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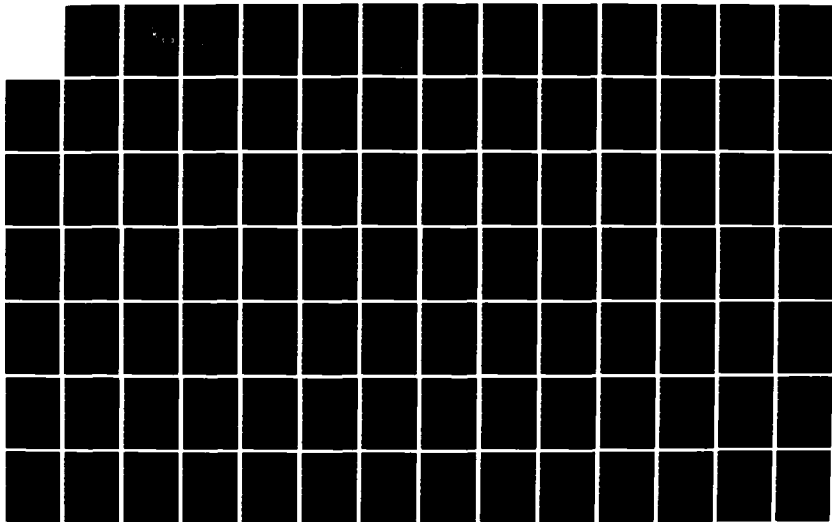
COPEs - A FORTRAN CONTROL PROGRAM FOR ENGINEERING  
SYNTHESIS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA  
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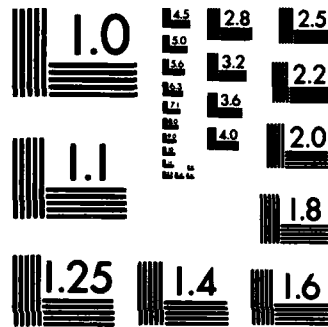
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COPES - A FORTRAN CONTROL PROGRAM  
FOR ENGINEERING SYNTHESIS  
BY  
LEROY E. MADSEN  
AND  
GARRET N. VANDERPLAATS  
March 1982

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Prepared for:  
Naval Postgraduate School  
Monterey, California  
93940

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Zoutendijk's method of feasible directions for constrained function minimization. Additionally, approximation techniques are available for use in optimization, and trade-off studies may be performed. A simple design example demonstrates the program capabilities. Programming guidelines are presented followed by sample input data and output for each program option.

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## ABSTRACT

A FORTRAN Control Program for Engineering Synthesis (COPES) has been developed for solving engineering design problems. The program maximizes or minimizes a numerically defined objective function subject to a set of inequality constraint functions. COPES uses the optimization program, CONMIN, which includes the conjugate direction method of Fletcher and Reeves for unconstrained function minimization and a modification of Zoutendijk's method of feasible directions for constrained function minimization. Additionally, approximation techniques are available for use in optimization, and trade-off studies may be performed. A simple design example demonstrates the program capabilities. Programming guidelines are presented followed by sample input data and output for each program option.

## I. INTRODUCTION

Most design processes require the minimization or maximization of some parameter which may be called the design objective. For the design to be acceptable, it must satisfy a variety of physical, aesthetic, economic and, on occasion, political limitations which are referred to here as design constraints. While part of the design problem may not be easily quantified, most of the design criteria can be described in numerical terms.

To the extent that the problem can be stated in numerical terms, a computer program can be written to perform the necessary calculations. For this reason, computer analysis is commonplace in most engineering organizations. For example, in structural design, the configuration, materials and loads may be defined and a finite element analysis computer code is used to calculate stresses, deflections and other response quantities of interest. If any of these parameters are not within the prescribed bounds, the engineer may change the structural member sizes and re-run the program. The computer code therefore provides only the analysis of a proposed design, with the engineer making the actual design decisions. This approach to design, which may be called computer-aided design, is commonly used today.

Another common use of analysis codes is in trade-off studies. For example, an aircraft trajectory analysis code may be run repetitively for several payloads, calculating the aircraft range, to determine the range-payload sensitivity.

A logical extension to computer-aided design is fully automated design, where the computer makes the actual design decisions, or to perform trade-off studies with a minimum of man-machine interaction. The purpose of the COPES program is to provide this automated design and trade-off capability. The user must provide a FORTRAN analysis program for analysis of the particular problem being considered. This analysis program is written according to a simple set of guidelines so that it can be easily coupled to the COPES program for automated design synthesis.

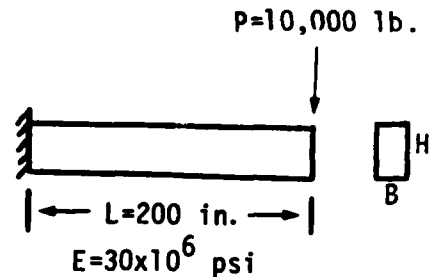
This document describes the capabilities of the COPES program and its usage. A simple design example is first presented to demonstrate the program capabilities. Guidelines are given for writing analysis codes which can be coupled directly to COPES. Finally the data organization is outlined and sample data is presented.

The most commonly used option of the COPES program will be for design optimization. Two approaches are available for this purpose. The first (NCALC = 2) is direct optimization of the function by the CONMIN optimization sub-program [Ref. 1]. An alternative to this is through the use of approximation techniques (NCALC = 6, Ref. 2). This second

option is usually more efficient for problems of under 6 design variables but which requires costly analysis, especially when multiple optimizations are to be performed.

DESIGN EXAMPLE

Assume it is required to design the cantilevered beam shown in Fig. 1. The objective is to find the minimum volume of material which will support the concentrated load. That is;



Minimize Volume = B·H·L (1) Figure 1 - Cantilevered Beam

The bending stress in the beam must not exceed 20,000 psi;

$$\sigma_b = \frac{Mc}{I} = \frac{6PL^2}{BH^2} \leq 20,000 \quad (2)$$

The shear stress must not exceed 10,000 psi;

$$\tau = \frac{3}{2} \frac{P}{A} = \frac{3P}{2BH} \leq 10,000 \quad (3)$$

and the deflection under the load must not exceed one inch;

$$\delta = \frac{PL^3}{3EI} = \frac{4PL^3}{EBH^3} \leq 1.0 \quad (4)$$

Additionally, geometric limits are imposed on the beam size so that;

$$0.5 \leq B \leq 5.0 \quad (5)$$

$$1.0 < H \leq 20.0 \quad (6)$$

$$H/B \leq 10.0 \quad (7)$$

Equation (1), the design objective, provides a measure of the efficiency of the design, while Eqs. (2-7) define the criteria which the structure must satisfy, and are referred to as constraints.

This design problem may be stated in general form;

Minimize  $F(\bar{X})$

Subject to:

$$G_j(\bar{X}) \leq 0 \quad i = 1, m$$

$$x_i^l \leq x_i \leq x_i^u$$

where  $\bar{X}$  is a vector containing the design variables  $B$  and  $H$  and  $G_j(\bar{X})$  are the constraints defined by Equations (2-7). There are eight constraints on the design. The objective and constraints are functions of the design variables.

While this problem is straightforward, its solution is not trivial because it is not known which constraints will be critical (i.e. which  $G_j(\bar{X}) = 0$ ) at the optimum.

One design approach is to assume that the bending and the displacement constraints are critical, so that Equations (2) and (4) are equalities, and then solve the two simultaneous equations for the design variables  $B$  and  $H$ . The remaining constraints are then checked to be sure they are satisfied, and if not, they are used to obtain a new design satisfying all constraints. When a design is obtained where two  $G_j(\bar{X}) = 0$  and the remaining  $G_j(\bar{X}) \leq 0$ , it is an acceptable design.

The design obtained here yields a volume of 6750 and satisfies all constraints. Note, however, that the objective function of Equation (1) played no part in the choice of design variables so that, using this approach, there is no assurance that a minimum volume design will be produced [Ref. 3]. More importantly, it is desirable to devise techniques for optimum design of systems which may be defined by more than two variables and by much more complex analysis, where the optimum design cannot be determined by inspection.

The COPES program provides this general capability by the use of the optimization program CONMIN [Ref. 1]. To use this design capability, a FORTRAN code must be provided which will calculate the various parameters. In writing the analysis code; 1) it is written in subroutine form with SUBROUTINE ANALIZ (ICALC) as the main routine, 2) it is segmented into INPUT, EXECUTION AND OUTPUT and 3) all parameters which may be design variables, object functions or constraints are contained in a single labeled common block called GLOBCM.

To demonstrate the simplicity with which a design-oriented analysis code can be written, the following FORTRAN subroutine was produced for the analysis of the cantilevered beam in Figure 1.

```

SUBROUTINE ANALIZ (ICALC)
COMMON /GLOBCM/ B,H,VOL,BSTRES,SHRSTR,DELTA,HB,E,AL
IF (ICALC.GT.1) GO TO 10
C --- INPUT OR INITIALIZATION.
B=2.5
H=10.
P=10,000.
E=30.E+6
AL=200.
WRITE (6,30)AL,P,E,B,H
RETURN
C --- EXECUTION.
10 CONTINUE
VOL=AL*B*H
BSTRES=6.*P*AL/(B*H*H)
SHRSTR=1.5*P/(B*H)
DELTA=4.*P*(AL**3)/(E*B*(H**3))
HB=H/B
IF (ICALC.LT.3) RETURN
C --- PRINT RESULTS.
20 WRITE (6,30)AL,P,E,B,H
WRITE (6,40)VOL,BSTRES,SHRSTR,DELTA,HB
30 FORMAT(/////5X,17HCANTILEVERED BEAM//5X,8HAL =,F9.3/5X,
* 8HP =,E12.5/5X,8HE =,E12.5//5X,8HB =,F9.3/5X,
* 8HH =,F9.3)
40 FORMAT(/5X,8HVOL =,F9.3//5X,8HBSTRES=,E12.5/5X,
8HSHRSTR=
* E12.5/5X,8HDELTA=,E12.5/5X,8HH/B =,F9.3)
RETURN
END

```

This routine may be executed as a simple analysis program by the following main program;

```

C MAIN PROGRAM TO EXECUTE SUBROUTINE ANALIZ.
DO 10 I = 1,3
10 CALL ANALIZ (I)
STOP
END

```

Moreover, ANALIZ can be coupled directly to the COPES program to perform this same function, or to perform optimization or trade-off studies.

This subroutine was coupled to COPES and an optimization

was performed (NCALC = 2) to yield the following design;

#### CANTILEVERED BEAM

L	=	200.00
P	=	.10000E+05
E	=	.30000E+08
B	=	1.82
H	=	18.16
VOL	=	6607.61
BSTRES	=	.20002E+05
SHRSTR	=	.45402E+03
DELTA	=	.97906E+00
H/B	=	9.98

The parameters L, P, E, B and H were input to the program and the remaining parameters were calculated. The design variables B and H were changed during the optimization process to obtain this design.

This design was achieved with 45 calls to ANALIZ with ICALC = 2 (45 analyses). This design could surely have been found with fewer analyses were it performed by hand calculations. However, once having written the analysis subroutine, numerous other designs may be obtained for different materials, loading, or design stresses with only minimal effort. Furthermore, the design obtained here of volume = 6607.6 is very near the theoretical optimum of 6603.9, while that which satisfied stress and displacement constraints simultaneously was not.

This very simple design example underscores the power of numerical optimization techniques and the ease with which they may be applied. The key to efficient use of the COPES program is the requirement that the ANALIZ code be written in a standard



format so that it may be coupled to COPES without modification. The following section contains guidelines for writing a design-oriented analysis code.

## II. PROGRAMMING GUIDELINES

In developing any computer code for engineering analysis, it is prudent to write the code in such a way that it is easily coupled to a general synthesis program such as COPES. Therefore, a general programming practice is outlined here which in no way inhibits the use of the computer program in its traditional role as an analytic tool, but allows for simple adaptation to COPES. This approach is considered good programming practice and provides considerable flexibility of design options. Only five basic rules must be followed:

- I. Write the code in subroutine form with the primary routine called as; SUBROUTINE ANALIZ (ICALC) The name ANALIZ is compatible with the COPES program and ICALC is a calculation control. Note that subroutine ANALIZ may call numerous other subroutines as required to perform the necessary calculations.
- II. Segment the program into INPUT, EXECUTION and OUTPUT. The calculation control, ICALC, will determine the portion of the analysis code to be executed.

ICALC = 1; the program reads all data required to perform the analysis. Also, any initialization of constants which will be used repetitively during execution is done here. This initial input information is printed here for later reference and for program debugging.

ICALC = 2: the program performs the execution phase of the analysis task. No data reading or printing is done here, except on user-defined scratch disc. Data may be printed here during program debugging, in which case it should be controlled by a print control parameter which is read during input. In this way, this print may be turned off after the program is debugged, but may be used again during future program expansion and debugging. The reason that printing is not normally allowed during execution is that when optimization is being done, the code will be called many times with ICALC = 2, resulting in voluminous print.

ICALC = 3: the results of the analysis are printed. Also the essential input parameters which may have been changed during optimization should be printed here for easy reference. In some cases, so much information is generated when ICALC = 2 that it would be inefficient to store it internally or on disc for printing when ICALC = 3. In this case, it may be desirable to actually execute when ICALC = 3 with a print code turned on to print his intermediate information. However, this approach should be avoided because it requires an additional complete execution of the program.

In summary, when;

ICALC = 1 Read input data.

ICALC = 2 Execute the analysis.

ICALC = 3 Print the results.

- III. Store all parameters which may be design variables, objective functions or constraints in a single labeled common block called GLOBCM. The order in which they are stored is arbitrary. A listing of the COPES program should be checked to see how many parameters may be stored in GLOBCM (the dimension of ARRAY). Initial distribution of COPES allows for 1500 parameters.
- IV. During execution or output, no parameters which are read during input should be updated. For example, if variable X is initialized during input, the execution segment must not update X such as  $X = X + 3.2$ . Instead a new variable,  $Y = X + 3.2$  should be defined.
- V. Write all programs in standard language, avoiding machine dependent capabilities such as multiple entry point (IBM), DEFINE statements (UNIVAC) and seven letter FORTRAN names (CDC). While this guideline is not essential to the use of the analysis code within the COPES program, it makes the analysis code much more transportable between different computer systems, a capability which easily justifies a slight reduction in efficiency on a given machine.

Adherence to these guidelines not only leads to a more readable and machine independent computer code, but allows

this code to be coupled to the COPES program without modification.

Having written the analysis code, it may be executed either with a simple main program or within the COPES program to perform the analysis. To insure that guideline IV is followed, the following main test program is recommended. Note that this program calls ANNALIZ twice with ICALC = 2 and ICALC = 3, to show that the same result is obtained repetitively

```
C MAIN PROGRAM TO CHECK SUBROUTINE ANALIZ,  
C READ, EXECUTE AND PRINT.  
  DO 10 ICALC = 1, 3  
10 CALL ANALIZ (ICALC)  
  C EXECUTE AND PRINT AGAIN TO BE SURE THE RESULTS  
  C DO NOT CHANGE.  
    DO 20 ICALC = 2, 3  
20 CALL ANALIZ (ICALC)  
  STOP  
  END
```

This program was executed with the ANALIZ subroutine for the cantilevered beam example to yield the following result:

CANTILEVERED BEAM

```
AL   = 200.00  
P    = .10000E+05  
E    = .30000E+08  
B    = 2.00  
H    = 5.00
```

#### CANTILEVERED BEAM

AL = 200.00  
P = .10000E+05  
E = .30000E+08  
B = 2.00  
H = 5.00  
VOL = 2000.00  
BSTRES = .24000E+06  
SHRSTR = .15000E+04  
DELTA = .42667E+02  
H/B = 2.50

#### CANTILEVERED BEAM

AL = 200.00  
P = .10000E+05  
E = .30000E+08  
B = 2.00  
H = 5.00  
VOL = 2000.00  
BSTRES = .24000E+06  
SHRSTR = .15000E+04  
DELTA = .42667E+02  
H/B = 2.50

This design was used as the initial design for the optimization presented previously. Note that, while the volume here is lower than the optimum, the bending stress and displacement each exceed the imposed limits by more than an order of magnitude.

Once the analysis code has been written, it can be coupled to the COPES program without modification. If it is desired to perform a simple analysis using COPES, only three data

cards are required for the COPES program, namely a TITLE card, a control parameter, NCALC = 1, and an END card. If the optimization or parametric analysis (sensitivity) capabilities of COPES are to be used, additional data must be read. This data will identify which parameters in the global common block, GLOBCM, are used. To set up the COPES data, the user must have a basic understanding of how the data in the global common block is accessed by COPES. This is outlined in the following section.

### III. DATA MANAGEMENT

In order to perform design operations, the COPES program must access the data in common block GLOBCM. This is done by defining the location in GLOBCM where a specified parameter resides. For example, consider the common block for the cantilevered beam;

```
COMMON/GLOBCM/B,H,VOL,BSTRES,SHRSTR,DELTA,HB,E,AL
```

The volume of material, VOL, is the third parameter in the common block; that is, it resides in location 3, referred to as the global location number. Similarly the bending stress, BSTRES, is in global location 4 and the beam width is in global location 1. Thus, the parameters are referred to by their respective location numbers in global common.

For convenience in preparing data for the COPES program, a simple "CATALOG" of parameters may be defined. For the cantilevered beam, this catalog would be;

<u>GLOBAL LOCATION</u>	<u>FORTTRAN NAME</u>	<u>DEFINITION</u>
1	B	Beam width
2	H	Beam height
3	VOL	Volume of Material
4	BSTRES	Maximum bending stress
5	SHRSTR	Maximum shear stress
6	DELTA	Deflection under the load
7	HB	Ratio, H/B



GLOBAL LOCATION	FORTTRAN NAME	DEFINITION
8	E	Young's modulus
9	AL	Length of beam

As another example, consider a global common block containing arrays;

```
COMMON/GLOBCM/A, Y(10), Q, C(2,2), H
```

The variable catalog for this common block is;

GLOBAL LOCATION	FORTTRAN NAME	DEFINITION
1	A	Area
2	Y(10)	Vector of y-coordinates
12	Q	.
13	C(2,2)	.
17	H	etc.

The dimensions are given with the FORTRAN name as a reminder that the parameter is an array. In this case, the third parameter in the Y array is in global location 4. Remembering that arrays are stored column by column the C(1,2) array location is in global location 15.

It will be seen that identifying parameters according to their location in GLOBCM provides a great deal of flexibility in using the COPES program for design.

Appendix A contains blank forms for writing the variable catalog for the user's particular problem.

#### IV. COPES TERMINOLOGY

The copes program currently provides six specific capabilities;

1. Simple analysis, just as if COPES was not used.
2. Optimization - Minimization or maximization of one calculated function with limits imposed on other functions using the CONMIN subprogram.
3. Sensitivity analysis - the effect of changing one or more design variables on one or more calculated functions.
4. Two-variable function space - analysis for all specified combinations of two design variables.
5. Optimum sensitivity - same as sensitivity analysis except at each step, the design optimized with respect to the remaining independent design variables.
6. Approximate optimization - optimization using approximation techniques. Usually more efficient than standard optimization for up to 6 design variables or if multiple optimizations are to be performed.

In defining the data required to execute the COPES program, the following definitions are useful:

Design Variables - Those parameters which the optimization program is allowed to change in order to improve the design. Design variables appear only on the right hand side

of equations in the analysis program. COPEs considers two types of design variables, independent and dependent. If two or more variables are always required to have the same value or be in a constant ratio, one is the independent variable while the remaining are dependent variables. For example, if the height is required to be 10 times the width of the cantilever beam, B would be the independent variable while H would be the dependent variable.

Objective Function - The parameter which is to be minimized or maximized during optimization. Also the parameters calculated as functions of specified design variables during a sensitivity or two-variable function space study. Objective functions always occur on the left side of equations, unless the objective function is also a design variable (the beam height may be minimized as an objective function if it is also a design variable. In this case the minimum height is found for which no constraints are violated). An objective function may be linear or non-linear, implicit or explicit, but must be a function of the design variables to be meaningful.

Constraint - Any parameter which must not exceed specified bounds for the design to be acceptable. Constraint functions, always appear on the left side of equations. Just as for objective functions, constraints may be linear or non-linear, implicit or explicit, but must be functions of the design variables.

Constraint Set - A group of constraints which appear consecutively in the global common block and which all have the same limits imposed. This is a convenience which allows several constraints to be identified with a minimum of data.

Global Common - Common block GLOBCM containing design information.

Global Location - Location of a particular parameter in GLOBCM.

## V. COPES DATA

The COPES program reads data from unit 5 and writes output on unit 6. Units 20 and 40 are used as scratch files. The scratch file numbers may be changed by changing two cards at the beginning of the COPES program.

In order to execute the COPES program it is necessary to provide formatted data for COPES, followed by data for the ANALIZ program which is coupled to COPES. This section defines the data which is required by COPES. The data is segmented into "BLOCKS" for convenience. All formats are alphanumeric for TITLE, and END cards, F10 for real data and I10 for integer data.

The COPES data begins with a TITLE card and ends with an END card. This is followed by data to be read by the user supplied subroutine ANALIZ or when ICALC = 1.

Comment cards may be inserted anywhere in the COPES data stack prior to the END card, and are identified by a dollar sign (\$) in column 1.

Data coding forms are provided in Appendix B.

## VI. UNFORMATTED DATA INPUT

While the user's sheet defines COPES data in formatted fields of ten, the data may actually be read in a simplified fashion by separating data by commas or one or more blanks. If more than one number is contained on an unformatted data card, a comma must appear somewhere on the card. If exponential numbers such as  $2.5+10$  are read on an unformatted card, there must be no embedded blanks. Unformatted cards may be intermingled with formatted cards. Real numbers on an unformatted card should have a decimal point.

### Examples:

Unformatted data;

5,7,1.3,1.0+20,0,-5.1

5,7,1.3,1.0+20,, -5.1

5 7 1.3 1.0+20,, -5.1

5        7 1.3, 1.0+20 0 -5.1

Equivalent formatted data;

col→	10	20	30	40	50	60	70	80
	5	7	1.3	1.0+20	0	-5.1		

Unformatted data;

2

2,3

2 3

Equivalent formatted data;

col+ 10      20      30

---

2

Note: This data has been right justified.

2      3

2 3

Note: This data contains no commas, so it is assumed to be formatted already.

Unformatted data;

1,2,3,4,5,6,7,8,9,10,11

Equivalent formatted data;

col+ 10      20      30      40      50      60      70      80

---

1

2

3

4

5

6

7

8

9

10

11

Note that two formatted data cards are created here.

Unformatted data;

1,2,3,4,5,6,

7,8,9,10,11

Equivalent formatted data;

col+ 10      20      30      40      50      60      60      80

---

1

2

3

4

5

6

7

8

9

10

11

Note that the above two examples do not produce the same formatted data cards.

DATA BLOCK A

DESCRIPTION: Title card.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
TITLE								20A4
CANTILEVERED BEAM DESIGN								

FIELD

CONTENTS

1-8 Any 80 character title may be given on this card.



DATA BLOCK B

DESCRIPTION: Program Control Parameters

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	FORMAT
NCALC	NDV	NSV	N2VAR	NXAPRX	IPNPUT	IPDBG	7I10
2	2	3	5	2	0	0	

FIELD

CONTENTS

- 1 NCALC: Calculation Control
- 0 - Read input and stop. Data of blocks A, B and V is required. Remaining data is optional.
  - 1 - One cycle through program. The same as executing ANALIZ stand-alone. Data of blocks A, B and V is required. Remaining data is optional.
  - 2 - Optimization. Data of blocks A-I and V is required. Remaining data is optional.
  - 3 - Sensitivity analysis. Data of blocks A, B, P, Q and V is required. Remaining data is optional.
  - 4 - Two variable function space. Data of blocks A, B, and R-V is required. Remaining data is optional.

CONTENTS

FIELD

1 - cont. NCALC:

- 5 - Optimum Sensitivity. Data of blocks A-I, P, Q, and V is required. Remaining data is optional.
- 6 - Optimization using approximation techniques. Data of blocks A-0 and V is required. Remaining data is optional.
- 2 NDV: Number of independent design variables in optimization.
- 3 NSV: Number of variables on which sensitivity analysis will be performed.
- 4 NZVAR: Number of objective functions in a two variable function space study.
- 5 NXAPRX: Number of X-variables for approximate analysis/optimization.
- 6 IPNPUT: Input print control.  
0 - Print card images of data plus formatted print of input data.  
1 - Formatted print only of input data.  
2 - No print of input data.
- 7 IPDBG: Debug print control.

DATA BLOCK C OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Integer optimization control parameters.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
IPRINT	ITMAX	ICNDIR	NSCAL	ITRM	LINOBJ	NACMXL		7I10
5	0	0	0	0	0	0		

FIELD

CONTENTS

- 1 IPRINT: Print control used in optimization.
  - 0 - No print during optimization.
  - 1 - Print initial and final optimization information.
  - 2 - Print above plus objective function value and design variable values at each iteration.
  - 3 - Print above plus constraint values, direction vector and move parameter at each iteration.
  - 4 - Print above plus gradient information.
  - 5 - Print above plus each proposed design vector, objective function and constraint values during the one-dimensional search.

FIELD

CONTENTS

- 2 ITMAX: Maximum number of optimization iterations allowed. DEFAULT = 20.
- 3 ICNDIR: Conjugate direction restart parameter. DEFAULT = NDV + 1.
- 4 NSCAL: Scaling parameter. GT.0 - Scale design variable to order of magnitude one every NSCAL iterations. LT.0 - Scale design variables according to user-input scaling values. Suggested values are 0 or NDV + 1.
- 5 ITRM: Number of consecutive iterations which must satisfy relative or absolute convergence criterion before optimization process is terminated. DEFAULT = 3.
- 6 LINOBJ: Linear objective function identifier. If the optimization objective is known to be a linear function of the design variables, set LINOBJ = 1. DEFAULT = Nonlinear.
- 7 NACMX1: One plus the maximum number of active constraints anticipated. DEFAULT = NDV + 2. If CONMIN writes an error message that the number of active and violated constraints exceeds N3-1, then NACMX1 must be increased (Note that NACMX1 = N3).

DATA BLOCK D OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Floating point optimization program parameters.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
FDCH	FDCHM	CT	CTMIN	CTL	CTLMIN	THETA		7F10
0.0	0.0	0.0	0.0	0.0	0.0	0.0		
DELFUN	DABFUN	ALPHAX	ABOJJI					4F10
0.0	0.0	0.0	0.0					

NOTE: TWO CARDS ARE READ HERE.

FIELD

CONTENT

- 1 FDCH: Relative change in design variables in calculating finite difference gradients. DEFAULT = 0.01.
- 2 FDCHM: Minimum absolute step in finite difference gradient calculations. DEFAULT = 0.01.

FIELD

CONTENTS

- 3 CT: Constraint thickness parameter. DEFAULT = -0.1.
- 4 CTMIN: Minimum absolute value of CT considered in the optimization process. DEFAULT = 0.004.
- 5 CTL: Constraint thickness parameter for linear constraints. DEFAULT = -0.01.
- 6 CTLMIN: Minimum absolute value of CTL considered in the optimization process. DEFAULT = 0.001.
- 7 THETA: Mean value of the push-off factor in the Method of Feasible Directions. DEFAULT = 1.0.
- 1 DELFUN: Minimum relative change in objective function to indicate convergence of the optimization process. DEFAULT = 0.001.
- 2 DABFUN: Minimum absolute change in objective function to indicate convergence of the optimization process. DEFAULT = 0.001 times the initial objective value.
- 3 ALPHAX: Maximum fractional change in any design variable for first estimate of the step in the one-dimensional search. DEFAULT = 0.1.
- 4 ABOBJI: Expected fractional change in the objective function for first estimate of the step in the one-dimensional search. DEFAULT = 0.1.

REMARKS:

- 1) The DEFAULT values for these parameters usually work well.

DATA BLOCK E OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Total number of design variables, design objective identification and sign.

FORMAT AND EXAMPLE

1	2	3	FORMAT
NDVTOT	IOBJ	SGNOPT	2I10,F10
0	3	-1.0	

FIELD

CONTENTS

- 1 NDVTOT: Total number of variables linked to the design variables. This option allows two or more parameters to be assigned to a single design variable. The value of each parameter is the value of the design variable times a multiplier, which may be different for each parameter. DEFAULT = NDV.
- 2 IOBJ: Global variable location associated with the objective function in optimization.
- 3 SGNOPT: Sign used to identify whether function is to be maximized or minimized. +1.0 indicates maximization. -1.0 indicates minimization. If SGNOPT is not unity in magnitude, it acts as a multiplier as well, to scale the magnitude of the objective.

DATA BLOCK F OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Design variable bounds, initial values and scaling factors.

FORMAT AND EXAMPLE

1	2	3	4	FORMAT
VLB	VUB	X	SCAL	4F10
.5	5.	0.0	0.0	

NOTE: READ ONE CARD FOR EACH OF THE NDV INDEPENDENT DESIGN VARIABLES.

FIELD

CONTENTS

- 1 VLB: Lower bound on the design variable. If VLB.LT.-1.0E+15, no lower bound.
- 2 VUB: Upper bound on the design variable. If VUB.GT.1.0E+15, no upper bound.
- 3 X: Initial value of the design variable. If X is non-zero, this will supercede the value initialized by the user-supplied subroutine ANALIZ.
- 4 SCAL: Design variable scale factor. Not used if NSCAL.GE.0 in Block C.



DATA BLOCK G OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Design variable identification.

FORMAT AND EXAMPLE

1	2	3	FORMAT
NDSGN	IDSGN	AMULT	2I10, F10
1-	1	1.0	

NOTE: READ ONE CARD FOR EACH OF THE NDVTOT DESIGN VARIABLES.

FIELD

CONTENTS

- 1 NDSGN: Design variable number associated with this parameter.
- 2 IDSGN: Global variable number associated with this parameter.
- 3 AMULT: Constant multiplier on this parameter. The value of the parameter will be the value of the design parameter, NDSGN, times AMULT. DEFAULT = 1.0.

DATA BLOCK H OMIT IF NDV = 0 IN BLOCK B

DESCRIPTION: Number of constraint sets.

FORMAT AND EXAMPLE

1	NCONS		FORMAT
4		I10	

FIELD

CONTENTS

1 NCONS: Number of constraint sets in the optimization problem.

REMARKS

1) If two or more adjacent parameters in the global common block have the same limits imposed, these are part of the same constraint set.

DATA BLOCK I OMIT IF NDV = 0 IN BLOCK B, OR NCONS = 0 IN BLOCK H

DESCRIPTION: Constraint identification and constraint bounds.

FORMAT AND EXAMPLE

1	2	3	4	FORMAT
ICON	JCON	LCON		3I10
4	0	0		
BL	SCAL1	BU	SCAL2	4F10
-1.0 +20	0.0	20000.	0.0	

NOTE: READ TWO CARDS FOR EACH OF THE NCONS CONSTRIANT SETS.

FIELD CONTENTS

- 1 ICON: First global number corresponding to the constraint set.
- 2 JCON: Last global number corresponding to the constraint set.  
DEFAULT = ICON.
- 3 LCON: Linear constraint identifier for this constraint set.  
LCON = 1 indicates linear constraints.

FIELD

CONTENTS

- 1 BL: Lower bound on the constrained variables. If BL.LT.-1.0E+15, no lower bound.
- 2 SCAL1: Normalization factor on lower bound. DEFAULT = MAX of ABS(BL), 0.1.
- 3 BU: Upper bound on the constrained variables. If BU.GT.1.0E+15, no upper bound.
- 4 SCAL2: Normalization factor on upper bound. DEFAULT = MAX of ABS(BU), 0.1.

REMARKS

- 1) The normalization factor should usually be defaulted.
- 2) The constraint functions sent to CONMIN are of the form;  
(BL - VALUE)/SCAL1 .LE. 0.0 and (VALUE - BU)/SCAL2 .LE. 0.0.
- 3) Each constrained parameter is converted to two constraints in CONMIN unless ABS(BL) or ABS(BU) exceeds 1.0E+15, in which case no constraint is created for that bound.

DATA BLOCK J OMIT IF NXAPRX = 0 IN BLOCK B

DESCRIPTION: Approximate analysis/optimization control parameters.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
NG	NXS	NXFS	NXA	INOM	ISCRX	ISCRXF	IPAPRX	8I10
5	1	1	1	0	0	0	1	
KMIN	KMAX	NPMAX	JNOM	INXLOC	INFLOC	MAXTRM		7I10
0	0	0	0	0	0			

FIELD

CONTENTS

- 1 NF: Number of functions to be approximated, Default = number of optimization objective and constraint functions.
- 2 NXS: Number of X-vectors read as data.
- 3 NXFS: Number of X-F pairs read as data.
- 4 NXA: If non-zero, the design variables read by SUBROUTINE ANALIZ form an X-vector.
- 5 INOM: Nominal X-vector. Default = best available.

FIELD

CONTENTS

- 6 ISCRX: File from which NXS X-vectors are read. Default = 5.
- 7 ISCRXF: File from which NXFS X-F pairs of data are read. Default = 5.
- 8 IPAPRX: Print Control. Values of 0-4 with increasing amounts of print for larger IPAPRX.
- 1 KMIN: Minimum number of approximation iterations. Default = 2 \* NDV + 1 - NXS - NXFS - NXA.
- 2 KMAX: Maximum number of approximation iterations. Default = 3 \* NXAPRX + 3 \* (NXAPRX + NXAPRX\*\*2)/2 + 1 - NXS - NXFS - NXA.
- 3 NPMAX: Maximum number of designs retained for Taylor series expansion.
- 4 JNOM: Number of iterations after which the best design is picked as nominal. Default = 2 \* NXAPRX + (NXAPRX + NXAPRX\*\*2).
- 5 INXLLOC: X-variable global location identifier. If INXLLOC = 0, the Taylor series expansion is on the design variables listed in BLOCK G.
- 6 INFLOC: Function global location identifier. If INFLOC = 0, the objective and constraint functions identified in BLOCKS E AND I are the functions on which the Taylor series expansion is performed.
- 7 MAXTRM: Terms retained in Taylor series expansion.
  - 1 - Linear only.
  - 2 - Linear plus diagonal elements of Hessian Matrix.
  - 3 - Full 2nd order expansion.DEFAULT = 3.

REMARKS

- 1) If ISCRX and/or ISCRXF file number is other than 5, the data read from that file is assumed to be binary data.
- 2) If NXS = NXFS = 0, NXA is defaulted to NXA = 1, even if it is read as zero. Also, a second vector of design variables is automatically defined by COPES to yield two independent designs to start the optimization.

DATA BLOCK K OMIT IF NXAPRX = 0 IN BLOCK B

DESCRIPTION: Bounds and multipliers for approximate optimization.

FORMAT AND EXAMPLE

	1	2	3	4	5	6	7	8	FORMAT
DXI		DX2	DX3	DX4	DX5	...	...	...	8F10
.5		2.							
XFACT1		XFACT2							
0.		0.							2F10

NOTE: TWO OR MORE CARDS ARE READ HERE.

FIELD

CONTENTS

- 1-8 DXI: Allowable change (in magnitude) of the Ith design variable during each approximate optimization.
- 1 XFACT1: Multiplier on DXI when the diagonal elements of the H matrix are available. Default = 1.5.
- 2 XFACT2: Multiplier on DXI when all elements of the H matrix are available.

DATA BLOCK L OMIT IF NXAPRX = 0 IN BLOCK B OR INXLOC = 0 IN BLOCK J

DESCRIPTION: Global locations of approximating variables.

FORMAT AND EXAMPLE:

	1	2	3	4	5	6	7	8	FORMAT
LOCX1		LOCX2	LOCX3	LOCX4	.....	.....	.....	.....	8110
	1								
		2							

NOTE: MORE THAN ONE CARD MAY BE READ HERE.

FIELD

1-8 LOCXI: Global location of Ith approximating variable.

CONTENTS

REMARKS

- 1) If INXLOC = 0 in BLOCK J, this data is not read. In this case, the data is defaulted to be the global locations of the design variables (IDSGN values in BLOCK G).



DATA BLOCK M OMIT IF NXAPRX = 0 IN BLOCK B OR INFLOC = 0 IN BLOCK J

DESCRIPTION: Global locations of functions to be approximated.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
LOC F1	LOC F2	LOC F3	LOC F4	.....	.....	.....	.....	8I10
3	5	6	4					

NOTE: MORE THAN ONE CARD MAY BE READ HERE.

FIELD

CONTENTS

1-8 LOC F I: Global location of Ith function to be approximated.

REMARKS

- 1) If INFLOC = 0 in BLOCK J, this data is not read. In this case, the data is defaulted to be the global locations of the objective function (IOBJ in BLOCK E) followed by the global locations of the constrained parameters (ICON-JCON in BLOCK I).

DATA BLOCK N OMIT IF NXAPRX = 0 in BLOCK B OR NXS = 0 IN BLOCK J

DESCRIPTION: X-Vectors for approximate optimization.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
XI1	XI2	XI3	XI4	...	...	...	...	8F10
4.	15.							

NOTE: NXS SETS OF DATA ARE READ HERE.

NOTE: MORE THAN ONE CARD MAY BE READ FOR EACH SET OF DATA.

FIELD

CONTENTS

1-8 XIJ: Jth value of Ith X-vector, J = 1, NXAPRX.

DATA BLOCK 0 OMIT IF NXAPRX = 0 IN BLOCK B OR NXFS = 0 IN BLOCK J

DESCRIPTION: X-F pairs of information for approximate optimization.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
X1	X2	X3	X4	...	...	...	...	8F10
2.	18.							
Y1	Y2	Y3	Y4	Y5	...	...	...	8F10
7200.	416.667	.914495	18518.519					

NOTE: NXFS SETS OF DATA ARE READ HERE.

NOTE: MORE THAN ONE CARD MAY BE REQUIRED FOR XI OR YI.

NOTE: NXAPRX VALUES OF X AND NF VALUES OF Y ARE READ FOR EACH SET OF DATA.

FIELD

CONTENTS

1-8 XI: Ith value of X, I = 1, NXAPRX.

1-8 YI: Ith value of Y, I = 1, NF.

DATA BLOCK P OMIT IF NSV = 0 IN BLOCK B

DESCRIPTION: Sensitivity objectives.

FORMAT AND EXAMPLE

	1	2	3	4	5	6	7	8	FORMAT
NSOBJ		IPSENS							2I10
	5	0							
NSN1		NSN2	NSN3	NSN4	NSN5	...	...	...	8I10
	3	4	5	6	7				

NOTE: TWO OR MORE CARDS ARE READ HERE.

FIELD

CONTENTS

- 1 NSOBJ: Number of separate objective functions to be calculated as functions of the sensitivity variables.
- 2 IPSENS: Print control. If IPSENS.GT.0, detailed print will be called at each step in the sensitivity analysis. DEFAULT = No print.
- 1-8 NSNI: Global variable number associated with the i-th sensitivity function.

REMARKS

- 1) More than eight sensitivity objectives are allowed. Add data cards as required to contain data.

DATA BLOCK Q OMIT IF NSV = 0 IN BLOCK B

DESCRIPTION: Sensitivity variables.

FORMAT AND EXAMPLE

	1	2	3	4	5	6	7	8	FORMAT
ISENS		NSENS							2I10
	9		4						
SNS1		SNS2	SNS3	SNS4	.....	.....	.....	.....	8F10
	200.	100.	150.	250.					

NOTE: READ ONE SET OF DATA FOR EACH OF THE NSV SENSITIVITY VARIABLES.

NOTE: TWO OR MORE CARDS ARE READ FOR EACH SET OF DATA.

FIELD                      CONTENTS

- 1    ISENS: Global variable number associated with the sensitivity variable.
- 2    NSENS: Number of values of this sensitivity variable to be read on the next card.
- 1-8    SENSI: Values of the sensitivity variable. I = 1, NSENS. I = 1 corresponds to the nominal value.

REMARKS

- 1) More than eight values of the sensitivity variable are allowed. Add data cards as required to contain the data.

DATA BLOCK R OMIT IF N2VAR = 0 IN BLOCK B

DESCRIPTION: Two variable function space control parameters.

FORMAT AND EXAMPLE

	1	2	3	4	5	FORMAT
N2VX		M2VX	N2VY	M2VY	IP2VAR	5110
	1		4	2	5	0

FIELD

CONTENTS

- 1 N2VX: Global location of the X-variable in the two variable function space.
- 2 M2VX: Number of values of X to be considered.
- 3 N2VY: Global location of the Y-variable in the two variable function space.
- 4 M2VY: Number of values of Y to be considered.
- 5 IP2VAR: Print control. If IP2VAR.GT.0, detailed print will be called at each step (each X-Y combination). DEFAULT = No print.

DATA BLOCK S OMIT IF N2VAR = 0 IN BLOCK B

DESCRIPTION: Functions to be evaluated in the two variable function space study.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
NZ1	NZ2	NZ3	NZ4	NZ5	...	...	...	8I10
3	4	5	6	7				

FIELD

CONTENTS

1-8 NZI: Global location corresponding to the Ith function of X and Y to be calculated. N2VAR values are read here.

REMARKS

- 1) More than eight functions are allowed. Add data cards as required to contain the data.

DATA BLOCK T OMIT IF N2VAR = 0 IN BLOCK B

DESCRIPTION: Values of the X-variable in a two variable function space study.

FORMAT AND EXAMPLE

	1	2	3	4	5	6	7	8	FORMAT
X1		X2	X3	X4	...	...	...	...	8F10
0.5		1.0	1.5	2.0					

FIELD

CONTENTS

1-8 XI: Values of the X-variable in the two variable function space. M2VX values are read here.

REMARKS

1) More than eight values are allowed. Add data cards as required to contain the data.



DATA BLOCK U OMIT IF NZVAR = 0 IN BLOCK B

DESCRIPTION: Values of the Y-variable in a two variable function space study.

FORMAT AND EXAMPLE

1	2	3	4	5	6	7	8	FORMAT
Y1	Y2	Y3	Y4	Y5	...	...	...	8F10
4.0	8.0	12.0	16.0	20.0				

FIELD

CONTENTS

1-8 YI: Values of the Y-variable in the two variable function space. M2VY values are read here.

REMARKS

1) More than eight values are allowed. Add data cards as required to contain the data.

DATA BLOCK V

DESCRIPTION: COPEs data 'END' card.

FORMAT AND EXAMPLE

1	FORMAT
END	3A1
END	

FIELD

CONTENTS

1 The word 'END' in columns 1-3.

REMARKS

- 1) This card MUST appear at the end of the COPEs data.
- 2) This ends the COPEs input data.
- 3) Data for the user-supplied routine, ANALIZ, follows this.

## VII. SAMPLE COMPUTER SOLUTIONS

Sample solutions are presented here for the various COPES program options defined by the parameter NCALC in DATA BLOCK B. The ANALIZ routine given in the design example section was used to produce the results given here. Note that SUBROUTINE ANALYZ does not read data, so only COPES data is required here. In the usual case where data is read as input to the analysis routine, this data would follow directly after the COPES 'END' card.

The output from a COPES program execution includes a title page followed by a copy of the input data. Then the required program executions are performed and final output information is printed. Figures 2-7 contain output for all options of COPES as follows:

<u>NCALC</u>	<u>FIGURE</u>	<u>PROBLEM SOLVED</u>
1	2	Analysis only
2	3	Optimization by CONMIN
3	4	Sensitivity study
4	5	Two-variable function space study
5	6	Optimum sensitivity
6	7	Optimization using approximation techniques

Note that data for the COPES program is read depending on the value of the parameters NDV, NSV, N2VAR and NXAPRX in DATA BLOCK B. The actual program execution is determined by the value of NCALC. Therefore, data may be read for all program options even though only one option of the program is to be executed. Figure 8 is a copy of the combined data for all the previous examples. This data may be used for any program option simply by changing the value of NCALC. Figure 9 is a copy of this same data using the simplified data input mode and Figure 10 is the same data without the comment cards.

```

CCCCCCC CCCCCC PPFPPP EEEEE SSSSSS
C C C C C C C C P P P P P P E E E E E
C C C C C C C C P P P P P P E E E E E
C C C C C C C C P P P P P P E E E E E
CCCCCCC CCCCCC PPFPPP EEEEE SSSSSS
C C C C C C C C P P P P P P E E E E E
C C C C C C C C P P P P P P E E E E E
CCCCCCC CCCCCC PPFPPP EEEEE SSSSSS

```

C C N T R C L P R O G R A M  
 F O R  
 E N G I N E E R I N G S Y N T H E S I S

T I T L E

CANTILEVERED BEAM ANALYSIS AND DESIGN

CARD IMAGES OF CONTRCL DATA

CARD	IMAGE
1)	CANTILEVERED BEAM ANALYSIS AND DESIGN
2)	1
3)	FNC

FIG. 2 - ANALYSIS ONLY

TITLE:  
CANTILEVERED BEAM ANALYSIS AND DESIGN

CONTROL PARAMETERS:  
 CALCULATIONAL CONTROL, NCALC = 1 0  
 NUMBER OF GLOBAL DESIGN VARIABLES, NCV = 0 0  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 0 0  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2VAR = 0 0  
 NUMBER OF APPROXIMATING VAR., NXAPRX = 0 0  
 INPUT INFLECTION PRINT CODE, IPNPUT = 0 0  
 DEBUG PRINT CODE, IPDBG = 0 0

CALCULATIONAL CONTROL, NCALC  
 VALUE  
 1 MEANING ANALYSIS  
 2 SINGLE ANALYSIS  
 3 OPTIMIZATION  
 4 SENSITIVITY  
 5 TWO-VARIABLE FUNCTION SPACE  
 6 APPROXIMATE OPTIMIZATION

\* \* ESTIMATED DATA STORAGE REQUIREMENTS

INPUT	REAL	AVAILABLE	INPUT	INTEGER	AVAILABLE
9	EXECUTION	5000	1	EXECUTION	1000
	5			1	

CANTILEVERED BEAM

AL	=	200.000
P	=	0.10000E 05
E	=	0.30000E 08
B	=	2.500
F	=	10.000

FIG. 2 - CONT.

CANTILEVERED BEAM

AL = 200.000 05  
PE = 0.10000E 08  
E = 0.30000E 08

R = 2.500  
H = 10.000

VCL = 5000.000

BSTRES = 6.48000E 05  
SHSTR = 0.60000E 03  
DELTA = 0.42667E 01  
1/2 = 4.000

PRCGFAP CALLS TO ANALIZ

ICALC CALLS  
1 1  
2 1  
3 1

FIG. 2 - CONCLD.

```

CCCCCCC      CCCCCC      PFFFFPP      EEEEEEE      SSSSSS
C          C          P          E          S
C          C          P          E          S
C          C          P          E          S
C          C          P          E          S
CCCCCCC      CCCCCC      P          E          S

```

C O N T R O L P R O G R A M  
 F O R  
 E N G I N E E R I N G S Y N T H E S I S

T I T L E

CANTILEVERED BEAM ANALYSIS AND DESIGN

CARD IMAGES OF CONTROL DATA

CARD	IMAGE
1)	CANTILEVERED BEAM ANALYSIS AND DESIGN
2)	\$ DATA BLOCK B
3)	\$ NCALC
4)	NDV
5)	\$ DATA BLOCK C - DEFAULT ALL BUT PRINT CONTROL
6)	\$ IPRINT
7)	\$

FIG. 3 - OPTIMIZATION



```

8) $ DATA BLOCK C - ALL DEFAULTS
9) 0.
10) C.
11) $ DATA BLOCK E IOBJ SGNOPT
12) 0. -1.
13) C.
14) $ DATA BLOCK F VUB
15) VLB
16) $ WIDTH, B 5.
17) $ HEIGHT, H 20.
18) $ DATA BLOCK G ICSGN APULT
19) 1 1.
20) 2 1.
21) $ WIDTH, B
22) $ HEIGHT, H
23) $ DATA BLOCK H
24) NCONS
25) $ DATA BLOCK I JCON ICON SCAL2
26) ICCN SCAL1 BU 20000. 0 0.
27) $ CONSTRAINT ON ESTRES 0
28) $ CONSTRAINT CN SHRSTR 10000. 0 0.
29) -1.0 +20 0.0 CN DELTA 1. 0 0.
30) $ CONSTRAINT CN F/B 0
31) -1.0 +20 0.0 CN DELTA 1. 0 0.
32) $ CONSTRAINT CN F/B 0
33) -1.0 +20 0.0 CN DELTA 1. 0 0.
34) $ CONSTRAINT CN F/B 0
35) -1.0 +20 0.0 CN DELTA 1. 0 0.
36) $ CONSTRAINT CN F/B 0
37) -1.0 +20 0.0 CN DELTA 1. 0 0.
38) $ CONSTRAINT CN F/B 0
39) -1.0 +20 0.0 CN DELTA 1. 0 0.
40) $ CONSTRAINT CN F/B 0
41) -1.0 +20 0.0 CN DELTA 1. 0 0.
42) $ CONSTRAINT CN F/B 0
43) -1.0 +20 0.0 CN DELTA 1. 0 0.
44) $ DATA BLOCKS J-L ARE NOT REQUIRED.
45) $ DATA BLOCK V
46) $ REQUIRED END CARD
47) END

```

TITLE: CANTILEVERED BEAM ANALYSIS AND DESIGN

CONTROL PARAMETERS:  
 CALCULATION CONTROL, NCALC = 2  
 NUMBER OF GLOBAL DESIGN VARIABLES, NDV = 2  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 0  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2VAR = 0  
 NUMBER OF APPROXIMATING VAR, NXAPRX = 0  
 INPUT INFORMATION PRINT CODE, IPNPUT = 0  
 DEBUG PRINT CODE, IPCBG = 0

CALCULATION CONTROL, NCALC  
 VALUE  
 1 MEANING ANALYSIS  
 2 OPTIMIZATION  
 3 SENSITIVITY  
 4 TWO-VARIABLE FUNCTION SPACE  
 5 OPTIMUM SENSITIVITY  
 6 APPROXIMATE OPTIMIZATION

\* \* OPTIMIZATION INFORMATION

GLOBAL VARIABLE NUMBER OF OBJECTIVE  
 MULTIPLIER (NEGATIVE INDICATES MINIMIZATION) = -0.1000E 01

CONIN PARAMETERS (IF ZERO, CONIN DEFAULT WILL OVER-RIDE)

IPRINT	ITMAX	ICDIR	NSCAL	ITRM	LINOBJ	NACMX1	NFDG
1	0	0	0	0	0	4	0
FDCH	FDCHM	CT	CTMIN				
0.0	0.0	0.0	0.0				
CTL	CTLMIN	THETA	PHI				
0.0	0.0	0.0	0.0				
DELFUN	CARFUN	ALPHAX	ABOBJ1				
0.0	0.0	0.0	0.0				

FIG. 3 - CONT.

DESIGN VARIABLE INFORMATION  
 NON-ZERO INITIAL VALUE WILL OVER-RIDE MODULE INPUT  
 C.V. I C.H.R. BOUND UPPER BOUND INITIAL VALUE SCALE  
 NO. 1 C.500000E 00 0.500000E C1 C.0 C.0  
 2 0.100000E 01 C.200000E 02 C.0 C.C

DESIGN VARIABLES GLOBAL MULTIPLYING  
 D.V. NO. VAR. NO. FACTOR  
 1 1 0.100000E 01  
 2 2 0.100000E 01

CONSTRAINT INFORMATION

THERE ARE 4 CONSTRAINT SETS  
 GLOBAL GLOBAL LINEAR  
 ID VAR. 1 VAR. 2 ID  
 1 4 0 0  
 2 5 0 0  
 3 6 0 0  
 4 7 0 0

TOTAL NUMBER OF CONSTRAINED PARAMETERS = 4

NORMALIZATION  
 LOWER BOUND 16 0.110000E 16  
 -C.110000E 16 0.110000E 16  
 -C.110000E 16 0.110000E 16  
 UPPER BOUND C5 0.200000E C5  
 C.100000E C1 0.100000E 01  
 C.100000E 02 C.100000E C2

\*\* ESTIMATED DATA STORAGE REQUIREMENTS

REAL EXECUTICN 129 INTEGER EXECUTICN 41  
 INPUT EXECUTICN 37 AVAILABLE 5000 INPUT EXECUTICN 21 AVAILABLE 1000

CANTILEVERED BEAM

AL = 100.000  
 P = C.100000E 05  
 E = C.200000E C6  
 E = 2.500  
 P = 10.000



FINAL OPTIMIZATION INFORMATION

OBJ = C.66C938E 04

DECISION VARIABLES (X-VECTOR)  
1) 0.16179E C1 0.18179E 02

CONSTRAINT VALUES (G-VECTOR)  
1) -0.12367E-02 -0.95461E CC -0.23254E-01 -0.31548E-04

THERE ARE 2 ACTIVE CONSTRAINTS  
CONSTRAINT NUMBERS ARE  
1 4

THERE ARE 0 VIOLATED CONSTRAINTS

THERE ARE C ACTIVE SIDE CONSTRAINTS

TERMINATION CRITERION  
ABS(1-OBJ(I-1))/OBJ(I) LESS THAN DELFUN FOR 3 ITERATIONS  
ABS(CBJ(I)-CBJ(I-1)) LESS THAN CABFUN FOR 3 ITERATIONS

NUMBER OF ITERATIONS = 9

OBJECTIVE FUNCTION WAS EVALUATED 35 TIMES

CONSTRAINT FUNCTIONS WERE EVALUATED 35 TIMES

OPTIMIZATION RESULTS

OBJECTIVE FUNCTION 3      FUNCTION VALUE 0.66094E 04  
 GLOBAL LOCATION

DESIGN VARIABLES		C.V. NO.	GLOBAL VAR. NO.	LOWER BOUND	VALUE	UPPER BOUND
ID		1	1	0.50000E 00	0.18179E 01	0.50000E 01
		2	2	0.10000E 01	0.18179E 02	0.20000E 02

DESIGN CONSTRAINTS

IC	GLOBAL VAR. NO.	LOWER BOUND	VALUE	UPPER BOUND
1	4	-0.11000E 16	0.19575E 05	0.20000E 05
2	5	-0.11000E 16	0.45390E 03	0.10000E 05
3	6	-0.11000E 16	0.97675E 00	0.10000E 01
4	7	-0.11000E 16	0.99997E 01	0.10000E 02

CANTILEVERED BEAM

AL	=	200.000	05
P	=	0.10000E 08	08
E	=	0.30000E 08	
B	=	1.818	
H	=	18.179	
VCL	=	6609.375	
BSTRES	=	0.19975E 05	05
SHRSTR	=	0.45390E 03	03
DELTA	=	0.97675E 00	00
H/B	=	10.000	

PROGRAM CALLS TO ANALIZ

IC	CALLS
1	1
2	36
3	2

FIG. 3 - CONCLUDED

```

CCCCCC  CCCCCG  PFFFFP  EEEEE  SSSSS
CC      CC      P      P      S
CC      CC      PFFFFP  EEEE   SSSSS
CC      CC      P      P      E
CCCCCC  C00000  P      P      EEEEE  SSSSS

```

C O N T R O L   P R O G R A M  
 F C R  
 E N G I N E E R I N G   S Y N T H E S I S

T I T L E  
 C A N T I L E V E R E D   B E A M   A N A L Y S I S   A N D   D E S I G N

FIG. 4 - SENSITIVITY STUDY

CARD IMAGES OF CONTROL DATA

CARD	IMAGE
1)	CANTILEVERED BEAM ANALYSIS AND DESIGN
2)	\$ DATA BLOCK B
3)	\$ NCALC 3 NDV 0 NSV 3
4)	\$ DATA BLOCKS C-C ARE NOT REQUIRED
5)	\$ DATA BLOCK P
6)	\$ NSOB J 5
7)	\$ NSN1 3 NSN2 4 NSN3 5 NSN4 6 NSN5 7
8)	\$ NSN1 3 NSN2 4 NSN3 5 NSN4 6 NSN5 7
9)	\$ DATA BLOCK Q
10)	\$ ISENS 1 NSNS 2
11)	\$ SNS1 1 SNS2 4
12)	\$ BEAM LENGTH 100.
13)	\$ 200.
14)	\$ BEAM WIDTH 1
15)	\$ 1.5
16)	\$ BEAM HEIGHT 2
17)	\$ 20.
18)	\$ BEAM HEIGHT 2
19)	\$ 1.5
20)	\$ BEAM HEIGHT 2
21)	\$ 20.
22)	\$ DATA BLOCKS R-U ARE NOT REQUIRED
23)	\$ DATA BLOCK V
24)	\$ 20.
25)	\$ REQUIRED END CARD
26)	END

FIG. 4 - CONT.



TITLE:  
CANTILEVERED BEAM ANALYSIS AND DESIGN

CONTROL PARAMETERS:  
 CALCULATION CONTROL, NCALC = 3  
 NUMBER OF GLOBAL DESIGN VARIABLES, NDV = 3  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 0  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2VAR = 0  
 NUMBER OF APPROXIMATING VAR, NXAPRX = 0  
 INPUT INFORMATION PRINT CODE, IPNPLT = 0  
 DEBUG PRINT CODE, IPRDBG = 0

CALCULATION CONTROL, NCALC  
 VALUE  
 1 MEANING ANALYSIS  
 2 SINGLE ANALYSIS  
 3 OPTIMIZATION  
 4 SENSITIVITY  
 5 TWO-VARIABLE FUNCTION SPACE  
 6 OPTIMUM SENSITIVITY  
 7 APPROXIMATE OPTIMIZATION

\* \* SENSITIVITY INFORMATION

PRINT CONTROL, IPSENS = 5  
 NUMBER OF SENSITIVITY OBJECTIVES = 5

GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY OBJECTIVES

NUMBER	GLOBAL VARIABLE	NOMINAL VALUE	OFF-NOMINAL VALUES
1	1	C-20000E 03	0.1000E 03 C-1500E 03
2	2	C-20000E 01	0.1500E 01 C-2500E 01
3	2	0.50000E 01	0.2000E 02 0.2500E 03

\* \* ESTIMATED DATA STORAGE REQUIREMENTS

FEAL	AVAILABLE	INPUT	EXECUTICN	AVAILABLE
1E	23	12	12	1000

FIG. 4 - CONT.

CANTILEVERED BEAM

AL = 200.000  
P = C.10000E 05  
E = C.30000E C8  
B = 2.500  
F = 10.000

STANDARD SENSITIVITY ANALYSIS RESULTS (NCALC=3)

TITLE  
CANTILEVERED BEAM ANALYSIS AND DESIGN

NUMBER OF SENSITIVITY VARIABLES, NSV = 3  
NUMBER OF SENSITIVITY OBJECTIVES, NSOBJ = 5

GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY VARIABLES  
1 2

GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY OBJECTIVES  
3 4 5 6 7

NOMINAL DESIGN INFORMATION

VALUES OF SENSITIVITY VARIABLES  
0.20000E C3 0.20000E 01 0.50000E 01

VALUES OF SENSITIVITY OBJECTIVE FUNCTIONS  
0.20000E 04 0.24000E 06 0.15000E 04 0.42667E 02 C.25000E 01

FIG. 4 - CONT.

SENSITIVITY ANALYSIS RESULTS

GLOBAL VARIABLE	S	F(X)
C.1000E 03	0.1000E 04 0.2500E 01	0.1200E 06 0.1500E 04 0.5333E 01
C.1500E 03	0.1500E 04 0.2500E 01	0.1800E 06 0.1500E 04 0.1800E 02
C.2500E 03	0.2500E 04 0.2500E 01	0.3000E 06 0.1500E 04 0.8333E 02

GLOBAL VARIABLE	1	F(X)
0.1500E 01	0.1500E 04 0.3333E 01	0.3200E 06 0.2000E 04 0.5689E 02
0.2500E 01	0.2500E 04 0.2000E 01	0.1920E 06 0.1200E 04 0.3413E 02

GLOBAL VARIABLE	2	F(X)
C.2000E 02	0.8000E 04 0.1000E 02	0.1500E 05 0.3750E 03 0.6667E 00

PROGRAM CALLS TO ANALYZ

ICALC	CALLS
1	1
2	7
3	0

FIG. 4 - CONCLUDED

```

CCCCCC 000000  P P P P P P  E E E E E E  S S S S S S
C C C C C C  P P P P P P  E E E E E E  S S S S S S
C C C C C C  P P P P P P  E E E E E E  S S S S S S
C C C C C C  P P P P P P  E E E E E E  S S S S S S
C C C C C C 000000  P P P P P P  E E E E E E  S S S S S S

```

C O N T R O L P R O G R A M  
 F C R  
 E N G I N E E R I N G S Y N T H E S I S

T I T L E  
 C A N T I L E V E R E D B E A M A N A L Y S I S A N D D E S I G N

FIG. 5 - TWO-VARIABLE FUNCTION SPACE STUDY

CARD IMAGES OF CONTROL DATA

CARD	IMAGE
11	CANTILEVERED BEAM ANALYSIS AND DESIGN
21	\$ DATA BLOCK B
31	\$ NCALC
41	\$ ADV 0 NSV 0 N2VAR 5
51	\$ DATA BLOCKS C-C ARE NOT REQUIRED
61	\$ DATA BLOCK F
71	\$ N2VX 4 M2VY 2
81	\$ M2VX 4 M2VY 5
91	\$ DATA BLOCK S
101	\$ NZ1 3 NZ2 4 NZ3 5 NZ4 6 NZ5 7
111	\$ DATA BLOCK T
121	\$ VALUES OF WIDTH, B
131	\$ X1 5 X2 1. X3 1.5 X4 2.
141	\$ X1 5 X2 1. X3 1.5 X4 2.
151	\$ DATA BLOCK U
161	\$ VALUES OF HEIGHT, H
171	\$ Y1 4 Y2 8. Y3 12. Y4 16. Y5 20.
181	\$ Y1 4 Y2 8. Y3 12. Y4 16. Y5 20.
191	\$ DATA BLOCK V
201	\$ REQUIRED END CARD
211	\$
221	END

FIG. 5 - CONT.

TITLE: CANTILEVERED BEAM ANALYSIS AND DESIGN

CONTROL PARAMETERS:  
 CALCULATIONAL CONTROL, NCALC = 4  
 NUMBER OF GLOBAL DESIGN VARIABLES, NDV = 0  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 0  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2V = 5  
 NUMBER OF APPROXIMATING POINTS, NXP = 0  
 INPUT INFORMATION PRINT CODE, IPNPR = 0  
 DEBUG PRINT CODE, IPDBG = 0

CALCULATIONAL CONTROL, NCALC  
 VALUE MEANING ANALYSIS  
 1 SINGLE ANALYSIS  
 2 OPTIMIZATION  
 3 SENSITIVITY  
 4 TWC-VARIABLE FUNCTION SPACE  
 5 OPTIMUM SENSITIVITY  
 6 APPROXIMATE OPTIMIZATION

\* \* TWC-VARIABLE FUNCTION SPACE MAPPING INFORMATION

PRINT CONTROL, IP2VAR = 0  
 GLOBAL VARIABLE NUMBERS ASSOCIATED WITH F(X,Y), M2VZ  
 3 4 5 6 7

GLOBAL VARIABLE NUMBER CORRESPONDING TO X, N2VX = 1

VALUES OF X-VARIABLE  
 0.5000E 00 0.1000E 01 0.1500E 01 0.2000E 01

GLOBAL VARIABLE NUMBER CORRESPONDING TO Y, N2VY = 2

VALUES OF Y-VARIABLE  
 0.4000E 01 0.8000E 01 0.1200E 02 0.1600E 02 0.2000E 02

\* \* ESTIMATED DATA STORAGE REQUIREMENTS

REAL	INTEGER	INPUT	EXECUTION	AVAILABLE
18	23	6	6	1000

FIG. 5 - CONT.

CANTILEVERED BEAM

AL = 200.000  
 E = 0.10000E 05  
 E = 0.30000E 08  
 B = 2.500  
 H = 10.000

TWO-VARIABLE FUNCTION SPACE RESULTS

TITLE  
 CANTILEVERED BEAM ANALYSIS AND DESIGN

GLOBAL NUMBER ASSOCIATED WITH X-VARIABLE, N2VX = 1  
 GLOBAL NUMBER ASSOCIATED WITH Y-VARIABLE, N2VY = 2

GLOBAL NUMBERS ASSOCIATED WITH F(X,Y)

X	Y	F(X,Y)
0.5000E 00	0.4000E 01	0.4000E 03 0.8000E 01
0.8000E 01	0.8000E 03 0.1600E 02	0.1500E 07 0.3750E 06
0.1200E 02	0.1200E 04 0.2400E 02	0.3750E 04 0.2500E 04
0.1600E 02	0.1600E 04 0.3200E 02	0.1667E 06 0.9375E 05
0.2000E 02	0.2000E 04 0.4000E 02	0.1875E 04 0.1500E 04
		0.3333E 03 0.4167E 02 0.1235E 02 0.5208E 01 0.2667E 01

FIG. 5 - CONT.

X	Y	F(X,Y)
C.1000E 01	0.2000E 02	C.4000E 04 0.2000E 02
	0.1600E 02	0.3200E 04 0.1600E 02
	0.1200E 02	C.2400E 04 0.1200E 02
	C.8000E 01	0.1600E 04 C.8000E 01
	0.4000E 01	0.8000E 03 0.4000E 01
		0.3000E 05
		0.4688E 05
		0.8333E 05
		0.1875E 06
		0.7500E 06
		0.2083E 02
		0.1875E 04
		0.2604E 01
		0.1250E 04
		0.6173E 01
		0.1875E 04
		0.2083E 02
		0.3750E 04
		0.1667E 03

X	Y	F(X,Y)
C.1500E 01	0.4000E 01	0.1200E 04 C.2667E 01
	0.8000E 01	0.2400E 04 0.5333E 01
	C.1200E 02	0.3600E 04 0.8000E 01
	0.1600E 02	0.4800E 04 C.1067E 02
	C.2000E 02	0.6000E 04 0.1333E 02
		0.5000E 06
		0.1250E 06
		0.5556E 05
		0.3125E 05
		0.6250E 03
		0.2000E 05
		0.8333E 03
		0.4115E 01
		0.1736E 01
		0.5000E 03
		0.1111E 03
		0.1389E 02
		0.1250E 04
		0.8889E 00

FIG. 5 - CONT.



X	Y	F(X, Y)
C.2000E C1	0.2000E C2	C.8000E 04 C.1000E 02
	0.1600E 02	0.6400E 04 0.8000E 01
	0.1200E 02	C.4800E 04 0.6000E 01
	0.8000E 01	0.3200E 04 0.4000E 01
C.4000E C1		0.1600E 04 C.2000E 01
		0.1500E 05
		0.2344E 05
		0.4167E 05
		0.9375E 05
		0.3750E 06
		C.3750E C3
		0.4688E C3
		C.6250E C3
		0.9375E C3
		0.1875E 04
		0.6667E 00
		C.1302E 01
		0.3086E 01
		C.1042E 02
		0.8333E 02

PROGRAM CALLS TO ANALYZ

ICALC	CALLS
1	2C
2	2C
3	2C

FIG. 5 - CONCLUDED

```

CCCCCCC  CCCCCC  PFFFFP  EEEEEEE  SSSSSS
C        C        P        E        S
C        C        P        E        S
C        C        P        E        S
C        C        P        E        S
CCCCCCC  CCCCCC  P        EEEEEEE  SSSSSS
C        C        P        E        S
C        C        P        E        S
C        C        P        EEEEEEE  SSSSSS

```

C O N T R O L   P R O G R A M  
 F C R  
 E N G I N E E R I N G   S Y N T H E S I S  
  
 T I T L E  
 C A N T I L E V E R B E A M   A N A L Y S I S   A N D   D E S I G N

FIG. 6 - OPTIMUM SENSITIVITY

CARD IMAGES OF CONTROL DATA

CARD	IMAGE
1)	CANTILEVERED BEAM ANALYSIS AND DESIGN
2)	\$ DATA BLOCK B
3)	\$ NCALC
4)	\$ NDV NSV
5)	\$ DATA BLOCK C - DEFAULT ALL BUT PRINT CONTROL
6)	\$ IPRINT
7)	\$ DATA BLOCK D - ALL DEFAULTS
8)	\$ 0.
9)	\$ 0.
10)	\$ DATA BLOCK E
11)	\$ NDV <sup>C</sup> TD <sup>C</sup>
12)	\$ IOBJ 3
13)	\$ SGACPT -1.
14)	\$ DATA BLOCK F
15)	\$ VLB
16)	\$ WIDTH, B
17)	\$ HEIGHT, B 5.
18)	\$ HEIGHT, H 2G.
19)	\$ DATA BLOCK G
20)	\$ ND <sup>C</sup> SGN
21)	\$ ICSGN
22)	\$ AMULT
23)	\$ WIDTH, B 1
24)	\$ HEIGHT, H 2
25)	\$ 1.
	\$ 1.

FIG. 6 - CONT.

```

26) $ DATA BLCK H
27) $ NCONS 4
28) $ DATA BLOCK I
29) $ ICON SCAL JCON LCON BU SCALZ
30) $ BL SCAL CN ESTRES
31) $ CCNSTRAINT CN 0 20000. 0 0.
32) $ -1.C +20 C.
33) $ CONSTRAINT CN STRSTR 0 10000. 0 0.
34) $ -1.C +20 C.
35) $ CONSTRAINT CN DELTA 0 1. 0 0.
36) $ -1.C +20 C.
37) $ CONSTRAINT CN F/B 0 10. 0 C.
38) $ DATA BLCKS J-C ARE NOT REQUIRED.
39) $ DATA BLOCK P
40) $ NSCBJ 7
41) $ NSN1 3
42) $ NSN2 4
43) $ NSN3 5
44) $ NSN4 6
45) $ NSN5 7
46) $ NSN6 1
47) $ NSN7 2
48) $ DATA BLCK C
49) $ ISENS 1
50) $ SNS1 2
51) $ SNS2 3
52) $ SNS3 4
53) $ SNS4 5
54) $ BEAM LENGTH 150. 250.
55) $ 200. WIDTH 1.5 2.5
56) $ BEAM HEIGHT 2
57) $ BEAM HEIGHT 2
58) $ BEAM HEIGHT 2
59) $ BEAM HEIGHT 2
60) $ BEAM HEIGHT 2
61) $ BEAM HEIGHT 2
62) $ BEAM HEIGHT 2
63) $ BEAM HEIGHT 2
64) $ BEAM HEIGHT 2
65) $ BEAM HEIGHT 2

```

FIG. 6 - CONT.

TITLE: LEVERED BEAM ANALYSIS AND DESIGN

CONTROL PARAMETERS:  
 CALCULATION CONTROL DESIGN VARIABLES, NALC = 5  
 NUMBER OF GLOBAL DESIGN VARIABLES, NDV = 2  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 3  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2VAR = 0  
 NUMBER OF APPROXIMATING VAR, NXAPRX = 0  
 INPUT INFORMATION PRINT CODE, IPNPLT = 0  
 DEBUG PRINT CODE, IPDEG = 0

CALCULATION CONTROL, NALC  
 VALUE MEANING ANALYSIS  
 1 SINGLE ANALYSIS  
 2 OPTIMIZATION  
 3 SENSITIVITY  
 4 TWO-VARIABLE FUNCTION SPACE  
 5 OPTIMUM SENSITIVITY  
 6 APPROXIMATE OPTIMIZATION

\* \* OPTIMIZATION INFORMATION

GLOBAL VARIABLE NUMBER OF OBJECTIVE  
 MULTIPLIER (NEGATIVE INDICATES MINIMIZATION) = -0.1000E 01 3  
 COMMON PARAMETERS (IF ZERO, COMMON DEFAULT WILL OVER-RIDE)  
 IPRINT ITPAX ICNDR NSCAL ITRM LINDBJ NACMX1 NFDG  
 1 C 0 0 0 0 4 0  
 FCCM FCCFM CT CTMIN  
 0.0 0.0 0.0 0.0  
 CTL CTLMIN THETA PHI  
 0.0 0.0 0.0 0.0  
 DELFUN DABFUN ALPHAX ABOBJ1  
 0.0 0.0 0.0 0.0

FIG. 6 - CONT.

DESIGN VARIABLE INFORMATION  
 NON-ZERO INITIAL VALUE WILL OVER-RIDE MODULE INPUT  
 D. V. LOWER BOUND UPPER BOUND INITIAL VALUE SCALE  
 NO. 1 0.50000E 01 0.50000E 01 0.0 0.0  
 2 0.10000E 01 0.20000E 02 0.0 0.0

DESIGN VARIABLES GLOBAL MULTIPLYING  
 C. V. VAR. NC. FACTOR  
 ID NO. 1 1 0.10000E 01  
 2 2 0.10000E 01

CCONSTRAINT INFORMATION

THERE ARE 4 CCONSTRAINT SETS  
 GLOBAL LINEAR  
 IC VAR. 1 VAR. 2 ID  
 1 4 0 0  
 2 5 0 0  
 3 6 0 0  
 4 7 0 0

TOTAL NUMBER OF CCONSTRAINED PARAMETERS = 4

NORMALIZATION  
 FACTOR LOWER BOUND UPPER BOUND NORMALIZATION  
 0.11000E 16 0.20000E 05  
 0.11000E 16 0.10000E 05  
 0.11000E 16 0.10000E 01  
 0.11000E 16 0.10000E 02

\* \* SENSITIVITY INFORMATION

PRINT CONTROL IPSENS = 9  
 NUMBER OF SENSITIVITY OBJECTIVES = 7  
 GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY OBJECTIVES  
 4 5 6 7 1 2

NUMBER	GLOBAL VARIABLE	NOMINAL VALUE	OFF-NOMINAL VALUES
1	9	C.20000E 03	0.1000E 03 0.1500E 03 C.2500E 03
2	1	0.20000E 01	0.1500E 01 0.2500E 01
3	2	C.50000E 01	0.2000E 02

\* \* ESTIMATED DATA STORAGE REQUIREMENTS

INPUT	REAL EXECUTION	AVAILABLE	INPUT	INTEGER EXECUTION	AVAILABLE
46	161	5000	34	58	1000

CANTILEVERED BEAM

AL	=	200.000	05
P	=	C.10000E	08
E	=	C.30000E	
B	=	2.500	
h	=	10.000	

FIG. 6 - CONT.

OPTIMUM SENSITIVITY ANALYSIS RESULTS (NCALC=5)

TITLE  
CANTILEVERED BEAM ANALYSIS AND DESIGN

NUMBER OF SENSITIVITY VARIABLES, NSV = 3  
NUMBER OF SENSITIVITY OBJECTIVES, NSOBJ = 7

GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY VARIABLES  
5 1 2

GLOBAL NUMBERS ASSOCIATED WITH SENSITIVITY OBJECTIVES  
3 4 5 6 7 1 2

OPTIMAL DESIGN INFORMATION

VALUES OF SENSITIVITY VARIABLES  
0.20000E 03 0.20000E 01 0.50000E 01

VALUES OF SENSITIVITY OBJECTIVE FUNCTIONS  
0.20000E 04 0.24000E 06 0.15000E 04 0.42667E 02 0.25000E 01  
0.20000E 01 0.50000E 01

FIG. 6 - CONT.



SENSITIVITY ANALYSIS RESULTS

GLOBAL VARIABLE	9	F(X)	
X			
0.1000E 03	C.2C82E 04 0.1C00E 02	0.1997E 01 0.1443E 01	C.7205E 03 0.1443E 02
0.1500E 03	0.4096E 04 0.1000E 02	0.1554E 05 0.1652E 01	0.5493E 03 0.1652E 02
0.2500E 03	C.1303E 05 0.7674E 01	0.1439E 01 0.2606E 01	0.2878E 03 0.2000E 02

GLOBAL VARIABLE	1	F(X)	
X			
0.1500E 01	0.6C00E 04 0.1333E 02	0.2000E 05 0.1500E 01	0.5000E 03 0.2000E 02
0.2500E 01	0.8137E 04 0.6510E 01	0.1812E 05 0.2500E 01	0.3687E 03 0.1627E 02

GLOBAL VARIABLE	2	F(X)	
X			
0.2000E 02	0.1042E 05 0.7674E 01	0.1151E 01 0.2606E 01	0.2878E 03 0.2000E 02

PROGRAM CALLS TC ANALIZ

ICALC	CALLS
1	103
2	
3	

```

CCCCCC  CCCCCG  P P P P P P  E E E E E E  S S S S S S
C C C C  C C C C  P P P P P P  E E E E E E  S S S S S S
C C C C  C C C C  P P P P P P  E E E E E E  S S S S S S
C C C C  C C C C  P P P P P P  E E E E E E  S S S S S S
CCCCCC  CCCCCG  C C C C C C  E E E E E E  S S S S S S

```

C C A T R C L P R O G R A M  
 F O R  
 E N G I N E E R I N G S Y N T H E S I S

T I T L E  
 C A N T I L E V E R E D B E A M A N A L Y S I S A N D D E S I G N

CARD IMAGES OF CONTROL DATA

CARD	IMAGE
1)	CANTILEVERED BEAM ANALYSIS AND DESIGN
2)	\$ DATA BLOCK B NDV NSV N2VAR NXAPRX
3)	1 6 2 0 0 1
4)	\$ DATA BLOCK C - DEFAULT ALL BUT PRINT CONTROL
5)	6 1 1
6)	IPRINT
7)	\$ DATA BLOCK C - ALL DEFAULTS
8)	C.
9)	0.
10)	0.
11)	\$ DATA BLOCK E IOB3 SGNDPT
12)	NDV T U T 0 -1.
13)	

FIG. 7 - OPTIMIZATION USING APPROXIMATION TECHNIQUES

```

14) $ DATA BLOCK F
15) $ VLR V/JB
16) $ WIDTH, B 5.
17) $ HEIGHT, H 2C.
18) $ DATA BLOCK G
19) $ WIDTH, B 1
20) $ HEIGHT, H 2
21) $ DATA BLOCK F
22) $ WIDTH, B 1
23) $ HEIGHT, H 2
24) $ DATA BLOCK I
25) $ JCCN BU LCN SCAL2
26) $ PL ICCN SCAL1
27) $ CCNSTRN CN ESTRES 0 20000. 0 0.
28) $ CCNSTRN CN SFRSTR 0 10000. 0 0.
29) $ CCNSTRN CN DELTA 0 1. 0 0.
30) $ CCNSTRN CN F/B 0 10. 0 0.
31) $ DATA BLOCK J
32) $ USE DEFAULTS W/PRE POSSIBLE EXCEPT PRINT CONTROL AND CANDIDATE DESIGNS
33) $ NF NXS NXS NSFS NXA INCH INFLCC ISCRXF ISCRXF IPAPRX
34) $ KMIN 0 KMAX 0 NPMAX 0 JNOM 0 INXLCC 0 MAXTRM 0
35) $ DATA BLOCK K
36) $ DX1 2
37) $ DX2 2
38) $ XFACT1 XFACT2
39) $ DATA BLOCK L
40) $ L NCT REQUIRED (INXLOC = 0)
41) $ DATA BLOCK M
42) $ M NCT REQUIRED (INFLOC = 0)
43) $ DATA BLOCK N
44) $ N REAC 4 CANDIDATE DESIGNS
45) $ X1
46) $ 1.
47) $ 2.
48) $ 3.
49) $ DATA BLOCK C
50) $ C NCT REQUIRED (NXFS = 0)
51) $ DATA BLOCK P
52) $ P-L ARE NOT REQUIRED.
53) $ DATA BLOCK V
54) $ V REQUIRED END CARD
55) $
56) $
57) $
58) $
59) $
60) $
61) $
62) $
63) $
64) $
65) $
66) $
67) $ END

```

FIG. 7 - CONT.

TITLE:  
CANTILEVERED BEAM ANALYSIS AND DESIGN

CCNTFOL PARAMETERS:  
 CALCULATION CONTROL, NCALC = 6  
 NUMBER OF GLOBAL DESIGN VARIABLES, NDV = 2  
 NUMBER OF SENSITIVITY VARIABLES, NSV = 0  
 NUMBER OF FUNCTIONS IN TWO-SPACE, N2VAR = 0  
 NUMBER OF APPROXIMATING VAR., NXAPRX = 1  
 INPUT INFORMATION PRINT CODE, IPNPUT = 0  
 DEBUG PRINT CODE, IPDEG = 0

CALCULATION CONTROL, NCALC

1 MEANING ANALYSIS  
 2 SINGLE ANALYSIS  
 3 OPTIMIZATION  
 4 SENSITIVITY  
 5 TWO-VARIABLE FUNCTION SPACE  
 6 APPROXIMATE OPTIMIZATION

\* \* OPTIMIZATION INFORMATION

GLOBAL VARIABLE NUMBER OF OBJECTIVE  
 MULTIPLIER (NEGATIVE INDICATES MINIMIZATION) = -0.100CE 01

CCMIN PARAMETERS (IF ZERO, CCMIN DEFAULT WILL OVER-RIDE)

IPPRINT	ITMAX	ICNDIR	NSCAL	ITRM	LINOBJ	NACMX1	NFDG
1	C	0	0	0	0	6	0
FCCH	FCCHM	CT	CTMIN	PHI	ALPHAX	ABOBJ1	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	
CTL	CTLMIN	DABFUN					
0.0	0.0	0.0					
DELFUN							
0.0							

DESIGN VARIABLE INFORMATION

NO.	INITIAL VALUE	UP	ER	BOUND	SCALE
1	0.50000E 01	0	1	0.0	0.0
2	0.20000E 02	0	2	0.0	0.0

FIG. 7 - CONT.

DESIGN VARIABLES GLOBAL MULTIPLYING  
 D.V. VAR. NG. FACTOR  
 NO. 1 1 0.10000E 01  
 2 2 0.10000E 01

CCONSTRAINT INFORMATION

THERE ARE 4 CCONSTRAINT SETS  
 GLOBAL GLCBL LINEAR  
 VAR. 1 VAR. 2 ID  
 1 4 0 0  
 2 5 0 0  
 3 6 0 0  
 4 7 0 0

NORMALIZATION  
 FACTOR 16  
 0.11000E 16  
 0.11000E 16  
 0.11000E 16

LOWER BOUND  
 -0.11000E 16  
 -0.11000E 16  
 -0.11000E 16

LPPER BOUND  
 0.20000E 05  
 0.10000E 05  
 0.10000E 02

TCTAL NUMBER CF CCONSTRAINED PARAMETERS = 4

\* \* AFFROXIMATE ANALYSIS/OPTIMIZATION INFCRMATION

NUMBER OF FUNCTIONS APPROXIMATED, NF = 0  
 NUMBER OF INPUT X-VECTORS, NPS = 4  
 NUMBER CF INPUT X-F PAIRS, NPFS = 0  
 X-VECTOR FROM ANALIZ, NPA = 0  
 ACNINAL DESIGN X-VECTORS, INOM = 0  
 READ UNIT FOR X-F PAIRS, ISCRX = 5  
 PRINT CCNTFCL, IPAPRX = 1  
 MINIMUM APPROXIMATING CYCLES, KMIN = 1  
 MAXIMUM APPROXIMATING CYCLES, KMAX = 12  
 MAXIMAL DESIGN USED IN FIT, NPMAX = 10  
 ACNINAL DESIGN PARAMETER, INJNOC = 10  
 X-LOCALTION INPUT PARAMETER, INFLOC = 0  
 F-LOCALTION INPUT PARAMETER, MAXTRM = 3  
 TAYLER SERIES I.D. CODE,

DELTA-X BCUNDS FOR APPRCXIMATE OPTIMIZATION  
 0.5000E 00 0.2000E 01

MULTIPLIER ON CELX, XFACT1 = 0.1500E 01  
 MULTIPLIER ON CELY, XFACT2 = 0.2000E 01

FIG. 7 - CONT.

GLOBAL LOCATIONS OF X-VARIABLES  
1 2

GLOBAL LOCATIONS OF FUNCTIONS  
3 4 5 6 7

X-VECTORS INPUT FROM UNIT 5

NUMBER 1 DESIGN 1  
C.10C0E 01 0.15CCE C2

NUMBER 2 DESIGN 2  
C.2000E 01 0.2000E C2

NUMBER 3 DESIGN 3  
C.40CCE 01 0.1000E 02

NUMBER 4 DESIGN 4  
C.30CCE 01 C.12CCE 02

\* \* ESTIMATED DATA STORAGE REQUIREMENTS

INPLT	REAL EXECUTION	AVAILABLE	INPUT	INTEGER EXECUTION	AVAILABLE
27	212	5000	28	60	1000

CANTILEVERED BEAM

AL	=	200.000	C5
PE	=	0.10000E 08	C8
B	=	2.500	
F	=	10.000	

FIG. 7 - CONT.

APPROXIMATE OPTIMIZATION ITERATION HISTORY  
 APPROXIMATING FUNCTION 1 IS THE OBJECTIVE  
 APPROXIMATING FUNCTIONS ASSOCIATED WITH CONSTRAINTS  
 2 3 4 5

DESIGN VARIABLE NUMBERS ASSOCIATED WITH APPROXIMATING VARIABLES  
 1 2

BEGIN ITERATION NUMBER 1  
 NOMINAL DESIGN NUMBER = 2  
 X-VECTOR  
 0.20000E C1 0.20000E 02  
 FUNCTION VALUES  
 0.80000E 04 0.15000E 05 0.37500E 03 0.66667E 00 0.10000E 02

RESULTS OF APPROXIMATE OPTIMIZATION

DELTA-X VECTOR  
 -0.61480E-01 -0.11224E 01  
 X-VECTOR  
 0.15285E C1 0.18878E 02  
 APPROXIMATE FUNCTION VALUES  
 0.73964E 04 0.15745E 05 0.44117E 03 0.10002E 01 0.99918E 01  
 PRECISE FUNCTION VALUES  
 0.73189E C4 0.17371E 05 0.40990E 03 0.81794E 00 0.97381E 01

BEGIN ITERATION NUMBER 2  
 NOMINAL DESIGN NUMBER = 5  
 X-VECTOR  
 0.19285E C1 0.18878E 02  
 FUNCTION VALUES  
 0.73189E 04 0.17371E 05 0.40590E 03 0.81794E 00 0.97381E C1

FIG. 7 - CONT.

RESULTS OF APPROXIMATE OPTIMIZATION

DELTA-X VECTOR  
0.21565E-01 -0.13725E 01

X-VECTOR  
0.19605E 01 0.17505E 02

APPROXIMATE FUNCTION VALUES  
0.67872E C4 0.19684E 05 0.43322E 03 C.10001E 01 C.90402E 01

PRECISE FUNCTION VALUES  
C.68637E 04 0.19975E C5 C.43708E 03 0.10143E 01 0.89289E 01

BEGIN ITERATION NUMBER 3

NOMINAL DESIGN NUMBER = 6

X-VECTOR  
C.156C5E C1 0.17505E 02

FUNCTION VALUES  
0.68637E 04 0.15575E C5 0.43708E 03 0.10143E 01 0.89289E 01

RESULTS OF APPROXIMATE OPTIMIZATION

DELTA-X VECTOR  
-0.10136E CC C.77502E 00

X-VECTOR  
0.18591E C1 C.18280E 02

APPROXIMATE FUNCTION VALUES  
C.67580E 04 0.15598E 05 0.45218E 03 0.98844E CC C.10000E 02

PRECISE FUNCTION VALUES  
0.67570E C4 C.15316E 05 0.44137E 03 C.93927E 00 C.98326E 01



BEGIN ITERATION NUMBER 4  
 NOMINAL DESIGN NUMBER = 7  
 X-VECTOR  
 0.18280E 02  
 FUNCTION VALUES  
 0.67970E 04 0.19316E 05 C.44137E 03 0.93927E 00 C.98326E 01

RESULTS OF APPROXIMATE OPTIMIZATION  
 DELTA-X VECTOR  
 -0.24565E-01  
 X-VECTOR  
 C.18242E 01 0.18188E 02  
 APPROXIMATE FUNCTION VALUES  
 C.66354E 04 0.20001E 05 0.45387E 03 C.98035E 00 C.99933E 01  
 PRECISE FUNCTION VALUES  
 C.66354E 04 0.15887E 05 0.45212E 03 0.97195E 00 C.99704E 01

BEGIN ITERATION NUMBER 5  
 NOMINAL DESIGN NUMBER = 8  
 X-VECTOR  
 0.18242E 01 C.18188E 02  
 FUNCTION VALUES  
 0.66354E 04 0.19887E 05 0.45212E 03 0.97195E 00 C.99704E 01

RESULTS OF APPROXIMATE OPTIMIZATION  
 DELTA-X VECTOR  
 -0.59226E-02  
 X-VECTOR  
 C.18182E 01 0.16179E 02  
 APPROXIMATE FUNCTION VALUES  
 0.66107E 04 0.19983E 05 0.45399E 03 0.97747E 00 C.10000E 02  
 PRECISE FUNCTION VALUES  
 C.66107E 04 0.19971E 05 0.45381E 03 0.97652E 00 C.99981E 01

FIG. 7 - CONT.

BEGIN ITERATION NUMBER 6  
NOMINAL DESIGN NUMBER = 9  
X-VECTOR  
C.18182E 01 0.18182E C2  
FUNCTION VALUES  
0.66107E 04 0.19971E 05 0.45381E 03 0.97652E 00 C.99981E 01

RESULTS OF APPROXIMATE OPTIMIZATION

DELTA-X VECTOR  
-0.15702E-04 -0.1C826E-01  
X-VECTOR  
0.18182E C1 0.18182E 02  
APPROXIMATE FUNCTION VALUES  
0.66067E 04 0.20000E C5 0.45417E 03 0.97861E 00 C.99935E 01  
PRECISE FUNCTION VALUES  
C.66067E C4 C.19995E 05 0.45409E 03 0.97828E 00 C.99922E 01

BEGIN ITERATION NUMBER 7  
NOMINAL DESIGN NUMBER = 10  
X-VECTOR  
0.18182E C1 C.18182E 02  
FUNCTION VALUES  
0.66067E 04 0.19995E 05 0.45409E 03 0.97828E 00 0.99922E C1

RESULTS OF APPROXIMATE OPTIMIZATION

OPTIMIZATION HAS PRODUCED AN X-VECTOR WHICH IS THE SAME AS A PREVIOUS DESIGN  
DELTA-X VECTOR 0.0  
X-VECTOR  
0.18182E 01 0.18182E 02

FIG. 7 - CONT.

AD-A133 039

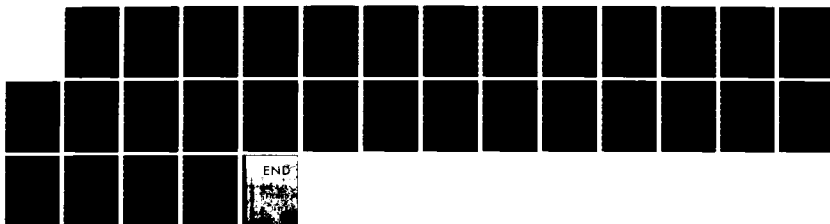
COPES - A FORTRAN CONTROL PROGRAM FOR ENGINEERING  
SYNTHESIS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA  
L E MADSEN ET AL. MAR 82 NPS69-81-003

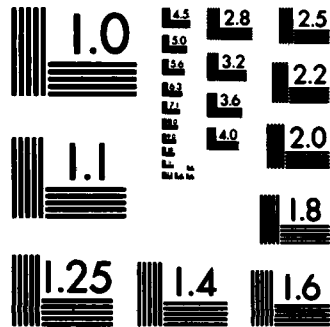
2/2

UNCLASSIFIED

F/G 9/2

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

THE FOLLOWING DESIGN IS NOT THE APPROXIMATE OPTIMUM

DELTA-X VECTOR  
0.50000E-02 0.20000E-01

X-VECTOR  
0.18232E 01 0.18188E 02

APPROXIMATE FUNCTION VALUES  
0.66221E 04 0.19881E 05 0.45210E 03 0.97124E 00 0.99727E 01

PRECISE FUNCTION VALUES  
0.66221E 04 0.19896E 05 0.45234E 03 0.97238E 00 0.99758E 01

BEGIN ITERATION NUMBER 8

NOMINAL DESIGN NUMBER = 10

X-VECTOR  
0.18182E 01 0.18168E 02

FUNCTION VALUES  
0.66067E 04 0.19995E 05 0.45409E 03 0.97828E 00 0.99922E 01

RESULTS OF APPROXIMATE OPTIMIZATION

DELTA-X VECTOR 0.0

X-VECTOR  
0.18182E 01 0.18168E 02

APPROXIMATE FUNCTION VALUES  
0.66067E 04 0.19995E 05 0.45409E 03 0.97828E 00 0.99922E 01

TWO CONSECUTIVE APPROXIMATE OPTIMIZATIONS HAVE PRODUCED THE SAME DESIGN  
OPTIMIZATION TERMINATED

FINAL RESULT OF APPROXIMATE OPTIMIZATION  
 NOMINAL DESIGN NUMBER = 10  
 X-VECTOR  
 C.18182E 01 0.18168E 02  
 FUNCTION VALUES  
 0.6607E 04 0.15595E 05 0.45409E 03 0.97828E 00 C.99922E 01

RESULTS OF APPROXIMATE ANALYSIS/OPTIMIZATION

TITLE  
 CANTILEVERED BEAM ANALYSIS AND DESIGN

GLOBAL LOCATIONS OF X-VARIABLES  
 1  
 2

GLOBAL LOCATIONS OF FUNCTIONS, FIX)  
 3  
 4  
 5  
 6  
 7

APPROXIMATION IS BASED ON 11 DESIGNS  
 NOMINAL DESIGN IS DESIGN NUMBER 10  
 VALUES OF X-VARIABLES  
 0.1818E 01 C.18181E 02

VALUES OF FUNCTIONS, FIX)  
 0.6607E 04 0.2000E 05 0.4541E 03 0.9783E 00 0.9992E 01

FIG. 7 - CONT.

COEFFICIENTS OF TAYLOR SERIES EXPANSION

PARAMETER 1 = GLOBAL VARIABLE 3  
LINEAR TERMS, DEL F  
0.3633E 04 0.3637E 03

NON-LINEAR TERMS, F, BEGINNING WITH DIAGONAL ELEMENT

FO<sup>1</sup> -0.6992E 00 0.1999E 03  
RCM<sup>2</sup> 0.2882E-01

PARAMETER 2 = GLOBAL VARIABLE 4  
LINEAR TERMS, DEL F  
-0.1231E 05 -0.2663E 04

NON-LINEAR TERMS, F, BEGINNING WITH DIAGONAL ELEMENT

RCW<sup>1</sup> 0.1481E 05 C.2444E C4  
RO<sup>2</sup> 0.7024E 03

PARAMETER 3 = GLOBAL VARIABLE 5  
LINEAR TERMS, DEL F  
-0.2674E C3 -0.3274E 02

NON-LINEAR TERMS, F, BEGINNING WITH DIAGONAL ELEMENT

RCW<sup>1</sup> 0.2492E 03 0.3669E 02  
RO<sup>2</sup> 0.8920E 01

PARAMETER 4 = GLOBAL VARIABLE 6  
LINEAR TERMS: DEL F  
-0.6454E 00 -0.1925E 00

NON-LINEAR TERMS, H, BEGINNING WITH DIAGONAL ELEMENT  
ROW 1 0.1021E 01 0.1589E 00  
ROW 2 0.5775E-01

PARAMETER 5 = GLOBAL VARIABLE 7  
LINEAR TERMS: DEL F  
0.5611E 01 0.4252E 00

NON-LINEAR TERMS, H, BEGINNING WITH DIAGONAL ELEMENT  
ROW 1 0.2661E 01 0.1113E 00  
ROW 2 0.1162E 00

FIG. 7 - CONT.



OPTIMIZATION RESULTS

OBJECTIVE FUNCTION 3      FUNCTION VALUE 0.66067E 04  
 GLOBAL LOCATION

DESIGN VARIABLES		GLOBAL VAR. NO.	LOWER BOUND	VALUE	UPPER BOUND
ID	D. V. NO.				
1	1	1	0.50000E 01	0.18182E 01	0.50000E 01
2	2	2	0.10000E 01	0.18168E 02	0.20000E 02

DESIGN CONSTRAINTS

IC	GLOBAL VAR. NO.	LOWER BOUND	VALUE	UPPER BOUND
1	4	-0.11000E 16	0.19555E 05	0.20000E 05
2	5	-0.11000E 16	0.45409E 03	0.10000E 05
3	6	-0.11000E 16	0.97828E 00	0.10000E 01
4	7	-0.11000E 16	0.95522E 01	0.10000E 02

CANTILEVERED BEAM

AL	=	200.000	05
P	=	C.10000E	08
B	=	1.818	
H	=	18.168	
VCL	=	6606.660	
RSTRES	=	C.19995E	05
SHRSTR	=	0.45409E	03
DELTA	=	C.57828E	00
F/R	=	5.992	

PROGRAM CALLS TC ANALIZ

IC	CALLS
1	1
2	11
3	1

FIG. 7 - CONCLUDED

```

CANT ILEVERED BEAM ANALYSIS AND DESIGN
$ DATA BLOCK 0
$   NCALC 1     NDV 2     NSV 3     NZVAR 4     NMAPRX 5
$ DATA BLOCK C - DEFAULT ALL BUT PRINT CONTROL
$   IPRINT 1
$ DATA BLOCK D - ALL DEFAULTS
0.
0.
$ DATA BLOCK E
$   NDVTOT 0     IOBJ 3     SGACPT -1.
$ DATA BLOCK F
$   VLB 1     VLB 2     VLB 3     VLB 4     VLB 5
$   WIDTH, B 5.
$   HEIGHT, H 20.
$ DATA BLOCK G
$   NDISEN 0     IDISEN 1     APULT 1
$   WIDTH, B 1
$   HEIGHT, H 2
$ DATA BLOCK H
$   NCON 1
$ DATA BLOCK I
$   ICON 1     JCCN 1     BU 1     LCON 1     SCALZ 1
$   BL 1     SCAL 1     STRES 1
$ CONSTRAINT ON STRES
-1 0 1 20 0 0 0 20000. 0 0.
-1 0 1 20 0 0 0 10000. 0 0.
-1 0 1 20 0 0 0 1. 0 0.
-1 0 1 20 0 0 0 10. 0 0.
$ DATA BLOCK J WHERE POSSIBLE EXCEPT PRINT CONTROL AND CANDIDATE DESIGNS
$   USE DEF 1     NSFS 0     NMAX 0     NMAPR 1
$   INOM 0     INFLOC 0     INXLOC 0     MAXTRM 0
$   KM IN 0     KMAX 0     JNDM 0

```

FIG. 8 - COMBINED DATA INPUT

```

$ DATA BLOCK K DX2
$ DX1 2
$ XFACT1 XFACT2
$ DATA BLOCK L NOT REQUIRED (INXLOC = 0)
$ DATA BLOCK M NOT REQUIRED (INFLOC = 0)
$ DATA BLOCK N READ 4 CANDIDATE DESIGNS
$ X1
  1.
  2.
  3.
  15.
  20.
  10.
  12.
$ DATA BLOCK O NOT REQUIRED (INXFS = 0)
$ DATA BLOCK P
$ NSOBJ
$ NSN1 NSN2 NSN3 NSN4 NSN5
  1 2 3 4 5 6 7
$ DATA BLOCK Q
$ ISENS NSENS
$ SNS1 SNS2
$ BEAM LENGTH
  200. 100. 150. 250.
$ BEAM WIDTH
  1 3
  1.5 2.5
$ BEAM HEIGHT
  2
  20.
$ DATA BLOCK R M2VX
  1 2 3 4
$ DATA BLOCK S NZ2 NZ3 NZ4 NZ5 NZ6 NZ7
  1 2 3 4 5 6 7
$ DATA BLOCK T
$ VALUES OF WIDTH, B
  X1 X2
  1. 1.5
  1. 2.
$ DATA BLOCK U
$ VALUES OF HEIGHT, H
  Y1 Y2 Y3 Y4 Y5
  1. 2. 12. 16. 20.
$ DATA BLOCK V
$ REQUIREC ENC CARD
  8.
END

```

```

CANTILEVERED BEAM ANALYSIS AND DESIGN
$ DATA BLOCK E      NDV      NSV      N2VAR      NXAPRX
$ DATA BLOCK C -- DEFAULT ALL BUT PRINT CONTROL
$ DATA BLOCK D -- ALL DEFAULTS
$ DATA BLOCK E      IOBJ      SGNOPT
$ DATA BLOCK F      VUB
$ WIDTH, E
$ HEIGHT, H
$ DATA BLOCK G      IDSGN      AMULT
$ WIDTH, B
$ HEIGHT, H
$ DATA BLOCK H      MCCNS
$ DATA BLOCK I      JCON      LCON      SCALZ
$ BL      SCAL      BU
$ CONSTRAINT ON B STRES
-1.0+20.0+20000
$ CONSTRAINT ON SHRSTR
-1.0+25.0+10000
$ CONSTRAINT ON DELTA
-1.0+20.0+10
$ CONSTRAINT ON H/E
-1.0+20.0+10
$ DATA BLOCK J
$ USE DEFAULTS WHERE POSSIBLE EXCEPT PRINT CONTROL AND CANDIDATE DESIGNS
$ NX$      NSFS      NXA      INOM      INXLOC      INFLOC      ISCRX      ISCRXF      IPAPRX
$ 4. . . . . KMAX      NPMAX      JNOM      INXLOC      INFLOC      MAXT FM
$ 0

```

FIG. 9 - SIMPLIFIED DATA INPUT

```

$ DATA BLCK K
$ DX1
$ XFACT1 XFACT2
0. $ DATA BLOCK L NOT REQUIRED (INXLOC = 0)
$ DATA BLOCK M NOT REQUIRED (IMFLOC = 0)
$ DATA BLOCK N. X2
1. .15.
2. .20.
4. .10.
3. .12.
$ DATA BLOCK O NOT REQUIRED (NXFS = 0)
$ DATA BLCK P
$ DATA NSOEJ
$ NSN1 NSN2 NSN3 NSN4 NSN5
3. 4. 5. 6. 7.
$ DATA BLOCK Q
$ ISENS
$ SAS2
$ BEAP LENGTH
9. 0. .100. .150. .250.
$ BEAM WIDTH
1. 3. 1. 5. 2. 5
3. BEAM HEIGHT
2. 2.
5. 2.
$ DATA BLOCK R M2VX M2VY M2VZ
1. 4. 5. 6. 7.
$ DATA BLCK S NZ2 NZ3 NZ4 NZ5
3. 4. 5. 6.
$ DATA BLCK T
$ VALUES OF WICHT, B X3 X4
$ X1
5. 1. 1. 5. 2.
$ DATA BLCK U
$ VALUES OF HEIGHT, H Y3 Y4 Y5
$ Y1
4. 8. 12. 16. 20.
$ DATA BLCK V
$ REQUIRED END CARD
END

```

FIG. 9 - CONCLUDED

CANTILEVERED BEAM ANALYSIS AND DESIGN

```

6:2.3.5.1
10.
0.3.5-1.
1.1.20.
2.1.1.
2.2.1.
4
- 1.0+20,0.,20000.
5
- 1.0+20,0.,10000.
6
- 1.0+20,0.,10.
7
- 1.0+20,0.,10.
0.4.0.0.0.1.
0
5.2.
0.
1.1.1.
2.1.20.
3.1.1.
3.1.2.
3.4.5.6.7
200.,100.,150.,250.
1.1
2.1
2.2
2.5.2.5
1.20.
1.4.4.5
3.4.5.6.7
4.1.1.12.5.2.
4.1.1.12.16.,20.
END

```

FIG. 10 - SIMPLIFIED DATA INPUT WITHOUT COMMENT CARDS

### VIII. REFERENCES

1. Vanderplaats, G. N., CONMIN - A Fortran Program for Constrained Function Minimization. User's Manual. NASA Technical Memorandum TMX-62282. Ames Research Center, August, 1973.
2. Vanderplaats, G. N., Approximation Concepts for Numerical Airfoil Design, NASA Technical Paper 1370, Ames Research Center, March, 1979.
3. Schmit, L. A., "Structural Design by Systematic Synthesis," Proc. 2nd Conference on Electronic Computation, ASCE, New York, 1960, pp. 105-122.

APPENDIX A  
GLOBAL CATALOG FORMS



GLOBAL CATALOG

GLOBAL LOCATION	FORTRAN NAME	DEFINITION

**APPENDIX B**  
**COPEs DATA FORMS**

COPEs DATA

DATA BLOCK A

TITLE	FORMAT
	20A4

\*

DATA BLOCK B

\$							COMMENT
NCALC	NDV	NSV	N2VAR	NXAPRX	IPNPUT	IPDBG	FORMAT
							7110

+

\*

DATA BLOCK C - OMIT IF NDV = 0

\$							COMMENT
IPRINT	ITMAX	ICNDIR	NSCAL	ITRM	LINOBJ	NACMX1	NFDG
							8110

+

\*

COPEs DATA

DATA BLOCK D - OMIT IF NDV = 0

+	\$	FDCH	FDCHM	CT	CTMIN	CTL	CTLMIN	THETA	COMMENT
*									FORMAT 7F10
*		DELFUN	DABFUN	ALPHAX	ABOBBJ1				FORMAT 4F10
*									
*									

DATA BLOCK E - OMIT IF NDV = 0

+	\$	NDVTOT	IOBJ	SGNOBJ	COMMENT
*					FORMAT 2I10,F10

DATA BLOCK F - OMIT IF NDV = 0

+	\$	VLB	VUB	X	SCAL	COMMENT
*						FORMAT 4F10

COPEX DATA

DATA BLOCK F - CONT.


COPEs DATA

DATA BLOCK G - OMIT IF NDV = 0

+	\$	NDSGN	IDSGN	AMULT	COMMENT
					FORMAT
					2110,F10

COPEs DATA

DATA BLOCK H - OMIT IF NDV = 0

+	\$				COMMENT
*		NCONS			FORMAT I10

DATA BLOCK I - OMIT IF NDV = 0 OR NCONS = 0

+	\$								COMMENT
*		ICON	JCON	LCON					FORMAT 3I10
+	\$								COMMENT
*		BL	SCAL1	BU	SCAL2				FORMAT 4F10
+	\$								
*		ICON	JCON	LCON					

COPE'S DATA

DATA BLOCK I - CONT.

\$							
BL	SCAL1	BU	SCAL2				
\$							
ICON	JCON	LCON					
\$							
BL	SCAL1	BU	SCAL2				
\$							
ICON	JCON	LCON					
\$							
BL	SCAL1	BU	SCAL2				



COPEX DATA

DATA BLOCK J - OMIT IF NXAPRX = 0

+										\$											COMMENT
NF	NXS	NXFS	NXA	INOM	ISCRX	ISCRXF	IPAPRX					FORMAT									
												8I10									
KMIN	KMAX	NPMAX	JNOM	INXLOC	INFLOC	MAXTRM					FORMAT										
											7I10										
													*								

DATA BLOCK K - OMIT IF NXAPRX = 0

+										\$											COMMENT
DX1	DX2	DX3	DX4	DX5	DX6	DX7	DX8					FORMAT									
												8F10									
												8F10									
XFACT1	XFACT2										FORMAT										
											2F10										
													*								

COPEX DATA

DATA BLOCK L - OMIT IF NXAPRX = 0 OR INXLOC = 0

									COMMENT
+	\$								
	LOCX1	LOCX2	LOCX3	LOCX4	LOCX5	LOCX6	LOCX7	LOCX8	FORMAT
*									8110
*									8110

DATA BLOCK M - OMIT IF NXAPRX = 0 OR INFLOC = 0

									COMMENT
+	\$								
	LOCF1	LOCF2	LOCF3	LOCF4	LOCF5	LOCF6	LOCF7	LOCF8	FORMAT
*									8110
*									8110

COPEs DATA

DATA BLOCK N - OMIT IF NXS = 0

								COMMENT
+	\$							
	XI1	XI2	XI3	XI4	XI5	XI6	XI7	XI8
								FORMAT
								8F10
								8F10
	\$							
	COMMENT							
	+							
	\$							
	XI1	XI2	XI3	XI4	XI5	XI6	XI7	XI8
								FORMAT
								8F10
								8F10
	\$							
	COMMENT							
	+							
	\$							
	XI1	XI2	XI3	XI4	XI5	XI6	XI7	XI8
								FORMAT
								8F10
								8F10
	\$							
	COMMENT							
	+							
	\$							
	XI1	XI2	XI3	XI4	XI5	XI6	XI7	XI8
								FORMAT
								8F10
								8F10

COPEs DATA

DATA BLOCK 0 - OMIT IF NXFS = 0

								COMMENT
+	\$							
	X1	X2	X3	X4	X5	X6	X7	X8
								8F10
								8F10
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
								8F10
								8F10
	\$							
	X1	X2	X3	X4	X5	X6	X7	X8
								8F10
								8F10
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
								8F10
								8F10

COPEs DATA

DATA BLOCK P - OMIT IF NSV = 0

+	\$								COMMENT	
		NSOBJ	IPSENS						FORMAT	
*									2110	
+	\$								COMMENT	
		NSN1	NSN2	NSN3	NSN4	NSN5	NSN6	NSN7	NSN8	FORMAT
*										8110

COPEs DATA

DATA BLOCK Q - OMIT IF NSV = 0

+	\$												COMMENT
		ISENS	NSENS										FORMAT
													2I10
+	\$												COMMENT
		SNS1	SNS2	SNS3	SNS4	SNS5	SNS6	SNS7	SNS8				FORMAT
													8F10

+	\$												COMMENT
		ISENS	NSENS										FORMAT
													2I10
+	\$												COMMENT
		SNS1	SNS2	SNS3	SNS4	SNS5	SNS6	SNS7	SNS8				FORMAT
													8F10

COPE\$ DATA

DATA BLOCK Q - CONT.

*	\$											COMMENT
	ISENS	NSNES									FORMAT	
*											2I10	
+	\$											COMMENT
	SNS1	SNS2	SNS3	SNS4	SNS5	SNS6	SNS7	SNS8			FORMAT	
*											8F10	

DATA BLOCK R - OMIT IF N2VAR = 0

*	\$				COMMENT
	N2VX	M2VX	N2VY	M2VY	FORMAT
*					4I10

COPEs DATA

DATA BLOCK S - OMIT IF N2VAR = 0

\$										COMMENT
NZ1	NZ2	NZ3	NZ4	NZ5	NZ6	NZ7	NZ8			FORMAT
										8I10

+

\*

DATA BLOCK T - OMIT IF N2VAR = 0

\$										COMMENT
X1	X2	X3	X4	X5	X6	X7	X8			FORMAT
										8F10

+

\*



COPEs DATA

DATA BLOCK U - OMIT IF N2VAR = 0

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	COMMENT
\$									
									FORMAT
									8F10

+

\*

DATA BLOCK V - COPEs END OF DATA CARD

END	FORMAT
END	3A1

\*

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**END**

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