had been $T_d$.

$r_i$ = burning rate experimentally determined at the specific regressed distance of interest normal to the original propellant surface of the explicit motor whose data are to be transformed.
Time Transformation Equation Derivation

Since burning rate is the rate at which a solid propellant is consumed,

\[ \bar{r} = \frac{w}{t} \]  \hspace{1cm} (22)

where

\( \bar{r} \) = average burning rate during time interval \( t \).

\( w \) = propellant thickness consumed (measured normal to the original propellant surface) during time interval \( t \).

Assuming that the thermal expansion of the propellant is negligible and substituting equation (22) in equation (20)

\[ \sigma_K = \left[ \frac{1}{T_d - \bar{T}_g} \right] \left[ \ln \frac{t_j}{t_f} \right] K_N \]  \hspace{1cm} (23)

where

\( t_j \) = estimated motor operating time interval at temperature \( \bar{T}_g \) (fig. 9).

\( t_f \) = estimated motor operating time interval at temperature \( T_d \) (fig. 9).
By rearranging equation (23), the measured operating time interval for each motor in the propellant temperature group \( T_g \) is transformed to the operating time interval corresponding to the desired propellant temperature

\[
\begin{align*}
    t_h &= \left[ \frac{t_i}{\sigma_K(T_d - T_i)} \right] e^{K_N} \\
\end{align*}
\]

(24)

where

- \( t_i \) = measured operating time interval of interest of the explicit motor whose data are to be transformed.
- \( t_h \) = estimated operating time interval of each motor at propellant temperature \( T_d \).

Thrust Related Calculations and Transformation Equation

In order to transform longitudinal thrust in the simplest manner and also to provide the capability of handling motors that utilize as many as four nozzles (with equal or unequal expansion ratios) and with a nozzle cant angle (such as the Apollo launch escape motor), the thrust measurements are first corrected to vacuum pressure altitude

\[
\overline{F}_{vi} = \overline{F}_i + P_a A_e \cos \phi
\]

(25)

where

- \( \overline{F}_{vi} \) = measured average longitudinal thrust of each motor during the time interval of interest corrected to vacuum pressure altitude.
- \( \overline{F}_i \) = measured average longitudinal thrust of each motor during the time interval of interest.
\( P_a \) = ambient pressure experienced by each motor during the time interval of interest.

\( A_e \) = total nozzle-exit area.

\( \phi \) = nozzle cant angle from the longitudinal centerline of the motor.

Equation (25) can also be used to correct thrust data to any pressure altitude of interest; however, it should be noted that there has been no attempt to evaluate the performance data during the time interval of nozzle flow separation.

The average longitudinal thrust for each motor in the propellant temperature group \( T_g \) (experimentally determined at the specific regressed distance for which \( \pi_K \) was calculated) is transformed to the average longitudinal thrust corresponding to the desired propellant temperature

\[
\bar{F}_{vh} = \bar{F}_{vi} \left( \frac{P_h}{P_i} \right)
\]  

where

\( \bar{F}_{vh} \) = average expected thrust of the explicit motor if the propellant temperature had been \( T_d \).

STATISTICAL ANALYSIS

When parameters are experimentally determined, it is desirable for design, performance, and reliability evaluations to establish limits or bounds which contain a desired percentage of a specific parameters population, with a confidence or probability that the intended condition is satisfied. The bounds thus established are called tolerance limits.

To determine these tolerance limits, a frequency distribution must be assumed. This paper assumes normal distribution since experience has
shown that the majority of experimental data is approximately normally distributed. Although a check for normality may be performed, moderate departure from the assumed distribution will not seriously affect the tolerance limits computed.

Given a sample of data, the mean is estimated by

$$\bar{X} = \frac{\Sigma X}{N} \quad (27)$$

and the standard deviation is estimated by

$$s = \sqrt{\frac{N\Sigma X^2 - (\Sigma X)^2}{N(N - 1)}} \quad (28)$$

where

\[ N = \text{the number of points in the sample.} \]

\[ X = \text{experimentally determined values that make up the sample.} \]

Now that estimates of the mean and standard deviation are known, tolerance limits may be determined. The tolerance limits are the bounds which with probability \( \gamma \) contain at least \( P \) percent of the population.

The tolerance limits are of the form

$$u = \bar{X} \pm Ks \quad (29)$$

where

\[ K = \text{tolerance factor.} \]
Note:

\[ K_1 = \text{tolerance factor for one-sided tolerance limits.} \]

\[ K_2 = \text{tolerance factor for two-sided tolerance limits.} \]

This equation may be applied in two different ways. It can be used to determine the two-sided tolerance limits (fig. 10), or for determining either the upper or the lower one-sided tolerance limit (fig. 11).

**Two-Sided Tolerance Limits**

The two-sided tolerance limits are the upper and the lower bounds that will enclose at least the desired percentage of the expected population with a preselected confidence. The tolerance factors required in equation (29) are given in table I with confidence \( \gamma \) for \( P \) percent of the expected population and \( N \) data points.

Example: A sample of 25 points with \( \bar{X} = 10.02 \) and \( s = 0.13 \).

Two-sided tolerance limits for 90 percent of the population with 95 percent confidence are desired. From table I, for \( P = 0.90 \) and \( \gamma = 0.95 \), \( K = 2.208 \).

\[
\bar{X} \pm K_2 s = 10.02 \pm (2.208)(0.13) = 10.02 \pm 0.29
\]

Therefore, with 95 percent confidence, at least 90 percent of the population lie between 9.73 and 10.31.

**One-Sided Tolerance Limits**

The one-sided tolerance limit is the upper or the lower bound below which or above which at least the desired percentage of the population can be expected to lie with a preselected confidence. The tolerance factors required in equation (29) are given in table II with confidence \( \gamma \) for \( P \) (where \( P = 1 - \alpha \)) percentage of the expected population and \( N \) data points.
Example: Find the one-sided tolerance limit for the preceding example. From table II, $K = 1.838$

$$u = \bar{X} \pm K \frac{s}{\sqrt{n}} = 10.02 \pm (1.838 \cdot 0.13) = 10.02 \pm 0.24$$

Therefore, with 95 percent confidence, at least 90 percent of the population lies either above 9.78 or below 10.26.

The computer program presented in appendix A calculates estimated standard deviation, one-sided tolerance limits, and two-sided tolerance limits for both physical data and transformed general performance parameters over selected time intervals. The computer program presented in appendix B calculates estimated standard deviation and one-sided tolerance limits or two-sided tolerance limits for transformed instantaneous performance data versus time.

GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM USING THE GROUP TRANSFORMATION METHOD

General Description

This computer program was written at the Manned Spacecraft Center in Fortran IV for the IBM 7094 computer with 32K storage. The program transforms general performance parameters for selected time intervals acquired from as many as three different propellant temperature groups to a like number of propellant temperatures of interest for a solid propellant rocket motor of fixed geometry and a given propellant. The transformations are performed for the average geometric configuration during the time intervals that correspond to the specific regressed distances of interest (such as burn time, action time, and tail-off time).

The actual regressed distances need not be known as long as the transformations are conducted at the average geometric configuration for the specific regressed distances. Statistical calculations are performed on both physical data and general performance parameters after the parameters have been transformed to the specific common temperatures of interest. The input format for the program is presented in table III.
Computer Deck Setup

This program exceeds 32K core storage, and the overlay feature of Fortran IV is employed to allow the program to be run as a single input job.

Six decks constitute the program in its entirety and include a calling program and five subroutines.

The actual deck setup for the IBM 7094 is illustrated in figure 12.

1. Setup Cards

$JOB card
$IBJOB card

2. Program

DRIVER
STATS
$ORIGIN ALPHA card
MOTORS
GLS1
$ORIGIN ALPHA card
MOT2
MOT3

3. Data

$DATA
DATA deck
7/8 card

**DRIVER.** - DRIVER is the executive routine required in an overlayed program. This routine never leaves the machine storage area and calls the various overlayed subroutines.

Subroutine STATS. - Subroutine STATS computes the mean and the standard deviation of an input array of given size. Due to the computer arithmetic methods, standard deviations were sometimes found to exist with a small non-zero value when all elements of the input array were identical. To avoid this difficulty, standard deviation is set to zero if its ratio to the mean is less than 0.00025. Since STATS is used by all overlayed sections of the program, it has been placed in the permanent storage area with DRIVER.
Subroutine MOTORS. - Subroutine MOTORS reads in all the data. It sorts the data for each motor into the proper propellant temperature group and does performance calculations on the input data. It calculates the transformation factors for pressures and times ($\pi_K$ and $\sigma_K$) and performs the transformations on these data.

Subroutine GLS1. - Subroutine GLS1 is used to calculate a second-order least-squares curve fit of the natural logarithms of the chamber pressures and the operation time intervals versus propellant temperature.

Subroutine MOT2. - Subroutine MOT2 calculates transformed thrusts, impulses and specific impulses, and the tolerance limits at each desired pressure altitude.

Subroutine MOT3. - Subroutine MOT3 calculates transformed burning rate, characteristic velocity, and their tolerance limits.

Program Restrictions

This program was written to perform the desired transformations for a maximum of 15 motors per experimental prefire propellant temperature group, 3 experimental prefire propellant temperature groups, and 9 time intervals such as ignition delay time, thrust rise time, burn time, total time, and so forth.

The input restrictions are that the number of propellant temperatures (to which the data are to be transformed) must equal the number of experimental temperature groups, the first ambient pressure (EXPA (1)) must equal zero psia (vacuum), and the desired temperatures must be in ascending order.

Care must be exercised in the evaluation of the program results. For example, outputs of specific impulse, total impulse, and chamber pressure integral are meaningless if instantaneous data are inputed. The evaluation of data acquired during nozzle flow separation is beyond the scope of this program; therefore, action time, tail-off time, and total time data must be carefully handled. It should be noted that the output values for characteristic velocity (CSTAR) are valid for total time only.
Output Formats

The output formats are basically of two types: transformed data and nontransformed data. Table IV presents a typical page of nontransformed data output. The type of output (time, pressure, thrust, or other parameters) is identified in the upper left corner of the page. The nine columns represent the motor operating time intervals of interest (such as ignition delay time, thrust rise time, burn time, total time, and so forth). Nine columns will always be printed out even though fewer time intervals are inputed. The non-used columns will be printed out as zeros. At the left of the page, each motor is identified by its alphanumeric identification code, and the motors are separated into propellant temperature groups (up to three). Means and standard deviations are printed out for the motors in each temperature group. In three instances (thrust, impulse, and specific impulse) identical formats are used for different values of pressure altitude. The pressure altitude is printed out at the top of the page.

Table V presents a typical output page of transformed data. Each output page represents one time interval such as ignition delay time, thrust rise time, burn time, total time, and so forth. The time interval is printed out in numerical form (time no. 1, time no. 2, time no. 3, and up to time no. 9) in the upper left corner of the page and must be correlated with the time definitions in the input data (time no. 1 = ignition delay time, time no. 2 = thrust rise time, time no. 3 = burn time, or up to time no. 9 = total time). The type of output (time, pressure, thrust, and other outputs) is printed out at the top of the page. The three columns represent the three propellant temperatures to which the input data have been transformed. At the left of the page each motor is identified by its alphanumeric identification code, and the motors are separated into the original propellant temperature groups (up to three). Means and standard deviations are printed out for motors in each temperature group. Means, standard deviations, and tolerance limits are printed out for the three groups as a whole. In three instances (thrust, impulse, and specific impulse) identical formats are used for different values of pressure altitude. The pressure altitude is printed out under the type of output.
SOLID PROPELLANT ROCKET MOTOR PERFORMANCE VERSUS
TIME COMPUTER PROGRAM USING THE GROUP
TRANSFORMATION METHOD

General Description

This computer program was written at the Manned Spacecraft Center in Fortran IV for the Univac 1107 computer with 65K storage. The program effectively transforms experimentally obtained thrust-and-chamber pressure versus time data (acquired for as many as three different propellant temperature groups) to a common propellant temperature of interest for a solid propellant rocket motor of fixed geometry and a given propellant. The transformations are performed at specific regressed distances normal to the original propellant surface. The actual regressed distance need not be known, as long as the transformations are conducted at a constant regressed distance (such as percents of burn time and percents of tail-off time). See figure 13.

Statistical calculations are performed on the test data after they have been transformed to the specific common temperature of interest. The input format for the program is presented in table VI.

Computer Deck Setup

Twelve decks constitute the program in its entirety, including a main program and 12 subroutines. The program for the Univac 1107 is illustrated in figure 14.

1. Setup Card
   $JOB card

2. Program
   MAIN
   SRCH1
   LSTSQ
   CURVE
   STATS
   GLS1
   ACCEND
   NORMLZ
   FIXIT
3. Data

XQT card
DATA deck
EOF card
FIN card

**MAIN program.** - The MAIN program reads in all data and sorts the data for each motor into its proper prefire propellant temperature group. It then calls the CURVE FIT routines to curve fit both input pressure and input thrust versus input time. It subdivides burn time and tail-off time into the required number of subintervals (fig. 13). Finally, it calls subroutine LSTSQ to compute the transformed data.

**Subroutine SRCH1.** - Subroutine SRCH1 computes time increments in terms of percent web time and percent tail-off time (fig. 13). The subroutine then selects from the CURVE FIT routines the proper cubic coefficients for the particular time increment being considered. After the proper coefficients have been selected, the subroutine uses them to compute the values of the ordinate (pressure or thrust) at each time increment and returns these values to the main program.

**Subroutine LSTSQ.** - Subroutine LSTSQ computes the transformation factors for pressures and times \( \left( \pi_K \text{ and } \sigma_K \right) \) and performs the transformations on these and thrust data at each percent web time and at each percent tail-off time and prints them out as final answers. Graphs of the final answers are also produced (see subroutine QUIKMV).

**Subroutine STATS.** - Subroutine STATS computes the mean and standard deviation of an input array of given size. Due to computer arithmetic methods, standard deviations were sometimes found to exist with a small nonzero value when all elements of the input array were identical. To avoid this difficulty, standard deviation is set to zero if its ratio to the mean is less than 0.00025.

**Subroutine GLS1.** - Subroutine GLS1 is used to calculate a second-order least-squares curve fit of the natural logarithms of chamber pressures, and motor operation times (at each experimentally determined percent web time and percent tail-off time) versus propellant temperature.
CURVE FIT routines. - The CURVE FIT routines consist of subroutines CURVE, ACCEND, NORMLZ, FIXIT, STDEV, CF2F1, and CF2F2. These subroutines fit an input ordinate array versus an input abscissa array using a piecewise cubic least-squares curve fit. Because of the piecewise nature of the fit there are NPTS-ICON +1 sets of cubic coefficients, where NPTS is the size of the input arrays, and ICON points are fit in each piece. Each coefficient set is valid over a limited interval. The coefficients may be printed out by setting input parameter IPRNT to 1.

Subroutine QUIKMOV. - Subroutine QUIKMOV is a MSC general plot routine for the SC-4020. It has not been included in appendix B since most facilities use plotting routines individually suited to the available plotting equipment. The call to this routine may be deleted, or a dummy routine substituted, without affecting the overall program.

Program Restrictions

This program was written to perform the desired transformation for as many as 15 motors per experimental propellant temperature group, 3 experimental propellant temperature groups, and 200 selected inputs of time with corresponding chamber pressure and thrust for each motor.

Since the program is limited to 200 inputs of time with corresponding chamber pressure and thrust for each motor, care must be exercised in choosing the input points in order that they best define the variation of chamber pressure and thrust versus time for each motor (fig. 15). Care must also be exercised in choosing the proper output points that best define the variations of chamber pressure and thrust versus time. This can be accomplished since burn time can be subdivided into as many as five subintervals, and tail-off time can be subdivided into as many as four subintervals. As many time increments (percents of web time and/or percents of tail-off time) as desired can be generated to define the variation of chamber pressure and thrust versus time for each subinterval as long as the total does not exceed 200 points (fig. 13).

Output Formats

The outputs consist of the transformed results in computer printout form, such as presented in tables VII and VIII, and SC-4020 graphs as shown in figures 16(a) and 16(b).
The transformed results present the statistics (mean and tolerance limits) of the transformed time, chamber pressure, and thrust at the desired percent of burn time and percent tail-off time. Transformed thrust statistics can be presented for as many as three desired pressure altitudes.

CONCLUDING REMARKS

The method and computer programs presented in this report were developed at the Manned Spacecraft Center specifically to evaluate the performance of the solid rockets used in the Apollo Launch Escape System. From the conception, however, the method of solution, including the machine programs, was intended to be generally applicable for any rocket motor utilizing a single propellant grain with no throttling capability.

The programs were designed for two types of evaluations. Often, in the requirements, motors are constrained to operate within a given performance regime during some portion of the firing, while delivering a specified nominal performance over the total operation. The program presented in appendix A was intended to evaluate the more stringent constraints placed upon the launch escape motor where both the maximum thrust level and the minimum impulse were specified for an initial phase of firing, and an overall minimum performance required for the abort mission.

The program presented in appendix B compares the transformed thrust-time and pressure-time relationships of all motors tested to define the expected limits of the performance at any temperature. This program has been used to describe the general thrust and pressure characteristics for documentation and product variance purposes.

It is anticipated that these programs will be valuable, particularly for contracting agencies and prime contractors, in the evaluation of solid rocket test data.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, June 29, 1966
## TABLE 1. - TWO-SIDED TOLERANCE FACTORS FOR NORMAL DISTRIBUTIONS

Factors $K$ such that the probability is $\gamma$ that at least a proportion $P$ of the distribution will be included between $\bar{X} \pm Ks$, where $\bar{X}$ and $s$ are estimates of the mean and the standard deviation computed from a sample of $N$

<table>
<thead>
<tr>
<th>$P$</th>
<th>$\gamma = 0.75$</th>
<th>$\gamma = 0.90$</th>
<th>$\gamma = 0.95$</th>
<th>$\gamma = 0.99$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>4.498</td>
<td>3.531</td>
<td>2.380</td>
<td>1.254</td>
</tr>
<tr>
<td>0.90</td>
<td>7.421</td>
<td>6.305</td>
<td>4.298</td>
<td>2.370</td>
</tr>
<tr>
<td>0.95</td>
<td>10.767</td>
<td>9.302</td>
<td>6.690</td>
<td>3.720</td>
</tr>
<tr>
<td>0.99</td>
<td>14.839</td>
<td>13.097</td>
<td>9.913</td>
<td>5.545</td>
</tr>
</tbody>
</table>

---

### TABLE I. - TWO-SIDED TOLERANCE FACTORS

FOR NORMAL DISTRIBUTIONS\(^a\) - Concluded

Factors \( K \) such that the probability is \( \gamma \) that at least a proportion \( P \) of the distribution will be included between \( \bar{X} \pm KS \), where \( \bar{X} \) and \( s \) are estimates of the mean and the standard deviation computed from a sample of \( N \)

<table>
<thead>
<tr>
<th>( P )</th>
<th>( N )</th>
<th>( \gamma = 0.75 )</th>
<th>( \gamma = 0.90 )</th>
<th>( \gamma = 0.95 )</th>
<th>( \gamma = 0.99 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.75</td>
<td>0.90</td>
<td>0.95</td>
<td>0.99</td>
</tr>
<tr>
<td>14</td>
<td>1.076</td>
<td>1.177</td>
<td>1.280</td>
<td>1.385</td>
<td>1.493</td>
</tr>
<tr>
<td>16</td>
<td>1.065</td>
<td>1.164</td>
<td>1.267</td>
<td>1.373</td>
<td>1.481</td>
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<td>1.259</td>
<td>1.365</td>
<td>1.473</td>
</tr>
<tr>
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<td>1.056</td>
<td>1.152</td>
<td>1.252</td>
<td>1.358</td>
<td>1.466</td>
</tr>
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<td>1.052</td>
<td>1.146</td>
<td>1.245</td>
<td>1.341</td>
<td>1.454</td>
</tr>
<tr>
<td>20</td>
<td>1.048</td>
<td>1.140</td>
<td>1.238</td>
<td>1.334</td>
<td>1.447</td>
</tr>
<tr>
<td>21</td>
<td>1.044</td>
<td>1.134</td>
<td>1.232</td>
<td>1.327</td>
<td>1.439</td>
</tr>
<tr>
<td>22</td>
<td>1.040</td>
<td>1.128</td>
<td>1.225</td>
<td>1.320</td>
<td>1.432</td>
</tr>
<tr>
<td>23</td>
<td>1.037</td>
<td>1.123</td>
<td>1.218</td>
<td>1.313</td>
<td>1.425</td>
</tr>
</tbody>
</table>

### TABLE II - ONE-SIDED TOLERANCE FACTORS FOR NORMAL DISTRIBUTIONS

Factors $K$ such that the probability is $\gamma$ that at least a proportion $1 - \alpha$ of the distribution will be less than $X = Ks$ (or greater than $X - Ks$), where $X$ and $s$ are estimates of the mean and standard deviation computed from a sample of size $N$.

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\gamma = 0.75$</th>
<th>$\gamma = 0.90$</th>
<th>$\gamma = 0.95$</th>
<th>$\gamma = 0.99$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N$</td>
<td>0.05</td>
<td>0.025</td>
<td>0.01</td>
<td>0.005</td>
</tr>
</tbody>
</table>

---

### TABLE III - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM

<table>
<thead>
<tr>
<th>Card number (a)</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CASE</td>
<td>A6</td>
<td>1-6</td>
<td>Case number being evaluated</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>HEADING</td>
<td>80H</td>
<td>2-80</td>
<td>Designation of the motor being evaluated</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>NTIMES</td>
<td>12</td>
<td>11-12</td>
<td>Integer designating the number of time intervals being evaluated (maximum of 9)</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Description of time interval no. 1</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 1 (such as ignition delay time)</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Description of time interval no. 2</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 2 (such as thrust rise time)</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Description of time interval no. 3</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 3 (such as ignition time)</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Description of time interval no. 4</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 4 (such as burn time)</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Description of time interval no. 5</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 5 (such as action time)</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Description of time interval no. 6</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 6 (such as tail-off time)</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Description of time interval no. 7</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 7 (such as total time)</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Description of time interval no. 8</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 8</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Description of time interval no. 9</td>
<td>80H</td>
<td>2-80</td>
<td>Definition of regressed distance no. 9</td>
<td>-</td>
</tr>
</tbody>
</table>

*Cards 4 through 12 are shown; however, only NTIMES cards are required.*
TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT 
ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>NP</td>
<td>I12</td>
<td>12</td>
<td>Integer designating the number of pressure altitudes at which the performance data are to be reported (up to 4)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>EXPA(1)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>F12.4</td>
<td>13-24</td>
<td>First pressure altitude at which the performance data are to be reported</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>EXPA(2)</td>
<td>F12.4</td>
<td>25-36</td>
<td>Continue for each individual pressure altitude at which the performance data are to be reported (up to 4)</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>EXPA(3)</td>
<td>F12.4</td>
<td>37-48</td>
<td>psia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EXPA(4)</td>
<td>F12.4</td>
<td>49-60</td>
<td>psia</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>NT&lt;sup&gt;c&lt;/sup&gt;</td>
<td>I12</td>
<td>12</td>
<td>Integer designating the number of prefire propellant temperatures to which the performance data are to be transformed (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>EXTEM(1)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>F12.4</td>
<td>13-24</td>
<td>First prefire propellant temperature to which the performance data are to be transformed</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>EXTEM(2)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>F12.4</td>
<td>25-36</td>
<td>Continue for each individual prefire propellant temperature to which the performance data are to be transformed (up to 3)</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>EXTEM(3)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>F12.4</td>
<td>37-48</td>
<td>°F</td>
<td></td>
</tr>
</tbody>
</table>

<sup>b</sup>The first pressure altitude (at which the performance data are to be reported) must be zero psia (vacuum).
<sup>c</sup>The number of prefire propellant temperatures (to which the data are to be transformed) must equal the number of experimental temperature groups; therefore, NT on card 14 must equal NT on card 15.
<sup>d</sup>The value of EXTEM(3) must be greater than EXTEM(2) and EXTEM(2) must be greater than EXTEM(1).
### TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>NT&lt;sup&gt;c&lt;/sup&gt;</td>
<td>I12</td>
<td>12</td>
<td>Integer designating the number of prefire propellant temperature group (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TGRP(1)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>F12.4</td>
<td>13-24</td>
<td>First prefire propellant temperature about which the motors are grouped (prefire propellant temperature group no. 1)</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>TGRP(2)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>F12.4</td>
<td>25-36</td>
<td>Continue for each individual prefire propellant temperature about which the motors are grouped (up to 3)</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>TGRP(3)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>F12.4</td>
<td>37-48</td>
<td>-</td>
<td>°F</td>
</tr>
<tr>
<td>16</td>
<td>G</td>
<td>F12.5</td>
<td>1-12</td>
<td>Acceleration of gravity</td>
<td>ft/sec&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>PHI</td>
<td>F12.5</td>
<td>13-24</td>
<td>Nozzle cant (from the longitudinal center line of the motor)</td>
<td>rad</td>
</tr>
<tr>
<td></td>
<td>NTOT</td>
<td>I2</td>
<td>25-26</td>
<td>Integer designating the time interval that is total time</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NBURN</td>
<td>I2</td>
<td>27-28</td>
<td>Integer designating the time interval that is burn time</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NFIRST&lt;sup&gt;f&lt;/sup&gt;</td>
<td>I2</td>
<td>29-30</td>
<td>Integer designating the first time interval that all data are to be evaluated (see note)</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>c</sup>The number of prefire propellant temperatures (to which the data are to be transformed) must equal the number of experimental temperature groups; therefore, NT on card 14 must equal NT on card 15.

<sup>e</sup>The value of TGRP(3) must be greater than TGRP(2), and TGRP(2) must be greater than TGRP(1).

<sup>f</sup>In some cases (as in ignition transient data, for example) it is desirable to transform only the time data. This is accomplished in the program by inputing "time only" data in the first few time intervals, and setting the value of NFIRST to indicate the first time interval that all data are to be evaluated.
### TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT
ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number (k)</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>CT1</td>
<td>F12.4</td>
<td>1-12</td>
<td>One-sided tolerance factor for transformed data</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td>F12.4</td>
<td>13-24</td>
<td>Two-sided tolerance factor for transformed data</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CP1</td>
<td>F12.4</td>
<td>25-36</td>
<td>One-sided tolerance factor for nontransformed data</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CP2</td>
<td>F12.4</td>
<td>36-48</td>
<td>Two-sided tolerance factor for nontransformed data</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>XMOT</td>
<td>A6</td>
<td>1-6</td>
<td>Motor number</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>FIRETP</td>
<td>F12.4</td>
<td>7-18</td>
<td>Prefire propellant temperature</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>ENDMOT</td>
<td>I2</td>
<td>19-2</td>
<td>Integer designating that the last motor to be processed has been reached (1 for last motor, 0 for all other motors)</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>AT1</td>
<td>E12.5</td>
<td>1-12</td>
<td>Throat area of nozzle no. 1</td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AT2</td>
<td>E12.5</td>
<td>13-24</td>
<td>Continue for each individual nozzle (up to 4)</td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AT3</td>
<td>E12.5</td>
<td>25-36</td>
<td>-</td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AT4</td>
<td>E12.5</td>
<td>37-48</td>
<td>-</td>
<td>in.²</td>
</tr>
</tbody>
</table>

*Cards 18 through 26 are required for each individual motor.*
### TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT
ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued.

<table>
<thead>
<tr>
<th>Card number (g)</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>AE1</td>
<td>E12.5</td>
<td>1-12</td>
<td>Exit area of nozzle no. 1</td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AE2</td>
<td>E12.5</td>
<td>13-24</td>
<td>Continue for each individual nozzle (up to 4)</td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AE3</td>
<td>E12.5</td>
<td>25-36</td>
<td></td>
<td>in.²</td>
</tr>
<tr>
<td></td>
<td>AE4</td>
<td>E12.5</td>
<td>37-48</td>
<td></td>
<td>in.²</td>
</tr>
<tr>
<td>21</td>
<td>WP</td>
<td>E12.5</td>
<td>1-12</td>
<td>Total propellant weight</td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>WEB</td>
<td>E12.5</td>
<td>13-24</td>
<td>Web thickness</td>
<td>in.</td>
</tr>
<tr>
<td></td>
<td>DENS</td>
<td>E12.5</td>
<td>25-36</td>
<td>Propellant density</td>
<td>lb/in.³</td>
</tr>
<tr>
<td></td>
<td>PAF</td>
<td>E12.5</td>
<td>37-48</td>
<td>Ambient pressure at the time of motor firing</td>
<td>psia</td>
</tr>
<tr>
<td>22</td>
<td>Time 1</td>
<td>F9.4</td>
<td>1-9</td>
<td>Time interval required to achieve regress distance no. 1</td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>F9.4</td>
<td>10-18</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>F9.4</td>
<td>19-27</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 4</td>
<td>F9.4</td>
<td>28-36</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 5</td>
<td>F9.4</td>
<td>37-45</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 6</td>
<td>F9.4</td>
<td>46-54</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 7</td>
<td>F9.4</td>
<td>55-63</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 8</td>
<td>F9.4</td>
<td>64-72</td>
<td></td>
<td>sec</td>
</tr>
<tr>
<td></td>
<td>Time 9</td>
<td>F8.4</td>
<td>73-80</td>
<td></td>
<td>sec</td>
</tr>
</tbody>
</table>

* Cards 18 through 26 are required for each individual motor.
### TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number (g)</th>
<th>Variable name (h)</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>INTP1</td>
<td>F9.4</td>
<td>1-9</td>
<td>Measured chamber pressure integral during Time interval 1</td>
<td>psia-sec</td>
</tr>
<tr>
<td></td>
<td>INTP2</td>
<td>F9.4</td>
<td>10-18</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>psia-sec</td>
</tr>
<tr>
<td></td>
<td>INTP3</td>
<td>F9.4</td>
<td>19-27</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP4</td>
<td>F9.4</td>
<td>28-36</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP5</td>
<td>F9.4</td>
<td>37-45</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP6</td>
<td>F9.4</td>
<td>46-54</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP7</td>
<td>F9.4</td>
<td>55-63</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP8</td>
<td>F9.4</td>
<td>64-72</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTP9</td>
<td>F8.4</td>
<td>73-80</td>
<td>psia-sec</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>P1</td>
<td>F9.4</td>
<td>1-9</td>
<td>Measured average chamber pressure during Time interval 1</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>F9.4</td>
<td>10-18</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>psia</td>
</tr>
</tbody>
</table>

 Cards 18 through 26 are required for each individual motor.

 Average or integral data (but not both) are required for a particular time interval; however, cards 23, 24, 25, and 26 are required because average and integral data may be intermingled with the various time intervals.
TABLE III. - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT
ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>P3</td>
<td>F9.4</td>
<td>19-27</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>F9.4</td>
<td>28-36</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P5</td>
<td>F9.4</td>
<td>37-45</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P6</td>
<td>F9.4</td>
<td>46-54</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P7</td>
<td>F9.4</td>
<td>55-63</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P8</td>
<td>F9.4</td>
<td>64-72</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>P9</td>
<td>F8.4</td>
<td>73-80</td>
<td></td>
<td>psia</td>
</tr>
<tr>
<td>25</td>
<td>INTF1</td>
<td>F9.4</td>
<td>1-9</td>
<td>Measured impulse during Time interval 1</td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF2</td>
<td>F9.4</td>
<td>10-18</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF3</td>
<td>F9.4</td>
<td>19-27</td>
<td></td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF4</td>
<td>F9.4</td>
<td>28-36</td>
<td></td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF5</td>
<td>F9.4</td>
<td>37-45</td>
<td></td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF6</td>
<td>F9.4</td>
<td>46-54</td>
<td></td>
<td>lbf-sec</td>
</tr>
<tr>
<td></td>
<td>INTF7</td>
<td>F9.4</td>
<td>55-63</td>
<td></td>
<td>lbf-sec</td>
</tr>
</tbody>
</table>

Superscript g: Cards 18 through 26 are required for each individual motor.

Superscript h: Average or integral data (but not both) are required for a particular time interval; however, cards 23, 24, 25, and 26 are required because average and integral data may be intermingled with the various time intervals.
### TABLE III - INPUT FORMAT FOR THE GENERAL SOLID PROPELLANT

ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM - Concluded

<table>
<thead>
<tr>
<th>Card number (g)</th>
<th>Variable name (h)</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>INTF8</td>
<td>F9.4</td>
<td>64-72</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>lb - sec</td>
</tr>
<tr>
<td></td>
<td>INTF9</td>
<td>F8.4</td>
<td>73-80</td>
<td></td>
<td>lb - sec</td>
</tr>
<tr>
<td>26</td>
<td>F1</td>
<td>F9.4</td>
<td>1-9</td>
<td>Measured average thrust during Time interval 1</td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td>F9.4</td>
<td>10-18</td>
<td>Continue for each individual time interval being evaluated (up to NTIMES)</td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>F9.4</td>
<td>19-27</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F4</td>
<td>F9.4</td>
<td>28-36</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>F9.4</td>
<td>37-45</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F6</td>
<td>F9.4</td>
<td>46-54</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F7</td>
<td>F9.4</td>
<td>55-63</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F8</td>
<td>F9.4</td>
<td>64-72</td>
<td></td>
<td>lbf</td>
</tr>
<tr>
<td></td>
<td>F9</td>
<td>F8.4</td>
<td>73-80</td>
<td></td>
<td>lbf</td>
</tr>
</tbody>
</table>

<i>Notes:</i>

- Cards 18 through 26 are required for each individual motor.
- Average or integral data (but not both) are required for a particular time interval; however, cards 23, 24, 25, and 26 are required because average and integral data may be intermingled with the various time intervals.
### TABLE IV - TYPICAL NONTRANSFORMED DATA OUTPUT FORMAT FOR THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM

**PA = -.000**

<table>
<thead>
<tr>
<th>IMPULSE MOTOR NO.</th>
<th>IT1</th>
<th>IT2</th>
<th>IT3</th>
<th>IT4</th>
<th>IT5</th>
<th>IT6</th>
<th>IT7</th>
<th>IT8</th>
<th>IT9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEMP GROUP 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37A</td>
<td>0.00</td>
<td>0.00</td>
<td>479.00</td>
<td>1510.67</td>
<td>1755.88</td>
<td>1781.61</td>
<td>271.11</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>70</td>
<td>0.00</td>
<td>0.00</td>
<td>730.06</td>
<td>1515.86</td>
<td>1728.77</td>
<td>1752.70</td>
<td>236.41</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>44A</td>
<td>0.00</td>
<td>0.00</td>
<td>530.96</td>
<td>1438.65</td>
<td>1757.28</td>
<td>1780.02</td>
<td>280.05</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>45A</td>
<td>0.00</td>
<td>0.00</td>
<td>544.38</td>
<td>1535.37</td>
<td>1772.00</td>
<td>1795.93</td>
<td>260.17</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>43A</td>
<td>0.00</td>
<td>0.00</td>
<td>549.86</td>
<td>1525.38</td>
<td>1771.66</td>
<td>1798.37</td>
<td>272.60</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
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<td>1556.49</td>
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<td>603.80</td>
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<td>1759.02</td>
<td>1783.93</td>
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<td>0.00</td>
<td>95.79</td>
<td>20.44</td>
<td>16.41</td>
<td>17.15</td>
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</tr>
<tr>
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<td></td>
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<td></td>
</tr>
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<td>1779.85</td>
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<td>780.61</td>
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<td>1771.82</td>
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<td>1787.62</td>
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<td>100.11</td>
<td>33.78</td>
<td>21.70</td>
<td>19.48</td>
<td>18.60</td>
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</tr>
<tr>
<td><strong>TEMP GROUP 3</strong></td>
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<td></td>
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<td>1820.64</td>
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<td>1801.22</td>
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<td>92.60</td>
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<td>682.98</td>
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<td>1747.85</td>
<td>1772.93</td>
<td>259.16</td>
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<td>1794.46</td>
<td>290.66</td>
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<td>729.60</td>
<td>1510.68</td>
<td>1777.23</td>
<td>1800.32</td>
<td>299.26</td>
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</tr>
<tr>
<td><strong>STAND. DEV.</strong></td>
<td>0.00</td>
<td>0.00</td>
<td>107.36</td>
<td>16.86</td>
<td>21.31</td>
<td>19.73</td>
<td>20.52</td>
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</tr>
</tbody>
</table>
TABLE V. - TYPICAL TRANSFORMED DATA OUTPUT FORMAT FOR THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE COMPUTER PROGRAM

[Transformed impulse]

<table>
<thead>
<tr>
<th>TIME NO. 5</th>
<th>PA = -0.00</th>
<th>TEMP1</th>
<th>TEMP2</th>
<th>TEMP3</th>
<th>TEMP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOTOR NO.</td>
<td>TEMP GROUP 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37A</td>
<td>70</td>
<td>44A</td>
<td>45A</td>
<td>43A</td>
<td>74A</td>
</tr>
<tr>
<td>1717.24</td>
<td>1598.79</td>
<td>1687.36</td>
<td>1708.40</td>
<td>1691.79</td>
<td>1690.42</td>
</tr>
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<td>1808.10</td>
<td>1683.38</td>
<td>1778.63</td>
<td>1798.20</td>
<td>1780.72</td>
<td>1779.28</td>
</tr>
<tr>
<td>Mean</td>
<td>Standard Dev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1682.33</td>
<td>42.56</td>
<td>44.69</td>
<td>49.20</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>TEMP GROUP 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>50A</td>
<td>38A</td>
<td>59A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1617.59</td>
<td>1725.21</td>
<td>1660.79</td>
<td>1707.16</td>
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<td></td>
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<tr>
<td>1704.09</td>
<td>1816.26</td>
<td>1748.16</td>
<td>1796.08</td>
<td></td>
<td></td>
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<tr>
<td>1884.33</td>
<td>2006.52</td>
<td>1930.84</td>
<td>1982.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>Standard Dev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1677.69</td>
<td>48.39</td>
<td>50.28</td>
<td>54.53</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>TEMP GROUP 3</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>64A</td>
<td>58A</td>
<td>65A</td>
<td>40A</td>
<td>78</td>
</tr>
<tr>
<td>1636.31</td>
<td>1672.84</td>
<td>1746.90</td>
<td>1676.67</td>
<td>1681.40</td>
<td>1633.62</td>
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<td>1840.02</td>
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<td>1769.57</td>
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<td>1947.95</td>
<td>2034.19</td>
<td>1950.87</td>
<td>1954.06</td>
<td>1896.29</td>
</tr>
<tr>
<td>Mean</td>
<td>Standard Dev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1675.19</td>
<td>37.51</td>
<td>39.56</td>
<td>44.65</td>
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<td></td>
</tr>
<tr>
<td>TOTAL MEAN</td>
<td>TOTAL Standard Dev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1678.30</td>
<td>39.28</td>
<td>41.30</td>
<td>45.56</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>CONFIDENCE ON NORMAL DISTRIBUTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ONE MIN</td>
<td>1537.47</td>
<td>1618.76</td>
<td>1789.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIDED MAX</td>
<td>1819.13</td>
<td>1914.86</td>
<td>2115.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWO MIN</td>
<td>1522.94</td>
<td>1603.48</td>
<td>1771.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIDED MAX</td>
<td>1833.66</td>
<td>1930.14</td>
<td>2131.97</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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TABLE VI- INPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR
PERFORMANCE VERSUS TIME COMPUTER PROGRAM

<table>
<thead>
<tr>
<th>Card number (a)</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NXNW</td>
<td>I6</td>
<td>1-6</td>
<td>Integer designating the number of subintervals into which web time is divided (up to 5)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NXNT</td>
<td>I6</td>
<td>7-12</td>
<td>Integer designating the number of subintervals into which tail-off time is divided (up to 4)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>F12.4</td>
<td>13-24</td>
<td>Prefire propellant temperature to which the performance data are to be transformed</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>PHI</td>
<td>F12.4</td>
<td>25-36</td>
<td>Nozzle cant angle (from the longitudinal center line of the motor)</td>
<td>rad</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td>F12.4</td>
<td>37-48</td>
<td>Tolerance factor (one- or two-sided)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NSW&lt;sup&gt;b&lt;/sup&gt;</td>
<td>I6</td>
<td>49-54</td>
<td>Integer designating the method by which T0 is to be determined (0 if T0 is inputed, 1 if T0 is to be determined by the program as a function of chamber pressure)</td>
<td>-</td>
</tr>
<tr>
<td>1A</td>
<td>PSIA&lt;sup&gt;b&lt;/sup&gt;</td>
<td>F10.0</td>
<td>1-10</td>
<td>Value of chamber pressure at which TO is determined (card not included if NSW = 0)</td>
<td>psia</td>
</tr>
<tr>
<td>2</td>
<td>PCTW1</td>
<td>F10.4</td>
<td>1-10</td>
<td>Upper limit of first web-time subinterval</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NW1</td>
<td>I6</td>
<td>11-16</td>
<td>Integer designating the number of equally divided percent-web-times in the first subinterval that time, chamber pressure, and thrust transformations are to be performed</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTW2</td>
<td>F10.4</td>
<td>17-26</td>
<td>Continue for each subinterval up to NXNW (last subinterval must equal 100 percent web time)</td>
<td>percent</td>
</tr>
</tbody>
</table>

<sup>a</sup>Cards 1 through 10 apply for all motors and are read in only once; however, cards 11 through 13 + \( \frac{NPTS}{2} \) are required for each motor and must be entered in sequence.

<sup>b</sup>Card 1A can be omitted if TO is an input value (NSW = 0).
TABLE VI. - INPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR
PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number (a)</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>NW2</td>
<td>I6</td>
<td>27-32</td>
<td>Continue for each subinterval up to NXNW (last subinterval must equal 100 percent web time)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTW3</td>
<td>F10.4</td>
<td>33-42</td>
<td></td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NW3</td>
<td>I6</td>
<td>43-48</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTW4</td>
<td>F10.4</td>
<td>49-58</td>
<td></td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NW4</td>
<td>I6</td>
<td>59-64</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTW5</td>
<td>F10.4</td>
<td>65-74</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>NW5</td>
<td>I6</td>
<td>75-80</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>PCTT1</td>
<td>F10.4</td>
<td>1-10</td>
<td>Upper limit of first tail-off time subinterval</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NT1</td>
<td>I6</td>
<td>11-16</td>
<td>Integer designating the number of equally divided percent tail-off times in the first subinterval that time, chamber pressure, and thrust transformations are to be performed</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTT2</td>
<td>F10.4</td>
<td>17-26</td>
<td>Continue for each subinterval up to NXNT (last subinterval must equal 100 percent tail-off time)</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NT2</td>
<td>I6</td>
<td>27-32</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PCTT3</td>
<td>F10.4</td>
<td>33-42</td>
<td></td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NT3</td>
<td>I6</td>
<td>43-48</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*a* Cards 1 through 10 apply for all motors and are read in only once; however, cards 11 through $13 + \frac{NPTS}{2}$ are required for each motor and must be entered in sequence.
TABLE VI. - INPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR

PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>PCTT4</td>
<td>F10.4</td>
<td>49-58</td>
<td>Continue for each subinterval up to NXNT (last subinterval must equal 100 percent tail-off time)</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>NT4</td>
<td>I6</td>
<td>59-64</td>
<td>Integer designating the number of prefire propellant temperatures about which the motors are grouped (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>NA</td>
<td>I12</td>
<td>1-12</td>
<td>Integer designating the number of prefire propellant temperatures about which the motors are grouped (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TGRP1</td>
<td>F12.4</td>
<td>13-24</td>
<td>First prefire propellant temperature about which the motors are grouped (prefire propellant temperature group no. 1)</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>TGRP2</td>
<td>F12.4</td>
<td>25-36</td>
<td>Continue for each prefire propellant temperature about which the motors are grouped (up to 3)</td>
<td>°F</td>
</tr>
<tr>
<td></td>
<td>TGRP3</td>
<td>F12.4</td>
<td>37-48</td>
<td>Integer designating the number of pressure altitudes at which thrust is to be reported (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>NP</td>
<td>I12</td>
<td>1-12</td>
<td>Integer designating the number of pressure altitudes at which thrust is to be reported (up to 3)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>EXPA1</td>
<td>F12.4</td>
<td>13-24</td>
<td>The first pressure altitude at which thrust is to be reported</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>EXPA2</td>
<td>F12.4</td>
<td>25-36</td>
<td>Continue for each pressure altitude at which thrust is to be reported (up to 3)</td>
<td>psia</td>
</tr>
<tr>
<td></td>
<td>EXPA3</td>
<td>F12.4</td>
<td>37-48</td>
<td>psia</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>HEADX</td>
<td>12A6</td>
<td>1-72</td>
<td>Heading for the abscissa of all graphs (time axis)</td>
<td>sec</td>
</tr>
<tr>
<td>7</td>
<td>HEAD1</td>
<td>12A6</td>
<td>1-72</td>
<td>Ordinate heading on plot of chamber pressure versus time</td>
<td>psia</td>
</tr>
</tbody>
</table>

\[ a \] Cards 1 through 10 apply for all motors and are read in only once; however, cards 11 through 13 + \( \frac{NPTS}{2} \) are required for each motor and must be entered in sequence.

\[ b \] The value of TGRP(3) must be greater than TGRP(2), and TGRP(2) must be greater than TGRP(1).
# TABLE VI. - INPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Continued

<table>
<thead>
<tr>
<th>Card number</th>
<th>Variable name</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>HEAD2</td>
<td>12A6</td>
<td>1-72</td>
<td>Ordinate heading on plot of thrust at pressure altitude no. 1 (EXPA 1) versus time</td>
<td>lbf</td>
</tr>
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<td>TT</td>
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<td>Total time for the motor</td>
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<td>TO</td>
<td>F12.4</td>
<td>55-66</td>
<td>Time offset (time that is zero percent web time)</td>
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<td>PCP</td>
<td>F12.4</td>
<td>67-78</td>
<td>Prefire chamber pressure (used to convert input chamber pressures from psig to psia)</td>
<td>psia</td>
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<td>NDMOT</td>
<td>H</td>
<td>80</td>
<td>Integer designating that the last motor to be processed has been reached (1 for last motor, 0 for all other motors)</td>
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<td>AE2</td>
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<td>13-24</td>
<td>Continue for each nozzle (up to 4)</td>
<td>in.²</td>
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Cards 1 through 10 apply for all motors and are read in only once; however, cards 11 through $13 + \frac{NPTS}{2}$ are required for each motor and must be entered in sequence. If fewer than three ambient pressures are used, cards 9 and 10 must be present, even as blank cards.
### TABLE VI. - INPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR

PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Concluded

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<td>13</td>
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<td>Integer designating number of points to be read in to define motor performance versus time (up to 200)</td>
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<td>ICON</td>
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<td>7-12</td>
<td>Integer designating the number of input points in piecewise curve fit (6 is a good choice)</td>
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<td>Integer designating that the curve fit coefficients are to be printed out (0 for no coefficients, 1 for all coefficients)</td>
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<td>14</td>
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<td>First time input in the performance input array</td>
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<td>Chamber pressure that corresponds to the time input in the performance input array</td>
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<td>Continue for each chamber pressure and thrust at the proper time (up to NPTS) at 2 times, pressures and thrusts inputs per card</td>
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*Cards 1 through 10 apply for all motors and are read in only once; however, cards 11 through 13 + \(\frac{NPTS}{2}\) are required for each motor and must be entered in sequence.*
### TABLE VII: TRANSFORMED TIME AND CHAMBER-PRESSURE STATISTICAL DATA OUTPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR PERFORMANCE VERSUS TIME COMPUTER PROGRAM

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### TABLE VII - TRANSFORMED TIME AND CHAMBER-PRESSURE STATISTICS

**DATA OUTPUT FORMAT FOR THE PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Continued**

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**Continued...**
### TABLE VII - TRANSFORMED TIME AND CHAMBER-PRESSURE STATISTICAL

**DATA OUTPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR**

**PERFORMANCE VERSUS TIME** COMPUTER PROGRAM - Continued

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TABLE VII - TRANSFORMED TIME AND CHAMBER-PRESSURE STATISTICAL DATA OUTPUT FORMAT FOR THE SOLID PROPELLANT ROCKET MOTOR PERFORMANCE VERSUS TIME COMPUTER PROGRAM - Concluded

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## TABLE VIII - TRANSFORMED TIME-AND-THRUST STATISTICAL DATA OUTPUT

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TABLE VIII. - TRANSFORMED TIME-AND-THRUST STATISTICAL DATA OUTPUT

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VERSUS TIME COMPUTER PROGRAM - Concluded

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52
(a) Longitudinal cross section.

(b) Typical internal-burning six-point star propellant grain configuration.

Figure 1. - Typical solid propellant rocket motor.
(c) Burning surface geometry of a typical internal-burning six-point star propellant grain configuration versus regressed distances normal to the original propellant surface.

Figure 1. - Concluded.
Figure 2. - Typical variation of propellant performance characteristics over extended burning rate and chamber pressure ranges.
Figure 3. - Typical performance variation of a solid propellant rocket motor of fixed geometry and given propellant that is tested at differing prefire propellant temperatures.

Figure 4. - Propellant burning surface area versus increasing distance burned normal to the original propellant surface for the six-point star propellant grain configuration shown in figures 1(b) and 1(c).

Figure 5. - Area ratio of propellant burning surface area to nozzle throat area versus increasing distance burned normal to the original propellant surface for the solid propellant rocket motor shown in figure 1.
Figure 6. - Typical variation of propellant performance characteristics over limited burning rate and chamber pressure ranges.
Figure 7. - Second-order, least-squares curve fit of experimentally determined chamber pressures at the individual regressed distance of interest normal to the original propellant surface versus prefire propellant temperature.

Figure 8. - Second-order, least-squares curve fit of experimentally determined burning rates at the individual regressed distance of interest normal to the original propellant surface versus prefire propellant temperature.
Figure 9. - Second-order, least-squares curve fit of experimentally determined motor operation times to the individual regressed distance of interest normal to the original propellant surface versus prefire propellant temperature.

Figure 10. - Example of two-sided tolerance limits for a normal distribution.

\[ u = \bar{X} \pm sK_2 \]  

where \( u \) are the upper and lower limits.
(a) Upper tolerance limit

\[ u_u = \bar{X} + sK_1 \]

(b) Lower tolerance limit

\[ u_l = \bar{X} - sK_1 \]

Figure 11. - Example of one-sided tolerance limits for a normal distribution.
Figure 12. - IBM 7094 deck setup for the general solid propellant rocket motor performance computer program using the group transformation method.
Figure 13. - Example of choosing the output points that will best define the variation of chamber pressure and thrust versus time.
Figure 14. - Univac 1107 deck setup for the solid propellant rocket motor performance versus time computer program using the group transformation method.
Figure 15. - Example of choosing the input points that will best define the variation of chamber pressure and thrust versus time.
(a) Typical transformed time and chamber pressure graphed outputs.

Figure 16. - Example of graphical format from the solid propellant rocket motor performance versus time computer program.
(b) Typical transformed time and thrust graphed outputs.

Figure 16. - Concluded.
REFERENCES


APPENDIX A

LISTING OF THE GENERAL SOLID PROPELLANT ROCKET MOTOR PERFORMANCE
COMPUTER PROGRAM USING THE GROUP TRANSFORMATION METHOD
**SIBJOB DRIVER**  
GO, SOURCE  
**SIBFTC DRIVER**  
**DRIVER PROGRAM FOR MOTORS**  
C  
C  
DIMENSION XX(4,60)  
DIMENSION EXPA(4), COUNT(4), WP (4,15), WEB(4,15), ATTOT(4,15),  
1 AETOT(4,15), P(9,4,15), MOTNO(4,15), FVAC1(9,4,15)  
COMMON G, CP1, NT, EXPA, COUNT, WP, WEB, ATTOT, AETOT,  
1 P, MOTNO, FVAC1, NTIMES, XX, NTOT, NURN, NFIRST, NP  
COMMON CP1, CP2, CT1, CT2, VEC1, VEC2, VEC3  
1 READ (5,10) CASE  
WRITE (6,11) CASE  
WRITE (6,21) READ (5,80)  
WRITE (6,80) READ (5,79) NTIMES  
WRITE (6,14) NTIMES  
DO 2 I = 1, NTIMES  
READ (5,80)  
2 WRITE (6,80)  
10 FORMAT (A6)  
11 FORMAT (1H1, A6/)  
14 FORMAT (1X //2, 33H TIMES WERE USED IN THIS ANALYSIS )  
21 FORMAT ( 46H GENERAL SOLID-FUEL ROCKET PERFORMANCE PROGRAM /  
1 120H ROCKET TEST FIRINGS CONDUCTED AT SEVERAL TEMPERATURES  
2 ARE EFFECTIVELY TRANSFORMED TO SPECIFIED TEMPERATURES OF INTEREST  
3 / 29H STATISTICAL ANALYSES ARE PERFORMED ON THE TEST FIRING  
4 DATA AFTER IT HAS BEEN TRANSFORMED //)  
79 FORMAT (10X, I2)  
80 FORMAT (A8H  
1 CALL MOTORS  
CALL MOT2  
CALL MOT3  
GO TO 1  
END  
**SIBFTC STATS**  
**SUBROUTINE STATS (X, N, XM, SD)**  
DIMENSION X(100)  
SUM1 = 0.  
SUM2 = 0.  
XNO = N  
XNO1 = XNO - 1.  
DENOM = XNO*XNO1  
DO 10 I = 1,N  
SUM1 = SUM1 + X(I)  
10 SUM2 = SUM2 + X(I)*X(I)  
XM = SUM1 / XNO  
XNUM = (XNO*SUM2 - SUM1*SUM1)  
IF (XNUM .LE. 0.) GO TO 14  
SD = SQRT(XNUM/DENOM).  
IF ((SD/XM) .LT. .00025) GO TO 14  
GO TO 15  
14 SD = 0.  
15 RETURN  
END
SOLID PROPELLANT ROCKET MOTOR TEST PROGRAM - FIRST HALF

DIMENSION ZZ(648), XX(4860)
COMMON G, CPHI, NT, EXPA, COUNT, WP, WEB, ATTOT, AEOT, P, MOTNO, FVAC1, NTIMES, XX, NTOT, NBURN, NFIRST, NP
COMMON CP1, CP2, CT1, CT2, VEC1, VEC2, VEC3
DIMENSION EXTEM(4), EXPA(4), EPS(4),
1 COUNT(4), SET1(45), SET2(45), SET3(45), SET4(45),
2 SET5(45), SET6(45), SET7(45), TGRP(3),
3 TENTRY(60), TENT2(60), ARRAY(464), ENTRY(960),
4 COEF1(9,4), COEF2(9,4), IFLAG(9), IFLAG(29)

DIMENSION X(4), TIME(9,4),15), INTP(9,4,15), P(9,4,15),
1 INTF(9,4,15), F(9,4,15), P1(9,4,15), P2(9,4,15),
2 P3(9,4,15), T1(9,4,15), T2(9,4,15), T3(9,4,15),
3 TSTP(9,4,15), INTPT2(9,4,15), INTPT3(9,4,15)

DIMENSION AT1(4,15), AT2(4,15), AT3(4,15), AT4(4,15), AE1(4,15),
1 AE2(4,15), AE3(4,15), AE4(4,15), WP(4,15), WER(4,15),
2 DEN(4,15), PAF(4,15), LNP(4,15), LNT(4,15),
3 MOTNO(4,15), TEMP(4,15), RU(4,15), KN(4,15)

DIMENSION MP(9,4), SDP(9,4), MF(9,4), SDF(9,4),
1 MTIMF(9,4), SDTIMF(9,4), MPT1(9,4), SPT1(9,4), MPT2(9,4),
2 SDPT2(9,4), MPT3(9,4), SDPT3(9,4), MPT4(9,4),
3 MTT1(9,4), SUT1(9,4), MTT2(9,4), SUT2(9,4), MTT3(9,4),
4 SUTT1(9,4), MTTT(9,4), SUTT2(9,4), MTTT2(9,4),
5 MINT1(9,4), SDINT1(9,4), MINT2(9,4), SDINT2(9,4),
6 SDINTT(9,4), MINTT(15), SDTEMP(15)

DIMENSION R1(4,15), R2(4,15), R3(4,15), R4TOT(4,15),
1 ETA(4,15), EA(4,15), EB(4,15), EC(4,15), ED(4,15),
2 ETOT(4,15),
3 CMIN(4), CMAX(4), C2MIN(4), C2MAX(4), C1TMN(4), C1TMX(4),
4 C2TMN(4), C2TMX(4)
DIMENSION C1MN(5), C1MX(5), C2MN(5), C2MX(5)
DIMENSION
1 FVAC1(9,4,15), WPU(9,4,15), ISP(9,4,15), IVAC1(9,4,15),
2 ISP1(9,4,15), I1Z(9,4,15), F12(9,4,15), ISPU12(9,4,15),
3 I13(9,4,15), F13(9,4,15), ISPU13(9,4,15), I14(9,4,15),
4 F14(9,4,15), ISPU14(9,4,15), CSTU(9,4,15)
DIMENSION MAT(5), SDAT(5), MAE(5), SDAE(5), ME(5), SUE(5)
DIMENSION MNTP(9,4), SDINTP(9,4), MINTF(9,4), SDINTF(9,4),
1 MWPU(9,4), SWPU(9,4), MISP(9,4), SDISP(9,4), MCSTU(9,4),
2 SOCSTU(9,4), MRU(4), SDRU(4), MKN(4), SDKN(4),
3 MIIVC1(9,4), SDIVC1(9,4), MFVC1(9,4), SDVFVC1(9,4), MIU11(9,4),
4 SDIU11(9,4), MII2(9,4), SII12(9,4), MF12(9,4), SDF12(9,4),
5 MIU12(9,4), SII12(9,4), MI13(9,4), SII13(9,4), MII3(9,4),
6 SOD13(9,4), MIU13(9,4), SII13(9,4), MII4(9,4), SDI14(9,4),
7 MF14(9,4), SDF14(9,4), MIU14(9,4), SDIU14(9,4), IL(4)
DIMENSION SIGP12(9), SIGP22(9), SIGP32(9), SIGP11(9),
1 SIGP11(9), SIGP31(9), SIGP31(9), SIGP12(9), SIGP13(9), SIGP23(9), SIGP33(9),
2 PIK11(9), PIK12(9), PIK13(9), PIK12(9), PIK22(9), PIK32(9),
3 PIK13(9), PIK23(9), PIK33(9)

EQUIVALENCE
6 (ZZ(505))  
7 (ZZ(541), SDIU11(1))  
8 (ZZ(577), SDIU13(1))  
9 (ZZ(613), SDIU14(1))

EQUIVALENT
1 (ZZ(1), MIVC1(1), MI12(1), MI13(1), MI14(1), MPT1(1)),
2 (ZZ(37), MPT2(1)),
3 (ZZ(73), MPT3(1)),
4 (ZZ(109), MFVC1(1), MF12(1), MF13(1), MF14(1), MTT1(1)),
5 (ZZ(145), MTT2(1)),
6 (ZZ(181), MTT3(1)),
7 (ZZ(217), MIU11(1), MIU12(1), MIU13(1), MIU14(1), MINT1(1)),
8 (ZZ(253), MINT2(1)),
9 (ZZ(289), MINT3(1))

INTEGER COUNT* ENDMOT

HEAL INTP  
INTF  
INTPT1  
INTPT2  
INTPT3  

1 MTEMP  
MTIME  
SDTIME  
MP  
WF  
MPT1  
MPT2  
MPT3  

2 MPTT  
MTTL  
MTT2  
MTT3  
MTT4  

3 MINT1  
LNT  
LNP  
MOTNO  
1SP  
IVAC1  
ISPU1  
I12  

4 ISPU12  
I13  
ISPU13  
I14  
ISPU14  
KN  
MINTP  
MINTF  

5 MWPU  
MISP  
MCSTU  
MRU  
MKN  
MIVC1  
MFVC1  
MIU11  

6 MI12  
MF12  
MI13  
MF13  
MIU13  
MI14  
MF14  
MIU14

REAL MAT  
MAE  
ME

C
C
C

INPUT FORMATS

1 FORMAT (112, 4F12.4)
2 FORMAT (2F12.5, 312)
3 FORMAT (4F12.4)
4 FORMAT (A6, F12.4, I2)
5 FORMAT (4E12.5)
6 FORMAT (8F9.4, F8.4)

C
C
C

OUTPUT FORMATS

16 FORMAT (10H THERE ARE I2, 46H AMBIENT PRESSURES BEING CONSIDERED,
1 THEY ARE / 4F12.4)
18 FORMAT (10HTHERE ARE I2, 46H EXACT TEMPERATURES BEING CONSIDERED,
1 THEY ARE / 4F12.4)
20 FORMAT (41H G AND PHI ARE CONSTANT FOR A RUN AND ARE / 2F12.5)
2001 FORMAT ( 62H TOTAL AREA ATA ATC ATD
1AT TOTAL / 10H MOTOR NO./)
2002 FORMAT (11HTEMP GROUP I2 // (1X, A6, 5X, 5F10.4))
2003 FORMAT ( 62HEXIT AREA AEA AER AEC AED
IAE TOTAL / 10H MOTOR NO./)
2004 FORMAT ( 62HEXPANSION RATIO EA ER EC ED
1E TOTAL / 10H MOTOR NO./)
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READ DATA AND GROUP IT INTO TEMPERATURE GROUPS

ASSIGN DATA FOR A MOTOR INTO PROPER TEMPERATURE GROUP

READ REMAINDFR OF DATA FOR A MOTOR

PROCEED WITH MAIN BODY OF PROGRAM

COMPUTE P(I,J,K), F(I,J,K) AND STATISTICS ON P, F AND TIME
DO 115 I = 1, NTIMES
   ISW = 1
   IF (P(I, J, K) .GT. 0.) ISW = ISW + 1
   IF (F(I, J, K) .GT. 0.) ISW = ISW + 2
   DO 115 J = 1, NT
   L = 0
   JJ = COUNT(J)
   DO 108 K = 1, JJ
   GO TO (104, 105, 106, 107), ISW
104 P(I, J, K) = INTP(I, J, K) / TIME(I, J, K)
105 F(I, J, K) = INTF(I, J, K) / TIME(I, J, K)
   GO TO 107
106 P(I, J, K) = INTP(I, J, K) / TIME(I, J, K)
107 L = L + 1
   SET1(L) = P(I, J, K)
   SET2(L) = F(I, J, K)
108 SET3(L) = TIME(I, J, K)
   CALL STATS (SET1, L, MP (I, J), SUP (I, J))
   CALL STATS (SET2, L, MF (I, J), SUF (I, J))
115 CALL STATS (SET3, L, MTIME(I, J), SUTMF(I, J))
   WRITE (6, 2005)
   DO 55 J = 1, NT
   JJ = COUNT(J)
   WRITE (6, 2006) J, (MOTNO(J, K), (TIME(I, J, K), I=1,9), K = 1, JJ)
55 WRITE (6, 2055) (MTIME(I, J), I=1,9), (SNTIME(I, J), I=1,9)
116 WRITE (6, 2007)
   DO 118 J = 1, NT
   JJ = COUNT(J)
   WRITE (6, 2046) J, (MOTNO(J, K), (P(I, J, K), I = 1,9), K = 1, JJ)
118 WRITE (6, 2060) (MP(I, J), I=1,9), (SMP(I, J), I=1,9)
   WRITE (6, 2014)
216 WRITE (6, 2015)
   DO 218 J = 1, NT
   JJ = COUNT(J)
   WRITE (6, 2045) J, (MOTNO(J, K), (F(I, J, K), I = 1,9), K = 1, JJ)
218 WRITE (6, 2080) (MF(I, J), I=1,9), (SMF(I, J), I=1,9).

C

DO 270 J = 1, NT
   L = 0
   JJ = COUNT(J)
   DO 260 K = 1, JJ
   L = L + 1
260 SET1(L) = TEMP(J, K)
   CALL STATS (SET1, L, MTEMP(J), SUTMP(J))
270 DO 704 J = 1, NT
   JJ = COUNT(J)
   DO 704 K = 1, JJ
   L = L + 1
   AETOT(J,K) = AE1(J,K) + AE2(J,K) + AE3(J,K) + AE4(J,K)
   ATTOT(J,K) = AT1(J,K) + AT2(J,K) + AT3(J,K) + AT4(J,K)
   EA(J,K) = AE1(J,K) / AT1(J,K)
   ER(J,K) = AE2(J,K) / AT2(J,K)
   EC(J,K) = AE3(J,K) / AT3(J,K)
   ED(J,K) = AE4(J,K) / AT4(J,K)
   ETOT(J,K) = AETOT(J,K) / ATTOT(J,K)

C

COMPUTE STATISTICS FOR TEMPERATURE

C

DO 270 J = 1, NT
   L = 0
   JJ = COUNT(J)
   DO 260 K = 1, JJ
   L = L + 1
260 SET1(L) = TEMP(J, K)
   CALL STATS (SET1, L, MTEMP(J), SUTMP(J))
270 DO 704 J = 1, NT
   JJ = COUNT(J)
   DO 704 K = 1, JJ
   L = L + 1
   AETOT(J,K) = AE1(J,K) + AE2(J,K) + AE3(J,K) + AE4(J,K)
   ATTOT(J,K) = AT1(J,K) + AT2(J,K) + AT3(J,K) + AT4(J,K)
   EA(J,K) = AE1(J,K) / AT1(J,K)
   ER(J,K) = AE2(J,K) / AT2(J,K)
   EC(J,K) = AE3(J,K) / AT3(J,K)
   ED(J,K) = AE4(J,K) / AT4(J,K)
   ETOT(J,K) = AETOT(J,K) / ATTOT(J,K)
\[
\begin{align*}
\text{SET1}(L) &= \text{AT1}(JrK) \\
\text{SET2}(L) &= \text{AT2}(JrK) \\
\text{SET3}(L) &= \text{AT3}(JrK) \\
\text{SET4}(L) &= \text{AT4}(JrK) \\
\text{SET5}(L) &= \text{ATTOT}(JrK) \\
\text{SET6}(L) &= \text{AE1}(JrK) \\
\text{SET7}(L) &= \text{AE2}(JrK) \\
\text{TENT2}(L) &= \text{AE3}(JrK)
\end{align*}
\]

\[
\begin{align*}
\text{CALL STATS} & (\text{SET1}, \text{MAT}(1), \text{SDE}(1)) \\
\text{CALL STATS} & (\text{SET2}, \text{MAT}(2), \text{SDE}(2)) \\
\text{CALL STATS} & (\text{SET3}, \text{MAT}(3), \text{SDE}(3)) \\
\text{CALL STATS} & (\text{SET4}, \text{MAT}(4), \text{SDE}(4)) \\
\text{CALL STATS} & (\text{SET5}, \text{MAT}(5), \text{SDE}(5)) \\
\text{CALL STATS} & (\text{SET6}, \text{MAE}(1), \text{SDAE}(1)) \\
\text{CALL STATS} & (\text{SET7}, \text{MAE}(2), \text{SDAE}(2)) \\
\text{CALL STATS} & (\text{TENT2}, \text{MAE}(3), \text{SDAE}(3))
\end{align*}
\]

\[
\begin{align*}
L &= 0 \\
\text{DO} & \ 1704 \ J = 1,\text{NT} \\
\text{JJ} &= \text{COUNT}(J) \\
\text{DO} & \ 1704 \ K = 1,\text{JJ} \\
L &= L + 1 \\
\text{SET1}(L) &= \text{EA}(JrK) \\
\text{SET2}(L) &= \text{EB}(JrK) \\
\text{SET3}(L) &= \text{EC}(JrK) \\
\text{SET4}(L) &= \text{ED}(JrK) \\
\text{SET5}(L) &= \text{ETOT}(JrK) \\
\text{SET6}(L) &= \text{AF4}(JrK)
\end{align*}
\]

\[
\begin{align*}
\text{CALL STATS} & (\text{SET1}, \text{MAT}(1), \text{SDE}(1)) \\
\text{CALL/stats} & (\text{SET2}, \text{MAT}(2), \text{SDE}(2)) \\
\text{CALL STATS} & (\text{SET3}, \text{MAT}(3), \text{SDE}(3)) \\
\text{CALL STATS} & (\text{SET4}, \text{MAT}(4), \text{SDE}(4)) \\
\text{CALL STATS} & (\text{SET5}, \text{MAT}(5), \text{SDE}(5)) \\
\text{CALL STATS} & (\text{SET6}, \text{MAE}(1), \text{SDAE}(1)) \\
\text{CALL STATS} & (\text{SET7}, \text{MAE}(2), \text{SDAE}(2)) \\
\text{CALL STATS} & (\text{TENT2}, \text{MAE}(3), \text{SDAE}(3))
\end{align*}
\]

\[
\begin{align*}
L &= 0 \\
\text{DO} & \ 1704 \ J = 1,\text{NT} \\
\text{JJ} &= \text{COUNT}(J) \\
\text{DO} & \ 1704 \ K = 1,\text{JJ} \\
L &= L + 1 \\
\text{IF} & \quad (\text{INTP}(I,JrK) \neq 0.) \text{ GO TO} 1070 \\
\text{INTP}(I,JrK) &= P(I,JrK) * \text{TIME}(I,JrK)
\end{align*}
\]

\[
\begin{align*}
\text{IF} & \quad (\text{INTF}(I,JrK) \neq 0.) \text{ GO TO} 1075 \\
\text{INTF}(I,JrK) &= F(I,JrK) * \text{TIME}(I,JrK)
\end{align*}
\]

\[
\begin{align*}
\text{DO} & \ 1075 \ I = \text{NFIRST} > \text{NTIMES} \\
\text{DO} & \ 1100 \ J = 1,\text{NT} \\
L &= L + 1 \\
\text{IF} & \quad (\text{INTP}(I,JrK) \neq 0.) \text{ GO TO} 1070 \\
\text{WPU}(I,JrK) &= \text{WP}(JrK) * \text{INTP}(I,JrK) / \text{INTP}(\text{NTOT},JrK) \\
\text{CSSTU}(I,JrK) &= \text{INTP}(I,JrK) * \text{ATTOT}(JrK) / \text{WPU}(I,JrK) \\
\text{ISP}(I,JrK) &= \text{INTF}(I,JrK) / \text{WPU}(I,JrK) \\
\text{FVAC1}(I,JrK) &= \text{F}(I,JrK) * \text{PAF}(JrK) * \text{ATTOT}(JrK) * \text{CPI} \\
\text{TENT2}(L) &= \text{CSSTU}(I,JrK) \\
\text{SET1}(L) &= \text{IVAC1}(I,JrK) \\
\text{SET2}(L) &= \text{INTP}(I,JrK)
\end{align*}
\]
SET3(L) = INTF(I,J,K)
SET4(L) = FVAC1(I,J,K)
SET5(L) = ISP(I,J,K)
SET6(L) = WPU(I,J,K)
1076 SET7(L) = ISP1(I,J,K)
CALL STATS (TENT2(L), MCSTU(I,J), SDSTU(I,J))
CALL STATS (SET1, L, MIVC1(I,J), SDIVC1(I,J))
CALL STATS (SET2, L, MINTP(I,J), SDINTP(I,J))
CALL STATS (SET3, L, MINTF(I,J), SDINTF(I,J))
CALL STATS (SET4, L, MFVC1(I,J), SDFVC1(I,J))
CALL STATS (SET5, L, MISP (I,J), SDISP (I,J))
CALL STATS (SET6, L, MWPU (I,J), SDWPU (I,J))
CALL STATS (SET7, L, MIU11(I,J), SDIU11(I,J))
1100 CONTINUE
C
WRITE (6,2008)
DO 1080 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (INTP(I,J,K), I=1,9), K=1,JJ)
1080 WRITE (6,2080) (MINTP(I,J), I=1,9), (SDINTP(I,J), I=1,9)
WRITE (6,2014)
WRITE (6,2016)
DO 1085 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (INTF(I,J,K), I=1,9), K=1,JJ)
1085 WRITE (6,2080) (MINTF(I,J), I=1,9), (SDINTF(I,J), I=1,9)
WRITE (6,2014)
WRITE (6,2017)
DO 1090 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (ISP(I,J,K), I=1,9), K=1,JJ)
1090 WRITE (6,2080) (MISP (I,J), I=1,9), (SDISP (I,J), I=1,9)
WRITE (6,2024) EXPA(1)
WRITE (6,2015)
DO 1096 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (FVAC1(I,J,K), I=1,9), K=1,JJ)
1096 WRITE (6,2080) (MFVC1(I,J), I=1,9), (SDFVC1(I,J), I=1,9)
WRITE (6,2024) EXPA(1)
WRITE (6,2017)
DO 1063 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (ISP1(I,J,K), I=1,9), K=1,JJ)
1063 WRITE (6,2080) (MIU11(I,J), I=1,9), (SDIU11(I,J), I=1,9)
C
IF (NP .LE. 1) GO TO 1099
DO 1101 I = NFIRST,NTIMES
DO 1101 J = 1,NT
L = 0
JJ = COUNT(J)
DO 1160 K = 1, JJ
 112(I,J,K) = IVAC1(I,J,K) - (EXPA(2)*AETOT(J,K)*CPYI)*TIME(I,J,K)
  F12(I,J,K) = I12(I,J,K) / TIME(I,J,K)
  ISPUI2(I,J,K) = I12(I,J,K) / WPU(I,J,K)
SET11(L) = I12(I,J,K)

SET4(L) = F12(I,J,K)
1160 CALL STATS (SET1, L, MI12(I,J), SDI12(I,J))
CALL STATS (SET4, L, MF12(I,J), SDF12(I,J))
1101 CALL STATS (SET7, L, MIU12(I,J), SDIU12(I,J))

C
WRITE (6,2024) EXP(A(2))
WRITE (6,2015)
DO 1071 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (F12(I,J,K), I=1,9), K=1, JJ)
1071 WRITE (6,2080) (MF12(I,J), I=1,9), (SDF12(I,J), I=1,9)
WRITE (6,2024) EXP(A(2))
WRITE (6,2016)
DO 1072 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (I12(I,J,K), I=1,9), K=1, JJ)
1072 WRITE (6,2080) (MI12(I,J), I=1,9), (SDIU12(I,J), I=1,9)
WRITE (6,2024) EXP(A(2))
WRITE (6,2017)
DO 1073 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (I12(I,J,K), I=1,9), K=1, JJ)
1073 WRITE (6,2080) (MIU12(I,J), I=1,9), (SDIU12(I,J), I=1,9)
IF (NP .LE. 2) 60 TO 1099

C
DO 1102 I = NFIRST, NTIMES
DO 1102 J = 1, NT
L = 0
JJ = COUNT(J)
DO 1180 K = 1, JJ
L = L + 1
113(I,J,K) = IVAC(I,J,K) - (EXP(A(3)) * AEOT(J,K) * CPHI) * TIME(I,J,K)
F13(I,J,K) = I13(I,J,K) / TIME(I,J,K)
ISPU13(I,J,K) = I13(I,J,K) / WPU(I,J,K)
SET7(L) = I13(I,J,K)
SET4(L) = F13(I,J,K)
1180 SET7(L) = ISPU13(I,J,K)
CALL STATS (SET1, L, MI13(I,J), SDI13(I,J))
CALL STATS (SET4, L, MF13(I,J), SDF13(I,J))
1102 CALL STATS (SET7, L, MIU13(I,J), SDIU13(I,J))

C
WRITE (6,2024) EXP(A(3))
WRITE (6,2015)
DO 1081 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (F13(I,J,K), I=1,9), K=1, JJ)
1081 WRITE (6,2080) (MF13(I,J), I=1,9), (SDF13(I,J), I=1,9)
WRITE (6,2024) EXP(A(3))
WRITE (6,2016)
DO 1082 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (I13(I,J,K), I=1,9), K=1, JJ)
1082 WRITE (6,2080) (MI13(I,J), I=1,9), (SDI13(I,J), I=1,9)
WRITE (6,2024) EXP(A(3))
WRITE (6,2017)
DO 1083 J = 1, NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K)), (I13(I,J,K), I=1,9), K=1, JJ)
1083 WRITE (6,2080) (MIU13(I,J), I=1,9), (SDIU13(I,J), I=1,9)
IF (NP .LE. 3) 60 TO 1099

C
DO 1103 I = NFIRST*INTIMES
DO 1103 J = 1,NT
L = 0
JJ = COUNT(J)
DO 1200 K = 1, JJ
L = L + 1
I14(I,J,K) = IVA14(I,J,K) - (EXPA(4)*AETOT(J,K)*CPSI)*TIME(I,J,K)
F14(I,J,K) = I14(I,J,K) / TIME(I,J,K)
ISPU14(I,J,K) = I14(I,J,K) / WPU(I,J,K)
SET1(L) = I14(I,J,K)
SET4(L) = F14(I,J,K)
1200 SET7(L) = ISPU14(I,J,K)
CALL STATS (SET1, L, MI14(I,J,), SMI14(I,J,))
CALL STATS (SET4, L, MF14(I,J,), SDF14(I,J,))
1103 CALL STATS (SET7, L, MIU14(I,J,), SMIU14(I,J,))
WRITE (6,2024) EXPA(4)
WRITE (6,2015)
DO 1091 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (F14(1,J,K), I=1,9), K=1, JJ)
1091 WRITE (6,2040) (MF14(I,J,), I=1,9), (SMF14(I,J,), I=1,9)
WRITE (6,2024) EXPA(4)
WRITE (6,2016)
DO 1092 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (I14(1,J,K), I=1,9), K=1, JJ)
1092 WRITE (6,2040) (MI14(I,J,), I=1,9), (SMI14(I,J,), I=1,9)
WRITE (6,2024) EXPA(4)
WRITE (6,2017)
DO 1093 J = 1,NT
JJ = COUNT(J)
WRITE (6,2045) J, (MOTNO(J,K), (ISMI14(I,J,K), I=1,9), K=1, JJ)
1093 WRITE (6,2080) (MIU14(I,J,), I=1,9), (SMU14(I,J,), I=1,9)
C
C COMPUTE RI, KN AND THEIR STATISTICS
C
1099 DO 1104 J = 1,NT
L = 0
JJ = COUNT(J)
DO 1120 K = 1, JJ
RU(J,K) = W EU(J,K) / TIME(NPURNJ,K)
KN(J,K) = G * INTP(NPURNJ,K) / (UFNS(J,K)*CSTU(NPURNJ,K)*RU(J,K))
SET6(L) = RU(J,K)
SET7(L) = KN(J,K)
1120 CONTINUE
CALL STATS (SET6, L, MRU ( J), SURU ( J))
CALL STATS (SET7, L, MKN ( J), SUKN ( J))
1104 CONTINUE
WRITE (6,2006)
DO 1095 J = 1,NT
JJ = COUNT(J)
WRITE (6,2046) J, (MOTNO(J,K), (CSTU(I,J,K), I = 1,9), K = 1, JJ)
1095 WRITE (6,2060) (MCSTU(I,J,),I=1,9), (SDCSTU(I,J,),I=1,9)
WRITE (6,2012)
DO 1077 J = 1,NT
JJ = COUNT(J)
WRITE (6,2046) J, (MOTNO(J,K), (WPU(I,J,K), I=1,9), K = 1, JJ)
1077 WRITE (6,2060) (MWPU(I,J,), I=1,9), (SDWPU(I,J,), I=1,9)
WRITE (6,2010)
DO 1098 J = 1,NT
JJ = COUNT(J)
79
WRITE (6,2044) J, (MOTNO(J,K), RU(J,K), KN(J,K), K=1,JJ)
WRITE (6,2063) MRRU(J), MKN(J), SDRU(J), SDRN(J)

C C PRINTOUT OF THROAT AREAS, EXIT AREAS AND AREA RATIOS
C C
WRITE (6,2001)
DO 701 J = 1,NT
JJ = COUNT(J)
WRITE (6,2002) J, (MOTNO(J,K), AT1(J,K), AT2(J,K), AT3(J,K),
AT4(J,K), ATTOT(J,K), K = 1, JJ)
WRITE (6,2070) MAT, SAN
WRITE (6,2071) C1MN, C1MX, C2MN, C2MX
DO 1706 K = 1,5
C1MN(K) = MAE(K) - CP1*SDE(K)
C1MX(K) = MAE(K) + CP1*SDE(K)
C2MN(K) = MAE(K) - CP2*SDE(K)
C2MX(K) = MAE(K) + CP2*SDE(K)
1706 C2MX(K) = MAE(K) + CP2*SDE(K)
WRITE (6,2003)
DO 702 J = 1,NT
JJ = COUNT(J)
WRITE (6,2002) J, (MOTNO(J,K), AE1(J,K), AE2(J,K), AE3(J,K),
AE4(J,K), AETOT(J,K), K = 1, JJ)
WRITE (6,2070) MAE, SDE
WRITE (6,2071) C1MN, C1MX, C2MN, C2MX
DO 1707 K = 1,5
C1MN(K) = ME (K) - CP1*SDE (K)
C1MX(K) = MF (K) + CP1*SDE (K)
C2MN(K) = ME (K) - CP2*SDE (K)
C2MX(K) = MF (K) + CP2*SDF (K)
1707 C2MX(K) = MF (K) + CP2*SDF (K)
WRITE (6,2004)
DO 703 J = 1,NT
JJ = COUNT(J)
WRITE (6,2002) J, (MOTNO(J,K), EA(J,K), EP(J,K), EC(J,K),
ED(J,K), ETTOT(J,K), K = 1, JJ)
WRITE (6,2070) ME, SDF
WRITE (6,2071) C1MN, C1MX, C2MN, C2MX

C C COMPUTE CONSTITUENTS OF LNP USING LEAST SQUARES
C
LL = 0
DO 282 J = 1,NT
JJ = COUNT(J)
DO 282 K = 1, JJ
LL = LL + 1
ENTRY(LL) = TEMP(J,K)
282 TENTRY(LL) = TENTRY(LL)**2
C
300 DO 301 I = 1, NMTIMES
IFLAG1(I) = 0
IFLAG2(I) = 0
IF (P(I,1,1)) 309, 308, 309
309 IFLAG1(I) = 1
GO TO 301
309 LL = 0
DO 300 J = 1, NT
JJ = COUNT(J)
DO 300 K = 1, JJ
LL = LL + 1
ENTRY(I,LL) = ALOG (P(I, J,K))
310 CONTINUE
311 CONTINUE
NM = COUNT(1) + COUNT(2) + COUNT(3)
C
DO 320 I = 1,NTIMES
IF(IFLAG1(I) - 1) 312,320,312
312 DO 315 LL = 1,NM
ARRAY(LL,1) = 1.
ARRAY(LL,2) = TENTRY(LL)
ARRAY(LL,3) = TENTRY(LL)
315 CALL GL51(ARRAY, X, IL, NM, 3, ALPHA, 0., 0.)
COEF1 (I,1) = X(1)
COEF1 (I,2) = X(2)
COEF1 (I,3) = X(3)
320 CONTINUE
C COMPUTE CONSTITUENTS OF LNT USING LEAST SQUARES
C
400 DO 411 I = 1,NTIMES
IF (TIME(I,1+1)) 408, 408, 409
408 IFLAG2(I) = 1
GO TO 411
409 LL = 0
DO 410 J = 1,NT
JJ = COUNT(J)
DO 410 K = 1,JJ
LL = LL + 1
ENTRY (LL) = ALOG (TIME(I,J,K))
410 CONTINUE
411 CONTINUE
C
DO 420 I = 1,NTIMES
IF (IFLAG2(I) - 1) 412,420,412
412 DO 415 LL = 1,NM
ARRAY(LL,1) = 1.
ARRAY(LL,2) = TENTRY(LL)
ARRAY(LL,3) = TENTRY(LL)
415 CALL GL51(ARRAY, X, IL, NM, 3, ALPHA, 0., 0.)
COEF2 (I,1) = X(1)
COEF2 (I,2) = X(2)
COEF2 (I,3) = X(3)
420 CONTINUE
C COMPUTE ACTUAL LNP AND LNT
C
450 DO 460 J = 1,NT
LNP(I,J) = COEF1(I,1)+ COEF1(I,2)*EXTEM(J)+ COEF1(I,3)*EXTEM(J)**2
460 LNT(I,J) = COEF2(I,1)+ COEF2(I,2)*EXTEM(J)+ COEF2(I,3)*EXTEM(J)**2
C
DO 462 I = 1,NTIMES
SET1(1) = 0.*
IF (MP(I,1) .GT. 0.) SET1(1) = COEF1(I,1) + COEF1(I,2)*MTEMP(1) + COEF1(I,3)*MTEMP(1)**2
1 SET1(2) = 0.*
IF (MP(I,2) .GT. 0.) SET1(2) = COEF1(I,1) + COEF1(I,2)*MTEMP(2) + COEF1(I,3)*MTEMP(2)**2
1 SET1(3) = 0.*
IF (MP(I,3) .GT. 0.) SET1(3) = COEF1(I,1) + COEF1(I,2)*MTEMP(3) + COEF1(I,3)*MTEMP(3)**2
1 PIK1(I) = (LNP(I,1) - SET1(1)) / (EXTEM(1) - MTEMP(1))
PIK2(I) = (LNP(I,2) - SET1(1)) / (EXTEM(2) - MTEMP(1))
PIK3(I) = (LNP(I,3) - SET1(1)) / (EXTEM(3) - MTEMP(1))
PIK21(I) = (LNPI(1)) - SET1(2)) / (EXTFM(1) - MTEMP(2))
PIK22(I) = (LNPI(2)) - SET1(2)) / (EXTFM(2) - MTEMP(2))
PIK23(I) = (LNPI(3)) - SET1(2)) / (EXTFM(3) - MTEMP(2))
PIK31(I) = (LNPI(1)) - SET1(3)) / (EXTFM(1) - MTEMP(3))
PIK32(I) = (LNPI(2)) - SET1(3)) / (EXTFM(2) - MTEMP(3))
PIK33(I) = (LNPI(3)) - SET1(3)) / (EXTFM(3) - MTEMP(3))

SET2(1) = 0.
IF (MTIME(I,1) .GT. 0.) SET2(1) = COEF2(I,1) + COEF2(I,2)*MTEMP(1) +
1 COEF2(I,3)*MTEMP(1)**2
SET2(2) = 0.
IF (MTIME(I,2) .GT. 0.) SET2(2) = COEF2(I,1) + COEF2(I,2)*MTEMP(2) +
1 COEF2(I,3)*MTEMP(2)**2
SET2(3) = 0.
IF (MTIME(I,3) .GT. 0.) SET2(3) = COEF2(I,1) + COEF2(I,2)*MTEMP(3) +
1 COEF2(I,3)*MTEMP(3)**2
SIGP11(I) = (SET2(1) - LNT(I,1)) / (EXTFM(1) - MTEMP(1))
SIGP12(I) = (SFT2(1) - LNT(I,2)) / (EXTFM(2) - MTEMP(1))
SIGP13(I) = (SFT2(1) - LNT(I,3)) / (EXTFM(3) - MTEMP(1))
SIGP21(I) = (SFT2(2) - LNT(I,1)) / (EXTFM(1) - MTEMP(2))
SIGP22(I) = (SFT2(2) - LNT(I,2)) / (EXTFM(2) - MTEMP(2))
SIGP23(I) = (SFT2(2) - LNT(I,3)) / (EXTFM(3) - MTEMP(2))
SIGP31(I) = (SFT2(3) - LNT(I,1)) / (EXTFM(1) - MTEMP(3))
SIGP32(I) = (SFT2(3) - LNT(I,2)) / (EXTFM(2) - MTEMP(3))
SIGP33(I) = (SFT2(3) - LNT(I,3)) / (EXTFM(3) - MTEMP(3))

462 SIGP33(I) = (SET2(3) - LNT(I,3)) / (EXTFM(3) - MTEMP(3))
WRITE (6,2050)
WRITE (6,2051) PIK11, PIK21, PIK31, PIK12, PIK22, PIK32, PIK13,
1 PIK23, PIK33
WRITE (6,2052) SIGP11, SIGP21, SIGP31, SIGP12, SIGP22, SIGP32, SIGP13,
1 SIGP23, SIGP33

C COMPUTE P TT ANI) TIME TT TRANSF0RMATITIONS - SFLCTOR
C CHOOSES WHICH TEMPERATURE DATA IS TO BE TRANSFORMED TO
C
I1 = 1
I2 = 2
I3 = 3
480 DO 60 I = 1, N TIMES
J = COUNT(I)
DO 500 K = 1, J
IF (IFLAG1(I) .EQ. 1) GO TO 501
PI(I,1,K) = P(I,1,K) * EXP (PIK11(I)*(EXTFM(1) - TEMP(1,K)))
501 IF (IFLAG2(I) .EQ. 1) GO TO 502
TI(I,1,K) = TIME(I,1,K) / (EXP (SIGP11(I)*(EXTFM(1) - TEMP(1,K))))
502 CONTINUE
DO 504 K = 1, J
IF (IFLAG1(I) .EQ. 1) GO TO 503
P2(I,1,K) = P(I,2,K) * EXP (PIK21(I)*(EXTFM(1) - TEMP(2,K)))
503 IF (IFLAG2(I) .EQ. 1) GO TO 504
T2(I,1,K) = TIME(I,2,K) / (EXP (SIGP21(I)*(EXTFM(1) - TEMP(2,K))))
504 CONTINUE
DO 508 K = 1, J
IF (IFLAG1(I) .EQ. 1) GO TO 508
P3(I,1,K) = P(I,3,K) * EXP (PIK31(I)*(EXTFM(1) - TEMP(3,K)))
508 IF (IFLAG2(I) .EQ. 1) GO TO 510
T3(I,1,K) = TIME(I,3,K) / (EXP (SIGP31(I)*(EXTFM(1) - TEMP(3,K))))
510 CONTINUE
JSAVE = 1
GO TO 580
C
520 DO 530 I = 1, N TIMES
JJ = COUNT(2)
DO 522 K = 1, J1
IF (IFLAG1(I) .EQ. 1) GO TO 521
P1(I,J2K) = P(I,J1K) * EXP (PIK12(I)*(EXTFM(2)-TEMP(1,I,K)))
521 IF (IFLAG2(I) .EQ. 1) GO TO 522
T1(I,J2K) = TIME(I,J1K) / (EXP (SIGP12(I)*(EXTFM(2)- TEMP(1,I,K))))
522 CONTINUE
DO 524 K = 1, J2
IF (IFLAG1(I) .EQ. 1) GO TO 523
P2(I,J2K) = P(I,J2K) * EXP (PIK22(I)*(EXTFM(2)-TEMP(2,I,K)))
523 IF (IFLAG2(I) .EQ. 1) GO TO 524
T2(I,J2K) = TIME(I,J1K) / (EXP (SIGP22(I)*(EXTFM(2)- TEMP(2,I,K))))
524 CONTINUE
DO 530 K = 1, J3
IF (IFLAG1(I) .EQ. 1) GO TO 528
P3(I,J3K) = P(I,J3K) * EXP (PIK32(I)*(EXTFM(3)-TEMP(3,I,K)))
528 IF (IFLAG2(I) .EQ. 1) GO TO 530
T3(I,J3K) = TIME(I,J1K) / (EXP (SIGP32(I)*(EXTFM(2)- TEMP(3,I,K))))
530 CONTINUE
JSAVE = 2
GO TO 580
C
540 DO 550 I = 1, NTIMES
JJ = COUNT(3)
DO 542 K = 1, J1
IF (IFLAG1(I) .EQ. 1) GO TO 541
P1(I,J3K) = P(I,J1K) * EXP (PIK13(I)*(EXTFM(3)-TEMP(1,I,K)))
541 IF (IFLAG2(I) .EQ. 1) GO TO 542
T1(I,J3K) = TIME(I,J1K) / (EXP (SIGP13(I)*(EXTFM(3)- TEMP(1,I,K))))
542 CONTINUE
DO 544 K = 1, J2
IF (IFLAG1(I) .EQ. 1) GO TO 543
P2(I,J3K) = P(I,J2K) * EXP (PIK23(I)*(EXTFM(3)-TEMP(2,I,K)))
543 IF (IFLAG2(I) .EQ. 1) GO TO 544
T2(I,J3K) = TIME(I,J1K) / (EXP (SIGP23(I)*(EXTFM(3)- TEMP(2,I,K))))
544 CONTINUE
DO 548 K = 1, J3
IF (IFLAG1(I) .EQ. 1) GO TO 547
P3(I,J3K) = P(I,J3K) * EXP (PIK33(I)*(EXTFM(3)-TEMP(3,I,K)))
547 IF (IFLAG2(I) .EQ. 1) GO TO 548
T3(I,J3K) = TIME(I,J1K) / (EXP (SIGP33(I)*(EXTFM(3)- TEMP(3,I,K))))
548 CONTINUE
JSAVE = 3
GO TO 580
C
C COMPUTE STATISTICS FOR PTT AND TIME TT
C
580 J = JSAVE
DO 640 I = 1, NTIMES
L = 0
M = 0
DO 620 K = 1, J1
L = L + 1
M = M + 1
TENTRY(L) = P1(I,J2K)
TENT2(L) = T1(I,J2K)
SET1(M) = P1(I,J2K)
620 SET4(M) = T1(I,J2K)
M = 0
DO 625 K = 1, J2
L = L + 1
M = M + 1
TENTRY(L) = P2(I*,J*K)
TENT2(L) = T2(I*,J*K)
SET2(M) = P2(I*,J*K)

625 SETS(M) = T2(I*,J*K)
K = 0
GO 630 K = 1*J3
L = L + 1
M = M + 1
TENTRY(L) = P3(I*,J*K)
TENT2(L) = T3(I*,J*K)
SET3(M) = P3(I*,J*K)

630 CALL STATS (SET1, J1, MPT1(I*,J*), SUP1(I*,J*))
CALL STATS (SET2, J2, MPT2(I*,J*), SUP2(I*,J*))
CALL STATS (SET3, J3, MPT3(I*,J*), SUP3(I*,J*))
CALL STATS (SET4, J1, MTT1(I*,J*), SUT1(I*,J*))
CALL STATS (SET5, J2, MTT2(I*,J*), SUT2(I*,J*))
CALL STATS (SET6, J3, MTT3(I*,J*), SUT3(I*,J*))
CALL STATS (TENTRY(L), MPTT(I*,J*), SUPPT(I*,J*))
640 CALL STATS (TENT2, L, MTTT(I*,J*), SUTTT(I*,J*))
IF (IFMSEL .GE. NT) GO TO 655
TEMSELT = TEMSELT + 1
GO TO 4A00

C COMPUTE INTEGRALS OF P TRANSFORMED
C
655 DO 700 I = 1*NTIMES
670 J = 1*NT
L = 0
M = 0
700 660 K = 1*J1
INTPT1 (I*,J*K) = P1(I*,J*K) * T1(I*,J*K)
L = L + 1
M = M + 1
TENTRY(L) = INTPT1(I*,J*K)

660 SET1(M) = INTPT1(I*,J*K)
M = 0
700 670 K = 1*J2
L = L + 1
M = M + 1
INTPT2 (I*,J*K) = P2(I*,J*K) * T2(I*,J*K)
TENTRY(L) = INTPT2(I*,J*K)
670 SET2(M) = INTPT2(I*,J*K)
M = 0
700 680 K = 1*J3
L = L + 1
M = M + 1
INTPT3 (I*,J*K) = P3(I*,J*K) * T3(I*,J*K)
TENTRY(L) = INTPT3(I*,J*K)
680 SET3(M) = INTPT3(I*,J*K)

C COMPUTE STATS ON INTEGRALS OF P TRANSFORMED
C
CALL STATS (SET1, J1, MINT1(I*,J*), S0INT1(I*,J*))
CALL STATS (SET2, J2, MINT2(I*,J*), S0INT2(I*,J*))
CALL STATS (SET3, J3, MINT3(I*,J*), S0INT3(I*,J*))
700 CALL STATS (TENTRY(L), MINTT(I*,J*), S0INTT(I*,J*))
575 DO 565 I = 1*NTIMES
WRITE (6,2030) I
WRITE (6,A2047)
WRITE (6,2040) I!, (M0THO(I*1,K), T1(I*,1*K), T1(I*,2*K), T1(I*,3*K), 1)
84
WRITE (6,2064) (MTT(I,J), J=1:4), (SDTT(I,J), J=1:4)
IF (INT .LE. 1) GO TO 561
WRITE (6,2040)12, (MOTNO(2,K), T2(I,1,K), T2(I,2,K), T2(I,3,K),
1 BLANK, K = 1,J2)
WRITE (6,2064) (MTT2(I,J), J=1:4), (SDTT2(I,J), J=1:4)
IF (NT .LE. 2) GO TO 561
WRITE (6,2040)13, (MOTNO(3,K), T3(I,1,K), T3(I,2,K), T3(I,3,K),
1 BLANK, K = 1,J3)
WRITE (6,2064) (MTT3(I,J), J=1:4), (SDTT3(I,J), J=1:4)
561 WRITE (6,2065) (MTT(I,J), J=1:4), (SDTT(I,J), J=1:4)
DO 562 J = 1,NT
C1MIN(J) = MTTT(I,J) - CT1*SDTTT(I,J)
C1MAX(J) = MTTT(I,J) + CT1*SDTTT(I,J)
C2MIN(J) = MTTT(I,J) - CT2*SDTTT(I,J)
C2MAX(J) = MTTT(I,J) + CT2*SDTTT(I,J)
562 WRITE (6,2062) C1MIN, C1MAX, C2MIN, C2MAX
565 CONTINUE
DO 570 I = 1,NTIMES
WRITE (6,2031) I
WRITE (6,2042)
WRITE (6,2048)
WRITE (6,2041)11, (MOTNO(1,K), INPT1(I,1,K), INPT1(I,2,K),
1 INPT1(I,3,K), HLANK, P1(I,1,K), P1(I,2,K), P1(I,3,K),
2 BLANK, K = 1,J1)
WRITE (6,2066) (MINT1(I,J), J =1:4), (MPI1(I,J), J=1:4),
1 (SUINT1(I,J), J =1:4), (SDPT1(I,J), J=1:4)
IF (NT .LE. 1) GO TO 564
WRITE (6,2041)12, (MOTNO(2,K), INPT2(I,1,K), INPT2(I,2,K),
1 INPT2(I,3,K), HLANK, P2(I,1,K), P2(I,2,K), P2(I,3,K),
2 BLANK, K = 1,J2)
WRITE (6,2066) (MINT2(I,J), J =1:4), (MPI2(I,J), J=1:4),
1 (SUINT2(I,J), J =1:4), (SDPT2(I,J), J=1:4)
IF (NT .LE. 2) GO TO 564
WRITE (6,2041)13, (MOTNO(3,K), INPT3(I,1,K), INPT3(I,2,K),
1 INPT3(I,3,K), HLANK, P3(I,1,K), P3(I,2,K), P3(I,3,K),
2 BLANK, K = 1,J3)
WRITE (6,2066) (MINT3(I,J), J =1:4), (MPI3(I,J), J=1:4),
1 (SUINT3(I,J), J =1:4), (SDPT3(I,J), J=1:4)
564 WRITE (6,2067) (MINTT(I,J), J =1:4), (MPIIT(I,J), J=1:4),
1 (SUINTT(I,J), J =1:4), (SDPTT(I,J), J=1:4)
DO 566 J = 1,NT
C1MIN(J) = MINTT(I,J) - CT1*SDINTT(I,J)
C1MAX(J) = MINTT(I,J) + CT1*SDINTT(I,J)
C2MIN(J) = MINTT(I,J) - CT2*SDINTT(I,J)
C2MAX(J) = MINTT(I,J) + CT2*SDINTT(I,J)
566 WRITE (6,2068) C1MIN, C1TMX, C1MAX, C1TMX,
1 C2MIN, C2TMN, C2MAX, C2TMX
570 CONTINUE
RETURN
END
$\text{BACK GLS1}
\text{STOP}
\text{GO TO GLS1(A X IL N M ALPHAS E1 E2)}
L I M E N S I O N : A(46,4), X(4), IL(4).
M N = M + 1
L L = L L + 1
D O 6 0 J = 1, M M
6 0 I L ( J ) = 0
I = 1
D O 3 K = 1, M M
I I = I + 1
D O 4 J = I I, N
I F ( A P S ( A ( J , K ) ) = E 1 ) / 4 , 4 , 6
6 T 1 = S Q R T ( ( A ( J , K ) ) * * 2 + ( A ( I , K ) ) * * 2 )
S = A ( J , K ) / T 1
C = A ( I , K ) / T 1
D O 5 L = K , M M
T 2 = C * A ( I , L ) + 5 * A ( J , L )
A ( J , L ) = 5 * A ( I , L ) + C * A ( J , L )
5 A ( I , L ) = T 2
L L = L L + 1
4 C O N T I N U E
I F ( A S ( A ( I , K ) ) = E 2 ) / 3 , 3 , 8
8 I L ( K ) = 1
I = I + 1
3 C O N T I N U E
X ( M M ) = - 1 , N
I I = M
L O 3 5 I = 1 , M
3 5 X ( I ) = 0.
L O 3 0 J = 1 , M
I F ( I L ( I I ) ) 3 0 , 3 0 , 3 1
3 1 S = 0 .
L L = I + 1
I = I L ( I I )
L O 3 2 K = L L , M M
3 2 S = S + A ( I , K ) * X ( K )
X ( I I ) = S / A ( I , I I )
3 0 I I = I I - 1
I F ( I L ( M M ) ) 5 0 , 5 1 , 5 0
5 1 A L P H A = 0 .
G O T O 5 2
5 0 I = I L ( M M )
A L P H A = A ( I , M M )
5 2 R E T U R N
E N D
SECOND LINK OF MOTORS PROGRAM

DIMENSION XX(4860), ZZ(2124)
COMMON G, CPHI, NT, EXPA, COUNT, WP, WFB, ATTOT, AETOT,
1 P, MTONO, FVAC1, NTIMES, XX, NTOT, NBURN, NFHIST, NP
COMMON CP1, CP2, CT1, CT2, VEC1, VEC2, VEC3
COMMON SET1, SET2, SET3, SET4, SET5, SET6, SET7, CMIN, CMAX,
1 C2MIN, C2MAX, C1TMN, C1TMX, C2TMN, C2T MX
DIMENSION SAVE1(9,4,15), SAVE2(9,4,15), SAVE3(9,4,15)
DIMENSION MFT1(9,4), SDFT1(9,4), MIT1 (9,4), SDIT1(9,4),
1 MFT2(9,4), SDFT2(9,4), MIT2 (9,4), SDIT2(9,4),
2 MFT3(9,4), SDFT3(9,4), MIT3 (9,4), SDIT3(9,4),
3 MFT4(9,4), SDFT4(9,4), MIT4 (9,4), SDIT4(9,4),
4 MFT5(9,4), SDFT5(9,4), MIT5 (9,4), SDIT5(9,4),
5 MFT6(9,4), SDFT6(9,4), MIT6 (9,4), SDIT6(9,4),
6 MFT7(9,4), SDFT7(9,4), MIT7 (9,4), SDIT7(9,4),
7 MFT8(9,4), SDFT8(9,4), MIT8 (9,4), SDIT8(9,4),
DIMENSION MIS1(9,4), SDIS1(9,4), MIS2(9,4), SDIS2(9,4),
3 MIS3(9,4), SDIS3(9,4), MIS4(9,4), SDIS4(9,4),
5 MIS5(9,4), SDIS5(9,4), MIS6(9,4), SDIS6(9,4),
6 MIS7(9,4), SDIS7(9,4), MIS8(9,4), SDIS8(9,4),
7 MIS9(9,4), SDIS9(9,4), MIS10(9,4), SDIS10(9,4),
8 MIS11(9,4), SDIS11(9,4), MIS12(9,4), SDIS12(9,4),
DIMENSION FT1(9,4,15), FT2(9,4,15), FT3(9,4,15), FT4(9,4,15), FT5(9,4,15), FT6(9,4,15),
7 FT7(9,4,15), FT8(9,4,15), FT9(9,4,15), FT10(9,4,15), FT11(9,4,15), FT12(9,4,15),
8 FT13(9,4,15), FT14(9,4,15), FT15(9,4,15), FT16(9,4,15), FT17(9,4,15), FT18(9,4,15),
9 FT19(9,4,15), FT20(9,4,15), FT21(9,4,15), FT22(9,4,15), FT23(9,4,15), FT24(9,4,15),
10 FT25(9,4,15), FT26(9,4,15), FT27(9,4,15), FT28(9,4,15), FT29(9,4,15), FT30(9,4,15),
DIMENSION RATIO1(9,4,15), RATIO2(9,4,15), RATIO3(9,4,15),
1 RATIO4(9,4,15), RATIO5(9,4,15), RATIO6(9,4,15), RATIO7(9,4,15), RATIO8(9,4,15),
2 RATIO9(9,4,15), RATIO10(9,4,15), RATIO11(9,4,15), RATIO12(9,4,15),
DIMENSION P1(9,4,15), P2(9,4,15), P3(9,4,15), P4(9,4,15),
5 P5(9,4,15), P6(9,4,15), P7(9,4,15), P8(9,4,15), P9(9,4,15), P10(9,4,15),
6 P11(9,4,15), P12(9,4,15), P13(9,4,15), P14(9,4,15), P15(9,4,15), P16(9,4,15),
7 P17(9,4,15), P18(9,4,15), P19(9,4,15), P20(9,4,15), P21(9,4,15), P22(9,4,15),
8 P23(9,4,15), P24(9,4,15), P25(9,4,15), P26(9,4,15), P27(9,4,15), P28(9,4,15),
9 P29(9,4,15), P30(9,4,15), P31(9,4,15), P32(9,4,15), P33(9,4,15), P34(9,4,15),
0 P35(9,4,15), P36(9,4,15), P37(9,4,15), P38(9,4,15), P39(9,4,15), P40(9,4,15),
1 P41(9,4,15), P42(9,4,15), P43(9,4,15), P44(9,4,15), P45(9,4,15), P46(9,4,15),
2 P47(9,4,15), P48(9,4,15), P49(9,4,15), P50(9,4,15), P51(9,4,15), P52(9,4,15),
3 P53(9,4,15), P54(9,4,15), P55(9,4,15), P56(9,4,15), P57(9,4,15), P58(9,4,15),
4 P59(9,4,15), P60(9,4,15), P61(9,4,15), P62(9,4,15), P63(9,4,15), P64(9,4,15),
5 P65(9,4,15), P66(9,4,15), P67(9,4,15), P68(9,4,15), P69(9,4,15), P70(9,4,15),
6 P71(9,4,15), P72(9,4,15), P73(9,4,15), P74(9,4,15), P75(9,4,15), P76(9,4,15),
7 P77(9,4,15), P78(9,4,15), P79(9,4,15), P80(9,4,15), P81(9,4,15), P82(9,4,15),
8 P83(9,4,15), P84(9,4,15), P85(9,4,15), P86(9,4,15), P87(9,4,15), P88(9,4,15),
9 P89(9,4,15), P90(9,4,15), P91(9,4,15), P92(9,4,15), P93(9,4,15), P94(9,4,15),
0 P95(9,4,15), P96(9,4,15), P97(9,4,15), P98(9,4,15), P99(9,4,15), P100(9,4,15),
\begin{verbatim}
5 (XX(2161), T2(1), IT21(1), IT22(1), ISP21(1), ISP22(1)),
6 (XX(2701), T3(1), IT31(1), IT32(1), ISP31(1), ISP32(1)),
7 (XX(3241), INTPT1(1)),
8 (XX(3781), INTPT2(1)),
9 (XX(4321), INTPT3(1))
EQUIVALENCE
1 (ZZ( 1), MFT11(1), MFT12(1), MFT13(1), MFT14(1), MWP1 (1)),
2 (ZZ( 37), MFT21(1), MFT22(1), MFT23(1), MFT24(1), MWP2 (1)),
3 (ZZ( 73), MFT31(1), MFT32(1), MFT33(1), MFT34(1), MWP3 (1)),
4 (ZZ(109), MIT11(1), MIT12(1), MIS11(1), MIS12(1)),
5 (ZZ(145), MIT21(1), MIT22(1), MIS21(1), MIS22(1)),
6 (ZZ(181), MIT31(1), MIT32(1), MIS31(1), MIS32(1))
EQUIVALENCE
1 (ZZ(217), SNFT11(1), SNFT12(1), SNFT13(1), SNFT14(1), SNWP1 (1)),
2 (ZZ(253), SNFT21(1), SNFT22(1), SNFT23(1), SNFT24(1), SNWP2 (1)),
3 (ZZ(289), SNFT31(1), SNFT32(1), SNFT33(1), SNFT34(1), SNWP3 (1)),
4 (ZZ(325), SDIT11(1), SDIT12(1), SDIS11(1), SDIS12(1)),
5 (ZZ(361), SDIT21(1), SDIT22(1), SDIS21(1), SDIS22(1)),
6 (ZZ(397), SDIT31(1), SDIT32(1), SDIS31(1), SDIS32(1))
EQUIVALENCE
1 (ZZ(433), MFTT11(1), MFTT12(1), MFTT13(1), MFTT4(1)),
2 (ZZ(469), SDFTT11(1), SDFTT21(1), SDFTT31(1), SDFTT4(1)),
3 (ZZ(505), FT11(1), FT12(1), FT13(1), FT14(1)),
4 (ZZ(545), FT21(1), FT22(1), FT23(1), FT24(1)),
5 (ZZ(585), FT31(1), FT32(1), FT33(1), FT34(1))
C
OUTPUT FORMATS
C
2014 FORMAT ( 34X, 5H PA = F5.2)
2032 FORMAT (1H1, 30X, 20H TRANSFORMED THKUST / 9H TIME NO.12)
2033 FORMAT (1H1, 30X, 20H TRANSFORMED IMPULSE / 9H TIME NO.12)
2034 FORMAT (1H1, 30X, 30H TRANSFORMED SPECIFIC IMPULSE / 9H TIME NO.12)
2037 FORMAT (1H1, 30X, 29H TRANSFORMED PROPellant WT. / 9H TIME NO.12)
2041 FORMAT (11H0TEMP GROUP I2 // (1X1A6V, 19X, 4F12.2))
2047 FORMAT ( 30X, 43H TEMP1 TEMP2 TEMP3 TEMP4 / 10H MOTOR NO.)
2062 FORMAT (34HCONFIDENCE ON NORMAL DISTRIBUTION /
1 26H ONE MIN 4F12.2 /
2 26H SAME MAX 4F12.2 /
3 26H TWO MIN 4F12.2 /
4 26H SAME MAX 4F12.2 )
2064 FORMAT (26HMEAN 4F12.2 /
1 26H STANDARD DEV. 4F12.2 )
2065 FORMAT (26HTOTAL MEAN 4F12.2 /
1 26H TOTAL STANDARD DEV. 4F12.2 )
C
I1 = 1
I2 = 2
I3 = 3
HBLANK = 0,
J1 = COUNT(1)
J2 = COUNT(2)
J3 = COUNT(3)
DO 696 1 = 1,504
696 ZZ(1) = 0,
CIMIN(4) = 0,
CIMAX(4) = 0,
C2MIN(4) = 0,
C2MAX(4) = 0,
LO 701 J = 1,NT
DO 697 K = 1,J1
697 VEC(J,K) = T1NJURN,J,K)
\end{verbatim}
DO 708 K = 1, J2
    L = L + 1
    M = M + 1
    RATIO2(I, J, K) = P2(I, J, K) / P(I, 2, K)
    FT21(I, J, K) = RATIO2(I, J, K) * FVAC1(I, 2, K) - EXP(1) * AETOT(2, K) * CPHI
    IT21(I, J, K) = FT21(I, J, K) * T2(I, J, K)
    TENTRY(L) = FT21(I, J, K)
    TENT2(L) = IT21(I, J, K)
    SET2(M) = FT21(I, J, K)
708 SET5(M) = IT21(I, J, K)
    M = 0
    DO 710 K = 1, J3
        L = L + 1
        M = M + 1
        RATIO3(I, J, K) = P3(I, J, K) / P(I, 3, K)
        FT31(I, J, K) = RATIO3(I, J, K) * FVAC1(I, 3, K) - EXP(1) * AETOT(3, K) * CPHI
        IT31(I, J, K) = FT31(I, J, K) * T3(I, J, K)
        TENTRY(L) = FT31(I, J, K)
        TENT2(L) = IT31(I, J, K)
        SET3(M) = FT31(I, J, K)
710 SET6(M) = IT31(I, J, K)
    CALL STATS(SET1, J1, MFT11(I, J), SDFT11(I, J))
    CALL STATS(SET4, J1, MIT11(I, J), SDIT11(I, J))
    CALL STATS(SET2, J2, MFT21(I, J), SDFT21(I, J))
    CALL STATS(SET5, J2, MIT21(I, J), SDIT21(I, J))
    CALL STATS(SET3, J3, MFT31(I, J), SDFT31(I, J))
    CALL STATS(SET6, J3, MIT31(I, J), SDIT31(I, J))
    CALL STATS(TENTRY, L, MFTT11(I, J), SDFTT11(I, J))
    CALL STATS(TENT2, L, MITT1(I, J), SDITT1(I, J))
752 CONTINUE
C
C PRINT THRUST, IMPULSE AND STATS FOR P1
C
DO 1710 I = 1, NTIMES
    WRITE (6, 2032) I
    WRITE (6, 2041) EXP(1)
    WRITE (6, 2047)
    WRITE (6, 2041) I, (MOTNO(I, J, K), FT11(I, 1, K), FT11(I, 2, K),
WRITE (6,2041) I2, (MOTNO(I2,K), FT21(I2,K), FT21(I2,K),
1
WRITE (6,2041) I3, (MOTNO(I3,K), FT31(I3,K), FT31(I3,K),
1
WRITE (6,2041) I4, (MOTNO(I4,K), FT41(I4,K), FT41(I4,K),
1
C2MIN(J) = MFTT1(I3,J) - CT2*SDFTT1(I3,J)
C2MAX(J) = MFTT1(I3,J) + CT2*SDFTT1(I3,J)
WRITE (6,2042) C1MIN, C1MAX, C2MIN, C2MAX
1710 CONTINUE
DO 1712 I = 1,NT
C1MIN(J) = MFTT1(I,J) - CT1*SDFTT1(I,J)
C1MAX(J) = MFTT1(I,J) + CT1*SDFTT1(I,J)
WRITE (6,2041) I1, (MOTNO(I1,K), IT11(I1,K), IT11(I1,K),
1
WRITE (6,2041) I2, (MOTNO(I2,K), IT21(I2,K), IT21(I2,K),
1
WRITE (6,2041) I3, (MOTNO(I3,K), IT31(I3,K), IT31(I3,K),
1
WRITE (6,2041) I4, (MOTNO(I4,K), IT41(I4,K), IT41(I4,K),
1
C2MIN(J) = MFTT1(I3,J) - CT2*SDFTT1(I3,J)
C2MAX(J) = MFTT1(I3,J) + CT2*SDFTT1(I3,J)
WRITE (6,2042) C1MIN, C1MAX, C2MIN, C2MAX
1712 CONTINUE
C
C COMPUTE TRANSFORMER PROPELLANT WEIGHT, SPECIFIC IMPULSE
C FOR P1 AND THEIR STATISTICS
C
DO 802 I = 1,NT
DO 802 J = 1,NT
L = 0
M = 0
DO 804 K = 1,1
L = L + 1
M = M + 1
WPI(I,J,K) = WP(I,K) * INTPT1(I,J,K) / INTPT1(NT0,I,J,K)
ISP11(I,J,K) = IT11(I,J,K) / WP(I,J,K)
SAVE1(I,J,K) = ISP11(I,J,K)
TENT1(L) = ISP11(I,J,K)
TENTK(L)=WPI(I,J,K)
SET4(M) = WPI(I,J,K)
804 SET1 (M) = ISP11(I,J,K)
M = 0
DO 806 K = 1,1
L = L + 1
M = M + 1
WP(I,J,K) = WP(2,J,K) * INTPT2(I,J,K) / INTPT2(NTOT,J,K)
ISP2(I,J,K) = IT21(I,J,K) / WP2(I,J,K)
SAVE2(I,J,K) = ISP2(I,J,K)
TENT2(L) = ISP21(I,J,K)
TENTRY2(L) = WP2(I,J,K)
SET5(M) = WP2(I,J,K)

806 SET (M) = ISP21(I,J,K)
M = 0
DO 808 K = 1, J3
L = L + 1
M = M + 1
WP3(I,J,K) = WP(3,K) * INTPT3(I,J,K) / INTPT3(NTOT,J,K)
ISP3(I,J,K) = IT31(I,J,K) / WP3(I,J,K)
SAVE3(I,J,K) = ISP3(I,J,K)
TENT3(L) = ISP31(I,J,K)
TENTRY3(L) = WP3(I,J,K)
SET6(M) = WP3(I,J,K)

808 SET3 (M) = ISP31(I,J,K)
CALL STATS (SET1, J1, MIS11(I,J), SDIS11(I,J)).
CALL STATS (SET2, J2, MIS21(I,J), SDIS21(I,J)).
CALL STATS (SET3, J3, MIS31(I,J), SDIS31(I,J)).
CALL STATS (SET4, J1, MWP1(I,J), SDWP1(I,J)).
CALL STATS (SET5, J2, MWP2(I,J), SDWP2(I,J)).
CALL STATS (SET6, J3, MWP3(I,J), SDWP3(I,J)).
CALL STATS (TENT2, L, MIS11(I,J), SDIST1(I,J)).
CALL STATS (TENTRY3, L, MWPT(I,J), SDWP(I,J)).

882 CONTINUE

C
PRINT PROPELLANT WT. AND SPECIFIC IMPULSE FOR P1
C
DO 812 I = 1, NTIMES
WRITE (6, 2037) I
WRITE (6, 2047)
WRITE (6, 2041) I1, (MOTNO(I1,K), WP1(I1,K), WP1(I1,K))
1
WRITE (6, 2064) (MWP1(I,J), J=1,4), (SDWP1(I,J), J=1,4)
IF (NT .LE. 1) GO TO 810
WRITE (6, 2041) I2, (MOTNO(I2,K), WP2(I2,K), WP2(I2,K))
1
WRITE (6, 2064) (MWP2(I,J), J=1,4), (SDWP2(I,J), J=1,4)
IF (NT .LE. 2) GO TO 810
WRITE (6, 2041) I3, (MOTNO(I3,K), WP3(I3,K), WP3(I3,K))
1
WRITE (6, 2064) (MWP3(I,J), J=1,4), (SDWP3(I,J), J=1,4)

810 WRITE (6, 2065) (MWPT(I,J), J=1,4), (SDWP(T,I,J), J=1,4)
DO 811 J = 1, NT
CIMIN(J) = MWPT(I,J) - CT*SDWP(I,J)
CIMAX(J) = MWPT(I,J) + CT*SDWP(I,J)
C2MIN(J) = MWPT(I,J) + CT2*SDWP(I,J)
C2MAX(J) = MWPT(I,J) - CT2*SDWP(I,J)

811 CONTINUE
DO 812 I = 1, NTIMES
WRITE (6, 2034) I
WRITE (6, 2047)
WRITE (6, 2041) I1, (MOTNO(I1,K), ISP11(I1,K), ISP11(I1,K))
1
WRITE (6, 2064) (MISP11(I,J), J=1,4), (SDISP11(I,J), J=1,4)
IF (NT .LE. 1) GO TO 810
WRITE (6, 2041) I2, (MISP11(I2,K), ISP11(I2,K), ISP11(I2,K))
1
DO 1775 I = 1, NTIMES
WRITE (6, 2034) I
WRITE (6, 2047)
WRITE (6, 2041) I1, (MISP11(I1,K), ISP11(I1,K), ISP11(I1,K))
1
WRITE (6, 2064) (MISP11(I,J), J=1,4), (SDISP11(I,J), J=1,4)
IF (NT .LE. 1) GO TO 1773
WRITE (6, 2041) I2, (MISP11(I2,K), ISP11(I2,K), ISP11(I2,K)),
91
ISP21(I,J,K), BLANK, K = 1,J2)
WRITE (6,E2064) (MIS21(I,J), J=1,4), (SDIS21(I,J), J=1,4)
IF (NT .LE. 2) GO TO 1773
WRITE (6,E2041)I3,(MOTNO(I3,K), ISP31(I,J,K)
ISP31(I,J,K), BLANK, K = 1,J3)
WRITE (6,E2064) (MIS31(I,J), J=1,4), (SDIS31(I,J), J=1,4)
1773 WRITE (6,E2065) (MIST1(I,J), J=1,4), (SDIST1(I,J), J=1,4)
DO 1774 J = 1,NT
C1MIN(J) = MIST1(I,J) - CT1*SDIST1(I,J)
C1MAX(J) = MIST1(I,J) + CT1*SDIST1(I,J)
C2MIN(J) = MIST1(I,J) - CT2*SDIST1(I,J)
C2MAX(J) = MIST1(I,J) + CT2*SDIST1(I,J)
1774 CONTINUE:
IF (NP .LE. 1) GO TO 835
C
COMPUTE THRUST AND IMPULSE FOR P2 AND THEIR STATISTICS
D0 1785 N = 2, NP
D0 767 I = 1,N
D0 767 J = 1,NT
L = 0
M = 0
D0 712 K = 1,J1
L = L + 1
M = M + 1
SAVE = FT11(I,J,K)
FT12(I,J,K) = RATIO1(I,J,K)*FVAC1(I,J,K)-EXPA(I,J,K)*AETOT(I,K)*CPHI
IT12(I,J,K) = SAVE1(I,J,K)*WP1(I,J,K)*FT12(I,J,K)/SAVE
TENTRY(L) = FT12(I,J,K)
TENT2(L) = IT12(I,J,K)
SET1 (M) = FT12(I,J,K)
712 SET4 (M) = IT12(I,J,K)
M = 0
D0 715 J = 1,J2
L = L + 1
M = M + 1
SAVE = FT22(I,J,K)
FT22(I,J,K) = RATIO2(I,J,K)*FVAC1(I,J,K)-EXPA(I,J,K)*AETOT(I,K)*CPHI
IT22(I,J,K) = SAVE2(I,J,K)*WP2(I,J,K)*FT22(I,J,K)/SAVE
TENTRY(L) = FT22(I,J,K)
TENT2(L) = IT22(I,J,K)
SET2 (M) = FT22(I,J,K)
715 SET5 (M) = IT22(I,J,K)
M = 0
D0 718 K = 1,J3
L = L + 1
M = M + 1
SAVE = FT32(I,J,K)
FT32(I,J,K) = RATIO3(I,J,K)*FVAC1(I,J,K)-EXPA(I,J,K)*AETOT(I,K)*CPHI
IT32(I,J,K) = SAVE3(I,J,K)*WP3(I,J,K)*FT32(I,J,K)/SAVE
TENTRY(L) = FT32(I,J,K)
TENT2(L) = IT32(I,J,K)
SET3 (M) = FT32(I,J,K)
718 SET6 (M) = IT32(I,J,K)
CALL STATS (SET1, J1, MFT12(I,J), SDFT12(I,J))
CALL STATS (SET4, J1, MFT12(I,J), SDFT12(I,J))
CALL STATS (SET2, J2, MFT22(I,J), SDFT22(I,J))
CALL STATS (SET5, J2, MFT23(I,J), SDFT23(I,J))
CALL STATS (SET3, J3, MFT32(I,J), SDFT32(I,J))
CALL STATS (SET6, J3, MFT32(I,J), SDFT32(I,J))
CALL STATS (TENTRY*L, MFTT2(I,J), SDFTT2(I,J))
CALL STATS (TENT2(I,J), MITT2(I,J), SDT2(I,J))

CONTINUE

PRINT THRUST, IMPULSE AND STATS FOR P2

DO 1710 I = 1, NTIMES
    WRITE (6, 2032) I
    WRITE (6, 2014) EXPAN(N)
    WRITE (6, 2047)
    WRITE (6, 2041) IT(i, (MTNO(I1,K), FT12(I,1,K), FT12(I,2,K),
    1 FT12(I,3,K), PLANK, K=1,J1)
    WRITE (6, 2064) (MFT2(I,J), J = 1,NT), (SUFT2(I,J), J = 1,NT)
    IF (NT .LE. 1) GO TO 1716
    WRITE (6, 2041) I2, (MTNO(I2,K), FT22(I,1,K), FT22(I,2,K),
    1 FT22(I,3,K), PLANK, K=1,J2)
    WRITE (6, 2064) (MFT2(I,J), J = 1,NT), (SUFT2(I,J), J = 1,NT)
    IF (NT .LE. 2) GO TO 1716
    WRITE (6, 2041) I3, (MTNO(I3,K), FT32(I,1,K), FT32(I,2,K),
    1 FT32(I,3,K), PLANK, K=1,J3)
1710 CONTINUE

DO 1720 I = 1, NTIMES
    WRITE (6, 2033) I
    WRITE (6, 2014) EXPAN(N)
    WRITE (6, 2047)
    WRITE (6, 2041) IT(i, (MTNO(I1,K), IT12(I,1,K), IT12(I,2,K),
    1 IT12(I,3,K), PLANK, K=1,J1)
    WRITE (6, 2064) (MIT2(I,J), J = 1,NT), (SUIT2(I,J), J = 1,NT)
    IF (NT .LE. 1) GO TO 1715
    WRITE (6, 2041) I2, (MTNO(I2,K), IT22(I,1,K), IT22(I,2,K),
    1 IT22(I,3,K), PLANK, K=1,J2)
    WRITE (6, 2064) (MIT2(I,J), J = 1,NT), (SUIT2(I,J), J = 1,NT)
    IF (NT .LE. 2) GO TO 1715
    WRITE (6, 2041) I3, (MTNO(I3,K), IT32(I,1,K), IT32(I,2,K),
    1 IT32(I,3,K), PLANK, K=1,J3)
1720 CONTINUE

DO 1719 J = 1, NT
    C1MIN(J) = MITT2(I,J) - C1*SDT2(I,J)
    C1MAX(J) = MITT2(I,J) + C1*SDT2(I,J)
    C2MIN(J) = MITT2(I,J) - C2*SDT2(I,J)
    C2MAX(J) = MITT2(I,J) + C2*SDT2(I,J)
1719 CONTINUE

CONTINUE

DO 1810 K = 1, J1
    L = L + 1
    M = M + 1
    ISP12(I,J,K) = IT12(I,J,K) / WP1(I,J,K)
SAVE1(I,J,K) = ISP12(I,J,K)
TENT2(L) = ISP12(I,J,K)

1810 SET1 (M) = ISP12(I,J,K)
M = 0
DO 1813 K = 1,J3
L = L + 1
M = M + 1
ISP22(I,J,K) = IT22(I,J,K) / WP2(I,J,K)
SAVE2(I,J,K) = ISP22(I,J,K)
TENT2(L) = ISP22(I,J,K)

1813 SET2 (M) = ISP22(I,J,K)
M = 0
DO 1814 K = 1,J3
L = L + 1
M = M + 1
ISP32(I,J,K) = IT32(I,J,K) / WP3(I,J,K)
SAVE3(I,J,K) = ISP32(I,J,K)
TENT2(L) = ISP32(I,J,K)

1814 SET3 (M) = ISP32(I,J,K)
CALL STATS (SET1, J1, MIS12(I,J), SDIST12(I,J))
CALL STATS (SET2, J2, MIS22(I,J), SDIST22(I,J))
CALL STATS (SET3, J3, MIS32(I,J), SDIST32(I,J))
CALL STATS (TENT2, L, MIST2(I,J), SDIST2(I,J))

897 CONTINUE

PRINT SPECIFIC IMPULSE FOR P2

DO 1780 I = 1,NTIMES
WRITE (6,2034) I
WRITE (6,2014) EXPA(N)
WRITE (6,2047)
WRITE (6,2041)I1, (MOTNO(I1,K), ISP12(I1,K), ISP12(I1,K),
1 ISP12(I1,K), PLANK, K = 1,J1)
WRITE (6,2064) (MIS12(I,J), J = 1,J4), (SDIST12(I,J), J = 1,J4)
IF (NT .LE. 1) GO TO 177A
WRITE (6,2041)I2, (MOTNO(I2,K), ISP22(I2,K), ISP22(I2,K),
1 ISP22(I2,K), PLANK, K = 1,J2)
WRITE (6,2064) (MIS22(I,J), J = 1,J4), (SDIST22(I,J), J = 1,J4)
IF (NT .LE. 2) GO TO 177A
WRITE (6,2041)I3, (MOTNO(I3,K), ISP32(I3,K), ISP32(I3,K),
1 ISP32(I3,K), PLANK, K = 1,J3)
WRITE (6,2064) (MIS32(I,J), J = 1,J4), (SDIST32(I,J), J = 1,J4)

1778 WRITE (6,2065) (MIST2(I,J), J = 1,J4), (SDIST2(I,J), J = 1,J4)
DO 1779 J = 1,NT
C1MIN(J) = MIST2(I,J) - CT1*SDIST2(I,J)
C1MAX(J) = MIST2(I,J) + CT1*SDIST2(I,J)
C2MIN(J) = MIST2(I,J) - CT2*SDIST2(I,J)
C2MAX(J) = MIST2(I,J) + CT2*SDIST2(I,J)
WRITE (6,2062) C1MIN, C1MAX, C2MIN, C2MAX

1780 CONTINUE
IF (NP .LE. 2) GO TO 835

1785 CONTINUE
RETURN
END
SIBFTC MOT3
SUBROUTINE MOT3
DIMENSION XX(4860)
COMMON G, CPHI, NT, EXPA, COUNT, WP, WER, ATTOT, AETOT,
1 P, MOTNO, FVAC1, NTIMES, XX, NTOT, NBURN, NFIRST, NP
COMMON CP1, CP2, CT1, CT2, VEC1, VEC2, VEC3
DIMENSION WP1 (9,4,15), WP2 (9,4,15), WP3 (9,4,15)
DIMENSION CST1 (9,4,15), CST2 (9,4,15), CST3 (9,4,15)
1 FVAC1 (9,4,15), INTPT1 (9,4,15), INTPT2 (9,4,15), INTPT3 (9,4,15)
2 P (9,4,15), ATTOT (4,15), AETOT (4,15), WP (4,15)
3 WEB (4,15), VEC1 (4,15), VEC2 (4,15), VEC3 (4,15)
4 R1 (4,15), R2 (4,15), R3 (4,15), MOTNO (4,15)
DIMENSION EXPA (4), C1MIN (4), C1MAX (4), C2MIN (4), C2MAX (4)
1 C1TMN (4), C1TMT (4), C2TMN (4), C2TMT (4), SET1 (15), SET2 (15)
2 SET3 (15), TENTRY (60), TENT2 (60), MH1 (4), MR2 (4), MR3 (4)
3 MRT (4), SD1 (4), SD2 (4), SD3 (4), SDRT (4), COUNT (4)
DIMENSION MCST1 (9,4), MCST2 (9,4), MCST3 (9,4), MCSTT (9,4)
1 SD1CST1 (9,4), SD2CST2 (9,4), SD3CST3 (9,4), SD4CSTT (9,4)
EQUALITY
1 (XX (1), WP1 (1), CST1 (1)),
2 (XX (541), WP2 (1), CST2 (1)),
3 (XX (1081), WP3 (1), CST3 (1)),
4 (XX (3241), INTPT1 (1)),
5 (XX (3781), INTPT2 (1)),
6 (XX (4231), INTPT3 (1))
REAL
1 MRT, MCST1, MCST2, MCST3, MCSTT, MR1, MR2, MR3
2 MOTNO, INTPT1, INTPT2, INTPT3
INTEGER COUNT
C
C OUTPUT FORMATS
2035 FORMAT (1H1, 30X, 36H TRANSFORMED CHARACTERISTIC VELOCITY /
1 9H TIME NO.12)
2036 FORMAT (1H1, 30X, 36H TRANSFORMED CHARACTERISTIC VELOCITY, 14X,
1 33H TRANSFORMED AVERAGE BURNING RATE /
2 9H TIME NO.12, 70X, 10H BASED ON WFB TIME )
2040 FORMAT (11H TEMP GROUP 12 // (1X, A6, 19X, 4F10.2, 10X, 4F10.4))
2041 FORMAT (11H TEMP GROUP 12 // (1X, A6, 19X, 4F10.2))
2047 FORMAT (29X, 36H TEMP1 TEMP2 TEMP3 TEMP4 /
1 10H MOTOR NO.)
2048 FORMAT (29X, 36H TEMP1 TEMP2 TEMP3 TEMP4, 17X,
1 36H TEMP1 TEMP2 TEMP3 TEMP4 /
2 10H MOTOR NO.)
2062 FORMAT (34H CONFIDENCE ON NORMAL DISTRIBUTION /
1 26H (ONE MIN 4F10.2 /
2 26H SIDED MAX 4F10.2 /
3 26H (TWO MIN 4F10.2 /
4 26H SIDED MAX 4F10.2 )
2064 FORMAT (26H MEAN /
1 26H STANDARD DEV.
2 26H TOTAL MEAN /
3 26H TOTAL STANDARD DEV.
4 26H TOTAL STANDARD DEV. /
5 26H TOTAL STANDARD DEV.
6 26H TOTAL STANDARD DEV. )
2068 FORMAT (34H CONFIDENCE ON NORMAL DISTRIBUTION /
1 26H (ONE MIN 4F10.2 /
2 26H SIDED MAX 4F10.2 /
3 26H (TWO MIN 4F10.2 /
4 26H SIDED MAX 4F10.2 /

95
C
I1 = 1
I2 = 2
I3 = 3
J1 = COUNT(1)
J2 = COUNT(2)
J3 = COUNT(3)
SDR1(I) = 0.
MCSTT(5*4) = 0.
BLANK = 0.
C
COMPUTE R TRANSFORMED AND ITS STATISTICS
C
DO 1050 J = 1*NT
L = 0
M = 0
DO 1010 K = 1*J1
L = L + 1
M = M + 1
R1(J,K) = WEB(1,K) / VEC1(J,K)
TENT2(L) = R1(J,K)
1010 SET1 (M) = R1(J,K)
M = 0
DO 1015 K = 1*J2
L = L + 1
M = M + 1
R2(J,K) = WEB(2,K) / VEC2(J,K)
TENT2(L) = R2(J,K)
1015 SET2 (M) = R2(J,K)
M = 0
DO 1020 K = 1*J3
L = L + 1
M = M + 1
R3(J,K) = WEB(3,K) / VEC3(J,K)
TENT2(L) = R3(J,K)
1020 SET3 (M) = R3(J,K)
CALL STATS (SET1, J1, MR1(J), SDR1(J))
CALL STATS (SET2, J2, MR2(J), SDR2(J))
CALL STATS (SET3, J3, MR3(J), SDR3(J))
CALL STATS (TENT2, L, MRT(J), SDR(J))
1050 CONTINUE
C
COMPUTE C-STAR AND ITS STATISTICS
C
DO 1000 I = NBURN, NTOT
DO 1000 J = 1*NT
L = 0
M = 0
DO 950 K = 1*J1
L = L + 1
M = M + 1
CST1(I,J,K) = INTPT1(NTOT,J,K) * G * ATTOT(1,K) / WP(1,K)
TENT2(L) = CST1(I,J,K)
950 SET1 (M) = CST1(I,J,K)
M = 0
DO 955 K = 1*J2
L = L + 1
M = M + 1
CST2(I,J,K) = INTPT2(NTOT,J,K) * G * ATTOT(2,K) / WP(2,K)
TENT2(L) = CST2(I,J,K)
955 SET2 (M) = CST2(I,J,K)
M = 0
DO 960 K = 1, J3
L = L + 1
M = M + 1
CST3(I, J, K) = INTPT3(NTOT, J, K) * 6 * ATTOT(3, K) / WP(3, K)
TENT2(L) = CST3(I, J, K)
960 SET3(M) = CST3(I, J, K)
CALL STATS (SET1, J1, MCST1(I, J), SDCST1(I, J))
CALL STATS (SET2, J2, MCST2(I, J), SDCST2(I, J))
CALL STATS (SET3, J3, MCST3(I, J), SDCST3(I, J))
CALL STATS (TENT2, L, MCSTT(I, J), SDCSTT(I, J))
1000 CONTINUE
DO 1795 I = NBURN, NTOT
DO 1785 J = 1, NT
C1MIN(J) = MCSTT(I, J) - CT1*SDCSTT(I, J)
C1MAX(J) = MCSTT(I, J) + CT1*SDCSTT(I, J)
C2MIN(J) = MCSTT(I, J) - CT2*SDCSTT(I, J)
C2MAX(J) = MCSTT(I, J) + CT2*SDCSTT(I, J)
1785 CMAX(J) = MCSTT(I, J) + CT2*SDCSTT(I, J)
IF (I.EQ. NBURN) GO TO 1786
WRITE (6, 2035) I
WRITE (6, 2047) 60 TO 1786
1786 WRITE (6, 2036) I
WRITE (6, 2048)
1788 IF (I.EQ. NBURN) GO TO 1791
WRITE (6, 2041) I1, (MOTNO(I1, K), CST1(I1, K), CST1(I2, K),
1 CST1(I3, K), BLANK, K = 1, J1)
WRITE (6, 2064) (MCST1(I, J), J = 1, 4), (SDCST1(I, J), J = 1, 4)
WRITE (6, 2041) I2, (MOTNO(I2, K), CST2(I1, K), CST2(I2, K),
1 CST2(I3, K), BLANK, K = 1, J2)
WRITE (6, 2064) (MCST2(I, J), J = 1, 4), (SDCST2(I, J), J = 1, 4)
WRITE (6, 2041) I3, (MOTNO(I3, K), CST3(I1, K), CST3(I2, K),
1 CST3(I3, K), BLANK, K = 1, J3)
WRITE (6, 2064) (MCST3(I, J), J = 1, 4), (SDCST3(I, J), J = 1, 4)
WRITE (6, 2065) (MCSTT(I, J), J = 1, 4), (SDCSTT(I, J), J = 1, 4)
WRITE (6, 2062) C1MIN, C1MAX, C2MIN, C2MAX
GO TO 1795
1791 WRITE (6, 2040) I1, (MOTNO(I1, K), CST1(I1, K), CST1(I2, K),
1 CST1(I3, K), 1 K), BLANK, R1(I1, K), R1(2, K), R1(3, K), BLANK, K = 1, J1)
WRITE (6, 2066) (MCST1(I, J), J = 1, 4), MR1, (SDCST1(I, J), J = 1, 4), SMR1
WRITE (6, 2040) I2, (MOTNO(I2, K), CST2(I1, K), CST2(I2, K),
1 CST2(I3, K), 1 K), BLANK, R2(I1, K), R2(2, K), R2(3, K), BLANK, K = 1, J2)
WRITE (6, 2066) (MCST2(I, J), J = 1, 4), MR2, (SDCST2(I, J), J = 1, 4), SMR2
WRITE (6, 2040) I3, (MOTNO(I3, K), CST3(I1, K), CST3(I2, K),
1 CST3(I3, K), 1 K), BLANK, R3(I1, K), R3(2, K), R3(3, K), BLANK, K = 1, J3)
WRITE (6, 2066) (MCST3(I, J), J = 1, 4), MR3, (SDCST3(I, J), J = 1, 4), SMR3
WRITE (6, 2067) (MCSTT(I, J), J = 1, 4), MR4, (SDCSTT(I, J), J = 1, 4), SMR4
10 1794 J = 1, NT
C1TMN(J) = MRT(J) - CT1*SORT(J)
C1TMX(J) = MRT(J) + CT1*SORT(J)
C2TMN(J) = MRT(J) - CT2*SORT(J)
C2TMX(J) = MRT(J) + CT2*SORT(J)
1794 C2TMX(J) = MRT(J) + CT2*SORT(J)
WRITE (6, 2068) C1MIN, C1TMN, C1TMX, C1TMX,
1 C2MIN, C2TMN, C2TMX, CPTMX
1795 CONTINUE
RETURN
END
APPENDIX B

LISTING OF THE SOLID PROPELLANT ROCKET MOTOR PERFORMANCE VERSUS TIME COMPUTER PROGRAM USING THE GROUP TRANSFORMATION METHOD
*P FOR MAIN

C GENERAL SOLID-PROPELLANT ROCKET MOTOR PERFORMANCE VS. TIME

C

DIMENSION XX(1700)
DIMENSION XLNP (3,15,200), FSAVE(3,15,200), PSAVE(3,15,200)
DIMENSION CC(200*4), PCO(200), FO(200), Y(200),
1 WPRNT(200), TREP(200), PC (200), T(200), F(200)
DIMENSION AE(3,15), AE2(3,15), AE3(3,15), AE4(3,15), WEB(3,15),
1 XMOTNO(3,15), TEMP(3,15), PAF(3,15), TAIL(3,15), AEOT(3,15)
DIMENSION TGRP(4), EXTEN(3), EXPAT(3), KOUNT(4), EPS(4)
DIMENSION RCDX(12), BCD1(12), BCD2(12), BCD3(12), BCD4(12)
DIMENSION PCTW(10), NW(10), BREAKW(10), WINC(10)
DIMENSION PCTT(5), NT(5), BREAKT(5), TINC(5)
DIMENSION NGO(10), NSTOP(10), XNW(10), XNT(5), SETI(10)
COMMON XX
COMMON XLNP, FSAVE, PSAVE
COMMON BCDX, BCD1, BCD2, BCD3, BCD4

EQUIVALENCE
1 C XX (1) , NSV2), (XX(3), ICON),
2 (XX (4), TAV), (XX( 5), N1), (XX( 6), NPRIME),
3 (XX( 7), NPTS), (XX( 8), TA), (XX( 9), TT),
4 (XX(10), WPC1), (XX(11), TPC1),
5 (XX(13), C T2), (XX(14), TREP), (XX(214), T),
6 (XX(414), CC), (XX(1214), NSV1), (XX(1215), NXXN),
7 (XX(1216), NA), (XX(1217), KOUNT), (XX(1221), TEMP),
8 (XX(1266), IPRN1), (XX(1267), N2), (XX(126A), TO),
9 (XX(1269), N P), (XX(1270), EXPAT), (XX(127S), AEOT)

EQUIVALENCE
1 (XX(131A), PAF), (XX(1363), CPHI), (XX(1364), TD),
2 (XX(1365), WPRNT), (XX(1565), XMOTNO), (XX(1601), NXXW),
3 (XX(1652), PCTW), (XX(1662), PCTT)

C

INPUT FORMATS

81 FORMAT (112, 4F12.4)
82 FORMAT (A6, 6F12,4, 1X, I1)
83 FORMAT (216, 3F12,4,16)
84 FORMAT (5(F10,4, I6))
85 FORMAT (4E12,5)
100 FORMAT (316)
101 FORMAT (2(E16,8, E12,5, E12,5))
102 FORMAT (12A6)

C

OUTPUT FORMATS

109 FORMAT (3AH1T HE FOLLOWING OUTPUT IS FOR MOTOR NO. A6)
110 FORMAT(54HO PCT WEB TIME TIME PC THRUST/)
111 FORMAT(F12,4,3F14,4)
112 FORMAT(54HO PCT TAILOFF TIME TIME PC THRUST/)

C

1 READ (5, 83) XNW, XNT, TD, PHI, CT2, NSW
IF (NSW .GT. 0) READ (5,84) PSIA
WRITE(6, 83) XNW, XNT, TD, PHI, CT2
READ (5, 84) (PCTW(I), NW(I), I = 1,NXNW)
WRITE(6, 84) (PCTW(I), NW(I), I = 1,NXNW)
READ (5, 84) (PCT(I), NT(I), I = 1, NXNT)
WRITE(6, 84) (PCT(I), NT(I), I = 1, NXNT)
READ (5, 81) NA, (TGRP(I), I = 1,NA)
WRITE(6, 81) NA, (TGRP(I), I = 1:NA)
READ (5, 81) NP, (EXPA(I), I = 1:NP)
WRITE(6, 81) NP, (EXPA(I), I = 1:NP)
READ (5,102) (RCDX(I),I=1:12)
WRITE(6,102) (RCDX(I),I=1:12)
READ (5,102) (RCD1(I),I=1:12)
WRITE(6,102) (RCD1(I),I=1:12)
READ (5,102) (RCD2(I),I=1:12)
WRITE(6,102) (RCD2(I),I=1:12)
READ (5,102) (RCD3(I),I=1:12)
WRITE(6,102) (RCD3(I),I=1:12)
READ (5,102) (RCD4(I),I=1:12)
WRITE(6,102) (RCD4(I),I=1:12)

C KOUNT(1) = 0
KOUNT(2) = 0
KOUNT(3) = 0
NG0(I) = 1
DO 4 I = 1,NXNW
NXW(I) = NW(I)
WINC(I) = 1. / XNW(I)
NG0(I+1) = NG0(I) + NW(I) + 1/I
NSTOP(I) = NG0(I+1) - 1
4 CONTINUE
DO 5 I = 1,NXNT
XNT(I) = NT(I)
TINC(I) = 1. / XNT(I)
ISUM = (NXNW + I + 1)
NG0(ISUM) = NG0(NXNW + I) + NT(I)
NSTOP(NXNW+I) = NG0(ISUM) - 1
5 CONTINUE

C IPASS = 0
CPHI = COS (PHI)
NSUM = NXNW + NXNT
NSV0 = NSTOP(NXNW)
NI = NSV0 - 1
NSV1 = NSV0 + 1
NSV2 = NSTOP(NSUM)
DO 7 I = 1,NXNW
7 SETI(I) = PCTW(I) * .61
DO 8 I = 1,NXNW
6 PCTW(I+1) = SETI(I)
PCTW(I) = 0.
DO 9 I = 1,NXNT
8 SETI(I) = PCTT(I) * .61
DO 10 I = 1,NXNT
9 PCTT(I+1) = SETI(I)
PCTT(I) = 0.

C GROUP MOTORS INTO TEMPERATURE GROUPS

C TGRP(M+1) = TGRP(MA) * 2.
15 READ (5, A2) XMOT, FIRFTP, PAX, IP, IT, TO, PCP, NMDOT
WRITE(6, A2) XMOT, FIRFTP, PAX, IP, IT, TO, PCP, NMDOT
LO 19 J = 1, NA
EPS(J) = (TGRP(J+1) - TGRP(J)) *.5
IF ( (TGRP(J) + EPS(J)) - FIRFTP) 19, 19, 25
19 CONTINUE
25 KOUNT(J) = KOUNT(J) + 1
K = KOUNT(J)
READ (5, A5) AE1(J,K), AE2(J,K), AE3(J,K), AE4(J,K)
WRITE(6, 105) AE1(J,K), AE2(J,K), AE3(J,K), AE4(J,K)  
TEMP(J,K) = FHETP  
XMOTNO(J,K) = XMOT  
PAF(J,K) = PAX  
WEH(J,K) = TB  
TAIL(J,K) = TT  
AE1(J,K) = AF1(J,K) + AE2(J,K) + AF3(J,K) + AE4(J,K)  
C  
READ(5, 100) NPTS, ICON, IPRTN  
WRITE(6, 100) NPTS, ICON, IPRTN  
READ(5, 101) (TREP(I), PC(I), F(I)), I=1,NPTS  
C  
U0 11 I=1,NPTS  
11 PC(I) = PC(I) + PCP  
PRES1 = 0.0  
PRES2 = 0.0  
IF(NSW .GE. 0) GO TO 5005  
5001 BREALW(I) = TO  
U0 26 I = 1,NXNW  
26 BREALW(I+1) = TO + PCTW(I+1)*TB  
BREALT(I) = TB + TO  
DO 28 I = 1,NXNT  
28 BREALT(I+1) = TB + PCTT(I+1)*(TT-TB) + TO  
C  
IF(PRES1 .LE. 0.0) GO TO 5002  
5002 CALL CURVE (TREP, PC, NPTS)  
IF(NSW .LE. 0) GO TO 5002  
TNEW = TREP(I) - 0.00001 - TAV  
U0 5003 I=1,NPINF  
TNEW = TNEW + 0.00001  
PRES1 = ((CC(1,4) + TONEW + CC(1,3)) + TONEW + CC(1,2))*TONEW + CC(1,1)  
PRES2 = (CC(1,1) + CC(1,2))*TONEW + CC(1,3)*TONEW**2  
1 + CC(1,4)*TONEW**3  
IF(PRES1 .GE. PS1A .OR. PRES2 .GE. PSIA) GO TO 5004  
5003 CONTINUE  
5004 TO = TONEW + TAV  
WRITE(6, 102) TO, PSIA, PRES1, PRES2  
1002 FORMAT(1H1, 2H3:TO= F10.4, 6X, 5HPS1A= F10.3, 6X, 6HPS2= F20.4, 1 6X, 6HPSF52= F20.4 )  
GO TO 5001  
5001 CALL SRC1(PCO)  
U0 30 L = 1, NSV2  
ARG = PCO(L)  
FSAVE(J,K,L) = ARG  
30 XLMP(J,K,L) = 2*L06(ARG)  
C  
CALL CURVE (IRFP, F, NPTS)  
CALL SRC1 (F0)  
U0 35 L = 1, NSV2  
35 PSAVE(J,K,L) = F0(L)  
C  
WRITE(6, 109) XMOTNO(J,K)  
WRITE(6, 110)  
U0 56 IJ = 1, MXNW  
AI = 0.  
NG = NG0(IJ)  
LSP = MSTOP(IJ)  
DELFW = PCTW(IJ+1) - PCTW(IJ)  
U0 56 I = NG, LSP  
IF (IJ .NE. 1) GO TO 53  
IF (I .GT. 1) GO TO 54  
53 AI = AI + 1
54 IF (IPASS .EQ. 1) GO TO 55
    WPRNT(I) = (PCTW(IJ) + WINC(IJ) *AI*DELPW) * 100.
55 WRITE (6, 111) WPRNT(I), T(I), PCO(I), FO(I)
56 CONTINUE
    WRITE (6, 112)
    LO 60  IJ = 1, NXNT
    AI = 0.
    NG = NG0 (IJ + NXNW)
    NSP = NSTOP(IJ + NXNW)
    DELPT = PCTT(IJ+1) - PCTT(IJ)
    LO 58  I = NG, NSP
    IF (IPASS .EQ. 1.) GO TO 5A
    AI = AI + 1.
    WPRNT(I) = (PCTT(IJ) + TINC(IJ)*AI*DELPT) * 100.
58 WRITE (6, 111) WPRNT(I), T(I), PCO(I), FO(I)
60 CONTINUE
    IF (IPASS = 1)
    IF (NDMOT) 65, 15, 65
65 CALL LSTSQ (1, NSV0, WEB, 1)
    CALL LSTSQ (NSV1, NSV2, TAIL, 2)
    GO TO 1
    END
COMMON XX
EQUIVALENCE
1 (XX( 4), TAV), (XX( 8), Th), (XX( 10), WPCT),
2 (XX(14), TREP), (XX( 214), T), (XX( 414), CC),
3 (XX(126A), TO), (XX( 1215), NINNT), (XX( 5), N1),
4 (XX(1601), NINNW), (XX( 7), NPTS), (XX( 9), TT),
5 (XX( 11), TPCT), (XX( 3), ICON)
EQUIVALENCE
1 (XX(1602), BREAKW), (XX(1612), BRTAK), (XX(1617), WINC),
2 (XX(1627), TINC), (XX(1632), N60), (XX(1642), NST0P)
NSUM = NXNW + NNSM
XI = 0.
NG = N60(IJ)
NSP = NST0P(IJ)
DELW = BREAKW(IJ+1) - BREAKW(IJ)
IK = IJ - NXNW
DELT = BRTAKT(IK+1) - BRTAKT(IK)
DO 40 I = NG, NSP
IF (I J GT. NXNW) GO TO 15
IF (I J LE. 1) GO TO 8
IF (I J LE. 1) GO TO 9
8 XI = XI + 1.
9 T(I) = BREAKW(IJ) + XI*WINC(IJ)*DELW
GO TO 21
15 XI = XI + 1.
T(I) = BRTAKT(IK) + XI*TINC(TK)*DELT
21 DO 28 J = 1, NPTS
IF (TREP(J) - T(I)) 28, 28, 22
22 JS = J - 3
IF (JS) 23, 23, 25
23 JS = I
GO TO 32
25 IF (JS LE. NPTS + NI) 32, 32, 26
26 JS = NPTS - NI
GO TO 32
28 CONTINUE
32 TQ = T(I) - TAV
Y(I) = ((CC(JS,4)*TQ + CC(JS,3))*TQ + CC(JS,2))*TQ + CC(JS,1)
40 CONTINUE
45 CONTINUE
RETURN
END
IP FOR LSTSQ

SUBROUTINE LSTSQ (NGOr NSTOPr TIMEr IPASS)
DIMENSION XX(1700)
DIMENSION XLNP (3,15,200), FSAtVE(3,15,200), FD1(3,15,200),
FD2 (3,15,200), FD3(3,15,200), PD(3,15,200)
DIMENSION C2MAX(200,3), C2MIN(200,3), XMFD(200,3),
1 PIK(3,200), XMNLNP(3,200), XMOTNO(3,15), AEOT(3,15),
2 PAF(3, 15), TEMP(3, 15), TIME(3, 15), ARRAY(46, 4),
3 XLNP(200), C1MIN (200), C1MAX (200), WPRNT(200),
4 XMTO(200), C3MIN (200), C3MAX (200), XMPTD(200),
5 SET1 (45), SET2 (45), XMTEMP (3), DENOM (3),
6 EXPA(3), SIGP (3), X (4), KOUNT (4),
7 IL (4), LGO (10), PCTW (10), PCTT (5),
8 WINC(10), TINC (5), SET3(45), TEMX(45)
DIMENSION BCDX(12), BCD1(12), BCD2(12), BCD3(12), BCD4(12)
COMMON XX
COMMON XLNP, FSAVE, PSAVE
COMMON BCDX, BCD1, BCD2, BCD3, BCD4
EQUIVALENCE
1 (XX( 5), N1), (XX (11), TPCT ), (XX (10), WPCT),
2 (XX(1216), NT), (XX(1217), KOUNT), (XX(1221), TEMPE),
3 (XX(1259), NP), (XX(1270), EXPA), (XX(1273), AEOT),
4 (XX(1318), PAF), (XX(1363), CPHI), (XX(1364), TU),
5 (XX(1365), WPRNT), (XX(1565), XMOTNO), (XX (13), CT2),
6 (XX (1), NSV2), (XX(1214), NSV1), (XX (1601), NNXW),
7 (XX(1632), LGO), (XX(1652), PCTW), (XX(1662), PCTT),
8 (XX(1617), WINC), (XX(1627), TINC)
EQUIVALENCE (XLNP(1), FD1(1), FD2(1), FD3(1), PD(1))

C C OUTPUT FORMATS
C 200 FORMAT (1H1, 13X, 56H TRANSFORMED TIMES
1 ER PRESSURE )
C 201 FORMAT (7H PCT., 16X, 3AH MEANS WITH TWO SIDED TOLERANCE LIMITS/
1 36H WER MIN. MAX.,7X, 30H MEAN MIN.
2 MAX. / 7H TIME )
C 202 FORMAT (1H1, 13X, 54H TRANSFORMED TIMES
1 AT PA = FA, 2)
C 205 FORMAT (1X, F6.2, 3F10.4, 3F12.4)
C 1201 FORMAT (5H PCT. / AH TAILOFF / 5H TIME )
C NSV0 = N1 + 1
C IF (IPASS = 2) 66, 72, 66
C 66 NM = KOUNT(1) + KOUNT(2) + KOUNT(3)
C C COMPUTE STATISTICS FOR TEMPERATURE
C DO 70 J = 1+NT
C LL = 0
C JJ = KOUNT(J)
C DO 68 K = 1+JJ
C LL = LL + 1
C 68 SET1(LL) = TEMP(J,K)
C CALL STATS (SET1, LL, XMTEMP(J), ARG)
C DENOM(J) = TU - XMTEMP(J)
C 70 CONTINUE
C C LEAST SQUARE FIT LOG OF BURN TIME VS. TEMP.
C DO 210 J = 1,NT
C 72 LL = 0
C 210 CONTINUE
JJ = KOUNT(J)
DO 210 K = J, JJ
LL = LL + 1
ARRAY(LL,1) = 1.
ARRAY(LL,2) = TEMP(J,K)
ARRAY(LL,3) = TEMP(J,K)**2
ARG = TIME(J,K)
ARRAY(LL,4) = ALOG(ARG)
210 CONTINUE
CALL GSL1 (ARRAY, X, IL, NM, 3, ALPHA, 0., 0.)
XLNPD(1) = (X(3)*TD + X(2))*TD + X(1)

C COMPUTE LOG OF MEANS OF BURN TIMES AND SIGP*S
C
UO 230 J = 1, NT
XMLNP(J,1) = (X(3)*XI TEMP(J) + X(2))*XMTemp(J) + X(1)
230 SIGP(J) = (XMLNP(J,1) - XLNPD(1)) / UENOM(J)

C COMPUTE TRANSFORMED TIMES AND IN THE SAME LOOP LFAST SQUARE
C FIT LOG OF PRESSURE VS. TEMP
C
IJ = 0
UO 240 L = NGO. NSTOP
IQ = IJ + 1 + (IPASS-1)*NXNW
IF (L. NE. LGO(IQ)) GO TO 231
IJ = IJ + 1
AL = 0.
INCR = 1 / IJ
XINC = XINC
231 AL = AL + 1
UO 235 J = 1, NT
JJ = KOUNT(J)
UO 235 K = J, JJ
LL = LL + 1
ARRAY(LL,4) = XMLP(J,K,L)
ARG = SIGP(J)*(TD) - TEMP(J,K))
TEM = TIME(J,K) / (EXP (ARG))
IF (IPASS - 1) 232, 232, 233
UELW = PCTW(LJ*1) - PCTW(LIJ)
SETL(LL) = TEM * (PCTW(LIJ) + (AL=XINC)*WINC(IJ)*UELW)
GO TO 235
233 DELT = PCTT(IJ+1) - PCTT(IJ)
TAM = TEM - TEMX(LL)
SETL(LL) = TEMX(LL) + TAM * (PCTT(IJ) + AL*TINC(IJ)*DELT)
235 CONTINUE
CALL STATS (SET1, LL, XMTD(L), SUU)
CIMIN(L) = XMTD(L) - CT2*SDTD
CIMAX(L) = XMTD(L) + CT2*SDTD
CALL GSL1 (ARRAY, X, IL, NM, 3, ALPHA, 0., 0.)
XLNPD(L) = (X(3)*TD + X(2))*TD + X(1)

C COMPUTE XMLNP FROM CURVE FIT AND PIK'S
C
UO 240 J = 1, NT
XMLNP(J,L) = (X(3)*XMLMP(J) + X(2))*XMLMP(J) + X(1)
PIKJ(J,L) = (XMLNP(J) - XMLNP(J,L)) / UENOM(J)
240 CONTINUE

C COMPUTE AND PRINT OUT TRANSFORMED PRESSURES
C

106
DO 100 L = NGO, NSTOP
LL = 0
DO 90 J = 1, NT
JJ = KOUNT(J)
DO 90 K = 1, JJ
LL = LL + 1
AR6 = PIKL(J, L) * (W) - TFMP(J, K)
PD(J, K, L) = EXP*(XLNP(J, K, L) + AR6)
SET3(LL) = PD(J, K, L)
90 CONTINUE
CALL STTS (SET3, NM, XMPLD(L), SDPTD)
C3MIN(L) = XMPLD(L) - CT2*SDPTD
C3MAX(L) = XMPLD(L) + CT2*SDPTD
100 CONTINUE
C
IF (IPASS - 2) 182, 101, 182
101 WRITE (6, 200)
WRITE (6, 201)
DO 105 L = 1, NSV2
IF (L - NSV1) 105, 104, 105.
104 WRITE (6, 1201)
105 WRITE (6, 205) WPRNT(L), XMPLD(L), C3MIN(L), C3MAX(L),
1 XMPLD(L), C3MIN(L), C3MAX(L)
CALL QUIKMD (-1, 46, RCDX, BCD1, -NSV2, C3MAX, C3MAX)
CALL QUIKMD (0, 67, RCDX, BCD1, -NSV2, XMPLD, XMPLD)
CALL QUIKMD (0, 77, RCDX, BCD1, -NSV2, C3MIN, C3MIN)
C
C
COMPUTE TRANSFORMED THRUSTS
C
182 DO 198 L = NGO, NSTOP
LL = 0
DO 190 J = 1, NT
JJ = KOUNT(J)
DO 190 K = 1, JJ
LL = LL + 1
RATIO = PD(J, K, L) / PSAVE(J, K, L)
FVAC = FSAVE(J, K, L) + PAF*(J, K) + AEFTOT(J, K)*CPHI
FD1(J, K, L) = RATIO*FVAC - EXPA*(AEFTOT(J, K)*CPHI
SET1(LL) = FD1(J, K, L)
IF (NP - 1) 190, 190, 194
184 FD2(J, K, L) = RATIO*FVAC - EXPA*(AEFTOT(J, K)*CPHI
SET2(LL) = FD2(J, K, L)
IF (NP - 2) 190, 190, 196
186 FD3(J, K, L) = RATIO*FVAC - EXPA*(AEFTOT(J, K)*CPHI
SET3(LL) = FD3(J, K, L)
190 CONTINUE
CALL STATS (SET1, NM, XMFLD(L, 1), SUFU)
C3MIN(L, 1) = XMFLD(L, 1) - CT2*SUFU
C3MAX(L, 1) = XMFLD(L, 1) + CT2*SUFU
IF (NP - 1) 194, 194, 194
194 CALL STATS (SET2, NM, XMFLD(L, 2), SUFU)
C3MIN(L, 2) = XMFLD(L, 2) - CT2*SUFU
C3MAX(L, 2) = XMFLD(L, 2) + CT2*SUFU
IF (NP - 2) 194, 194, 196
196 CALL STATS (SET3, NM, XMFLD(L, 3), SUFU)
C3MIN(L, 3) = XMFLD(L, 3) - CT2*SUFU
C3MAX(L, 3) = XMFLD(L, 3) + CT2*SUFU
198 CONTINUE
C
IF (IPASS - 2) 209, 301, 200
301 M = 0
204 M = M + 1
WRITE (6, 202) EXPA(M)
WRITE (6, 201)
DO 206 L = 1, NSV2
IF (L .NE. NSV1) 206, 207, 206
207 WRITE (6, 1201)
206 WRITE (6, 205) WPRNT(L), XMTD(L), C1MIN(L), C1MAX(L),
1 XMFD(L,M), C2MIN(L,M), C2MAX(L,M)
IF (M .GT. NP) 204, 218, 218
218 CALL QUIKMV (-1, 46, BCDX, BCD2, -NSV2, C1MAX, C2MAX(1,1))
CALL QUIKMV ( 0, 67, RCDX, BCD2, -NSV2, XMTD, XMFD(1,1))
CALL QUIKMV ( 0, 77, RCDX, BCD2, -NSV2, C1MIN, C2MIN(1,1))
IF (NP .GT. 1) 209, 209, 220
220 CALL QUIKMV (-1, 46, RCDX, HCD3, -NSV2, C1MAX, C2MAX(1,2))
CALL QUIKMV ( 0, 67, RCDX, HCD3, -NSV2, XMTD, XMFD(1,2))
CALL QUIKMV ( 0, 77, RCDX, BCD3, -NSV2, C1MIN, C2MIN(1,2))
IF (NP .GT. 2) 209, 209, 222
222 CALL QUIKMV (-1, 46, HCDX, HCD4, -NSV2, C1MAX, C2MAX(1,3))
CALL QUIKMV ( 0, 67, HCDX, BCD4, -NSV2, XMTD, XMFD(1,3))
CALL QUIKMV ( 0, 77, HCDX, BCD4, -NSV2, C1MIN, C2MIN(1,3))
209 RETURN
END
*IP FOR CURVF
SHAROUTDF CURVF (T, S, N)
C CURVE FIT
DIMENSION XX(1700)
DIMENSION ALD(400), DFL(400), ALC(400), ALY(1000), TL(200),
1 T(200), S(200), A3(200), SC(200), DP(200),
2 NLR(200), CC(200, 4)
COMMON XX
EQUIVALENCE
1 (XX( 3), ICON), (XX( 4), TAV), (XX( 41), CC),
2 (XX(1266), IPRNT)
WRITE (6,111)
110 FORMAT (2F15.5)
111 FORMAT (1H1,12HINPUT ARRAYS)
WRITE (6,110) (T(I),S(I), I=1,N)
C ***THE ELEMENTS OF THE T AND S ARRAYS ARE ARRANGED IN ASCENDING ORDER
C *AND ARE THEN NORMALIZED.
CALL ACCENT(T,S,N)
CALL NORMLZ(T,TC,N,TAV)
CALL NORMLZ(S,SC,N,SAV)
DO 1 I=1,N
1 ALD(2*I)=TC(I)
DO 1 J=1,N
1 ALD(2*I-1)=SC(I)
C HERE **EDIMS PIECEWISE FITS WITH CUBICS, EMBRACING M POINTS AT TIME
K = 1
M = ICON
IF(M-2*(M/2))23,24,23
23 IS=0
GO TO 25
24 IS=1
25 M+HSM/2
NK = M
MM=M+1-M
IF (IPRNT) 62, 64, 62
62 WRITE (6, 63) TAV, M
63 FORMAT(78HFOUILLING M PPF COEFFICIENTS OF SLIGHTLY DISCONTINUOUS CUB
631ICS IN THE DTY (TIME'=12,7.25H), FOR TIME RANGES SHOWN. A/B/H/T,TIME
632ANGL COEFS OF O**1 COEFF OF O**1 COEFF OF O**1 C
633(1,0**1**1,0**1**2) POINTS LINKED PER SET/*/ C
C ***COMPUTING THE COEFFICIENTS OF THE CUBICS AND STORING THEM IN THE
C CC ARRAY
64 L0 52 I=1,MM
CALL CF2F1(0,ALC,0,A3,ALD(2*I-1),3,M)
CALL CF2F2(0,0,ALC,3,NFR3,3)
CC(I+1) = DER(I) + SAV
1=1.
L0 52 J=1,3
1= N * FLOAT (J)
52 CC(I+J) = DER(2*J+1) / A
CALL CF2F1(0,ALC,0,A3,ALD(3),M)
C ***COMPUTING THE DISCREPANCIES FOR THE PIECEWISE FITS.
L0 53 I=1,N
W=I-(MH-IS)
IF(W-57,57,56
56 IF(W+MM)$59,58,57
58 CALL CF2F1(0,ALC,0,A3,ALD(2*J-1),3,M)
57 CALL CF2F2(TC(I),ALC,3,DER,0,3)
53 DPI(I) = SC(I) - DER(I)
E=T(I)
109
IZ=MH-IS
H=T(IZ+1)
DO 166 I = 1,MM
IF (IPRNT) 51, 55, 51
51 WRITE (6, 54) P, H, (CC(I,J), J=1,4)
54 FORMAT(F7.2,3H TOF8.2,4E17.8)
55 H=H
J=I+MH+1-IS
IF(I+1-MM)164,165,165
165 J=N
H = T(J)
GO TO 166
164 H=T(J)
166 CONTINUE
WRITE (6,124) MK
127 FORMAT (17H PIECEWISE CUBICS / 21H NO. OF POINTS LINKED ,IP)
WRITE (6,127)
WRITE (6,153) T(J),S(J),DP(J)
CALL STDEV (UP,N,S2)
WRITE (6, 11) S2
11 FORMAT (19H STD. DEV. F11.6)
RETURN
END

*IP FOR STATS
SUBROUTINE STATS (X, N, XM, SD)
DIMENSION X(100)
SUM1 = 0.
SUM2 = 0.
XNO = N
XNO1 = XNO - 1.
DENOM = XNO*XNO1
DO 10 I = 1,N
SUM1 = SUM1 + X(I)
10 SUM2 = SUM2 + X(I)*X(I)
XM = SUM1 / XNO
XNUM = (XNO*SUM2 - SUM1*SUM1)
IF (XNUM .LT. 0.) GO TO 14
SD = SQRT(XNUM/DENOM)
IF ((SD/XM) .LT. .00025) GO TO 14
SD TO 15
14 SD = 0.
15 RETURN
END
IP FOR GLS1

SUBROUTINE GLS1(U,X,IL,N,M,ALPHA,E1,E2)

DIMENSION A(46,4), B(46,4), X(4), IL(4)

MM=M+1

DO 2 J = 1,N
DO 2 K = 1,MM

2 A(J,K) = B(J,K)

LL=1

DO 60 J=1,MM

I=1

DO 3 K=1,MM

II=I+1

DO 4 J=II,N

IF (ABS(A(J,K))=E1) GO TO 6

6 T1=SQRT((A(J,K))**2+(A(I,K))**2)

S=A(J,K)/T1

C=A(I,K)/T1

DO 5 SL=K,MM

T2=C*A(I,L)+S*A(J,L)

A(J,L)=S*A(I,L)+C*A(J,L)

5 A(I,L)=T2

LL=LL+1

4 CONTINUE

IF (ABS(A(I,K))=E2) GO TO 8

8 IL(K)=I

I=I+1

3 CONTINUE

X(MM)=1.0

II=M

DO 35 I=1,M

35 X(I)=0.

DO 30 J=1,M

IF (IL(I))>30,30,31

30 S=0.

LL=II+1

I=IL(II)

DO 32 K=LL,MM

32 S=S+A(I,K)*X(K)

X(II)=-S/A(I,II)

II=II-1

IF (IL(MM))>50,51,50

51 ALPHAS=0.

GO TO 52

50 I=IL(MM)

ALPHAS=A(I,MM)

52 RETURN

END
'IP FOR ACCFN

SUBROUTINE ACCFN(X,Y,N)
C
C  THIS SR SORTS (X,Y) POINTS INTO A SEQUENCE OF
C  ASCENDING X VALUES.
C
C  N IS THE NO. OF POINTS IN THE SEQUENCE
C  WHILE X AND Y ARE ASSOCI.
C
C  THEY DID BEFORE SORTING. N IS THE NO. OF POINTS.
C
C  DIMENSIONS OF ABOVE VARIABLES ARE ACTUALLY EFFECTED BY
C  HIGHER (CALLING) PROGRAM OR SR.
C
C  EQUIVALENCE (I,T)

J = 1
C
C  J IS THE INDEX OF THE NEXT MEMBER OF THE SET OF
C  POINTS WHICH WILL
C  BE ORDERED BY OPERATIONS IN THE INNER LOOP DO K UN T.
C  GO TO 3
C
C  THE ABOVE TRANSFER AVOIDS MIS-OFFRATION IF N=1 OR LESS, USE CARD
C  NO 305. NORMALLY, PROGRESS TO STMT. 4.

4 K = J
C
C  K IS THE TENTATIVE INDEX OF THE SMALLEST UN-OORDERED X VALUE.
C
C  SO FAR UNORDERED.

5 I = I + 1
C
C  IF(X(I)-X(K)) > R, R
C  1 K = I
C  8 IF(I-N) < 7, 7
C
C  K IS NO LONGER TENTATIVE. IT IS UNDEFINED THE INDEX OF SMALLEST X.
C
C  SO FAR UNORDERED.

7 IF(K-J) > 9, 2
C
C  BOTH X AND Y HAVE BEEN SWAPPED, USING T AS A TEMPORARY STORAGE.

2 I = X(K)
C
C  X(K) = X(J)
C  X(J) = T
C
C  Y(K) = Y(J)
C
C  Y(J) = T
C
C
C  RETURN
END

'IP FOR NORMLZ

SUBROUTINE NORMLZ(X,Y,N,AV)
C
C  THIS ROUTINE AVERAGES N ELEMENTS IN X ARRAY GETTING AV AS THE
C  RESULT. IT THEN PRODUCES ARRAY Y WHICH IS SAME AS X*MINUS AV,
C
C  TERM BY TERM
C
C  DIMENSION X(1),Y(1)

AV = X(1)
C
C  1 AV = AV + X(I)
C  4 V = AV / FLOAD(N)
C  6 I = I + 1

2 Y(1) = X(I) - AV
C
C  RETURN
END

112
*IP FOR FIXIT

SUBROUTINE FIXIT(A,N,N2,N7)
DIMENSION A(10,1), R(5,1), N(50), KK(4), S1(15), S2(15)
DO 200 J=N2,N7
DO 100 I=1,N
100 D(I)=A(J,I)
200 CALL STDEV(N,N,S1(J))
   KK(1)=A
   KK(2)=I
   KK(3)=I
   KK(4)=I
   DO 400 J=I+4
   DO 300 I=1,N
300 U(I)=R(J,I)
400 CALL STDEV(N,N,S2(J))
   WRITE (6, 11) (S1(J), J=N2,N7), (S2(J), J=1,4)
11 FORMAT(15H0, STD. DEV. =F11.6, 2X=F11.6)
RETURN
END

*IP FOR STDEV

SUBROUTINE STDEV(X,N,S)
DIMENSION X(1)
SUMX=0.
XSQR=0.\nENSN
DO 100 I=1,N
SUMX=SUMX+X(I)
100 XSQR=XSQR+(X(I)**2)
SP=XSQR-((SUMX**2)/EN)
S = SQRT (SP / (EN - 1.))
RETURN
END
IP FOR CF2F1

SIMRoutines CF2F1(J, ALCT, ALW, ALU, K, N)
DIMENSION TMP(2), ALW(N), ALC(1)
K6=6*K+4
FK=K
IT=2
IF(IT)11,1,11
11 NT = 3
1 IF(J)33,3,33
33 TMP(2)=0.0
GO TO 2
3 ALC(K6+4)=0.0
ALC(K6+3)=0.0
FN=N
NN=0
DO 5 I=1,N
NN = NN + NT
MN = ALC(K6+4)+ALD(NN)
5 ALC(K6+3)=ALC(K6+3)+ALD(NN-1)
TMP(1)=ALC(K6+3)/FN
ALC(K6+3)=TMP(1)
TMP(2)=ALC(K6+4)/FN
ALC(K6+4)=TMP(2)
2 FN=0
NM=-2
DO 6 I=1,N
NM=NM+5
NN = NN + NT
ALD(NM)=ALD(NN)-TMP(2)
6 ALD(NM-1)=ALD(NN-1)-TMP(1)
N=2
NN=4
DO 8 I=1,N
NN=NN+5
IF(IT)77,7,77
77 NM = NM + NT
ALW(NN)=ALD(NM)
GO TO 8
7 ALW(NN)=1.0
8 CONTINUE
NN=0
DO 9 I=1,N
NN=NN+5
9 ALW(NN)=1.0
FJJ=0.0
ALC(K6+5)=J
IF(J)17,15,17
17 FJJ=FJJ+1.0
NN=0
DO 18 I=1,N
NN=NN+5
18 ALW(NN)=ALW(NN)*ALW(NN-2)
IF(FJJ=ALC(K6+5))17,15,15
15 ALC(K6+1)=0.0
ALC(K6+2)=0.0
ALC(K6-2)=0.0
NN=4
DO 19 I=1,N
NN=NN+5
TMP(1)=ALW(NN)*ALW(NN+4)
$\text{ALC(K6+2)} = \text{TMP}(1) * \text{ALW}(\text{NN+1}) + \text{ALC(K6+2)}$

$\text{TMP(1)} = \text{TMP}(1) * \text{ALW(NN+4)}$

$\text{ALC(K6+1)} = \text{TMP}(1) + \text{ALC(K6+1)}$

$\text{ALC(K6-2)} = \text{TMP}(1) * \text{ALW(\text{NN+2})} + \text{ALC(K6-2)}$

$\text{ALC(K6-2)} = \text{ALC(K6-2)} / \text{ALC(K6+1)}$

$\text{ALC(K6+2)} = \text{ALC(K6+2)} / \text{ALC(K6+1)}$

$\text{ALC(K6-3)} = \text{ALC(K6-3)} * 0$

$L3 = 0$

$L1 = -1$

$L4 = 0$

$K6 = K6 - 6$

$\text{IF}(FJ-J-KK) 115, 122, 122$

$\text{IF}(FJ-J-KK) 115, 122, 122$

$\text{ALC(K6+2)} = 0 * 0$

$\text{ALC(K6+1)} = 0 * 0$

$\text{ALC(K6-2)} = 0 * 0$

$I = N - 4$

$DO I = 1, N$

$L1 = \text{NN+5}$

$L2 = \text{NN+L1}$

$L3 = \text{NN+L4}$

$\text{TMP}(1) = \text{ALC(K6+3)} * \text{ALW(L2+4)}$

$\text{ALW(L2+4)} = (\text{ALW(\text{NN+2})} - \text{ALC(K6+4)}) * \text{ALW(L5+4)} - \text{TMP}(1)$

$\text{TMP(1)} = \text{ALW(L2+4)} * \text{ALW(\text{NN})}$

$\text{ALC(K6+2)} = \text{TMP}(1) * \text{ALW(\text{NN+1})} + \text{ALC(K6+2)}$

$\text{ALC(K6+1)} = \text{TMP}(1) * \text{ALC(K6+1)}$

$\text{ALC(K6-2)} = \text{TMP}(1) * \text{ALW(\text{NN+3})} + \text{ALC(K6-2)}$

$\text{ALC(K6-2)} = \text{ALC(K6-2)} / \text{ALC(K6+1)}$

$\text{ALC(K6+2)} = \text{ALC(K6+2)} / \text{ALC(K6+1)}$

$\text{ALC(K6-3)} = \text{ALC(K6-3)} / \text{ALC(K6+7)}$

$IF(L3) > 42, 120, 122$

$L3 = 1$

$L1 = 0$

$L4 = 1$

$DO TO 113$

$HT TURN$
*IP FOR CF2F2

SUBROUTINE CF2F2(ARG*ALC*KRA*DER*IO*K) CF2
DIMENSION TMP(6),ALC(1),DER(1) CF2
XBAR=ARG CF2
FKB=KCF2
K6=6*KCF2
IF(ALC(K6+5))22,22,22 CF2
22 XBAR=XMAR-ALC(K6+4) CF2
22 FJJ=ALC(K6+5) CF2
NN=K6+6 CF2
NQ=I4+1 CF2
DO 23 I=1,NQ CF2
NN=NN+6 CF2
23 ALC(NN)=0.0 CF2
TMP(1)=0.0 CF2
24 TMP(2)=1.0 CF2
25 IF(ALC(K6+5)-TMP(1))2311,2311,231 CF2
2311 TMP(1)=TMP(1)+1.0 CF2
TMP(2)=TMP(2)*XBAR CF2
IF(TMP(2))25,24,25 CF2
231 ALC(K6)=TMP(2) CF2
IF(TMP(1))2,2322,2322,232 CF2
2322 K6=K6 CF2
236 KK6=K6-6 CF2
IF(XMAR2,2344,234 CF2
234 TMP(2)=ALC(KK6+6) CF2
ALC(KK6+6)=0.0 CF2
GO TO 235 CF2
234 TMP(2)=ALC(KK6+6)/XBAR CF2
235 ALC(KK6)=TMP(2)*TMP(1) CF2
TMP(1)=TMP(1)-1.0 CF2
IF(TMP(1))236,232,236 CF2
232 NN=1 CF2
TMP(1)=ALC(K6+2) CF2
TMP(2)=ALC(K6+1) CF2
KK6S=K6 CF2
KK6S=K6+6 CF2
DO 241 I=1,NQ CF2
KK6S=KK6-6 CF2
NN=NN+2 CF2
DER(NN)=TMP(1)*ALC(KK6) CF2
241 DER(NN+1)=ALC(KK6)**2/TMP(2) CF2
242 L3=0 CF2
L7=0 CF2
L1=1 CF2
L4=6 CF2
26 IF(FJJ-FKR)2111,2111,211 CF2
2111 FJJ=FJJ+1.0 CF2
KK6=KK6S CF2
NN=1 CF2
TMP(1)=ALC(KK6-2) CF2
TMP(2)=ALC(KK6-3) CF2
TMP(3)=ALC(KK6-4) CF2
TMP(4)=ALC(KK6-5) CF2
KK6S=KK6-6 CF2
TMP(6)=0.0 CF2
KK6S=KK6+6 CF2
DO 29 I=1,NQ CF2
KK6=KK6-6 CF2
NN=NN+2 CF2
L6=KK6+L7 CF2
L2=KK6+L1
TMP(5)=TMP(2)*ALC(L2)
TMP(5)=(XRAR-TMP(1))*ALC(L6)-TMP(5)
L5=KK6+L4
ALC(L2)=TMP(6)*ALC(L5)+TMP(5)
DER(NN)=ALC(L2)*TMP(3)+DER(NN)
DER(NN+1)=((ALC(L2)**2)/TMP(4))+DER(NN+1)
29 TMP(6)=TMP(6)+1.0
IF(L3)242,30,242
30 L3=1
L1=0
L4=5
L7=-1
GO TO 26
211 IF(ALC(K6+5))212,212,212
212 DER(1)=DER(1)+ALC(K6+3)
212 RETURN
END
* X0T MAIN
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