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PROGRAM TITLE: OPERATING INSTRUCTIONS FOR MOMENT METHOD CIRCUIT ANALYSIS ON THE RECOMP II

PROGRAM CLASSIFICATION: General

AUTHORS: A. Lechler, M. Duffy, J. E. Drennan
Battelle Memorial Institute

PURPOSE: To present detailed operating instructions for the circuit subroutine generator (compiler) and the moment method computer programs which have recently been developed and checked out on the RECOMP.

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OPERATING INSTRUCTIONS FOR MOMENT METHOD CIRCUIT ANALYSIS ON THE RECOMP II

The purpose is to present detailed operating instructions for the circuit subroutine generator (compiler) and the moment method computer programs which have recently been developed and checked out on the RECOMP.

The programs are logically divided into two sections:

I Circuit subroutine generation (compilation), and

II Moment method circuit analysis.

Division I is essentially performed by loading one tape and typing one set of input. The results are one tape punched from the computer. The operating instructions are described in Section I.

Division II consists of two phases. Phase 1 is the calculation of partial derivitives and is performed by loading two tapes, typing one set of input and waiting for the typeout of the partials. Phase 2 consists of loading a third tape, typing one more set of input and waiting for the typeout of the output parameter variances. The operating instructions are described in Section II.

Limitations

Throughout the programming of this problem, an effort was made to conserve space so that as large a circuit as possible could be used in this analysis. Even so, the memory size of the RECOMP makes certain limitations necessary, the most important of which are given below:

(1) The number of input parameters must be not greater than 30.

(2) The number of output parameters must be not greater than 25.

(3) The size of the matrix of coefficients must be not greater than 12 x 12.

(4) The number of constants appearing in the matrix equation other than the constant 1, must be not greater than 49. If the same constant appears more than once it is counted for each appearance. (Error stop 0002.0)

(5) The number of orders generated by the compiler must be not greater than 896. (Error stop 0004.0)

(6) The number of pairs of parenthesis in any one expression (i.e., matrix element, failure test, or stress function) must be not greater than 10. (Error stop 0001.0)

(7) During compilation a table called the A table is generated. The table contains for each input parameter:
   A) One word of identification
   B) One word for each appearance of that particular input parameter in any matrix element.
This table must contain not more than 150 words. (Error stop 0003.0)

Round off error

During the calculation of partials the method used to solve the matrix equation is a convergence technique. As the program is now written each solution must agree with the value of the same solution from the previous iteration to a tolerance of .0001. This means that each matrix solution whose absolute value is not less than 1, is accurate to 5 significant figures.

A glance at the formula used to calculate the partial derivitives (Ref. 1 above) will reveal, however, that when an input parameter has very little affect on an output parameter,(i.e., the partial is very small) numbers which are very nearly equal are subtracted. When this occurs, significant figures are lost on occasion. In the flight control flip flop (i.e., the test case), during the calculation of partials all five significant figures were lost. This means that some of the partials were not accurate, even in the first significant figure. At first thought this seems critical. However we anticipate that those partials which are inaccurate will contribute very little to the output variances any way. So the output variances should be accurate to at least 2 or 3 significant figures. If, however, the situation is still considered critical, the tolerance on the matrix solutions may be tightened by modifying the floating point number in locations 1506 and 1507 on Tape No. 1, the calculation of partials tape. This increase in accuracy will only be achieved at the expense of computer time.

The sample problem used to check out these programs was the flight control flip flop. The matrix, stress functions, failure test, and computer input and output are included in Appendix A of this IOL.

I. Circuit Subroutine Generation (Compilation)

In order to generate the circuit subroutine tape, the following steps should be performed in sequence.

(1) Load tape #3 (compiler tape).

(2) Verify tape #3.

(3) Push "start" button. *

(4) Shortly thereafter the computer will type "MATRIX ORDER" and stop, waiting for the size of the matrix of coefficients (≤ 12) to be typed. Type this value and hit "carriage return".

(5) Immediately thereafter the computer will type "COEFFICIENTS"; do a carriage return; and stop, waiting for the non-zero matrix elements to be entered.

(6) For each non-zero matrix element two lines of information must be typed. They are:

a. The location of the matrix element in the following form: row, comma, column, carriage return. e.g., for the second element in the third row type "3" "," "2" "carriage return". For the third element of the dependent column vector of a 10 x 10 matrix, type "3" "," "11" "carriage return".

b. The algebraic representation of the matrix element in the following format, which is intuitively oriented:

1) The entire expression must be enclosed in parentheses. Other sets of parentheses are used, as needed, to avoid ambiguity in the algebraic expression.

2) This expression must be a function of A's and constants only.
The A's are the identification of the input parameters; these should be assigned prior to compilation. The subscripts of the A's are not enclosed in parantheses. Immediately preceding each A "letter shift" must be typed and immediately following each A "figure shift" must

* The location counter should be set at 0100.0. This should be done at the end of the tape; if not a new tape should be made.

be typed. The only two times these two keys are hit is in typing the letters A, V, GE, G, L, LE, or L or in typing the word STOP (each of these letters will be described as they appear).

The constants are typed in the following format: xx---x.xx---x i.e., the value of the constant (≤ 500 000 000 000) without using an exponent and including a decimal point.

e.g., 6. , 6.0, 6.5, .5, 0.5.

3) Four operations are permitted.

+ add
- subtract
& multiply
/ divide

Multiplications and divisions are performed first (from left to right) and then additions and subtractions.

e.g., (A1 +A2/A3) is compiled as:
divide A2 by A3 and then add A1 to the quotient.
(12.+2./3.) = 12.66
((A1+A2)/A3) is compiled as:
add A1 to A2 and then divide the sum by A3.
((12.+2.)/3.) = 4.66
(A1 & A2 & A3) is compiled as:
multiply A1 by A2 and then multiply this product by A3.
(12. & 2. & 3.) = 24. & 3. = 72.
(A1 & (A2 & A3)) is compiled as:
multiply A2 by A3 and then multiply this product by A1.
(12. & (2. & 3.)) = 12. & 6. = 72.
(A1/A2 & A3) is compiled as:
divide A1 by A2 and then multiply this quotient by A3.
(12./2. & 3.) = 18.
(A1/(A2 & A3)) is compiled as:
divide A1 by the product of A2 and A3.
(12./(2. & 3.)) = 2.

(7) After the computer types "COEFFICIENTS" and the carriage returns then, for each non-zero matrix element, type:

a. "row number", "comma", "column number", "carriage return".

b. When the computer stops type: "left parenthesis", "algebraic representation of the matrix element", "right parenthesis", "carriage return".
e.g., If $\frac{A1}{A2+A3} = A4$ were in row 3, column 3, one would type:

3
,
3
carriage return
(
letter shift
A
figure shift
1
/
(
letter shift
A
figure shift
2
+
letter shift
A
figure shift
3
)
=
letter shift
A
figure shift
4
)
carriage return

(8) For each non-zero matrix element the generated instructions for evaluating each matrix element are punched out and the computer halts when it is ready to receive the next matrix element. Repeat Step (7). When all non-zero matrix elements have been entered and the computer is ready to accept another element type: "letter shift", "STOP", "carriage return".

(9) The computer will immediately type "FUNCTIONS"; the carriage will return; and the computer will stop, waiting for the first stress function to be typed. With two exceptions these are entered exactly the same as the coefficients.

a. There is no identification line typed i.e., Nothing like "1,3 carriage return" is typed

b. These functions may depend on not only the A's (the input parameters) and constants but on the V's (the matrix solutions) as well. The first element in the matrix solution vector is V1 the second V2, etc.

e.g. Suppose $\frac{V1 \& A1}{6.5} + V3$ were a stress function. One would type:

(
letter shift
V
figure shift
1
&
letter shift
A
figure shift
1
/
6
.
5
+
letter shift
V
figure shift
3
)
carriage return

(10) For each stress function the generated instructions for evaluating it are punched out and the computer stops when it is ready to receive the next stress function. Repeat Step (9). When all stress functions have been entered and the computer is ready to receive another, type "letter shift", "STOP", "carriage return".

(11) The computer will immediately type "FAILURE TESTS"; the carriage will return; and the computer will stop, waiting for the first failure test to be typed. Each failure test consists of two algebraic expressions, each of which is completely enclosed in parentheses, and the two are separated by one of the following four expressions.

a. GE
b. G
c. LE
d. L

In order for the circuit to fail:

a. If GE is used, the expression on the left must be greater than or equal to the expression on the right.

b. If G is used, the expression on the left must be greater than the expression on the right.

c. If LE is used, the expression on the left must be less than or equal to the expression on the right.

d. If L is used, the expression on the left must be less than the expression on the right.

Within each of the two expressions (referred to above as "the expression on the left" and "the expression on the right") typing is exactly the same as for the stress functions.

e.g., Suppose a circuit will fail when $\left(\frac{V1 \,\&\, V2}{A1 + V2}\right) \leq \left(V2\right)^2$

One would type:

(
letter shift
V
figure shift
1
&
letter shift
V
figure shift
2
/
(
letter shift
A
figure shift
1
+
letter shift
V
figure shift
2
)
)
letter shift
L
E

figure shift
(
letter shift
V
figure shift
2
&
letter shift
V
figure shift
2
)
carriage return

(12) For each failure test the generated instructions for determining the success or failure of the circuit are punched out and the computer stops when it is ready to receive the next failure test. Repeat step (11). When all failure tests have been entered and the computer is ready to accept another failure test type "letter shift", "STOP", "carriage return".

(13) The computer will punch out the memory of the compiler, the A table, and stop at 0006.0. This is the end of the program. Advance the tape and tear it off. This is the complete compiled portion of the circuit subroutine, ready to be read into the machine for Phase II (calculation of partials and variances).

(14) There are error halts programmed into the compiler. These can be distinguished from stops where the computer is waiting for typed information by the alpha light on the console. This light will be on if the computer is waiting for information from the typewriter. The error halts are identified by the location lights on the console.

0001.0 - There are too many parentheses in a statement. Each of the coefficients and stress functions and each half of the failure test may have up to ten sets of parentheses.

0002.0 - There are too many constants in the compiled program. The number of constants, counting each repeated occurrence separately but not counting the constant 1.0, must be less than fifty.

0003.0 - The A table is too big. The number of input parameters (the A's) plus the number of non-zero matrix elements each of them appears in must not be greater than one hundred and fifty.

0004.0 - There are too many orders in the compiled program. The number of orders must not exceed eight hundred and ninety six.

0005.0 - The number of left parentheses is not equal to the number of right parentheses. Push the appropriate numbered start switch as described below.

0006.0 - This is the end of the program.

1220.0 - Something has been typed wrong; e.g., a figure shift when it was not needed or two letter shifts before an A or V. Push the "start" button (not one of the numbered start buttons). The tape will automatically be reset and the computer will soon stop, ready for the statement to be typed in again. In the case of the coefficients the identification, "row", "comma", "column", "carriage return", must be re-entered also.

There are three numbered start switches at the right hand side of the console. These are to be used in conjunction with error stop 0005.0 and any other time when an error in the type-in has been made and recognized before the carriage return is hit which sends the computer on to compiling and punching out an algebraic statement. Simply press the error reset button and then the appropriate start button.

SW #1 - This switch is to be used during the "coefficients" phase of the compiling. It can be used any time before the carriage return following the algegraic statement has been hit. Thus it can be used if an error in the identification is discovered while one is typing in the corresponding algebraic statement. In all cases the identification, "row", "comma", "column", "carriage return", must be typed again, as well as the algebraic statement.

SW #2 - This switch is to be used during the "stress functions" phase of the compiling. The algebraic statement must be re-entered from the typewriter.

SW #3 - This switch is used during the "failure tests" phase of the compiling. The algebraic statements must be retyped.

It is hoped that these error halts will catch most of the errors of the typist but no attempt was made to catch all errors. If there is an error, noticed later by the typist, but not noticed by the machine at the time of compilation of that statement, there is only one easy thing to do - start over.

MOMENT METHOD OPERATING INSTRUCTIONS

II. Calculation of Partial Derivitives, and Variances of Output Parameters

Upon completion of the circuit subroutine compiler, calculation of the partial derivitives and variances of output parameters may begin. The following steps should be performed in sequence.

(1) Load tape #1 (calculation of partials tape)

(2) Verify tape #1.

(3) Load the compiled circuit subroutine tape, i.e., the tape that was punched during the compilation phase.

(4) Verify the circuit subroutine tape.

(6) The computer will immediately type "N IS", and stop waiting for the number of different input parameters, i.e., the number of different A's. Type the value of N, and hit carriage return.

(7) The computer will immediately type "ITS IS", and stop waiting for the number of different output parameters, (i.e., number of matrix solutions + the number of functions). Type the value of ITS, and hit carriage return.

(8) The computer will immediately type "MEANS", do a carriage return and stop waiting for the means of each input parameter to be typed in. Type:

   a. The mean value of input parameter A_i in the format * ±xxxxx---x.xxx---x i.e., Type the value of $\overline{A_i}$ without using an exponent and be sure to include the decimal point.

   b. Hit the carriage return.

   c. Do (a) and (b) for i = 1,2,3,4...N. After each carriage return be sure to wait for the computer to stop before typing the next mean value.

(9) The Recomp will then solve the matrix equation with all parameters at their mean value. If any of the failure tests indicate failure, the Recomp will stop with (5060.1) in the location counter. This stop probably means that

* If any mean or correlation coefficient is negative type "-", if they are positive, however, do not type a sign.

something is wrong with the equivalent circuit. Pushing the start button will cause the mean matrix solutions to be typed out in decimal floating point, five words per line. If the circuit passes all the failure tests the mean matrix solutions will automatically be typed out in decimal floating point, five words per line.

(10) In <u>either</u> case after the type-out of the mean matrix solutions, the computer will proceed automatically to the calculations of partials. This operation will run interrupted for a fairly long period of time. For a 6 x 6 matrix, 21 input parameters and 2 functions the time required is one hour and 23 minutes. As the partials are calculated they are typed out (decimal floating point, five words per line) in groups of ITS. The first group will be:

$$\partial v_1/\partial x_1,\ \partial v_2/\partial x_1,\ \partial v_3/\partial x_1,\ \ldots\ \partial v_{ITS}/\partial x_1,$$

the second

$$\partial v_1/\partial x_2,\ \partial v_2/\partial x_2,\ \partial v_3/\partial x_2,\ \ldots\ \partial v_{ITS}/\partial x_2,$$

and so on until the last group, which will be

$$\partial v_1/\partial x_n,\ \partial v_2/\partial x_n,\ \partial v_3/\partial x_n,\ \ldots\ \partial v_{ITS}/\partial x_n.$$

The approximate time required for the calculation of partials can be determined by noting the time elapsed between the type-out of the mean matrix solutions and the type-out of the first set of partials and multiplying by N.

(11) After all the partials are calculated, the Recomp will stop with (0003) in the location counter.

(12) The next thing to do is load Tape#2 (calculation of Variance Tape). <u>Be sure not to use a memory zero routine.</u>

(13) Verify Tape #2.

(14) Push the start button. *

(15) The Recomp will immediately type "Variances", do a carriage return and stop waiting for the variance of each input parameter to be typed. Type:

(A) The variance of input parameter A_i in the format xxx---x.xxx---x i.e., type the value of $\sigma^2 A_i$ without using an exponent and be sure to include the decimal point.

(B) Hit the carriage return.

(C) Do (A) and (B) for i=1,2,3 ... N. After each carriage return be sure to wait for the computer to stop before typing the next variance.

(16) After the variances are read in, the computer is ready to accept the correlation coefficients for all input parameters of multi-parameter parts. For each such part it is necessary to type in the following information:

(A) Part I.D. (any 2-digit identification for the part) this number will appear in the output as an identification of the part.

(B) NOP, the number of parameters in the part.

(C) For every possible combination of parameters in the identified part a correlation coefficient must be typed in, even if it is zero. Along with this correlation coefficient the input parameter numbers of the two parameters being correlated are typed.

The above information is typed as follows:

(17) The computer will type "MULTI PARA PARTS", do a carriage return, type "PART ID", and stop waiting for a multi-parameter part identification. Type any two-digit number you choose. Do not hit the carriage return. The computer will immediately type "NOP", and stop waiting for the number of parameters in this multi-parameter part to be typed. Type the value of NOP, and hit carriage return.

(18) The computer will immediately type "CORR COEFF", do a carriage return and stop waiting for the correlation coefficients for this part to be typed in. For every possible pair of input parameters in this multi-parameter part type:

* The location counter should be set to 0100.0, if it is not, the location counter will have to be set from the keyboard. If this is the case, a new tape #2 should be punched including the setting of the location counter to 0100.0.

(A) The correlation coefficient in the format* $\pm$.xxxx---x, i.e., type the number without using an exponent, and be sure to include the decimal point.

(B) Hit the space bar, and wait for the Recomp to stop.

(C) Type the input parameter number of one of the two parameters being correlated.

(D) Hit the space bar, and wait for the computer to stop.

(E) Type the input parameter number of the second of the two parameters being correlated.

(F) Hit the carriage return.

(G) Perform staps (A) through (F) for all possible combinations of the parameters in this part (i.e., if there are n input parameters in this part, $\frac{n(n-1)}{2}$ lines of correlation coefficients must be typed).

(19) When the input for one multi-parameter part is completed the computer types "PART ID" again, expecting input for another multi-parameter part. If there are more multi-parameter parts, repeat steps 17 and 18, when there are no more multi-parameter parts, type letter shift, END.

(20) The input is now complete. The computer automatically starts to calculate the output parameter variances. For each of the ITS output parameters the following information is typed out.

(21) The computer types "VAR of i" (i is the number of the output parameter being evaluated), does a carriage return and types out the total variance of output parameter i in decimal floating point. It then does a carriage return, types "ST DV IS", does a carriage return and types the standard deviation of output parameter i in decimal floating point.

(22) The Recomp next types "PERCENT OF VAR DUE TO EACH PARA", and does a carriage return.

(23) It will then type out N lines of information. Each line will contain two numbers. The first is in decimal floating point and represents the percent of the total variance of output parameter i that is attributable to the input parameter whose identification is the second number on the same line.

* If any mean or correlation coefficient is negetive type "-", if they are positive, however, do not type a sign.

(24) Next the computer types "PERCENT OF VAR DUE TO EACH PART", and does a carriage return.

(25) One line of output is then typed for each multi-parameter part for which input data has been typed in. Each line contains two numbers. The first is in decimal floating point and is the percent of the total variance of output parameter i that is attributable to the multi-parameter part whose identification is the second number on the same line.

(26) Steps (21) through (26) are performed for each output parameter (i.e., for i=1, 2, 3 --- ITS)

(27) The program is finished and stops with (0002) in the location counter. For a circuit with 21 input parameters, 8 output parameters, and 3 multi-parameter parts. The variance section required 29 minutes including typing in the data.

J. E. Drennan

J. E. Drennan
Battelle Memorial Institute

Appendix A (Sample Problem)

As mentioned above, the sample problem used to check out these programs is the flight control flip flop. This circuit and the same set of data that was used on the Recomp were run through the Moment Method program on the IBM 709. The output is labeled:

00 6380-53 (004) 100 27 J DUFFY 3043-054 06/03/20

If this output is not available at N.A.A., it can be obtained from A. Lechler at Battelle Memorial Institute.

TABLE 1 The Flight Control Flip Matrix as Provided by the Designer or the Circuit Analyst.

		1	2	3	4	5	6		
$\frac{V_D - S_2}{R_{F8}} - \frac{V_{KR}}{R_0} - I_{E0} + \frac{K_D}{R_9+R_{F5}}$		$\frac{1}{R_9+R_{F5}} + \frac{1}{R_0} + \frac{1}{R_d} + \frac{1}{R_{F8}} + \frac{1}{R_2+R_{CR4}}$	$-\frac{1}{R_0}$	$-\frac{1}{R_2+R_{CR4}}$	$-\frac{1}{R_d} - \frac{1}{R_9+R_{F5}}$	0	0		V_1
$\frac{V_{KR}}{R_0} - \frac{V_{BE}}{R_b}$		$-\frac{1}{R_0}$	$\frac{1}{R_b} + \frac{1}{R_0} + \frac{1}{R_{CX}}$	$-\frac{1}{R_b}$	0	0	$-\frac{1}{R_{CX}}$		V_2
$\frac{V_{BE}}{R_b} - \frac{S_2}{R_5}$	=	$-\frac{1}{R_2+R_{CR4}}$	$-\frac{1}{R_b}$	$\frac{1}{R_2+R_{CR4}} + \frac{1}{R_5} + \frac{1}{R_4} + \frac{1}{R_b}$	0	$-\frac{1}{R_4}$	0	×	V_3
$\frac{-S_2}{R_8} - \frac{K_D}{R_9+R_{F5}} + I_{C0} + I_{E0}$		$-\frac{1}{R_d} - \frac{1}{R_9+R_{F5}}$	0	0	$\frac{1}{R_7} + \frac{2}{R_d} + \frac{1}{R_8} + \frac{1}{R_9+R_{F5}}$	$-\frac{1}{R_d}$	$-\frac{1}{R_7}$		V_4
$\frac{S_1}{R_3} - I_{C0}$		0	0	$-\frac{1}{R_4}$	$-\frac{1}{R_d}$	$\frac{1}{R_3} + \frac{1}{R_{L1}} + \frac{1}{R_d} + \frac{1}{R_4}$	0		V_5
$\frac{S_1}{R_6}$		0	$-\frac{1}{R_{CX}}$	0	$-\frac{1}{R_7}$	0	$\frac{1}{R_6} + \frac{1}{R_7} + \frac{1}{R_{L2}} + \frac{1}{R_{CX}}$		V_6

CONSTANTS

$R_{CR4} = 1 \times 10^6$ ohms

$K_D = .5$ volts

$V_{KR} = .026$ volts

$R_d = 30 \times 10^6$ ohms

FUNCTIONS

$$\left[\frac{V_3 - V_1}{R_2 + R_{CR4}}\right]^2 R_2$$

$$\frac{(S_1 - V_5)^2}{R_3}$$

FAILURE TEST

$V_6 \leq -16$

TABLE 2 Flight Control Flip Flop After Input Parameters have been Assigned Identifications

		MATRIX 1	2	3	4	5	6		
$\frac{A_3 - A_{19}}{A_{15}} - \frac{.026}{A_{21}} - A_{17} + \frac{.5}{A_{11} + A_{14}}$		$\frac{1}{A_{11}+A_{14}} + \frac{1}{A_{21}} + \frac{1}{3} \times 10^{-7} + \frac{1}{A_{15}} + \frac{1}{A_6 + 1{,}000{,}100.}$	$-\frac{1}{A_{21}}$	$-\frac{1}{A_6 + 1{,}000{,}000.}$	$-\frac{1}{3} \times 10^{-7} - \frac{1}{A_{11} + A_{14}}$	0	0		V_1
$\frac{.026}{A_{21}} - \frac{A_{20}}{A_5}$		$-\frac{1}{A_{21}}$	$\frac{1}{A_5} + \frac{1}{A_{21}} + \frac{1}{A_4}$	$-\frac{1}{A_5}$	0	0	$-\frac{1}{A_4}$		V_2
$\frac{A_{20}}{A_5} - \frac{A_{19}}{A_9}$	=	$-\frac{1}{A_6 + 1{,}000{,}000.}$	$-\frac{1}{A_5}$	$\frac{1}{A_6 + 1{,}000{,}000.} + \frac{1}{A_9} + \frac{1}{A_8} + \frac{1}{A_5}$	0	$-\frac{1}{A_8}$	0	x	V_3
$\frac{-A_{19}}{A_{10}} - \frac{.5}{A_{11} + A_{14}} + A_{16} + A_{17}$		$-\frac{1}{3} \times 10^{-7} - \frac{1}{A_{11} + A_{14}}$	0	0	$\frac{1}{A_2} + \frac{2}{3} \times 10^{-7} + \frac{1}{A_{10}} + \frac{1}{A_{11} + A_{14}}$	$-\frac{1}{3} \times 10^{-7}$	$-\frac{1}{A_2}$		V_4
$\frac{A_{18}}{A_7} - A_{16}$		0	0	$-\frac{1}{A_8}$	$-\frac{1}{3} \times 10^{-7}$	$\frac{1}{A_7} + \frac{1}{A_{12}} + \frac{1}{3} \times 10^{-7} + \frac{1}{A_8}$	0		V_5
$\frac{A_{18}}{A_1}$		0	$-\frac{1}{A_4}$	0	$-\frac{1}{A_2}$	0	$\frac{1}{A_1} + \frac{1}{A_2} + \frac{1}{A_{13}} + \frac{1}{A_4}$		V_6

FUNCTIONS

$$\left[\frac{(V_3 - V_1)}{A_6 + 1{,}000{,}000.}\right]^2 A_6$$

$$\frac{(A_{18} - V_5)^2}{A_7}$$

FAILURE TESTS

$$V_6 \leq -16.$$

MATRIX ORDER 6
COEFFICIENTS
1,1
(1./(A11+A14)+1./A21+.00000003333+1./A15+1./(A6+1000000.))

1,2
(-1./A21)

1,3
(-1./(A6+1000000.))

1,4
(-.00000003333-1./(A11+A14))

1,7
((A3-A19)/A15-.026/A21-A17+.5/(A11+A14))

2,1
(-1./A21)

2,2
(1./A5+1./A21+1./A4)

2,3
(-1./A5)

2,6
(-1./A4)

2,7
(.026/A21-A20/A5)

3,1
(-1./(A6+1000000.))

3,2
(-1./A5)

3,3
(1./(A6+1000000.)+1./A9+1./A8+1./A5)

3,5
(-1./A8)

3,7
(A20/A5-A19/A9)

4,1
(-.00000003333-1./(A11+A14))

4,4
(1./A2+.00000006667+1./A10+1./(A11+A14))

4,5
(-.00000003333)

4,6
(-1./A2)

```
4,7
(-A19/A10-.5/(A11+A14)+A16+A17)

5,3
(-1./A8)

5,4
(-.00000003333)

5,5
(1./A7+1./A12+.00000003333+1./A8)

5,7
(A18/A7-A16)

6,2
(-1./A4)

6.4
(-1./A2)

6.6
(1./A1+1./A2+1./A13+1./A4)

6,7
(A18/A1)

STOP

FUNCTIONS
(((V3-V1)/(A6+1000000.))&((V3-V1)/(A6+1000000.))&A6)

((A18-V5)&(A18-V5)/A7)

STOP

FAILURE TESTS
(V6)LE(-16.)

STOP

N IS21
ITS IS8
MEANS
3300.
9100.
6.2
10.
350.
10000.
3300.
9100.
33000.
33000.
10000.
5000.
1000.
```

25.
10.
.0000005
.000001
25.
25.
.5
.5

-18463485 +02 -18420641 +02 -16994322 +02 -19324729 +02 93108267 +01
-18110236 +02

-38495695 -04 -40419799 -04 -38784192 -04 -52152548 -04 -69560491 -05
-78948597 -04 -83099568 -14 66142217 -07

17198094 -07 21104762 -07 20127708 -07 -61049262 -04 29056274 -09
99265952 -07 84384964 -16 -27636697 -11

98592984 +00 98523291 +00 94537997 +00 85515616 +00 16953383 +00
97243294 +00 -11680098 -08 -16120276 -02

-39731677 -03 -41788452 -03 -40094622 -03 13667030 -01 -71138584 -04
30210886 -01 -10454531 -12 67642887 -06

-30136533 -05 -31656186 -05 25356278 -02 -26203241 -05 45458624 -03
-31243333 -05 73123805 -10 -43224741 -05

-14551914 -11 54049965 -13 48265581 -09 -33122929 -12 86351060 -10
-41161129 -12 13944452 -16 -82143878 -12

-24424649 -05 -25645439 -05 -89174330 -04 -25029393 -05 -23664007 -02
-25315257 -05 -24982488 -11 22501134 -04

-24645268 -05 -25877272 -05 -90009022 -04 -21242919 -05 50210207 -03
-25539755 -05 -25216560 -11 -47742826 -05

69498662 -07 72972590 -07 25380703 -05 61933305 -07 45502765 -06
72023186 -07 71105425 -13 -43266719 -08

44565539 -07 45710172 -07 43904352 -07 21763166 -04 90537589 -08
68655807 -07 -19044771 -16 -86087739 -10

47041509 -08 38892686 -08 37024643 -08 -14979761 -04 -15013521 -09
-12396186 -07 -28852937 -16 14299800 -11

63139966 -06 66295763 -06 23052388 -04 64703244 -06 61173648 -03
65442240 -06 64582038 -12 -58167513 -05

-17610990 -03 -18491227 -03 -17742971 -03 -23858720 -03 -31822496 -04
-36117362 -03 -38016213 -13 30258704 -06

41197162 -08 32959393 -08 29780146 -08 -14980277 -04 -22797999 -09
-12706731 -07 -33113081 -16 17713491 -11

33178173 -01 33154720 -01 31813602 -01 28777422 -01 57050944 -02
32723980 -01 -39305464 -10 -54247406 -04

68421856 +01 69810822 +01 -53470314 +02 41743268 +04 -16408001 +04
11405814 +02 -17372468 -05 15601742 +02

-13018878 +01 -10753207 +01 -10228920 +01 41675120 +04 40946450 -01
34443802 +01 80291626 -08 -38897265 -03

34605053 -02 36334686 -02 21725431 -01 45186292 -02 49827199 +00
65758240 -02 52610802 -09 -47378640 -02

-98647546 +00 -98579950 +00 -95609738 +00 -98195906 +00 -17146213 +00
-97312904 +00 87501860 -09 16303631 -02

-11386434 -02 -11960596 -02 95806706 +00 -99004238 -03 17176184 +00
-11804754 -02 27629228 -07 -16332129 -02

-46930908 -03 33189554 -01 31835809 -01 14797321 -01 57083150 -02
32743187 -01 93052571 -09 -54278082 -04
VARIANCE
500.
3500.
.01
8.
10000.
4500.
500.
3500.
500000.
500000.
4500.
1000.
45.
50.
10.
.00000000001
.00000000004
.03
.03
.0015
.02

MULTI PARA PARTS

PART ID 10 NOP 2
CORR COEFF
0. 3 15
PART ID 11 NOP 4
CORR COEFF
.01 4 5
0. 4 20
.01 4 21
0. 5 20
.01 5 21
0. 20 21
PART ID 12 NOP 2
CORR COEFF
.01 16 17
PART ID END
VAR UF 01

49926392 -01
ST DV IS

22344214 +00
PERCENT OF VAR DUE TO EAC PARA

14841033 -02 01

20734736 -08 02

19469813 +02 03

25294937 -02 04

18190993 -03 05

19086337 -16 06

59744302 -05 07

42579932 -04 08

48371852 -05 09

19890154 -05 10

19945495 -09 11

79850660 -06 12

27954381 -02 13

16997084 -11 14

22048282 +02 15

68225965 -06 16

12350289 -06 17

71956505 -03 18

58474106 +02 19

38952606 -05 20

88230284 -05 21

PERCENT OF VAR DUE TO EACH PART

41518095 +02 10

27414778 -02 11

79995699 -06 12

VAR OF 02

49879389 -01

ST DV IS

22333694 +00
PERCENT OF VAR DUE TO EACH PARA

16377106 -02 01

31254162 -08 02

19460618 +02 03

28007956 -02 04

20090746 -03 05

26356165 -19 06

65927889 -05 07

46987669 -04 08

53378750 -05 09

20944721 -05 10

13646688 -09 11

88115116 -06 12

30847707 -02 13

10889483 -11 14

22037869 +02 15

71090986 -06 16

84336403 -07 17

79404094 -03 18

58449024 +02 19

43020524 -05 20

44168399 -01 21

PERCENT OF VAR DUE TO EACH PART

41498488 +02 10

46907382 -01 11

79034909 -06 12

VAR OF 03

11224404 +00

ST DV IS

33502841 +00
PERCENT OF VAR DUE TO EACH PARA

67006390 -03 01

12632619 -08 02

79625001 +01 03

11457740 -02 04

57280621 +02 05

93395148 -12 06

35423089 -02 07

25262529 -01 08

28695514 -02 09

85866123 -06 10

54958010 -10 11

47344393 -03 12

12621237 -02 13

39505755 -12 14

90170073 +01 15

18533282 -04 16

33912242 -07 17

12615217 -01 18

24432177 +02 19

12266472 +01 20

18059197 -01 21

PERCENT OF VAR DUE TO EACH PART

16979507 +02 10

58541600 +02 11

18583050 -04 12

VAR OF 04

47041513 -01
ST DV IS

21689055 +00
PERCENT OF VAR DUE TO EACH PARA

28909447 -02 01

27729855 -01 02

15545673 +02 03

31765597 +01 04

14595828 -03 05

10495151 -17 06

66586990 -05 07

33574935 -04 08

40769673 -05 09

50342279 +00 10

21465499 -02 11

88996070 -06 12

54453464 -02 13

23852200 -04 14

17604451 +02 15

26951428 +00 16

13431750 +01 17

13021270 -02 18

61493142 +02 19

31254853 -05 20

93092538 -02 21

PERCENT OF VAR DUE TO EACH PART

33150124 +02 10

31890034 +01 11

16247227 +01 12

VAR OF 05

15131386 -01
ST DV IS

12300970 +00
PERCENT OF VAR DUE TO EACH PARA

15988825 -03 01

19528512 -11 02

18994767 +01 03

26756031 -03 04

13656954 +02 05

22175281 -12 06

18504096 +02 07

58314069 +01 08

68417446 -03 09

27086265 -06 10

67034589 -12 11

24731475 +01 12

30116345 -03 13

17174525 -13 14

21510323 +01 15

12945618 +00 16

40310107 -09 17

49223833 +02 18

58287971 +01 19

29245956 +00 20

43069228 -02 21

PERCENT OF VAR DUE TO EACH PART

40505091 +01 10

13957608 +02 11

12945604 +00 12

VAR OF 06

55915037 -01
ST DV IS

23646360 +00
PERCENT OF VAR DUE TO EACH PARA

55735285 -02 01

61679387 -07 02

16911832 +02 03

13058349 +02 04

17457663 -03 05

13635104 -17 06

57306788 -05 07

40829389 -04 08

46385906 -05 09

42149841 -05 10

12366879 -08 11

76592757-06 12

10498226 -01 13

14438068 -10 14

19151536 +02 15

16928330 -05 16

77188698 -06 17

23200265 -02 18

50808158 +02 19

37383200 -05 20

38348046 -01 21

PERCENT OF VAR DUE TO EACH PART

36063368 +02 10

13110022 +02 11

24875819 -05 12

VAR OF 07

54741198 -16
ST DV IS

73987295 -08
PERCENT OF VAR DUE TO EACH PARA

63074415 -07 01

45528556 -10 02

24921754 -01 03

15972938 -06 04

97679464 +02 05

15984577 -11 06

57006854 -02 07

40656072 -01 08

46180770 -02 09

33128915 -09 10

68435002 -11 11

76191968 -03 12

11880532 -06 13

10015090 -12 14

28222245 -01 15

40114270 -04 16

42843641 -08 17

15168992 -01 18

41960579 -01 19

20917721 +01 20

31635332 -01 21

PERCENT OF VAR DUE TO EACH PART

53144000 -01 10

99837949 +02 11

40110263 -04 12

VAR OF 08

13680783 -05
ST DV IS

11696487 -02
PERCENT OF VAR DUE TO EACH PARA

15988824 -03 01

19540216 -11 02

18994767 +01 03

26756130 -03 04

13656954 +02 05

22194837 -12 06

18504095 +02 07

58314069 +01 08

68417465 -03 09

27085798 -06 10

67260718 -12 11

24731476 +01 12

30116342 -03 13

11467463 -13 14

21510326 +01 15

12945696 +00 16

40233457 -09 17

49223832 +02 18

58287971 +01 19

29245956 +00 20

43069316 -02 21

PERCENT OF VAR DUE TO EACH PART

40505093 +01 10

13957608 +02 11

12945681 +00 12