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AIRPLANE RESPONSIVE ENGINE SELECTION (ARES). VOLUME I. ARES USE--ETC(U)
APR 78 G J ECKARD, M J HEALY F33615-73-C-2084
UNCLASSIFIED AFAPL-TR-78-13-VOL-1 NL

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LEVEL II

AFAPL-TR-78-13
Volume I

AIRPLANE RESPONSIVE ENGINE SELECTION
ARES User Guide

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APRIL 1978

TECHNICAL REPORT AFAPL-TR-78-13
Final Report for Period 15 October 1973 – 15 July 1977

AIR FORCE AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

This technical report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: AFAPL-TR-78-13 Vol. I (18) (19) TR-78-13-VOL-1	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) AIRPLANE RESPONSIVE ENGINE SELECTION (ARES). VOLUME I. ARES USERS GUIDE.	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report Oct 1973 through Feb 1978
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Glenn J. Eckard and Michael J. Healy Boeing Computer Services	8. CONTRACT OR GRANT NUMBER(s): (15) F33615-73-C-2084
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The Boeing Company Boeing Aerospace Company Boeing Military Airplane Development Seattle, Washington 98124	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Program Element 62203F Project 3066 Task 306611 Work Unit 30661115 (16) 3066 (17) 11
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Aero Propulsion Laboratory (TBA) AF Wright Aeronautical Laboratories (AFSC) Wright-Patterson AFB OH 45433	12. REPORT DATE: (11) April 1978
	13. NUMBER OF PAGES: 240
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 239p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(9) Final rept. 15 Oct 73-15 Jul 77,

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft engines, Correlation, Data processing, Design, Experimental design, Latin squares, Mathematical models, Optimization, Parametric equations, Performance, Regression analysis, Strategic bombing, Surfaces, Tactical aircraft, Thermodynamics, Variability.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objectives of the Airplane Responsive Engine Selection (ARES) program were to develop and apply improved analytical techniques for airplane and engine design selection and integration. These objectives were attained in large part by the development of the ARES data management system, the use of which is described in this document. The ARES system allows the efficient management of multi-dimensional parametric analyses with sufficient accuracy for conceptual and preliminary design activities. When used properly, along the guidelines described, it will prove itself to be a powerful analytical tool.

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FOREWORD

This volume is one of two which comprise the final report on ARES Contract F33615-73-C-2084 activity. This volume provides direction to the application of the ARES Data Management System. Volume II reports the inputs, processes and results of early applications of the ARES method as it evolved during the duration of the contract. The program was conducted by the Boeing Aerospace Company, Seattle, Washington, with the support of the Government Products Division, Pratt and Whitney Aircraft group, West Palm Beach, Florida, and under the direction of the Performance Branch, Turbine Engine Division, Air Force Aero Propulsion Laboratory. The work was funded under Project 3066, Task 306611, Work Unit 3066 11 15 during the period October 1973 to December 1977. Technical management of the program was provided by Capt. A. E. Fanning, for the Air Force Aero Propulsion Laboratory and Mr. R. C. Sutton, for the Boeing Aerospace Company, with the support of Mr. W. F. Zavatkay of Pratt and Whitney Aircraft. Contributors to the ARES effort include G. J. Banken, G. J. Eckard, L. D. Hawkins, M. J. Healy and S. G. Kyle. This report was submitted in April 1978.

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SUMMARY

Effective parametric analysis in more than about four independent variables can become extremely cumbersome and economically impractical using traditional methods. This is because data for a fully determined parametric space must be generated and analyzed. The number of independent variable, parametric combinations which must be processed to fully determine design space is ℓ^n, where ℓ is the number of levels for which each of the independent variables is examined and n is the number of independent variables. Obviously, as n approaches ten, the parametric analysis problem becomes formidable if not impossible (ℓ^n = 59,049 parametric combination for ℓ = 3 and n = 10).

It is easy to identify ten important design parameters which should be examined in preliminary design analyses of almost any advanced weapon system. These design parameters can include airframe variables, propulsion system variables and operational variables. They should be examined simultaneously to properly account for interactive effects. However, by the very nature of conceptual and preliminary design phases of activity, time and budget limitations prevent comprehensive analyses of this magnitude using traditional methods.

The ARES data management system was developed to address this deficiency. The ARES system allows efficient, multi-dimensional parametric analyses with relative economy. As a result, preliminary design analyses need not be compromised by reduction of independent parameters of interest, simplification of analysis methods or by neglecting interactive effects.

The ARES method depends upon proper statistical selection of only a fraction of the parametric design combinations which comprise fully determined design space.

Two major analysis elements are responsible for this reduction in the amount of data required for parametric investigation. These elements are (1) a method of fitting simple approximating functions to dependent variable data values, and (2) an optimization method which makes efficient use of the approximating functions to explore design regimes offering maximal performance. These two elements are embodied in computer programs known respectively as the regressor and the optimizer. Included along with these two programs are a number of others which aid in selection of data, data base monitoring and updating, and unification of results. Taken together, these programs are known as the ARES Data Management System.

The ARES system elements are:

1. The Design Selector, LATBIN
2. The Data Base Modification programs, SUBARES and ADDARES
3. The Regression program, MANE
4. The Optimization program, OAPEN
5. The Validation program, EVAQF

The programs are generally utilized in the order listed, with the user's performance program interjected between (1) and (2) for the generation of dependent parameters.

The initial element in the ARES method is the Design Selector. The Design Selector is a method for choosing the combinations of independent design variables to be run on a "simulator" to get a data base from which regression "surfaces" of the dependent variables will be generated. The method uses Orthogonal Latin Squares and in general, chooses $(n + 1)^2$ design combinations for data base generation.

The designs selected during the foregoing activity are evaluated by processing them through performance analyses. In the ARES system, this is called simulation. That is the performance of each design is analytically simulated to determine the system characteristics of each. System characteristics include geometrical parameters, mass properties and performance levels, where performance can encompass subsystem performance, airplane mission capability, system costs, and the like. Mathematical models or simulators of varying degrees of complexity are used to generate these characteristics.

The ARES data management system is not dependent upon any one simulator. Whatever is used at this stage in ARES application, need only be appropriately compatible with design selection output and regression analysis input requirements. However, actual system characteristics simulation can be performed by hand, by computer or by collecting statistical or experimental data.

The next activity in the ARES method is regression or "surface fit" analyses. Here, coefficients are derived for a quadratic function that represents a least squares fit through dependent parameter variations which are due to changes in the independent parameters. The result could be called a curve fit in one or two dimensions. However, the derivation is performed for up to ten independent variables with the ARES system and the multi-dimensional fit may be more properly characterized as a surface rather than a curve. Therefore, the functions derived in the ARES system are referred to as surfaces or surface fits.

Once acceptable regression surfaces have been obtained for all important dependent variables, the optimization program OAPEN is used to explore regions of design optima. The regression surface coefficients are input to the program, along with specifications for the kind of performance optima desired. The OAPEN program finds these optima and outputs the independent design variable combinations and dependent performance variable values at which each different optimum condition is achieved.

Identification of optimal design regions-of-interest and development of sensitivities for optimal designs is accomplished using the ARES optimization element. This program is an application of Fletcher-Reeves conjugate gradient, penalty function minimization. Using this logic, optima may be identified for various degrees of constraint on both requirements and independent variables.

Validation is the important final step in an ARES application. In validation, optimal design performance predicted by the ARES method is checked or validated against performance generated in the simulator or performance model for the same set of independent parameters.

The ARES data management system is a state-of-the-art preliminary design analysis tool. With it, the user can examine up to ten independent variables in parametric analyses at relatively low cost. The method is not difficult to use and a high probability of successful application can be assured if the guidelines presented in this document are adhered to.

SECTION I

INTRODUCTION

Traditional parametric analyses involve plots of curves representing the many independent/dependent variable relationships which may be present. It is felt that three or four representative values for each independent variable must be used to get a reasonable data sample for this type of analysis. All or almost all combinations of the independent variables at four values each must be sampled to get the requisite plot data. If there are, say, ten independent variables in the study, this means sampling essentially 4^{10} combinations, or over one million data points. Obviously, the cost in terms of sampling resources (e.g., computer runs) is prohibitive, to say nothing of the follow-up analysis, which would involve many manhours. For this reason, a practical limit on parametric analysis has traditionally been to use four or fewer independent variables. This can severely limit the scope of an investigation, since all other design/mission factors must then be held fixed.

The ARES method allows a parametric analysis to be done with data taken at only a small fraction of the number of design/mission combinations required by traditional methods. For example, a 10-variable ARES analysis requires on the order of 100 independent variable combinations to be sampled for performance data. Thus, preliminary design analyses with many variables are made possible, and in many cases all important independently-varying factors can be investigated.

Two major analysis elements are responsible for this reduction in the amount of data required for parametric investigation. These elements are (1) a method of fitting simple approximating functions to the dependent variable data values, and (2) an optimization method which efficiently uses the approximating functions to explore design regimes offering maximal performance. These two elements are embodied in computer programs known respectively as the regressor and the optimizer. Included along with these two programs are a number of others which aid in selection of data, data base monitoring and updating, and unification of results. Taken together, these programs are known as the ARES Data Management System.

A computer program is often used to generate performance (dependent variable) data values for combinations of system design and mission parameters (independent variables), which are the input. Such a computer program is referred to as a performance simulator, or simply simulator. Simulators are typically fairly costly to run for a great many independent variable combinations, and as mentioned, many combinations would be required for a traditional analysis with many variables.

The ARES method solves this problem by generating an approximation to the simulator using the performance output from a limited number of independent variable combinations, or sample points. This approximation method is referred to as surface fitting.

If there are n independent variables, each dependent variable can be represented as a hypersurface in (n+1)-dimensional space. Each point on the surface can be represented by n+1 coordinate values, the first n being values for the independent variables and the (n+1)-th coordinate being the corresponding value for the dependent variable. An example is shown for n = 2 in Figure 1.

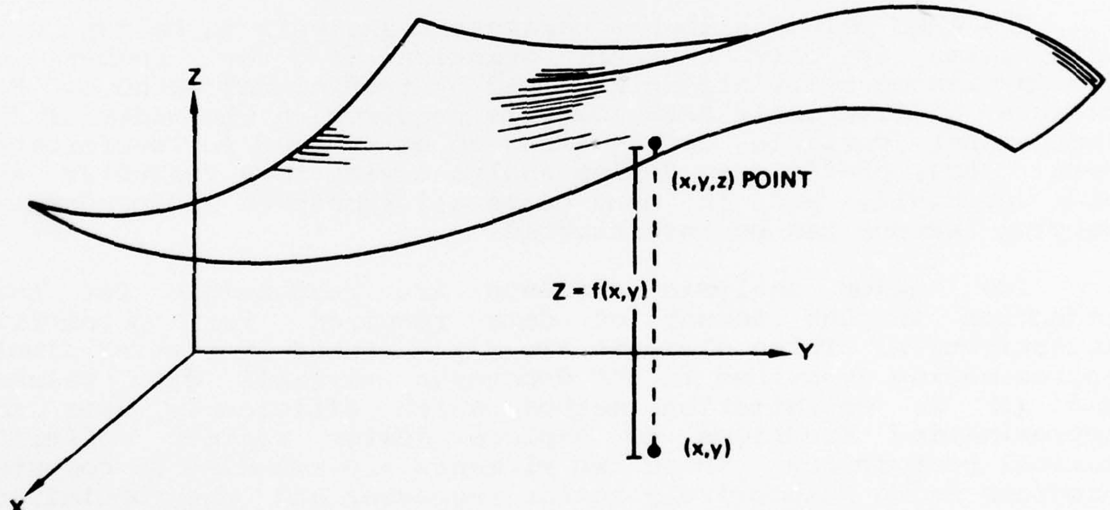


Figure 1. Two-Dimensional Hypersurface in Three-Dimensional Space

The simplified ARES representation consists of fairing a second order (quadratic) surface through a number of sample data points on the imaginary dependent variable surface. The simulator outputs the (n+1)-th coordinate value corresponding to each sample combination of the n independent variables. Since the dependent variable may well have higher than second-order variations in its surface, it is wise not to rely on an exact fit to the data. The simplified second-order surface is therefore selected so that the sum of squares of differences between true dependent variable values and second-order surface values is a minimum (least squares fit technique).

The ARES system elements are:

1) The Design Selector, LATIN

2) The Data Base Modification programs SUBARES and ADDARES

3) The Regression program, MANE

4) The Optimization program, OAPEN

5) The Validation program, EVAQF.

The programs are generally utilized in the order listed, with the user's simulators interjected between (1) and (2).

The Design Selector accepts as input the number of independent variables, n, and lower and upper limits on the values each variable may have in the ensuing analysis. It outputs the sample point combinations of independent variable values for which dependent variable values are to be obtained from the simulator. These combinations are selected by the Design Selector to be well-dispersed uniformly throughout the boxlike region of n-dimensional space specified by the input limits. This is done to insure that a truly n-dimensional sample is taken, with no biasing due to clustering of data and no degeneracy due to sample points accumulating in an (n+1)-dimensional hyperplane. The program method is an application of Orthogonal Latin Squares (OLS).

The output from program LATIN is a set of sample points in the form of values for the independent variables. The values range from lower to upper limit in each variable, and are arranged sequentially in combinations such that the cross-correlation between any pair of independent variables is zero, to aid in making the distribution of sample points uniform in n-dimensional space.

This set of sample points is given to the simulator program as input. The simulator computes the requested performance values and outputs a list containing the independent variable combinations and their associated dependent variable values. This list, referred to as a data base, consists of a sequence of observations of a set of variables and is, hence, in the form of input data for a regression analysis program.

The regression analysis program, MANE, accepts the independent/dependent variable observations and generates a set of coefficients for each dependent variable of interest. The coefficients express the dependent variable as a quadratic or second-order polynomial in the n independent variables. The coefficients are output in the format required by the optimizer program, OAPEN.

The user edits the coefficient file output by MANE to append instructions for OAPEN. This is required because OAPEN needs to know what kinds of optima to locate. The user specifies that one of the dependent variables is to be minimized (e.g., takeoff gross weight) or maximized (e.g., range) subject to performance constraints on the other dependent variables. OAPEN interrogates the coefficients for all the dependent variables and finds the required optimum combination of independent variable values. Repeated calls to the optimization procedure can be made, varying the constrained performance levels or interchanging constrained variables with the variable being minimized (maximized). In this way, relationships between different optima can be charted to yield information on how the design/mission parameters interact.

Following the optimization analysis of program OAPEN, it is essential that results be checked by running the simulator at or near many of the optima. This is important because the surface fitting process embodied in the regressor does not provide accurate error estimates. The error estimates output by MANE, in the form of surface fit residuals at the sample points, are useful as a guide, but the analysis results should be carefully examined and validated in the user's simulator. Program EVAQF has been provided for this purpose. EVAQF compares simulator-derived dependent variable values at the optimum independent variable combinations with values predicted using the surface fit coefficients output by MANE.

What the user has at the end of an ARES analysis is a series of tables and carpet-plots of curves representing interactions between optimized variables. The independent variable combinations in the tables define a region or regions of potentially high payoff. The plots show the effects of varying the requirements used to define the optima. The validation results give a reading on surface error for different optima. The actual dependent variable values output by the simulator at the validation points should be used in place of surface fit values at these points when performance estimates are desired.

The main advantage of the ARES method is that it makes economically feasible the parametric analysis of a system with more than four independent variables. The major expense of the analysis is in running the simulator at a number of sample points to get surface fit data. Once the surface coefficients have been generated, they can be used repeatedly by the highly economical ARES optimizer, OAPEN, to obtain many optima.

The main disadvantage with the ARES method is that it does not contain a reliable error estimation capability. The user must carefully monitor the progress of data gathering, surface fitting, and optimization analysis and final validation to get a feeling for the magnitude and distribution of surface errors for the dependent variables. It may be necessary to run the user's simulator and hence incur the expense of generating performance data to (a) find out if an ARES analysis is possible on the output of the particular simulator, or (b) get the information necessary to redesign the simulator to get a good ARES analysis. Success depends on getting a good approximation to potentially high-order variations using simple second-order functions.

Ways to deal with these potential problem areas are presented in later sections of this document. In many cases, it has been possible to avoid the potential pitfalls of inadequate error estimates and aborted or spurious results from the user's performance simulator. A guiding philosophy for ARES applications is presented, with detailed cautionary notes and helpful hints.

SECTION II

DESIGN SELECTION

2.1 Introduction

The initial element of the ARES method is the Design Selector. The Design Selector is a method for choosing the combinations of independent design variables to be run on a "simulator" to get a data base from which regression surfaces of the dependent variables will be generated. Once all the design points have been processed, a regression analysis is used to surface fit each dependent variable as a surface over the n-dimensional space of the independent variables. The surface fits are obtained as sets of coefficients for quadratic polynomials in n variables.

Before using the Design Selector, the user must define the limits of investigation. First, the problem must be formulated mathematically in terms of independent and dependent variables. Fixed values which will be used for the entire investigation must be specified for all quantities other than independent variables which are input to the simulator. The environment within which the simulator will be run, must be carefully considered, for it is imperative that the simulations all be run under the same conditions. This includes values for fixed inputs, error tolerance limits, the version of program code used, and physical execution environment (file access, I/O formats, etc.). Deviations from run to run may add a fatal noise component to the systematic effects of the independent variables, making the data useless. Also, follow-up runs to validate the results of the optimization analysis downstream must be run under the same conditions as the original regression data base runs.

Currently, the ARES method requires that the user investigate the entire n-dimensional box region lying within fixed lower/upper limits on the independent variables. Thus, a lower and an upper limit must be specified for each independent variable. The subsequent analysis involves potentially any combination of independent variable values within these limits.

2.2 The OLS Method

Once the important variables have been selected and their lower/upper limits chosen, a number of design points lying within these limits are needed. Least squares regression surfaces will be fit to the design point simulation values for each dependent variable.

The literature of response surface analysis and experimental design (or sampling) is full of methods for selecting points out of n-dimensional space (Reference 1). However, these methods are based on statistical considerations which do not necessarily apply to the applications considered here, and are somewhat inflexible where flexibility is needed. The type of data generated for ARES method analysis is here assumed not to result from experimentation subject to random variables such as experimental error. Instead, the dependent variables should have repeatable values at the design points because the simulator is a computer program run under a fixed environment. Also, any lack of fit encountered (a quadratic polynomial will not usually fit the data values exactly) should be evidence that the dependent variable is actually a well-behaved (smooth) function of higher than quadratic order (see for example Figure 2.), and should not be caused by a random component in the data values (see Figure 3.).

Even though established experimental designs are not used, an orderly sampling scheme is still needed. In order to represent the effects of the independent variables individually and in combination in the regression surface coefficients, the data points must be scattered throughout design space. Assuming nothing about the relative importance of one subregion of design space over any other subregion, a uniform distribution is desired. An often-suggested sampling scheme is to simply use a random number generator to select coordinate values for the design points. However, random numbers used in this fashion do not necessarily yield a uniform distribution in n-dimensional space (even if the random numbers are selected from a uniform distribution) (Reference 2), and may well accumulate in an (n-1)-dimensional plane. Figure 4. compares a uniform and random sample for the case n - 2 variables.

The sampling scheme used in ARES is a dispersion of design points generated by Orthogonal Latin Squares (OLS). This method scatters the designs over design space in such a way that cross-correlations between independent variables are zero. Also, designs cannot tend to form a cluster in a subregion since the distribution is uniform. There is much room for improvement over the OLS method, particularly if the user does not wish to sample a rectangular box region in design space. However, the OLS has in most cases provided needed flexibility.

The OLS method is based on the concept of orthogonality. For in-depth treatment of the subject of latin squares, the reader is referred to References 3, 4, 5, or 6, in increasing order of mathematical background required. Orthogonality can be interpreted in a practical way for this discussion.

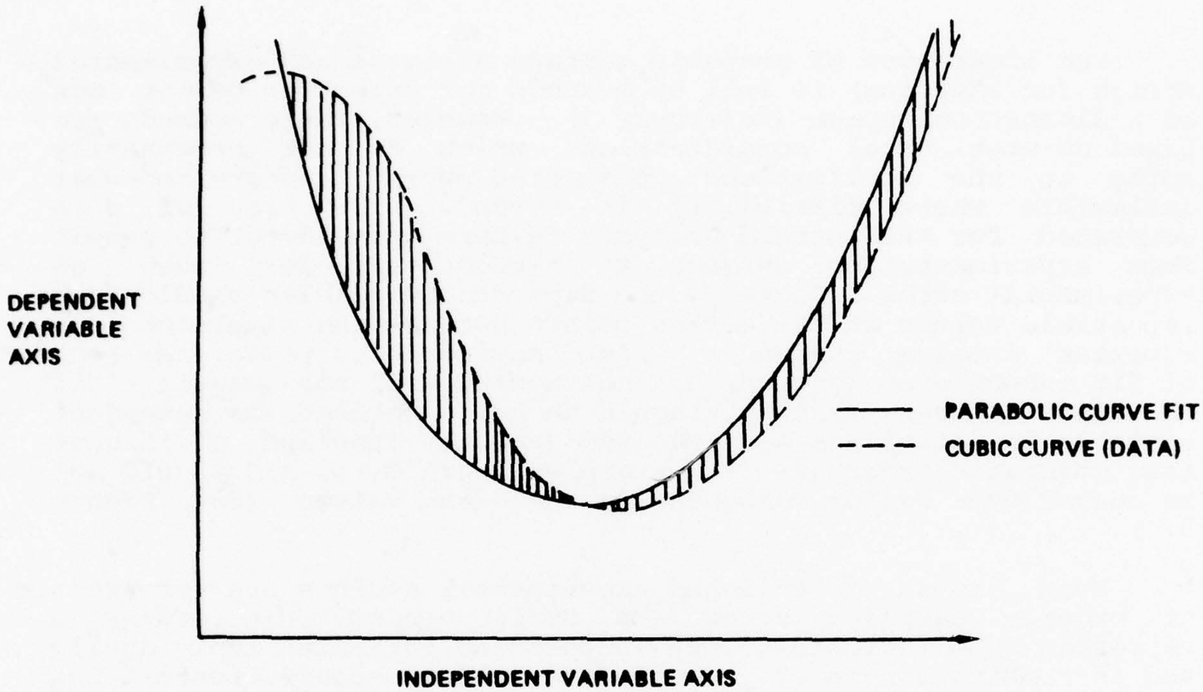


Figure 2. Lack of Fit

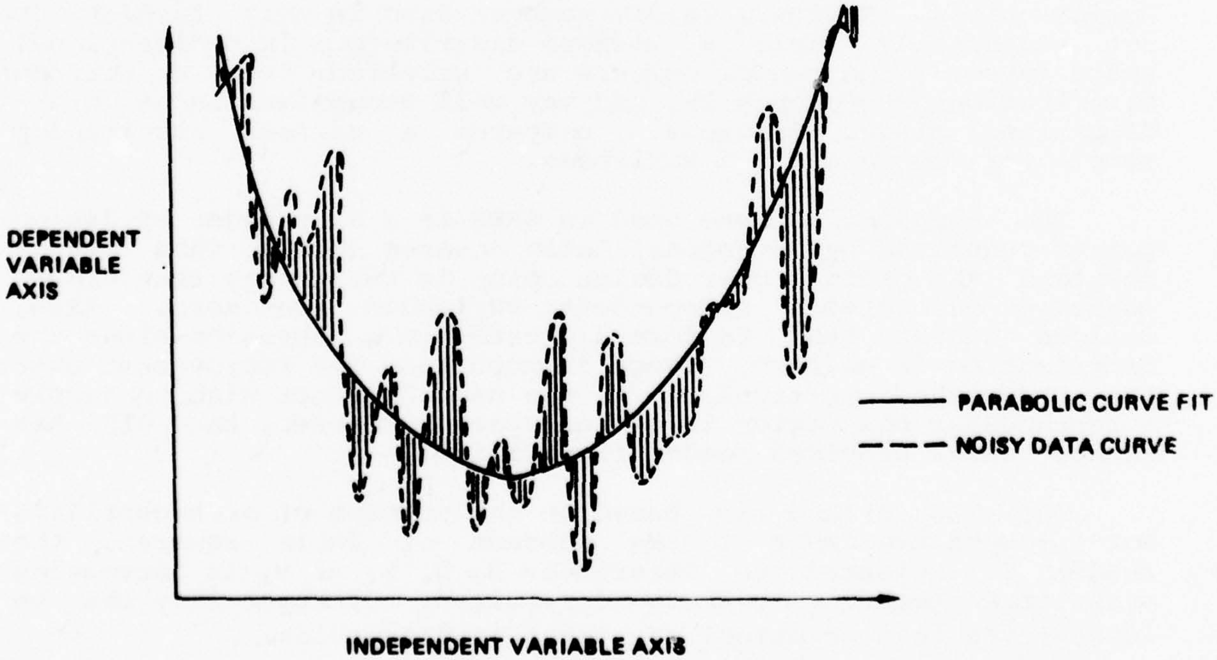
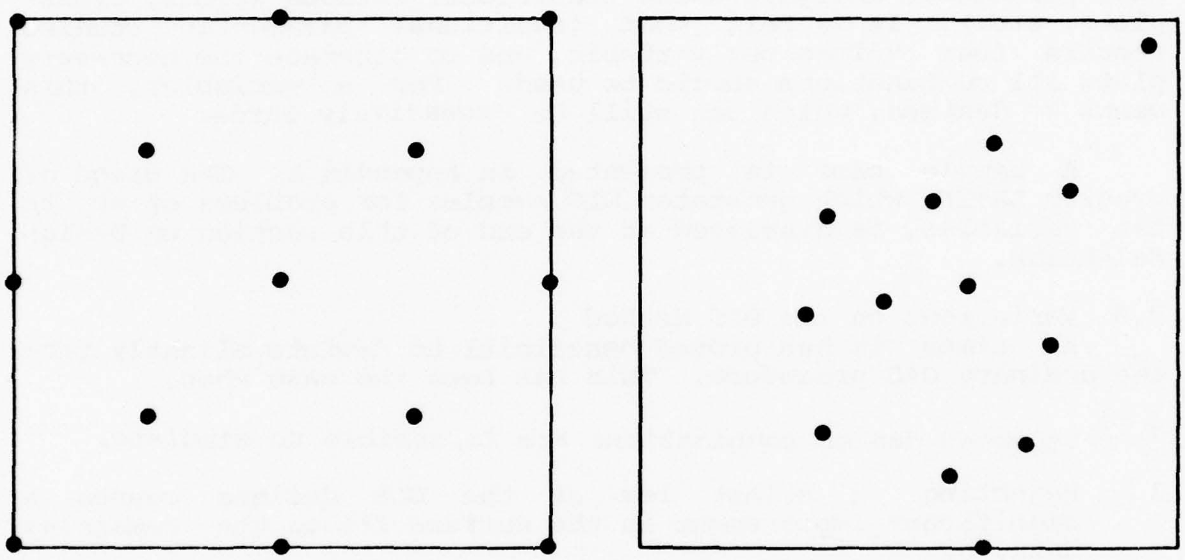


Figure 3. Noise



UNIFORM A

RANDOM B

Figure 4. Hypothetical 2-Dimensional Sample Distributions

Each variable is selected to have a fixed number of values between its lower and upper limits. The values are evenly-spaced, and the same number of values is used for all variables (this number is provided automatically by the method). Orthogonality is then interpreted to mean that every combination of values of any two variables appears once in the sample. This yields slightly in excess of n^2 designs. For 10 independent variables, the variables are each sampled at 11 values, and 121 total designs are created. Were all possible combinations of values of all the variables used, the number of designs resulting would be astronomical.

The number of designs selected by the OLS method can best be compared with an estimate of the number of designs needed for a full parametric analysis using traditional methods (plots, cross-plots, etc.). It is felt that traditional parametric studies require four values per variable, and to generate the necessary plots all combinations should be used. For n variables, this means 4^n designs, which can still be excessively large.

A sample case is presented in Appendix A. The usage of program LATIN, which generates OLS samples for problems of up to ten variables, is discussed at the end of this section on Design Selection.

2.3 Variations on the OLS Method

At times it has proved beneficial to deviate slightly from the ordinary OLS procedure. This has been the case when,

1) Selected design combinations are impossible to simulate,

2) Rejecting a select few of the OLS designs causes a significant improvement in the surface fit to the remaining data, or

3) Significant cost reduction can be achieved by generating fewer combinations of some of the variables than the total specified by the OLS selection.

Examples will be presented to illustrate (1) and (3). For (2), no modification of the OLS selection procedure is proposed except that subsequent parametric analysis should avoid regions of design space lying close to the rejected points. Since this may be difficult to do, this method of improving surface fits should be used with great care. Very few points should be rejected, and their location relative to other designs noted. More will be said about this in the section on Regression.

A deviation from the OLS design selection method, as applied to unscaled variables in square-space, was evolved to handle the skewed design space problem illustrated in Figure 5. . The curves on the figure show relationships between the design variables X1, X2, X3 and X4. Not shown is the further relationship of these variables to a fifth, X5. Note that the feasible upper and lower bounds on X3 are dependent upon the

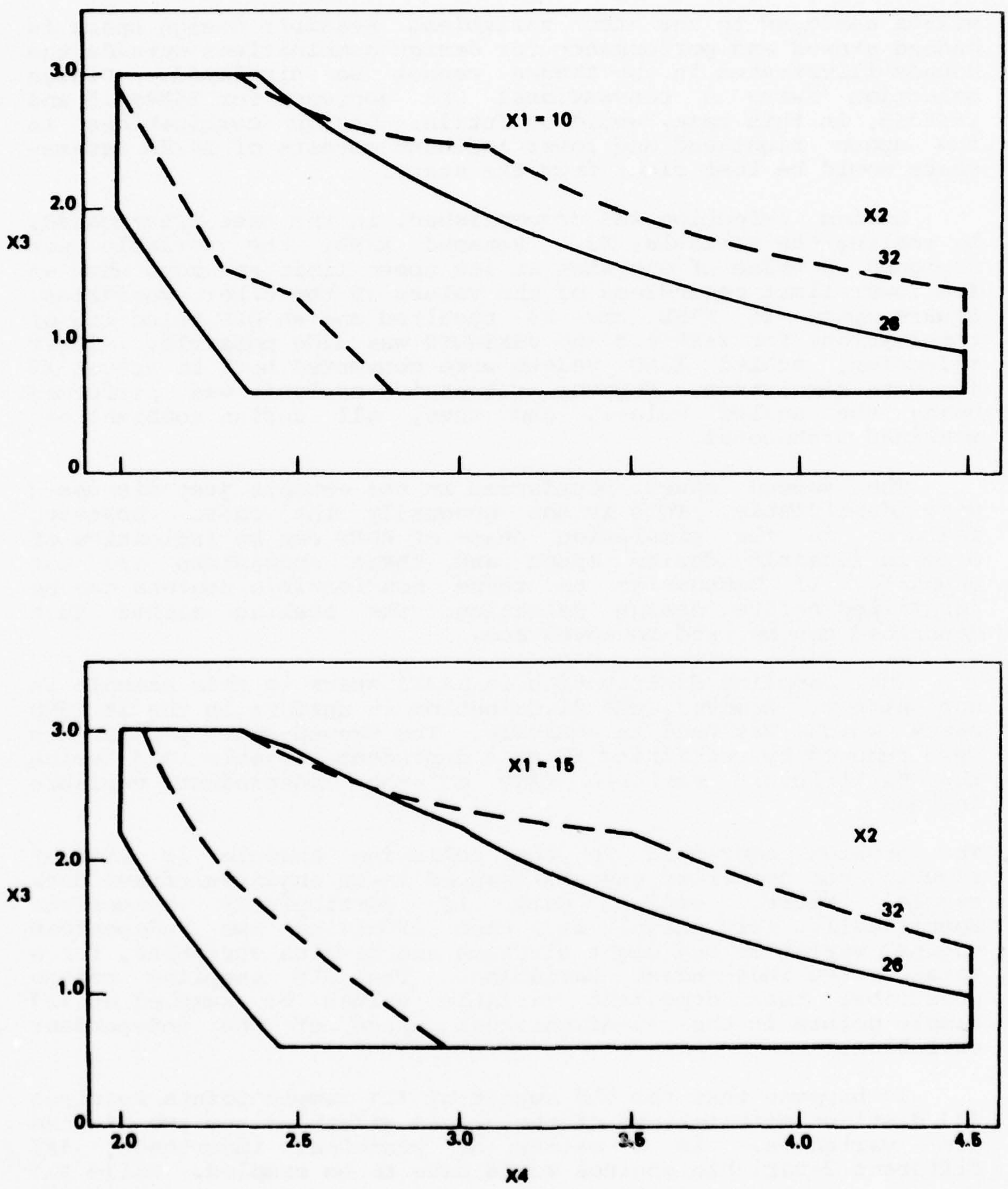


Figure 5. Skewed Design Space

values assigned to the other variables. Feasible design space is indeed skewed and performance for design combinations outside the bounds illustrated in the figure cannot be simulated. Design selection using a conventional OLS approach for 2≤X4≤4.5 and .6≤X3≤3, in this case, would be futile. Design combinations in the upper righthand and lower lefthand corners of X4/X3 square-space would be lost right from the start.

Design selection was accomplished, in the case illustrated, by scaling the variable, X3. Renamed X3ND, the variable was assigned a value of one when at its upper limit and zero when at its lower limit regardless of the values of the other variables. Square-space in X3ND and X4 resulted and an OLS selection of combinations for 2≤X4≤4.5 and 0≤X3ND≤1 was made possible. After selection, scaled X3ND values were converted back to actual X3 for data simulation. However, regression analysis was performed using the scaled values, and thus, all design combinations remained orthogonal.

The skewed space boundaries in the example just discussed were *identifiable*. This is not generally the case. However, failures in the simulation phase of ARES can be indicative of skew in feasible design space and these encounters are not unusual. If boundaries on these non-feasible regions can be identified before design selection, the scaling method just described can be used to advantage.

The sampling distribution in X4/X3 space in this example is not uniform. However, the distribution is uniform in the X4/X3ND space which was used in analysis. The skewed-space problem has been removed by redefining X3 as a dependent variable and using the "artificial" variable X3ND as the independent variable instead.

The problem addressed in the following example is that of reducing the number of engines sampled in an engine/airframe data sample where engine data is particularly expensive. Specifically, this example is a case involving two independent engine variables and eight airframe and mission variables, for a total of ten independent variables. The OLS sampling method prescribes that dependent variable values be sampled at 121 sample points in the 10-dimensional space of the independent variables.

It happens that the OLS subset of 121 sample points requires 121 distinct combinations of the eleven values of any two of the ten variables. As a matter of practical importance, 121 different 2-variable engines would have to be sampled. While 121 sample points is thought to be a reasonable sample size for quadratic function approximation in ten independent variables, it is unreasonably large for two variables, particularly when expensive engine samples are involved.

A way was found to drastically reduce the sample size in the OLS method for any 2-variable subset of n>2 variables. This modification preserves the orthogonality property of the OLS method. Thus, the sample points remain well-dispersed over the boxlike region in n-dimensional space encompassed by the total possible combinations of values for the n independent variables. The method can, however, cause unequal weighting of some of the 2-variable combinations in the reduced sample. In the present example, this means that some engines in the reduced sample are used in more of the total 121 data points than are some of the other engines. This affects the quality of the surfaces obtained in the regression analysis, to some unknown degree.

The replacement of eleven values by five for the two engine variables is illustrated in Figure 6. Also shown is the unequal weighting effect. Each row-column block in the 5-by-5 square of 25 engine combinations in Figure 6. contains the number of times that engine is used with different combinations of the eight airframe/mission variables (which still have their original eleven values).

BPR VALUES

THTR VALUES: ORIGINAL	THTR VALUES: REVISED	BPR 0.20, 0.38 → 0.20	BPR 0.56, 0.74 → 0.65	BPR 0.92, 1.10, 1.28 → 1.10	BPR 1.46, 1.64 → 1.55	BPR 1.82, 2.00 → 2.00
1.0000, 1.0150	1.0000	4	4	6	4	4
1.0300, 1.0450	1.0375	4	4	6	4	4
1.0600, 1.0750, 1.0900	1.0750	6	6	9	6	6
1.1050, 1.1200	1.1125	4	4	6	4	4
1.1350, 1.1500	1.1500	4	4	6	4	4

Figure 6. Revised Values and Repeated Combinations of Revised Values

Note that an engine whose revised BPR and THTR values are replacing two original values for each variable is used four times in the revised data sample. An engine whose revised BPR value replaces two original BPR values but whose revised THTR value replaces three original values is used six times, and so on. Originally, the four, six or nine engine replicates (whichever occurs) were all different engines, but in the revised data set distinct levels were replaced with repeats (e.g., BPR = 0.20 occurs in place of the original BPR = 0.20 and BPR = 0.38 values), hence the combinations were repeated. It is this replication of combinations that causes the unequal weighting referred to earlier. For example, the revised engine defined by (BPR, THTR) = (1.10, 1.075) is used nine times in the data sample, hence it is weighted much more heavily than any of the combinations which are used four times, such as (BPR, THTR) = (0.20, 1.00). This unequal weighting follows a symmetric pattern, however (Figure 6-), and there should be no biasing toward an "off-center" portion of BPR-THTR space.

This revision to the OLS method can be used for any data case if only two variables are to undergo reduced sampling. If the OLS method calls for ℓ values for each of the n independent variables to be sampled, there will be ℓ^2 distinct sample points, and also ℓ^2 distinct combinations of the two variables x_i and x_j for which a reduced sample is desired. Select a number r which satisfies $4 \leq r < \ell$. Replace the ℓ values of each of x_i and x_j with r equally spaced values. This is done selectively, i.e., it must be specified which of the original values each of the r new values is replacing. The data set is then revised by marking out the old x_i and x_j values and marking in their replacements. The result will be ℓ^2 distinct sample points with only r^2 distinct combinations of x_i and x_j values. These will be repeated, resulting in ℓ^2 total combinations (this follows because the new values were "marked in" in the list of original sample points). Unequal numbers of repeated combinations, if they occur, will cause unequal weighting of the different combinations.

2.4 Usage for the OLS with Variations

To use the ARES method, the user must formulate a parametric analysis in terms of independent (design) and dependent variables. Sample dependent variable values must be produced at a number of independent variable design point combinations by running a design/performance simulator. This results in a design data base consisting of the independent variable values and dependent variable values for each design case. Surfaces are fit to the dependent variables by regression on a multivariable quadratic polynomial. Then, the surfaces are used in two ways:

1. Performance Mode The quadratic coefficients are used to obtain performance estimates at any desired design point.

2. Optimization Mode - An optimization program uses the coefficients to drive the independent variables toward any desired performance optimum.

The user must take care to use the coefficients in performance or optimization mode only within the box region of specified lower/upper bounds on the independent variables. These bounds must be input to the OLS design selector. The results will be a set of designs selected to lie on or within the box region specified by the bounds.

Almost all of the designs will lie on a face of the box where one or more variables take on lower or upper bound values. Hence, the bounds should be chosen to avoid undue risk in running the performance simulator.

Avoiding extreme values of design variables is desirable from another standpoint. The smaller the box region, the more likely it is that quadratic polynomials will fit the dependent variables. If possible, selection of the variables themselves should take into account the fact that quadratics will be used to approximate their effects on performance. (Of course, too small a box region is parametrically illogical and could cause continuum problems.)

If a would-be independent variable is expected to produce highly nonlinear effects on the dependent variables, perhaps its role can be exchanged for that of a dependent variable which varies more smoothly. It may also be possible to smooth the surfaces by replacing one or more variables by an artificial variable, as in the case of the X3 replacement variable X3ND. Choosing variables will be discussed at length in the section on Simulation.

After the variables and appropriate excursion limits for them have been chosen, program LATIN can be run to obtain the selected design combinations. The output is a list of design combinations (a design data base without dependent variables). These can be input to the simulator to obtain performance values for the dependent variables. For any specified number of variables from four to ten, program LATIN generates an OLS set of design combinations. Each variable is sampled at a selected (output) number of values evenly-spaced between and including its limits (input). Table 1. is a list of the number of values per variable, ℓ, and number of design combinations ℓ^2, generated by LATIN as a function of number of variables, n.

Table 1. Design Selection Relationships

Number of variables (n)	Number of values per variable (l)	Number of designs generated (l^2)
4	5	25
5	7	49
6	7	49
7	8	64
8	9	81
9	11	121
10	11	121

For n = 2 or 3 variables, parametric analysis can be done by traditional methods. However, if ARES usage is desired, then for two variables use all combinations of the two variables at five values per variable (a 5 X 5 grid). For three variables, use the OLS for four variables by using only the first three columns of output values from LATIN. ARES is currently not structured for more than ten variables, although it can easily be extended, largely by changing program limits.

2.5 Program LATIN Usage

Program LATIN generates design combinations in an OLS pattern. The user inputs the number of variables n and the names and excursion limits of the variables. Because of ARES development requirements, LATIN is designed to accept independent variable names in a fixed order. The output format is fixed for each variable and reflects the expected range of the variable in ARES original usage. Program LATIN is the only ARES method element whose input and output are specific to the original method in this way.

The actual form of the fixed LATIN format is dictated by the fact that originally, performance for the selected designs was always simulated on the Boeing Engine/Airframe Matching (BEAM) program. The order in which the independent variables are programmed for BEAM is very important. Airframe variable names are programmed first and must be in the following order: per cent change in body length (DELBDY), aspect ratio (AR), outer panel wing thickness to chord ratio (T/C), takeoff wing loading (W/S), maximum uninstalled thrust to weight ratio (T/W), high lift technology coefficient (CLTCH), leading edge sweep angle for fixed sweep wings (SWEEP) and takeoff gross weight (TOGW). Engine variables are as follows: fan pressure ratio (FPR), overall pressure ratio (OPR), turbine inlet temperature (T4), normalized nozzle area schedule ratio (A8) and throttle ratio (THTR). Variables that are not required for a given design space are omitted, however, the order of the remaining variables remains the same.

To use the LATIN design selector for other than BEAM variables, the user should first generate a LATIN selection by inputting BEAM variable names together with appropriate bounds as follows: If, say, a 5-variable case is being run, input the first five BEAM names from the preceding paragraph. The LATIN output will be in the form of columns, each one headed by a variable name, with seven equally spaced values from lower to upper bound distributed in the columns. The first 49 values in each column will be seven repeats of each of the seven values. This forms the first of two latin square distributions output by

LATIN. The remaining 42 values form the second (the missing seven values would have given redundant designs when all variables are considered). The next step is to replace BEAM variables in the columns with the user's own variables. First, calculate the seven equally-spaced values from lower bound to upper bound for each variable. Next, go through each LATIN output column, replacing first the variable name at the top and then the values of the variable corresponding to each BEAM value, in the order of occurence of BEAM values. Only the first 49 values in each column need be used to get a complete OLS design selection. In general, for n variables, only the first ℓ^2 values (Table 1.) need be used.

LATIN is designed to generate two latin squares of design cases for the independent variable design space. Due to the design of the latin squares, the second latin square generates design cases that are identical to first latin square cases except for changes to the first independent variable. Only the eight independent variable design space yields no partial duplication of the design cases. Normal usage is to use only the first latin square, e.g, the first 49 cases if n = 5 or 6. If ℓ is the number of values for the n independent variables, LATIN generates $2\ \ell^2 - \ell$ different designs or combinations of variables/levels. For example, LATIN generates 91 design cases for a six independent variable design space, where $\ell = 7$ values per variable.

Data input required by LATIN is as follows:

1) Title Card (8A10 Format)
2) Number of airframe variables, number of engine variables (2F10.0 Format)
3) Variable name, design space lower limit, upper limit (A10, F10.0 Format) which completes the input.

Two output files are generated by LATIN: TAPE2 and PUNCH. TAPE2 output file contains the title card and lists the design cases generated. This file can be submitted for EMPOS vellums or disposed to the printer for a record of the design cases. It is the file on which user-specified variables are to be substituted for BEAM variables as described earlier. PUNCH output file is generated so that the airframe variables for the LATIN cards used in BEAM are in the correct fields for mission performance simulation. This file is useless unless BEAM is the simulator program used. Otherwise, the simulator input must be hand-punched from the user-revised TAPE2 listing.

As previously mentioned, each output column has a unique fixed format. This is illustrated in the following example which shows Mainstream EKS online inputs for LATIN required for a six variable case (four airframe, two engine variables) to be run on BEAM:

```
N> GET,LATIN
N> BATCH, 70000
C> LATIN
I> DESIGN CASES FOR 6 VARIABLE CASE (TITLE)
 (1)      Column    (11)                (21)
I> 4.               2.
I> AR               6.                  10.
I> T/C              .08                 .12
I> W/S              145.                225
I> T/W              .36                 .60
I> FPR              2.0                 4.0
I> OPR              10.                 30.
STOP
C> REWIND, PUNCH
C> CMEDIT,TAPE2
E> FIL PFN (Permanent File Name)
C> COPYBF,PUNCH, PFN
E> CMEDIT,PFN
```

The files are edited in order to make them permanent EKS files until necessary data such as vellums, punched cards or both are obtained. TAPE2 listing for the first 49 designs in the sample case is shown on Table 2. . As mentioned before, a total of 91 designs is actually output.

2.6 Monitoring Variations on the OLS Method

It was mentioned earlier that it may prove beneficial to deviate slightly from the OLS procedure. If designs are deleted from the OLS data sample, either because the simulator won't run them or to improve regressions, the n-dimensional sampling distribution may be adversely affected. One way of determining this is to check the cross-correlations between independent

Table 2.2 TAPE2 Listing for First 49 Designs in Six Variable Sample Case

DESIGN CASES FOR 6 VARIABLE CASE (TITLE)

CASE	AR	T/C	W/S	T/W	FPR	OPR
1	6.0	.080	145.0	.360	2.00	10.0
2	6.7	.087	158.3	.400	2.33	13.3
3	7.3	.093	171.7	.440	2.67	16.7
4	8.0	.100	185.0	.480	3.00	20.0
5	8.7	.107	198.3	.520	3.33	23.3
6	9.3	.113	211.7	.560	3.67	26.7
7	10.0	.120	225.0	.600	4.00	30.0
8	6.7	.093	185.0	.520	3.67	30.0
9	7.3	.100	198.3	.560	4.00	10.0
10	8.0	.107	211.7	.600	2.00	13.3
11	8.7	.113	225.0	.360	2.33	16.7
12	9.3	.120	145.0	.400	2.67	20.0
13	10.0	.080	158.3	.440	3.00	23.3
14	6.0	.087	171.7	.480	3.33	26.7
15	7.3	.107	225.0	.400	3.00	26.7
16	8.0	.113	145.0	.440	3.33	30.0
17	8.7	.120	158.3	.480	3.67	10.0
18	9.3	.080	171.7	.520	4.00	13.3
19	10.0	.087	185.0	.560	2.00	16.7
20	6.0	.093	198.3	.600	2.33	20.0
21	6.7	.100	211.7	.360	2.67	23.3
22	8.0	.120	171.7	.560	2.33	23.3
23	8.7	.080	185.0	.600	2.67	26.7
24	9.3	.087	198.3	.360	3.00	30.0
25	10.0	.093	211.7	.400	3.33	10.0
26	6.0	.100	225.0	.440	3.67	13.3
27	6.7	.107	145.0	.480	4.00	16.7
28	7.3	.113	158.3	.520	2.00	20.0
29	8.7	.087	211.7	.440	4.00	20.0
30	9.3	.093	225.0	.480	2.00	23.3
31	10.0	.100	145.0	.520	2.33	26.7
32	6.0	.107	158.3	.560	2.67	30.0
33	6.7	.113	171.7	.600	3.00	10.0
34	7.3	.120	185.0	.360	3.33	13.3
35	8.0	.080	198.3	.400	3.67	16.7
36	9.3	.100	158.3	.600	3.33	16.7
37	10.0	.107	171.7	.360	3.67	20.0
38	6.0	.113	185.0	.400	4.00	23.3
39	6.7	.120	198.3	.440	2.00	26.7
40	7.3	.080	211.7	.480	2.33	30.0
41	8.0	.087	225.0	.520	2.67	10.0
42	8.7	.093	145.0	.560	3.00	13.3
43	10.0	.113	198.3	.480	2.67	13.3
44	6.0	.120	211.7	.520	3.00	16.7
45	6.7	.080	225.0	.560	3.33	20.0
46	7.3	.087	145.0	.600	3.67	23.3
47	8.0	.093	158.3	.360	4.00	26.7
48	8.7	.100	171.7	.400	2.00	30.0
49	9.3	.107	185.0	.440	2.33	10.0

variables. The original OLS sample is selected automatically to have zero correlations between independent variables.

However, this is not a hard requirement, and it is possible to use modified samples and obtain good results as long as cross-correlations between independent variables do not get too close to unity.

"How close is too close" is not known, but it is thought that an arbitrary cutoff limit of 0.4 is reasonable. If the magnitude of the coefficient of linear correlation of two independent variables exceeds this value, further adjustment should be made to shift the correlation to within ±0.4. Adjustment can be made as follows: If two variables show high correlation, replace any design which reinforces the correlation by one with all variables having the same values as before but with one of the variables in the highly-correlated pair at or near its opposite limit. Thus, suppose the two variables, x_1 and x_2 have high negative correlation and variable x_1 ranges from 0 to 1 and variable x_2 ranges from 2 to 5. Find a design point with x_1 at 0 and x_2 at 5, say. This reinforces the negative correlation because x_1 is at its lower limit while x_2 is at its upper limit. Replace the design point with one identically the same except that x_2 has the value 2 (its lower limit). This contradicts the negative correlation.

More than one such replacement may be necessary to lower correlations between all variables affected. Each replacement consists of two operations - deletion of a data point from the design selection set, and addition of a replacement point. It is necessary to check the resulting correlations before running the added design, otherwise a simulation run may be wasted on an ineffectual replacement. Correlation can be inspected using the regressor described in Section IV.

SECTION III

SIMULATION

3.1 Introduction

The designs selected during the activity described in Section II (input) are evaluated by processing them through performance analyses. In the ARES system, this is called simulation. That is the performance of each design is analytically <u>simulated</u> to determine system characteristics (output). System characteristics include geometrical parameters, mass properties and performance levels, where performance can encompass subsystem performance, airplane mission capability, system costs, and the like. Mathematical models of varying degrees of complexity are required to generate the characteristics.

The ARES data management system is not dependent upon any one simulator. Whatever is used at this stage in ARES application, need only be appropriately compatible with design selection output and regression analysis input requirements. However, actual system characteristics simulation can be performed by hand, by computer or by collecting statistical or experimental data.

Several types of simulators were used during the development of the ARES method. All of them were digital computer programs. They included four parametric engine cycle matching programs, three different versions of an airplane performance program and a life cycle cost program. Since its development, many other types of performance models have been used in applications of the data management system.

Specifically, simulation is the generation of dependent characteristic sets for each of the designs defined by the independent parameter combinations. Large parametric studies, involving up to ten independent parameters, require that a large number of these designs be processed (121 designs for the ten variable problem). While this is orders of magnitude fewer designs than would have been required in a traditional analysis, it is a somewhat disturbing level of processing to get used to, particularly if an engine program must be used to generate data for processing in an airplane performance program.

Indeed, most of the resources consumed in an ARES application are expended in the simulation phase. This necessary expenditure is required compensation for the comprehensive array of information that will finally result. However, because

```
BOEING ENGINE/AIRPLANE MATCHING PROGRAM      WEIGHTS                    WEIGHTS                    AERO DATA                    TAKEOFF AND LANDIN
MISSION 901               NOV 09, 1976       ENGINES             5311   **OEW             29197    WING LOADING         95.0    TAKEOFF DIST      200
 FIX TOGW --- RANGE CAPABILITY               EXHAUST SYS            0   INT PAYLOAD         340    REF WING AREA       569.5    TAKEOFF VEL KT
  ARES FIGHTER - MODEL 209                   ACCESSORIES           70   EXT PAYLOAD        4000    WING AWET           991.2    AMB TEMP         59.0
                                             FUEL SYSTEM          765   EXT TANKS            -0    L.E. SWEEP           35.0    TAKEOFF GW       5410
  ENGINE DATA             ENGINE DATA        CONTROLS              30   FUEL AVAIL        20563    AR                  4.500    FLUSH TIME          .
LIBRARY NO.     8888  SCALE FACTOR     .964  STARTING SYS         100   **GROSS WT        54100    T/C                  .040    LANDING DIST
DESIGNATION   VGT888  NO OF ENGINES       1  **PROPULSION        6275                              MAC                10.648    LANDING VEL KT 120.
PRESSURE RATIO 25.00  FN SLS MIL      35878  CONTROLS            1187   OPERATING REFERENCE        CLMAX USABLE         1.54
BYPASS RATIO     .00  FN SLS MAX      49501  HYDRAULICS           330     M TO M    ALT     PS                                    MISSION TOTALS
T4 DESIGN       2600  T/W UNINST MAX   .915  ELECTRICAL           670                              BODY STATION         AREA    RANGE              81
T7 DESIGN       3400  T/W INST MAX     .812  AVIONICS            2275                                5.67               2.67    HOURS            2.15
TOTAL AIRFLOW 305.73                         FURNISHINGS          470                               19.42              16.20    MISSION FUEL     1953
FRT FLANGE DIA  4.02         WEIGHT          AIR COND             506                               30.33              26.40    RESERVE FUEL      102
CUST CONN DIA   3.79  WING             5880  MISC                 860                               30.33              36.56    INFLT REFUEL
ACAPT          10.16  HOR TAIL          844  **FIXED EQUIP       6298                               34.37              39.29    FUELAVA-FUELREQ
INLET LENGTH  429.04  VERT TAIL         283  CREW+EQUIP           470        AERO DATA              34.42 (A10)        37.12    WT ADDED
DUCT LENGTH    30.98  BODY             4526  UNUS FUEL+OIL        246   BODY AWET        1323.7     65.34              25.73
ENG LENGTH     12.91  LDG GEAR         1978  GUN+P/L PROV         690   BODY VOLUME      2220.8     72.50              17.88    AERO APP
EXH LENGTH      -.13  ENG SECTION       302  **NON-EXP LOAD      1406   EMPENNAGE AWET  337.8       78.25 (ACC)        11.27    PROP APP
                      AIR INDUCTION    1406                             NACELLE AWET         .0     78.25              11.27    WT   APP
                      **STRUCTURES    15219
```

	TAKOFF	CLIMB	CRUISE	LOITER	CRUISE	SIZE	SIZE	SIZE	SIZE	SIZE	TURN	CRUISE	CRUISE	LOITER
A/P WT	54108	53248	52146	49775	48669	49647	49647	49647	49647	49647	43479	38583	34308	32523
ALT	-0	-0	40075	40916	20000	30006	30000	20000	20000	20000	20000	20000	45857	0
MACH	.166	.300	.910	.920	1.900	.850	.900	1.500	1.500	1.500	1.500	1.500	.910	.320
L.E. SWEEP	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000
N. MILES	0	18	202	0	106	0	0	0	0	0	0	106	300	0
HOURS	.0042	.0401	.5410	.2500	.1154	.0000	.0000	.0000	.0000	.0000	.0127	.1154	.5746	.5000
FUEL	852	1101	2371	1106	8607	0	0	0	0	0	1400	4275	1705	1956
RANGE FAC	0	0	6066	0	1119	0	0	0	0	0	0	956	5672	0
(T-D)/D MIN	.000	118.497	.000	.000	.000	.091	4.330	.704	.531	.156	.156	.000	.000	.000
P(S) MIL	.00	.00	106.08	103.91	-32.89	105.72	199.62	-11.26	-166.08	-519.28	-35.47	2.16	126.53	.00
P(S) MAX	.00	.00	107.54	109.28	725.89	310.03	339.10	732.57	577.75	224.55	813.90	959.31	222.66	.00
REQ ENG SIZE	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
PCT MIL	1.407	1.000	.399	.410	1.035	1.408	1.502	1.006	1.006	1.006	1.006	.998	.358	.073
PCT AUG	1.000	.000	.000	.000	.043	1.000	1.000	1.000	1.000	1.000	1.000	.000	.000	.000
PCT MAX	1.000	.601	.269	.276	.573	1.000	1.000	1.000	1.000	1.000	1.000	.553	.241	.051
L/D	13.608	12.989	12.741	12.343	1.596	12.242	11.430	1.665	4.285	5.393	1.420	1.312	12.493	13.608
CD PARASITE	.0000	.0150	.0162	.0164	.0146	.0153	.0154	.0146	.0146	.0146	.0146	.0134	.0164	.0151
CD W(WAVE)	.0000	.0000	.0006	.0013	.0159	.0000	.0000	.0159	.0159	.0159	.0159	.0159	.0003	.0000
CD LIFT	.0000	.0076	.0133	.0126	.0011	.0058	.0045	.0003	.0060	.0189	.0010	.0010	.0099	.0116
CD INL REF	.0000	.0000	.0006	.0006	.0013	.0004	.0005	.0013	.0013	.0013	.0013	.0013	.0006	.0000
CD EXH REF	.0000	.0009	.0009	.0009	.0022	.0009	.0009	.0022	.0022	.0022	.0022	.0022	.0009	.0010
DIN REF/DACAP	.0000	.0000	.0321	.0338	.0702	.0236	.0304	.0702	.0702					
DIN PS/DACAP	.0000	.0000	.0337	.0327	.0063	-.0016	.0000	.0063	.0063	.0063	.0063	.0065	.0457	.0016
DAFT REF/DA10	.0162	.0140	.0140	.0140	.0338	.0140	.0140	.0338	.0338	.0338	.0338	.0338	.0140	.0150
DAFT PS/DA10	-.0003	.0023	.0040	.0042	.0111	-.0004	-.0006	-.0005	-.0005	-.0005	-.0005	.0118	.0042	.0032
FN	44970	30863	4068	4033	30486	22261	23150	53201	53201	53201	53201	29403	2746	2390
FN UNINST	46210	31982	4440	4401	32101	23246	24190	54754	54754	54754	54754	31032	3051	2492
SFC	1.637	1.055	1.096	1.097	1.315	1.916	1.929	2.198	2.198	2.198	2.198	1.204	1.150	1.637
WC CORR.	305.7	305.7	293.8	297.1	352.9	305.7	305.7	352.9	352.9	352.9	352.9	352.7	278.9	140.0
AE/ACAPT	.0000	1.0408	.5766	.5818	.7849	.7563	.7474	.7849	.7849	.7849	.7849	.7844	.5478	.5318
RECOVER FAC	.945	.978	.979	.978	.950	.965	.965	.950	.950	.950	.950	.950	.980	.992
DINL PS/FN	.0000	.0000	.0191	.0183	.0032	-.0002	.0000	.0018	.0016	.0018	.0018	.0034	.0290	.0011
PT0/P0	4.525	5.163	4.195	4.298	10.937	8.466	8.698	10.169	10.169	10.169	10.169	10.947	3.922	1.278
A9/A10	.1890	.1379	.1450	.1465	.2440	.2262	.2360	.3033	.3033	.3033	.3033	.2496	.1409	.1045
A9/ACC	.6227	.4542	.4777	.4838	.8041	.7452	.7776	.9994	.9994	.9994	.9994	.7926	.4641	.3444
DAFT PS/FN	-.0000	.0008	.0043	.0046	.0207	-.0002	-.0004	-.0005	-.0005	-.0005	-.0005	.0227	.0096	.0075
CV	.987	.987	.986	.986	.984	.985	.985	.978	.978	.978	.978	.984	.965	.985

Figure 7. Simulator Output Example

```
 PUNCH CARD OUTPUT
FPR       OPR       TR        ABX       TCLAT     TWLAT     AR        WINGLD
LESWP     GW        STRUCW    PPWT      FIXWT     ULOAD     TRANGE    ALT     ( 4)
ALT     ( 6)ALT     (10)ALT   (11)ALT   (12)MACH  ( 4)MACH  (12)NMILE ( 4)NMILE ( 6)
NMILE   (11)SHOURS( 4)SHOURS(10)DFUEL ( 4)DFUEL ( 6)DFUEL (10)DFUEL (11)DFUEL (12)
RFACT   ( 6)RFACT  (11)RFACT (12)TMDOD ( 4)EMDRY ( 4)EMDRY ( 7)EMDRY ( 8)EMDRY ( 9)
EMAUG   ( 4)EMAUG  ( 6)EMAUG ( 7)EMAUG ( 8)EMAUG ( 9)EMAUG (10)PSMIL ( 6)PSMIL (11)
PSMIL   (12)PAUG   ( 6)PAUG  (11)PSOA  ( 6)PSOA  (11)LD    ( 4)LD    ( 5)LD    ( 6)
LD      ( 7)LD     ( 8)LD    ( 9)LD    (10)LD    (11)LD    (12)FN    ( 4)FN    ( 6)
FN      (10)FN     (11)SFC   ( 4)SFC   ( 6)SFC   (10)SFC   (11)AEAC  ( 4)AEAC  ( 5)
AEAC    ( 6)AEAC   ( 7)AEAC  ( 8)AEAC  ( 9)AEAC  (10)AEAC  (11)AEAC  (12)DINLFN( 4)
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DFNDPS( 6)DFNCV ( 6)APWT  ( 4)APWT  ( 5)APWT  ( 6)APWT  ( 7)APWT  (10)APWT  (11)
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3.500E+01 5.410E+04 1.522E+04 6.275E+03 6.298E+03 1.406E+03 1.085E+03 4.095E+04
5.933E+04 6.056E+04 6.418E+04 4.582E+04 9.101E-01 9.102E-01 4.176E+01 1.910E+02
2.424E+02 4.879E-02 8.000E-02 2.382E+03 3.124E+03 2.387E+03 3.072E+03 1.785E+03
2.775E+03 2.841E+03 5.670E+03 6.513E-01 1.034E+02-1.991E+02-1.485E+03-4.153E+03
1.867E+02 1.207E+02 7.032E+01-1.215E+03-3.884E+03 1.194E+02 1.582E+00 1.586E+00
3.572E-01 6.065E-01 6.080E-01 8.074E-01 8.076E-01 1.269E+01 1.892E+00 4.211E+00
4.440E+00 3.620E+00 2.402E+00 4.187E+00 4.339E+00 1.249E+01 1.447E+04 1.102E+04
1.282E+04 8.610E+03 1.897E+00 1.915E+00 2.328E+00 1.927E+00 7.460E-01 8.685E-01
8.623E-01 8.612E-01 8.612E-01 8.612E-01 8.612E-01 8.579E-01 5.474E-01 1.942E-06


2.221E-03-1.526E-03-5.073E-06 5.879E-16 8.883E-01 3.370E-02 1.677E-02-2.083E-03
5.513E-16 3.052E-02 4.977E+04 4.739E+04 4.687E+04 4.965E+04 4.348E+04 3.736E+04
3.429E+04 1.597E+00 1.010E+00 1.010E+00 1.010E+00 1.959E+00 1.211E+00 1.211E+00
1.211E+00 1.383E+00 6.614E-01 1.741E+00 9.994E-01  .0        .0        .0
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 PUNCH CARD OUTPUT
FPR       OPR       TR        ABX       TCLAT     TWLAT     AR        WINGLD
LESWP     GW        STRUCW    PPWT      FIXWT     ULOAD     OWE       FIF
AMPRWT    ENGWT1    SFCMLU    VIS     ( 1)FUELTM  DIAFF     DEXH      ENGL
ACAPD     FNSLSD    TRANGE    TOUIST    TAIRFL    SWEXP     HTLAW     VTLAW
A6        A9        BDAWET    VLAND     ALT     ( 3)ALT   ( 4)ALT   (13)MACH  ( 3)
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1.947E+04 5.311E+03 8.617E-01 6.070E+02 9.071E+03 4.024E+00 3.788E+00 1.291E+01
1.016E+01 3.588E+04 8.127E+02 2.001E+03 3.857E+02 4.947E+02 1.023E+02 6.618E+01
3.712E+01 1.127E+01 1.324E+03 1.206E+02 4.007E+04 4.092E+04 4.586E+04 9.101E-01
9.200E-01 9.102E-01 2.820E+02 1.064E+02 5.410E-01 1.154E-01 1.912E-02 1.265E-02
8.525E+02 1.101E+03 2.371E+03 1.106E+03 4.607E+03 1.480E+03 4.275E+03 1.785E+03
1.956E+03 6.066E+03 1.119E+03 9.564E+02 5.672E+03 8.911E-01 1.041E+02 1.039E+02
1.857E+02 1.996E+02-1.126E+01-1.661E+02-5.193E+02 1.875E+02 1.893E+02 7.259E+02
3.100E+02 3.391E+02 7.326E+02 5.778E+02 2.245E+02 8.139E+02 3.992E-01 4.098E-01
1.035E+00 9.982E-01 3.579E-01 7.274E-02 4.335E-02  .C       5.730E-01 5.527E-01
1.274E+01 1.234E+01 1.596E+00 1.224E+01 1.143E+01 1.665E+00 4.285E+00 5.393E+00
1.428E+00 1.312E+00 1.249E+01 1.361E+01 4.068E+03 4.033E+03 3.049E+04 5.320E+04
2.940E+04 2.746E+03 1.096E+00 1.097E+00 1.315E+00 2.198E+00 1.264E+00 1.150E+00
5.766E-01 5.818E-01 7.849E-01 7.563E-01 7.474E-01 7.849E-01 7.849E-01 7.849E-01
7.849E-01 7.844E-01 5.478E-01 5.318E-01 9.786E-01 9.497E-01 1.908E-02 1.831E-02
3.208E-03 1.838E-03 1.838E-03 3.432E-03 2.900E-02 8.290E-03 8.605E-03 2.065E-02
1.977E-04-3.709E-04-5.396E-04-5.396E-04-5.396E-04 2.272E-02 9.784E-03 5.892E-02
5.909E-02 2.761E-02 2.766E-02 6.507E-02 3.991E-02 3.962E-02 6.228E-03 6.322E-03
4.777E-02 1.750E-02 1.681E-02 3.041E-03 3.246E-03 2.611E-02 7.606E-03 7.896E-03
1.958E-02 2.149E-02 8.810E-03-1.508E-03-1.405E-03 1.823E-03 1.823E-03-4.150E-04
1.618E+00 2.710E+00 2.757E+00 1.010E+00 1.010E+00 1.010E+00 1.909E+00 3.149E+00
3.373E+00 5.903E+00 5.903E+00 5.903E+00 6.743E+00 5.215E+04 4.970E+04 4.867E+04
4.965E+04 4.965E+04 4.348E+04 3.858E+04 3.431E+04 3.252E+04  .0        .0
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Figure 8. Simulator Output for One ARES Design

resource consumption in this phase of analysis is relatively high, risk of compromising the analyses in simulation should be minimized.

To this purpose, the mathematical models to be used in simulation should be selected or developed along several guidelines that have evolved from some considerable experience with the ARES system. Due to the independence of ARES from any particular simulator, these guidelines will be generally stated in later paragraphs.

A more specific statement can be made relative to simulator input and output. Orderly processing of the some 100 cases involved, can be accomplished by careful coding of input logic. This is particularly important if a large number of engine designs are involved. Provision must be made for processing the proper total design case. The proper engine should be analytically processed with the proper airframe. Since a large number of designs are involved, this input manipulation should be automated where possible.

One simulator output page is presented in Figure 7. . Any of the data shown on the figure are potential characteristics of interest. Obviously, a large number of them are available. In the illustrative case, about 300 were actually output for examination in the ARES system. The output for one case is illustrated in Figure 8. . The user should be aware of several simulator output requirements suggested by the figure. First, output size can be large and by its very magnitude can be difficult to control. Second, proper identification of variable names is necessary so that the output logic can locate data for parameters of interest. Third, the simulator output should be in regression analysis input format so that the transfer of large amounts of data between these two programs can be accomplished in a straightforward manner. A reasonable degree of automation is suggested.

Since ARES-type systems are applicable to conceptual, preliminary phases in the design process, they are not required to have absolute precision. They need only enough precision to properly predict the leverage of design variables and requirements and design regions-of-interest. Accuracy of the data management system should be consistent with the level of definition available during preliminary design and the accuracy of performance simulators used in the data management system should be of a similar level.

A means to increase data management system accuracy while increasing its economy at the same time is suggested. Some of the simulators which have been used in ARES system applications are "high precision" analytical tools. They are of higher precision than the data management system in the first place and because of their "precision" they have a detrimental effect on data management system accuracy as described below. Built-in higher order analytical logic and limits imply a high level of analytical accuracy (most probably inconsistent with the available detail of system definition) but prevent the data management system from adequately representing the simulated data. Also, (because of conviction in the high quality of the performance simulators) the "problem" is generally formulated to a degree of detail that, again, implies high precision and severely impacts the ability of the data management system to represent output.

A perfectly accurate simulator, operating on a detailed set of requirements, will generate data that cannot be accurately represented by least squares fits with quadratic polynomials. This is because real life does not always occur quadratically. On the other hand, a quadratic simulation of real life is many times not unreasonable and such a simulator can generate data that can be perfectly represented by quadratic fits. Obviously, some compromise is suggested and just such a compromise is much more appropriate to preliminary design analyses than "perfect" simulation.

A common understanding as to the levels of precision required in problem formulation, simulation input definition, simulation logic and data management system output must be developed. When this occurs, less complex problem statements (mission representations, for example), decreased input requirements and appropriately adjusted simulator logic with a minimum of built-in limits, will result. These kinds of adjustments will provide a higher probability of successful application of the ARES system.

Most probably, the less complex analysis proposed above, will have a cost benefit, as well as, yielding a more acceptable result. However, relative to the large cost benefit of the data management system in the first place, additional economy due to more appropriate problem formulation, or any other system adjustment will be small.

3.2 Guidelines for ARES-Type Simulations

There are se[illegible]al problem areas which potentially impact the results of an ARES [illegible]pplication. Simulator program design and execution runs should be performed accordingly. The problem areas are (a) lack-of-fit, (b) noise, (c) skewed space, (d) simulation failure, and (e) consistency. Guidelines for dealing with these key problem areas will be presented after the problem areas are first discussed.

Lack-of-Fit

Parametric study independent variables in a highly detailed simulation often have highly nonlinear effects on output variables. Thus, functional forms are created for which quadratic approximations are inadequate. The resulting surface fit error is known as lack-of-fit.

Figure 2. illustrates lack-of-fit in a case of one-dimensional surfaces or curves. The dashed curve represents a hypothetical cubic, of the general form $y = a_1 x^3 + a_2 x^2 + a_3 x + a_4$. The solid curve represents a least squares quadratic, $y = b_1 x^2 + b_2 x + b_3$, which is attempting to approximate the cubic, and the shading between the curves shows the lack-of-fit.

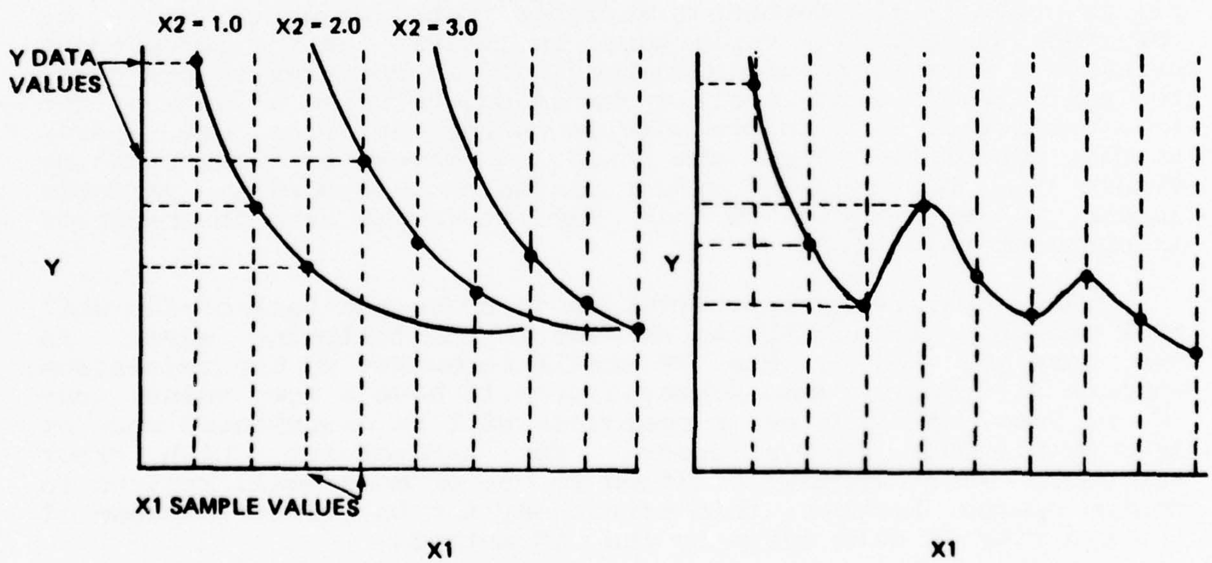
Noise

A significant cause of surface fit error other than lack-of-fit is noise in the dependent variable data values. Noise is observed as erratic variations in values as the independent parameters vary over allowed ranges. It is not always practical to tell whether surface fit error is due to noise or lack-of-fit in a particular case, since some dependent variables may appear highly convoluted from the data. However, as illustrated by Figure 3. , noise (dashed curve) can make a dependent variable appear non-systematic in the way it varies over the range of independent variables.

The separate characteristics of noise and lack-of-fit will most probably (if at all) be evident in the following ways. In the case of noise, the R^2 statistic output by the regression surface fit program (see Regression) will have a low value, say .7 or less, and high error residuals will be distributed more or less evenly over design space. For lack-of-fit, high error residuals will appear localized to one or more small regions in design space. However, this effect may not be evident because of the sparsity of data taken by the OLS method.

Noise can arise from problems in computation, e.g., round-off error, or it can be the result of obtaining dependent variable values by a solution method which is inherently overly sensitive to small changes in the independent variables. A possible cause which is sometimes overlooked is the introduction of "hidden variables". Hidden variables can be introduced by varying input quantities other than the independent variables. Alternatively, hidden variables can result from allowing the simulation to alter input values for the independent variables and yet giving the regression program the original input values as data.

Figures 9. A and 9. B illustrate the hidden variable effect for a case where y is supposedly a function of x_1 only, but another important parameter, x_2, is inadvertently varied while taking data. In Figure 9. A, three curves for $y = f(x_1)$ are shown along with data point samples. The three curves are the effect on y of having x_2 at successive values $x_2=1$, $x_2=2$ and $x_2=3$. The $y=f(x_1,x_2)$ surface sample points are shown projected onto the x_1-y plane in Figure 9. B, with an apparent curve drawn through them to dramatize the erraticity present. This is the curve the regression program would be trying to fit by fairing through with a simple parabola (i.e., a one-dimensional quadratic).



A. EFFECT OF "HIDDEN VARIABLE" X2 ON (x1, Y) DATA POINTS.

B. OBSERVED EFFECT ON Y WHEN ONLY (X1, Y) POINTS ARE PLOTTED, WITH X2 NEGLECTED.

Figure 9. Hidden Variable Effect

Skewed Space

The term skewed space arises from warping of the design space box region (see Figure 5.). This warping results from revisions to the user-specified independent variable excursion limits which are imposed by the simulator. The OLS distribution of design points throughout a rectangular box encompassing the user's limits results in some design variable combinations which lie at the extremes of some of the variables. Often the simulator will fail at such design points. This may be anticipated beforehand or it may not be a known problem until the simulator is run on the OLS designs.

In either case, the result is loss of design points from the OLS selection. If many designs are lost, the result can be a design set which is no longer well-distributed. For example, the designs may tend to accumulate in a hyperplane in the n-dimensional space of the independent variables. A hyperplane accumulation of feasible designs implies a functional dependence among one or more of the variables, i.e., the data sample is not really n-dimensional. One way of checking for this is to inspect the cross-correlations between independent variables in the surviving OLS points.

Simulator Failure

As opposed to design failure, which was talked to in the preceding two paragraphs, simulation failure refers to fatal computational problems within the simulator itself. Sometimes a skewed space distribution results, but computational failure may well result in a non-systematic distribution of failures throughout design space.

Miniscule changes in one or more independent variables usually turns a failure into a success. When this type of behavior is encountered, noise may well be present in the output from the successful runs. The computational problems should be solved before attempting an ARES analysis.

Consistency

The simulator must be run under a fixed set of conditions with only the independent variables changing. Violation of this all important requirement can easily occur when large data bases are being handled, when simulator runs for different designs are monitored by different individuals, or when a time lapse of perhaps days or weeks occurs between the running of designs. Close communication and careful record-keeping are mandatory in ARES, but especially at this stage. The greatest computer resource cost in an ARES application is normally incurred during simulation, and re-doing a set of design simulations can be relatively costly. If inconsistencies go unnoticed, the entire analysis is in jeopardy.

3.3 Addressing Simulation Problem Areas

Suggestions for solving or alleviating the aforementioned simulation problems are given in this section. General considerations and untried solutions, as well as actual experience, are presented.

An obvious way to reduce lack-of-fit and possibly prevent noise is model simplification. Many simulators are too complex to allow the derivation of explicit mathematical expressions for the dependent variables as functions of the independent variables. However, it may be possible to foresee that some mathematical solution procedure in the simulator logic can be reformulated to simplify the variational effects of input variables on an output variable. If this can be done without unacceptable accuracy loss, and if the simplification itself does not introduce noise, then simplification can be used to tailor dependent variables so that they are more easily fit by quadratics. The loss of accuracy in design point calculations may be compensated by the ability to do a large parametric analysis using the simplified output.

In some cases, a dependent variable results from an accumulation of results from different solution processes which interact. This sometimes occurs when different stages in a process are simulated to get an end result. For example, the total fuel consumption of an airplane flying a mission is the sum of fuel consumed on each mission segment, e.g., during takeoff, climb, and cruise to some pre-assigned location. The fuel available for consumption on a particular segment depends on the total consumption of previous segments. Thus, the calculated fuel consumption values for the different mission segments interact. This can have complicating effects on any dependent variables which express airplane performance for the overall mission.

In such a case, it might be advantageous to reformulate the simulation surface fit problem in the following way: If possible, simulate the mission segments each independently of the others and output certain mission factor variables as dependent variables. These mission factor variables would be normalized versions of original mission segment variables and would represent the performance of the airplane design being flown. An example would be fuel consumed per mile for climb or cruise. Regression surfaces would be obtained for each mission segment variable. These regression surfaces would be applicable over the entire design region of investigation, as usual. Hopefully, the segment variables would be better fit by the simple regression surfaces than the original overall performance variables. Linear combinations of the regression surfaces with appropriate coefficients would be used to obtain performance over the entire mission for any desired design within independent design variable limits.

Again, the question of accuracy of the reformulated process enters in. It may be impossible to obtain reasonable results by using the approximation technique of linear combinations of segments, for it is required to derive performance variables for each segment and also to derive coefficients for additive combinations of the segments.

The foregoing example uses the concept of decomposition as well as simplification. In more than one sense, the simulation/surface fit problem is broken down into more manageable segments, where quadratic functions may approximate the dependent variables more closely. It is the simplified form of the linear combinations which are used to achieve the decomposition that cause the inaccuracies of model revision.

The skewed space problem can sometimes be solved by relaxation of physical constraints during simulation. These constraints can sometimes be applied while using the optimization element of ARES, which solves constrained optimization problems. Thus, the simulator is allowed to produce values for the dependent variables at design points which would otherwise fail in the simulator due to violation of feasibility requirements. An actual application from airplane/mission simulation is relaxation of mass conservation requirements when airplane range is a dependent variable. If an independent design variable combination produces an airplane which runs out of fuel on some leg of the mission, the range is adjusted downward as if the airplane had to fly backward to recover spent fuel with which to complete its mission. In these cases, negative range values occur over the mission segment of interest. However, a complete OLS set of designs is enabled to run, thus preventing data loss which would have led to a skewed design distribution in n-dimensions. A bonus is usually incurred in the form of a simpler dependent variable which is more easily fit by a least squares quadratic. This occurs because the interaction of mission segments caused by the fuel limits applied previously was complicating the design variable effects on output.

To avoid non-feasible regions, constraints can be applied to the relaxed dependent variables during optimization analysis, e.g., range can be constrained to positive values. The feasibility problem may be automatically eliminated if the criterion for optimality is maximum range, for an optimum design with range maximized will usually not have a negative capability. If the quadratic surfaces representing range as well as other dependent variables are good fits, the resulting optimum should be realistic.

Relaxation can sometimes be applied to the internal solution procedures in a simulator to prevent simulator failure. In this type of application, relaxation is applied to allow convergence of the model at a design point to get dependent variable values, and does not necessarily yield unrealistic results. For example, a particular simulator may calculate a dependent variable y by solving a nonlinear equation $f(x)=x_i$ iteractively, where x_i is an independent design variable. Suppose that $f(z^k)$ is evaluated at each iterate z^k by interpolating in some fashion on a decreasing sequence of tabulated values $f^1, f^2, \ldots, f^m$ corresponding to values $z=a^1, a^2, \ldots, a^m$ (Figure 3.4), with $f^1=x_i^{max}$ and $f=x^{min}$. Because of a desire to avoid the risk in extrapolating or because values for f(z) for z outside the range $a^i \leq z \leq a^m$ may not have physical meaning, the designer of the simulator program may have provided that the program halt execution if an iterate z^k lies outside the range $a^i \leq z \leq a^m$. This is simulator failure, for it could well be that the iterative search procedure would jump back inside the range of tabulated values in the next iteration were an evaluation of $f(z^k)$ allowed to proceed by careful use of extrapolation.

In Figure 10. , the solid curve in the range $a^i \leq z \leq a^m$ is the interpolation function, and extrapolated values outside the tabulated range lie on the dashed curve. The solution $f(y)=x^i$ always occurs within the range of tabulation because of the restriction $x_i^{min} \leq x_i \leq x_i^{max}$ and the monotonicity of the curve shown. The thin lines with arrows joining the iteration points p^{k-1}, p^k and p^{k+1} are a geometric view of Newton iterations converging toward the solution.

In this example, relaxation has allowed convergence to a solution, thereby preventing simulator failure. The solution is always safely within the interpolation range because the x_i limits are encompassed by the tabulated data values for $x=f(z)$. Allowing violation of the interpolation limits was solely a means of obtaining a converged solution.

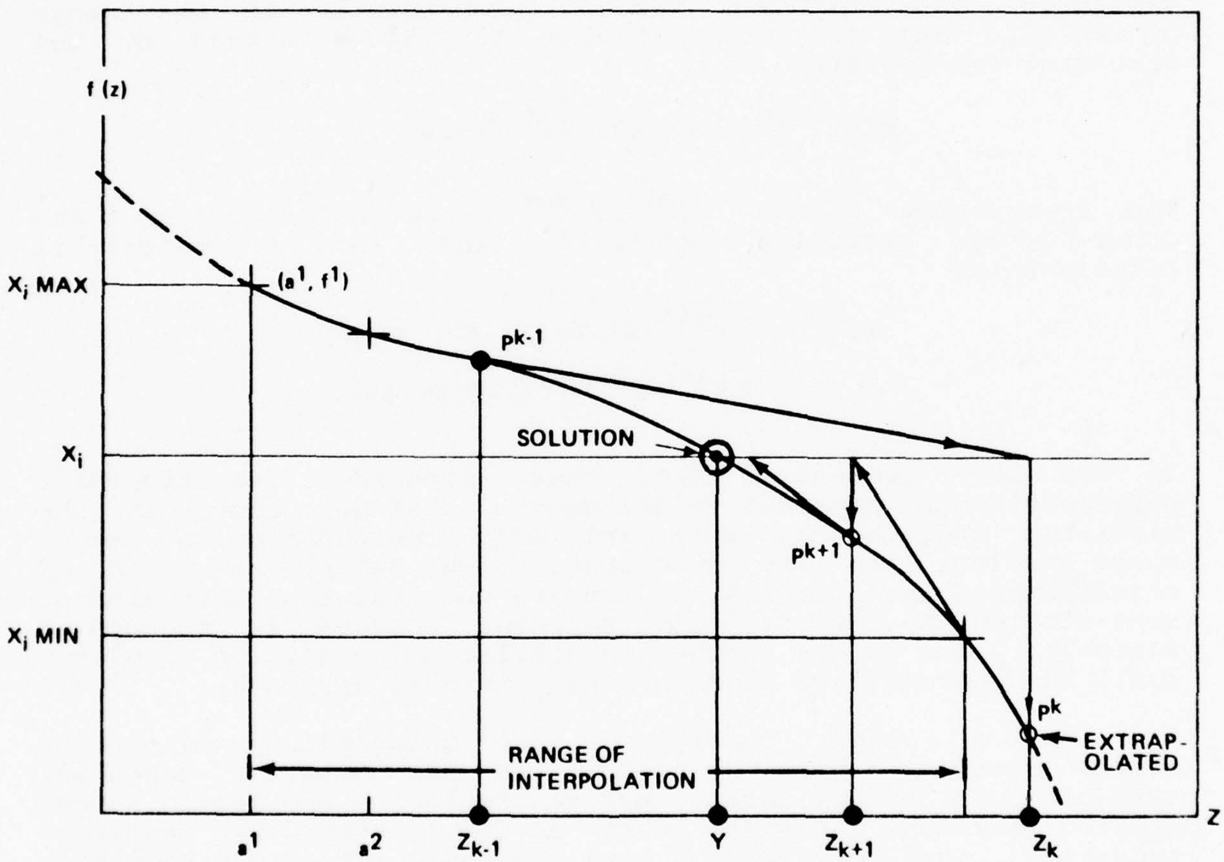


Figure 10. Simulator Failure Prevention by Relaxation

A promising method for dealing with the skewed space problem is substitution of variables. An example of substitution in an actual ARES application was presented in the section on Design Selection. The replacement variable X3ND was used in place of X3 to get a box region with no data loss. This was made possible by the fact that skewed space could be represented by variable lower and upper bounds for X3 which were functions of the other design variables. Thus, X3ND was varied independently in the range $0 \leq X3ND \leq 1$, and the corresponding X3 values needed by the simulator were obtained by

$$X3 = X3^{min} * (1 - X3ND) + X3^{max} * X3ND$$

The lower/upper bounds $X3^{min}/X3^{max}$ are calculated from the other design variables X1, X2, X4 and X5 by functional relationships

$$X3^{min} = F^{min}(X1,X2,X4,X5) \text{ and}$$

$$X3^{max} = F^{max}(X1,X2,X4,X5).$$

In the case presented here, these functional relationships represent actual physical relationships that were coded in the simulator and, hence, were initially the cause of the skewed space problem. The X3ND substitution was simply a means of transforming the problem to remove constraints. This kind of substitution impacts the design selector because it changes a variable, and it may change the simulation, e.g., the simulator could be programmed to transform X3ND into X3 as above.

Lack of proper control of the calculations within the simulator can be a cause of noise. In one case, a dependent variable was being output by a simulation program in a very erratic fashion. Results were so poor that the resulting regression surface variation barely matched 50% of the variation in the data (the R^2 value was less than 0.5 - see Regression). The cause was discovered to be in a table look-up embedded in the calculations. It was found that a much closer spacing of tabulated values was needed to provide adequate interpolation accuracy and prevent ambiguous quantities from jeapordizing calculated values downstream.

Thus, greater detail as opposed to simplification or relaxation is sometimes needed. Simplification may reduce lack-of-fit but introduce noise. Conflicting aims in the simulator design can crop up because of the necessity to have stability in the calculations and yet achieve a surface which can be closely approximated with a quadratic.

Achieving stability and accuracy in computation is the subject matter of numerical analysis, and the reader is referred to the literature or a numerical analyst for any needed help.

Consistency was mentioned as one of the potential problem areas in simulation for use with ARES. This will be discussed in the next section, which is concerned with running the simulator to get a usable data base and follow-up data in an ARES analysis.

3.4 Running the Simulator

The majority of computer resource expenditures incurred in an ARES application will usually be in simulator runs to build a data base for regression. The designs selected by the OLS design selector are input to the simulator and performance values are obtained as dependent variables. For an analysis with ten independent variables, the OLS design selector selects 121 designs for simulation. This can require a sizable amount of computer processing.

3.5 Cautionary Notes

Obviously, it is of utmost importance that the simulator runs be processed carefully. In the initial problem formulation the expected influence of all potential design variables should be reviewed to insure that no important effects are ignored. Once designs are run, the introduction of an additional independent variable is not possible. It is possible to delete independent variables, however. Hence, although it is desirable to use as few independent variables as possible to reduce cost it is wise to consider including all variables of potential importance within the present ARES capability of ten variables.

During simulation data-gathering, some designs may fail or give performance values for the dependent variables which jeopardize the surface fits. Loss of a few designs may be acceptable as long as the survivors do not accumulate in a hyperplane in design space. Lost points should be noted for later reference, so that evaluation of the regression surfaces in a neighborhood of any lost point can be avoided if possible. Cross-correlations between the independent variables in the surviving designs should be checked to insure that correlations do not approach unity. It is sometimes possible to compensate partially for data loss by artificially introducing additional designs to the data set to lower the cross-correlation.

If data loss occurs sporadically throughout design space, however, the validity of simulator results is in question and the simulator should be analyzed (see the previous section). A major loss of designs requires drastic measures, perhaps to the extent of revising the choice of variables investigated and re-doing the entire simulation phase. The same problem can occur with traditional analyses, the difference being largely that an ARES method analysis is performed on more than just three variables. Hence, the problem formulation can be more complex and results harder to foresee, and the risk in cost is greater. These risk factors are to be expected when doing a full analysis in higher dimensions.

A crucial decision point may be reached once the designs have been run on the simulator. Noise may be present in the model, and the model itself may have to be re-examined. This may not become known until regression surfaces are obtained and extremely poor surface fit statistics (e.g., R^2 less than 0.70) are noted. (Regression alone, however, will not distinguish noise from lack-of-fit in the design data base produced by the OLS method.)

Practical considerations may enter in also. For example, suppose the simulation of a design is partly successful, yielding data for some but not all of the dependent variables. Should the mission data be obtained some other way, or should the design be regarded as lost? For consistency reasons, supplying the missing data by bypassing or adjusting the simulator can be risky. However, it may be that the loss is due purely to simulator failure (see last chapter), and adjustments to allow generation of the missing data are justified.

This section on cautioning information for simulator computer runs will end with a discussion of consistency. This all-important simulation problem area was deferred to this section because the last section, where it was introduced, dealt mainly with guidelines for programming the simulator.

The simulator program must be run under a fixed set of conditions when generating the regression input data and also the follow-up validation data for a single parametric analysis. Otherwise, variables other than the independent design variables originally chosen for analysis may well be contributing variations to the data. This causes noise in the data, as was illustrated in the discussion of noise in the last major section. An exception to running under fixed input conditions other than independent variables might be justified to prevent simulator failure at some designs. However, if the simulator calculations cannot be reprogrammed to avoid convergence failure, noise in the data would seem to be an inherent problem of the simulator being used.

With the exception of possible cases where simulator failure is controlled by carefully varying input parameters such as convergence tolerances, the input other than the intended design variations should be kept constant. This may require careful record-keeping, to help insure that simulations run at different times are consistent. This will most likely be a problem in spanning the gap in time between generation of regression input from the OLS design selection and generation of follow-up data to validate the optima obtained by using the regression surfaces in the optimization element of ARES.

3.6 Simulator Usage to Interface with ARES

It is desirable for the user to develop an automatic interface between simulator I/O and ARES if existing formats and usage are incompatible. The LATIN punch file output was discussed in the last section. Its fixed nature makes it an immediate candidate for revision, for it may not be usable as simulator input without first changing names and values for the variables. Another consideration is that the ordering of designs on the file may need changing to match the simulator's convenience in stepping through successive values of design variables to run several designs in one computer execution. This is easily done by editing the file, since the variable values are blocked by design point, i.e. the values for one design are grouped together. Thus, designs can be reordered by reordering blocks of input lines before running the simulator.

The ease of performing higher-dimensional analyses on the simulator output may make it attractive to obtain data for a great many dependent variables. For a 10-dimensional analysis 121 designs are selected by the OLS method. In this case, a data base consisting of multiples of 121 numerical values is produced and must be stored on some permanent storage medium for input to the regression program. Since the regression program requires the independent variables as well as a dependent variable to obtain surface fit coefficients, the simulator output file must contain 1210 numerical values for the independent variables and 121 additional values for each dependent variable in a 10-dimensional analysis. Were 10 dependent variables sampled in the simulator, 1210 +1210 = 2420 numbers would be output.

To aid in data management ARES requires that the names of all variables be stored along with the numerical values as a set of alphameric labels at the beginning of the data file. For 10 independent and 10 dependent variables, this adds 10 + 10 = 20 more items to the file, for a total of 2440 items in the above example.

The simulator output file is to be input to the regression program, hence it must obey the regression input format for the design data base. The complete file is described in the next chapter, under Regression Program Usage.

Following the information at the beginning of the file, including the variable names, the variable values are listed for each design point. The values for all variables at each design point are grouped together. Thus designs can be added to the file or deleted out by adding or deleting a block of input lines. The order of occurrence of independent and dependent variables is unimportant, but the order must be the same for each design and must match the order of the variable names at the beginning of the file. Thus, only consistency is required in the order of variables; there is no demand for a pre-specified order from a preselected set of variables, as was required for LATIN input.

The data from the OLS sample will, if all or almost all designs run successfully, be a well-dispersed sample of points in n-dimensional design space. However, the data points are not useful for one-dimensional cross-sectional plots because of the OLS dispersion. In general, data points are non-collinear, the one exception being the first few points in the OLS sample.

The data file is most conveniently stored on some rapidly accessed permanent storage device, such as disc. It can then be accessed by the regression program, SUBARES, ADDARES,or the surface fit residual check program EVAQF. Program EVAQF is intended mainly for validation using follow-up data, however, validation data has the same format as regression data.

3.7 Simulation Data Management

Data handling errors in the initial stages of an ARES application have far-reaching effects downstream, and regeneration of data is costly. Hence, physical key punching of data changes and handling of cards and tapes should be eliminated as much as possible by making use of interface programs and disc files. However, retention of punched cards and tapes as a back-up medium is encouraged.

Careful record-keeping is essential. An ARES analysis produces volumes of data, and often valuable information about the contents or mode of obtaining a particular data file is lost. It is recommended that a set of report forms with standard format be developed to keep track of (a) data file contents and production history and (b) computer program run results for each ARES element as well as the user's own programs (e.g., the simulator).

Program execution results which impact existing results should be transmitted instantly. Thus, design failures should be deleted from the regression data base file as soon as they become known. Simulator output interface may make this automatic by building up the regression data base as the designs are run instead of relying on transmission of dependent variable values to an existing design file.

ARES provides two programs to aid in deletion/addition of data in a data base in regression input format. Program SUBARES deletes designs and program ADDARES adds hand-coded data to existing observations. ADDARES is intended for use when more dependent variables are to be added to the variables already included in the designs in the data base.

3.8 Usage of SUBARES and ADDARES

It is assumed that SUBARES and ADDARES object codes are available as permanent files under the user's account.

<u>User Instructions for SUBARES</u>

PURPOSE: Program SUBARES copies an existing ARES file to a new ARES file omitting specified cases from the new file.

USAGE: GET, SUBARES
SUBARES, OLD,NEW,DELETED

(1) OLD is the logical unit containing the original ARES file. The default name is OLD. OLD is not changed by SUBARES.

(2) NEW is the logical unit containing the edited ARES file. The default name is NEW. NEW has exactly the same independent variable definitions as OLD with fewer data cases.

(3) DELETED is the logical unit containing a list of deleted cases. The default name is OUTPUT.

INPUT: SUBARES will request the numbers of the cases to be deleted. The case numbers are typed as a string of integers separated from one another by at least one blank or a comma. These numbers are entered on as many lines as required with any convenient number of them on any line. A blank line signals the completion of the input sequence. The case numbers may be entered in any order. Case number refers to the sequential index of the case on file OLD. The fifth case in order on OLD is case number 5 and so forth.

OUTPUT: Each deleted case is reported to the user on file DELETED. The report includes the case number and the values of the independent variables for each case.

RESTRICTIONS; A maximum of 100 cases may be deleted in any single SUBARES execution.

FILE POSITIONING: Old must be positioned by the user prior to execution. Both OLD and NEW are rewound after execution.

EXAMPLE: Delete cases 5, 13, and 20 from OLDARES writing NEWARES. The reported deletions will be contained on OUTPUT to help illustrate usage from a time-sharing terminal. Note the case numbers have been input to illustrate continuation past the first line and random order.

```
C >REWIND,OLDARES
C >GET,SUBARES
C >SUBARES,OLDARES,NEWARES

 INPUT CASE NUMBERS TO BE DELETED
 NULL CARD TERMINATES SEQUENCE - 1 to 30 CASE NO/CARD
I>5 20
I>13
I>
                         DELETED CASES
  NO     OPR          T4           A8          T/W          T/C
         W/S          AR           LESWP       TOGW

   5      1.750E+01    2.900E+03    5.000E-01   1.080E+00    4.500E-02
          1.000E+02    2.800E+00    5.400E+01   6.000E+04

  13      2.350E+01    3.200E+03     .0         1.160E+00    4.200E-02
          1.000E+02    2.200E+00    6.200E+01   7.200E+04

  20      1.900E+01    3.020E+03    8.000E-01   9.200E-01    3.300E-02
          7.000E+01    1.300E+00    5.000E+01   6.000E+04

STOP
```

USER INSTRUCTIONS FOR ADDARES

PURPOSE: Program ADDARES adds new dependent variables to those of an existing ARES file creating a new file with the expanded dependent variable data set.

USAGE: GET,ADDARES
ADDARES,DATA,OLD,NEW

(1) DATA is the logical unit containing the data to be added to the ARES file. The default name is INPUT.

(2) OLD is the logical unit containing the original ARES file. The default name is OLD. OLD is not changed by ADDARES.

(3) New is the logical unit containing the resulting ARES file. The default name is NEW. Each data case in NEW will contain all of the information on OLD with the new data from DATA appended.

INPUT: File DATA has the following format. All data is in standard ARES format, eight field-ten digit. DATA has the same structure as the ARES dependent variable sets.

(1) Card-1, col. 1-10 The number of new dependent variables. Decimal point required.

(2) Card-2, Dependent variable names punched eight/card using as many cards as required.

(3) Card-3, Dependent variable values corresponding to the names on card-2. Card-3 sets are repeated for each data case on the original ARES file preserving the order. Decimal points required.

RESTRICTION: The total number of dependent variables, old plus new, cannot exceed five hundred.

DIAGNOSTICS: If the number of cases on DATA and OLD do not exactly correspond the program will report which file is exhausted and print the current data case on the other file. NEW has been written, but is almost certainly incorrect.

FILE POSITIONING: OLD must be positioned by the user prior to execution. Both OLD and NEW are rewound after execution.

SECTION IV

REGRESSION

4.1 Introduction

In traditional parametric analyses, combinations of parametric variables for which data will be gathered are selected and, then, dependent variable data are generated for each combination. The design selection and simulation activities described in preceding sections are ARES equivalents for these traditional steps. The next logical step in the traditional parametric study, in its simplest form, is graphing of the dependent data against independent parameters. Regression/"surface fit" analysis is the ARES equivalent for the latter exercise. Of course, no graphs are actually constructed in this ARES step. Indeed, manually developed plots of simulation output (n > 2) are an impossibility. This is due to the sparse, orthogonal array of available designs as illustrated in Figure 11 , using a three-dimensional example.

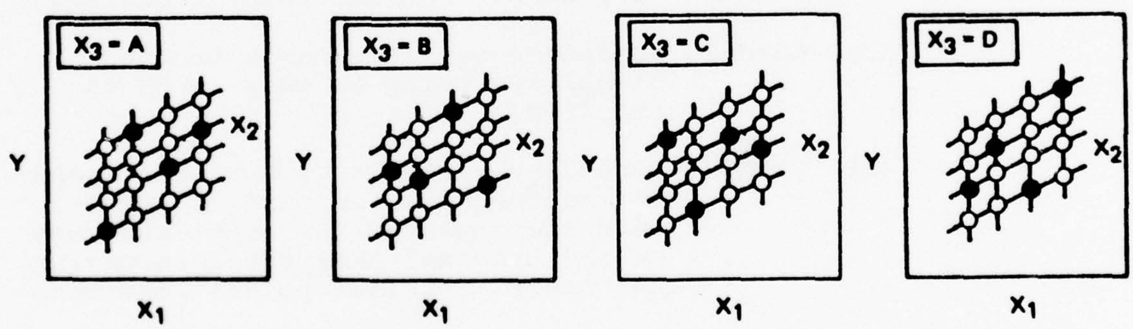


Figure 11. Distribution of Designs

(Visualization of the ARES method using one, two or three-dimensional examples can tend to mislead the user. In the first place, the ARES system is not competitive with traditional approaches for one or two variable problems. Second, two variable ARES data is determined sufficiently to allow graphing; an impossibility in higher dimensions. Finally, in the three variable case, four levels of each independent parameter are selected. This is a popular number of levels for traditional analyses regardless of dimension but is encountered only for n =

3 in ARES system application. Therefore, the user is alerted to avoid incorrect inferences from low dimensional, illustrative examples. Higher level n-dimensional space continues to be as incomprehensible as ever.)

To accurately graph the variation of a hypothetical dependent variable, y, due to parametric variation of the independent parameters x_1, x_2 and x_3, the 64 points indicated by open and closed symbols on Figure 4.1 are required. The design selection/simulation steps in an ARES application would yield only the sixteen closed symbol points. Ovbiously, any attempt to manually develop lines through just the closed symbols would be chancey at best, since it is difficult to absorb guidance from more than one of the x_3 relationships at a time. This guidance is generated mathematically in the ARES system.

In the illustrative example for n = 3, 25 percent of the "traditionally desirable" amount of data is provided with the ARES system. The variation of this provision as n increases, is presented in Table 3. . At n = 10, an incomprehensibly small .012 percent of a "desirable" amount is made available. One can see how the graphing difficulties illustrated for n = 3, become impossibilities for higher n even if plots in up to ten variables could be comprehended.

Table 3. Fraction of "Traditionally Desirable" Data Provided by OLS

VARIABLES	OLS LEVELS	OLS COMBINATIONS	TRADITIONAL COMBINATIONS	OLS FRACTION OF TRADITIONAL
4	5	25	256	9.8%
5	7	49	1,024	4.8%
6	7	49	4,096	1.2%
7	8	64	16,384	.39%
8	9	81	65,536	.12%
9	11	121	262,144	.046%
10	11	121	1,048,576	.012%
n	ℓ	ℓ^2	4^n	$100 \times \ell^2/4^n$

Illustration of an independent/dependent (x/y) variable relationship can be developed by fairing a line through plotted data. Well ordered data can be fitted exactly. Less well behaved data requires some compromise. In such a case, residuals may be minimized by using a technique like least squares fits. In any case, a functional form $y = f(x)$, of the graphed relationship could be derived and this is quite often done.

This is always done in the regression/"surface fit" phase of an ARES system application and at this point the ARES multi-dimensional capability is paid for by some loss of precision.

Manual graphing of well behaved plotted data and derivation of coefficients in a functional form to represent the resultant relationship can be accomplished to a high level of precision. This is partially due to the fact that any number of functional forms are available to the user. He may pick the form that is most applicable to his specific problem.

These options are not available in the ARES system. A single functional form is used. It is a quadratic of the form,

$$y=b_0+b_1x_1+b_2x_2 \dots +b_nx_n+b_{11}x_1^2+b_{12}x_1 x_2 \dots +b_{nn}x_n^2$$

Obviously, this single functional form is not applicable to all types of y variation. Therefore, ARES regression/"surface fit" analyses must employ the least squares fit "compromise" most of the time. Consequently, most of the time, there will be some lack of precision in the analytical approximation derived in the analyses. The magnitude of the error depends upon the degree of non-quadratic curvature exhibited by the dependent variable of interest.

It should be noted that the degradation of precision discussed here should not be due to dependent variable misbehavior. The least squares fit compromise is used in manual graphing when poorly conditioned data is encountered. Since ARES simulation data is normally generated by computer analyses they are expected to be well conditioned and relatively free of noise. Therefore, the least squares fit compromise along with some resultant degradation of precision, occur in the ARES method due to non-quadratic curvature.

In ARES regression/"surface fit" analyses, coefficients are derived for a quadratic function that represents a least squares fit through dependent parameter variations which are due to changes in a number of independent parameters. The result could be called a curve fit in one or two dimensions. However, the derivation is performed for up to ten independent variables with the ARES system and the multi-dimensional fit may be more properly characterized as a surface rather than a curve.

Therefore, the functions derived in the ARES system are referred to as surfaces or surface fits.

Do not think that what has been described is more difficult than it is. It has been shown that no new or unique analyses are used to this point in the ARES data management system. The tools or programs may be different but the steps that are used in traditional parametric analyses are also used in the ARES system. It will be shown that this is true in successive analytical steps as well.

The big difference between the two levels of analysis is the number of variables that are exercised. The ability to handle a large number of variables simultaneously is the justification for the ARES system. This capability is made available for some inherent lack of precision. However, the accuracy of the system is not inconsistent with the conceptual and preliminary desigr activities for which the system is intended. When these considerations are realized, problems can be formulated accordingly and the system can become a powerful analytical tool.

The regression/"surface fit" element of the ARES data management system is discussed in detail in succeeding sections.

4.2 Least Squares Quadratics

Least squares surfaces are used in the ARES surface fit element because they provide convenient methods for fitting to data values when a fit to overall trends is desired instead of an exact fit to the data values.

In the ARES parametric analysis method, a very simple, second-order model is used to approximate the user's simulation model in multi-dimensional space. This is done with a small fraction of the data required for a traditional parametric analysis.

The simulator may produce complex, higher-order variations in the output data when several independent variables are varied simultaneously in the selected designs which are input. From these variations, the ARES method selects the dominant trends and generates a simple surface with just enough curvature to avoid the gross errors of linear approximations, which have no curvature.

Following surface generation for each of the dependent variables in the user's parametric study, the ARES optimization program can be used, at little additional cost, to explore design regions with potentially high payoff. While using the surfaces in the analysis, it must be kept in mind that a simplified, second-order least squares fit model may deviate from the complex model in the simulator. There are two major potential causes of this:

1) Lack of fit because the simulator is not a second-order, function generator, and

2) Noise in the simulator output.

Lack of fit is inherent in the use of second order or quadratic surface fit functions. Noise, however, is a simulator problem, as discussed in the section on simulation. Results from the ARES method depend heavily on how well these problem areas are suppressed. Unfortunately, a good method of measuring the extent of these problems in the user's analysis is not made available by ARES. This is why follow-up validation of optima via further simulator runs is a strongly recommended part of the ARES procedure.

A quadratic polynomial in the *n independent* simulation variables $x_1, x_2, \ldots, x_n$ is used to form a functional surface to approximate the true surface of each dependent y variable. The sample designs selected by the ARES design selector are input sequentially to the simulator as combinations of values for x_1, $x_2, \ldots, x_n$. For each design point, a y value is obtained for each dependent variable to be analyzed. Each set of y's is combined with the corresponding $x_1, \ldots, x_n$ combination in a data case for the regression data base. The regressor program finds, for each y variable, a set of coefficients for a quadratic or second-order polynomial

$$y=b_0+b_1x_1+....+b_nx_n+b_{11}x_1^2+b_{12}x_1x_2+....$$

in the x_i independent variables. The quadratic contains all terms x_1x_2, x_1x_3, $\ldots x_2^2$, $x_2\ _3$, ..., up to x_n^2.

The quadratic expresses simple interactions of each pair of variables in the x_ix_j terms and expresses single-variable quadratic effects in the x_i^2 terms. Two examples are given to illustrate quadratics. An example of a one-dimensional quadratic is given to illustrate lack-of-fit and noise, and a two-dimensional quadratic to illustrate the use of a multi-dimensional polynomial in regression program output format.

Figure 2. shows a one-dimensional second-order surface (a parabolic curve) as a solid line superimposed over a dashed line

representing possibly a third-order surface. Lack-of-fit is illustrated by the shaded area between the two surfaces. The second-order surface could have an equation like $y = 5 - 2x + x^2$, where in this case, $b_0 = 5$, $b_1 = -2$, and $b_{11} = 1$. Since there is only one independent variable, it is referred to as x rather than x_1. Figure 3. shows the same surface faired through data points contaminated by noise. The dashed curve is a hypothetical continuation of simulator output between the sample points shown, and again the shading shows the surface fit error.

The two-dimensional example is given next to illustrate the differences between the quadratic equation as written and the regressor output formats for its coefficients. A typical quadratic with n = 2 variables x_1 and x_2 is:

$$y=3+x_1x_1^2+0.5x_1x_2+x_2^2$$

In this example, $b_0=3, b_1=1, b_2=0$ (no x_2 term), $b_{11}=-1, b_{12}=0.5$ and $b_{22} = 1$, a total of six coefficients. In the three-dimensional space of x_1, x_2, and y, this quadratic equation describes a surface, which can be visualized by taking the y value at each (x_1, x_2) point to be surface elevation over the x_1-x_2 plane. Suppose the variables x_1, x_2, and y were given hollerith designators X1, X2, and Y, respectively, and these had been input along with names X1*X2, X1*X2, and X2*X2, respectively, for the terms x_1^2, x_1x_2, and x_2^2. The coefficients would be printed out as follows:

```
PUNCH QUADRATIC COEFFICIENTS AS FOLLOWS    Y
1      3.00000E+00  CONSTANT
2      1.00000E+00  X1
3       .0          X2
4     -2.00000E+00  X1*X1
5      5.00000E-01  X1*X2
6      2.00000E+00  X2*X2
```

This is, with minor details missing, how the list of the six regression surface coefficients would appear following several pages of descriptive output for the regression on the Y variable. It is not necessary to give the variables the particular names shown in this example.

Note that coefficients of all the square terms (X1*X1 and X2*X2 in example) are doubled in the printout. This form is compatible with the input requirements of the optimizer. However, if the output coefficients are to be used in applications other than on the optimizer, the user must remember to halve the square term coefficients.

As mentioned earlier, quadratic coefficients can be used other than in optimization mode. Design performance can be predicted for designs not run on the simulator, with proper caution to (a) evaluate the quadratics only within the design selector lower/upper bounds on x_i variables, and (b) use the performance y values only as preliminary design-type estimates.

A byproduct of the use of quadratics is easy evaluation of partial derivatives with respect to each x_i. This feature is used to advantage by the optimization analysis program, but its use is otherwise discouraged. Partial derivative error in this method of surface fitting is often much larger than the error in the surface approximation to the dependent variable. Figure 12. illustrates this phenomenon in a one-dimensional case. Error residuals are illustrated by vertical bars between corresponding points on a hypothetical dependent variable surface (dashed curve) and its least squares quadratic approximation (solid curve). The slope of each curve is indicated by tangents drawn through the corresponding points. In the case illustrated, surface error residuals may well lie within tolerable limits. However, in the neighborhood of the maximum of the least squares curve, the difference in slope of the tangents is very large and can be misleading if used to extrapolate trends.

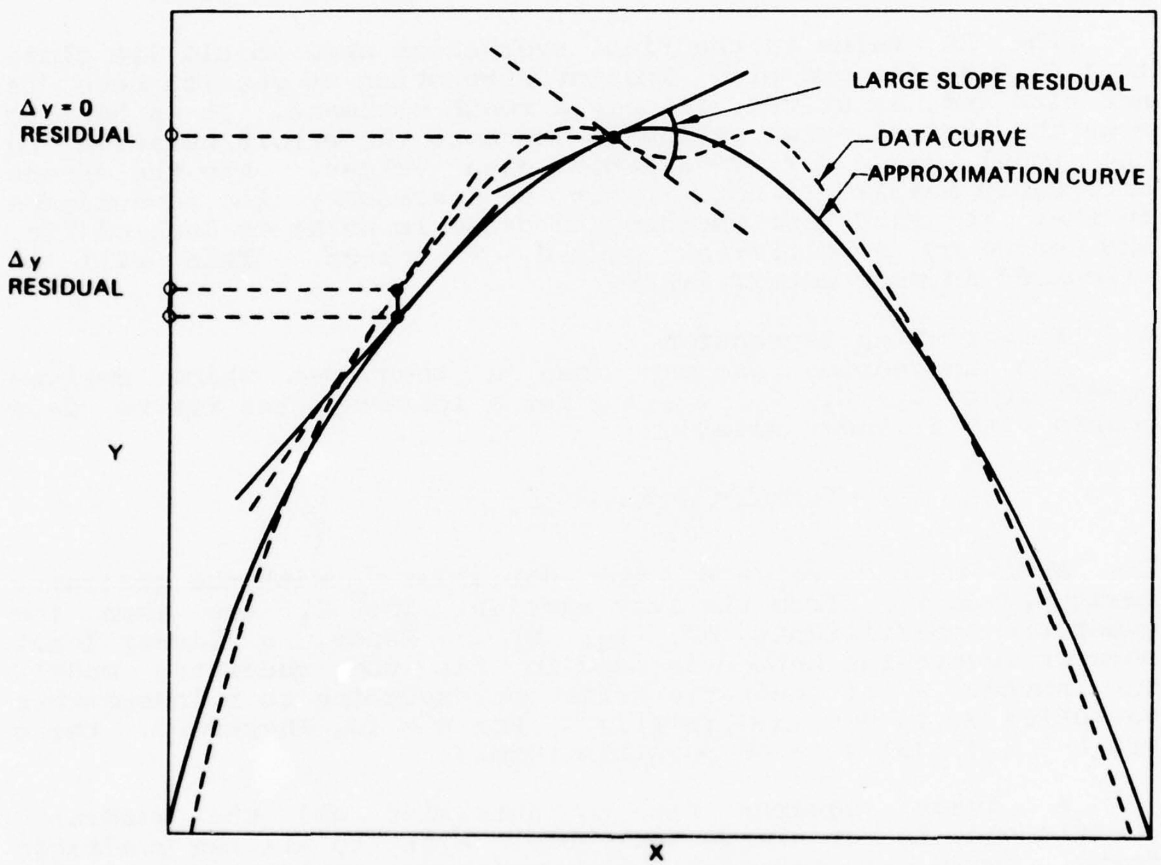


Figure 12. Slope Error in an Approximating Curve

It was stated earlier that a good method of measuring the extent of lack-of-fit and noise problems is not available in ARES. However, rough error estimates can be obtained during both the regression phase and the validation phase and used as a guide. The regression analysis yields statistical indicators which can be interpreted even though their statistical character may be questionable in present usage. The best numbers for the user to examine are the multiple correlation coefficient-squared (R^2) and the list of error residuals printed out by the regressor.

The R^2 value in the final regression step should lie close to 1.0, 0.98 for example. The interpretation of results here is not firm and, as stated, is only a rough estimate. It is best to scan the list of error residuals and note the errors relative to the total range of y-variable data values. Are the errors acceptably small? If not, it may be necessary to investigate further to find out whether the cause is noise or lack-of-fit, and decide on a different course of action. This will be discussed in more detail later.

4.3 Forward-Step Regression

The regression program uses a technique which derives coefficients C_0, C_1, C_2, ..., C_N for a least-squares fit to data points with a linear model

$$\hat{y} = C_0+C_1Z_1+C_2Z_2+\ldots+C_NZ_N$$

The ARES method replaces the variables Z_i with the quadratic terms x_i and x_{ij} from the last section. The C_i are then the quadratic coefficients b_0, b_i, b_{ij}. Hence, a linear least squares regression method is used to fit the quadratic model. The number N of quadratic terms corresponding to n independent variables x_i is $N = (n+1)(n+2)/2$. For n = 10, therefore, there are $N = (11)(12)/2 = 66$ possible terms.

A least squares fit to determine all the quadratic coefficients is not always desirable. A fit to all the quadratic terms, known as forced-fit regression may yield a surface with extraneous curvature. It usually happens that most of the terms are non-competitive as regards their ability to express the data variations of a given dependent variable. In such cases, a small subset of terms (for example, 20 out of a possible 66) expresses the variations as well as can be expected for a quadratic fit. It would seem that a least squares fit would yield near-zero coefficients for the noncompetitive terms. This is not always the case. The least squares coefficients may be such that the noncompetitive terms cancel each other at the data points but introduce troublesome extraneous variations in between.

Stepwise regression is used to select a set of terms which expresses data variations with a minimum of added extraneous variations. Stepwise regression simply alters the existing regression model at each step by adding and deleting terms in a systematic fashion. A least squares fit to the existing model is done to get coefficients and also to statistically analyze the significance of (a) each term in the existing model and (b) each term not in the existing model, were it to be included in the model.

The stepwise regression procedure employed uses a modified forward selection technique. While this method does not necessarily provide the best subset of regressor terms it does examine the effect of the introduction of a new term upon those previously included in the regression.

Whenever a step has been completed, the stepwise procedure searches for a new term to be introduced and proceeds in the following sequence of stages:

1. Choose the term to enter the regression model which has the largest squared partial correlation coefficient with the surface fit residuals from the previous step.

2. Test the partial correlation coefficient in order to determine if it is significantly non-zero.

    a. If it is significantly non-zero, proceed with the next stage.

    b. If it is not significantly non-zero, terminate the stepwise procedure.

3. Introduce the new term into the model and solve for the new estimates of the regression coefficients.

4. Test significance to the regression of those terms previously in the model.

    a. If any term is now insignificant, delete it from the model and analyze the reduced model.

    b. If all terms are significant, proceed.

5. Calculate new partial correlation coefficients for all terms not presently in the model and go to stage 1.

In this fashion, terms are added to and deleted from the model until the partial correlations of the remaining terms are too small to be significant.

In the usual application of regression analysis, the word "significant" has a precise meaning. Regression has traditionally been done on data which contains a certain amount of randomness, for example due to experimental error in the laboratory. Statistical significance tests are based on certain assumptions made about the random variables present in the data.

However, it is felt that the usual ARES application would not allow random variables to be a component in the data. The ARES method can be applied to laboratory data, but the risks here are very large. In this document, it is assumed that the method is applied, as intended, to noise-free data obtained by digital computer simulation. Thus, the important contribution to the error residuals comes from lack-of-fit due to the inadequacy of quadratics to fully express simulator reality. This lack-of-fit may well appear very systematic and non-random.

Fortunately, it is only the statistics and not the least squares solutions at each step generated by the regression program which depend on the assumption of random variables in the data. For a given selection of terms, the least squares coefficients are those which minimize the residual sum-of-squares. This is a problem in linear algebra, and not statistics. The statistical procedure in the regression program is retained for convenience because it can be used to impose an arbitrary cutoff level for admitting the most effective terms into the regression model.

The regressor has two main modes of execution. These are forward-step and backward-step regression. Forward-step regression starts with the constant term b_0 being the only term in the regression model. At each step, one of the terms b_1, b_2, ..., b_{11}, b_{12}, ..., b_{nn} is added to the model and new values found for the b's already in the model. Also, the b's in the model are tested to see if introduction of the new term has caused some of them to lose their "significance". If so, they are dropped from the model. The procedure stops when none of the candidate terms looks "significant" enough to enter the model.

The backward-step process is the same at each step as the forward-step process. The differences are that (a) the backward-step process starts with <u>all</u> the terms in the model (i.e., a forced-fit) and (b) the process stops when none of the terms in the existing model tests out to be "non-significant". Hence, in backward mode, terms are deleted (with some being reentered when appropriate) until all remaining terms pass the statistical test for retention.

Additionally, the user has the ability to force terms to enter or remain in the model. In this way, the user can force the resulting regression surface to have a dependency on certain terms regardless of their regression significance. This capability may be useful when the user feels strongly that certain terms should be affecting the surface curvature. It is not guaranteed that stepwise regression will retain such terms. The regression program is merely trying to select a model such that the sum of squares of residuals at the data points is a minimum.

The regression mode normally used is forward-step. It has been common practice to force the pure quadratic terms x_i^2 into the model when it was felt necessary to force some of the x_i variables to affect a surface quadratically.

4.4 Useage of the Regression Program

The regression program (MANE) has two input files, known internally to the program as TAPE1 and INPUT. File TAPE1 is the design data base of independent and dependent variable values, in the same format read by SUBARES and ADDARES. The useage of TAPE1 with these other data management programs is reviewed for clarity.

For SUBARES, the useage is:

```
SUBARES,OLD,NEW,DELETED.
```

Here the object code is on a file called SUBARES, and TAPE1 exists in two versions, called OLD and NEW in this example. The OLD file is input, the NEW file is output as a modified design data base, and file DELETED lists the deleted design cases. For ADDARES, the useage is, in a somewhat similar fashion,

```
ADDARES,DATA,OLD,NEW.
```

The DATA file contains data values to be added to the design cases in OLD, the NEW file results, and again both OLD and NEW represent the TAPE1 data base for regression. Refer back to SUBARES and ADDARES useage in the section, Simulation.

Unlike the other ARES data management programs, the regressor program MANE uses all data on file TAPE1, including the first few lines. This is during the initial input phase, when the independent variables are read and stored for all designs.

Subsequently, MANE reads from INPUT to get instructions for a regression, and then rewinds and reads TAPE1, this time only to get the values for the dependent variable for the regression. The regression is then performed, resulting in several pages of descriptive output (how much depends on the program option selected) and, finally, the quadratic coefficients output on file PUNCH. These coefficients can be used directly by the optimization program for parametric analysis.

The process of reading instructions from INPUT and then rewinding and reading dependent variable values from TAPE1 is repeated for each regression. The INPUT file is a NAMELIST file and reads namelist options into a list storage location called LIST. Most of these options have defaults, as described below.

After the initial reading of independent variable values from TAPE1, the quadratic terms are generated. This is done by carrying out the multiplications $x_i * x_j$ of data values at each design point for all pairs of independent variables x_i, x_j. These "manufactured" variables $x_i * x_j$, are stored once and for all and used along with the x_i values themselves for all regressions following.

The useage of MANE is as follows:

MANE,TAPE1,INPUT,OUTPUT,PUNCH.

The data files TAPE1,INPUT,OUTPUT, and PUNCH, do not have to be specified in the call to MANE if the indicated names are used.

The TAPE1 format is as follows. Each item begins a new input line (card image).

Item 1 (8A10 Format) 80 - column title

Item 2 (F10.0 Format) Number of independent variables to be read in for all regression cases.

Item 3 (8A10 Format) Independent variable names, in the order they are to be considered whenever the regression surface coefficients are used.

Item 4 (F10.0 Format) Number of 10- column data fields

in each design case.

Item 5 (8A10 Format) Independent and dependent variable names in the order in which values for the variables appear in each design case. Names must occur as data fields do, i.e., if data field #132 is not used in the following design cases, name #132 should be left as a blank 10-column field. Order of independent and dependent variables is immaterial as long as data values have the same order. The names must be left-adjusted in their 10-column fields.

Item 6 (8E10.0 Format) Design cases, consisting of values for each variable in the same arrangement as the names in Item 5, i.e., values for a variable must appear in all design cases in the same 10-column field as the corresponding name in Item 5. Each case must contain the same number of 10-column fields, eight to a line as in Item 5.

Item 7 As soon as an end-of-file or a data field of 9999999. or greater is encountered, reading of TAPE1 will end.

The NAMELIST format of file INPUT enables the user to input instructions for each regression in a free field format. The regressor does not have a FORTRAN free-field input module in its source code, as do programs EVAQF and OAPEN. Instead, NAMELIST provides the regressor with the convenience of free-field input for the regressions.

Each line (card image) on INPUT is all or part of a NAMELIST record. A NAMELIST record begins with a blank column followed by a dollar sign ($). It ends with $ after the NAMELIST variables which are to be given new values are reset in a series of X = value statements set off by commas. For the regressor, the list name used is LIST, and this name must follow the $ at the beginning of each NAMELIST record.

The format of "value" in each X = value statement must be ANSI standard for the "X" variable name, e.g., if "x" is a name beginning with one of the letters I through N, then "value" must be integer format. A sample NAMELIST record for the regressor is:

```
$LIST LOC=41, XSTOP=1. $
```

Note that the name LOC is of integer type and XSTOP is of real type, by ANSI standard. Hence, the values are, respectively, integer format for LOC and real for XSTOP.

The items in the NAMELIST list are given below. All have defaults except the parameter LOC, which specifies the dependent variable for a regression case.

Item 1 SL - option for changing the significance level for adding/deleting variables to/from the regression model. Default value is .05. A value of .2 is recommended to improve inadequate fits.

Item 2 LOC - field number in the regression data base (TAPE1) for the dependent variable for the current regression case. No default.

Item 3 TYPE - input a positive number if a regression on the logarithm of the dependent variable is desired. Default is non-log regression.

Item 4 NJ - number of non-constant terms to be forced to enter or remain in the regression model. Default value is 0.

Item 5 IND(1) - array containing the indices of the terms to be forced. To find out how to derive the index of a term, refer to the discussion below. Default values are 0.

Item 6 IC - indicator for forward or backward step regression. For a backward step regression, IC = 1. The default is IC = 0, or forward step regression.

Item 7 IP - printout control. Default value is IP = 2, which gives all printout at the final regression step. Setting IP = 5 will yield printout at each step.

Item 8 XSTOP - positive value if this is the last regression case on the INPUT file. Default value is 0.

Once an option has been set at some value, it remains set at that value until re-set in a later regression case. For example, the regression case corresponding to the NAMELIST record

$LIST LOC = 27, NJ = 2, IND(1) = 3,18 $

will have quadratic terms 3 and 18 (see below) forced into the regression model for dependent variable number 27 in the regression data base. This will hold true for all following regressions until a NAMELIST record with the expression NJ = 0 appears (IND need not be reset if NJ is reset to zero).

In order to know how to specify IND indices for forced terms, it is necessary to first understand the order of quadratic terms used by the regressor. This will now be reviewed. If x_1, x_2, ..., x_n are the independent variables, there are (n + 1) (n + 2)/2 terms, and these occur in the following order:

$$(\text{constant}), x_1, x_2, \ldots, x_n, x_1^2, x_1x_2, x_1x_3, \ldots,$$
$$x_1x_n, x_2^2, x_2x_3, x_2x_4, \ldots, x_2x_n, x_3^2, \ldots,$$
$$x_{n-1}^2, x_{n-1}x_n, x_n^2$$

Note that there is one constant term, n terms x_1, x_2, x_n, n terms

$$x_1^2, x_1x_2, \ldots, x_1x_n, \text{n-1 terms } x_2^2, x_2, x_3, \ldots, x_2x_n$$

and so on, down to two terms, x_{n-1}^2, $x_{n-1}\ x_n$, and finally the one term x_n^2. It must be further noted that the regressor does not count the constant term in the IND numbering scheme. Then the first term is x_1, the second is x_2, the n-th term is x_n, the (n+1)-st term is x_1^2, and so on.

For example, suppose there are n = 7 independent variables, and suppose it is desired to force the term $x_4 x_6$. Counting up, there are seven terms x_1, ..., x_7, seven more for x_1^2, $x_1 x_2$, ..., $x_1 x_7$, six for x_2^2, ..., $x_2 x_7$, five for x_3^2, ..., $x_3 x_7$, and then the three terms x_4^2, $x_4 x_5$, and finally, $x_4 x_6$. Hence, the IND index of $x_4 x_6$ is 7 + 7 + 6 + 5 + 3 = 28. The total quadratic polynomial (including the constant) has (7+1) (7+2)/2 = 36 terms.

SUCCESSFUL COMPLETION AND ERROR CODES

The MANE completion code is returned in variable IERR where NWRGSN SUCCESSFUL COMPLETION CODE = IERR.

IERR≥0 Successful completion

IERR=0	No more independent variables qualify to be entered or deleted.
IERR=1	Single variable looping detected. Looping means the variable is repeatedly inserted and then deleted. NWRGSN stops after the deletion.
IERR=2	Double variable looping detected.
IERR=3	Present step deleted a variable, and the only variables left in equation are those to be forced.
IERR=4	2*MQ steps have been computed.
IERR=5	NJ=M-1, no selection process.
IERR=6	All independent variables have been entered in the equation.

The MANE unsuccessful completion code returns as NWRGSN ERROR COMPLETION CODE = IERR.

IERR≤0 Error termination

IERR=-1	Error return from subroutine
IERR=-2	PIT for entry test statistic. PIT error code equals IERR (see PIT abstract).
IERR=-3	Error return from subroutine PIT for delete
IERR=-4	test statistic. PIT error code equals IERR-2 (see PIT abstract).
IERR=-5	No independent variable qualifies to be entered, and a constant term was not specified: process cannot start.
IERR=-6	Overdetermined system of equations is singular.
IERR=-7	Variable selected to be deleted is the only variable left in the equation, and a constant term was not specified.
IERR=-8	MQ not in the range M≤MQ≤M+1
IERR=-9	IR≥M
IERR=-10	NJ≥M
IERR=-11	A row index in IND is either less than M or less than 1.
IERR=-12	SL not in the range 0≤SL≤.9.
IERR=-13	N too small.
IERR=-14	Dependent variable zero or constant in all observations

SECTION V

INTERROGATION

5.1 Optimization

Once acceptable regression surfaces have been obtained for all the important dependent variables, the optimization program OAPEN can be used to explore regions of design optima. The regression surface coefficients are input to the program, along with specifications for the kind of performance optima desired. The OAPEN program finds these optima and outputs the independent design variable combinations and dependent performance variable values at which each different optimum condition is achieved.

The specification for an optimum in OAPEN includes two major items, (a) the identification of a performance variable to be held to a maximum or a minimum and (b) the specification, for some subset of the other dependent variables of minimum or maximum performance levels which they cannot violate. Also specified are lower and upper limits for the independent variables, and these limits should be at or within the limits of the data used in regression (to avoid extrapolation into regions where no data was taken).

An example drawn from airplane preliminary design is as follows: A simulator program is available which describes the performance of an airplane on a design mission. The airplane design is conceptually fixed by the simulator program and by certain design parameters which are always input with the same values for a given concept. Differing designs within the concept are achieved by varying another set of design parameters which are used as the independent variables in a parametric study. These are, in the present example, FPR (engine fan pressure ratio), OPR (engine overall pressure ratio), T4 (design turbine inlet temperature), A8 (engine airflow schedule parameter), THTR (throttle ratio), T/W (thrust-to-weight ratio), T/C (wing thickness-to-chord ratio), W/S (wing loading), AR (aspect ratio), and TOGW (takeoff gross weight). Regression data is obtained by giving the simulator as input all the combinations of design variable values specified by the Design Selector program, LATIN. For each combination, performance is output in the form of values for the dependent variables RANGE (mission range capability), SSDALT (supersonic dash altitude), NPEN (maneuver capability), and TODIST (takeoff distance), among others.

The regression program accepts the design input/output combinations and produces regression coefficients to describe each dependent variable as a simple quadratic. Assuming that these performance approximations are good (the regression residuals look acceptably small), the coefficients are now ready to be input to OAPEN. It remains to decide on a set of specifications to go along with the coefficients and tell the program where to look for optimum designs. Suppose it is desired to explore designs having maximum range capability subject to restrictions on field length required for takeoff, maneuver capability, and supersonic dash altitude. Restricting field length to 6,000 ft., maneuver g-loading above 2.70, and dash altitude to 50,000 ft or above leads to the following constrained optimization specification:

Maximize RANGE
Subject to NPEN ≥ 2.70
TODIST ≤ 6000
SSDALT ≥ 50,000

Thus, the specification is to maximize RANGE with constraints on NPEN, TODIST, and SSDALT. The OAPEN program does this by using the coefficients to get function values and partial derivatives for RANGE, NPEN, TODIST, and SSDALT at a number of iterative design points. Given a starting point in terms of values for the independent variables FPR, OPR, T4, etc., the program solves iteratively for values which yield the performance required by the specification given above.

It is often desirable to explore many different optima in a comprehensive study and then examine the tradeoffs. For example, the effect on RANGE (and any of the other variables) of specifying different minimum values for SSDALT can be studied over a sequence of optima. Also, different combinations of objective function (the function to be minimized or maximized) and constrained functions can be tried. For example, a minimum TODIST can be sought with accompanying constraints on RANGE, NPEN, and SSDALT, viz.:

Minimize TODIST
Subject to NPEN ≥ 2.70
SSDALT ≥ 50,000
RANGE ≥ 2,000

where RANGE has units of nautical miles.

5.2 The Penalty Function

The OAPEN program solves for a constrained optimum by the penalty function method, hence its name, OAPEN (Optimization Analysis by PENalty function). In this method, a constrained optimum is found by iteratively solving for the limit of a sequence of unconstrained minima. That is, the constrained minimization/maximization of an objective function is replaced by the minimization of a sequence of penalty functions which combine the objective and constraints.

Going back to the first optimum specifications which was given as an example, suppose the RANGE function is to be maximized subject to the constraints shown. Then the form of each penalty function in the sequence is

$$PEN_K = -RANGE + P_K * \Sigma \text{ (Constraint Violations)}^2.$$

Minimization of (-RANGE) will maximize RANGE, and the sum (Σ) of squares over all constraints adds a positive number for each constraint which is violated at the current iterative point of evaluation (P_K is a positive coefficient). For each K = 1, 2, ..., PEN_K is minimized in an iterative minimization procedure which calls for evaluation of PEN_K at successive design points to find the minimum.

At each trial design, the regression surface coefficients yield values for the dependent variables. If NPEN is below 2.70, TODIST above 6,000 ft, or SSDALT below 50,000 ft, the corresponding violations are squared and added to the -RANGE value via the $P_K * \Sigma(...)^2$ term in the PEN_K function. The P_K factor is a coefficient common to all penalty terms and is used to increase emphasis on the constraints when appropriate.

The effect of the $P_K * \Sigma$ - term is to add positive numbers to the negative of RANGE whenever constraints are violated. Since PEN_K is to be minimized, this causes the next search iteration to "veer away" from regions of constraint violation. Thus, the next set of OPR, FPR, T4, etc., values will yield performance closer to specs and/or greater RANGE capability. The final solution, providing there is one, will satisfy all performance constraints to within pre-specified tolerance limits. Also, RANGE will be at a local maximum subject to the constraints imposed.

The penalty method used has a double iteration loop. The inner loop minimizes the penalty function PEN_K for a fixed value of K (i.e., the coefficient P_K is fixed, while RANGE, NPEN, TODIST, and SSDALT vary). Values for the independent variables OPR, etc., are found for PEN_K at a minimum. At this minimum, some of the constraints may well be violated to some degree. The magnitude of each constraint violation is checked against the constraint tolerance value, and if any violation is outside tolerance the outer loop is stepped through another iteration. This is done by (a) increasing the value of P_K to increase emphasis on the constraints, setting K to K+1, and (b) stepping the inner loop through a number of iterations to minimize the new PEN_K. A solution has been found when no more outer loop iterations are necessary.

The inner loop iterations, to minimize a penalty function PEN_K for fixed K, are an application of the method of conjugate gradients (Reference 7) to function minimization. The gradient vector of potential derivatives of PEN_K with respect to each independent variable OPR, FPR, etc., is used along with the function value for PEN_K at each iterative design point. The minimization search proceeds along the successive conjugate directions. A minimum for PEN_K is reached when changes to the independent variables for the next iteration are detected to be smaller in magnitude than a pre-specified solution tolerance for the inner loop.

The lower/upper bound box constraints for the independent variables are not incorporated in the penalty function. Instead, the inner loop search is directly constrained to avoid violating box limits. This is done by cutting back on a search direction vector when box violation is about to occur.

5.3 Characteristics of the Optimization Method

Important characteristics of the method used in OAPEN are:

1) The gradient vector is required in addition to function values for each dependent variable.

2) The starting point for finding an optimum can be anywhere within the box region, regardless of whether constraints are satisfied.

3) The optima found are local, not global.

4) Convergence usually occurs after K=2 penalty function minimizations.

5) All variables, independent and dependent, should be scaled to the same units using the coding feature of OAPEN.

6) Each optimum must be checked to guarantee validity.

The use of gradients makes possible an efficient optimization which uses a great deal of the information contained in the regression coefficients. The gradients are obtained by OAPEN automatically from the coefficients.

The user can input any design combination within the box limits. This will be used as a starting point for the iterative optimization search. The constraints on dependent variables need not be satisfied at the starting point. A local optimum will be found. Several of these should be located to better the chances of finding a global optimum. This can be done by sequentially specifying several different starting points scattered throughout design space.

Normally, only two penalty function minimizations are needed per optimum when the program default options for solution tolerances are used. The program limit is five penalty minimizations, but more than three occurring is usually indicative of trouble. If extremely tight tolerances are used, however, three or more minimizations may be required. If none of the constraints are binding at the solution (an unconstrained optimization could have been performed had this been known in advance), only one minimization will be needed.

All variables, independent or dependent, should be scaled (coded) to the same order of magnitude, on the order of unity (1.0). In engineering units, the values and range of variation of the variables may differ widely. To correct for this, OAPEN scales all variables according to user specifications. More will be said of this later.

Finally, a cautionary note is included re: solution accuracy. The OAPEN method is not foolproof and it is possible to incur a large error in locating an optimum. Answers should always be checked by perturbing them slightly. The OAPEN program provides automatic evaluation along lines parallel to the coordinate axes, at a user-specified distance from the optimum. If the objective function value improves significantly and constraints violations remain within tolerance at some perturbation point, the located optimum is in error.

5.4 The OAPEN Program-Structure and Basic Usage

5.4.1 Structure of Code

The OAPEN program package contains several subroutines in addition to the main program, all in FORTRAN. Some of the subroutines form an input module which reads key word commands in a free field format. This input module is the same as that used by program EVAQF.

Key words are used to control the execution mode of OAPEN, with numerical values following most of the key words. Using these key word commands, the user instructs OAPEN to read coefficients, set up the coding transformations for the variables, evaluate the functions, set up an optimization specification, or find an optimum. Repeated use of the commands provides the capability to do many optimizations and/or performance evaluations during one computer execution run.

The heart of the optimization package is a subroutine which performs box-constrained minimization of the penalty function by the method of conjugate gradients. Another initial component of the OAPEN package is a function box subroutine which returns quadratic function values and partial derivatives at any design point. When OAPEN is solving for an optimum, these two components work together in the iterative solution process. The minimization subroutine, FRBC, supplies the function box with a trial solution of independent variable values. Using this and the stored quadratic coefficients, the function box computes function values and partial derivatives for the objective and constraint functions, and also for the penalty function which combines these functions as shown earlier. Next, FRBC accepts the function and derivative values and computes a step toward a penalty function minimum. It then supplies the function box with a revised set of independent variable values, and the iteration continues.

Subroutine FRBC calls the function box subroutine for performance values at each iterative design point. The function box outputs a penalty function value which is large if performance does not meet specifications. Thus, FRBC uses the function box to iteratively solve for independent variable values which yield a specified level of performance. This is referred to as optimization mode. Program OAPEN can also call the function box, to get performance values for specified independent variable values. This is referred to as performance mode.

5.4.2 Execution Control via the Function Stack

The OAPEN program has bookkeeping capabilities which make it possible to perform successive optimizations with a minimum of change to the input specifications. Different combinations of objective and constraint functions, as well as different constraint levels, can be tried.

The basis for the OAPEN capability is a simple push-down memory stack for constraint functions. This stack keeps track of the order of the quadratic functions in storage. This order is changed when a new optimization specification is made. When an optimization call is made, the number of constraints is specified by the user. The constrained functions are automatically selected as those at the top of the stack. Thus; if fifteen sets of function coefficients have been input to OAPEN and an optimization call is made which specifies that there are four constraints, only the top four functions in the stack will be included in the penalty function along with the objective function.

The basic sequence of key word commands for a typical OAPEN execution is as follows:

1) SET FUN to enter the coefficients into computer storage.

2) SET CODING to enter the coding (scaling) transformations for all independent and dependent variables.

3) SET CONSTRAINTS to set up an optimization specification

4) CALL FR to locate an optimum according to (3)

5) SET XSAVE to save the optimum as a starting point for a later optimization (if desired).

6) CALL FUN to perturb the optimum to check the answer and get sensitivities.

7) Repeat (3), (4), (5), (6) for successive optima depending on what is desired.

Step (3) is repeated only if the optimization specification is changed. It is unnecessary to repeat it if, for example, only the starting point is to be changed for a new optimization, since the starting point is entered under the CALL FR command. To recall a previous optimum which has been saved with the SET XSAVE command, one uses the sub-command X=XSAVE in lieu of a starting point with the CALL FR command. The CALL FUN command is optional.

A brief account of the internal OAPEN operations resulting step-by-step from the command sequence (1) - (6) is given here to help clarify the usage of OAPEN before going into detailed usage. SET FUN is followed by initialization parameters and finally the coefficients for the regression surface quadratics. This causes the coefficients to be stored in the order input, i.e., the first function entered is first in order. Each function has a reserved storage location for storing a constraint level in addition to its quadratic coefficients. This location is initialized to zero. If a CALL FR command is executed without any prior SET

CONSTRAINTS commands having been executed, function number 1 will be automatically minimized and the constrained functions, which begin with function number 2, will be automatically constrained to be less than or equal to zero, e.g.,

$$NPEN \leq 0.$$

The SET CODING command is followed in part by coding transformations. Each transformation consists of two numbers, A and B. Each variable V will be scaled internally in the program as (V-A)/B. For example, A could be the minimum value V is expected to have over all of design space and B the total range of V over design space. Then the coded (V-A)/B values would be expected to range between 0 and 1.

The SET CONSTRAINTS command does two things: (a) it sets up the optimization specification whether to minimize or maximize, what the constraint inequalities are (LE or GE), and what values to use, and (b) it lines up the functions in the function stack to correspond to the constraints. The objective function, to maximize or minimize, is in position 1. The constrained functions start with position 2, which is the top of the push-down stack of coefficients. As each constraint

NAME LE VALUE

or

NAME GE VALUE

is input, the function NAME is placed in position 2, at the top. The other functions occur at positions 3, 4, 5, etc. For example, the specification

```
RANGE MAX
NPEN GE 2.7
TODIST LE 6000
SSDALT GE 50000
```

will result in the following order of functions, from first to last: RANGE, SSDALT, TODIST, NPEN.

Also, the constraint value 2.70 will be coded and stored in its reserved position with the NPEN coefficients, and similarly for the TODIST and SSDALT constraint values. In addition, the program now has the knowledge that RANGE is to be maximized (not minimized) and that NPEN and SSDALT have GE (not LE) constraints.

Now a CALL FR command with the PENALTY 3 sub-command will cause the following optimization problem to be solved:

Maximize RANGE
Subject to SSDALT ≥ 50000
TODIST ≤ 6000
NPEN ≥ 2.7

(Note that the above is not an optimization input specification.)

A CALL FR with PENALTY 2 will solve the same problem except that the NPEN constraint will be ignored. A PENALTY 1 will cause only SSDALT (at the top of the stack, but the bottom of the specification) to be constrained, and leaving out the PENALTY sub-command will cause an unconstrained maximization of RANGE to take place.

New constraints can be added or old ones changed via subsequent SET CONSTRAINTS commands.

For example,

SET CONSTRAINTS
NPEN GE 3

will cause the NPEN constraint level to change from 2.70 to 3.00 and the new stack order will be RANGE, NPEN, SSDALT, TODIST. Here NPEN, the latest constraint specified, has moved to position 2 (at the top of the push-down stack) and the other functions "pushed down" to positions 3 and 4. Adding a never-before-used constraint function will have the same effect on the stack, i.e.,

SET CONSTRAINTS
VLAND LE 125

will change the stack order by placing VLAND in position 2 and "pushing down" the others, to get RANGE, VLAND, SSDALT, TODIST, NPEN from the original RANGE, SSDALT, TODIST, NPEN. Note that the length of the stack has increased by one, since VLAND has not previously been used (although its coefficients were input under SET FUN). Re-specifying a constraint in the middle of the stack has the effect of the following example: Suppose RANGE, VLAND, SSDALT, TODIST, NPEN is the stack order and the TODIST constraint is to be changed, say by

SET CONSTRAINTS
TODIST LE 5000

Again, the latest constraint function used in a specification, TODIST, goes to position 2. The stack is "pushed down" to the former position of TODIST, the new order being RANGE, TODIST, VLAND, SSDALT, NPEN.

The above discussion explains the stack order resulting from re-specification of constraints and addition of new ones. Objective functions can also be changed, or an objective and constraint function swapped. For example,

```
TODIST MIN
SSDALT GE 50000
RANGE GE 2000
NPEN GE 2.7
VLAND LE 125
```

will set up an optimization specification to minimize TODIST subject to the indicated constraints, and the new stack order will be TODIST, VLAND, NPEN, RANGE, SSDALT.

<u>Detailed OAPEN Usage</u>

The usage is given by an example. First, however, a usage brief will be given for the free-field input module, which is common to OAPEN and also EVAQF. The module consists of the subroutine RDFREE, which is called by the user program to read one 80-column input line. RDFREE calls RDCARD, which is the main subroutine of a package including subroutines ALPFPT and two system-dependent character manipulation routines. In the FTN-compiled version of the RDFREE package, these two routines are called GETCHR and PUTCHR. PUTCHR is an entry point to GETCHR, which is in FORTRAN extended, as is the entire OAPEN package.

Conversion to different computer systems which have FORTRAN extended capability should be accomplished without difficulty by supplying local versions for GETCHR and PUTCHR, and by changing the number of characters per word, NCHAR, in RDCARD. In most systems, the corresponding code for GETCHR and PUTCHR are the subroutines GET and PUT.

Subroutine RDFREE usage is as follows:

```
DIMENSION WORD(20)
CALL RDFREE (WORD, NW, IU)
```

WORD - Array of up to 20 items read in free field format

NW - If greater than zero, number of items read

- If equal zero, an end-of-file was read on unit IU

- If less than zero, attempt to read too many data items (a message is written out on logical unit 6).

IU - Input logical unit number.

Free-field input guidelines:

1. Up to 20 input words per line. To fill an array of more than 20 words, use repeated calls to RDFREE.

2. Word separators are blank or comma (but not both) and end-of-line.

3. Data items can be hollerith or numeric, but do not use ' (single quote mark).

4. Hollerith items of more than 10 character width will be truncated to 10 characters (for conversion to machines with different word length, change NCHAR in subroutine RDCARD to change this restriction).

5. Numeric input can be any length up to end-of-line. Numbers can be integer or real, E- or F- format. They will be stored as real.

6. Exponents in E- format must be two digits or less and no greater than 38 in absolute value. The E must not be preceeded by a blank, e.g., use 1E-5 instead of E-5.

Usage Example

A sample data set for input to OAPEN is shown with the resulting output following in Appendix C. This sample data set is the standard OAPEN test data set.

The SET FUN command begins the data and signifies that coefficients for the regression functions are to be read. Note the other items on the SET FUN line. These and the items on other lines preceding the coefficients are parameter initialization. For numeric parameters, input is always in the form NAME VALUE, i.e., the parameter name or a key word followed by a value. Most parameters remain at their input values until changed in a subsequent input line. Exceptions will be noted.

The parameter FUNCT is given the value 2 so that the function box for uncoded coefficients will be used. As mentioned before, the alternative is to use the function box for coefficients which are coded to correspond to the variables (FUNCT 1, the default option). LENGTH 66 specifies 66 coefficients per function. Recall that for n variables, (n+1)(n+2)/2 coefficients are required for a quadratic. The next item, N 10, specifies n = 10 variables, hence (N+1)*(N+2))/2 = 66 coefficients. Finally, LABEL signifies that a title for the function box input is to be read. The title comprises the next line, which is read as a fixed-field 80-column line (an exception to the free-field input) and will be printed out just as it appears here.

Note that the first line ended with LABEL. The title is regarded by OAPEN as an array of hollerith information. An array name must always occur at the end of an input line (perhaps followed by a single value) and the array values begin the next line. This is true of fixed-field (title) or free-field, numeric or hollerith arrays. The array name must always be the last parameter at the end of the line preceding the line on which array values begin.

The next line contains the single word, VARIABLES. This is the key to read the array (next line) of names for the N = 10 independent variables. If no names are read, OAPEN uses the default names X1, X2, ..., up to X10, depending on the number of independent variables.

Finally, the coefficients for each function are read. Each function's coefficients are preceded by the function name (e.g., RNG801, TODIST) on the line preceding the coefficients. Two numbers following each function name are optional user information only and are not read. They give the minimum and range, respectively, of the regression data values for the function. The coefficients are read by reading consecutive free-field input lines until 66 coefficients have been read, then, the next dependent variable name is read (on the first line following the coefficients for the preceding dependent variable). The SET FUN input phase ends when a 999 is read in place of a dependent variable name. The program limit is 50 functions in 10 variables. In the example, 15 functions are read.

The next command is SET CODING, and again input parameters must be set in addition to the main feature, which for this input phase are the coding transformations. The ON 0. signifies that the coding capability is to be turned on, the 0. being present merely to satisfy the OAPEN input requirement that a key word (other than an array name) always be followed by a value. The TRAN 25 signifies that 25 (A,B) transformation pairs are to be read, and the transformations follow; ten for the independent variables, followed by fifteen for the dependent variables, in the order the variables were read in. A 999 signifies an end to transformation input.

Now the program is ready to perform optimizations. An initial specification is set up via the SET CONSTRAINTS command. The format of the following lines, up to the 999 which ends this phase, should be familiar. The specification shown sets up the optimization problem:

Maximize RNG802
Subject to TODIST ≤ 6000
TSC$$$ ≥ 1
BPR ≤ 3
etc.

Some of these constraints are included only for visibility, since only objective and constraint function values at the optimum are printed out. For example, 1,000,000 n.mi. far exceeds any value that the airplane range variable RNG801 is ever likely to take. However, inclusion of the constraint RNG801 LE 1,000,000 insures that the value of RNG801 at the optimum will be printed out, provided the PENALTY sub-command under CALL FR specifies a large enough number of constraints to encompass the RNG801 constraint.

The CALL FR command for the first optimum to be located comes next. EPS 1E-5 sets a convergence tolerance for the inner loop in optimization. This tolerance specifies that a penalty function has been minimized when each coded independent variable would change by less than the EPS value for the next iteration. The DELX 1.E-4 specifies that the partial derivatives supplied by the function box are to be checked by finite differences around the optimum, where DELX is the finite-difference step size for derivative approximations. The X is the independent variable array name, and the next line contains starting values for the independent variables for the first optimization. On the next line, PENALTY 10 specifies that there are 10 constraints for this optimization. Had the PENALTY value been smaller, constraints from the stack would be included in the order SSDALT, ACLTMDOD, etc. The BOOST 100 specifies that the penalty terms are to be multiplied by 100 following each penalty function minimization, to increase emphasis on the constraints for the next minimization. Minimizations will occur until all the coded constraints are satisfied to within the tolerance value, EPSCON 1E-2. the TITLE array is a title specific to this optimum. Finally, BOX specifies that there are lower/upper bound box constraints on the independent variables, and these follow on the next line in (lower, upper) pairs.

This completes the input for the first optimum. The OAPEN program will now locate the optimum specified in the SET CONSTRAINTS command using parameter values specified under CALL FR. Most of the parameters have defaults, i.e. EPS 1E-5, DELX 0. (no finite differences), PENALTY 0 (no constraints), BOOST 50., EPSCON 1E-2, TITLE blank, and no box constraints (in which case the CALL FR input sequence must end with a 999 line). All parameters remain at the values to which they were last set except DELX, PENALTY, TITLE, and BOX, which are zeroed out or nullified prior to reading CALL FR input.

The user is reminded that BOX limits should lie within the region where data for the regression-derived coefficients were gathered, to avoid extrapolation with the quadratics. Extrapolation errors are potentially much larger in magnitude than surface evaluation errors within the box region of data. Another facet of the box limit is that they prevent the optimization search from trying to locate an optimum at infinity.

Other parameters of importance are not used in this first CALL FR command. IPRINT and MAXFN are not used at all in this sample data set, hence a discussion is in order. MAXFN is the maximum number of function box evaluations allowed per penalty function minimization, and provides an upper limit for safety. Its default value is 500. The IPRINT value specifies printout from the minimization procedure every IPRINT - th iteration. Thus, IPRINT 1 would cause every iteration to be printed out, IPRINT 2 every other iteration, etc. Its default value is MAXFN, which means that only the first and last iteration are printed. The printout includes coded values for the penalty function (F) and for the independent variables (x) at the current iteration. IPRINT must be reset each time if intermediate printout is desired.

For the next optimum in the example, the lower bound on the independent variable FPR is to be reset to 3.0 to observe the effect on the optimum. The starting point is to be the last optimum. Hence, the first CALL FR input sequence is followed by a SET XSAVE command, which saves the first optimum, and the X=XSAVE sub-command in the second CALL FR sequence specifies the saved optimum as a starting point. Note the BOX limits, which are the same except that the FPR lower bound is 3 instead of 2. Also, note that PENALTY is of necessity, again specified as 10. The other parameters, however, automatically remain at their previous values.

The third optimum should be identical with the first. Note that now only the starting point, TITLE, PENALTY,and BOX need be set. The preceding SET XSAVE turns out to be extraneous, since optimum 2 is never used. Optimum 3, however, is used as the starting point for optimization 4.

The fourth optimum illustrates the FIX capability of OAPEN, which provides for fixing any selected subset of independent variables during an optimization (as long as two variables are left free). They can be fixed at the X=XSAVE values or they can be reset to specified values before FIXing. In the example, FPR is first reset to 3 and then FIXed. the FIX 1 specifies that one variable is to be FIXed, and the name of the variable follows on the next input line. The sub-command could have been FIX 2, FIX 3, etc., up to FIX 8 (leaving 2 free variables), with the appropriate names on the next input line. The default value for FIX is 0 (all variables free). FIX must be set for each optimization in which the capability is used.

Up to now, the CALL FUN capability, to perturb the optima in evaluation mode, to check answers, has not been illustrated. This is because each use of CALL FUN NOP-1, which puts OAPEN into perturbation mode, generates a great deal of output. For n variables, 2n+1 perturbation points with both coded and uncoded values are printed out. For n=10, this totals 21 perturbation points. These points include re-evaluation of the functions at the optimum and at each of two points along lines through the optimum parallel to the coordinate axes. The two points are located a fraction of the box-limit range away from the optimum, one at a positive distance away and the other in the negative direction. The fraction is given on the line following CALL FUN NOP -1. For example, the perturbation points parallel to the THTR axis are located a distance ±0.0015 THTR units from the optimum. This is because the box-limited range THTR in the last optimization was 1.15-1.00=0.15, and the perturbation factor is 0.01, hence 0.01*0.15=0.0015 THTR units.

An alternative way of perturbing a point is shown in the next CALL FUN sequence. Here the NOP 0 indicates that perturbation is to occur at a user-specified point between user-specified limits. Otherwise, this perturbation mode is the same as that previously described. The central point follows on the next input line, followed by lines containing, respectively, the lower and upper box limits to be used in determining perturbation range. Finally, the perturbation factor is entered on a separate line, as before.

A recommended way of obtaining sensitivities of dependent variables about the optimum is by repeated use of CALL FUN NOP -1 using different perturbation factors, for example 0.01, 0.05, 0.10. In this way, all functions included in the penalty function will be evaluated at ±0.01, ±0.05, and ±0.10 perturbation units from the optimum in each coordinate direction.

The next CALL FUN sequence is a simple example of performance or evaluation mode execution of OAPEN. The NOP 2 tells the program there are two evaluation points the program limit is 50), and each of the points of evaluation is input on a separate input line. NOP followed by a positive integer value puts OAPEN in this mode.

The final two optima in the example illustrate location of an unconstrained (except for box limits) optimum in two different ways. First, easily-satisfied constraints are put on a number of dependent variables via SET CONSTRAINT. This is purely for visibility, since the "constrained" functions will then have their values printed out at the optimum in addition to the objective function value. The last optimum is a simple (box limited) but otherwise unconstrained optimization, made possible by simply excluding the PENALTY sub-command from the CALL FR command sequence. The last two optima should be identical, since the same starting point was used.

The output resulting from this example (Appendix C) is largely self-explanatory. The coefficients are read back to the user, first as individual functions, then in packed form (with one location per function for a constraint value). Next follow the coding, initial optimization specification, and then the optima. Note the rearrangement of the function stack following execution of each SET CONSTRAINTS command.

5.4.3 Interrogation Modes

The optimization program is fast and economical to run. Its efficiency derives from the relative simplicity of the "surfaces" upon which it operates. This characteristic is the underlying principle upon which the data management system is based. A result is great flexibility in the interrogation phase of system application. Many modes of surface interrogation have evolved with time. Most of the known modes are described in the following paragraphs.

Performance

The "performance" mode of surface interrogation is the fastest and most direct mode. In this mode, the optimization logic is not active. Functions are simply evaluated for input values of the independent variables. This mode might be used to develop simple non-constrained, non-optimum sensitivities, "thumbprints", point design performance data, etc. Input requirements are satisfied with the function box call code, title, variable identification, surface coefficients and performance mode control inputs. A sample input is illustrated below.

```
SET FUN FUNCT 2 LENGTH 66 N 10 LABEL
STRATEGIC VGT FAN OPTIMIZATION
VARIABLES
FPR OPR BPRND A8 THSK TOW TOC WOS AR TOGW
TODIST
7.48430E+03 0. 0. 0. -3.74 .......
     (up to 66 coefficients for the function, TODIST, and
      variable name and 66 coefficients for each succeeding
      function.)
999
SET PENALTY NC 3
999
CALL FUN NOP 2
2 10 .3 .6 1 .35 .09 180 7 280000
3 10 .3 .6 1 .40 .09 180 7 280000
999
```

Unconstrained Optimization

The next simplest mode of operation in interrogation is unconstrained optimization. In this mode, the optimization logic comes into play. With no constraints specified, the logic attempts the maximization or minimization of a figure-of-merit or cost function subject to constraint by the limits of design space alone.

Coding of variables is encouraged whenever optimization is performed. Therefore, this is the first added input to that used in the performance mode. Coding is essentially normalization of variables and each variable's minimum value and range of variation serves the role of normalizing parameters very adequately. Adequacy of the normalizers affect the convergence accuracy. These values are available from the regression analysis output.

Following the coding transforms, additional inputs are the optimizer calls, search starting point and independent variable design limits. The inputs appear as follows:

```
0.    2.7300E+02      -7.94        (last line of dependent
                                    variable coefficients)
999
SET CODING ON 0. TRAN 12
```

```
    2,2 10,20 2400.,800.
        0,1  1.00,.15
        (free field input minimums and ranges for independent
         and dependent variables up to total of twelve sets
         in this example)
999
SET CONSTRAINTS
RANGE MAX
999
CALL FR EPS 1E-5 X
2  10  2400  9  1  .3  .1  150  7  300000
BOX
2,4  10,30  2400,3200  0,1  1,1.15 ....... up to ten sets.
```

The example illustrated would cause a dependent function named RANGE to be maximized to within a tolerance of .001% . The optimization search begins at a FPR=2, OPR=10, T4=2400, etc. This design definition has come to be called a "starting point". The search will be constrained within the design space defined by the limits listed after BOX, i.e., $2 \le FPR \le 4$, $10 \le OPR \le 30$, etc.

Starting Point Checks

Having introduced an interrogation mode involving optimization it is appropriate at this point to discuss "starting point checks". This is an exercise which should be done at the start of any optimization study. It is the first step in defense against local optima, a phenomena which is prevalent in multi-dimensional optimization, particularly, in heavily constrained design space.

The exercise is accomplished by simply starting the optimization search at a variety of points in design space. An optimal starting point is determined by that point which yields the least minimum (or greatest maximum). There can be no guarantee that even this optimum is the global solution. This chance can be improved as more starting point variations are used. Six or so is recommended.

Input is simply repeated usage of an optimization call with only the X values varying.

Constrained Optimization

From unconstrained optimization we move logically to constrained optimization. This mode of interrogation can take several forms depending upon whether constraint functions are intentionally made inactive or not. Input format is the same in either case with only constraint function levels varying.

Constraints are imposed as follows:

```
SET CONSTRAINTS
RANGE MAX
TODIST LE 5000
ALT GE 25000
999
CALL FR EPS 1E-5 X
2  10  2400  0  1  .3  .1  150  7  300000
PENALTY 2 BOOST 100 EPSCON 1E-3
BOX
2,4  10,30  2400,..........
```

The example shown causes the range maximization to be constrained by two (PENALTY 2) other considerations. TODIST must be no greater than 5000 and ALT must be at least 25000.

Violations of these two requirements enter a penalty function in the optimization process and are magnified according to the value of BOOST (100 in the example). The optimization converges when violations become less than .1% (EPSCON 1E-3) of specified values.

It is assumed that constraints will be active in the optimization, that is, will actually affect it, if reasonable requirements are used. For example, if a TODIST of 5000 is difficult to attain for a maximum RANGE solution then this constraint should affect the result. RANGE obtained in such an optimization would be expected to be less than that obtained in an exercise where a constraint such as TODIST LE 50000 is used.

By specifying an unreasonably large (or small for GE constraints) value for such a constraint, it becomes inactive and does not affect the maximization. However, the value of TODIST is evaluated at the optimum and, therefore, the constraint input becomes an informational tool. (Only the specified cost and constraining functions are evaluated at an optimum.)

If, in the example just presented, PENALTY 1 were used instead of PENALTY 2, only the ALT constraint would be active and/or evaluated. Only the PENALTY bottom constraints are considered.

The sample input shown below illustrates how constraints are varied in successive optimizations.

```
SET CONSTRAINTS
RANGE MAX
```

```
TODIST LE 5000
ALT GE 25000
999
CALL FR EPS 1E-5 X
2  10  2400 .......
PENALTY 2 BOOST 100 EPSCON 1E-3          First Optimization
BOX
2,4 10,..........
CALL FR X
2  10  ........
PENALTY 1                                Second
BOX
2,4  10,......
SET CONSTRAINTS
VLAND LE 100
999                                      Third
CALL FR X
2  10  ......
PENALTY 2
BOX
2,4  10,......
```

The first optimization is constrained by TODIST and ALT. The second is constrained by ALT alone. The third is constrained by ALT and VLAND. If PENALTY 3 had been used in the third optimization, TODIST,ALT and VLAND become the constraints.

Another mode of constraint variation allows the development of a sensitivity to constraint level. Inputs are,

```
SET CONSTRAINTS
RANGE MAX
TODIST LE 5000
ALT GE 25000
VLAND LE 100
999
CALL FR EPS 1E-5 X
2  10  ........
PENALTY 3 BOOST 100 EPSCON 1E-3
BOX
2,4  10,........
SET CONSTRAINTS
ALT GE 30000
999
CALL FR X
2  10  ......
PENALTY 3
BOX
```

```
2,4  10,........
.
.
.
```

The foregoing inputs would cause an optimization to be constrained by ALT GE 25000, then ALT GE 30000, etc. Set up in this way, a search is conducted from a fixed starting point to successive optima which become increasingly distant from the one determined initially (assuming the changing constraint is increased or decreased monotonically).

Development of this type of sensitivity can be a second defense against local optima. Resulting optima can be expected to fall into a family unless local optima are encountered. However, to be most effective, an alternate method of input stacking for sensitivity development is recommended.

<u>SET XSAVE</u>

The SET XSAVE command is used to start an optimization search at the previous result.

```
CALL FR EPS 1E-5 X
2  10  2400  0  .3  .1  150  7  300000
PENALTY 2 BOOST 100 EPSCON 1E-3
BOX
2,4  10,30  2400,........
SET XSAVE
SET CONSTRAINTS
ALT GE 30000
999
CALL FR X=XSAVE
PENALTY 3
BOX
2,4  10,......
SET XSAVE
SET CONSTRAINTS
ALT GE 35000
999
CALL FR X=XSAVE
PENALTY 3
BOX
2,4  10,......
```

This mode of operation usually yields a much better behaved result, than the former particularly if a good starting point is established for the initial optimization. SET XSAVE is recommended for all sensitivity exercises.

Independent Variable Sensitivity

Independent variable sensitivity is easily generated using the FIX command. An optimization exercise of this type is stacked as follows:

```
CALL FR EPS 1E-5 X
2 10 2400 .......
PENALTY 3 BOOST 100 EPSCON 1E-3
FIX 2
FPR OPR
BOX
2,4  10,......
SET XSAVE
CALL FR X=XSAVE
PENALTY 3 OPR 12 FIX 2
FPR OPR
BOX
2,4  10,......
SET XSAVE
CALL FR X=XSAVE
PENALTY 3 OPR 14 FIX 2
FPR OPR
BOX
2,4  10,......
```

These inputs would yield three optima. The initial optimum would be obtained for FPR = 2 and OPR = 10. The second optimum has FPR = 2 and OPR = 12. The final optimum has FPR = 2 and OPR = 14.

Any reasonable number of independent variables may be fixed in this way.

```
PENALTY 3 FPR 2 OPR 10 T4 2400 FIX 4
FPR OPR T4 TOGW
```

For this example new values have been specified for FPR, OPR and T4 while TOGW will be fixed at the value obtained in the previous optimization. Convergence problems may be expected if an inordinate number of independent variables are fixed in constrained optimization.

Using an Independent Variable as a Figure-of-merit

When an ARES application is formulated, independent variables and figures of merit are identified. In some applications, potential merit parameters are selected as independent variables instead. Takeoff gross weight (TOGW) for example, could act as either, depending upon whether range or some other performance parameter is specified (TOGW is figure-of-merit) or varying dependently (TOGW is independent variable). In this example, if TOGW is selected as an independent variable, it can still be treated as a merit parameter in interrogation. Indeed, any independent variable can be treated that way or as a constraint.

Input is modified as follows:

A function must be formed for the dependent, independent variable. This is quite easy using the free field format of the optimizer. Using TOGW for example, change the variable name to WGOT to avoid confusion and fake in a function which equates WGOT to TOGW.

```
WGOT

0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0
```

The 1 is the linear TOGW term coefficient. Therefore, the relationship becomes WGOT = 1*TOGW. The only restriction in constructing this input is twenty terms to a line. Input coding transforms for WGOT. These would be the same as those for TOGW. Increase the number of transforms in SET CODING ON 0 TRAN 13. Use WGOT as the cost function (WGOT MIN) or a constraint function (WGOT LE 200000). Some misbehavior may occur if, as a cost function, optima occur near independent variable design limits.

Weighted Optimization

The possibilities of simultaneous "optimization" of more than one function have not been exercised to any great degree but the possibility deserves mention. Functions can be combined by algebraic addition of like terms. Weighting is accomplished by multiplying all coefficients of each function by a selected constant. Functions should be normalized to equalize unweighted contributions due to variable magnitudes.

Graphic Display

Using any or all of the interrogation modes just described, a great deal of information can be generated. To best display this information, an automatic plotting or computerized graphics capability is recommended. Plotting options are available on most computer systems and implementation of these options for processing interrogation output is not difficult. Therefore, selection and implementation of a particular capability is left to the user.

Output resulting from optimization exercises is generally quite non-linear. Many of these non-linearities may be attributed to encounters with either design (independent) variable limits or specified constraints. Encounters of both kinds are illustrated in Figure 5.1. The figure illustrates the behavior of a hypothetical figure-of-merit (FOM) constraint and independent variable, X_2, as another independent variable, X_1, is varied between its minimum and maximum allowable values. Starting at minimum X_1, X_2 is limited to its minimum value, the constraint is not active and the FOM is increasing (FOM maximization is the assumed objective in this example). As X_1 increases, the constraint becomes active, X_2 moves away from its lower limit and a local optimum in the FOM is identified. Increasing X_1 still more causes neither X_2 nor the constraint to limit the FOM and a better optimum is established. As X_1 is increased above its optimum value, the upper limit of X_2 is encountered and this introduces additional non-linearities in the constraint and FOM curves.

The user is encouraged to remain alert to encounters of the type just described and to display interrogation results accordingly. As one can imagine, more than a few optima must be generated to properly represent non-linearities. This is of little concern, since the optimizer is very economical to use. With a sufficient amount of data in hand, one should then take care to limit graphic display to the same constraints that the optimizer used in generating the output.

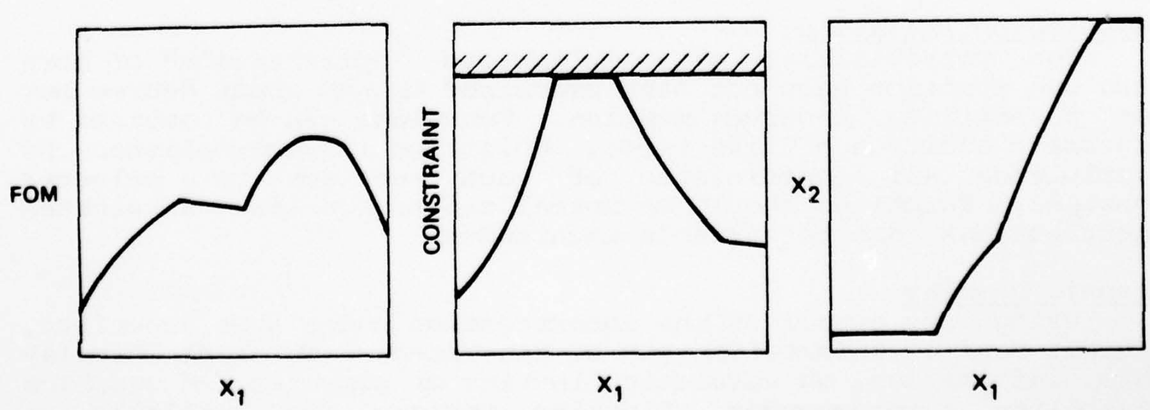


Figure 13. Graphic Display Characteristics

5.5 OAPEN Subroutine Descriptions

AXIAL	Provides perturbation points along the X_i axes for sensitivities in performance mode	
BREAK	Expands on array by providing space for a new column in the middle with specified index	
CNTRCT	Deletes a column with specified index from an array	
CODV	ENTRY CODV	Transforms variables from real-world units to coded (scaled) units using input coding transformations
	ENTRY DECODV	Transforms back to real-world units
	ENTRY DCODDV	Transforms the (coded) gradient vector of a dependent variable to real-world units
	ENTRY DCDELV	Transforms the (coded) difference of two values of a variable to real-world units
EVOC	Error message for unrecognizable instruction	
FDCHK	Performs finite-difference checks on the partial derivatives output by QF	

OAPEN Subroutine Descriptions-2

FR	Fletcher-Reeves conjugate gradient minimization of an unconstrained function of several independent variables
FRBC	FR with lower/upper bounds on the independent variables
FUN1	Function box for use with coded quadratic coefficients (regression is performed on coded variables to get the coefficients). Returns function and partial derivative values for objective and constrained functions when independent variables are input.
FUN2	Same as FUN1 except that uncoded quadratic coefficients are used (coefficients correspond to real-world units for the dependent and independent variables).
FUN3	Space reserved for an optional user-compiled function box.
QF	Returns quadratic function value and gradient vector of partial derivatives when independent variables are input.
SCALE	Scales initial penalty function value to match the magnitude of the initial objective function value.

OAPEN Subroutine Descriptions-3

The following subroutines make up the OAPEN free-field input package:

RDFREE	Reads an input line of up to 20 items (mixed alpha and numeric) and stores values as hollerith or floating point in a data array. Also returns a count of the number of items read (zero means end-of-file).	
RDCARD	More general free-field input routine called by RDFREE	
ALPFPT	Determines whether input item is alpha or numeric	
GETCHR	ENTRY GETCHR	Extracts a character from a string
	ENTRY PUTCHR	Inserts a character in a string

NOTE: GETCHR and PUTCHR can be replaced with system subroutines GET and PUT if available.

AD-A057 392 BOEING AEROSPACE CO SEATTLE WA BOEING MILITARY AIRPL--ETC F/G 21/5
AIRPLANE RESPONSIVE ENGINE SELECTION (ARES). VOLUME I. ARES USE--ETC(U)
APR 78 G J ECKARD, M J HEALY F33615-73-C-2084

UNCLASSIFIED AFAPL-TR-78-13-VOL-1 NL

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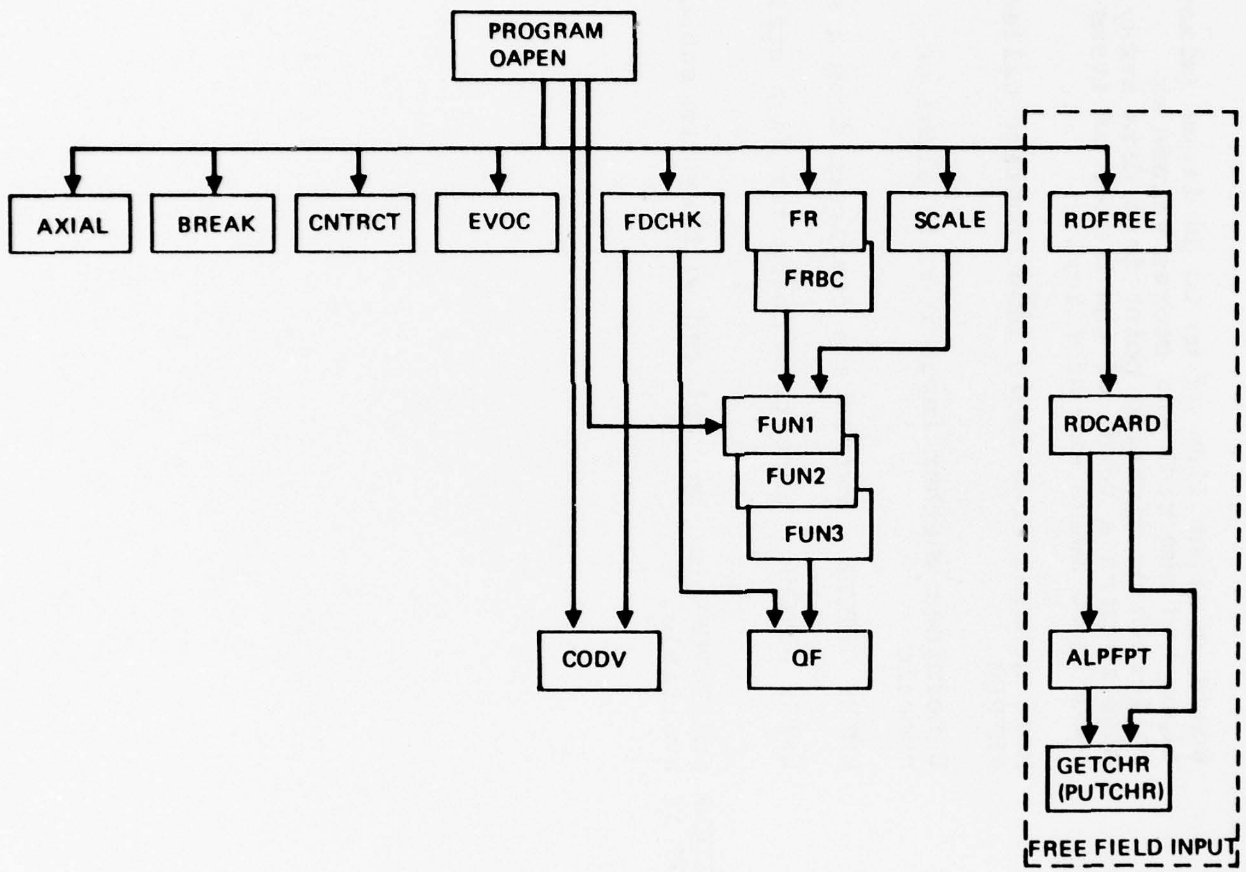
A057392



OAPEN Subroutine Call Diagram

SECTION VI

VALIDATION

6.1 Introduction

Validation is the important step in an ARES application where surface fit accuracy is checked at and/or near designs which have been identified for further investigation. Of course, a preliminary accuracy check should always be performed by examining the regression residuals. If the errors at this stage are deemed acceptable, the regression functions can be used in optimization mode or in evaluation mode, to investigate parametrically the performance variations over design space. However, the regression residual check yields only a rough estimate of expected error when the surfaces are evaluated at non-regression design points. Hence, evaluations at or in the neighborhood of certain non-regression designs should always be made by running the simulator at these designs.

Validation can be performed at either of two junctures: immediately following derivation of regression surfaces, or following the parametric analysis which uses the surfaces. If validation is done immediately after regression, it serves as an adjunct to examination of regression residuals. Performance data is gathered at points scattered over design space but not used in regression, and the regression surface values are compared with actual performance values by forming residuals at these new designs. For an n-dimensional design study, at least n+1 non-regression designs are desirable for this mode, and they must be well-dispersed over design space. In extremely good cases (say, maximum error is five percent of the range of dependent parameter variation), this sort of overall validation may be sufficient.

However, there are still uncertainties in this procedure and it is best to check the final designs of interest. Parametric analysis will identify limited regions of designs worthy of detailed study. These regions should be small in size compared to the totality of design space investigated in the study. In this case, validation designs can be scattered sparsely over these limited regions and yet be fairly closely spaced. If the identified regions are not small, many validation runs must be made to gather actual performance data for all designs of interest.

6.2 Validation Program EVAQF

Program EVAQF performs a simple analysis of validation residuals. It has two input files, in the same fashion as programs SUBARES, ADDARES, and the regressor, MANE. One of these known internally to the program as TAPE1. The other file is INPUT, and again as usual, it contains instructions on what the program is to do with the data base. The format for INPUT is free-field, with key words used to signify execution option.

The restrictions on free-field input are the same as for OAPEN, since the same input module is used. Hence, the free-field input guidelines will not be reported here. However, the total EVAQF input sequence will be described.

Item 1. (alphameric) Names of the independent variables plus names of dependent variables for which quadratics are to be validated. Names must match (character by character) those on the design data base, TAPE1. Names must be 10 characters or less. A 999 terminates reading of up to 30 names (remember, free-field input restricts the user to 20 names on a given input line. Hence, more than one line is needed for Item 1 if more than 20 names are read).

Item 2. (Numeric) Enter number of dependent variables, N.

Item 3. If the word is the alphameric word SKIP, it must be followed by a number designating the number of lines to skip over on TAPE1 before reading design data base. If first word is numeric, it is the only word and it specifies the number of data fields in each design case on TAPE1.

EVAQF reads design data base (TAPE1):

Item 4. If Item 3. above was 'SKIP m' the first m lines are skipped. The next line (Item 4) must be a number specifying the number of data fields in each design case (floating point). If Item 3 was numeric, go to Item 5 (do not use Item 4 for input).

Item 5. (8A10 Format) Independent and dependent (if any) variable names in the order in which values for the variables appear in each design case. Names must occur as data fields do, i.e., if data field #132 is not used in the following design cases, name #132 should be left as a blank 10-column field. Order of independent and dependent variables is immaterial as long as data values have the same order. The names must be <u>left-adjusted</u> in their 10-column fields.

Item 6. (8E10.0 Format) Design cases, consisting of values for each variable in the same arrangement as the names in Item 5, i.e., values for a variable must appear in all design cases in the same 10-column field as the corresponding name in Item 5. Each case must contain the same number of 10-column fields, eight to a line, as in Item 5.

Item 7. As soon as an end-of-file or a data field of 9999999. or greater is encountered, reading of TAPE1 will end and EVAQF will resume reading from file INPUT in free field format.

EVAQF resumes free field read from file INPUT. The input stream is now variable, for several execution options are available and may be used repeatedly. An end-of-file terminates execution. The execution options are each specified by key word input. The options include,

1. reading a title block which is printed out with the results,

2. specifying coding transformations for the variables if coded coefficients from regression are used, and

3. reading the coefficients of a quadratic surface-fit function corresponding to one of the dependent variables whose name appears in Item 1.

When coefficients are read, a residual analysis is done automatically after evaluating the function at each data base design point combination of the independent variables.

The key word input options are detailed as follows:

Item 8. A key word. Acceptable key words are TITLE, TRAN, or a dependent variable name read in during Item 1 input. However, do not use REG or ADDED as a dependent variable name (otherwise, any 10-character name is acceptable so long as it does not contain an embedded' (single quote mark)).

Item 9. If key word is TITLE, the next line will be read as an 80-column title. This title will be printed out whenever a residual analysis is performed on a function. It can be changed by again specifying TITLE under Item 8, then reading the new title. If key word is TRAN, the A,B coding transformation pairs will be read, first for independent variables and then dependent variables, as in the OAPEN SET CODING input. The transformations must have the same order as the corresponding variable names in Item 1. Transformations must be read only once, before any coded coefficients are read in. Finally, if key word is a dependent variable name, the coefficients will be read starting on the next input line (Item 9). The number of coefficients is automatically calculated as ((N+1)*(N+2))/2, where N was input under Item 2. Coefficients are input in the same fashion as for OAPEN.

The coefficients output by the ARES regressor can be used directly by EVAQF. It is only required that the independent variable names be input to EVAQF under Item 1 in the same order used in regression. This is necessary because the coefficients must be used in a consistent fashion, i.e., their interpretation is order-dependent.

File INPUT and the resulting output for a sample case are shown in Appendix D. The design data base for this example contains sixteen combinations of seven independent variables together with data values for about 300 dependent variables. Of these, a total of fourteen dependent variables are read into computer storage by execution of the Item 1 input. For some of the dependent variables, more than one set of coefficients is evaluated.

Note that the program calculates that there are 36 = ((7+1)*(7+2))/2 quadratic coefficients for each function to be evaluated. This calculation is triggered by the input of '7' for the number of independent variables. Each set of coefficients is printed out with the 'QF' case number and dependent variable name. This is followed by a list of true and predicted independent variable values, followed by the residuals. In the fourth column, the residuals are listed as a percent of true value (magnitude), and in the fifth column, as a percent of the data range of the dependent variable.

Finally, the maximum and average are listed for (a) the residual values, (b) the residuals as percent of range, and (c) the residuals as percent of magnitude. This is followed by a calculation of the mean square residual, labeled 'MS'. The square root of MS can be thought of as a sort of 'expected error', although any such statistical interpretation of ARES results can be, as mentioned before, misleading.

It is recommended that the list of residuals as percent of range (P.C. RAN F) be scanned to determine whether the surface fit has "validated". Generally, less than 5.0 percent error is regarded as good, especially if the regression residuals had similar values.

SECTION VII

MANAGING THE DATA MANAGEMENT SYSTEM

The ARES data management system addresses a formidable problem with a number of computer programs and provision for man in the loop at all interfaces. The consequence of this arrangement is the production of large amounts of data to storage, printout, microfiche copies of output, plotted output, punched cards, etc. Although this accumulation may be large, it is far, far less than that which would be generated in a traditional approach to the same problem. However, the accumulation that is produced in an application of ARES can and should be managed efficiently to derive maximum benefit from the system.

A manual or log should be used to assist in the management of an ARES application. The sections that should be contained in this manual are described in the following paragraphs.

The first section in the manual should summarize the problem formulation. This includes identification of the role of the system being investigated, major distinguishing characteristics of the point of departure, important requirements that may be imposed on the system, known independent and dependent variables of interest, including probable figures-of-merit, simulators that will be used and major modifications that they might require, the timing of the analysis and the personnel and organizational structures involved in it.

The second section should document the design selection phase. Items reported here include the number and names of variables that will be used, their ranges and a brief summary of the reasons for their selection. Potentially important variables that will not be used and the reasons for their exclusion should be reported. This section should also contain the number of levels and, hence, designs that will be investigated. The section is concluded with a tabulation of the actual independent variable combinations at which simulations will be attempted. Design failures in simulation, notable outliers discovered in regression and designs which are conspicuous for any other reason can be noted on this listing. Of course, any massive adjustments to the original design selection and reasons for the adjustment should be reported in this section.

Very little computer output is generated in the phases discussed in the preceding paragraphs. However, in the succeeding steps, substantial amounts of data on a variety of media are generated. Provisions should be made for data storage on computer permanent file and magnetic tape and for paper, fiche and card storage in a safe, convenient location. A full blown, ten variable analysis which involves a parametric engine family can require up to 10,000 sectors of permanent file space and most of a large cabinent for output storage. The next section of the management manual should be comprised of logs for computer account numbers, resource accounting, file names and status, tape numbers and contents and output storage.

Data base generation or simulation is the next logical step in the application of ARES and this activity should be documented next. Information appropriate to the use of any simulator model should be reported. Typical models are parametric cycle matching engine models, airplane sizing and performance models, life cycle cost models, etc.

If engine simulation models are used, the simulation section of the manual should contain;

- Program identification, cycle concept and name, number, source
- A representative cross-sectional view of the engine concept
- One-size airflow
- Important assumptions pertinent to the simulation
- A description of the assumed inlet and nozzle, if appropriate
- Bleed and horsepower extraction schedules
- A representation of the data matrix that is generated (Mach number, altitude, powersetting)
- Identification of data points and engine designs that fail in simulation
- Description of resulting adjustments, if any.

Paper output from the engine simulation need be no more than enough to check and correct the simulation (an error listing for example). It is worthwhile to copy all output from the final simulation to microfiche. Production engine data should be stored on permanent file and backed up with a copy on magnetic tape. When the user is satisfied with the engine data set, paper output can be purged.

Airplane performance simulation should be reported by providing;

- Program identification including descriptions of any new logic and subroutines

- System concept and name
- Point-of-departure three-view, number, designer
- Distinguishing characteristics of point-of-departure
- Important assumptions pertinent to the simulation

    - Drag methods
    - Bookkeeping methods
    - Propulsion system installation
    - Structural weight methods
    - Mission model

- An illustration of mission profiles
- Mode of simulation (convergence on weight or range, off design missions, etc.)
- Identification of airplane designs that fail in simulation
- Description of resulting adjustments, if any
- A copy of typical, important output listings
- A tabulation of the names of all the dependent variables for which data is gathered.

Production, system characteristics simulation can produce a large amount of output. In most cases, this output should be examined to identify failed cases and/or potential problem areas in design space. Printout is the most convenient media for the examination but the printout should be retained only until the user is satisfied that the production, system characteristics data base is adequate. The production data base should be copied to permanent file, microfiche and tape. When these duplicate records have been generated, paper output can be purged.

If data base input/outputs (independent/dependent variables) are not overly large, copies of them can be included in this section of the manual. "Stand-alone" life cycle cost model I/O, for instance, is usually sufficiently small as to allow this. Once again, a description of input, assumptions, output, etc. of simulation models like life cycle cost, should be reported here.

Normally, this section of the manual should be concluded with a summary statement of the user's opinions relative to the success of the simulation phase and any advice he might be able to offer to future users. Problem variables and simulation modes can be identified. In case of poor problem formulation or massive failures in simulation due to some other deficiency, some applications can end at this point. It is particularly important, in those cases, that the situation be summarized here.

Occasionally, the unfortunate circumstance occurs where investigation of some additional dependent variable(s) is desired and no provision has been made for the parameter(s) at the simulator output interface. Inclusion of these data must be performed manually. The data must be carefully hand coded from output, key punched and read into memory. The program ADDARES performs the latter function. It should be noted that any undiscovered errors in coding and keypunching may be absorbed forever and will affect successive analyses to an unknown degree. Copies of any such additional data should be included in the manual.

The next section of the manual should be devoted to the regression analysis phase. Regression analysis can be performed in several steps. Initially, only the most important functions can be fitted. These are the figures-of-merit, constraints and major informational parameters. Successive steps of analysis can be devoted to secondary informational surfaces. The names of all fitted functions should be recorded in the manual. As regression analyses progress, statistical data by which adequacy of the fits may be judged should be recorded by the function names. The polynomial coefficients which are generated should be assembled on permanent file. When a coefficient set is finalized, the data should be copied on punched cards. Obviously poor fits should be so noted and, if retained, handled with appropriate caution.

The amount of paper that is generated in this phase will depend upon the number of functions analyzed. Whatever the amount, it need be retained only until the aforementioned statistics have been recorded and appropriate copies of the coefficients are at hand.

Some fits can be improved by modification of the basic data set, i.e., deletion of a limited number of data cases. Any modification such as this should be noted. Of course, successive regressions on a particular function will yield successive sets of fit statistics and these too, should be appropriately recorded. Coefficient sets that are superseded should be eliminated from memory and card copies immediately.

Success or failure in application of the ARES data management system is generally determined by success or failure in regression analysis. Unfortunately, the degree of success experienced in this phase cannot be quantified accurately without some attempt at "validation". Validation consists of evaluating the surfaces obtained in regression against data that is not used in their generation. These data should be distributed throughout the design space and should not approximate to any great degree, any of the data derived from the orginial design selection.

Validation is usually performed following surface interrogation. However, the user is encouraged to attempt at least a preliminary validation following regression analysis. If successful, he can then proceed with confidence into successive phases. The data used in validation, surface fit evaluations and prognosis for the application should be noted in the manual.

The regression section of the manual should be concluded with a summary report on the regression analysis activity. Once again, an application may end with this phase and it would be beneficial to future users to know why, if the reasons can be identified.

The next section of the manual should be devoted to the interrogation phase. Due to the flexibility of the interrogation program and the resultant large variety of modes of operation made available, this phase can be almost unlimited in scope. Care must be exercised, therefore, to avoid duplication of effort, unnecessary consumption of resources and frivolous or illogical analyses. While the "optimizer" is very economical to operate, an unlimited amount of use can become expensive.

Optimizer output per se, should be retained only temporarily. It is unnecessary to obtain printout at all. Single point optima should be recorded as they are obtained and identified in the manual. Results of multi-point optimization exercises should be stored on permanent file only long enough to be plotted. The plots of these data should be assembled in a logical order and retained in a centralized record.

Popular optimizer input files should be copied to cards as soon as practical and definitely when analyses which use them have been completed. There is a tendency to forget about files which are not used for a time and these files move to archive and eventually are purged.

Items which should be recorded in this section of the manual are optimizer control variables, proven starting points for optimizer search, single point optima, popular constraints, convergence problem areas and the like. If the application is directed toward the identification of a design region-of-interest, this region, when it is identified, can be compared to the point of departure and a validation of the result.

The final section of the manual should deal with the validation phase. Comparisons of simulated design point performance and interrogation output are tabulated here. Copies of plotted comparisons should be included. Error levels should be identified. Finally, a summary critique of the application, identification of associated documentation and recommendations as to future use should be the concluding entry.

Organization of data which are to be retained and a final purge of unwanted accumulations complete the application.

An ARES application can consume a substantial chunk of budget. What is obtained for this expenditure is largely up to the user. By careful formulation of his problem, a well planned execution along the guidelines presented in this guide and an organized manipulation of input/output data media the budget expenditure can be totally justified. However, if a user leaps headlong into a haphazard and disorganized application, he can easily end up with piles and piles of just plain garbage.

APPENDIX A

LATIN INPUT/OUTPUT SAMPLE

PRECEDING PAGE NOT FILMED
BLANK

```
N GET,LATBIN
N BATCH,70000
C LATBIN
I DESIGN CASES FOR SEVEN VARIABLE CASE(TITLE)
I 4.        3.
I W/S       80.       160.
I T/W       .8        1.2
I SWEEP     30.       70.
I TOGW      40000.    80000.
I OPR       9.        18.
I T4        2350.     3400.
I THTR      1.        1.36
STOP
SAVE,TAPE2=LSNAME
SAVE,PUNCH=PCNAME
COPYBF,TAPE2
```

DESIGN CASES FOR SEVEN VARIABLE CASE(TITLE)

CASE	W/S	T/W	SWEEP	TOGW	OPR	T4	THTR
1	80.0	.800	30.0	40000	9.0	2350	1.0000
2	91.4	.857	35.7	45714	10.3	2500	1.0514
3	102.9	.914	41.4	51429	11.6	2650	1.1029
4	114.3	.971	47.1	57143	12.9	2800	1.1543
5	125.7	1.029	52.9	62857	14.1	2950	1.2057
6	137.1	1.086	58.6	68571	15.4	3100	1.2571
7	148.6	1.143	64.3	74286	16.7	3250	1.3086
8	160.0	1.200	70.0	80000	18.0	3400	1.3600
9	91.4	1.029	64.3	80000	12.9	3100	1.1029
10	80.0	1.086	70.0	74286	11.6	2950	1.1543
11	114.3	1.143	52.9	68571	10.3	3400	1.0000
12	102.9	1.200	58.6	62857	9.0	3250	1.0514
13	137.1	.800	41.4	57143	18.0	2500	1.3086
14	125.7	.857	47.1	51429	16.7	2350	1.3600
15	160.0	.914	30.0	45714	15.4	2800	1.2057
16	148.6	.971	35.7	40000	14.1	2650	1.2571
17	102.9	.857	52.9	74286	18.0	2800	1.2571
18	114.3	.800	58.6	80000	16.7	2650	1.2057
19	80.0	.971	64.3	62857	15.4	2500	1.3600
20	91.4	.914	70.0	68571	14.1	2350	1.3086
21	148.6	1.086	30.0	51429	12.9	3400	1.0514
22	160.0	1.029	35.7	57143	11.6	3250	1.0000
23	125.7	1.200	41.4	40000	10.3	3100	1.1543
24	137.1	1.143	47.1	45714	9.0	2950	1.1029
25	114.3	1.086	41.4	45714	14.1	3250	1.3600
26	102.9	1.029	47.1	40000	15.4	3400	1.3086
27	91.4	1.200	30.0	57143	16.7	2950	1.2571
28	80.0	1.143	35.7	51429	18.0	3100	1.2057
29	160.0	.857	64.3	68571	9.0	2650	1.1543
30	148.6	.800	70.0	62857	10.3	2800	1.1029
31	137.1	.971	52.9	80000	11.6	2350	1.0514
32	125.7	.914	58.6	74286	12.9	2500	1.0000
33	125.7	1.143	70.0	57143	15.4	2650	1.0514
34	137.1	1.200	64.3	51429	14.1	2800	1.0000
35	148.6	1.029	58.6	45714	18.0	2350	1.1543
36	160.0	1.086	52.9	40000	16.7	2500	1.1029
37	80.0	.914	47.1	80000	10.3	3250	1.2571
38	91.4	.971	41.4	74286	9.0	3400	1.2057
39	102.9	.800	35.7	68571	12.9	2950	1.3600
40	114.3	.857	30.0	62857	11.6	3100	1.3086
41	137.1	.914	35.7	62857	16.7	3400	1.1543

42	125.7	.971	30.0	68571	18.0	3250	1.1029
43	160.0	.800	47.1	74286	14.1	3100	1.0514
44	148.6	.857	41.4	80000	15.4	2950	1.0000
45	91.4	1.143	58.6	40000	11.6	2800	1.3600
46	80.0	1.200	52.9	45714	12.9	2650	1.3086
47	114.3	1.029	70.0	51429	9.0	2500	1.2571
48	102.9	1.086	64.3	57143	10.3	2350	1.2057
49	148.6	1.200	47.1	68571	11.6	2500	1.2057
50	160.0	1.143	41.4	62857	12.9	2350	1.2571

DESIGN CASES FOR SEVEN VARIABLE CASE(TITLE)

CASE	W/S	T/W	SWEEP	TOGW	OPR	T4	THTR
51	125.7	1.086	35.7	80000	9.0	2800	1.3086
52	137.1	1.029	30.0	74286	10.3	2650	1.3600
53	102.9	.971	70.0	45714	16.7	3100	1.0000
54	114.3	.914	64.3	40000	18.0	2950	1.0514
55	80.0	.857	58.6	57143	14.1	3400	1.1029
56	91.4	.800	52.9	51429	15.4	3250	1.1543
57	160.0	.971	58.6	51429	10.3	2950	1.3086
58	148.6	.914	52.9	57143	9.0	3100	1.3600
59	137.1	.857	70.0	40000	12.9	3250	1.2057
60	125.7	.800	64.3	45714	11.6	3400	1.2571
61	114.3	1.200	35.7	74286	15.4	2350	1.1029
62	102.9	1.143	30.0	80000	14.1	2500	1.1543
63	91.4	1.086	47.1	62857	18.0	2650	1.0000
64	80.0	1.029	41.4	68571	16.7	2800	1.0514
65	91.4	1.029	64.3	80000	12.9	3100	1.1029
66	80.0	1.086	70.0	74286	11.6	2950	1.1543
67	114.3	1.143	52.9	68571	10.3	3400	1.0000
68	102.9	1.200	58.6	62857	9.0	3250	1.0514
69	137.1	.800	41.4	57143	18.0	2500	1.3086
70	125.7	.857	47.1	51429	16.7	2350	1.3600
71	160.0	.914	30.0	45714	15.4	2800	1.2057
72	148.6	.971	35.7	40000	14.1	2650	1.2571
73	102.9	.857	52.9	74286	18.0	2800	1.2571
74	114.3	.800	58.6	80000	16.7	2650	1.2057
75	80.0	.971	64.3	62857	15.4	2500	1.3600
76	91.4	.914	70.0	68571	14.1	2350	1.3086
77	148.6	1.086	30.0	51429	12.9	3400	1.0514
78	160.0	1.029	35.7	57143	11.6	3250	1.0000
79	125.7	1.200	41.4	40000	10.3	3100	1.1543
80	137.1	1.143	47.1	45714	9.0	2950	1.1029
81	114.3	1.086	41.4	45714	14.1	3250	1.3600
82	102.9	1.029	47.1	40000	15.4	3400	1.3086
83	91.4	1.200	30.0	57143	16.7	2950	1.2571
84	80.0	1.143	35.7	51429	18.0	3100	1.2057
85	160.0	.857	64.3	68571	9.0	2650	1.1543
86	148.6	.800	70.0	62857	10.3	2800	1.1029
87	137.1	.971	52.9	80000	11.6	2350	1.0514
88	125.7	.914	58.6	74286	12.9	2500	1.0000
89	125.7	1.143	70.0	57143	15.4	2650	1.0514
90	137.1	1.200	64.3	51429	14.1	2800	1.0000
91	148.6	1.029	58.6	45714	18.0	2350	1.1543

92	160.0	1.086	52.9	40000	16.7	2500	1.1029
93	80.0	.914	47.1	80000	10.3	3250	1.2571
94	91.4	.971	41.4	74286	9.0	3400	1.2057
95	102.9	.800	35.7	68571	12.9	2950	1.3600
96	114.3	.857	30.0	62857	11.6	3100	1.3086
97	137.1	.914	35.7	62857	16.7	3400	1.1543
98	125.7	.971	30.0	68571	18.0	3250	1.1029
99	160.0	.800	47.1	74286	14.1	3100	1.0514
100	148.6	.857	41.4	80000	15.4	2950	1.0000

DESIGN CASES FOR SEVEN VARIABLE CASE(TITLE)

CASE	W/S	T/W	SWEEP	TOGW	OPR	T4	THTR
101	91.4	1.143	58.6	40000	11.6	2800	1.3600
102	80.0	1.200	52.9	45714	12.9	2650	1.3086
103	114.3	1.029	70.0	51429	9.0	2500	1.2571
104	102.9	1.086	64.3	57143	10.3	2350	1.2057
105	148.6	1.200	47.1	68571	11.6	2500	1.2057
106	160.0	1.143	41.4	62857	12.9	2350	1.2571
107	125.7	1.086	35.7	80000	9.0	2800	1.3086
108	137.1	1.029	30.0	74286	10.3	2650	1.3600
109	102.9	.971	70.0	45714	16.7	3100	1.0000
110	114.3	.914	64.3	40000	18.0	2950	1.0514
111	80.0	.857	58.6	57143	14.1	3400	1.1029
112	91.4	.800	52.9	51429	15.4	3250	1.1543
113	160.0	.971	58.6	51429	10.3	2950	1.3086
114	148.6	.914	52.9	57143	9.0	3100	1.3600
115	137.1	.857	70.0	40000	12.9	3250	1.2057
116	125.7	.800	64.3	45714	11.6	3400	1.2571
117	114.3	1.200	35.7	74286	15.4	2350	1.1029
118	102.9	1.143	30.0	80000	14.1	2500	1.1543
119	91.4	1.086	47.1	62857	18.0	2650	1.0000
120	80.0	1.029	41.4	68571	16.7	2800	1.0514

APPENDIX B

MANE OUTPUT SAMPLE

AIAA ENGINE UTILIZATION STUDY

REGRESSION CASE 1

```
 1 OPR
 2 GW
 3 WINGLD
 4 MACH(05)
 5 NALT
 6 PSOA(05)
 7 OPR * OPR
 8 OPR * GW
 9 OPR * WING
10 OPR * MACH
11 OPR * NALT
12 OPR * PSOA
13 GW  * GW
14 GW  * WING
15 GW  * MACH
16 GW  * NALT
17 GW  * PSOA
18 WING* WING
19 WING* MACH
20 WING* NALT
21 WING* PSOA
22 MACH* MACH
23 MACH* NALT
24 MACH* PSOA
25 NALT* NALT
26 NALT* PSOA
27 PSOA* PSOA
28 TRANGE
```

STEPWISE LINEAR REGRESSION USING HOUSEHOLDER TRANSFORMATIONS - NMRGSN

TOTAL NUMBER OF OBSERVATIONS = 49

TOTAL NUMBER OF VARIABLES IS 28

RESPONSE VARIABLE IS 28

CONSTANT TERM (VAR. NO. 29) IS COMPUTED

INDEPENDENT VARIABLES ALWAYS IN REGRESSION ARE 29

SIGNIFICANCE LEVEL FOR ENTERING REGRESSION IS .050

SIGNIFICANCE LEVEL FOR LEAVING REGRESSION IS .150

MEANS AND STANDARD DEVIATIONS

VAR. NO.	1	2	3	4	5	6	7	8	9	10
MEAN	2.2500E+01	5.5000E+04	1.0000E+02	1.5000E+00	5.0000E-01	8.7518E-01	5.3125E+02	1.2375E+06	2.2500E+03	3.3750E+01
STD. DEV.	5.0000E+00	1.0000E+04	1.6671E+01	2.0000E-01	3.3287E-01	8.3156E-02	2.2604E+02	3.5882E+05	6.3060E+02	8.8034E+00

VAR. NO.	11	12	13	14	15	16	17	18	19	20
MEAN	1.1250E+01	1.9692E+01	3.1250E+09	5.5000E+06	8.2500E+04	2.7500E+04	4.8134E+04	1.0278E+04	1.5000E+02	5.0000E+01
STD. DEV.	8.0692E+00	4.7789E+00	1.1034E+09	1.3670E+06	1.8708E+04	1.9268E+04	9.9044E+03	3.3430E+03	3.2194E+01	3.4760E+01

VAR. NO.	21	22	23	24	25	26	27	28
MEAN	8.7519E+01	2.2900E+00	7.5000E-01	1.3128E+00	3.6080E-01	4.3759E-01	7.7286E-01	8.1256E+02
STD. DEV.	1.6856E+01	6.0100E-01	5.1355E-01	2.1586E-01	3.4642E-01	2.9552E-01	1.4569E-01	1.6911E+02

CORRELATION COEFFICIENTS

VAR. NO.	1	2	3	4	5	6	7	8	9	10
1	1.00000000	.00000000	.00000000	.00000000	.00000000	.00164432	.99540227	.76640632	.79289790	.85194275
2	.00000000	1.00000000	.00000000	.00000000	.00000000	-.00132528	.00000000	.62705971	.00000000	.00000000
3	.00000000	.00000000	1.00000000	.00000000	.00000000	.00037657	.00000000	.00000000	.59484399	-.00000000
4	.00000000	.00000000	.00000000	1.00000000	.00000000	.00328865	.00000000	.00000000	.00000000	.51116565
5	.00000000	.00000000	.00000000	.00000000	1.00000000	-.00000737	.00000000	.00000000	.00000000	.00000000
6	.00164432	-.00132528	.00037657	.00328865	-.00000737	1.00000000	.00136126	.00034712	.00156240	.00327706
7	.99540227	.00000000	.00000000	.00000000	.00000000	.00136126	1.00000000	.76288259	.78925237	.84802575
8	.76640632	.62705971	.00000000	.00000000	.00000000	.00034712	.76288259	1.00000000	.60997852	.65491289
9	.79289790	.00000000	.59484399	.00000000	.00000000	.00156240	.78925237	.60997852	1.00000000	.67925749
10	.85194275	.00000000	-.00000000	.51116565	.00000000	.00327706	.84802575	.65491289	.67925749	1.00000000
11	.30981884	.00000000	.00000000	-.00000000	.92815437	.00051705	.30839438	.24463220	.24910957	.26397305
12	.91609539	-.00057011	.00017021	.00143701	.00000321	.39289199	.91176299	.70473196	.72648761	.78251434
13	.00000000	.99691516	.00000000	.00000000	.00000000	-.00138458	.00000000	.62512533	.00149878	.00128684
14	.00000000	.73155540	.67078479	.00000000	-.00000000	-.00093104	.00168178	.46085509	.40103095	.00519073
15	.00000000	.80178373	.00000000	.58797473	-.00000000	.00074578	.00147796	.50462837	.00529474	.30207043
16	.00000000	.25949965	-.00000000	-.00000000	.95016568	-.00035079	.00477662	.16274760	.00860739	.00484268
17	.00070985	.88296001	.00002649	.00142021	-.00000334	.46069418	.00290502	.55710856	.00476269	.00500231
18	.00000000	.00000000	.99740448	.00000000	.00000000	.00040881	.00000000	.00145065	.59330006	.00235699
19	-.00000000	-.00000000	.77675654	.62122705	-.00000000	.00230896	.00286365	.00540728	.46546566	.31754741
20	-.00000000	-.00000000	.23980573	.00000000	.95760441	.00021090	.00223742	.00838494	.14527792	.00677691
21	.00083274	-.00079820	.86583035	.00160134	.00006213	.49387492	.00069170	.00440146	.51844827	.00397136
22	.00000000	.00000000	.00000000	.99833749	.00000000	.00333382	.00000000	.00115929	-.00000188	.51031583
23	-.00000000	-.00000000	.00000000	.19472360	.97225397	.00053883	.00001538	.00445774	.00640371	.10321727
24	.00108255	-.00085611	.00019786	.81285557	-.00006036	.58004995	.00196174	.00427727	.00355471	.41765742
25	.00000000	.00000000	.00000000	.00000000	.96087241	-.00080963	.00000000	.01123704	.00522477	.00916020
26	.00023791	-.00018639	.00012788	.00039450	.98555463	.14099856	.00276889	.00334012	.00336796	.00443313
27	.00157497	-.00127062	.00049917	.00299435	.00015030	.99915734	.00130412	.00032490	.00316587	.00372335
28	-.00692704	.46917392	.30376988	-.36788111	.62059282	.20761058	.00015816	.29545919	.17807123	-.19188309

VAR. NO.	11	12	13	14	15	16	17	18	19	20
1	.30981884	.91609539	.00000000	.00000000	.00000000	.00000000	.00070985	.00000000	-.00000000	-.00000000
2	.00000000	-.00057011	.99691516	.73155540	.80178373	.25949965	.88296001	.00000000	-.00000000	-.00000000
3	.00000000	.00017021	.00000000	.67078479	.00000000	-.00000000	.00002649	.99740448	.77675654	.23980573
4	-.00000000	.00143701	.00000000	.00000000	.58797473	-.00000000	.00142021	.00000000	.62122705	.00000000
5	.92815437	.00000321	.00000000	-.00000000	-.00000000	.95016568	-.00000334	.00000000	-.00000000	.95760441
6	.00051705	.39289199	-.00138458	-.00093104	.00074578	-.00035079	.46069418	.00040881	.00230896	.00021090
7	.30839438	.91176299	.00000000	.00168178	.00147796	.00477662	.00290502	.00000000	.00286365	.00223742
8	.24463220	.70473196	.62512533	.46085509	.50462837	.16274760	.55710856	.00145065	.00540728	.00838494
9	.24910957	.72648761	.00149878	.40103095	.00529474	.00860739	.00476269	.59330006	.46546566	.14527792
10	.26397305	.78251434	.00128684	.00519073	.30207043	.00484268	.00500231	.00235699	.31754741	.00677691
11	1.00000000	.28828539	.00002006	.00948140	.00544131	.89088431	.00458356	.00213786	.00798278	.89287391

12	.28828539	1.00000000	.00137113	.00359836	.00383160	.00363949	.18091022	.00199186	.00327823	.00356969
13	.00002006	.00137113	1.00000000	.72929867	.79931035	.25869913	.88019056	.00000000	.00235057	.00358600
14	.00948140	.00359836	.72929867	1.00000000	.58981434	.19506044	.64716144	.66904376	.52104189	.16567535
15	.00544131	.00383160	.79931035	.58981434	1.00000000	.21267960	.70874354	.00000381	.36803851	.00428125
16	.89088431	.00363949	.25869913	.19506044	.21267960	1.00000000	.23094622	.00355366	.00448823	.90981836
17	.00458356	.18091022	.88019056	.64716144	.70874354	.23094622	1.00000000	.00090804	.00305116	.00510687
18	.00213786	.00199186	.00000000	.66904376	.00000381	.00355366	.00090804	1.00000000	.77474045	.23918331
19	.00798278	.00327823	.00235057	.52104189	.36803851	.00448823	.00305116	.77474045	1.00000000	.18836745
20	.89287391	.00356969	.00358600	.16567535	.00428125	.90981836	.00510687	.23918331	.18836745	1.00000000
21	.00456792	.19588653	.00012261	.58132783	.00242446	.00519971	.22815187	.86360993	.67567813	.20777153
22	.00343180	.00218497	.00000000	.00203278	.58699722	.00001234	.00283990	.00000000	.62019425	.00131906
23	.90914311	.00448756	.00293705	.00396601	.11450742	.92944880	.00429316	.00136679	.12263428	.93360108
24	.00626418	.22895190	-.00089488	.00171755	.47923048	.00469001	.26870563	.00181763	.50708563	.00467975
25	.89183792	-.00039530	.00000000	-.00009120	.00862088	.91298798	.00298229	.00000000	.00410775	.92013565
26	.91479590	.05745365	.00087138	.00421878	.00380329	.93839270	.06594718	.00014294	.00398134	.94759592
27	.00309842	.39251499	-.00132173	-.00006992	.00190087	.00084497	.46034756	.00052108	.00223788	.00228374
28	.58758317	.07282314	.45691065	.55753945	.17198516	.73137863	.51325865	.30159464	.01144878	.67528865

VAR. NO.	21	22	23	24	25	26	27	28
1	.00083274	.00000000	-.00000000	.00108255	.00000000	.00023791	.00157497	-.00692704
2	-.00079820	.00000000	-.00000000	-.00085611	.00000000	-.00018639	-.00127062	.46917392
3	.86583035	.00000000	.00000000	.00019786	.00000000	.00012788	.00049917	.30376988
4	.00160134	.99833749	.19472360	.81285557	.00000000	.00039450	.00299435	-.36788111
5	.00006213	.00000000	.97225397	-.00006036	.96087241	.98555463	.00015030	.62059282
6	.49387492	.00333382	.00053883	.58004995	-.00080963	.14099856	.99915734	.20761058
7	.00069170	.00000000	.00001538	.00196174	.00000000	.00276889	.00130412	.00015816
8	.00440146	.00115929	.00445774	.00427727	.01123704	.00334012	.00032490	.29545919
9	.51844827	-.00000188	.00640371	.00355471	.00522477	.00336796	.00316587	.17807123
10	.00397136	.51031583	.10321727	.41765742	.00916020	.00443313	.00372335	-.19188309
11	.00456792	.00343180	.90914311	.00626418	.89183792	.91479590	.00309842	.58758317
12	.19588653	.00218497	.00448756	.22895190	-.00039530	.05745365	.39251499	.07282314
13	.00012261	.00000000	.00293705	-.00089488	.00000000	.00087138	-.00132173	.45691065
14	.58132783	.00203278	.00396601	.00171755	-.00009120	.00421878	-.00006992	.55753945
15	.00242446	.58699722	.11450742	.47923048	.00862088	.00380329	.00190087	.17198516
16	.00519971	.00001234	.92944880	.00469001	.91298798	.93839270	.00084497	.73137863
17	.22815187	.00283990	.00429316	.26870563	.00298229	.06594718	.46034756	.51325865
18	.86360993	.00000000	.00136679	.00181763	.00000000	.00014294	.00052108	.30159464
19	.67567813	.62019425	.12263428	.50708563	.00410775	.00398134	.00223788	.01144878
20	.20777153	.00131906	.93360108	.00467975	.92013565	.94759592	.00228374	.67528865
21	1.00000000	.00297945	.00432708	.28645800	.00629631	.07168923	.49353121	.36378290
22	.00297945	1.00000000	.19439987	.81154412	.00000000	.00118096	.00301989	-.36509485
23	.00432708	.19439987	1.00000000	.15941855	.93421201	.95979419	.00141892	.50955298
24	.28645800	.81154412	.15941855	1.00000000	.00248464	.08259450	.57936215	-.16762063
25	.00629631	.00000000	.93421201	.00248464	1.00000000	.94688308	-.00061164	.63526892

26	.07168923	.00118096	.95979419	.08259450	.94688308	1.00000000	.14102444	.64192934
27	.49353121	.00301989	.00141892	.57936215	-.00061164	.14102444	1.00000000	.20821650
28	.36378290	-.36509485	.50955298	-.16762063	.63526892	.64192934	.20821650	1.00000000

CORRECTED REGRESSION COEFFICIENTS

INDEPENDENT VARIABLES ARE 29 16 23 21 25 20 17
5

STANDARD DEVIATION OF RESIDUALS = 3.75274426E+01

MULT. CORR. COEFF. SQUARED (R**2) = .95879509

ANOVA TABLE

SOURCE	SS	DF	MS	F
REGRESSION	1.3435649E+06	7	1.9193785E+05	1.3628959E+02
RESIDUALS	5.7740667E+04	41	1.4083089E+03	
CORRECTED TOTAL	1.4013056E+06	48		

REGRESSION COEFFICIENTS AND STANDARD DEVIATIONS

VAR. NO.	COEFFICIENT	STD. DEV.
29	3.08839699000397E+02	4.85298755520937E+01
16	8.46822159157556E-03	1.41033199438239E-03
23	-6.16971590196816E+02	4.48753099407538E+01
21	1.98900513055624E+00	5.10407012430399E-01
25	2.35275898527716E+02	5.58999087658076E+01
20	2.54550858662438E+00	8.13632372559319E-01
17	4.25381066469965E-03	8.97274210103698E-04
5	2.85159020112967E+02	1.29303495496042E+02

DISPERSION MATRIX

VAR. NO.	29	16	23	21	25	20	17	5
29	1.6723E+00	1.9033E-05	-6.3957E-02	-9.4507E-03	3.6274E-01	1.1772E-02	-1.5130E-05	-2.5829E+00
16	1.9033E-05	1.4124E-09	-4.2506E-06	1.6451E-07	1.2162E-07	-1.8493E-07	-6.9418E-10	-5.2933E-05
23	-6.3957E-02	-4.2506E-06	1.4299E+00	-1.9153E-04	-1.1046E-03	-4.5202E-04	1.6738E-06	-1.8648E+00
21	-9.4507E-03	1.6451E-07	-1.9153E-04	1.8498E-04	-5.7404E-04	-2.2186E-04	-1.4166E-07	1.3998E-02
25	3.6274E-01	1.2162E-07	-1.1046E-03	-5.7404E-04	2.2188E+00	6.9855E-04	-7.5731E-08	-2.2937E+00
20	1.1772E-02	-1.8493E-07	-4.5202E-04	-2.2186E-04	6.9855E-04	4.7007E-04	1.6082E-07	-3.6855E-02
17	-1.5130E-05	-6.9418E-10	1.6738E-06	-1.4166E-07	-7.5731E-08	1.6082E-07	5.7168E-10	1.9663E-05
5	-2.5829E+00	-5.2933E-05	-1.8648E+00	1.3998E-02	-2.2937E+00	-3.6855E-02	1.9663E-05	1.1872E+01

RESIDUALS

OBS. NO.	OBSERVED	PREDICTED	RESIDUALS	STDZ RESIDUALS
1	5.4980000E+02	5.4833556E+02	1.4644425E+00	3.9023242E-02
2	1.1230000E+03	1.1604768E+03	-3.7476844E+01	-9.9865170E-01
3	8.5450000E+02	8.4003615E+02	1.4463852E+01	3.8542066E-01
4	7.6870000E+02	7.1810920E+02	5.0590797E+01	1.3481014E+00
5	1.1110000E+03	1.1252098E+03	-1.4209840E+01	-3.7865197E-01
6	8.3690000E+02	8.4764319E+02	-1.0743191E+01	-2.8627560E-01
7	6.9590000E+02	6.5008377E+02	4.5816232E+01	1.2208727E+00
8	6.2890000E+02	6.1138626E+02	1.7513743E+01	4.6669162E-01
9	8.3270000E+02	9.0844769E+02	-7.5747692E+01	-2.0184613E+00
10	7.4180000E+02	8.1640492E+02	-7.4604919E+01	-1.9880097E+00
11	9.3510000E+02	9.3031896E+02	4.7810410E+00	1.2740119E-01
12	7.6140000E+02	7.6292344E+02	-1.5234390E+00	-4.0595333E-02
13	7.6460000E+02	7.5241032E+02	1.2189677E+01	3.2482034E-01
14	7.0330000E+02	7.1458537E+02	-1.1285370E+01	-3.0072313E-01
15	7.1860000E+02	6.8934219E+02	2.9257811E+01	7.7963776E-01
16	7.2120000E+02	7.3036084E+02	-9.1608364E+00	-2.4411033E-01
17	6.1150000E+02	5.7052289E+02	4.0977111E+01	1.0919239E+00
18	8.6570000E+02	9.1085222E+02	-4.5152218E+01	-1.2031787E+00
19	7.5350000E+02	7.1610868E+02	3.7391321E+01	9.9637276E-01
20	9.3080000E+02	8.6881366E+02	6.1986345E+01	1.6517604E+00
21	1.1050000E+03	1.0865810E+03	1.8418951E+01	4.9081285E-01
22	8.4040000E+02	7.8637032E+02	5.4029685E+01	1.4397380E+00
23	6.8150000E+02	6.5207627E+02	2.9423734E+01	7.8405914E-01
24	1.0890000E+03	1.0845066E+03	4.4934194E+00	1.1973689E-01
25	6.9520000E+02	7.1750580E+02	-2.2305795E+01	-5.9438623E-01
26	8.3010000E+02	8.1606358E+02	1.4036420E+01	3.7403082E-01
27	7.3110000E+02	7.2959545E+02	1.5045518E+00	4.0092041E-02
28	1.1510000E+03	1.1055452E+03	4.5454817E+01	1.2112421E+00
29	8.9270000E+02	9.0237326E+02	-9.6732604E+00	-2.5776498E-01
30	5.1200000E+02	5.8756524E+02	-7.5565237E+01	-2.0135994E+00
31	6.9880000E+02	6.9800172E+02	7.9827877E-01	2.1271867E-02
32	8.3770000E+02	8.2368997E+02	1.4010033E+01	3.7332769E-01
33	5.8980000E+02	6.6470454E+02	-7.4904538E+01	-1.9959937E+00
34	8.3390000E+02	8.5805705E+02	-2.4157052E+01	-6.4371699E-01
35	9.8780000E+02	1.0439524E+03	-5.6152449E+01	-1.4963036E+00
36	1.0420000E+03	1.0276793E+03	1.4320682E+01	3.8160559E-01
37	8.8180000E+02	8.5736505E+02	2.4434951E+01	6.5112220E-01
38	7.9690000E+02	7.9302929E+02	3.8707078E+00	1.0314339E-01
39	8.6940000E+02	8.2873414E+02	4.0665863E+01	1.0836300E+00
40	5.3030000E+02	5.4266074E+02	-1.2360740E+01	-3.2937869E-01

41	7.1480000E+02	7.5216049E+02	-3.7360491E+01	-9.9555122E-01
42	6.6220000E+02	6.9484793E+02	-3.2647932E+01	-8.6997487E-01
43	1.1780000E+03	1.1760276E+03	1.9724114E+00	5.2559173E-02
44	1.0330000E+03	1.0034286E+03	2.9571370E+01	7.8799321E-01
45	7.4440000E+02	7.4121352E+02	3.1864759E+00	8.4910553E-02
46	6.5550000E+02	6.6469489E+02	-9.1948851E+00	-2.4501763E-01
47	9.9740000E+02	9.6745639E+02	2.9943611E+01	7.9791238E-01
48	7.3400000E+02	7.3503491E+02	-1.0349125E+00	-2.7577486E-02
49	5.9070000E+02	6.0200669E+02	-1.1306692E+01	-3.0129129E-01

NWRGSN SUCCESSFUL COMPLETION CODE = 0

RESIDUALS

OBS. NO.	RESIDUAL	RESIDUAL/STD DEV
1	1.464442E+00	8.659721E-03
2	-3.747684E+01	-2.216127E-01
3	1.446385E+01	8.552943E-02
4	5.059080E+01	2.991597E-01
5	-1.420984E+01	-8.402738E-02
6	-1.074319E+01	-6.352796E-02
7	4.581623E+01	2.709262E-01
8	1.751374E+01	1.035644E-01
9	-7.574769E+01	-4.479206E-01
10	-7.460492E+01	-4.411630E-01
11	4.781041E+00	2.827184E-02
12	-1.523439E+00	-9.008587E-03
13	1.218968E+01	7.208150E-02
14	-1.128537E+01	-6.673404E-02
15	2.925781E+01	1.730109E-01
16	-9.160836E+00	-5.417099E-02
17	4.097711E+01	2.423109E-01
18	-4.515222E+01	-2.669997E-01
19	3.739132E+01	2.211070E-01
20	6.198634E+01	3.665453E-01
21	1.841895E+01	1.089172E-01
22	5.402968E+01	3.194950E-01
23	2.942373E+01	1.739920E-01
24	4.493419E+00	2.657104E-02
25	-2.230580E+01	-1.319014E-01
26	1.403642E+01	8.300189E-02
27	1.504552E+00	8.896901E-03
28	4.545482E+01	2.687890E-01
29	-9.673260E+00	-5.720111E-02
30	-7.556524E+01	-4.468417E-01
31	7.982788E-01	4.720480E-03
32	1.401003E+01	8.284586E-02
33	-7.490454E+01	-4.429347E-01
34	-2.415705E+01	-1.428485E-01
35	-5.615245E+01	-3.320476E-01
36	1.432068E+01	8.468282E-02
37	2.443495E+01	1.444918E-01
38	3.870708E+00	2.288875E-02
39	4.066586E+01	2.404704E-01
40	-1.236074E+01	-7.309305E-02
41	-3.736049E+01	-2.209247E-01
42	-3.264793E+01	-1.930578E-01
43	1.972411E+00	1.166351E-02
44	2.957137E+01	1.748651E-01
45	3.186476E+00	1.884266E-02
46	-9.194885E+00	-5.437233E-02
47	2.994361E+01	1.770662E-01
48	-1.034913E+00	-6.119772E-03
49	-1.130669E+01	-6.686012E-02

PUNCH QUADRATIC COEFFICIENTS AS FOLLOWS TRANGE 5.12000E+02 6.66000E+02 INFLUENCE COEFFICIENTS

1	3.08840E+02	CONSTANT	.00000
2	.0	OPR	.00000
3	.0	GW	.00000
4	.0	WINGLD	.00000
5	.0	MACH(05)	.00000
6	2.85159E+02	NALT	.56129
7	.0	PSOA(05)	.00000
8	.0	OPR * OPR	.00000
9	.0	OPR * GW	.00000
10	.0	OPR * WING	.00000
11	.0	OPR * MACH	.00000
12	.0	OPR * NALT	.00000
13	.0	OPR * PSOA	.00000
14	.0	GW * GW	.00000
15	.0	GW * WING	.00000
16	.0	GW * MACH	.00000
17	8.46822E-03	GW * NALT	.96484
18	4.25381E-03	GW * PSOA	.24914
19	.0	WING* WING	.00000
20	.0	WING* MACH	.00000
21	2.54551E+00	WING* NALT	.52323
22	1.98901E+00	WING* PSOA	.19825
23	.0	MACH* MACH	.00000
24	-6.16972E+02	MACH* NALT	-1.87361
25	.0	MACH* PSOA	.00000
26	4.70552E+02	NALT* NALT	.48196
27	.0	NALT* PSOA	.00000
28	.0	PSOA* PSOA	.00000

APPENDIX C

OAPEN INPUT/OUTPUT SAMPLE

```
SET FUN FUNCT 2 LENGTH 66 N 10 LABEL
OAPEN CHECKOUT ON FGT DATA
VARIABLES
FPR OPR T4 A8 THTR T/W T/C W/S AR TOGW
RNG801      5.63700E+03   5.10300E+03
 6.83361E+03 -1.30604E+03  7.42740E+01  .0            .0            .0
  .0           .0            .0          .0           3.95810E-02   .0
  .0           .0            .0          .0           1.28586E+03   .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0          9.03421E-05
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0          -1.38020E+04   .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0           2.52992E-04 -1.03203E-07
TODIST      3.82700E+03  6.88300E+03
 1.23926E+04  .0            .0           .0            .0           .0
-4.62533E+04 -5.18087E+04  1.02100E+02   .0            .0           .0
  .0           .0            .0        -1.06797E+02    .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0         -9.50264E+03
  .0           .0            .0         9.43430E+04  8.66177E+04 -1.25985E+02
  .0           .0          2.80946E+05 -1.81266E+02    .0           .0
 8.07442E-02  .0            .0           .0           3.48602E-05   .0
LDGVEL      1.09200E+02  3.93000E+01
 9.12644E+01  .0            .0           .0            .0           .0
  .0         -3.96405E+02  4.49014E-01   .0          -3.90574E-05   .0
-2.63156E-02  .0            .0           .0            .0           .0
  .0           .0            .0          .0            .0          1.91528E-02
  .0          4.00865E-01   .0           .0            .0         -5.44327E-07
  .0           .0            .0          .0          -1.27530E-02   .0
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0            .0          1.32924E+02
  .0           .0            .0          .0            .0           .0
 2.68752E+00  .0            .0           .0            .0           .0
-7.86810E-04  .0            .0           .0          -9.80846E-07  1.16610E-10
NPEN        1.74700E+00  2.33200E+00
-1.53728E+01  .0            .0           .0           1.11714E+00  2.85510E+01
  .0           .0            .0          .0            .0           .0
  .0           .0            .0          .0           9.42742E-01   .0
```

.0	.0	8.23790E-08	8.12208E-04	.0	-5.85915E-03
.0	.0	.0	-1.63781E-04	.0	.0
.0	-1.40182E-04	.0	.0	.0	.0
.0	.0	.0	.C	-6.16530E-01	-3.6385E+00
.0	.0	.0	-2.22274E+01	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	-5.33926E-02	5.04252E-01	.0
.0	.0	.0	.0	.0	.0
RFLTMDOD	1.36100E-01	2.23590E+00			
-9.88320E-01	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
-1.36347E-02	.0	.0	.0	1.61526E+00	.0
.0	2.16902E-02	.0	2.64428E-03	.0	.0
.0	-3.48237E-02	.0	.0	-1.88113E-03	-7.81822E-09
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	-3.31111E-03	.0	.0	.0	.0
.0	3.10540E-02	.0	.0	.0	.0
.0	.0	.0	-2.19935E-02	.0	.0
.0	.0	.0	.0	1.46568E-07	.0
FLTIME	2.30600E+00	6.09000E-01			
4.13768E+00	.0	.0	1.42366E-04	.0	.0
-7.17985E+00	.0	4.33032E-03	.0	.0	.0
.0	.0	.0	-4.55186E-02	4.27774E-02	1.68997E-01
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
-6.12195E-08	.0	.0	.0	.0	1.87264E-07
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	-1.71723E+00
.0	.0	.0	1.21354E+01	3.40687E+00	-5.65107E-03
.0	.0	.0	-6.74960E-03	.0	.0
.0	.0	.0	.0	.0	.0
ACLTMDOD	3.18400E-03	1.13382E+00			
9.79231E-01	.0	.0	.0	.0	.0
.0	-2.94312E+01	.0	.0	1.77791E-06	.0
.0	.0	.0	-7.61902E-02	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	-6.43465E-09
.0	.0	.0	.0	.0	.0
.0	.0	-8.23076E-02	.0	.0	.0
.0	.0	5.90130E-08	.0	2.45831E+00	.0
.0	.0	.0	.0	.0	1.66490E-03
.0	.0	1.86079E+02	.0	.0	.0
.0	.0	.0	.0	4.92202E-08	-5.24124E-12

RNG802	1.45400E+03	1.46900E+03			
-1.31746E+02	.0	7.11561E+01	.0	.0	.0
.0	.0	.0	.0	1.08506E-02	-1.39172E+02
.0	.0	9.64058E+01	.0	.0	.0
1.05921E+00	.0	3.57544E-04	-3.01128E+00	.0	6.63418E+00
.0	.0	.0	-7.58857E-02	.0	4.02217E-05
.0	-2.09688E-01	.0	.0	.0	.0
.0	.0	-4.76540E+02	2.11414E+02	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	-1.07752E+04	.0
.0	.0	.0	.0	-1.12349E+02	.0
.0	.0	.0	.0	.0	-2.74147E-08
SEG801A	5.63700E+03	2.30800E+03			
-3.04015E+02	.0	3.04040E+02	.0	.0	.0
.0	.0	.0	2.26072E+02	5.01023E-02	.0
.0	.0	-1.23618E+02	.0	.0	.0
.0	.0	-2.16888E-03	-1.29072E+01	.0	.0
.0	1.47649E+02	.0	.0	.0	.0
.0	.0	-1.86836E-01	.0	.0	.0
.0	.0	4.64889E+02	.0	.0	-5.90968E+03
.0	1.01861E+02	.0	.0	-1.20176E+04	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	-4.61032E-04	-9.05124E-08
SSDALT	4.25200E+04	1.46100E+04			
5.38878E+04	.0	.0	.0	6.84048E+03	.0
.0	.0	.0	.0	.0	.0
.0	.0	5.33165E+02	.0	.0	.0
-1.59685E+01	.0	.0	-7.63294E+00	.0	.0
1.92411E+02	.0	.0	.0	.0	.0
.0	-2.62767E+00	.0	.0	.0	.0
.0	.0	-3.66274E+03	.0	.0	.0
0	.0	.0	.0	.0	.0
.0	.0	.0	.0	9.61253E+04	.0
.0	-5.35216E-03	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
108GNR	5.63700E+03	5.10300E+03			
6.83361E+03	-1.30604E+03	7.42740E+01	.0	.0	.0
.0	.0	.0	.0	3.95810E-02	.0
.0	.0	.0	.0	1.28586E+03	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	9.03421E-05
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0

.0	.0	.0	.0	-1.38020E+04	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	2.52992E-04	-1.03203E-07
BPR	2.00000E-01	2.80000E+00			
1.63095E+01	-7.59807E+00	2.23865E-01	7.58302E-03	.0	-2.45693E+01
.0	.0	.0	.0	.0	1.44880E+00
.0	-3.31682E-04	.0	2.63907E+00	.0	.0
.0	.0	.0	-4.31560E-03	1.46772E-05	.0
-1.46243E-01	.0	.0	.0	.0	.0
-1.12651E-06	.0	-2.81837E-03	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	2.09058E+01	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
NMILE(25)	2.45000E+02	5.21000E+02			
-8.81369E+01	.0	.0	.0	.0	.0
.0	.0	.0	.0	3.17971E-03	.0
.0	.0	2.103110E+01	.0	.0	-4.28437+02
.0	.0	.0	.0	.0	3.71596E+00
.0	.0	.0	2.13922E-02	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	-9.73518E+01	.0	-2.40844E+02	.0
.0	.0	.0	.0	.0	-9.99239E+02
.0	.0	7.81119E-04	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	-8.70140E-09
NMILE(26)	2.53500E+02	2.85700E+02			
-5.45763E+01	.0	1.38300E+01	.0	.0	.0
.0	.0	.0	.0	2.10926E-03	-2.70786E+01
.0	.0	1.87610E+01	.0	.0	.0
2.05910E-01	.0	6.96629E-05	-5.85311E-01	.0	1.29220E+00
.0	.0	.0	-1.47481E-02	.0	7.82122E-06
.0	-4.08159E-02	.0	.0	.0	.0
.0	.0	-9.26769E+01	4.11526E+01	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	-2.09617E+03	.0
.0	.0	.0	.0	-2.18289E+01	.0
.0	.0	.0	.0	.0	-5.33029E-09
TSC$$$	1.66204E+04	1.41274E+04			
8.59749E+03	.0	-1.17442E+02	.0	-3.99812E+02	.0
.0	.0	.0	.0	3.90374E-02	.0
.0	.0	7.72498E+01	.0	.0	.0

```
 .0          .0           .0          4.07602E+00  3.65505E-03  .0
 .0          .0           .0           .0          2.78333E+00 -8.88326E-05
 .0          .0           .0           .0           .0          .0
 .0          .0           .0           .0           .0          2.29591E+03
 .0          .0           .0           .0          1.59586E+03  .0
 .0         1.26204E+02   .0           .0           .0          .0
 .0         2.73597E-02   .0          6.83632E+01 -7.74489E+02 -5.25228E-02
 .0        -1.02030E+00 -2.51332E-05   .0          5.64453E-04 -1.37265E-08
999
SET CODING ON O. TRAN 25
2,2 10,20 2400,800 -1,2 1,.15 .35,.2 .08,.04 140,80
6,4 200000,300000 5637,5103 3827,6883 109,39 1.75,2.33 .136,2.236
2.3,.61 .0032,1.134 1454,1469 5637,2308 42520,14610 5637,5103 .2,2.8
245,521 253.5,285.7 16620.4,14127.4
999
SET CONSTRAINTS
RNG802 MAX
TODIST LE 6000
TSC$$$ GE 1
BPR LE 3
LDGVEL LE 125
NPEN GE 2.93
FLTIME LE 2.6
RNG801 LE 1000000
RFLTMDOD GE .18
ACLTMDOD GE .05
SSDALT GE 50000
999
CALL FR EPS 1E-5 DELX 1.E-4 X
2 30 2900 .12 1.15 .4 .08 140 10 275000
PENALTY 10 BOOST 100  EPSCON 1E-2 TITLE
FIND FGT INITIAL OPTIMUM
BOX
2,4 10,30 2400,3200 -1,1 1.0,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
SET XSAVE
CALL FR X=XSAVE
PENALTY 10 TITLE
FIND OPTIMUM FOR FPR(L.B.)=3.0 X=XSAVE
BOX
3,4 10,30 2400,3200 -1,1 1,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
SET XSAVE
CALL FR X
2 30 2900 .12 1.15 .4 .08 140 10 275000
PENALTY 10 TITLE
```

```
RELOCATE OPTIMUM 1
BOX
2,4 10,30 2400,3200 -1,1 1,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
SET XSAVE
CALL FR X=XSAVE
FPR 3 FIX 1
FPR
PENALTY 10 TITLE
FIND FPR=3.0(FIXED) OPTIMUM
BOX
2,4 10,30 2400,3200 -1,1 1,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
SET XSAVE
CALL FR X
2 26 2400 .2 1.15 .39 .08 140 6 275000
PENALTY 10 TITLE
AFAPL CONVERSION OPTIMUM (FEB. 1976)
BOX
2,4 10,30 2400,3200 -1,1 1.0,1.15 .35,.55 .08,.12 140,220 6,10 200000,275000
CALL FUN NOP -1
.01
CALL FUN NOP 0
2.06849 24.1998 2400.01 .216992 1.15 .394425 .08 140 6 275000
2 10 2400 -1 1.0 .35 .08 140 6 200000
4 30 3200 1 1.15 .55 .12 220 10 275000
.01
CALL FUN NOP 2
2.06849 24.1998 2400.01 .216992 1.15 .394425 .08 140 6 275000
2.08849 24.1998 2400.01 .216992 1.15 .394425 .08 140 6 275000
SET CONSTRAINTS
TODIST LE 1000000
BPR LE 1000000
LDGVEL LE 1000000
NPEN GE 0.
FLTIME LE 1000000
RFLTMDOD GE 0.
ACLTMDOD GE 0.
SSDALT GE 0.
999
CALL FR X
2 30 2900 .12 1.15 .4 .08 140 10 275000
PENALTY 10 TITLE
FIND RNG802 MAX WITH NONBINDING CONSTRAINTS PRESENT
BOX
2,4 10,30 2400,3200 -1,1 1,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
```

```
CALL FR X
2 30 2900 .12 1.15 .4 .08 140 10 275000
TITLE
FIND RNG802 MAX WITH NO. CONSTRAINTS SET = 0
BOX
2,4 10,30 2400,3200 -1,1 1,1.15 .35,.55 .08,.12 140,220 6,10 200000,500000
```

INSTRUCTION TO OAPEN --- SET FUN
OAPEN CHECKOUT ON FGT DATA

FUNCTION 1 RNG801 COEFFICIENTSO

.68336E+04	-.13060E+04	.74274E+02	0.	0.
0.	0.	0.	0.	0.
.39581E-01	0.	0.	0.	0.
0.	.12859E+04	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.90342E-04
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	-.13802E+05	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.25299E-03
-.10320E-06				

FUNCTION 2 TODIST COEFFICIENTSO

.12393E+05	0.	0.	0.	0.
0.	-.46253E+05	-.51809E+05	.10210E+03	0.
0.	0.	0.	0.	0.
-.10680E+03	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.95026E+04	0.	0.
0.	.94343E+05	.86618E+05	-.12599E+03	0.
0.	.28095E+06	-.18127E+03	0.	0.
.80744E-01	0.	0.	0.	.34860E-04
0.				

FUNCTION 3 LDGVEL COEFFICIENTSO

.91264E+02	0.	0.	0.	0.
0.	0.	-.39641E+03	.44901E+00	0.
-.39057E-04	0.	-.26316E-01	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	.19153E-01	0.
.40087E+00	0.	0.	0.	-.54433E-06
0.	0.	0.	0.	-.12753E-01

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	.13292E+03	0.	0.
0.	0.	0.	0.	.26875E+01
0.	0.	0.	0.	0.
-.78681E-03	0.	0.	0.	-.98085E-06
.11661E-09				

FUNCTION 4 NPEN COEFFICIENTSO

-.15373E+02	0.	0.	0.	.11171E+01
.28551E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	.94274E+00	0.	0.	0.
.82379E-07	.81221E-03	0.	-.58592E-02	0.
0.	0.	-.16378E-03	0.	0.
0.	-.14018E-03	0.	0.	0.
0.	0.	0.	0.	0.
-.61653E+00	-.36385E+01	0.	0.	0.
-.22227E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.53393E-01	.50425E+00	0.
0.	0.	0.	0.	0.
0.				

FUNCTION 5 RFLTMDOD COEFFICIENTSO

-.98832E+00	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.13635E-01	0.	0.
0.	.16153E+01	0.	0.	.21690E-01
0.	.26443E-02	0.	0.	0.
-.34824E-01	0.	0.	-.18811E-02	-.78182E-08
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	-.33111E-02	0.
0.	0.	0.	0.	.31054E-01
0.	0.	0.	0.	0.
0.	0.	-.21994E-01	0.	0.
0.	0.	0.	0.	.14657E-06
0.				

FUNCTION 6 FLTIME COEFFICIENTSO

.41377E+01	0.	0.	.14237E-03	0.
0.	-.71799E+01	0.	.43303E-02	0.
0.	0.	0.	0.	0.

-.45519E-01	.42777E-01	.16900E+00	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.61219E-07	0.	0.	0.	0.
.18726E-06	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.17172E+01	0.	0.
0.	.12135E+02	.34069E+01	-.56511E-02	0.
0.	0.	-.67496E-02	0.	0.
0.	0.	0.	0.	0.
0.				

FUNCTION 7 ACLTMDOD COEFFICIENTSO

.97923E+00	0.	0.	0.	0.
0.	0.	-.29431E+02	0.	0.
.17779E-05	0.	0.	0.	0.
-.76190E-01	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.64346E-08
0.	0.	0.	0.	0.
0.	0.	0.	-.82308E-01	0.
0.	0.	0.	0.	.59013E-07
0.	.24583E+01	0.	0.	0.
0.	0.	0.	.16649E-02	0.
0.	.18608E+03	0.	0.	0.
0.	0.	0.	0.	.49220E-07
-.52412E-11				

FUNCTION 8 RNG802 COEFFICIENTSO

-.13175E+03	0.	.71156E+02	0.	0.
0.	0.	0.	0.	0.
.10851E-01	-.13917E+03	0.	0.	.96406E+02
0.	0.	0.	.10592E+01	0.
.35754E-03	-.30113E+01	0.	.66342E+01	0.
0.	0.	-.75886E-01	0.	.40222E-04
0.	-.20969E+00	0.	0.	0.
0.	0.	0.	-.47654E+03	.21141E+03
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.10775E+05	0.	0.
0.	0.	0.	-.11235E+03	0.
0.	0.	0.	0.	0.
-.27415E-07				

FUNCTION 9 SEG801A COEFFICIENTSO

-.30402E+03	0.	.30404E+03	0.	0.
0.	0.	0.	0.	.22607E+03
.50102E-01	0.	0.	0.	-.12362E+03
0.	0.	0.	0.	0.
-.21689E-02	-.12907E+02	0.	0.	0.
.14765E+03	0.	0.	0.	0.
0.	0.	-.18684E+00	0.	0.
0.	0.	0.	.46489E+03	0.
0.	-.59097E+04	0.	.10186E+03	0.
0.	-.12018E+05	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.46103E-03
-.90512E-07				

FUNCTION 10 SSDALT COEFFICIENTSO

.53888E+05	0.	0.	0.	.68405E+04
0.	0.	0.	0.	0.
0.	0.	0.	0.	.53317E+03
0.	0.	0.	-.15969E+02	0.
0.	-.76329E+01	0.	0.	.19241E+03
0.	0.	0.	0.	0.
0.	-.26277E+01	0.	0.	0.
0.	0.	0.	-.36627E+04	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	.96125E+05	0.	0.
-.53522E-02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.				

FUNCTION 11 108GNR COEFFICIENTSO

.68336E+04	-.13060E+04	.74274E+02	0.	0.
0.	0.	0.	0.	0.
.39581E-01	0.	0.	0.	0.
0.	.12859E+04	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.90342E-04
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	-.13802E+05	0.	0.	0.
0.	0.	0.	0.	0.

0.	0.	0.	0.	0.
0.	0.	0.	0.	.25299E-03
-.10320E-06				

FUNCTION 12 BPR COEFFICIENTSO

.16310E+02	-.75981E+01	.22387E+00	.75830E-02	0.
-.24569E+02	0.	0.	0.	0.
0.	.14488E+01	0.	-.33168E-03	0.
.26391E+01	0.	0.	0.	0.
0.	-.43156E-02	.14677E-04	0.	-.14624E+00
0.	0.	0.	0.	0.
-.11265E-05	0.	-.28184E-02	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.20906E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.				

FUNCTION 13 NMILE(25) COEFFICIENTSO

-.88137E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
.31797E-02	0.	0.	0.	.21031E+02
0.	0.	-.42844E+03	0.	0.
0.	0.	0.	.37160E+01	0.
0.	0.	.21392E-01	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	-.97352E+02	0.
-.24084E+03	0.	0.	0.	0.
0.	0.	-.99924E+03	0.	0.
.78112E-03	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.87014E-08				

FUNCTION 14 NMILE(26) COEFFICIENTSO

-.54576E+02	0.	.13830E+02	0.	0.
0.	0.	0.	0.	0.
.21093E-02	-.27079E+02	0.	0.	.18761E+02
0.	0.	0.	.20591E+00	0.
.69663E-04	-.58531E+00	0.	.12922E+01	0.
0.	0.	-.14748E-01	0.	.78212E-05
0.	-.40816E-01	0.	0.	0.

```
  O.             O.             O.             -.92677E+02    .41153E+02
  O.             O.             O.             O.             O.
  O.             O.             O.             O.             O.
  O.             O.             -.20962E+04    O.             O.
  O.             O.             O.             -.21829E+02    O.
  O.             O.             O.             O.             O.
  -.53303E-08

FUNCTION  15  TSC$$$      COEFFICIENTSO
   .85975E+04    O.             -.11744E+03    O.             -.39981E+03
  O.             O.             O.             O.             O.
   .39037E-01    O.             O.             O.              .77250E+02
  O.             O.             O.             O.             O.
  O.              .40760E+01     .36551E-02    O.             O.
  O.             O.             O.              .27833E+01    -.88833E-04
  O.             O.             O.             O.             O.
  O.             O.             O.             O.             O.
  O.              .22959E+04    O.             O.             O.
  O.              .15959E+04    O.             O.              .12620E+03
  O.             O.             O.             O.             O.
   .27360E-01    O.              .68363E+02    -.77449E+03    -.52523E-01
  O.             -.10203E+01    -.25133E-04    O.              .56445E-03
  -.13727E-07

NEW NUMBERS FOR FUN. BOX 2      1005 LOCATIONS ARE RESERVED FOR   15 FUNCTIONSO
IN   10 VARIABLES,O
EACH WITH    66 COEFFICIENTS AND (IF NEEDED) ONE CONSTRAINT VALUE
OAPEN CHECKOUT ON FGT DATA

THE FOLLOWING FUNCTIONS ARE STORED IN FUNCTION BOX  2
IN THE ORDER INDICATED

RNG801    TODIST    LDGVEL    NPEN      RFLTMDOD  FLTIME    ACLTMDOD  RNG802
SEG801A   SSDALT    108GNR    BPR       NMILE(25) NMILE(26) TSC$$$
   .68336E+04    -.13060E+04     .74274E+02    O.             O.
  O.             O.             O.             O.             O.
   .39581E-01    O.             O.             O.             O.
  O.              .12859E+04    O.             O.             O.
  O.             O.             O.             O.             O.
  O.             O.             O.             O.              .90342E-04
  O.             O.             O.             O.             O.
  O.             O.             O.             O.             O.
  O.             O.             O.             O.             O.
  O.             -.13802E+05    O.             O.             O.
```

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.25299E-03
-.10320E-06	0.	.12393E+05	0.	0.
0.	0.	0.	-.46253E+05	-.51809E+05
.10210E+03	0.	0.	0.	0.
0.	0.	-.10680E+03	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.95026E+04
0.	0.	0.	.94343E+05	.86618E+05
-.12599E+03	0.	0.	.28095E+06	-.18127E+03
0.	0.	.80744E-01	0.	0.
0.	.34860E-04	0.	0.	.91264E+02
0.	0.	0.	0.	0.
0.	-.39641E+03	.44901E+00	0.	-.39057E-04
0.	-.26316E-01	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	.19153E-01	0.	.40087E+00
0.	0.	0.	-.54433E-06	0.
0.	0.	0.	-.12753E-01	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	.13292E+03	0.	0.	0.
0.	0.	0.	.26875E+01	0.
0.	0.	0.	0.	-.78681E-03
0.	0.	0.	-.98085E-06	.11661E-09
0.	-.15373E+02	0.	0.	0.
.11171E+01	.28551E+02	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	.94274E+00	0.	0.
0.	.82379E-07	.81221E-03	0.	-.58592E-02
0.	0.	0.	-.16378E-03	0.
0.	0.	-.14018E-03	0.	0.
0.	0.	0.	0.	0.
0.	-.61653E+00	-.36385E+01	0.	0.
0.	-.22227E+02	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	-.53393E-01	.50425E+00
0.	0.	0.	0.	0.
0.	0.	0.	-.98832E+00	0.

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.13635E-01	0.	0.	0.	.16153E+01
0.	0.	.21690E-01	0.	.26443E-02
0.	0.	0.	-.34824E-01	0.
0.	-.18811E-02	-.78182E-08	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	-.33111E-02	0.	0.	0.
0.	0.	.31054E-01	0.	0.
0.	0.	0.	0.	0.
-.21994E-01	0.	0.	0.	0.
0.	0.	.14657E-06	0.	0.
.41377E+01	0.	0.	.14237E-03	0.
0.	-.71799E+01	0.	.43303E-02	0.
0.	0.	0.	0.	0.
-.45519E-01	.42777E-01	.16900E+00	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.61219E-07	0.	0.	0.	0.
.18726E-06	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.17172E+01	0.	0.
0.	.12135E+02	.34069E+01	-.56511E-02	0.
0.	0.	-.67496E-02	0.	0.
0.	0.	0.	0.	0.
0.	0.	.97923E+00	0.	0.
0.	0.	0.	0.	-.29431E+02
0.	0.	.17779E-05	0.	0.
0.	0.	-.76190E-01	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	-.64346E-08	0.	0.	0.
0.	0.	0.	0.	0.
-.82308E-01	0.	0.	0.	0.
0.	.59013E-07	0.	.24[illegible]83E+01	0.
0.	0.	0.	0.	0.
.16649E-02	0.	0.	.18608E+03	0.
0.	0.	0.	0.	0.
0.	.49220E-07	-.52412E-11	0.	-.13175E+03
0.	.71156E+02	0.	0.	0.
0.	0.	0.	0.	.10851E-01
-.13917E+03	0.	0.	.95406E+02	0.
0.	0.	.10592E+01	0.	.35754E-03

-.30113E+01	0.	.66342E+01	0.	0.
0.	-.75896E-01	0.	.40222E-04	0.
-.20969E+00	0.	0.	0.	0.
0.	0.	-.47654E+03	.21141E+03	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	-.10775E+05	0.	0.	0.
0.	0.	-.11235E+03	0.	0.
0.	0.	0.	0.	-.27415E-07
0.	-.30402E+03	0.	.30404E+03	0.
0.	0.	0.	0.	0.
.22607E+03	.50102E-01	0.	0.	0.
-.12362E+03	0.	0.	0.	0.
0.	-.21689E-02	-.12907E+02	0.	0.
0.	.14765E+03	0.	0.	0.
0.	0.	0.	-.18684E+00	0.
0.	0.	0.	0.	.46489E+03
0.	0.	-.59097E+04	0.	.10186E+03
0.	0.	-.12018E+05	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.46103E-03	-.90512E-07	0.	.53888E+05	0.
0.	0.	.68405E+04	0.	0.
0.	0.	0.	0.	0.
0.	0.	.53317E+03	0.	0.
0.	-.15969E+02	0.	0.	-.76329E+01
0.	0.	.19241E+03	0.	0.
0.	0.	0.	0.	-.26277E+01
0.	0.	0.	0.	0.
0.	-.36627E+04	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.96125E+05	0.	0.	-.53522E-02	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.68336E+04	-.13060E+04	.74274E+02	0.	0.
0.	0.	0.	0.	0.
.39581E-01	0.	0.	0.	0.
0.	.12859E+04	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.90342E-04
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

0.	0.	0.	0.	0.
0.	-.13802E+05	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.25299E-03
-.10320E-06	0.	.16310E+02	-.75981E+01	.22387E+00
.75830E-02	0.	-.24569E+02	0.	0.
0.	0.	0.	.14488E+01	0.
-.33168E-03	0.	.26391E+01	0.	0.
0.	0.	0.	-.43156E-02	.14677E-04
0.	-.14624E+00	0.	0.	0.
0.	0.	-.11265E-05	0.	-.28184E-02
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	.20906E+02	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.88137E+02
0.	0.	0.	0.	0.
0.	0.	0.	0.	.31797E-02
0.	0.	0.	.21031E+02	0.
0.	-.42844E+03	0.	0.	0.
0.	0.	.37160E+01	0.	0.
0.	.21392E-01	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	-.97352E+02	0.	-.24084E+03
0.	0.	0.	0.	0.
0.	-.99924E+03	0.	0.	.78112E-03
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.87014E-08
0.	-.54576E+02	0.	.13830E+02	0.
0.	0.	0.	0.	0.
0.	.21093E-02	-.27079E+02	0.	0.
.18761E+02	0.	0.	0.	.20591E+00
0.	.69663E-04	-.58531E+00	0.	.12922E+01
0.	0.	0.	-.14748E-01	0.
.78212E-05	0.	-.40816E-01	0.	0.
0.	0.	0.	0.	-.92677E+02
.41153E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	-.20962E+04	0.
0.	0.	0.	0.	-.21829E+02

0.	0.	0.	0.	0.
0.	-.53303E-08	0.	.85975E+04	0.
-.11744E+03	0.	-.39981E+03	0.	0.
0.	0.	0.	.39037E-01	0.
0.	0.	.77250E+02	0.	0.
0.	0.	0.	0.	.40760E+01
.36551E-02	0.	0.	0.	0.
0.	.27833E+01	-.88833E-04	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	.22959E+04
0.	0.	0.	0.	.15959E+04
0.	0.	.12620E+03	0.	0.
0.	0.	0.	.27360E-01	0.
.68363E+02	-.77449E+03	-.52523E-01	0.	-.10203E+01
-.25133E-04	0.	.56445E-03	-.13727E-07	0.

INSTRUCTION TO OAPEN --- SET CODING

THE CODING TRANSFORMATIONS AS PAIRS A,B ARE AS FOLLOWS
THE USAGE IS V(CODED) = (V(UNCODED) - A)/B

.20000E+01	.20000E+01	.10000E+02	.20000E+02	.24000E+04
.80000E+03	-.10000E+01	.20000E+01	.10000E+01	.15000E+00
.35000E+00	.20000E+00	.80000E-01	.40000E-01	.14000E+03
.80000E+02	.60000E+01	.40000E+01	.20000E+06	.30000E+06
.56370E+04	.51030E+04	.38270E+04	.68830E+04	.10900E+03
.39000E+02	.17500E+01	.23300E+01	.13600E+00	.22360E+01
.23000E+01	.61000E+00	.32000E-02	.11340E+01	.14540E+04
.14690E+04	.56370E+04	.23080E+04	.42520E+05	.14610E+05
.56370E+04	.51030E+04	.20000E+00	.28000E+01	.24500E+03
.52100E+03	.25350E+03	.28570E+03	.16620E+05	.14127E+05

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INSTRUCTION TO OAPEN ---      SET        CONSTRAINT

THE FOLLOWING FUNCTIONS ARE STORED IN FUNCTION BOX  2
IN THE ORDER INDICATED

RNG801     TODIST     LDGVEL     NPEN       RFLTMDOD  FLTIME     ACLTMDOD  RNG802
SEG801A    SSDALT     108GNR     BPR        NMILE(25) NMILE(26) TSC$$$
RNG802     MAX

TODIST     LE              .60000E+04

TSC$$$     GE              .10000E+01

BPR        LE              .30000E+01

LDGVEL     LE              .12500E+03

NPEN       GE              .29300E+01

FLTIME     LE              .26000E+01

RNG801     LE              .10000E+07

RFLTMDOD   GE              .18000E+00

ACLTMDOD   GE              .50000E-01

SSDALT     GE              .50000E+05

NEW NUMBERS FOR FUN. BOX 2       1005 LOCATIONS ARE RESERVED FOR    15 FUNCTIONSO
IN   10 VARIABLES,0
EACH WITH     66 COEFFICIENTS AND (IF NEEDED) ONE CONSTRAINT VALUE
OAPEN CHECKOUT ON FGT DATA

THE FOLLOWING FUNCTIONS ARE STORED IN FUNCTION BOX  2
IN THE ORDER INDICATED

RNG802     SSDALT     ACLTMDOD   RFLTMDOD   RNG801     FLTIME     NPEN       LDGVEL
BPR        TSC$$$     TODIST     SEG801A    NMILE(25) NMILE(26) 108GNR
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INSTRUCTION TO OAPEN ---     CALL      FR

UNCODED X VECTOR
FPR         .20000E+01  OPR          .30000E+02  T4          .29000E+04
A8          .12000E+00  THTR         .11500E+01  T/W         .40000E+00
T/C         .80000E-01  W/S          .14000E+03  AR          .10000E+02
TOGW        .27500E+06
FIND FGT INITIAL OPTIMUM

LOWER AND UPPER BOUNDS ON X
    .20000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE      .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)      .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS           1 FUNCTION EVALUATIONS      F =     -.6359832602628E+00      AT X =
   .1000000000317E-04     .9999900000000E+00     .6250000000000E+00     .5600000000000E+00     .9999900000000E+00

   .2500000000000E+00     .9999999994736E-05     .9999999997490E-05     .9999900000000E+00     .2500000000000E+00

   64 ITERATIONS         135 FUNCTION EVALUATIONS      F =     -.1043000335083E+01      AT X =
   .2771260211439E+00     .8565868329116E+00   0.                       .6742929436477E+00     .9999900000000E+00

   .1210414937184E+00     .9999999994736E-05     .9999999997490E-05   0.                       .8960621594411E+00


PENALTY FUNCTION ITERATION      1      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      1.5590 SECONDS
PENALTY COEFFICIENT        .10000E+01     PENALTY VALUE      .49586E-02     CONSTRAINT VECTOR (CODED)
  0.           0.          0.           0.           .80647E-01
  0.           0.          0.           0.           .58423E-01
---------- PENALTY FUNCTION HAS NOT CONVERGED --- MULTIPLY COEFFICIENT BY      .10000E+03 ----------

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS           1 FUNCTION EVALUATIONS      F =     -.5521003386478E+00      AT X =
   .2771260211439E+00     .8565868329116E+00   0.                       .6742929436477E+00     .9999900000000E+00

   .1210414937184E+00     .9999999994736E-05     .9999999997490E-05   0.                       .8960621594411E+00
```

```
30 ITERATIONS        74 FUNCTION EVALUATIONS     F =     -.1036793082406E+01     AT X =
 .2741265076482E+00    .8562207599282E+00    0.                          .6736438312365E+00     .9999900000000E+00

 .2146253464347E+00    0.                    .9999999997490E-05    0.                           .8949548213060E+00

PENALTY FUNCTION ITERATION      2     MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      2.4230 SECONDS
PENALTY COEFFICIENT      .10000E+03     PENALTY VALUE      .20583E-03    CONSTRAINT VECTOR (CODED)
   0.           0.            0.            0.            0.
   0.           0.            0.            0.             .20289E-02
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
  0 ITERATIONS        1 FUNCTION EVALUATIONS     F =     -.1036793082406E+01     AT X =
 .2741265076482E+00    .8562207599282E+00    0.                          .6736438312365E+00     .9999900000000E+00

 .2146253464347E+00    0.                    .9999999997490E-05    0.                           .8949548213060E+00

  1 ITERATIONS        4 FUNCTION EVALUATIONS     F =     -.1036793082617E+01     AT X =
 .2741253140043E+00    .8562207880622E+00    0.                          .6736436645241E+00     .99999000000[illegible]E+00

 .2146238653743E+00    0.                    .9999999997490E-05    0.                           .8949556145219E+00

PENALTY FUNCTION ITERATION      2     MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      2.4790 SECONDS
PENALTY COEFFICIENT      .10000E+03     PENALTY VALUE      .20601E-03    CONSTRAINT VECTOR (CODED)
   0.           0.            0.            0.            0.
   0.           0.            0.            0.             .20298E-02
---------- PENALTY FUNCTION CONVERGED ----------0
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------------OPTIMUM   1 (UNCODED)      77/04/06.-----------

OAPEN CHECKOUT ON FGT DATA
FIND FGT INITIAL OPTIMUM
FPR        .25483E+01  OPR        .27124E+02  T4         .24000E+04
A8         .34729E+00  THTR       .11500E+01  T/W        .39292E+00
T/C        .80000E-01  W/S        .14000E+03  AR         .60000E+01
TOGW       .46849E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802     ) VALUE      .29774E+04

CONSTRAINT VECTOR
   0.            0.            0.            0.            0.
   0.            0.            0.            0.            .13971E+02

OBJECTIVE FUNCTION GRADIENT
RNG802
   -.53698E+01   .12812E-03   -.72822E-01   -.73240E-02
    .73421E+02  -.86202E+03   -.49079E+04    .64078E+00
   -.89879E+01   .92799E-05

FINITE DIFFERENCE CHECK
   -.53698E+01   .12812E-03   -.72822E-01   -.73240E-02    .73421E+02
   -.86202E+03  -.49079E+04    .64078E+00   -.89879E+01    .92799E-05

CONSTRAINED FUNCTION VALUES O
SSDALT     .53858E+05  ACLTMDOD   .51830E+00  RFLTMDOD   .58733E+00
RNG801     .96479E+04  FLTIME     .25944E+01  NPEN       .31569E+01
LDGVEL     .11828E+03  BPR        .98073E+00  TSC$$$     .27384E+05
TODIST     .60140E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.20504E+04   .14233E+02   -.91256E+00    .62069E+03
    .52190E+04   .51826E+04    .37770E+05   -.40692E+02
   0.           -.21030E-02

FINITE DIFFERENCE CHECK
   -.20504E+04   .14233E+02   -.91256E+00    .62069E+03    .52190E+04
    .51826E+04   .37770E+05   -.40692E+02   0.            -.21030E-02
ACLTMDOD
```

```
  -.87619E-01   -.30145E-02   0.             -.33758E-03
   .77178E+00    .30601E+01   -.14545E+02     .65418E-03
   .23059E-01   -.53626E-06

FINITE DIFFERENCE CHECK
  -.87619E-01   -.30145E-02   0.             -.93758E-03    .77178E+00
   .30601E+01   -.14545E+02    .65418E-03     .23059E-01   -.53626E-06
RFLTMDOD
   .39498E+00    .83473E-02   0.             -.19867E-01
   .18632E+00    .31715E+01   -.30791E+01    -.17595E-02
   .10747E+00    .66734E-06

FINITE DIFFERENCE CHECK
   .39498E+00    .83473E-02   0.             -.19867E-01    .18632E+00
   .31715E+01   -.30791E+01   -.17595E-02     .10747E+00    .66734E-06
RNG801
  -.80079E+03    .11660E+03   0.             0.
  -.54231E+04   -.12596E+05   0.             0.
   .11852E+03   -.47998E-02

FINITE DIFFERENCE CHECK
  -.80079E+03    .11660E+03   0.             0.            -.54231E+04
  -.12596E+05   0.            0.              .11852E+03   -.47998E-02
FLTIME
  -.22018E-01   0.             .21656E-04    0.
  -.25337E+00   -.28211E+01   -.11505E+01     .20193E-02
  0.            0.

FINITE DIFFERENCE CHECK
  -.22018E-01   0.             .21656E-04    0.            -.25337E+00
  -.28211E+01   -.11505E+01    .20193E-02    0.            0.
NPEN
   .40902E+00   -.29336E-02   -.48683E-04     .88447E-01
   .29895E+01    .21882E+01   -.57131E+01    -.87139E-02
   .40340E-01    .20992E-06

FINITE DIFFERENCE CHECK
   .40902E+00   -.29336E-02   -.48683E-04     .88447E-01    .29895E+01
   .21882E+01   -.57131E+01   -.87139E-02     .40340E-01    .20992E-06
LDGVEL
  -.71380E+00   -.15791E+00   -.10202E-02     .51951E+00
   .10634E+02    .26998E+02   -.27415E+03     .33886E+00
   .59648E+00   -.50768E-05
```

```
FINITE DIFFERENCE CHECK
   -.71380E+00   -.15791E+00   -.10202E-02    .51951E+00    .10634E+02
    .26998E+02   -.27415E+03    .33886E+00    .59648E+00   -.50768E-05
BPR
   -.16673E+01   -.26147E-01    .11912E-02   0.
   -.45335E+01   0.            0.            0.
   0.            0.

FINITE DIFFERENCE CHECK
   -.16673E+01   -.26147E-01    .11912E-02   0.           -.45335E+01
   0.            0.            0.            0.            0.
TSC$$$
    .26828E+02   -.23027E+02    .99141E-01   -.19287E+02
    .13843E+04    .14653E+05   -.18885E+05   -.12427E+02
    .28027E+03    .36614E-01

FINITE DIFFERENCE CHECK
    .26828E+02   -.23027E+02    .99141E-01   -.19287E+02    .13843E+04
    .14653E+05   -.18885E+05   -.12427E+02    .28027E+03    .36614E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.10324E+04   -.19892E+05   -.31604E+05    .49400E+02
    .16332E+02    .20916E-03

FINITE DIFFERENCE CHECK
   -.12282E+03   0.            0.            0.           -.10324E+04
   -.19892E+05   -.31604E+05    .49400E+02    .16332E+02    .20916E-03
---------------------------------------------------------------------


INSTRUCTION TO OAPEN  ---     SET       XSAVE
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INSTRUCTION TO OAPEN  ---     CALL      FR

SET X TO XSAVE =
FPR          .25483E+01  OPR          .27124E+02  T4           .24000E+04
A8           .34729E+00  THTR         .11500E+01  T/W          .39292E+00
T/C          .80000E-01  W/S          .14000E+03  AR           .60000E+01
TOGW         .46849E+06
FIND OPTIMUM FOR FPR(L.B.)=3.0 X=XSAVE

LOWER AND UPPER BOUNDS ON X
    .30000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE       .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)      .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS    500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS           1 FUNCTION EVALUATIONS     F =      -.1025677786046E+01      AT X =
    .5000100000000E+00    .8562207880622E+00    .1000000000204E-04    .6736436645241E+00    .9999900000000E+00

    .2146238653743E+00    .9999999994736E-05    .9999999997490E-05    .1000000000317E-04    .8949556145219E+00

    62 ITERATIONS        134 FUNCTION EVALUATIONS     F =      -.1035305721460E+01      AT X =
    .5000000000000E+00    .8700200885471E+00    .5731633300456E-05    .7212511266091E+00    .9999900000000E+00

    .1111014568591E+00    .9999999994736E-05    .1046685767971E-01    .7365910178692E-05    .9167294357086E+00


PENALTY FUNCTION ITERATION      1      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      1.5510 SECONDS
PENALTY COEFFICIENT        .10000E+01      PENALTY VALUE       .49514E-02      CONSTRAINT VECTOR (CODED)
   0.             0.             0.             0.             .76813E-01
   0.             0.             0.             0.             .63266E-01
---------- PENALTY FUNCTION HAS NOT CONVERGED --- MULTIPLY COEFFICIENT BY       .10000E+03 ----------

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS           1 FUNCTION EVALUATIONS     F =      -.5451184567681E+00      AT X =
    .5000000000000E+00    .8700200885471E+00    .5731633300456E-05    .7212511266091E+00    .9999900000000E+00

    .1111014568591E+00    .9999999994736E-05    .1046685767971E-01    .7365910178692E-05    .9167294357086E+00
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```
   19 ITERATIONS        47 FUNCTION EVALUATIONS     F =     -.1028865034510E+01     AT X =
  .5000000000000E+00     .8709591228912E+00     .5731633300456E-05     .7213812773137E+00     .9999900000000E+00

  .2011317172262E+00    0.                     0.                                     .7365910178692E-05     .9160802478443E+00


PENALTY FUNCTION ITERATION      2      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME       2.1010 SECONDS
PENALTY COEFFICIENT        .10000E+03     PENALTY VALUE       .20088E-03     CONSTRAINT VECTOR (CODED)
   0.           0.           0.           0.           0.
   0.           0.           0.           0.            .20044E-02
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS         1 FUNCTION EVALUATIONS     F =     -.1028865034510E+01     AT X =
  .5000000000000E+00     .8709591228912E+00     .5731633300456E-05     .7213812773137E+00     .9999900000000E+00

  .2011317172262E+00    0.                     0.                                     .7365910178692E-05     .9160802478443E+00

    1 ITERATIONS         4 FUNCTION EVALUATIONS     F =     -.1028865034517E+01     AT X =
  .5000000000000E+00     .8709592916823E+00     .5731633300456E-05     .7213812918742E+00     .9999900000000E+00

  .2011314087327E+00    0.                     0.                                     .7365910178692E-05     .9160801622576E+00


PENALTY FUNCTION ITERATION      2      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME       2.1560 SECONDS
PENALTY COEFFICIENT        .10000E+03     PENALTY VALUE       .20092E-03     CONSTRAINT VECTOR (CODED)
   0.           0.           0.           0.           0.
   0.           0.           0.           0.            .20046E-02
---------- PENALTY FUNCTION CONVERGED ----------0
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-------------OPTIMUM   2 (UNCODED)        77/04/06.------------

OAPEN CHECKOUT ON FGT DATA
FIND OPTIMUM FOR FPR(L.B.)=3.0 X=XSAVE
FPR           .30000E+01  OPR         .27419E+02  T4          .24000E+04
A8            .44276E+00  THTR        .11500E+01  T/W         .39023E+00
T/C           .80000E-01  W/S         .14000E+03  AR          .60000E+01
TOGW          .47482E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802     ) VALUE      .29657E+04

CONSTRAINT VECTOR
   O.           O.           O.           O.           O.
   O.           O.           O.           O.            .13798E+02

OBJECTIVE FUNCTION GRADIENT
RNG802
   -.56771E+02   .85320E-03  -.92842E-01   .75401E-03
    .93606E+02  -.86202E+03  -.48789E+04   .10969E+01
   -.89879E+01   .89194E-05

CONSTRAINED FUNCTION VALUES 0
SSDALT        .52974E+05  ACLTMDOD    .46562E+00  RFLTMDOD    .75835E+00
RNG801        .93206E+04  FLTIME      .25921E+01  NPEN        .33438E+01
LDGVEL        .11785E+03  BPR         .36749E+00  TSC$$$      .27582E+05
TODIST        .60138E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.19995E+04   .11983E+02  -.11634E+01   .51183E+03
    .52758E+04   .51487E+04   .37511E+05  -.47906E+02
   O.           -.20886E-02
ACLTMDOD
   -.87619E-01  -.30553E-02  O.           -.84219E-02
    .73073E+00   .30601E+01  -.14545E+02   .64969E-03
    .23371E-01  -.56574E-06
RFLTMDOD
    .38661E+00   .30117E-02  O.           -.19867E-01
    .18632E+00   .38909E+01  -.30791E+01  -.17595E-02
    .11733E+00   .66504E-06
RNG801
```

```
   -.80426E+03    .11717E+03   0.           0.
   -.53859E+04   -.12015E+05   0.           0.
    .12013E+03   -.54272E-02
FLTIME
   -.22134E-01   0.            .21656E-04  0.
   -.27393E+00   -.28346E+01  -.10833E+01   .20346E-02
   0.            0.
NPEN
    .40700E+00   -.32535E-02  -.62067E-04   .88383E-01
    .29895E+01    .25552E+01  -.60604E+01  -.87621E-02
    .40340E-01    .24714E-06
LDGVEL
   -.72155E+00   -.17250E+00  -.10202E-02   .52515E+00
    .10634E+02    .27117E+02  -.27415E+03   .33886E+00
    .58301E+00   -.44983E-05
BPR
   -.10128E+01   -.27419E-01   .10457E-02  0.
   -.33844E+01   0.           0.           0.
   0.            0.
TSC$$$
    .34203E+02   -.22389E+02   .10022E+00   .15610E+02
    .13800E+04    .14826E+05  -.18999E+05  -.12587E+02
    .28467E+03    .36427E-01
TODIST
   -.12282E+03   0.           0.           0.
   -.10806E+04   -.20147E+05  -.31838E+05   .49740E+02
    .16552E+02    .20916E-03
------------------------------------------------------------------

INSTRUCTION TO OAPEN  ---    SET      XSAVE
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INSTRUCTION TO OAPEN  ---     CALL      FR

UNCODED X VECTOR
FPR          .20000E+01  OPR          .30000E+02  T4           .29000E+04
A8           .12000E+00  THTR         .11500E+01  T/W          .40000E+00
T/C          .80000E-01  W/S          .14000E+03  AR           .10000E+02
TOGW         .27500E+06
RELOCATE OPTIMUM 1

LOWER AND UPPER BOUNDS ON X
    .20000E+01    .40000E+01    .10000E+02    .30000E+02    .24000E+04
    .32000E+04   -.10000E+01    .10000E+01    .10000E+01    .11500E+01
    .35000E+00    .55000E+00    .80000E-01    .12000E+00    .14000E+03
    .22000E+03    .60000E+01    .10000E+02    .20000E+06    .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE      .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)     .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS          1 FUNCTION EVALUATIONS      F =      -.6359832602628E+00      AT X =
    .1000000000317E-04     .9999900000000E+00     .6250000000000E+00     .5600000000000E+00     .9999900000000E+00

    .2500000000000E+00     .9999999999473bE-05    .9999999997490E-05     .9999900000000E+00     .2500000000000E+00

    64 ITERATIONS        135 FUNCTION EVALUATIONS      F =      -.1043000335083E+01      AT X =
    .2771260211439E+00     .8565868329116E+00    0.                      .6742929436477E+00     .9999900000000E+00

    .1210414937184E+00     .9999999994736E-05     .9999999997490E-05    0.                      .8960621594411E+00


PENALTY FUNCTION ITERATION      1      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      1.5820 SECONDS
PENALTY COEFFICIENT       .10000E+01      PENALTY VALUE       .49586E-02      CONSTRAINT VECTOR (CODED)
   0.            0.            0.            0.            .80647E-01
   0.            0.            0.            0.            .58423E-01
---------- PENALTY FUNCTION HAS NOT CONVERGED --- MULTIPLY COEFFICIENT BY       .10000E+03 ----------

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS          1 FUNCTION EVALUATIONS      F =      -.5521003386478E+00      AT X =
    .2771260211439E+00     .8565868329116E+00    0.                      .6742929436477E+00     .9999900000000E+00

    .1210414937184E+00     .9999999994736E-05     .9999999997490E-05    0.                      .8960621594411E+00
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```
   30 ITERATIONS        74 FUNCTION EVALUATIONS     F =    -.1036793082406E+01     AT X =
  .2741265076482E+00    .8562207599282E+00    0.                     .6736438312365E+00    .9999900000000E+00

  .2146253464347E+00    0.                        .9999999997490E-05    0.                    .8949548213060E+00

PENALTY FUNCTION ITERATION      2     MAXIMUM ALLOWED     50
ACCUMULATED CP MINIMIZATION TIME      2.4370 SECONDS
PENALTY COEFFICIENT      .10000E+03     PENALTY VALUE      .20583E-03     CONSTRAINT VECTOR (CODED)
   0.             0.             0.             0.             0.
   0.             0.             0.             0.              .20289E-02
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS         1 FUNCTION EVALUATIONS     F =    -.1036793082406E+01     AT X =
  .2741265076482E+00    .8562207599282E+00    0.                     .6736438312365E+00    .9999900000000E+00

  .2146253464347E+00    0.                        .9999999997490E-05    0.                    .8949548213060E+00

    1 ITERATIONS         4 FUNCTION EVALUATIONS     F =    -.1036793082617E+01     AT X =
  .2741253140043E+00    .8562207880622E+00    0.                     .6736436645241E+00    .9999900000000E+00

  .2146238653743E+00    0.                        .9999999997490E-05    0.                    .8949556145219E+00

PENALTY FUNCTION ITERATION      2     MAXIMUM ALLOWED     50
ACCUMULATED CP MINIMIZATION TIME      2.4910 SECONDS
PENALTY COEFFICIENT      .10000E+03     PENALTY VALUE      .20601E-03     CONSTRAINT VECTOR (CODED)
   0.             0.             0.             0.             0.
   0.             0.             0.             0.              .20298E-02
---------- PENALTY FUNCTION CONVERGED ----------0
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------------OPTIMUM   3 (UNCODED)      77/04/06.------------

OAPEN CHECKOUT ON FGT DATA
RELOCATE OPTIMUM 1
FPR           .25483E+01  OPR         .27124E+02  T4          .24000E+04
A8            .34729E+00  THTR        .11500E+01  T/W         .39292E+00
T/C           .80000E-01  W/S         .14000E+03  AR          .60000E+01
TOGW          .46849E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802    ) VALUE      .29774E+04

CONSTRAINT VECTOR
   0.           0.           0.           0.           0.
   0.           0.           0.           0.            .13971E+02

OBJECTIVE FUNCTION GRADIENT
RNG802
   -.53698E+01    .12812E-03   -.72822E-01   -.73240E-02
    .73421E+02   -.86202E+03   -.49079E+04    .64078E+00
   -.89879E+01    .92799E-05

CONSTRAINED FUNCTION VALUES 0
SSDALT        .53858E+05  ACLTMDOD    .51830E+00  RFLTMDOD    .58733E+00
RNG801        .96479E+04  FLTIME      .25944E+01  NPEN        .31569E+01
LDGVEL        .11828E+03  BPR         .98073E+00  TSC$$$      .27384E+05
TODIST        .60140E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.20504E+04    .14233E+02   -.91256E+00    .62069E+03
    .52190E+04    .51826E+04    .37770E+05   -.40692E+02
   0.            -.21030E-02
ACLTMDOD
   -.87619E-01   -.30145E-02   0.            -.93758E-03
    .77178E+00    .30601E+01   -.14545E+02    .65418E-03
    .23059E-01   -.53626E-06
RFLTMDOD
    .39498E+00    .83473E-02   0.            -.19867E-01
    .18632E+00    .31715E+01   -.30791E+01   -.17595E-02
    .10747E+00    .66734E-06
RNG801
```

```
    -.80079E+03    .11660E+03   0.             0.
    -.54231E+04   -.12596E+05   0.             0.
     .11852E+03   -.47998E-02
FLTIME
    -.22018E-01   0.             .21656E-04   0.
    -.25337E+00   -.28211E+01   -.11505E+01    .20193E-02
    0.            0.
NPEN
     .40902E+00   -.29336E-02   -.48683E-04    .88447E-01
     .29895E+01    .21882E+01   -.57131E+01   -.87139E-02
     .40340E-01    .20992E-06
LDGVEL
    -.71380E+00   -.15791E+00   -.10202E-02    .51951E+00
     .10634E+02    .26998E+02   -.27415E+03    .33886E+00
     .59648E+00   -.50768E-05
BPR
    -.16673E+01   -.26147E-01    .11912E-02   0.
    -.45335E+01   0.            0.            0.
    0.            0.
TSC$$$
     .26828E+02   -.23027E+02    .99141E-01   -.19287E+02
     .13843E+04    .14653E+05   -.18885E+05   -.12427E+02
     .28027E+03    .36614E-01
TODIST
    -.12282E+03   0.            0.            0.
    -.10324E+04   -.19892E+05   -.31604E+05    .49400E+02
     .16332E+02    .20916E-03
------------------------------------------------------------------------

INSTRUCTION TO OAPEN  ---     SET       XSAVE
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INSTRUCTION TO OAPEN  ---      CALL      FR

SET X TO XSAVE =
FPR         .25483E+01  OPR         .27124E+02  T4          .24000E+04
A8          .34729E+00  THTR        .11500E+01  T/W         .39292E+00
T/C         .80000E-01  W/S         .14000E+03  AR          .60000E+01
TOGW        .46849E+06

RESET FPR        TO        .30000E+01

   1 INDEPENDENT VARIABLES ARE FIXED AS FOLLOWS
FPR         .30000E+01
FIND FPR=3.0(FIXED) OPTIMUM

LOWER AND UPPER BOUNDS ON X
    .20000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE       .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)      .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS          1 FUNCTION EVALUATIONS     F =     -.1025678715141E+01     AT X =
    .5000000000000E+00    .8562207680622E+00    .1000000000204E-04    .6736436645241E+00    .9999900000000E+00

    .2146238653743E+00    .9999999994736E-05    .9999999997490E-05    .1000000000317E-04    .8949556145219E+00

    40 ITERATIONS         85 FUNCTION EVALUATIONS     F =     -.1035306112400E+01     AT X =
    .5000000000000E+00    .8700208079592E+00   0.                     .7212523811659E+00    .9999900000000E+00

    .1111014007369E+00    .9999999994736E-05    .1046615519368E-01    .3828810847040E-05    .9167292355962E+00


PENALTY FUNCTION ITERATION      1     MAXIMUM ALLOWED       50
ACCUMULATED CP MINIMIZATION TIME       .9920 SECONDS
PENALTY COEFFICIENT        .10000E+01    PENALTY VALUE      .49513E-02     CONSTRAINT VECTOR (CODED)
   0.            0.            0.            0.            .76813E-01
   0.            0.            0.            0.            .63265E-01
---------- PENALTY FUNCTION HAS NOT CONVERGED --- MULTIPLY COEFFICIENT BY       .10000E+03 ----------

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
```

```
   0 ITERATIONS          1 FUNCTION EVALUATIONS     F =    -.5451238269486E+00     AT X =
  .5000000000000E+00    .8700208079592E+00    0.                        .7212523811659E+00    .9999900000000E+00

  .1111014007369E+00    .9999999994736E-05    .1046615519368E-01    .3828810847040E-05    .9167292355962E+00

  18 ITERATIONS         46 FUNCTION EVALUATIONS     F =    -.1028865416864E+01     AT X =
  .5000000000000E+00    .8709295587266E+00    0.                        .7213735059443E+00    .9999900000000E+00

  .2011322427150E+00    0.                    0.                        .3828810847040E-05    .9160864682269E+00

PENALTY FUNCTION ITERATION      2      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      1.5300 SECONDS
PENALTY COEFFICIENT     .10000E+03     PENALTY VALUE     .20083E-03     CONSTRAINT VECTOR (CODED)
  0.          0.          0.          0.          0.
  0.          0.          0.          0.           .20041E-02
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
   0 ITERATIONS          1 FUNCTION EVALUATIONS     F =    -.1028865[illegible]6864E+01     AT X =
  .5000000000000E+00    .8709295587266E+00    0.                        .7213735059443E+00    .9999900000000E+00

  .2011322427150E+00    0.                    0.                        .3828810847040E-05    .9160864682269E+00

   1 ITERATIONS          4 FUNCTION EVALUATIONS     F =    -.1028865416928E+01     AT X =
  .5000000000000E+00    .8709307398817E+00    0.                        .7213736833158E+00    .9999900000000E+00

  .2011312902511E+00    0.                    0.                        .3828810847040E-05    .9160859462665E+00

PENALTY FUNCTION ITERATION      2      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME      1.5870 SECONDS
PENALTY COEFFICIENT     .10000E+03     PENALTY VALUE     .20094E-03     CONSTRAINT VECTOR (CODED)
  0.          0.          0.          0.          0.
  0.          0.          0.          0.           .20047E-02
---------- PENALTY FUNCTION CONVERGED ----------0
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-----------OPTIMUM   4 (UNCODED)      77/04/06.------------

OAPEN CHECKOUT ON FGT DATA
FIND FPR=3.0(FIXED) OPTIMUM
FPR          .30000E+01  OPR          .27419E+02  T4           .24000E+04
A8           .44275E+00  THTR         .11500E+01  T/W          .39023E+00
T/C          .80000E-01  W/S          .14000E+03  AR           .60000E+01
TOGW         .47483E+06

THE FOLLOWING INDEPENDENT VARIABLES WERE HELD FIXED DURING THIS OPTIMIZATION
FPR

OPTIMAL OBJECTIVE FUNCTION (RNG802    ) VALUE      .29657E+04

CONSTRAINT VECTOR
   0.            0.            0.            0.            0.
   0.            0.            0.            0.             .13798E+02

OBJECTIVE FUNCTION GRADIENT
RNG802
  -.56772E+02    .25416E-02   -.92839E-01    .51787E-02
   .93603E+02   -.86202E+03   -.48789E+04    .10969E+01
  -.89879E+01    .88489E-05

CONSTRAINED FUNCTION VALUES 0
SSDALT       .52974E+05  ACLTMDOD     .46562E+00  RFLTMDOD     .75835E+00
RNG801       .93205E+04  FLTIME       .25921E+01  NPEN         .33438E+01
LDGVEL       .11785E+03  BPR          .36750E+00  TSC$$$       .27582E+05
TODIST       .60138E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.19995E+04    .11988E+02   -.11634E+01    .51190E+03
   .52756E+04    .51487E+04    .37511E+05   -.47906E+02
   0.           -.20886E-02
ACLTMDOD
  -.87619E-01   -.30553E-02    0.           -.84206E-02
   .73073E+00    .30601E+01   -.14545E+02    .64969E-03
   .23371E-01   -.56575E-06
RFLTMDOD
   .38661E+00    .30102E-02    0.           -.19867E-01
```

```
   .18632E+00    .38910E+01   -.30791E+01   -.17595E-02
   .11733E+00    .66505E-06
RNG801
  -.80426E+03    .11717E+03   0.            0.
  -.53859E+04   -.12015E+05   0.            0.
   .12013E+03   -.54274E-02
FLTIME
  -.22134E-01   0.             .21656E-04   0.
  -.27393E+00   -.28346E+01   -.10833E+01    .20346E-02
  0.            0.
NPEN
   .40700E+00   -.32538E-02   -.62065E-04    .88387E-01
   .29895E+01    .25553E+01   -.60604E+01   -.87621E-02
   .40340E-01    .24714E-06
LDGVEL
  -.72154E+00   -.17250E+00   -.10202E-02    .52514E+00
   .10634E+02    .27116E+02   -.27415E+03    .33886E+00
   .58301E+00   -.44977E-05
BPR
  -.10128E+01   -.27417E-01    .10457E-02   0.
  -.33843E+01   0.            0.            0.
  0.            0.
TSC$$$
   .34202E+02   -.22391E+02    .10022E+00    .15610E+02
   .13800E+04    .14826E+05   -.18999E+05   -.12587E+02
   .28467E+03    .36427E-01
TODIST
  -.12282E+03   0.            0.            0.
  -.10806E+04   -.20147E+05   -.31838E+05    .49740E+02
   .16553E+02    .20916E-03
------------------------------------------------------------


INSTRUCTION TO OAPEN  ---     SET       XSAVE
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INSTRUCTION TO OAPEN  ---     CALL      FR

UNCODED X VECTOR
FPR          .20000E+01  OPR          .26000E+02  T4           .24000E+04
A8           .20000E+00  THTR         .11500E+01  T/W          .39000E+00
T/C          .80000E-01  W/S          .14000E+03  AR           .60000E+01
TOGW         .27500E+06
AFAPL CONVERSION OPTIMUM (FEB. 1976)

LOWER AND UPPER BOUNDS ON X
    .20000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .27500E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE       .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)     .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS          1 FUNCTION EVALUATIONS     F =     -.7083436330246E+00     AT X =
    .1000000000317E-04     .8000000000000E+00     .1000000000204E-04     .6000000000000E+00     .9999900000000E+00

    .2000000000000E+00     .9999999994736E-05     .9999999997490E-05     .1000000000317E-04     .2499900000000E+00

    37 ITERATIONS         77 FUNCTION EVALUATIONS     F =     -.7142246268500E+00     AT X =
    .1433486808764E-02     .7100607549371E+00    0.                      .5999554422792E+00     .9999900000000E+00

    .1401571212785E+00     .9999999994736E-05     .9999999997490E-05     .2048328013871E-06     .2499900000000E+00


PENALTY FUNCTION ITERATION       1      MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME        .9170 SECONDS
PENALTY COEFFICIENT        .10000E+01      PENALTY VALUE        .49656E-02     CONSTRAINT VECTOR (CODED)
   0.               0.              .41033E-02    0.                  .82167E-01
    .24868E-01     0.              0.             0.                  .50442E-01
---------- PENALTY FUNCTION HAS NOT CONVERGED --- MULTIPLY COEFFICIENT BY      .10000E+03 ----------

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS          1 FUNCTION EVALUATIONS     F =     -.2226325805358E+00     AT X =
    .1433486808764E-02     .7100607549371E+00    0.                      .5999554422792E+00     .9999900000000E+00

    .1401571212785E+00     .9999999994736E-05     .9999999997490E-05     .2048328013871E-06     .2499900000000E+00
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```
   38 ITERATIONS        203 FUNCTION EVALUATIONS      F =      -.7087086042287E+00      AT X =
   .3408857101306E-01     .7100705738103E+00     0.                          .6087489234975E+00      .9999900000000E+00

   .2223284908619E+00     0.                     0.                          0.                      .2499900000000E+00

PENALTY FUNCTION ITERATION      2       MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME        3.2880 SECONDS
PENALTY COEFFICIENT        .10000E+03      PENALTY VALUE       .69659E-04     CONSTRAINT VECTOR (CODED)
  0.             0.             0.             0.             .99813E-03
   .56761E-03    0.             0.             0.             .27341E-03
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS          1 FUNCTION EVALUATIONS      F =      -.7087086042287E+00      AT X =
   .3408857101306E-01     .7100705738103E+00     0.                          .6087489234975E+00      .9999900000000E+00

   .2223284908619E+00     0.                     0.                          0.                      .2499900000000E+00

    1 ITERATIONS          3 FUNCTION EVALUATIONS      F =      -.7087086053884E+00      AT X =
   .3408675983854E-01     .7100700432232E+00     0.                          .6087477922721E+00      .9999900000000E+00

   .2223242566397E+00     0.                     0.                          0.                      .2499900000000E+00

PENALTY FUNCTION ITERATION      2       MAXIMUM ALLOWED      50
ACCUMULATED CP MINIMIZATION TIME        3.3330 SECONDS
PENALTY COEFFICIENT        .10000E+03      PENALTY VALUE       .70210E-04     CONSTRAINT VECTOR (CODED)
  0.             0.             0.             0.             .10022E-02
   .56896E-03    0.             0.             0.             .27591E-03
---------- PENALTY FUNCTION CONVERGED ----------0
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-----------OPTIMUM   5 (UNCODED)      77/04/06.-----------

OAPEN CHECKOUT ON FGT DATA
AFAPL CONVERSION OPTIMUM (FEB. 1976)
FPR          .20682E+01  OPR          .24201E+02  T4           .24000E+04
A8           .21750E+00  THTR         .11500E+01  T/W          .39446E+00
T/C          .80000E-01  W/S          .14000E+03  AR           .60000E+01
TOGW         .27500E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802     ) VALUE      .24952E+04

CONSTRAINT VECTOR
   0.            0.            0.            0.             .61133E-03
   -.13257E-02   0.            0.            0.             .18991E+01

OBJECTIVE FUNCTION GRADIENT
RNG802
   -.20251E+02    .15866E+00   -.45606E-01   -.38304E+01
    .45982E+02   -.86202E+03   -.49245E+04    .35409E+00
   -.89879E+01    .50245E-02

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55106E+05  ACLTMDOD     .57681E+00  RFLTMDOD     .23836E+00
RNG801       .87191E+04  FLTIME       .26000E+01  NPEN         .29287E+01
LDGVEL       .12188E+03  BPR          .20061E+01  TSC$$$       .20086E+05
TODIST       .60019E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21196E+04    .36545E+02   -.57151E+00    .84012E+03
    .46566E+04    .62182E+04    .37918E+05   -.33026E+02
   0.            -.21112E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16731E-02
    .81214E+00    .30601E+01   -.14545E+02    .65674E-03
    .13535E-01    .48901E-06
RFLTMDOD
    .43733E+00    .86229E-02   0.            -.19867E-01
    .18632E+00    .24979E+01   -.30791E+01   -.17595E-02
    .74631E-01    .69020E-06
RNG801
```

```
   -.79881E+03    .99118E+02    0..            0.
   -.54444E+04   -.13213E+05    0.             0.
    .69572E+02    .14905E-01
FLTIME
   -.21952E-01   0.             .21656E-04    0.
   -.23152E+00   -.28230E+01   -.12264E+01    .20106E-02
   0.            0.
NPEN
    .39453E+00   -.45471E-02   -.30489E-04    .10462E+00
    .29895E+01    .18157E+01   -.52408E+01   -.82351E-02
    .40340E-01    .17037E-06
LDGVEL
   -.63687E+00   -.41821E-01   -.10202E-02    .46352E+00
    .10634E+02    .25827E+02   -.27415E+03    .33886E+00
    .79040E+00   -.26049E-04
BPR
   -.23628E+01   -.13533E-01    .13075E-02   0.
   -.53730E+01   0.            0.            0.
   0.            0.
TSC$$$
    .16801E+02   -.17753E+02    .88457E-01   -.56373E+02
    .13867E+04    .93591E+04   -.90203E+04   -.75643E+01
    .16292E+03    .39571E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.98109E+03   -.19747E+05   -.31471E+05    .49206E+02
    .95865E+01    .20916E-03
-----------------------------------------------------------------

  INSTRUCTION TO OAPEN  ---     CALL       FUN
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X POINTS AND FUNCTION VALUES, FOLLOWED BY GRADIENT, FOR OBJECTIVE FUNCTION  2
OAPEN CHECKOUT ON FGT DATA

PERTURBATION     1     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
     .20682E+01     .24201E+02     .24000E+04     .21750E+00     .11500E+01
     .39446E+00     .80000E-01     .14000E+03     .60000E+01     .27500E+06
     .24952E+04
    -.20251E+02     .15866E+00    -.45606E-01    -.38304E+01     .45982E+02
    -.86202E+03    -.49245E+04     .35409E+00    -.89879E+01     .50245E-02
    0.             0.             0.             0.              .61133E-03
    -.13257E-02    0.             0.             0.              .18991E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55106E+05  ACLTMDOD     .57681E+00  RFLTMDOD     .23836E+00
RNG801       .87191E+04  FLTIME       .26006E+01  NPEN         .29287E+01
LDGVEL       .12188E+03  BPR          .20061E+01  TSC$$$       .20086E+05
TODIST       .60019E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
    -.21196E+04     .36545E+02    -.57151E+00     .84012E+03
     .46566E+04     .62182E+04     .37918E+05    -.33026E+02
    0.             -.21112E-02
ACLTMDOD
    -.87619E-01    -.17695E-02    0.             -.16731E-02
     .81214E+00     .30601E+01    -.14545E+02     .65674E-03
     .13535E-01     .48901E-06
RFLTMDOD
     .43733E+00     .86229E-02    0.             -.19867E-01
     .18632E+00     .24979E+01    -.30791E+01    -.17595E-02
     .74631E-01     .69020E-06
RNG801
    -.79881E+03     .99118E+02    0.             0.
    -.54444E+04    -.13213E+05    0.             0.
     .69572E+02     .14905E-01
FLTIME
    -.21952E-01    0.              .21656E-04    0.
    -.23152E+00    -.28230E+01    -.12264E+01     .20106E-02
    0.             0.
NPEN
     .39453E+00    -.45471E-02    -.30489E-04     .10462E+00
     .29895E+01     .18157E+01    -.52408E+01    -.82351E-02
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    .40340E-01    .17037E-06
LDGVEL
   -.63687E+00   -.41821E-01   -.10202E-02    .46352E+00
    .10634E+02    .25827E+02   -.27415E+03    .33886E+00
    .79040E+00   -.26049E-04
BPR
   -.23628E+01   -.13533E-01    .13075E-02   0.
   -.53730E+01   0.            0.            0.
   0.            0.
TSC$$$
    .16801E+02   -.17753E+02    .88457E-01   -.56373E+02
    .13867E+04    .93591E+04   -.90203E+04   -.75643E+01
    .16292E+03    .39571E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.98109E+03   -.19747E+05   -.31471E+05    .49206E+02
    .95865E+01    .20916E-03

PERTURBATION     2     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20882E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
    .39446E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24948E+04
   -.23035E+02    .15866E+00   -.45606E-01   -.19023E+01    .45982E+02
   -.86202E+03   -.49245E+04    .37527E+00   -.89879E+01    .50317E-02
   0.            0.            0.            0.             .17228E-03
   0.            0.            0.            0.            0.

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55064E+05  ACLTMDOD     .57505E+00  RFLTMDOD     .24710E+00
RNG801      .87031E+04  FLTIME       .26002E+01  NPEN         .29366E+01
LDGVEL      .12187E+03  BPR          .19591E+01  TSC$$$       .20086E+05
TODIST      .59994E+04

PERTURBATION     3     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20482E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
    .39446E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24956E+04
   -.17468E+02    .15866E+00   -.45606E-01   -.57585E+01    .45982E+02
   -.86202E+03   -.49245E+04    .33291E+00   -.89879E+01    .50174E-02
   0             0.            0.            0.             .10504E-02
```

-.92163E-02	0.	0.	0.	.43554E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55149E+05	ACLTMDOD	.57856E+00	RFLTMDOD	.22961E+00
RNG801	.87350E+04	FLTIME	.26011E+01	NPEN	.29208E+01
LDGVEL	.12190E+03	BPR	.20536E+01	TSC$$$	.20085E+05
TODIST	.60044E+04				

PERTURBATION 4 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24401E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27500E+06
.24952E+04				
-.20251E+02	-.44360E+00	-.45606E-01	-.25036E+01	.45982E+02
-.86202E+03	-.49245E+04	.33891E+00	-.89879E+01	.50326E-02
0.	0.	0.	0.	.61133E-03
-.22189E-02	0.	0.	0.	.18991E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55113E+05	ACLTMDOD	.57645E+00	RFLTMDOD	.24013E+00
RNG801	.87389E+04	FLTIME	.26006E+01	NPEN	.29278E+01
LDGVEL	.12187E+03	BPR	.20033E+01	TSC$$$	.20082E+05
TODIST	.60019E+04				

PERTURBATION 5 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24001E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27500E+06
.24951E+04				
-.20251E+02	.76092E+00	-.45606E-01	-.51572E+01	.45982E+02
-.86202E+03	-.49245E+04	.36927E+00	-.89879E+01	.50165E-02
0.	0.	0.	0.	.61133E-03
-.40001E-03	0.	0.	0.	.18991E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55099E+05	ACLTMDOD	.57716E+00	RFLTMDOD	.23668E+00
RNG801	.86992E+04	FLTIME	.26006E+01	NPEN	.29296E+01
LDGVEL	.12189E+03	BPR	.20087E+01	TSC$$$	.20089E+05
TODIST	.60019E+04				

PERTURBATION 6 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24080E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27500E+06
.24948E+04				
-.20251E+02	.15866E+00	-.45606E-01	-.55079E+01	.45982E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.78262E-03
-.15696E-02	0.	0.	0.	.18991E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55102E+05	ACLTMDOD	.57681E+00	RFLTMDOD	.23836E+00
RNG801	.87191E+04	FLTIME	.26002E+01	NPEN	.29284E+01
LDGVEL	.12187E+03	BPR	.20165E+01	TSC$$$	.20086E+05
TODIST	.60019E+04				

PERTURBATION 7 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.23920E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27500E+06
.24956E+04				
-.20251E+02	.15866E+00	-.45606E-01	-.21529E+01	.45982E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.43612E-03
-.10818E-02	0.	0.	0.	.18991E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55111E+05	ACLTMDOD	.57681E+00	RFLTMDOD	.23836E+00
RNG801	.87191E+04	FLTIME	.26004E+01	NPEN	.29289E+01
LDGVEL	.12189E+03	BPR	.19956E+01	TSC$$$	.20085E+05
TODIST	.60019E+04				

PERTURBATION 8 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E-01	.24201E+02	.24000E+04	.23750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27500E+06
.24950E+04				
-.18323E-02	.29134E+00	-.49800E-01	-.13361E+02	.50210E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.61133E-03
0.	0.	0.	0.	.18991E+01

CONSTRAINED FUNCTION VALUES 0

```
SSDALT        .55122E+05  ACLTMDOD     .57676E+00  RFLTMDOD     .23796E+00
RNG801        .87191E+04  FLTIME       .26006E+01  NPEN         .29308E+01
LDGVEL        .12189E+03  BPR          .20061E+01  TSC$$$       .20085E+05
TODIST        .60019E+04

PERTURBATION     9     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+02    .24000E+04    .19750E+00    .11500E+01
    .39446E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24952E+04
   -.22179E+02    .25976E-01   -.41412E-01    .57004E+01    .41753E+02
   -.86202E+03   -.49245E+04    .35409E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .61133E-03
   -.34182E-02   0.            0.            0.             .18991E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55089E+05  ACLTMDOD     .57682E+00  RFLTMDOD     .23875E+00
RNG801        .87191E+04  FLTIME       .26006E+01  NPEN         .29266E+01
LDGVEL        .12187E+03  BPR          .20061E+01  TSC$$$       .20087E+05
TODIST        .60019E+04

PERTURBATION     10     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+02    .24000E+04    .21750E+00    .11515E+01
    .39446E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24953E+04
   -.20251E+02    .15866E+00   -.45606E-01   -.35133E+01    .45982E+02
   -.86202E+03   -.49245E+04    .35409E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .26405E-03
   0.            0.            0.            0.             .42745E+00

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55113E+05  ACLTMDOD     .57802E+00  RFLTMDOD     .23863E+00
RNG801        .87109E+04  FLTIME       .26003E+01  NPEN         .29331E+01
LDGVEL        .12190E+03  BPR          .19981E+01  TSC$$$       .20088E+05
TODIST        .60004E+04

PERTURBATION     11     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+02    .24000E+04    .21750E+00    .11485E+01
    .39446E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
```

```
 .24951E+04
-.20251E+02    .15866E+00   -.45606E-01   -.41475E+01    .45982E+02
-.86202E+03   -.49245E+04    .35409E+00   -.89879E+01    .50245E-02
0.            0.            0.            0.             .95861E-03
-.58350E-02   0.            0.            0.             .33707E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55099E+05  ACLTMDOD     .57559E+00  RFLTMDOD     .23808E+00
RNG801      .87272E+04  FLTIME       .26010E+01  NPEN         .29242E+01
LDGVEL      .12187E+03  BPR          .20142E+01  TSC$$$       .20084E+05
TODIST      .60034E+04

PERTURBATION    12     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
 .20382E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
 .39646E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
 .24935E+04
-.20251E+02    .15866E+00   -.45606E-01   -.38304E+01    .45982E+02
-.86202E+03   -.49461E+04    .35409E+00   -.89879E+01    .50245E-02
0.            0.            0.            0.            0.
0.            0.            0.            0.            0.

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55119E+05  ACLTMDOD     .58293E+00  RFLTMDOD     .24335E+00
RNG801      .86926E+04  FLTIME       .25950E+01  NPEN         .29323E+01
LDGVEL      .12193E+03  BPR          .20061E+01  TSC$$$       .20104E+05
TODIST      .59626E+04

PERTURBATION    13     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
 .20682E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
 .39246E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
 .24969E+04
-.20251E+02    .15866E+00   -.45606E-01   -.38304E+01    .45982E+02
-.86202E+03   -.49030E+04    .35409E+00   -.89879E+01    .50245E-02
0.            0.            0.            0.             .62816E-02
-.49570E-02   0.            0.            0.             .41581E+02

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55094E+05  ACLTMDOD     .57068E+00  RFLTMDOD     .23336E+00
RNG801      .87455E+04  FLTIME       .26063E+01  NPEN         .29250E+01
LDGVEL      .12183E+03  BPR          .20061E+01  TSC$$$       .20067E+05
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TODIST        .60416E+04

PERTURBATION    14     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
    .39446E+00    .80400E-01    .14000E+03    .60000E+01    .27500E+06
    .24932E+04
   -.20251E+02    .15866E+00   -.45606E-01   -.38304E+01    .45982E+02
   -.86633E+03   -.49245E+04    .35409E+00   -.90329E+01    .50245E-02
   0.            0.            0.            0.             .12079E-03
   -.34220E-02   0.            0.            0.            0.

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55121E+05  ACLTMDOD     .57100E+00  RFLTMDOD     .23712E+00
RNG801        .87191E+04  FLTIME       .26001E+01  NPEN         .29266E+01
LDGVEL        .12177E+03  BPR          .20061E+01  TSC$$$       .20082E+05
TODIST        .59893E+04

PERTURBATION    15     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+02    .24000E+04    .21750E+00    .11500E+01
    .39446E+00    .79600E-01    .14000E+03    .60000E+01    .27500E+06
    .24972E+04
   -.20251E+02    .15866E+00   -.45606E-01   -.38304E+01    .45982E+02
   -.85771E+03   -.49245E+04    .35409E+00   -.89430E+01    .50245E-02
   0.            0.            0.            0.             .11019E-02
   0.            0.            0.            0.             .14510E+02

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55091E+05  ACLTMDOD     .58264E+00  RFLTMDOD     .23959E+00
RNG801        .87191E+04  FLTIME       .26011E+01  NPEN         .29308E+01
LDGVEL        .12199E+03  BPR          .20061E+01  TSC$$$       .20089E+05
TODIST        .60145E+04

PERTURBATION    16     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20682E+01    .24201E+C2    .24000E+04    .21750E+00    .11500E+01
    .39446E+00    .80000E-01    .14080E+03    .60000E+01    .27500E+06
    .24955E+04
   -.19404E+02    .97951E-01   -.45606E-01   -.38304E+01    .45982E+02
   -.86202E+03   -.49245E+04    .35409E+00   -.89879E+01    .50245E-02
```

0.	0	0.	0.	.22198E-02
-.79138E-02	0.	0.	0.	.41290E+02

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55080E+05	ACLTMDOD	.57733E+00	RFLTMDOD	.23695E+00
RNG801	.87191E+04	FLTIME	.26022E+01	NPEN	.29221E+01
LDGVEL	.12215E+03	BPR	.20061E+01	TSC$$$	.20080E+05
TODIST	.60413E+04				

PERTURBATION 17 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.13920E+03	.60000E+01	.27500E+06
.24949E+04				
-.21098E+02	.21937E+00	-.45606E-01	-.38304E+01	.45982E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55133E+05	ACLTMDOD	.57628E+00	RFLTMDOD	.23976E+00
RNG801	.87191E+04	FLTIME	.25990E+01	NPEN	.29353E+01
LDGVEL	.12161E+03	BPR	.20061E+01	TSC$$$	.20092E+05
TODIST	.59626E+04				

PERTURBATION 18 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60400E+01	.27500E+06
.24948E+04				
-.20251E+02	.15866E+00	-.45606E-01	-.38304E+01	.45982E+02
-.86202E+03	-.49290E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.61133E-03
0.	0.	0.	0.	.22825E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55106E+05	ACLTMDOD	.57735E+00	RFLTMDOD	.24134E+00
RNG801	.87219E+04	FLTIME	.26006E+01	NPEN	.29303E+01
LDGVEL	.12191E+03	BPR	.20061E+01	TSC$$$	.20092E+05
TODIST	.60023E+04				

PERTURBATION 19 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.59600E+01	.27500E+06
.24956E+04				
-.20251E+02	.15866E+00	-.45606E-01	-.38304E+01	.45982E+02
-.86202E+03	-.49200E+04	.35409E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.61133E-03
-.29393E-02	0.	0.	0.	.15156E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55106E+05	ACLTMDOD	.57626E+00	RFLTMDOD	.23537E+00
RNG801	.87163E+04	FLTIME	.26006E+01	NPEN	.29271E+01
LDGVEL	.12185E+03	BPR	.20061E+01	TSC$$$	.20079E+05
TODIST	.60015E+04				

PERTURBATION 20 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27575E+06
.24990E+04				
-.19983E+02	.18883E+00	-.45606E-01	-.38304E+01	.45982E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50040E-02
0.	0.	0.	0.	.61133E-03
-.11979E-02	0.	0.	0.	.20560E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55105E+05	ACLTMDOD	.57717E+00	RFLTMDOD	.23887E+00
RNG801	.87302E+04	FLTIME	.26006E+01	NPEN	.29288E+01
LDGVEL	.12186E+03	BPR	.20061E+01	TSC$$$	.20115E+05
TODIST	.60021E+04				

PERTURBATION 21 FUNCTION BOX 20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE

.20682E+01	.24201E+02	.24000E+04	.21750E+00	.11500E+01
.39446E+00	.80000E-01	.14000E+03	.60000E+01	.27425E+06
.24914E+04				
-.20519E+02	.12849E+00	-.45606E-01	-.38304E+01	.45982E+02
-.86202E+03	-.49245E+04	.35409E+00	-.89879E+01	.50451E-02
0.	0.	0.	0.	.61133E-03
-.14535E-02	0.	0.	0.	.17422E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55108E+05	ACLTMDOD	.57644E+00	RFLTMDOD	.23784E+00
RNG801	.87079E+04	FLTIME	.26006E+01	NPEN	.29285E+01
LDGVEL	.12190E+03	BPR	.20061E+01	TSC$$$	.20056E+05
TODIST	.60017E+04				

INSTRUCTION TO OAPEN --- CALL FUN

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X POINTS AND FUNCTION VALUES, FOLLOWED BY GRADIENT, FOR OBJECTIVE FUNCTION  2
OAPEN CHECKOUT ON FGT DATA

PERTURBATION     1     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
    .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24952E+04
   -.20343E+02    .16026E+00   -.45501E-01   -.35723E+01    .45875E+02
   -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .71676E-03
   -.13139E-02   0.            0.            0.             .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55105E+05  ACLTMDOD     .57666E+00  RFLTMDOD     .23839E+00
RNG801      .87192E+04  FLTIME       .26007E+01  NPEN         .29287E+01
LDGVEL      .12188E+03  BPR          .20054E+01  TSC$$$       .20086E+05
TODIST      .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16315E-02
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48898E-06
RFLTMDOD
    .43728E+00    .86157E-02   0.            -.19867E-01
    .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74643E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14904E-01
FLTIME
   -.21954E-01   0.             .21656E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20109E-02
   0.            0.
NPEN
    .39450E+00   -.45455E-02   -.30418E-04    .10466E+00
    .29895E+01    .18163E+01   -.52390E+01   -.82349E-02
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    .40340E-01     .17040E-06
LDGVEL
   -.63683E+00    -.41856E-01    -.10202E-02     .46349E+00
    .10634E+02     .25826E+02    -.27415E+03     .33886E+00
    .79029E+00    -.26047E-04
BPR
   -.23624E+01    -.13526E-01     .13074E-02    0.
   -.53719E+01    0.             0.             0.
   0.             0.
TSC$$$
    .16763E+02    -.17760E+02     .88451E-01    -.56349E+02
    .13867E+04     .93592F+04    -.90217E+04    -.75644E+01
    .16291E+03     .39570E-01
TODIST
   -.12282E+03    0.             0.             0.
   -.98112E+03    -.19751E+05    -.31474E+05     .49211E+02
    .95866E+01     .20916E-03

PERTURBATION     2     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20885E+01     .24200E+02     .24000E+04     .21699E+00     .11500E+01
    .39443E+00     .80000E-01     .14000E+03     .60000E+01     .27500E+06
    .24948E+04
   -.23126E+02     .16026E+00    -.45501E-01    -.16442E+01     .45875E+02
   -.86202E+03    -.49241E+04     .37573E+00    -.89879E+01     .50316E-02
   0.             0.             0.             0.              .27768E-03
   0.             0.             0.             0.              .19005E+00

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55062E+05  ACLTMDOD     .57491E+00  RFLTMDOD     .24714E+00
RNG801      .87032E+04  FLTIME       .26003E+01  NPEN         .29366E+01
LDGVEL      .12187E+03  BPR          .19584E+01  TSC$$$       .20086E+05
TODIST      .60002E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04     .36557E+02    -.57018E+00     .85277E+03
    .46563E+04     .62182E+04     .37914E+05    -.33350E+02
   0.             -.21110E-02
ACLTMDOD
   -.87619E-01    -.17695E-02    0.             -.16315E-02
    .81050E+00     .30601E+01    -.14545E+02     .65668E-03
    .13536E-01     .48898E-06
```

```
RFLTMDOD
     .43728E+00      .83430E-02     0.               -.19867E-01
     .18632E+00      .25307E+01    -.30791E+01       -.17595E-02
     .75077E-01      .69021E-06
RNG801
    -.79886E+03      .99118E+02     0.               0.
    -.54439E+04     -.13187E+05     0.               0.
     .69573E+02      .14904E-01
FLTIME
    -.21954E-01     0.               .21656E-04      0.
    -.23244E+00     -.28226E+01    -.12231E+01        .20109E-02
    0.              0.
NPEN
     .39450E+00     -.45455E-02    -.30418E-04        .10466E+00
     .29895E+01      .18351E+01    -.52390E+01       -.82349E-02
     .40340E-01      .17205E-06
LDGVEL
    -.63683E+00     -.42383E-01    -.10202E-02        .46349E+00
     .10634E+02      .25826E+02    -.27415E+03        .33836E+00
     .79029E+00     -.26047E-04
BPR
    -.23334E+01     -.13526E-01     .13007E-02       0.
    -.53191E+01     0.              0.               0.
    0.              0.
TSC$$$
     .16763E+02     -.17760E+02     .88451E-01       -.54804E+02
     .13867E+04      .93592E+04    -.90217E+04       -.75644E+01
     .16291E+03      .39570E-01
TODIST
    -.12282E+03     0.              0.               0.
    -.98326E+03     -.19751E+05    -.31474E+05        .49211E+02
     .95866E+01      .20916E-03

PERTURBATION     3     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
     .20485E+01      .24200E+02     .24000E+04        .21699E+00      .11500E+01
     .39443E+00      .80000E-01     .14000E+03        .60000E+01      .27500E+06
     .24956E+04
    -.17559E+02      .16026E+00    -.45501E-01       -.55004E+01      .45875E+02
    -.86202E+03     -.49241E+04     .33336E+00       -.89879E+01      .50173E-02
    0.              0.              0.               0.               .11558E-02
    -.92038E-02     0.              0.               0.               .51027E+01
```

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55147E+05	ACLTMDOD	.57841E+00	RFLTMDOD	.22965E+00		
RNG801	.87352E+04	FLTIME	.26012E+01	NPEN	.29208E+01		
LDGVEL	.12189E+03	BPR	.20529E+01	TSC$$$	.20085E+05		
TODIST	.60051E+04						

GRADIENTS OF CONSTRAINT FUNCTIONS

SSDALT			
-.21199E+04	.36557E+02	-.57018E+00	.83144E+03
.46563E+04	.62182E+04	.37914E+05	-.32711E+02
0.	-.21110E-02		
ACLTMDOD			
-.87619E-01	-.17695E-02	0.	-.16315E-02
.81354E+00	.30601E+01	-.14545E+02	.65668E-03
.13536E-01	.48898E-06		
RFLTMDOD			
.43728E+00	.88884E-02	0.	-.19667E-01
.18632E+00	.24661E+01	-.30791E+01	-.17595E-02
.74209E-01	.69021E-06		
RNG801			
-.79886E+03	.99118E+02	0.	0.
-.54439E+04	-.13238E+05	0.	0.
.69573E+02	.14904E-01		
FLTIME			
-.21954E-01	0.	.21656E-04	0.
-.23062E+00	-.28243E+01	-.12298E+01	.20109E-02
0.	0.		
NPEN			
.39450E+00	-.45455E-02	-.30418E-04	.10466E+00
.29895E+01	.17974E+01	-.52390E+01	-.82349E-02
.40340E-01	.16875E-06		
LDGVEL			
-.63683E+00	-.41330E-01	-.10202E-02	.46349E+00
.10634E+02	.25826E+02	-.27415E+03	.33886E+00
.79029E+00	-.26047E-04		
BPR			
-.23913E+01	-.13526E-01	.13140E-02	0.
-.54247E+01	0.	0.	0.
0.	0.		
TSC$$$			
.16763E+02	-.17760E+02	.88451E-01	-.57894E+02
.13867E+04	.93592E+04	-.90217E+04	-.75644E+01
.16291E+03	.39570E-01		
TODIST			

```
   -.12282E+03    0.             0.             0.
   -.97898E+03    -.19751E+05    -.31474E+05     .49211E+02
    .95866E+01     .20916E-03

PERTURBATION    4     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01     .24400E+02     .24000E+04     .21699E+00     .11500E+01
    .39443E+00     .80000E-01     .14000E+03     .60000E+01     .27500E+06
    .24952E+04
   -.20343E+02    -.44200E+00    -.45501E-01    -.22455E+01     .45875E+02
   -.86202E+03    -.49241E+04     .33937E+00    -.89879E+01     .50325E-02
   0.             0.             0.             0.              .71676E-03
   -.22068E-02    0.             0.             0.              .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55112E+05  ACLTMDOD     .57631E+00  RFLTMDOD     .24017E+00
RNG801       .87390E+04  FLTIME       .26007E+01  NPEN         .29278E+01
LDGVEL       .12187E+03  BPR          .20026E+01  TSC$$$       .20032E+05
TODIST       .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04     .35030E+02    -.57018E+00     .84211E+03
    .46948E+04     .62182E+04     .37914E+05    -.33031E+02
   0.             -.21110E-02
ACLTMDOD
   -.87619E-01    -.17695E-02    0.             -.16315E-02
    .81202E+00     .30601E+01    -.14545E+02     .65666E-03
    .13536E-01     .48769E-06
RFLTMDOD
    .43456E+00     .91445E-02    0.             -.19867E-01
    .18632E+00     .24915E+01    -.30791E+01    -.17595E-02
    .74267E-01     .68864E-06
RNG801
   -.79886E+03     .99118E+02    0.             0.
   -.54439E+04    -.13213E+05    0.             0.
    .69573E+02     .14922E-01
FLTIME
   -.21954E-01    0.              .21656E-04    0.
   -.23153E+00    -.28235E+01    -.12264E+01     .20109E-02
   0.             0.
NPEN
    .39450E+00    -.43830E-02    -.30418E-04     .10348E+00
```

```
     .29895E+01    .18163E+01   -.52390E+01   -.82676E-02
     .40340E-01    .17040E-06
LDGVEL
    -.64210E+00   -.41856E-01   -.10202E-02    .46732E+00
     .10634E+02    .25906E+02   -.27415E+03    .33886E+00
     .79029E+00   -.26156E-04
BPR
    -.23624E+01   -.14389E-01    .13103E-02   0.
    -.54012E+01   0.            0.            0.
    0.            0.
TSC$$$
     .16763E+02   -.16945E+02    .89182E-01   -.56349E+02
     .13867E+04    .93592E+04   -.90217E+04   -.75644E+01
     .16347E+03    .39553E-01
TODIST
    -.12282E+03   0.            0.            0.
    -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
     .95866E+01    .20916E-03

PERTURBATION     5     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
     .20685E+01    .24000E+02    .24000E+04    .21699E+00    .11500E+01
     .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
     .24951E+04
    -.20343E+02    .76252E+00   -.45501E-01   -.48991E+01    .45875E+02
    -.86202E+03   -.49241E+04    .36972E+00   -.89879E+01    .50164E-02
    0.            0.            0.            0.             .71676E-03
    -.38858E-03   0.            0.            0.             .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55097E+05  ACLTMDOD      .57702E+00  RFLTMDOD     .23672E+00
RNG801       .86994E+04  FLTIME        .26007E+01  NPEN         .29296E+01
LDGVEL       .12189E+03  BPR           .20080E+01  TSC$$$       .20089E+05
TODIST       .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
    -.21199E+04    .38084E+02   -.57018E+00    .84211E+03
     .46178E+04    .62182E+04    .37914E+05   -.33031E+02
    0.            -.21110E-02
ACLTMDOD
    -.87619E-01   -.17695E-02   0.            -.16315E-02
     .81202E+00    .30601E+01   -.14545E+02    .65668E-03
```

```
     .13536E-01     .49027E-06
RFLTMDOD
     .44001E+00     .80868E-02     0.             -.19867E-01
     .18632E+00     .25054E+01     -.30791E+01    -.17595E-02
     .75019E-01     .69177E-06
RNG801
    -.79886E+03     .99118E+02     0.             0.
    -.54439E+04    -.13213E+05     0.             0.
     .69573E+02     .14886E-01
FLTIME
    -.21954E-01    0.              .21656E-04    0.
    -.23153E+00    -.28235E+01    -.12264E+01     .20109E-02
    0.             0.
NPEN
     .39450E+00    -.47079E-02    -.30418E-04     .10583E+00
     .29895E+01     .18163E+01    -.52390E+01    -.82021E-02
     .40340E-01     .17040E-06
LDGVEL
    -.63157E+00    -.41856E-01    -.10202E-02     .45966E+00
     .10634E+02     .25746E+02    -.27415E+03     .33886E+00
     .79029E+00    -.25938E-04
BPR
    -.23624E+01    -.12663E-01     .13044E-02    0.
    -.53427E+01    0.             0.             0.
    0.             0.
TSC$$$
     .16763E+02    -.18575E+02     .87720E-01    -.56349E+02
     .13867E+04     .93592E+04    -.90217E+04    -.75644E+01
     .16236E+03     .39588E-01
TODIST
    -.12282E+03    0.             0.             0.
    -.98112E+03    -.19751E+05    -.31474E+05     .49211E+02
     .95866E+01     .20916E-03

PERTURBATION     6     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
     .20685E+01     .24200E+02     .24080E+04     .21699E+00     .11500E+01
     .39443E+00     .80000E-01     .14000E+03     .60000E-01     .27500E+06
     .24949E+04
    -.20343E+02     .16026E+00    -.45501E-01    -.52498E+01     .45875E+02
    -.86202E+03    -.49241E+04     .35455E+00    -.89879E+01     .50245E-02
    0.             0.             0.             0.              .88804E-03
    -.15573E-02    0.             0.             0.              .26464E+01
```

```
CONSTRAINED FUNCTION VALUES 0
SSDALT      .55100E+05  ACLTMDOD     .57666E+00  RFLTMDOD     .23839E+00
RNG801      .87192E+04  FLTIME       .26009E+01  NPEN         .29284E+01
LDGVEL      .12187E+03  BPR          .20158E+01  TSC$$$       .20086E+05
TODIST      .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .82109E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16315E-02
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48898E-06
RFLTMDOD
    .43728E+00    .86157E-02   0.            -.19867E-01
    .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74643E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14904E-01
FLTIME
   -.21954E-01   0.             .21166E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20124E-02
   0.            0.
NPEN
    .39450E+00   -.45455E-02   -.30418E-04    .10354E+00
    .29895E+01    .18163E+01   -.52390E+01   -.82349E-02
    .40340E-01    .17040E-06
LDGVEL
   -.63683E+00   -.41856E-01   -.10202E-02    .46349E+00
    .10634E+02    .25826E+02   -.27425E+03    .33886E+00
    .79029E+00   -.26047E-04
BPR
   -.23650E+01   -.13408E-01    .12984E-02   0.
   -.53945E+01   0.            0.            0.
   0.            0.
TSC$$$
    .16763E+02   -.17731E+02    .88451E-01   -.56349E+02
    .13867E+04    .93592E+04   -.90217E+04   -.75644E+01
    .16291E+03    .39570E-01
```

```
TODIST
   -.12282E+03   0.            0.            0.
   -.98112E+03   -.19751E+05   -.31474E+05   .49211E+02
    .95866E+01    .20916E-03

PERTURBATION     7     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .23920E+04    .21699E+00    .11500E+01
    .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24956E+04
   -.20343E+02    .16026E+00   -.45501E-01   -.18948E+01    .45875E+02
   -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .54155E-03
   -.10706E-02   0.            0.            0.             .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55109E+05  ACLTMDOD     .57666E+00  RFLTMDOD     .23839E+00
RNG801      .87192E+04  FLTIME       .26005E+01  NPEN         .29289E+01
LDGVEL      .12189E+03  BPR          .19949E+01  TSC$$$       .20085E+05
TODIST      .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .86313E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16315E-02
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48898E-06
RFLTMDOD
    .43728E+00    .86157E-02   0.            -.19867E-01
    .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74643E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14904E-01
FLTIME
   -.21954E-01   0.             .22145E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20094E-02
   0.            0.
NPEN
```

```
   .39450E+00   -.45455E-02   -.30418E-04    .10578E+00
   .29895E+01    .18163E+01   -.52390E+01   -.82349E-02
   .40340E-01    .17040E-06
LDGVEL
  -.63683E+00   -.41856E-01   -.10202E-02    .46349E+00
   .10634E+02    .25826E+02   -.27405E+03    .33886E+00
   .79029E+00   -.26047E-04
BPR
  -.23597E+01   -.13643E-01    .13164E-02   0.
  -.53494E+01   0.            0.            0.
  0.            0.
TSC$$$
   .16763E+02   -.17789E+02    .88451E-01   -.56349E+02
   .13867E+04    .93592E+04   -.90217E+04   -.75644E+01
   .16291E+03    .39570E-01
TODIST
  -.12282E+03   0.            0.            0.
  -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
   .95866E+01    .20916E-03

PERTURBATION      8      FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
   .20685E+01    .24200E+02    .24000E+04    .23699E+00    .11500E+01
   .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
   .24951E+04
  -.18414E+02    .29294E+00   -.49694E-01   -.13103E+02    .50103E+02
  -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50245E-02
  0.            0.            0.            0.             .71676E-03
  0.            0.            0.            0.             .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55121E+05  ACLTMDOD    .57661E+00  RFLTMDOD    .23800E+00
RNG801      .87192E+04  FLTIME      .26007E+01  NPEN        .29308E+01
LDGVEL      .12189E+03  BPR         .20054E+01  TSC$$$      .20084E+05
TODIST      .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21092E+04    .36557E+02   -.62274E+00    .76885E+03
   .46563E+04    .62182E+04    .37914E+05   -.33031E+02
  0.            -.21110E-02
ACLTMDOD
  -.87619E-01   -.17695E-02   0.            -.32777E-02
```

```
    .81202E+00      .30601E+01     -.14545E+02      .65668E-03
    .13536E-01      .49016E-06
RFLTMDOD
    .43728E+00      .86157E-02     0.              -.19867E-01
    .18632E+00      .24984E+01     -.30791E+01     -.17595E-02
    .74577E-01      .69021E-06
RNG801
   -.79886E+03      .99118E+02     0.              0.
   -.54439E+04     -.13213E+05     0.              0.
    .69573E+02      .14904E-01
FLTIME
   -.21954E-01     0.               .21656E-04     0.
   -.23153E+00     -.28235E+01     -.12264E+01      .20109E-02
   0.              0.
NPEN
    .39450E+00     -.46626E-02     -.33222E-04      .10466E+00
    .29895E+01      .18039E+01     -.53117E+01     -.82349E-02
    .40340E-01      .17040E-06
LDGVEL
   -.63683E+00     -.41473E-01     -.10202E-02      .46349E+00
    .10634E+02      .25826E+02     -.27415E+03      .33886E+00
    .79079E+00     -.26047E-04
BPR
   -.23624E+01     -.13526E-01      .13074E-0[illegible]    0.
   -.53719E+01     0.              0.              0.
   0.              0.
TSC$$$
    .18308E+02     -.17760E+02      .88451E-01     -.56349E+02
    .13867E+04      .93592E+04     -.89757E+04     -.75644E+01
    .16291E+03      .39570E-01
TODIST
   -.12282E+03     0.              0.              0.
   -.98112E+03     -.19751E+05     -.31474E+05      .49211E+02
    .95866E+01      .20916E-03

PERTURBATION     9     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01      .24200E+02      .24000E+04      .19699E+00      .11500E+01
    .39443E+00      .80000E-01      .14000E+03      .60000E+01      .27500E+06
    .24952E+04
   -.22271E+02      .27576E-01     -.41307E-01      .59585E+01      .41647E+02
   -.86202E+03     -.49241E+04      .35455E+00     -.89879E+01      .50245E-02
   0.              0.              0.              0.               .71676E-03
```

```
   -.34070E-02   0.            0.            0.            .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT     .55087E+05  ACLTMDOD     .57668E+00  RFLTMDOD     .23879E+00
RNG801     .87192E+04  FLTIME       .26007E+01  NPEN         .29266E+01
LDGVEL     .12187E+03  BPR          .20054E+01  TSC$$$       .20087E+05
TODIST     .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21306E+04    .36557E+02   -.51763E+00    .91536E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.             .14636E-04
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48780E-06
RFLTMDOD
    .43728E+00    .86157E-02   0.            -.19867E-01
    .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74709E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14904E-01
FLTIME
   -.21954E-01   0.             .21656E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20109E-02
   0.            0.
NPEN
    .39450E+00   -.44283E-02   -.27615E-04    .10466E+00
    .29895E+01    .18286E+01   -.51662E+01   -.82349E-02
    .40340E-01    .17040E-06
LDGVEL
   -.63683E+00   -.42239E-01   -.10202E-02    .46349E+00
    .10634E+02    .25826E+02   -.27415E+03    .33886E+00
    .79029E+00   -.26047E-04
BPR
   -.23624E+01   -.13526E-01    .13074E-02   0.
   -.53719E+01   0.            0.            0.
   0.            0.
TSC$$$
    .15218E+02   -.17760E+02    .88451E-01   -.56349E+02
    .13867E+04    .93592E+04   -.90676E+04   -.75644E+01
```

```
  .16291E+03     .39570E-01
TODIST
 -.12282E+03   0.             0.            0.
 -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
  .95866E+01    .20916E-03

PERTURBATION    10     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
  .20685E+01     .24200E+02     .24000E+04     .21699E+00     .11515E+01
  .39443E+00     .80000E-01     .14000E+03     .60000E+01     .27500E+06
  .24953E+04
 -.20343E+02     .16026E+00    -.45501E-01    -.32552E+01     .45875E+02
 -.86202E+03    -.49241E+04     .35455E+00    -.89879E+01     .50245E-02
 0.             0.             0.             0.              .36946E-03
 0.             0.             0.             0.              .11747E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55112E+05  ACLTMDOD     .57788E+00  RFLTMDOD     .23867E+00
RNG801      .87111E+04  FLTIME       .26004E+01  NPEN         .29331E+01
LDGVEL      .12190E+03  BPR          .19973E+01  TSC$$$       .20088E+05
TODIST      .60012E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
 -.21199E+04     .36846E+02    -.57018E+00     .84211E+03
  .46563E+04     .62182E+04     .37914E+05    -.33031E+02
 0.             -.21110E-02
ACLTMDOD
 -.87733E-01    -.17695E-02    0.             -.16315E-02
  .81202E+00     .30638E+01    -.14545E+02     .65668E-03
  .13536E-01     .48898E-06
RFLTMDOD
  .43728E+00     .86157E-02    0.             -.19867E-01
  .18632E+00     .24984E+01    -.30791E+01    -.17595E-02
  .74689E-01     .69021E-06
RNG801
 -.79886E+03     .99118E+02    0.             0.
 -.54439E+04    -.13233E+05    0.             0.
  .69573E+02     .14904E-01
FLTIME
 -.22022E-01    0.              .21656E-04    0.
 -.23153E+00    -.28235E+01    -.12290E+01     .20109E-02
 0.             0.
```

```
NPEN
     .39450E+00   -.45455E-02   -.30418E-04    .10466E+00
     .29561E+01    .18163E+01   -.52390E+01   -.82349E-02
     .40340E-01    .17040E-06
LDGVEL
    -.63683E+00   -.41856E-01   -.10202E-02    .46349E+00
     .10634E+02    .25826E+02   -.27395E+03    .33886E+00
     .79029E+00   -.26047E-04
BPR
    -.23584E+01   -.13745E-01    .13031E-02   0.
    -.53405E+01   0.            0.            0.
    0.            0.
TSC$$$
     .16763E+02   -.17760E+02    .88451E-01   -.56349E+02
     .13867E+04    .93616E+04   -.90217E+04   -.75644E+01
     .16310E+03    .39570E-01
TODIST
    -.12298E+03   0.            0.            0.
    -.98112E+03   -.19751E+05   -.31488E+05    .49211E+02
     .95866E+01    .20916E-03

PERTURBATION      11      FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
     .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11485E+01
     .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
     .24952E+04
    -.20343E+02    .16026E+00   -.45501E-01   -.38894E+01    .45875E+02
    -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50245E-02
    0.            0.            0.            0.             .10641E-02
    -.58232E-02   0.            0.            0.             .41181E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55098E+05  ACLTMDOD     .57544E+00  RFLTMDOD     .23811E+00
RNG801      .87274E+04  FLTIME       .26011E+01  NPEN         .29242E+01
LDGVEL      .12187E+03  BPR          .20135E+01  TSC$$$       .20083E+05
TODIST      .60041E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
    -.21199E+04    .36268E+02   -.57018E+00    .84211E+03
     .46563E+04    .62182E+04    .37914E+05   -.33031E+02
    0.            -.21110E-02
ACLTMDOD
```

```
   -.87504E-01   -.17695E-02   0.             -.16315E-02
    .81202E+00    .30565E+01  -.14545E+02      .65668E-03
    .13536E-01    .48898E-06
RFLTMOD
    .43728E+00    .86157E-02   0.             -.19867E-01
    .18632E+00    .24984E+01  -.30791E+01     -.17595E-02
    .74596E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.              0.
   -.54439E+04   -.13192E+05   0.              0.
    .69573E+02    .14904E-01
FLTIME
   -.21886E-01   0.             .21656E-04     0.
   -.23153E+00   -.28235E+01  -.12239E+01      .20109E-02
   0.            0.
NPEN
    .39450E+00   -.45455E-02  -.30418E-04      .10466E+00
    .30228E+01    .18163E+01  -.52390E+01     -.82349E-02
    .40340E-01    .17040E-06
LDGVEL
   -.63683E+00   -.41856E-01  -.10202E-02      .46349E+00
    .10634E+02    .25826E+02  -.27435E+03      .33886E+00
    .79029E+00   -.26047E-04
BPR
   -.23663E+01   -.13306E-01    .13116E-02     0.
   -.54033E+01   0.            0.              0.
   0.            0.
TSC$$$
    .16763E+02   -.17760E+02    .88451E-01    -.56349E+02
    .13867E+04    .93568E+04  -.90217E+04     -.75644E+01
    .16272E+03    .39570E-01
TODIST
   -.12266E+03   0.            0.              0.
   -.98112E+03   -.19751E+05  -.31460E+05      .49211E+02
    .95866E+01    .20916E-03

PERTURBATION     12      FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04     .21699E+00     .11500E+01
    .39643E+00    .80000E-01    .14000E+03     .60000E+01     .27500E+06
    .24935E+04
   -.20343E+02    .16026E+00  -.45501E-01     -.35723E+01     .45875E+02
   -.86202E+03   -.49457E+04    .35455E+00    -.89879E+01     .50245E-02
```

```
 0.           0.           0.           0.           0.
 0.           0.           0.           0.           0.

CONSTRAINED FUNCTION VALUES 0
SSDALT     .55117E+05  ACLTMDOD    .58278E+00  RFLTMDOD    .24339E+00
RNG801     .86928E+04  FLTIME      .25951E+01  NPEN        .29323E+01
LDGVEL     .12193E+03  BPR         .20054E+01  TSC$$$      .20104E+05
TODIST     .59633E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21199E+04   .36557E+02  -.57018E+00   .84211E+03
   .46563E+04   .62182E+04   .38106E+05  -.33031E+02
  0.           -.21217E-02
ACLTMDOD
  -.87619E-01  -.17695E-02  0.           -.16315E-02
   .81694E+00   .30601E+01  -.14545E+02   .66001E-03
   .13536E-01   .48898E-06
RFLTMDOD
   .44051E+00   .85460E-02  0.           -.19867E-01
   .18632E+00   .24984E+01  -.30791E+01  -.17595E-02
   .74643E-01   .69021E-06
RNG801
  -.79629E+03   .99118E+02  0.           0.
  -.54715E+04  -.13213E+05  0.           0.
   .69573E+02   .14904E-01
FLTIME
  -.21869E-01  0.            .21656E-04  0.
  -.23153E+00  -.27992E+01  -.12196E+01   .19996E-02
  0.           0.
NPEN
   .39636E+00  -.45455E-02  -.30418E-04   .10342E+00
   .29895E+01   .18163E+01  -.52390E+01  -.82349E-02
   .40340E-01   .17040E-06
LDGVEL
  -.63683E+00  -.41055E-01  -.10202E-02   .46349E+00
   .10634E+02   .25826E+02  -.27415E+03   .33886E+00
   .79567E+00  -.26047E-04
BPR
  -.23624E+01  -.13526E-01   .13074E-02  0.
  -.53719E+01  0.           0.           0.
  0.           0.
TSC$$$
   .16763E+02  -.17760E+02   .88451E-01  -.56349E+02
```

```
   .13899E+04    .93592E+04   -.90217E+04   -.75644E+01
   .16291E+03    .39625E-01
TODIST
  -.12282E+03   0.            0.            0.
  -.98112E+03   -.19562E+05   -.31301E+05    .48959E+02
   .95866E+01    .20916E-03

PERTURBATION    13     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
   .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
   .39243E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
   .24970E+04
  -.20343E+02    .16026E+00   -.45501E-01   -.35723E+01    .45875E+02
  -.86202E+03   -.49026E+04    .35455E+00   -.89879E+01    .50245E-02
  0.            0.            0.            0.             .63879E-02
  -.49465E-02   0.            0.            0.             .42336E+02

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55092E+05  ACLTMDOD     .57054E+00  RFLTMDOD     .23340E+00
RNG801       .87456E+04  FLTIME       .26064E+01  NPEN         .29251E+01
LDGVEL       .12183E+03  BPR          .20054E+01  TSC$$$       .20067E+05
TODIST       .60423E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
   .46563E+04    .62182E+04    .37722E+05   -.33031E+02
  0.            -.21003E-02
ACLTMDOD
  -.87619E-01   -.17695E-02   0.            -.16315E-02
   .80710E+00    .30601E+01   -.14545E+02    .65335E-03
   .13536E-01    .48898E-06
RFLTMDOD
   .43405E+00    .86853E-02   0.            -.19867E-01
   .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
   .74643E-01    .69021E-06
RNG801
  -.80144E+03    .99118E+02   0.            0.
  -.54162E+04   -.13213E+05   0.            0.
   .69573E+02    .14904E-01
FLTIME
  -.22040E-01   0.             .21656E-04   0.
  -.23153E+00   -.28477E+01   -.12332E+01    .20222E-02
```

```
  0.             0.
NPEN
    .39261E+00   -.45455E-02   -.30418E-04    .10589E+00
    .29895E+01    .18163E+01   -.52390E+01   -.82349E-02
    .40340E-01    .17040E-06
LDGVEL
   -.63683E+00   -.42658E-01   -.10202E-02    .46349E+00
    .10634E+02    .25826E+02   -.27415E+03    .33886E+00
    .78492E+00   -.26047E-04
BPR
   -.23624E+01   -.13526E-01    .13074E-02   0.
   -.53719E+01   0.            0.            0.
  0.             0.
TSC$$$
    .16763E+02   -.17760E+02    .88451E-01   -.56349E+02
    .13835E+04    .93592E+04   -.90217E+04   -.75644E+01
    .16291E+03    .39516E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.98112E+03   -.19939E+05   -.31647E+05    .49463E+02
    .95866E+01    .20916E-03

PERTURBATION    14    FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
    .39443E+00    .80400E-01    .14000E+03    .60000E+01    .27500E+06
    .24933E+04
   -.20343E+02    .16026E+00   -.45501E-01   -.35723E+01    .45875E+02
   -.86633E+03   -.49241E+04    .35455E+00   -.90329E+01    .50245E-02
  0.             0.            0.            0.             .22618E-03
   -.34095E-02   0.            0.            0.            0.

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55120E+05  ACLTMDOD     .57086E+00  RFLTMDOD     .23716E+00
RNG801      .87192E+04  FLTIME       .26002E+01  NPEN         .29266E+01
LDGVEL      .12177E+03  BPR          .20054E+01  TSC$$$       .20082E+05
TODIST      .59901E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
    .46563E+04    .62566E+04    .37914E+05   -.33031E+02
  0.             -.21110E-02
```

AD-A057 392 BOEING AEROSPACE CO SEATTLE WA BOEING MILITARY AIRPL--ETC F/G 21/5
AIRPLANE RESPONSIVE ENGINE SELECTION (ARES). VOLUME I. ARES USE--ETC(U)
APR 78 G J ECKARD, M J HEALY F33615-73-C-2084
UNCLASSIFIED AFAPL-TR-78-13-VOL-1 NL

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ACLTMDOD
   -.87619E-01     -.17695E-02     0.              -.16315E-02
    .81202E+00      .30601E+01     -.14470E+02      .65668E-03
    .13536E-01      .48898E-06
RFLTMDOD
    .43728E+00      .86157E-02     0.              -.19867E-01
    .18632E+00      .24984E+01     -.30791E+01     -.17683E-02
    .74643E-01      .69021E-06
RNG801
   -.79886E+03      .99118E+02     0.              0.
   -.54439E+04     -.13213E+05     0.              0.
    .69573E+02      .14904E-01
FLTIME
   -.21887E-01     0.               .21656E-04     0.
   -.23222E+00     -.28221E+01     -.12264E+01      .20082E-02
   0.              0.
NPEN
    .39450E+00     -.45455E-02     -.30418E-04      .10320E+00
    .29895E+01      .18163E+01     -.52390E+01     -.82562E-02
    .40542E-01      .17040E-06
LDGVEL
   -.63683E+00     -.41856E-01     -.10253E-02      .46349E+00
    .10687E+02      .25826E+02     -.27415E+03      .33886E+00
    .79029E+00     -.26047E-04
BPR
   -.23624E+01     -.13526E-01      .13074E-02     0.
   -.53719E+01     0.              0.              0.
   0.              0.
TSC$$$
    .16763E+02     -.17760E+02      .88451E-01     -.55430E+02
    .13867E+04      .93592E+04     -.90217E+04     -.75370E+01
    .16260E+03      .39549E-01
TODIST
   -.12282E+03     0.              0.              0.
   -.98492E+03     -.19716E+05     -.31362E+05      .49139E+02
    .95866E+01      .20916E-03

PERTURBATION     15     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01      .24200E+02      .24000E+04      .21699E+00      .11500E+01
    .39443E+00      .79600E-01      .14000E+03      .60000E+01      .27500E+06
    .24972E+04
   -.20343E+02      .16026E+00     -.45501E-01     -.35723E+01      .45875E+02
```

```
   -.85771E+03    -.49241E+04     .35455E+00    -.89430E+01     .50245E-02
   0.             0.             0.             0.              .12073E-02
   0.             0.             0.             0.              .15258E+02

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55090E+05  ACLTMDOD      .58249E+00  RFLTMDOD      .23962E+00
RNG801        .87192E+04  FLTIME        .26012E+01  NPEN          .29308E+01
LDGVEL        .12199E+03  BPR           .20054E+01  TSC$$$        .20089E+05
TODIST        .60153E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04     .36557E+02    -.57018E+00     .84211E+03
    .46563E+04     .61797E+04     .37914E+05    -.33031E+02
   0.             -.21110E-02
ACLTMDOD
   -.87619E-01    -.17695E-02    0.             -.16315E-02
    .81202E+00     .30601E+01    -.14619E+02     .65668E-03
    .13536E-01     .48898E-06
RFLTMDOD
    .43728E+00     .36157E-02    0.             -.19867E-01
    .18632E+00     .24984E+01    -.30791E+01    -.17507E-02
    .74643E-01     .69021E-06
RNG801
   -.79886E+03     .99118E+02    0.             0.
   -.54439E+04    -.13213E+05    0.             0.
    .69573E+02     .14904E-01
FLTIME
   -.22022E-01    0.              .21656E-04    0.
   -.23085E+00    -.28248E+01    -.12264E+01     .20136E-02
   0.             0.
NPEN
    .39450E+00    -.45455E-02    -.30418E-04     .10611E+00
    .29895E+01     .18163E+01    -.52390E+01    -.82135E-02
    .40138E-01     .17040E-06
LDGVEL
   -.63683E+00    -.41856E-01    -.10151E-02     .46349E+00
    .10581E+02     .25826E+02    -.27415E+03     .33886E+00
    .79029E+00    -.26047E-04
BPR
   -.23624E+01    -.13526E-01     .13074E-02    0.
   -.53719E+01    0.             0.             0.
   0.             0.
TSC$$$
```

```
    .16763E+02    -.17760E+02     .88451E-01    -.57267E+02
    .13867E+04     .93592E+04    -.90217E+04    -.75917E+01
    .16322E+03     .39591E-01
TODIST
   -.12282E+03    0.             0.             0.
   -.97732E+03    -.19785E+05    -.31586E+05     .49284E+02
    .95866E+01     .20916E-03

PERTURBATION    16     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01     .24200E+02     .24000E+04     .21699E+00     .11500E+01
    .39443E+00     .80000E-01     .14080E+03     .60000E+01     .27500E+06
    .24955E+04
   -.19495E+02     .99551E-01    -.45501E-01    -.35723E+01     .45875E+02
   -.86202E+03    -.49241E+04     .35455E+00    -.89879E+01     .50245E-02
   0.             0.             0.             0.              .23254E-02
   -.79018E-02    0.             0.             0.              .42041E+02

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55078E+05  ACLTMDOD      .57719E+00  RFLTMDOD      .23699E+00
RNG801       .87192E+04  FLTIME        .26023E+01  NPEN          .29221E+01
LDGVEL       .12215E+03  BPR           .20054E+01  TSC$$$        .20080E+05
TODIST       .60420E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21327E+04     .36557E+02    -.57018E+00     .84211E+03
    .46563E+04     .62182E+04     .37914E+05    -.33031E+02
   0.             -.21110E-02
ACLTMDOD
   -.87619E-01    -.17695E-02    0.             -.16315E-02
    .81202E+00     .30615E+01    -.14545E+02     .65668E-03
    .13536E-01     .48898E-06
RFLTMDOD
    .43728E+00     .86157E-02    0.             -.19867E-01
    .18632E+00     .24984E+01    -.30967E+01    -.17595E-02
    .74643E-01     .69021E-06
RNG801
   -.79886E+03     .99118E+02    0.             0.
   -.54439E+04    -.13213E+05    0.             0.
    .69573E+02     .14904E-01
FLTIME
   -.21954E-01    0.              .21805E-04    0.
```

```
  -.23153E+00    -.28280E+01    -.12318E+01     .20109E-02
  0.             0.
NPEN
   .39450E+00    -.46765E-02    -.30418E-04     .10466E+00
   .29895E+01     .18163E+01    -.52817E+01    -.82349E-02
   .40340E-01     .17040E-06
LDGVEL
  -.63683E+00    -.41856E-01    -.10202E-02     .46349E+00
   .10634E+02     .25826E+02    -.27415E+03     .33823E+00
   .79029E+00    -.26047E-04
BPR
  -.23624E+01    -.13526E-01     .13074E-02    0.
  -.53719E+01    0.             0.             0.
  0.             0.
TSC$$$
   .16763E+02    -.17760E+02     .88451E-01    -.56349E+02
   .13867E+04     .93592E+04    -.89670E+04    -.75644E+01
   .16210E+03     .39550E-01
TODIST
  -.12282E+03    0.             0.             0.
  -.98112E+03    -.19851E+05    -.31619E+05     .49276E+02
   .95866E+01     .20916E-03

PERTURBATION     17      FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
   .20685E+01     .24200E+02     .24000E+04     .21699E+00     .11500E+01
   .39443E+00     .80000E-01     .13920E+03     .60000E+01     .27500E+06
   .24950E+04
  -.21190E+02     .22097E+00    -.45501E-01    -.35723E+01     .45875E+02
  -.86202E+03    -.49241E+04     .35455E+00    -.89879E+01     .50245E-02
  0.             0.             0.             0.             0.
  0.             0.             0.             0.             0.

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55131E+05  ACLTMDOD     .57614E+00  RFLTMDOD     .23980E+00
RNG801      .87192E+04  FLTIME       .25991E+01  NPEN         .29353E+01
LDGVEL      .12161E+03  BPR          .20054E+01  TSC$$$       .20092E+05
TODIST      .59633E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21071E+04     .36557E+02    -.57018E+00     .84211E+03
   .46563E+04     .62182E+04     .37914E+05    -.33031E+02
```

```
   0.              -.21110E-02
ACLTMDOD
   -.87619E-01     -.17695E-02     0.              -.16315E-02
    .81202E+00      .30588E+01     -.14545E+02      .65668E-03
    .13536E-01      .48898E-06
RFLTMDOD
    .43728E+00      .86157E-02     0.              -.19867E-01
    .18632E+00      .24984E+01     -.30615E+01     -.17595E-02
    .74643E-01      .69021E-06
RNG801
   -.79886E+03      .99113E+02     0.              0.
   -.54439E+04     -.13213E+05     0.              0.
    .69573E+02      .14904E-01
FLTIME
   -.21954E-01     0.               .21506E-04     0.
   -.23153E+00     -.28189E+01     -.12210E+01      .20109E-02
   0.              0.
NPEN
    .39450E+00     -.44144E-02     -.30418E-04      .10466E+00
    .29895E+01      .18163E+01     -.51963E+01     -.82349E-02
    .40340E-01      .17040E-06
LDGVEL
   -.63683E+00     -.41856E-01     -.10202E-02      .46349E+00
    .10634E+02      .25826E+02     -.27415E+03      .33949E+00
    .79029E+00     -.26047E-04
BPR
   -.23624E+01     -.13526E-01      .13074E-02     0.
   -.53719E+01     0.              0.              0.
   0.              0.
TSC$$$
    .16763E+02     -.17760E+02      .88451E-01     -.56349E+02
    .13867E+04      .93592E+04     -.90764E+04     -.75644E+01
    .16373E+03      .39591E-01
TODIST
   -.12282E+03     0.              0.              0.
   -.98112E+03     -.19650E+05     -.31329E+05      .49147E+02
    .95866E+01      .20916E-03

PERTURBATION     18     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01      .24200E+02      .24000E+04      .21699E+00      .11500E+01
    .39443E+00      .80000E-01      .14000E+03      .60400E+01      .27500E+06
    .24949E+04
```

-.20343E+02	.16026E+00	-.45501E-01	-.35723E+01	.45875E+02
-.86202E+03	-.49286E+04	.35455E+00	-.89879E+01	.50245E-02
0.	0.	0.	0.	.71676E-03
0.	0.	0.	0.	.30298E+01

CONSTRAINED FUNCTION VALUES 0

SSDALT	.55105E+05	ACLTMDOD	.57720E+00	RFLTMDOD	.24138E+00
RNG801	.87220E+04	FLTIME	.26007E+01	NPEN	.29303E+01
LDGVEL	.12191E+03	BPR	.20054E+01	TSC$$$	.20092E+05
TODIST	.60030E+04				

GRADIENTS OF CONSTRAINT FUNCTIONS

SSDALT

-.21199E+04	.36557E+02	-.57018E+00	.84211E+03
.46563E+04	.62182E+04	.37914E+05	-.33031E+02
0.	-.21110E-02		

ACLTMDOD

-.87619E-01	-.17695E-02	0.	-.16315E-02
.81202E+00	.30601E+01	-.14545E+02	.65668E-03
.13536E-01	.49095E-06		

RFLTMDOD

.43815E+00	.85404E-02	0.	-.19999E-01
.18757E+00	.24984E+01	-.30791E+01	-.17595E-02
.74643E-01	.69607E-06		

RNG801

-.79886E+03	.99118E+02	0.	0.
-.54439E+04	-.13213E+05	0.	0.
.69573E+02	.14915E-01		

FLTIME

-.21954E-01	0.	.21656E-04	0.
-.23153E+00	-.28235E+01	-.12264E+01	.20109E-02
0.	0.		

NPEN

.39450E+00	-.45455E-02	-.30418E-04	.10466E+00
.29895E+01	.18163E+01	-.52188E+01	-.82349E-02
.40340E-01	.17040E-06		

LDGVEL

-.63683E+00	-.41856E-01	-.10202E-02	.46349E+00
.10634E+02	.25933E+02	-.27415E+03	.33886E+00
.79029E+00	-.26087E-04		

BPR

-.23624E+01	-.13526E-01	.13074E-02	0.
-.53719E+01	0.	0.	0.
0.	0.		

```
TSC$$$
    .16763E+02   -.17649E+02    .88451E-01   -.56349E+02
    .13917E+04    .93592E+04   -.90526E+04   -.76052E+01
    .16291E+03    .39593E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
    .95866E+01    .21056E-03

PERTURBATION    19     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
    .39443E+00    .80000E-01    .14000E+03    .59600E+01    .27500E+06
    .24956E+04
   -.20343E+02    .16026E+00   -.45501E-01   -.35723E+01    .45875E+02
   -.86202E+03   -.49196E+04    .35455E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .71676E-03
   -.29275E-02   0.            0.            0.             .22629E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT        .55105E+05  ACLTMDOD     .57612E+00  RFLTMDOD      .23541E+00
RNG801        .87164E+04  FLTIME       .26007E+01  NPEN          .29271E+01
LDGVEL        .12185E+03  BPR          .20054E+01  TSC$$$        .20079E+05
TODIST        .60023E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16315E-02
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48701E-06
RFLTMDOD
    .43642E+00    .86909E-02   0.            -.19734E-01
    .18508E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74643E-01    .68435E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14894E-01
FLTIME
```

```
   -.21954E-01   0.             .21656E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20109E-02
   0.            0.
NPEN
    .39450E+00   -.45455E-02   -.30418E-04    .10466E+00
    .29895E+01    .18163E+01   -.52591E+01   -.82349E-02
    .40340E-01    .17040E-06
LDGVEL
   -.63683E+00   -.41856E-01   -.10202E-02    .46349E+00
    .10634E+02    .25718E+02   -.27415E+03    .33886E+00
    .79029E+00   -.26008E-04
BPR
   -.23624E+01   -.13526E-01    .13074E-02   0.
   -.53719E+01   0.            0.            0.
   0.            0.
TSC$$$
    .16763E+02   -.17871E+02    .88451E-01   -.56349E+02
    .13816E+04    .93592E+04   -.89907E+04   -.75236E+01
    .16291E+03    .39548E-01
TODIST
   -.12282E+03   0.            0.            0.
   -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
    .95866E+01    .20777E-03

PERTURBATION    20     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
    .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27575E+06
    .24990E+04
   -.20074E+02    .19043E+00   -.45501E-01   -.35723E+01    .45875E+02
   -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50039E-02
   0.            0.            0.            0.             .71676E-03
   -.11861E-02   0.            0.            0.             .28033E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55103E+05  ACLTMDOD    .57703E+00  RFLTMDOD    .23891E+00
RNG801      .87304E+04  FLTIME      .26007E+01  NPEN        .29288E+01
LDGVEL      .12186E+03  BPR         .20054E+01  TSC$$$      .20115E+05
TODIST      .60028E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
```

```
      .46563E+04      .62142E+04      .37914E+05     -.33031E+02
     0.              -.21110E-02
    ACLTMDOD
     -.87619E-01     -.17744E-02     0.              -.15873E-02
      .81202E+00      .30601E+01     -.14545E+02      .65666E-03
      .13572E-01      .48505E-06
    RFLTVDOD
      .43728E+00      .86098E-02     0.              -.19867E-01
      .18632E+00      .24984E+01     -.30791E+01     -.17595E-02
      .74753E-01      .69021E-06
    RNG801
     -.79886E+03      .99186E+02     0.              0.
     -.54439E+04     -.13213E+05     0.              0.
      .69763E+02      .14827E-01
    FLTIME
     -.21954E-01     0.               .21656E-04     0.
     -.23153E+00     -.28235E+01     -.12264E+01      .20109E-02
     0.              0.
    NPEN
      .39456E+00     -.45455E-02     -.30418E-04      .10466E+00
      .29895E+01      .18163E+01     -.52390E+01     -.82349E-02
      .40340E-01      .17040E-06
    LDGVEL
     -.63683E+00     -.42265E-01     -.10202E-02      .46349E+00
      .10634E+02      .25826E+02     -.27415E+03      .33886E+00
      .78956E+00     -.25960E-04
    BPR
     -.23624E+01     -.13526E-01      .13074E-02     0.
     -.53719E+01     0.              0.              0.
     0.              0.
    TSC$$$
      .16763E+02     -.17827E+02      .88451E-01     -.56349E+02
      .13867E+04      .93797E+04     -.90611E+01     -.75832E+01
      .16334E+03      .39560E-01
    TODIST
     -.12282E+03     0.              0.              0.
     -.98112E+03     -.19751E+05     -.31474E+05      .49211E+02
      .96127E+01      .20916E-03

    PERTURBATION     21     FUNCTION BOX  20

    THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
      .20685E+01      .24200E+02      .24000E+04      .21699E+00      .11500E+01
      .39443E+00      .80000E-01      .14000E+03      .60000E-01      .27425E+06
```

```
   .24915E+04
  -.20611E+02     .13009E+00    -.45501E-01    -.35723E+01     .45875E+02
  -.86202E+03    -.49241E+04     .35455E+00    -.89879E+01     .50451E-02
  0.             0.             0.             0.              .71676E-03
  -.14417E-02    0.             0.             0.              .24895E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55106E+05  ACLTMDOD    .57629E+00  RFLTMDOD    .23787E+00
RNG801      .87080E+04  FLTIME      .26007E+01  NPEN        .29286E+01
LDGVEL      .12190E+03  BPR         .20054E+01  TSC$$$      .20056E+05
TODIST      .60025E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21199E+04     .36557E+02    -.57018E+00     .84211E+03
   .46563E+04     .62222E+04     .37914E+05    -.33031E+02
  0.             -.21110E-02
ACLTMDOD
  -.87619E-01    -.17647E-02    0.             -.16758E-02
   .81202E+00     .30601E+01    -.14545E+02     .65668E-03
   .13499E-01     .49291E-06
RFLTMDOD
   .43728E+00     .86215E-02    0.             -.19867E-01
   .18632E+00     .24984E+01    -.30791E+01    -.17595E-02
   .74533E-01     .69021E-06
RNG801
  -.79886E+03     .99050E+02    0.             0.
  -.54439E+04    -.13213E+05    0.             0.
   .69383E+02     .14982E-01
FLTIME
  -.21954E-01    0.              .21656E-04    0.
  -.23153E+00    -.28235E+01    -.12264E+01     .20109E-02
  0.             0.
NPEN
   .39443E+00    -.45455E-02    -.30418E-04     .10466E+00
   .29895E+01     .18163E+01    -.52390E+01    -.82349E-02
   .40340E-01     .17040E-06
LDGVEL
  -.63683E+00    -.41448E-01    -.10202E-02     .46349E+00
   .10634E+02     .25826E+02    -.27415E+03     .33886E+00
   .79103E+00    -.26135E-04
BPR
  -.23624E+01    -.13526E-01     .13074E-02    0.
  -.53719E+01    0.             0.             0.
```

```
  0.            0.
TSC$$$
    .16763E+02   -.17693E+02     .88451E-01   -.56349E+02
    .13867E+04    .93386E+04   -.89823E+04   -.75455E+01
    .16249E+03    .39581E-01
TODIST
   -.12282E+03   0.             0.             0.
   -.98112E+03   -.19751E+05   -.31474E+05    .49211E+02
    .95604E+01    .20916E-03


INSTRUCTION TO OAPEN  ---      CALL      FUN
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X POINTS AND FUNCTION VALUES, FOLLOWED BY GRADIENT, FOR OBJECTIVE FUNCTION  2
OAPEN CHECKOUT ON FGT DATA

PERTURBATION     1     FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
    .20685E+01    .24200E+02    .24000E+04    .21699E+00    .11500E+01
    .39443E+00    .80000E-01    .14000E+03    .60000E+01    .27500E+06
    .24952E+04
   -.20343E+02    .16026E+00   -.45501E-01   -.35723E+01    .45875E+02
   -.86202E+03   -.49241E+04    .35455E+00   -.89879E+01    .50245E-02
   0.            0.            0.            0.             .71676E-03
   -.13139E-02   0.            0.            0.             .26464E+01

CONSTRAINED FUNCTION VALUES 0
SSDALT      .55105E+05  ACLTMDOD     .57666E+00  RFLTMDOD     .23839E+00
RNG801      .87192E+04  FLTIME       .26007E+01  NPEN         .29287E+01
LDGVEL      .12188E+03  BPR          .20054E+01  TSC$$$       .20086E+05
TODIST      .60026E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.21199E+04    .36557E+02   -.57018E+00    .84211E+03
    .46563E+04    .62182E+04    .37914E+05   -.33031E+02
   0.            -.21110E-02
ACLTMDOD
   -.87619E-01   -.17695E-02   0.            -.16315E-02
    .81202E+00    .30601E+01   -.14545E+02    .65668E-03
    .13536E-01    .48898E-06
RFLTMDOD
    .43728E+00    .86157E-02   0.            -.19867E-01
    .18632E+00    .24984E+01   -.30791E+01   -.17595E-02
    .74643E-01    .69021E-06
RNG801
   -.79886E+03    .99118E+02   0.            0.
   -.54439E+04   -.13213E+05   0.            0.
    .69573E+02    .14904E-01
FLTIME
   -.21954E-01   0.             .21656E-04   0.
   -.23153E+00   -.28235E+01   -.12264E+01    .20109E-02
   0.            0.
NPEN
    .39450E+00   -.45455E-02   -.30418E-04    .10466E+00
    .29895E+01    .18163E+01   -.52390E+01   -.82349E-02
```

```
   .40340E-01     .17040E-06
LDGVEL
  -.63683E+00    -.41856E-01    -.10202E-02     .46349E+00
   .10634E+02     .25826E+02    -.27415E+03     .33886E+00
   .79029E+00    -.26047E-04
BPR
  -.23624E+01    -.13526E-01     .13074E-02    0.
  -.53719E+01    0.             0.             0.
  0.             0.
TSC$$$
   .16763E+02    -.17760E+02     .88451E-01    -.56349E+02
   .13867E+04     .93592E+04    -.90217E+04    -.75644E+01
   .16291E+03     .39570E-01
TODIST
  -.12282E+03    0.             0.             0.
  -.98112E+03    -.19751E+05    -.31474E+05     .49211E+02
   .95866E+01     .20916E-03

PERTURBATION      2      FUNCTION BOX  20

THE DECODED X, OBJECTIVE FUNCTION F AND GRAD F, AND CONSTRAINT VECTOR VALUES ARE
   .20885E+01     .24200E+02     .24000E+04     .21699E+00     .11500E+01
   .39443E+00     .80000E-01     .14000E+03     .60000E+01     .27500E+06
   .24948E+04
  -.23126E+02     .16026E+00    -.45501E-01    -.16442E+01     .45875E+02
  -.86202E+03    -.49241E+04     .37573E+00    -.89879E+01     .50316E-02
  0.             0.             0.             0.              .27768E-03
  0.             0.             0.             0.              .19005E+00

CONSTRAINED FUNCTION VALUES 0
SSDALT       .55062E+05  ACLTMDOD      .57491E+00  RFLTMDOD      .24714E+00
RNG801       .87032E+04  FLTIME        .26003E+01  NPEN          .29366E+01
LDGVEL       .12187E+03  BPR           .19584E+01  TSC$$$        .20086E+05
TODIST       .60002E+04

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
  -.21199E+04     .36557E+02    -.57018E+00     .85277E+03
   .46563E+04     .62182E+04     .37914E+05    -.33350E+02
  0.             -.21110E-02
ACLTMDOD
  -.87619E-01    -.17695E-02    0.             -.16315E-02
   .81050E+00     .30601E+01    -.14545E+02     .65668E-03
   .13536E-01     .48898E-06
```

```
RFLTMDOD
     .43728E+00     .83430E-02     0.              -.19867E-01
     .18632E+00     .25307E+01    -.30791E+01      -.17595E-02
     .75077E-01     .69021E-06
RNG801
    -.79886E+03     .99118E+02     0.               0.
    -.54439E+04    -.13187E+05     0.               0.
     .69573E+02     .14904E-01
FLTIME
    -.21954E-01    0.              .21656E-04      0.
    -.23244E+00    -.28226E+01    -.12231E+01       .20109E-02
    0.             0.
NPEN
     .39450E+00    -.45455E-02    -.30418E-04       .10466E+00
     .29895E+01     .18351E+01    -.52390E+01      -.82349E-02
     .40340E-01     .17205E-06
LDGVEL
    -.63683E+00    -.42383E-01    -.10202E-02       .46349E+00
     .10634E+02     .25826E+02    -.27415E+03       .33886E+00
     .79029E+00    -.26047E-04
BPR
    -.23334E+01    -.13526E-01     .13007E-02      0.
    -.53191E+01    0.             0.               0.
    0.             0.
TSC$$$
     .16763E+02    -.17760E+02     .88451E-01      -.54804E+02
     .13867E+04     .93592E+04    -.90217E+04      -.75644E+01
     .16291E+03     .39570E-01
TODIST
    -.12282E+03    0.             0.               0.
    -.98326E+03    -.19751E+05    -.31474E+05       .49211E+02
     .95866E+01     .20916E-03
```

```
INSTRUCTION TO OAPEN  ---     SET       CONSTRAINT

THE FOLLOWING FUNCTIONS ARE STORED IN FUNCTION BOX  2
IN THE ORDER INDICATED

RNG802    SSDALT    ACLTMDOD  RFLTMDOD  RNG801    FLTIME    NPEN      LDGVEL
BPR       TSC$$$    TODIST    SEG801A   NMILE(25) NMILE(26) 108GNR

TODIST    LE          .10000E+07

BPR       LE          .10000E+07

LDGVEL    LE          .10000E+07

NPEN      GE         0.

FLTIME    LE          .10000E+07

RFLTMDOD  GE         0.

ACLTMDOD  GE         0.

SSDALT    GE         0.

NEW NUMBERS FOR FUN. BOX 2      1005 LOCATIONS ARE RESERVED FOR   15 FUNCTIONSO
IN   10 VARIABLES,0
EACH WITH    66 COEFFICIENTS AND (IF NEEDED) ONE CONSTRAINT VALUE
OAPEN CHECKOUT ON FGT DATA

THE FOLLOWING FUNCTIONS ARE STORED IN FUNCTION BOX  2
IN THE ORDER INDICATED

RNG802    SSDALT    ACLTMDOD  RFLTMDOD  FLTIME    NPEN      LDGVEL    BPR
TODIST    RNG801    TSC$$$    SEG801A   NMILE(25) NMILE(26) 108GNR
```

```
INSTRUCTION TO OAPEN  ---     CALL      FR

UNCODED X VECTOR
FPR          .20000E+01  OPR          .30000E+02  T4          .29000E+04
A8           .12000E+00  THTR         .11500E+01  T/W         .40000E+00
T/C          .80000E-01  W/S          .14000E+03  AR          .10000E+02
TOGW         .27500E+06
FIND RNG802 MAX WITH NONBINDING CONSTRAINTS PRESENT

LOWER AND UPPER BOUNDS ON X
    .20000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE      .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)     .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS             1 FUNCTION EVALUATIONS      F =     -.6359832602628E+00      AT X =
    .1000000000317E-04    .9999900000000E+00    .6250000000000E+00    .5600000000000E+00    .9999900000000E+00

    .2500000000000E+00    .9999999994736E-05    .9999999997490E-05    .9999900000000E+00    .2500000000000E+00

    83 ITERATIONS           170 FUNCTION EVALUATIONS      F =     -.1118515102194E+01      AT X =
    .6060369698635E+00    .7719886157155E+00   0.                    .7290563355533E+00    .1000000000000E+01

   0.                     .9999999994736E-05    .1000000000000E+01   0.                    .9167044632524E+00


PENALTY FUNCTION ITERATION      1      MAXIMUM ALLOWED     50
ACCUMULATED CP MINIMIZATION TIME       1.9410 SECONDS
PENALTY COEFFICIENT        .10000E+01    PENALTY VALUE    0.            CONSTRAINT VECTOR (CODED)
   0.             0.             0.             0.             0.
   0.             0.             0.             0.             0.
---------- PENALTY FUNCTION CONVERGED ----------0

CONVERGENCE CHECK --- RESTART MINIMIZATION ---

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
     0 ITERATIONS             1 FUNCTION EVALUATIONS      F =     -.1118515102194E+01      AT X =
    .6060369698635E+00    .7719886157155E+00   0.                    .7290563355533E+00    .1000000000000E+01
```

```
0.             .9999999994736E-05   .1000000000000E+01   0.                 .9167044632524E+00

 1 ITERATIONS      3 FUNCTION EVALUATIONS    F =     -.1118515102206E+01    AT X =
.6060309786861E+00  .7719869533723E+00   0.              .7290575285055E+00   .1000000000000E+01

0.             .9999999994736E-05   .1000000000000E+01   0.                 .9167026898229E+00

PENALTY FUNCTION ITERATION     1     MAXIMUM ALLOWED     50
ACCUMULATED CP MINIMIZATION TIME     1.9840 SECONDS
PENALTY COEFFICIENT     .10000E+01     PENALTY VALUE     0.          CONSTRAINT VECTOR (CODED)
  0.         0.         0.         0.         0.
  0.         0.         0.         0.         0.
---------- PENALTY FUNCTION CONVERGED ----------0
```

```
--------------------------------------------------------------------

-----------OPTIMUM   6 (UNCODED)       77/04/06.-----------

OAPEN CHECKOUT ON FGT DATA
FIND RNG802 MAX WITH NONBINDING CONSTRAINTS PRESENT
FPR          .32121E+01  OPR          .25440E+02  T4           .24000E+04
A8           .45812E+00  THTR         .11500E+01  T/W          .35000E+00
T/C          .80000E-01  W/S          .22000E+03  AR           .60000E+01
TOGW         .47501E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802     ) VALUE       .30971E+04

CONSTRAINT VECTOR
   0.           0.           0.           0.           0.
   0.           0.           0.           0.           0.

OBJECTIVE FUNCTION GRADIENT
RNG802
   -.67421E-03    .28464E-04   -.96061E-01   -.20385E-02
    .96852E+02   -.86202E+03   -.44454E+04    .14717E+01
   -.89880E+01    .42641E-08

CONSTRAINED FUNCTION VALUES 0
SSDALT       .48209E+05  ACLTMDOD     .37636E+00  RFLTMDOD     .53126E+00
FLTIME       .28918E+01  NPEN         .26542E+01  LDGVEL       .14159E+03
BPR          .23110E+00  TODIST       .11518E+05  RNG801       .93894E+04
TSC$$$       .26045E+05

GRADIENTS OF CONSTRAINT FUNCTIONS
SSDALT
   -.32688E+04    .27093E+02   -.12038E+01    .56867E+03
    .48949E+04    .51477E+04    .33644E+05   -.51292E+02
   0.            -.18733E-02
ACLTMDOD
   -.87619E-01   -.30565E-02   0.            -.96745E-02
    .61568E+00    .31933E+01   -.14545E+02    .58272E-03
    .23380E-01   -.55308E-06
RFLTMDOD
    .34862E+00   -.37145E-02   0.            -.19867E-01
    .18632E+00    .43024E+01   -.48386E+01   -.17595E-02
    .12563E+00    .68051E-06
FLTIME
```

	-.23854E-01	0.	.36637E-04	0.
	-.28359E+00	-.37657E+01	-.17245E+01	.22619E-02
	0.	0.		
NPEN				
	.36909E+00	-.18054E-01	-.64219E-04	.12478E+00
	.29895E+01	.27457E+01	-.10388E+02	-.84380E-02
	.40340E-01	.26461E-06		
LDGVEL				
	-.66946E+00	-.19401E+00	-.10202E-02	.48724E+00
	.10634E+02	.26323E+02	-.27415E+03	.27592E+00
	.47472E+00	-.33990E-05		
BPR				
	-.70554E+00	-.18877E-01	.94627E-03	0.
	-.25352E+01	0.	0.	0.
	0.	0.		
TODIST				
	-.12282E+03	0.	0.	0.
	-.11033E+04	-.34020E+05	-.49823E+05	.61268E+02
	.16559E+02	.20916E-03		
RNG801				
	-.85599E+03	.11719E+03	0.	0.
	-.48307E+04	-.11742E+05	0.	0.
	.12017E+03	-.56253E-02		
TSC$$$				
	.35389E+02	-.30473E+02	.92984E-01	.31993E+02
	.13158E+04	.14831E+05	-.13504E+05	-.12591E+02
	.19764E+03	.33489E-01		

```
INSTRUCTION TO OAPEN  ---     CALL      FR

UNCODED X VECTOR
FPR           .20000E+01  OPR          .30000E+02  T4            .29000E+04
A8            .12000E+00  THTR         .11500E+01  T/W           .40000E+00
T/C           .80000E-01  W/S          .14000E+03  AR            .10000E+02
TOGW          .27500E+06
FIND RNG802 MAX WITH NO. CONSTRAINTS SET = 0

LOWER AND UPPER BOUNDS ON X
    .20000E+01     .40000E+01     .10000E+02     .30000E+02     .24000E+04
    .32000E+04    -.10000E+01     .10000E+01     .10000E+01     .11500E+01
    .35000E+00     .55000E+00     .80000E-01     .12000E+00     .14000E+03
    .22000E+03     .60000E+01     .10000E+02     .20000E+06     .50000E+06
NUMBER OF INDEPENDENT VARIABLES  10 ERROR TOLERANCE      .10000E-04
NONLINEAR CONSTRAINT TOLERANCE (IF APPLICABLE)     .10000E-01
MAXIMUM NUMBER OF FUNCTION EVALUATIONS   500

FLETCHER-REEVES MINIMIZATION,FUNCTION BOX  2
    0 ITERATIONS          1 FUNCTION EVALUATIONS     F =     -.6359832602628E+00     AT X =
    .1000000000317E-04     .9999900000000E+00     .6250000000000E+00     .5600000000000E+00     .9999900000000E+00

    .2500000000000E+00     .9999999994736E-05     .9999999997490E-05     .9999900000000E+00     .2500000000000E+00

    83 ITERATIONS       170 FUNCTION EVALUATIONS     F =     -.1118515102194E+01     AT X =
    .6060369698635E+00     .7719886157155E+00    0.                      .7290563355533E+00     .1000000000000E+01

   0.                      .9999999994736E-05     .1000000000000E+01    0.                      .9167044632524E+00


ELAPSED CP TIME      .2800 SECONDS
```

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-----------------------------------------------------------------------

-----------OPTIMUM   7 (UNCODED)       77/04/06.------------

OAPEN CHECKOUT ON FGT DATA
FIND RNG802 MAX WITH NO. CONSTRAINTS SET = 0
FPR            .32121E+01  OPR            .25440E+02  T4             .24000E+04
A8             .45811E+00  THTR           .11500E+01  T/W            .35000E+00
T/C            .80000E-01  W/S            .22000E+03  AR             .60000E+01
TOGW           .47501E+06

OPTIMAL OBJECTIVE FUNCTION (RNG802     ) VALUE       .30971E+04
-----------------------------------------------------------------------


---------------------------- END  OAPEN ----------------------------
```

APPENDIX D

EVAQF INPUT/OUTPUT SAMPLE

```
OPR A8 T/W AR W/S LESWP TOGW
RNG901 TODIST VLAND TIMENC(06) NMXAUG(07) RNG902
FIXWT FIF FUELTM DEXH ENGL BDAWET
BMDRY(08) TURNS 999
7
304
RNG901      4.76200E+02  5.19700E+02
-2.17054E+02   .0          -1.27885E+02   .0             .0            .0
  .0          3.05492E-02    .0            .0             .0            .0
 5.67876E-02   .0            .0            .0             .0           1.46058E+01
  .0          2.91432E+00  -1.65512E-03  2.47240E+02     .0            .0
-3.20120E+00 -6.84570E-03    .0            .0             .0            .0
  .0            .0           .0            .0             .0          -2.86017E-07
TODIST      1.44000E+03  1.15500E+04
 6.80698E+03   .0            .0            .0             .0            .0
-2.26491E+02   .0            .0            .0             .0            .0
  .0         -3.93729E-01    .0            .0             .0            .0
  .0            .0           .0          8.23376E+03     .0          -3.92406E+01
-1.50832E+02   .0            .0            .0             .0            .0
  .0          1.36598E+00    .0          6.15011E+00     .0            .0
VLAND       1.11700E+02  1.57400E+02
 1.95459E+02   .0            .0            .0             .0            .0
-4.08133E+00 -9.37046E-04    .0            .0          -2.75927E-01    .0
  .0            .0           .0            .0             .0            .0
  .0            .0           .0            .0             .0           2.42787E-01
  .0            .0           .0            .0           3.43677E-02    .0
  .0          6.62659E-03    .0          1.03842E-01     .0           1.02956E-08
TIMENC(06) 8.70100E-03  7.27890E-02
 2.29473E-01   .0          -8.37005E-02 -1.92084E-01 -2.92485E-03 -1.08012E-03
  .0            .0           .0            .0             .0          -8.55517E-05
  .0            .0           .0          2.68226E-02   2.73315E-02   6.04921E-03
 1.73026E-04   .0            .0          1.14073E-01     .0           2.71592E-04
  .0            .0           .0            .0             .0            .0
 5.66962E-06   .0            .0            .0          -2.53295E-09    .0
NMXAUG(07) 1.55400E+00  2.54900E+00
 3.26002E+00   .0            .0            .0             .0            .0
  .0            .0           .0            .0             .0            .0
  .0            .0           .0            .0             .0            .0
  .0            .0           .0            .0           3.11164E-01    .0
  .0            .0           .0         -1.29894E-03     .0            .0
  .0         -1.88393E-04    .0            .0             .0            .0
RNG902     -1.62700E+02  1.93870E+03
-1.60761E+03   .0            .0            .0             .0            .0
  .0          7.79457E-02    .0            .0             .0            .0
```

1.42801E-01	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
-1.21328E+01	-6.71230E-03	.0	.0	.0	.0
-8.96102E-02	2.06698E-01	.0	-3.08471E-01	.0	-8.14738E-07
FIXWT	5.60400E+03	1.23500E+03			
5.45795E+03	.0	.0	.0	.0	.0
-1.46783E+01	2.89182E-02	.0	.0	8.88293E-01	.0
.0	.0	-1.99350E-05	.0	.0	.0
.0	.0	.0	4.43076E+01	9.45060E+00	.0
-1.17639E+00	6.24897E-04	-1.27803E+00	-4.69982E-02	.0	2.86314E-04
2.53106E-03	5.80303E-03	-1.82309E-05	2.37296E-01	-1.75173E-04	-3.01480E-08
FIF	6.79300E+03	3.65870E+04			
-2.26630E+04	.0	.0	.0	.0	6.07698E+01
2.89250E+02	7.50916E-01	.0	.0	4.03225E+01	.0
.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0
.0	-1.44614E-01	.0	9.96693E+00	-2.01924E+01	-1.94574E-02
-1.61480E+00	1.08413E+00	1.80945E-03	-5.46448E+00	-2.96281E-03	.0
FUELTM	3.71000E+03	1.61500E+04			
-6.72536E+03	.0	.0	.0	.0	.0
1.26054E+02	2.75840E-01	.0	-2.83570E+01	.0	.0
.0	.0	.0	.0	.0	.0
.0	.0	1.20334E-02	-3.38377E+03	.0	1.61117E+01
.0	.0	2.08651E+02	.0	-9.71985E+00	-1.16302E-02
-4.76821E-01	5.68163E-01	6.20101E-04	-2.41625E+00	-1.21878E-03	.0
DEXH	3.15800E+00	2.84600E+00			
2.09553E+00	-4.00111E-02	1.94832E+00	.0	.0	.0
2.66794E-02	.0	.0	-4.03253E-02	.0	.0
.0	.0	.0	.0	.0	-7.87391E-02
-7.59546E-04	-1.22892E-02	.0	.0	.0	.0
.0	3.21331E-05	3.14820E-02	.0	-1.23418E-03	.0
.0	.0	.0	-3.06796E-04	.0	.0
ENGL	9.11100E+00	8.88900E+00			
1.72665E+00	-1.06818E-01	2.66577E-01	5.66815E+00	.0	.0
.0	9.58632E-05	6.20576E-03	-2.39855E-02	3.25694E-02	.0
.0	.0	6.08881E-07	5.48933E-01	.0	.0
.0	.0	.0	-3.01243E+00	.0	.0
.0	4.44723E-05	.0	-1.16714E-04	.0	.0
.0	.0	.0	.0	.0	-8.75765E-10
BDAWET	1.14300E+03	6.03000E+02			
6.58166E+02	.0	2.33798E-02	.0	.0	3.15879E+00
.0	3.91740E-03	1.46694E-01	-4.52223E+00	-1.99757E+00	.0
-1.48425E-02	.0	.0	.0	.0	-1.04332E+01
-4.47981E-01	-8.59873E-01	.0	.0	.0	-4.27436E-01

1.18800E+00	4.18242E-03	.0	.0	-1.05126E-01	.0
-3.17354E-02	1.70391E-02	2.57566E-05	-5.63893E-02	-1.02863E-05	.0
RNG901	4.76200E+02	5.19700E+02			
6.58469E+00	.0	.0	.0	2.03892E+02	.0
1.39215E+01	.0	-2.56947E-01	.0	.0	.0
.0	.0	1.76933E-04	-4.69489E+01	.0	.0
.0	.0	.0	4.26794E+01	-2.86233E+01	-1.27789E+00
-2.59756E+00	.0	-2.91330E+01	.0	-1.45148E+00	.0
-1.05649E-02	.0	6.01809E-05	-1.92440E-01	3.05569E-05	-1.03147E-07
RNG902	-1.62700E+02	1.93870E+03			
-2.30713E+03	7.63321E+01	.0	.0	.0	.0
.0	8.13025E-02	-3.41377E+00	.0	.0	.0
.0	.0	.0	-3.07788E+01	.0	.0
.0	.0	.0	-3.84378E+02	9.66767E+01	.0
-6.96849E+00	-9.53189E-03	-4.13825E+01	1.17896E+00	-1.99659E+00	.0
-1.01686E-01	2.12826E-01	.0	-3.10478E-01	.0	-8.21454E-07
EMDRY(08)	-2.77600E+02	1.50660E+03			
-3.44267E+03	3.26470E+01	.0	2.81535E+03	.0	5.67957E+00
.0	3.45814E-02	-1.05487E+00	1.04363E+01	-3.15987E+01	.0
.0	.0	.0	-4.69297E+02	-1.38125E+02	2.60419E+01
.0	.0	.0	-7.05210E+02	.0	.0
.0	-3.61285E-03	-2.50741E+00	.0	.0	.0
-2.53764E-02	.0	.0	1.20060E-01	.0	-4.45991E-07
TURNS	9.53300E-02	1.02667E+00			
-1.50570E+00	5.50243E-02	.0	2.26537E+00	3.79826E-01	.0
.0	.0	-2.28711E-03	.0	.0	.0
.0	.0	.0	1.94542E-01	.0	.0
.0	.0	.0	-1.65921E+00	.0	-4.23317E-03
.0	.0	-7.61745E-02	.0	.0	-2.46776E-06
3.81308E-05	.0	.0	-1.52773E-05	.0	1.11174E-10
TODIST	1.44000E+03	1.15500E+04			
6.75088E+03	.0	.0	.0	.0	.0
-2.24185E+02	.0	-1.21444E+00	.0	.0	.0
.0	.0	.0	2.93079E+02	.0	.0
.0	.0	.0	9.07251E+03	.0	-4.90556E+01
-1.46811E+02	.0	-8.88812E+00	.0	.0	.0
1.53094E-01	1.24663E+00	.0	6.15027E+00	.0	-4.82489E-08
VLAND	1.11700E+02	1.57400E+02			
1.89712E+02	.0	.0	.0	.0	.0
-3.63336E+00	-1.18508E-03	2.58277E-02	.0	.0	.0
.0	-1.33446E-02	.0	1.12223E+00	.0	.0
.0	.0	.0	-8.74422E+00	.0	2.83249E-01
.0	.0	6.20153E-01	.0	.0	.0
-1.97848E-04	6.26515E-03	.0	1.02557E-01	.0	1.44303E-08

```
TIMENC(06) 8.70100E-03  7.27890E-02
 1.80083E-01   .0          -1.40277E-01 -1.71506E-01 -8.57878E-03   .0
  .0           .0          -3.72407E-05  7.77937E-04   .0           .0
  .0           .0            .0          3.57956E-02  2.91628E-02  9.11569E-03
  .0          2.69118E-04  5.33712E-07  1.22705E-01   .0           .0
  .0           .0          8.73947E-04   .0           .0           .0
 1.63517E-06 -4.60880E-06   .0          1.14911E-05 -6.54972E-09 -8.32512E-13
NMXAUG(07) 1.55400E+00  2.54900E+00
-9.94552E-01   .0            .0          3.34400E+00  1.24588E+00 -4.05257E-02
 1.08623E-01   .0          2.70258E-05   .0           .0           .0
  .0           .0            .0         -2.26489E-01   .0           .0
  .0          2.38247E-03   .0          -9.88275E-01   .0          -2.61770E-03
-1.85791E-02   .0          -1.51876E-01 -1.00555E-03 -8.91059E-03   .0
 2.54578E-04   .0          5.02664E-08 -1.46882E-03 -6.88075E-08  1.27003E-12
```

RANGE OF VARIABLES IN DATA

	OPR	A8	T/W	AR
MIN	.11880E+02	.12500E+00	.75000E+00	.17140E+01
MAX	.23130E+02	.88000E+00	.13500E+01	.42900E+01
RANGE	.11250E+02	.75500E+00	.60000E+00	.25760E+01

	W/S	LESWP	TOGW	RNG901
MIN	.80360E+02	.37850E+02	.42860E+05	.51380E+03
MAX	.14460E+03	.72140E+02	.77140E+05	.97630E+03
RANGE	.64240E+02	.34290E+02	.34280E+05	.46250E+03

	TODIST	VLAND	TIMENC(06)	NMXAUG(07)
MIN	.18480E+04	.11660E+03	.94170E-02	.16670E+01
MAX	.10630E+05	.22830E+03	.37030E-01	.37670E+01
RANGE	.87820E+04	.11170E+03	.27613E-01	.21000E+01

	RNG902	FIXWT	FIF	FUELTM
MIN	.99280E+02	.56860E+04	.91950E+04	.49180E+04
MAX	.18900E+04	.66900E+04	.35640E+05	.15930E+05
RANGE	.17907E+04	.10040E+04	.26445E+05	.11012E+05

	DEXH	ENGL	BOAWET	EMDRY(08)
MIN	.36060E+01	.96420E+01	.11930E+04	-.30820E+04
MAX	.55810E+01	.16340E+02	.17220E+04	-.14070E+04
RANGE	.19750E+01	.66980E+01	.52900E+03	.16750E+04

	TURNS
MIN	.57270E+00
MAX	.95540E+00
RANGE	.38270E+00

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.10114E+00	.37516E-01
PERCENT DEVIATION	.48164E+01	.17865E+01
PCT MAG NMXAUG(07)	.60674E+01	.15610E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.31221672E-01	16.	.19513545E-02

OF 1 REPRESENTING VARIABLE 8 RNG901

-.21705E+03	0.	-.12789E+03	0.	0.
0.	0.	.30549E-01	0.	0.
0.	0.	.56788E-01	0.	0.
0.	0.	.14606E+02	0.	.29143E+01
-.16551E-02	.24724E+03	0.	0.	-.32012E+01
-.68457E-02	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.28602E-06				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.91440E+03	.88638E+03	.28022E+02	.30645E+01	.60587E+01
2	.74000E+03	.69730E+03	.42700E+02	.57703E+01	.92325E+01
3	.57960E+03	.58884E+03	-.92401E+01	.15942E+01	.19979E+01
4	.66500E+03	.65713E+03	.78686E+01	.11833E+01	.17013E+01
5	.64170E+03	.69887E+03	-.57172E+02	.89035E+01	.12362E+02
6	.72250E+03	.72506E+03	-.25557E+01	.35373E+00	.55259E+00
7	.75010E+03	.73825E+03	.11847E+02	.15794E+01	.25615E+01
8	.61970E+03	.60272E+03	.16980E+02	.27401E+01	.36714E+01
9	.71940E+03	.73320E+03	-.13796E+02	.19178E+01	.29830E+01
10	.74490E+03	.76205E+03	-.17149E+02	.23022E+01	.37080E+01
11	.67150E+03	.62279E+03	.48707E+02	.72535E+01	.10531E+02
12	.62360E+03	.60201E+03	.21587E+02	.34618E+01	.46676E+01
13	.85340E+03	.82741E+03	.25991E+02	.30456E+01	.56198E+01
14	.61290E+03	.62796E+03	-.15057E+02	.24567E+01	.32556E+01
15	.97630E+03	.98522E+03	-.89163E+01	.91328E+00	.19279E+01
16	.51380E+03	.50379E+03	.10006E+02	.194[illegible]5E+01	.21635E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.57172E+02	.21100E+02
PERCENT DEVIATION	.12362E+02	.45621E+01
PCT MAG RNG901	.89095E+01	.30308E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.10864415E+05	16.	.67902591E+03

OF 2 REPRESENTING VARIABLE 9 TODIST

.68070E+04	0.	0.	0.	0.
0.	-.22649E+03	0.	0.	0.
0.	0.	0.	-.39373E+00	0.
0.	0.	0.	0.	0.
0.	.82338E+04	0.	-.39241E+02	-.15083E+03
0.	0.	0.	0.	0.
0.	.13660E+01	0.	.61501E+01	0.
0.				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.55420E+04	.59642E+04	-.42223E+03	.76187E+01	.48079E+01
2	.18480E+04	.14171E+04	.43093E+03	.23319E+02	.49070E+01
3	.20060E+04	.14749E+04	.53111E+03	.26476E+02	.60477E+01
4	.33910E+04	.33996E+04	-.85825E+01	.25310E+00	.97728E-01
5	.40200E+04	.44353E+04	-.41525E+03	.10330E+02	.47284E+01
6	.30040E+04	.28403E+04	.16373E+03	.54506E+01	.18644E+01
7	.33460E+04	.34815E+04	-.13549E+03	.40494E+01	.15429E+01
8	.21970E+04	.22864E+04	-.89399E+02	.40691E+01	.10180E+01
9	.19150E+04	.20455E+04	-.13052E+03	.68155E+01	.14862E+01
10	.18780E+04	.19551E+04	-.77053E+02	.41029E+01	.87740E+00
11	.31680E+04	.31657E+04	.23002E+01	.72607E-01	.26192E-01
12	.51370E+04	.55393E+04	-.40225E+03	.78305E+01	.45804E+01
13	.34430E+04	.35011E+04	-.58073E+02	.16867E+01	.66127E+00
14	.40340E+04	.42177E+04	-.18375E+03	.45549E+01	.20923E+01
15	.10630E+05	.99626E+04	.66744E+03	.62788E+01	.76001E+01
16	.34950E+04	.32664E+04	.22856E+03	.65397E+01	.26026E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.66744E+03	.24667E+03
PERCENT DEVIATION	.76001E+01	.28088E+01
PCT MAG TODIST	.26476E+02	.74654E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.15913492E+07	16.	.99459324E+05

OF 3 REPRESENTING VARIABLE 10 VLAND

.19546E+03	0.	0.	0.	0.
0.	-.40813E+01	-.93705E-03	0.	0.
-.27593E+00	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	.24279E+00	0.
0.	0.	0.	.34368E-01	0.
0.	.66266E-02	0.	.10384E+00	0.
.10296E-07				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.17270E+03	.17481E+03	-.21121E+01	.12230E+01	.18909E+01
2	.13000E+03	.12712E+03	.28752E+01	.22117E+01	.25741E+01
3	.16280E+03	.16372E+03	-.91798E+00	.56387E+00	.82183E+00
4	.19690E+03	.20162E+03	-.47250E+01	.23997E+01	.42301E+01
5	.18960E+03	.19210E+03	-.25024E+01	.13198E+01	.22403E+01
6	.15110E+03	.15063E+03	.46963E+00	.31081E+00	.42044E+00
7	.14050E+03	.13842E+03	.20832E+01	.14827E+01	.18650E+01
8	.11660E+03	.11922E+03	-.26223E+01	.22490E+01	.23477E+01
9	.14110E+03	.14252E+03	-.14232E+01	.10086E+01	.12741E+01
10	.13030E+03	.13060E+03	-.29631E+00	.22740E+00	.26527E+00
11	.16340E+03	.16155E+03	.18536E+01	.11344E+01	.16594E+01
12	.22760E+03	.22812E+03	-.52119E+00	.22899E+00	.46660E+00
13	.15780E+03	.15934E+03	-.15428E+01	.97768E+00	.13812E+01
14	.20440E+03	.20491E+03	-.51196E+00	.25047E+00	.45833E+00
15	.22830E+03	.23088E+03	-.25815E+01	.11307E+01	.23111E+01
16	.22340E+03	.22245E+03	.95090E+00	.42565E+00	.85130E+00

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.47250E+01	.17493E+01
PERCENT DEVIATION	.42301E+01	.15661E+01
PCT MAG VLAND	.23997E+01	.10715E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.69626274E+02	16.	.43516421E+01

OF 4 REPRESENTING VARIABLE 11 TIMENC(06)

.22947E+00	0.	-.83700E-01	-.19206E+00	-.29249E-02
-.10801E-02	0.	0.	0.	0.
0.	-.85552E-04	0.	0.	0.
.26823E-01	.27332E-01	.60492E-02	.17303E-03	0.
0.	.11407E+00	0.	.27159E-03	0.
0.	0.	0.	0.	0.
.56696E-05	0.	0.	0.	-.25329E-08
0.				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.20580E-01	.18508E-01	.20715E-02	.10066E+02	.75019E+01
2	.12190E-01	.10147E-01	.20432E-02	.16761E+02	.73992E+01
3	.97890E-02	.11345E-01	-.15560E-02	.15895E+02	.56349E+01
4	.94170E-02	.12595E-01	-.31781E-02	.33749E+02	.11509E+02
5	.14830E-01	.16135E-01	-.13053E-02	.88017E+01	.47271E+01
6	.15710E-01	.17902E-01	-.21916E-02	.13950E+02	.79368E+01
7	.23760E-01	.27207E-01	-.34465E-02	.14506E+02	.12481E+02
8	.37030E-01	.35413E-01	.16175E-02	.43679E+01	.58576E+01
9	.97850E-02	.98491E-02	-.64097E-04	.65505E+00	.23213E+00
10	.12300E-01	.97741E-02	.25259E-02	.20536E+02	.91475E+01
11	.16510E-01	.15492E-01	.10176E-02	.61634E+01	.36852E+01
12	.11620E-01	.12854E-01	-.12341E-02	.10621E+02	.44694E+01
13	.14930E-01	.14617E-01	.31268E-03	.20943E+01	.11324E+01
14	.12020E-01	.10560E-01	.14603E-02	.12149E+02	.52883E+01
15	.19010E-01	.12213E-01	.67971E-02	.35756E+02	.24616E+02
16	.97490E-02	.49274E-02	.48216E-02	.49457E+02	.17461E+02

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16 DATA POINTS (OBSERVATIONS)
                          MAXIMUM      AVERAGE
RESIDUALS (ABS VAL)     .67971E-02   .22277E-02
PERCENT DEVIATION       .24616E+02   .80675E+01
PCT MAG TIMENC(06)      .49457E+02   .15970E+02

ALL DATA REPRESENTS ADDED OBSERVATIONS

  SOURCE                  SS             DF       MS
 RESIDUALS          .12261015E-03   16.     .76631342E-05


OF  5     REPRESENTING VARIABLE 12 NMXAUG(07)
 .32600E+01  0.           0.           0.           0.
0.           0.           0.           0.           0.
0.           0.           0.           0.           0.
0.           0.           0.           0.           0.
0.           0.            .31116E+00  0.           0.
0.           0.           -.12989E-02  0.           0.
0.          -.18839E-03   0.           0.           0.
0.
```

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.22410E+01	.21027E+01	.13826E+00	.61695E+01	.65838E+01
2	.37670E+01	.33829E+01	.38409E+00	.10196E+02	.18290E+02
3	.36150E+01	.36954E+01	-.80371E-01	.22233E+01	.38272E+01
4	.22390E+01	.20042E+01	.23475E+00	.10485E+02	.11179E+02
5	.26320E+01	.26595E+01	-.27508E-01	.10451E+01	.13099E+01
6	.25330E+01	.25985E+01	-.65499E-01	.25858E+01	.31190E+01
7	.25800E+01	.25747E+01	.52504E-02	.20350E+00	.25002E+00
8	.24590E+01	.29079E+01	-.44894E+00	.18257E+02	.21378E+02
9	.30010E+01	.30499E+01	-.48857E-01	.16280E+01	.23265E+01
10	.35970E+01	.35009E+01	.96125E-01	.26724E+01	.45774E+01
11	.27090E+01	.26971E+01	.11921E-01	.44006E+00	.56768E+00
12	.19930E+01	.19247E+01	.68306E-01	.34273E+01	.32527E+01
13	.24540E+01	.23757E+01	.78279E-01	.31898E+01	.37276E+01
14	.22610E+01	.20433E+01	.21772E+00	.96293E+01	.10368E+02
15	.16670E+01	.14900E+01	.17698E+00	.10617E+02	.84276E+01
16	.24960E+01	.28635E+01	-.36749E+00	.14723E+02	.17500E+02

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.44894E+00	.15315E+00
PERCENT DEVIATION	.21378E+02	.72927E+01
PCT MAG NMXAUG(07)	.18257E+02	.60932E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.67116555E+00	16.	.41947847E-01

OF 6 REPRESENTING VARIABLE 13 RNG902

-.16076E+04	0.	0.	0.	0.
0.	0.	.77946E-01	0.	0.
0.	0.	.14280E+00	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	-.12133E+02
-.67123E-02	0.	0.	0.	0.
-.89610E-01	.20670E+00	0.	-.30847E+00	0.
-.81474E-06				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.16310E+04	.15105E+04	.12053E+03	.73901E+01	.67310E+01
2	.11900E+04	.10749E+04	.11509E+03	.96711E+01	.64268E+01
3	.36490E+03	.31022E+03	.54677E+02	.14984E+02	.30534E+01
4	.81280E+03	.87485E+03	-.62046E+02	.76336E+01	.34648E+01
5	.72450E+03	.74734E+03	-.22837E+02	.31521E+01	.12753E+01
6	.98090E+03	.85972E+03	.12118E+03	.12354E+02	.67672E+01
7	.11180E+04	.10724E+04	.45634E+02	.40817E+01	.25483E+01
8	.58490E+03	.67931E+03	-.94412E+02	.16142E+02	.52723E+01
9	.10290E+04	.99986E+03	.29141E+02	.28319E+01	.16273E+01
10	.10960E+04	.10582E+04	.37756E+02	.34449E+01	.21084E+01
11	.69750E+03	.61877E+03	.78734E+02	.11288E+02	.43968E+01
12	.66470E+03	.62707E+03	.37633E+02	.56617E+01	.21016E+01
13	.14700E+04	.13703E+04	.99708E+02	.67829E+01	.55681E+01
14	.55100E+03	.59374E+03	-.42743E+02	.77574E+01	.23869E+01
15	.18900E+04	.18305E+04	.59481E+02	.31472E+01	.33216E+01
16	.99280E+02	.20409E+01	.97239E+02	.97944E+02	.54302E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.12118E+03	.69928E+02
PERCENT DEVIATION	.67672E+01	.39050E+01
PCT MAG RNG902	.97944E+02	.13392E+02

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.95466834E+05	16.	.59666771E+04

OF 7 REPRESENTING VARIABLE 14 FIXWT

.54580E+04	0.	0.	0.	0.
0.	-.14678E+02	.28918E-01	0.	0.
.88829E+00	0.	0.	0.	-.19935E-04
0.	0.	0.	0.	0.
0.	.44308E+02	.94506E+01	0.	-.11764E+01
.62490E-03	-.12780E+01	-.46998E-01	0.	.28631E-03
.25311E-02	.58030E-02	-.18231E-04	.23730E+00	-.17517E-03
-.30148E-07				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.60940E+04	.60943E+04	-.27777E+00	.45580E-02	.27666E-01
2	.65140E+04	.65164E+04	-.24436E+01	.37516E-01	.24341E+00
3	.59880E+04	.59948E+04	-.68465E+01	.11434E+00	.68192E+00
4	.60860E+04	.60825E+04	.35326E+01	.58045E-01	.35186E+00
5	.59990E+04	.59972E+04	.18155E+01	.30263E-01	.18082E+00
6	.62150E+04	.62134E+04	.16014E+01	.25766E-01	.15950E+00
7	.60510E+04	.60521E+04	-.11102E+01	.18347E-01	.11058E+00
8	.59840E+04	.59846E+04	-.56806E+00	.94930E-02	.56580E-01
9	.66900E+04	.66853E+04	.47246E+01	.70622E-01	.47058E+00
10	.64970E+04	.65009E+04	-.39279E+01	.60458E-01	.39123E+00
11	.58710E+04	.58673E+04	.37193E+01	.63350E-01	.37044E+00
12	.58100E+04	.58081E+04	.19149E+01	.32959E-01	.19073E+00
13	.62520E+04	.62557E+04	-.36895E+01	.59013E-01	.36748E+00
14	.57440E+04	.57441E+04	-.11547E+00	.20103E-02	.11501E-01
15	.61310E+04	.61154E+04	.15621E+02	.25480E+00	.15559E+01
16	.56860E+04	.56947E+04	-.86803E+01	.15266E+00	.86457E+00

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.15621E+02	.37668E+01
PERCENT DEVIATION	.15559E+01	.37717E+00
PCT MAG FIXWT	.25480E+00	.62137E-01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.46107356E+03	16.	.28817098E+02

OF 8 REPRESENTING VARIABLE 15 FIF

-.22663E+05	0.	0.	0.	0.
.60770E+02	.28925E+03	.75092E+00	0.	0.
.40323E+02	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
-.14461E+00	0.	.99669E+01	-.20192E+02	-.19457E-01
-.16148E+01	.10841E+01	.18095E-02	-.54645E+01	-.29628E-02
0.				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.29430E+05	.29422E+05	.80925E+01	.27497E-01	.30601E-01
2	.29580E+05	.29054E+05	.52640E+03	.17796E+01	.19906E+01
3	.13270E+05	.12785E+05	.48482E+03	.36535E+01	.18333E+01
4	.27560E+05	.27370E+05	.19018E+03	.69007E+00	.71916E+00
5	.21150E+05	.21246E+05	-.96130E+02	.45452E+00	.36351E+00
6	.22960E+05	.22789E+05	.17097E+03	.74465E+00	.64652E+00
7	.22680E+05	.22859E+05	-.17915E+03	.78991E+00	.67745E+00
8	.15140E+05	.15292E+05	-.15204E+03	.10042E+01	.57494E+00
9	.34060E+05	.34253E+05	-.19290E+03	.56635E+00	.72943E+00
10	.26160E+05	.25834E+05	.32597E+03	.12461E+01	.12326E+01
11	.14130E+05	.14384E+05	-.25443E+03	.18007E+01	.96213E+00
12	.19830E+05	.19611E+05	.21892E+03	.11040E+01	.82782E+00
13	.35640E+05	.34960E+05	.68030E+03	.19088E+01	.25725E+01
14	.13960E+05	.14293E+05	-.33296E+03	.23851E+01	.12591E+01
15	.34410E+05	.34654E+05	-.24365E+03	.70808E+00	.92135E+00
16	.91950E+04	.91998E+04	-.47969E+01	.52168E-01	.18139E-01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.68030E+03	.25386E+03
PERCENT DEVIATION	.25725E+01	.95995E+00
PCT MAG FIF	.36535E+01	.11822E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.15312640E+07	16.	.95703999E+05

OF 9 REPRESENTING VARIABLE 16 FUELTM

-.67254E+04	0.	0.	0.	0.
0.	.12605E+03	.27584E+00	0.	-.28357E+02
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.12033E-01	-.33838E+04	0.	.16112E+02	0.
0.	.20865E+03	0.	-.97199E+01	-.11630E-01
-.47682E+00	.56816E+00	.62010E-03	-.24163E+01	-.12188E-02
0.				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.12590E+05	.12721E+05	-.13091E+03	.10398E+01	.11888E+01
2	.13860E+05	.13844E+05	.16027E+02	.11563E+00	.14554E+00
3	.67200E+04	.68069E+04	-.86880E+02	.12929E+01	.78896E+00
4	.13570E+05	.13892E+05	-.32187E+03	.23719E+01	.29229E+01
5	.10460E+05	.10366E+05	.93776E+02	.89652E+00	.85158E+00
6	.10710E+05	.10463E+05	.24726E+03	.23088E+01	.22455E+01
7	.10570E+05	.10385E+05	.18533E+03	.17534E+01	.16830E+01
8	.73400E+04	.74375E+04	-.97460E+02	.13278E+01	.88503E+00
9	.15930E+05	.16053E+05	-.12262E+03	.76974E+00	.11135E+01
10	.12090E+05	.12032E+05	.58276E+02	.48202E+00	.52921E+00
11	.68800E+04	.70008E+04	-.12079E+03	.17557E+01	.10969E+01
12	.99570E+04	.99553E+04	.16861E+01	.16933E-01	.15311E-01
13	.15790E+05	.15846E+05	-.56112E+02	.35536E+00	.50955E+00
14	.70280E+04	.72517E+04	-.22369E+03	.31829E+01	.20313E+01
15	.14330E+05	.14399E+05	-.69189E+02	.48283E+00	.62831E+00
16	.49180E+04	.47336E+04	.18436E+03	.37486E+01	.16741E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.32187E+03	.12602E+03
PERCENT DEVIATION	.29229E+01	.11443E+01
PCT MAG FUELTM	.37486E+01	.13668E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.36731332E+06	16.	.22957082E+05

OF 10 REPRESENTING VARIABLE 17 DEXH

.20955E+01	-.40011E-01	.19483E+01	0.	0.
0.	.26679E-01	0.	0.	-.40325E-01
0.	0.	0.	0.	0.
0.	0.	-.78739E-01	-.75955E-03	-.12289E-01
0.	0.	0.	0.	0.
.32133E-04	.31482E-01	0.	-.12342E-02	0.
0.	0.	0.	-.30680E-03	0.
0.				

FOLLOWING ARE THE TRUE DEPENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.39940E+01	.39365E+01	.57461E-01	.14387E+01	.29094E+01
2	.52030E+01	.52920E+01	-.88951E-01	.17096E+01	.45038E+01
3	.47740E+01	.47171E+01	.56852E-01	.11909E+01	.28766E+01
4	.52030E+01	.52976E+01	-.94575E-01	.18177E+01	.47886E+01
5	.48610E+01	.48271E+01	.33902E-01	.69743E+00	.17165E+01
6	.44600E+01	.44826E+01	-.22611E-01	.50698E+00	.11449E+01
7	.40100E+01	.41834E+01	-.17342E+00	.43247E+01	.87809E+01
8	.36060E+01	.39145E+01	-.30847E+00	.85544E+01	.15619E+02
9	.55810E+01	.56602E+01	-.79180E-01	.14187E+01	.40091E+01
10	.48310E+01	.48322E+01	-.11841E-02	.24511E-01	.59956E-01
11	.36570E+01	.37845E+01	-.12745E+00	.34852E+01	.64533E+01
12	.44330E+01	.45217E+01	-.88683E-01	.20007E+01	.44906E+01
13	.44680E+01	.45185E+01	-.50493E-01	.11301E+01	.25566E+01
14	.37370E+01	.37036E+01	.33412E-01	.89408E+00	.16917E+01
15	.40170E+01	.39437E+01	.73310E-01	.18250E+01	.37119E+01
16	.40170E+01	.39536E+01	.63395E-01	.15782E+01	.32099E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.30847E+00	.84585E-01
PERCENT DEVIATION	.15619E+02	.42828E+01
PCT MAG DEXH	.85544E+01	.20373E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.19372039E+00	16.	.12107525E-01

OF 11 REPRESENTING VARIABLE 18 ENGL

.17267E+01	-.10682E+00	.26658E+00	.56682E+01	0.
0.	0.	.95863E-04	.62058E-02	-.23986E-01
.32569E-01	0.	0.	0.	.60888E-06
.54893E+00	0.	0.	0.	0.
0.	-.30124E+01	0.	0.	0.
.44472E-04	0.	-.11671E-03	0.	0.
0.	0.	0.	0.	0.
-.87576E-09				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.12100E+02	.12064E+02	.36499E-01	.30165E+00	.54493E+00
2	.15770E+02	.15725E+02	.45221E-01	.28676E+00	.67515E+00
3	.14470E+02	.14393E+02	.77345E-01	.53452E+00	.11547E+01
4	.15770E+02	.15719E+02	.50965E-01	.32318E+00	.76089E+00
5	.13000E+02	.13020E+02	-.20110E-01	.15469E+00	.30024E+00
6	.11930E+02	.11927E+02	.34173E-02	.28645E-01	.51020E-01
7	.10720E+02	.10772E+02	-.52124E-01	.48623E+00	.77820E+00
8	.96420E+01	.97132E+01	-.71197E-01	.73840E+00	.10630E+01
9	.16340E+02	.16518E+02	-.17771E+00	.10875E+01	.26531E+01
10	.14140E+02	.14261E+02	-.12120E+00	.85715E+00	.18095E+01
11	.10710E+02	.10776E+02	-.66203E-01	.61815E+00	.98840E+00
12	.12980E+02	.13100E+02	-.12006E+00	.92495E+00	.17925E+01
13	.14720E+02	.14702E+02	.18127E-01	.12314E+00	.27063E+00
14	.12320E+02	.12296E+02	.24232E-01	.19669E+00	.36177E+00
15	.13240E+02	.13192E+02	.48398E-01	.36554E+00	.72257E+00
16	.13240E+02	.13211E+02	.29178E-01	.22038E+00	.43562E+00

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.17771E+00	.60124E-01
PERCENT DEVIATION	.26531E+01	.89764E+00
PCT MAG ENGL	.10875E+01	.45298E+00

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.89334081E-01	16.	.55833800E-02

OF 12 REPRESENTING VARIABLE 19 BDAWET

.65817E+03	0.	.23380E+03	0.	0.
.31588E+01	0.	.39174E-02	.14669E+00	-.45222E+01
-.19976E+01	0.	-.14843E-01	0.	0.
0.	0.	-.10433E+02	-.44798E+00	-.85987E+00
0.	0.	0.	-.42744E+00	.11880E+01
.41824E-02	0.	0.	-.10513E+00	0.
-.31735E-01	.17039E-01	.25757E-04	-.56389E-01	-.10286E-04
0.				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.14270E+04	.14194E+04	.75550E+01	.52943E+00	.14282E+01
2	.15930E+04	.16004E+04	-.74402E+01	.46705E+00	.14065E+01
3	.13820E+04	.13738E+04	.81532E+01	.58995E+00	.15412E+01
4	.16110E+04	.16076E+04	.34473E+01	.21398E+00	.65166E+00
5	.14170E+04	.14048E+04	.12233E+02	.86330E+00	.23125E+01
6	.14090E+04	.14075E+04	.15163E+01	.10761E+00	.28663E+00
7	.13300E+04	.13434E+04	-.13439E+02	.10104E+01	.25404E+01
8	.11930E+04	.12334E+04	-.40384E+02	.33851E+01	.76341E+01
9	.17220E+04	.17307E+04	-.86814E+01	.50415E+00	.16411E+01
10	.15160E+04	.15088E+04	.72337E+01	.47716E+00	.13674E+01
11	.12290E+04	.12396E+04	-.10598E+02	.86232E+00	.20034E+01
12	.13970E+04	.13989E+04	-.19125E+01	.13690E+00	.36153E+00
13	.15660E+04	.15612E+04	.48370E+01	.30888E+00	.91437E+00
14	.12650E+04	.12622E+04	.28384E+01	.22438E+00	.53655E+00
15	.15050E+04	.15129E+04	-.78697E+01	.52290E+00	.14877E+01
16	.12510E+04	.12517E+04	-.70466E+00	.56327E-01	.13321E+00

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.40384E+02	.86777E+01
PERCENT DEVIATION	.76341E+01	.16404E+01
PCT MAG BOWET	.33851E+01	.64124E+00

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.24917591E+04	16.	.15573494E+03

OF 13 REPRESENTING VARIABLE 8 RNG901

.65847E+01	0.	0.	0.	.20389E+03
0.	.13922E+02	0.	-.25695E+00	0.
0.	0.	0.	0.	.17693E-03
-.46949E+02	0.	0.	0.	0.
0.	.42679E+02	-.28623E+02	-.12779E+01	-.25976E+01
0.	-.29133E+02	0.	-.14515E+01	0.
-.10565E-01	0.	.60181E-04	-.19244E+00	.30557E-04
-.10315E-06				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.91440E+03	.89001E+03	.24391E+02	.26674E+01	.52737E+01
2	.74000E+03	.73789E+03	.21075E+01	.28479E+00	.45567E+00
3	.57960E+03	.54423E+03	.35371E+02	.61027E+01	.76478E+01
4	.66500E+03	.68254E+03	-.17541E+02	.26377E+01	.37925E+01
5	.64170E+03	.65927E+03	-.17574E+02	.27387E+01	.37998E+01
6	.72250E+03	.75181E+03	-.29311E+02	.40569E+01	.63376E+01
7	.75010E+03	.76064E+03	-.10545E+02	.14058E+01	.22799E+01
8	.61970E+03	.62345E+03	-.37503E+01	.60518E+00	.81088E+00
9	.71940E+03	.73230E+03	-.12897E+02	.17927E+01	.27885E+01
10	.74490E+03	.74207E+03	.28315E+01	.38012E+00	.61223E+00
11	.67150E+03	.68438E+03	-.12876E+02	.19174E+01	.27839E+01
12	.62360E+03	.62099E+03	.26094E+01	.41844E+00	.56419E+00
13	.85340E+03	.84973E+03	.36668E+01	.42967E+00	.79283E+00
14	.61290E+03	.59889E+03	.14011E+02	.22860E+01	.30294E+01
15	.97630E+03	.97616E+03	.14271E+00	.14617E-01	.30856E-01
16	.51380E+03	.46770E+03	.46102E+02	.89728E+01	.99681E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.46102E+02	.14733E+02
PERCENT DEVIATION	.99681E+01	.31855E+01
PCT MAG RNG901	.89728E+01	.22944E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.61335543E+04	16.	.38334714E+03

OF 14 REPRESENTING VARIABLE 13 RNG902

-.23071E+04	.76332E+02	0.	0.	0.
0.	0.	.81302E-01	-.34138E+01	0.
0.	0.	0.	0.	0.
-.30779E+02	0.	0.	0.	0.
0.	-.38438E+03	.96677E+02	0.	-.69685E+01
-.95319E-02	-.41383E+02	.11790E+01	-.19966E+01	0.
-.10169E+00	.21283E+00	0.	-.31048E+00	0.
-.82145E-06				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.16310E+04	.15287E+04	.10231E+03	.62726E+01	.57131E+01
2	.11900E+04	.11149E+04	.75089E+02	.63100E+01	.41932E+01
3	.36490E+03	.30607E+03	.58832E+02	.16123E+02	.32854E+01
4	.81280E+03	.80162E+03	.11181E+02	.13757E+01	.62440E+00
5	.72450E+03	.74588E+03	-.21380E+02	.29509E+01	.11939E+01
6	.98090E+03	.91690E+03	.64002E+02	.65248E+01	.35741E+01
7	.11180E+04	.10713E+04	.46665E+02	.41739E+01	.26059E+01
8	.58490E+03	.66351E+03	-.78609E+02	.13440E+02	.43896E+01
9	.10290E+04	.97359E+03	.55408E+02	.53846E+01	.30942E+01
10	.10960E+04	.11175E+04	-.21479E+02	.19597E+01	.11994E+01
11	.69750E+03	.66879E+03	.28708E+02	.41158E+01	.16031E+01
12	.66470E+03	.68843E+03	-.23733E+02	.35704E+01	.13253E+01
13	.14700E+04	.14077E+04	.62335E+02	.42405E+01	.34810E+01
14	.55100E+03	.57152E+03	-.20522E+02	.37245E+01	.11460E+01
15	.18900E+04	.17272E+04	.16279E+03	.86131E+01	.90906E+01
16	.99280E+02	.42839E+02	.56441E+02	.56851E+02	.31519E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.16279E+03	.55592E+02
PERCENT DEVIATION	.90906E+01	.31045E+01
PCT MAG RNG902	.56851E+02	.91019E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.71512060E+05	16.	.44695038E+04

OF 15 REPRESENTING VARIABLE 20 EMDRY(08)

-.34427E+04	.32647E+02	0.	.28154E+04	0.
.56796E+01	0.	.34581E-01	-.10549E+01	.10436E+02
-.31599E+02	0.	0.	0.	0.
-.46930E+03	-.13813E+03	.26042E+02	0.	0.
0.	-.70521E+03	0.	0.	0.
-.36129E-02	-.25074E+01	0.	0.	0.
-.25376E-01	0.	0.	.12006E+00	0.
-.44599E-06				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	-.14840E+04	.27454E+03	-.17585E+04	.11850E+03	.10499E+03
2	-.15930E+04	.51983E+03	-.21128E+04	.13263E+03	.12614E+03
3	-.15970E+04	.78176E+03	-.23788E+04	.14895E+03	.14202E+03
4	-.30820E+04	.95731E+03	-.40393E+04	.13106E+03	.24115E+03
5	-.22710E+04	.57869E+03	-.28497E+04	.12548E+03	.17013E+03
6	-.25260E+04	.49116E+03	-.30172E+04	.11944E+03	.18013E+03
7	-.15480E+04	.12260E+03	-.16706E+04	.10792E+03	.99737E+02
8	-.14710E+04	-.13543E+03	-.13356E+04	.90793E+02	.79735E+02
9	-.24760E+04	.98120E+03	-.34592E+04	.13960E+03	.20652E+03
10	-.17600E+04	.69912E+03	-.24591E+04	.13972E+03	.14681E+03
11	-.14070E+04	.39556E+03	-.18026E+04	.12811E+03	.10762E+03
12	-.28510E+04	.95503E+03	-.38060E+04	.13350E+03	.22723E+03
13	-.15300E+04	.45751E+03	-.19875E+04	.12990E+03	.11866E+03
14	-.19060E+04	.64755E+03	-.25535E+04	.13397E+03	.15245E+03
15	-.19030E+04	.43280E+03	-.23358E+04	.12274E+03	.13945E+03
16	-.21550E+04	.83061E+03	-.29856E+04	.13854E+03	.17825E+03

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.40393E+04	.25345E+04
PERCENT DEVIATION	.24115E+03	.15131E+03
PCT MAG EMDRY(08)	.14895E+03	.12755E+03

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.11191879E+09	16.	.69949245E+07

OF 16 REPRESENTING VARIABLE 21 TURNS

-.15057E+01	.55024E-01	0.	.22654E+01	.37983E+00
0.	0.	0.	-.22871E-02	0.
0.	0.	0.	0.	0.
.19454E+00	0.	0.	0.	0.
0.	-.16592E+01	0.	-.42332E-02	0.
0.	-.76175E-01	0.	0.	-.24678E-05
.38131E-04	0.	0.	-.15277E-04	0.
.11117E-09				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.88620E+00	.84749E+00	.38712E-01	.43683E+01	.10115E+02
2	.85260E+00	.96049E+00	-.10789E+00	.12654E+02	.28191E+02
3	.79810E+00	.90610E+00	-.10800E+00	.13533E+02	.28221E+02
4	.70880E+00	.79813E+00	-.89328E-01	.12603E+02	.23341E+02
5	.65650E+00	.73605E+00	-.79555E-01	.12118E+02	.20788E+02
6	.70760E+00	.79319E+00	-.85591E-01	.12096E+02	.22365E+02
7	.83680E+00	.65695E+00	.17985E+00	.21493E+02	.46996E+02
8	.57270E+00	.57396E+00	-.12568E-02	.21941E+00	.32834E+00
9	.73120E+00	.76327E+00	-.32072E-01	.43863E+01	.83805E+01
10	.81530E+00	.74885E+00	.66451E-01	.81505E+01	.17364E+02
11	.95540E+00	.83231E+00	.12309E+00	.12884E+02	.32165E+02
12	.69370E+00	.70771E+00	-.14010E-01	.20197E+01	.36609E+01
13	.93180E+00	.87593E+00	.55867E-01	.59956E+01	.14598E+02
14	.88190E+00	.89843E+00	-.16526E-01	.18739E+01	.43182E+01
15	.87320E+00	.74423E+00	.12897E+00	.14770E+02	.33701E+02
16	.79180E+00	.88527E+00	-.93474E-01	.11805E+02	.24425E+02

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.17985E+00	.76291E-01
PERCENT DEVIATION	.46996E+02	.19935E+02
PCT MAG TURNS	.21493E+02	.94356E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.12834490E+00	16.	.80215561E-02

OF 17 REPRESENTING VARIABLE 9 TODIST

.67509E+04	0.	0.	0.	0.
0.	-.22419E+03	0.	-.12144E+01	0.
0.	0.	0.	0.	0.
.29308E+03	0.	0.	0.	0.
0.	.90725E+04	0.	-.49056E+02	-.14681E+03
0.	-.88881E+01	0.	0.	0.
.15309E+00	.12466E+01	0.	.61503E+01	0.
-.48249E-07				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.55420E+04	.60219E+04	-.47991E+03	.86594E+01	.54647E+01
2	.18480E+04	.14376E+04	.41037E+03	.22206E+02	.46729E+01
3	.20060E+04	.16959E+04	.31007E+03	.15457E+02	.35308E+01
4	.33910E+04	.34459E+04	-.54897E+02	.16189E+01	.62511E+00
5	.40200E+04	.44285E+04	-.40855E+03	.10163E+02	.46521E+01
6	.30040E+04	.30189E+04	-.14892E+02	.49575E+00	.16958E+00
7	.33460E+04	.34704E+04	-.12445E+03	.37193E+01	.14171E+01
8	.21970E+04	.22987E+04	-.10171E+03	.46295E+01	.11582E+01
9	.19150E+04	.19334E+04	-.18400E+02	.96082E+00	.20952E+00
10	.18780E+04	.18014E+04	.76556E+02	.40765E+01	.87174E+00
11	.31680E+04	.31099E+04	.58102E+02	.18340E+01	.66160E+00
12	.51370E+04	.54624E+04	-.32539E+03	.63342E+01	.37051E+01
13	.34430E+04	.33941E+04	.48871E+02	.14194E+01	.55649E+00
14	.40340E+04	.42329E+04	-.19889E+03	.49304E+01	.22648E+01
15	.10630E+05	.99453E+04	.68468E+03	.64410E+01	.77964E+01
16	.34950E+04	.33571E+04	.13792E+03	.39461E+01	.15704E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.68468E+03	.21585E+03
PERCENT DEVIATION	.77964E+01	.24579E+01
PCT MAG TODIST	.22206E+02	.60557E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.13360402E+07	16.	.83502516E+05

OF 18 REPRESENTING VARIABLE 10 VLAND

.18971E+03	0.	0.	0.	0.
0.	-.36334E+01	-.11851E-02	.25828E-01	0.
0.	0.	0.	-.13345E-01	0.
.11222E+01	0.	0.	0.	0.
0.	-.87442E+01	0.	.28325E+00	0.
0.	.62015E+00	0.	0.	0.
-.19785E-03	.62651E-02	0.	.10256E+00	0.
.14430E-07				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.17270E+03	.17368E+03	-.98252E+00	.56892E+00	.87960E+00
2	.13000E+03	.12748E+03	.25232E+01	.19409E+01	.22589E+01
3	.16280E+03	.16301E+03	-.20548E+00	.12622E+00	.18396E+00
4	.19690E+03	.20216E+03	-.52612E+01	.26720E+01	.47101E+01
5	.18960E+03	.19376E+03	-.41600E+01	.21941E+01	.37242E+01
6	.15110E+03	.14945E+03	.16473E+01	.10902E+01	.14747E+01
7	.14050E+03	.13799E+03	.25114E+01	.17875E+01	.22483E+01
8	.11660E+03	.11810E+03	-.15013E+01	.12876E+01	.13440E+01
9	.14110E+03	.14135E+03	-.25148E+00	.17823E+00	.22514E+00
10	.13030E+03	.13040E+03	-.98963E-01	.75950E-01	.88597E-01
11	.16340E+03	.16199E+03	.14051E+01	.85991E+00	.12579E+01
12	.22760E+03	.22895E+03	-.13493E+01	.59284E+00	.12080E+01
13	.15780E+03	.15995E+03	-.21477E+01	.13610E+01	.19227E+01
14	.20440E+03	.20514E+03	-.73886E+00	.36148E+00	.66147E+00
15	.22830E+03	.22794E+03	.35658E+00	.15619E+00	.31923E+00
16	.22340E+03	.22124E+03	.21637E+01	.96854E+00	.19371E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.52612E+01	.17065E+01
PERCENT DEVIATION	.47101E+01	.15278E+01
PCT MAG VLAND	.26720E+01	.10138E+01

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.77469390E+02	16.	.48418369E+01

OF 19 REPRESENTING VARIABLE 11 TIMENC(06)

.18008E+00	0.	-.14028E+00	-.17151E+00	-.85788E-02
0.	0.	0.	-.37241E-04	.77794E-03
0.	0.	0.	0.	0.
.35796E-01	.29163E-01	.91157E-02	0.	.26912E-03
.53371E-06	.12271E+00	0.	0.	0.
0.	.87395E-03	0.	0.	0.
.16352E-05	-.46088E-05	0.	.11491E-04	-.65497E-08
-.83251E-12				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,0
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.20580E-01	.21561E-01	-.98100E-03	.47667E+01	.35527E+01
2	.12190E-01	.14927E-01	-.27367E-02	.22450E+02	.99107E+01
3	.97890E-02	.18384E-01	-.85946E-02	.87799E+02	.31125E+02
4	.94170E-02	.71552E-02	.22618E-02	.24018E+02	.81910E+01
5	.14830E-01	.17455E-01	-.26252E-02	.17702E+02	.95071E+01
6	.15710E-01	.17454E-01	-.17440E-02	.11101E+02	.63158E+01
7	.23760E-01	.24533E-01	-.77330E-03	.32546E+01	.28005E+01
8	.37030E-01	.27211E-01	.98189E-02	.26516E+02	.35559E+02
9	.97850E-02	.12726E-01	-.29414E-02	.30060E+02	.10652E+02
10	.12300E-01	.10551E-01	.17487E-02	.14217E+02	.63327E+01
11	.16510E-01	.20142E-01	-.36316E-02	.21996E+02	.13152E+02
12	.11620E-01	.16950E-01	-.53296E-02	.45866E+02	.19301E+02
13	.14930E-01	.11631E-01	.32993E-02	.22098E+02	.11948E+02
14	.12020E-01	.75960E-02	.44240E-02	.36805E+02	.16021E+02
15	.19010E-01	.94881E-02	.95219E-02	.50089E+02	.34483E+02
16	.97490E-02	.86401E-02	.11089E-02	.11374E+02	.40157E+01

16 DATA POINTS (OBSERVATIONS)

	MAXIMUM	AVERAGE
RESIDUALS (ABS VAL)	.98189E-02	.38463E-02
PERCENT DEVIATION	.35559E+02	.13929E+02
PCT MAG TIMENC(06)	.87799E+02	.26882E+02

ALL DATA REPRESENTS ADDED OBSERVATIONS

SOURCE	SS	DF	MS
RESIDUALS	.37003294E-03	16.	.23127059E-04

OF 20 REPRESENTING VARIABLE 12 NMXAUG(07)

-.99455E+00	0.	0.	.33440E+01	.12459E+01
-.40526E-01	.10862E+00	0.	.27026E-04	0.
0.	0.	0.	0.	0.
-.22649E+00	0.	0.	0.	.23825E-02
0.	-.98828E+00	0.	-.26177E-02	-.18579E-01
0.	-.15188E+00	-.10056E-02	-.89106E-02	0.
.25458E-03	0.	.50266E-07	-.14688E-02	-.68807E-07
.12700E-11				

FOLLOWING ARE THE TRUE DEPENDENDENT VARIABLE
VALUES, CORRESPONDING QUADRATIC FUNCTION VALUES,O
RESIDUALS, AND PER CENT TRUE VALUE AND RANGE, RESP.

OBS.	TRUE VALUE	FUN VALUE	RESIDUAL	P.C. MAG F	P.C. RAN F
1	.22410E+01	.22543E+01	-.13271E-01	.59219E+00	.63195E+00
2	.37670E+01	.37082E+01	.58756E-01	.15598E+01	.27979E+01
3	.36150E+01	.35850E+01	.30007E-01	.83008E+00	.14289E+01
4	.22390E+01	.22612E+01	-.22187E-01	.99094E+00	.10565E+01
5	.26320E+01	.26905E+01	-.58461E-01	.22212E+01	.27839E+01
6	.25330E+01	.25627E+01	-.29666E-01	.11712E+01	.14127E+01
7	.25800E+01	.25477E+01	.32350E-01	.12539E+01	.15405E+01
8	.24590E+01	.24476E+01	.11386E-01	.46304E+00	.54220E+00
9	.30010E+01	.30421E+01	-.41051E-01	.13679E+01	.19548E+01
10	.35970E+01	.35764E+01	.20577E-01	.57205E+00	.97984E+00
11	.27090E+01	.27379E+01	-.28897E-01	.10667E+01	.13761E+01
12	.19930E+01	.19285E+01	.64500E-01	.32363E+01	.30714E+01
13	.24540E+01	.24244E+01	.29609E-01	.12065E+01	.14099E+01
14	.22610E+01	.22701E+01	-.90619E-02	.40079E+00	.43152E+00
15	.16670E+01	.15659E+01	.10114E+00	.60674E+01	.48164E+01
16	.24960E+01	.25453E+01	-.49334E-01	.19765E+01	.23493E+01

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