AN IMPLEMENTATION OF THE DISTRIBUTED PROGRAMMING
STRUCTURAL SYNTHESIS SYSTEM (PROSSS)

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STRUCTURAL SYNTHESIS SYSTEM (PROSSS)

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INTRODUCTION

Numerous approaches have been documented for combining optimization
techniques with an analysis capability (e.g., refs. 1-4). The PROgraming
Structural Synthesis System (PROSSS), described in reference 4, was first
implemented entirely on a CDC CYBER computer. This implementation is
described in reference 5. PROSSS was then distributed between a mainframe and
a minicomputer (ref. 6) to provide the user easier access to intermediate
results, more control over the flow of the problem, and an interactive
modeling and data generation capability (ref. 7).

This document describes the implementation of the distributed version of
PROSSS, the second step in a series of implementations. After an overview
which explains PROSSS in general with respect to this implementation, the
remainder of this document is devoted to describing (1) each component of the
system, (2) how to examine the intermediate results, (3) how to restart the
system, and (4) results from a sample problem exercising the options of this
implementation. Appendices contain listings to clarify the descriptions of
the components of the system contained in the body of this paper.

It is not the purpose of this paper to be a self-contained user's guide
for PROSSS. Its purpose is to demonstrate a method for implementing a
flexible software system that combines large complex programs with small,
user-supplied, problem-dependent programs and distributes their execution
between a mainframe and a minicomputer.

OVERVIEW OF THIS IMPLEMENTATION

This distributed implementation of the PROgram Structural Synthesis
System (PROSSS) combines a general purpose finite-element computer program for
structural analysis (SPAR, ref. 8), a state-of-the-art optimization program
(CONMIN, ref. 9), and several user-supplied, problem-dependent computer
programs. The results are flexibility of the optimization procedure
organization and versatility of the formulation of constraints and design
variables.

Figure 1 is a flow chart of the analysis-optimization process for this
implementation. The process results in a minimized objective function,
typically the mass. Notice that the analysis and optimization programs are
executed repeatedly by looping through the system until the process is stopped
by a user-defined termination criterion. This is referred to as the
repeatable part of PROSSS. However, some of the analysis, such as model
definition, need only be done one time and the results are saved for future
use. This analysis is performed outside of the loop and referred to as the
nonrepeatable part of PROSSS. The user must write some small, simple FORTRAN
programs to interface between the analysis and optimization programs. One of
these programs, the front processor, converts the design variables output from
the optimizer into a suitable format for input into the analyzer. Another,
the end processor, retrieves the behavior variables and, optionally, their
gradients from the analysis program and evaluates the objective function and
constraints and optionally their gradients. These quantities are output in a
format suitable for input into the optimizer. These user-supplied programs
are problem-dependent because they depend primarily upon which finite elements are being used in the model.

The analysis is always performed on the mainframe, in this implementation a CDC 6600, because the CPU on the mainframe is much faster than that of the minicomputer. The end processor is also executed on the mainframe to reduce the large amounts of data generated by the analysis program to the small amount of data (e.g., objective function and constraints) required by the optimizer. This limits the amount of data transmitted between the two computers.

The optimization is always performed on the minicomputer, in this implementation a PRIME 750, because the optimizer requires a significant memory allocation and the minicomputer has virtual memory. The front processor is also executed on the minicomputer and, as in the case of the end processor, the amount of data transmitted between the two computers is reduced to the minimum. The data transmitted from the front processor to the analysis program consist of updated design variable information.

Five options exist for organization of optimization procedures comprising nonlinear and piecewise linear programming with analytical and finite-difference gradients. These options are shown in Table I. One of the primary differences between the distributed implementation of PROSSS and the first implementation described in reference 5 is the method of controlling the flow of the options. In the first implementation, each option is controlled by a complex sequence of Control Data Corporation-Cyber Control Language (CDC-CCL (ref. 10)), while the flow of the options in the distributed implementation of PROSSS is controlled by FORTRAN programs using FORTRAN-callable system subroutines (ref. 11). Although presented in the context of structural analysis,
these organizations are independent of the type of analysis. The same system concept could be used for aerodynamic optimization of, for example, a wing, if the analyzer had a capability for computational aerodynamics.

The system is intended to be used in the following three basic ways:

1. as a research tool for development of optimization techniques where it offers an interface to efficient analysis and flexibility of execution and sequencing,

2. as a test bed for trying new structural analysis techniques tailored toward efficient use in optimization loop, and

3. as an application tool that can be adopted to a very wide scope of different types of problems.

Before trying to implement this system, the user should be thoroughly familiar with references 4, 5, 6, 8 and 9.

COMPONENTS OF THE SYSTEM

There are seven primary components for the distributed implementation of PROSSS including (1) the driver program, (2) the front processor, (3) CONMIN-the optimizer, (4) procedures transmitting jobs between the PRIME minicomputer and CDC mainframe computer, (5) SPAR-the analyzer, (6) the end processor, and (7) the plotting program. Each component and the files associated with them are explained in detail in the following subsections. Files generated by the system are not shown. Only those files that must be created by the user are shown.

The Driver Program

As previously mentioned, each option in PROSSS is controlled by a FORTRAN program using FORTRAN-callable procedure files. While each option uses its own main driver program, there is a group of eight subroutines common to each
option. A typical flowchart of an option is shown in figure 2. The listings of the program and subroutines are shown in Appendix A. The driver program performs the following functions: (1) initialization, (2) restarting, (3) controlling the flow of the option, and (4) termination.

The driver program first reads one line from a file named NAMEij where ij is the option number without the decimal. For example, a file named NAME11 contains the input data for option 1.1. This first line in NAMEij contains the following variables:

| NRSTRT | ø - not restarting  
|        | 1 - restarting     |
| ICR    | ø - data not created by a data generator  
|        | 1 - data created by a data generator     |
| NR     | ø - no nonrepeatable analysis is to be done  
|        | 1 - perform nonrepeatable analysis        |
| NOPT   | the option number (e.g. 11)              |
| NAMES  | the name of the file to be sent to the CDC 6600 (four characters in length) |
| COUNT  | the number of passes made through the analysis program (initially one) |

The format is (3(I1,1X),I2,1x,A4,1x,I3).
An example of a NAMEij file is as follows:

```
Ø Ø Ø 11 ANOS   1
STRP3    file containing starting design variables
CONP1    file containing CONMIN parameters
CONS     file containing constants for front processors
RRSNG    file containing repeatable runstream with no analytical gradients
JIM      UFD name
DPROSS   SUBUFD name
SSPROUT  file containing SPAR output
SCNMNIO  file containing end processor output
NRLANG   file containing non-repeatable SPAR library
123456   user number
XYZ      password
123456   charge number
EPFUBIP  file containing end processor
EPFUIN   file containing input to end processor
FPFUS    Ø   file containing front processor (Ø mean compile)
CONMS1   1   file containing CONMIN main program (1 means do not compile)
```

If NRSTRT is equal to zero, subroutine INIT is called to create a temporary procedure file called INITPRC. INIT reads the remainder of file NAMEij and creates edit procedures on file INITPRC to replace general file names in procedure files executing other components of the system with specific file names depending upon the problem being solved. Files for other components of the system are created depending on the option number. (This is transparent to the user.)
If ICR is not equal to zero, then INIT calls subroutine CRSNPT. This subroutine reads data from a file called NAMECRRS, edits a file created by the data generator, and inserts a file containing problem-dependent data. An example of a NAMECRRS file is as follows:

1
SPARIN  number of design variables
TOPSPARIN file created by a data generator for input to SPAR

If NR is not equal to zero, then INIT calls subroutine NONRPT. This subroutine reads data from a file called NAMENR and creates a procedure file (TONOSNR, described below) to be sent to the CYBER to perform the nonrepeatable part of the analysis. An example of a NAMENR file is as follows:

TSPARIN  non-repeatable SPAR runstream
70000  field length required on CDC 6600
NONI  non-repeatable job name

If NRSTRT equals 1, then subroutine RSTRT is called instead of subroutine INIT. This subroutine sets up a procedure file named RSTRTPRC to reinitialize the files saved for restarting the program.

If the nonrepeatable part of the analysis is required (NR = 0), a job has been sent to the CDC 6600 to perform this analysis. At this point, subroutine STCHEK is called. This subroutine calls subroutine COMSTA which returns the status of a file that has been transmitted to the CDC 6600 computer. If COMSTA determines that the job has not yet completed executing on the CDC 6600 (because no file has been returned to the PRIME), then it returns a status of zero. If the job has completed executing on the CDC 6600 and a file has been returned to the PRIME, the status is returned as one. When the status cannot be determined, an error has occurred and the status is returned as -1.
Subroutine STCHEK checks the status returned from COMSTA. If the status is one, then control is passed back to the driver program. If the status is -1, subroutine ERRMSG is called to print an error message, and the job is terminated. If the status is zero, a system routine is called to put the job on the PRIME to "sleep" for 2 minutes while waiting for the CDC 6600 to finish processing. After 2 minutes, the job "awakens" and again calls subroutine COMSTA to determine if the file has been returned from the CDC 6600. The "sleep" and "awake" process continues until the CDC 6600 has finished processing the analysis and returned the output file to the PRIME. This concept makes efficient use of the PRIME's resources.

Once the nonrepeatable part of the analysis program has been completed, the driver enters the optimization loop shown in figure 1. It will remain in this loop until an error is encountered, a loop limit (default is 999) is met, or the termination criteria are satisfied. In the optimization loop, procedure files executing the optimization program and front processor program (described below) are called. The front processor creates a file containing updated design variable information to be transmitted to the CDC 6600. The file sent to the CDC 6600 to perform the repeatable part of the analysis must have a unique job name to facilitate the return checking done by subroutine COMSTA. Subroutine UPDSF is called to create a temporary procedure file (UPDTE) for assigning this unique job name. The job name is created from the NAMES variable from the first line of the NAMEij file coupled with the loop counter.

Two temporary files containing the names of files pertaining to the specific problem at hand are created during initialization from two permanent files containing general file names. One temporary file, the names coming from the NAMES variable on the NAMEij file, is created from a permanent file
called TONOS. TONOS is a file containing CDC-CCL statements to execute the repeatable analysis (SPAR) and end processor on the CDC 6600. The second temporary file, called TSENDPRC is created from the permanent file SENDPRC. SENDPRC is a PRIME procedure file for appending the data file created by the front processor to the temporary file created from TONOS and then transmitting that file to the CDC 6600. Once the TSENDPRC file has been executed and processing is transferred to the CDC 6600 for the repeatable part of the analysis, then subroutine STCHEK is again called to test for the status of the file to be returned from the CDC 6600. The same checking, "sleeping," and "awakening" pattern described above for the nonrepeatable analysis is also followed here.
A sample listing of a TONOS file is shown below. This listing contains the
general names that are replaced by specific, problem dependent names during
initialization.

```
JOB,T100,CM700000.
USER,USERNO,PASSWRD.
CHARGE,CHARGENO,LRC.
DELIVER,$UDS$UBUD$TCMNOI
RFL,700000.
REDUCE(-)
MAP,OFF.
COPYCR,INPUT,SPFPOUT.
REWIND,SPFPOUT.
GET,RUNSTREAM,MERGF.
EDIT,RUNSTREAM,,MERGF.
EDIT,RUNSTREAM,,MERGF,EDOUT.
REWIND,RUNSTREAM.
GET,SPAR=SPAR14I,DCU=DCU14I.
GET,SPARL=SPAROUT.
SPAR,RUNSTREAM,SPAROUT.
REWIND,SPAROUT.
REWIND,SPARLD.
GET,EPXXXX,ENDINXX.
GET,SPARLIB.
LDSET(LIB=SPARLIB,PRESET=ZERO)
EPXXXX,ENDINXX,CNMNOI.
REPLACE,SPAROUT=DUMOUT,CNMNOI=DUMIO.
REWIND,CNMNOI.
COPYSBF,CNMNOI,OUTPUT.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
EXIT.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
```
A sample SENDPRC file is:

```
SAVE TEMP
DELETE UPDTE
APPEND SENDFILE SPFPOUT
DELETE CNMNIO
RJSEND SENDFILE CDC
DELETE SPFPOUT
R TEMP
```

After the analysis output file, TCMNIO, is returned from the CDC 6600, the driver program checks for the existence of a file called GONOGO. GONOGO is created by the CONMIN main program when the termination criteria have been met. If GONOGO exists, then the optimization process stops. If GONOGO does not exist, then the optimization loop continues by calling the EDPRC procedure file. This procedure file edits TCMNIO to remove any extraneous information, such as the dayfile, returned from the CDC 6600. This leaves only the objective function and constraint data required for input into CONMIN. At this point, the optimization loop begins a new iteration. A sample EDPRC file is:

```
SAVE TEMP
ED TCMNIO
END CNMNIO
D10000
T
BEGIN CNMNIO
D
UNLOAD CNMNIO 10000
FIL
DELETE TCMNIO
R TEMP
```
The Optimizer

The procedure file called from the driver program to execute CONMIN, the optimizer, is named CNMNPRC1. Whenever any procedure file is called from the driver program, the first instruction in the procedure file is to save the current address. The final instruction in the procedure file is to return control to the saved address. The CNMNPRC1 procedure file performs four functions: (1) saves restart files, (2) opens and closes files for CONMIN input and output, (3) executes CONMIN, and (4) save cumulative plotting and optimization data. A listing of CNMNPRC1 is below:

SAVE TEMP
ED PASS
FIL SPASS
ED CNMNI0
FIL SCNMNIO
ED CONREST
FIL SCONREST
OPEN TPL0T 12 2
OPEN PLTDATA 11 3
OPEN PASS 7 3
OPEN CNMNI0 5 3
OPEN CONREST 3 3
OPEN CONOUT 2 2
OPEN CONPAR 1 1
SEG CONMIN
C 1
C 2
C 3
C 5
C 11
C 12
APPEND PLTDATA TPL0T
DELETE TPL0T
APPEND CONOUTHOLD CONOUT
DELETE CONOUT
R TEMP
Three files are required to restart CONMIN. File PASS contains the number of passes made through CONMIN--one initially and two on each subsequent pass. File CNMNIO contains the objective function and constraints found in the repeatable analysis. File CONREST contains all of the remaining data saved from the preceding pass through CONMIN. These files are saved as temporary files named SPASS, SCNMNIO, and SCONREST, respectively.

Other files open for CONMIN input and output include TPLOT, PLTDATA, CONOUT, and CONPAR. TPLOT contains the plotting data created in this (and only this) pass through CONMIN. PLTDATA contains a cumulative history for the objective function, design variables, and constraints for the entire run. CONOUT contains the output listing for only this pass through CONMIN. CONPAR contains the output listing for this pass through CONMIN. CONPAR contains the initialization values for the parameters input to CONMIN. This file must be created by the user and is input via a free-field format. A description of these variables, except for JSC, can be found in reference 9. The variable JSC is used to determine the linear constraint identification vector, JSC. If JSC is -999, then all of the constraints are known to be a linear function of the design variables. If JSC is zero, then all of the constraints are nonlinear. If JSC is other than these two numbers, then a file, ISCFILE, must be created by the user containing the constraint numbers (in I4 format) of the linear constraints if JSC is positive or the constraint numbers of the nonlinear constraints if JSC is negative. JSC in this last case is the number of constraints in ISCFILE. ISCFILE is opened and closed within CONMIN. Another file, STARTX, is also opened and closed within CONMIN and must be created by the user. This file contains the number of design variables in I5.
format followed on succeeding lines by the starting values of the design
variables in 6E13.5 format. A sample CONPAR file is:

5 3 20 190 0 1 0
4 0 0 0.0 0.0 0.0 0.25 0.0 0.0
0.125 5. 0.25 0.000000001 0 20 200 100 100 200
0.0 0.0 0.005 0.1 0.0 0.0 10 1.0.

A sample STARTX file is:

3
0.50000E=0.1 0.10000E 01 0.40000E 01

Once the restart files have been saved and the necessary files have been
opened, the CNMNPRCI executes CONMIN. CONMIN consists of a group of nine
subroutines as defined in reference 9. These routines are never changed by
the user. The routines are called by a CONMIN main program written by the
user dependent upon the problem to be solved. An example of a main program is
listed in Appendix B. In addition to calling the CONMIN subroutines, the
CONMIN main program is responsible for reading and writing data from and to
the above files. After executing CONMIN, CNMNPRCI closes all files that
remain open.

The final task performed by CNMNPRCI is to append the temporary files
containing the plotting data (TPlot) and CONMIN output listing (CONOUT) to the
permanent cumulative files PLTDATA and CONOUTHOLD, respectively. TPlot and
CONOUT are deleted and control is returned to the driver program.

The Front Processor

The procedure file called from the driver program to execute the front
processor, FPFUS, is named FRONTPRC. The front processor is supplied by the
user and converts the design variables output from CONMIN on file CNMNIO to

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a file SPFPOUT formatted suitable for input into the SPAR analysis program. A listing of FRONTPRC follows:

```
SAVE TEMP
OPEN CNMNIO 1 1
OPEN SPFPOUT 2 2
OPEN CONSXX 3 1
R *FPROCESSOR
C 1
C 2
C 3
R TEMP
```

The FRONTPRC procedure file opens the CNMNIO and SPFPOUT files. In addition, a file called CONSXX, supplied by the user if necessary and containing certain constants such as the cross section dimensions of a beam, is also opened. The format of the CONSXX file is determined by the user because the user writes the front processor program dependent upon what elements are used in the finite-element model. An example of a front processor is then executed, all open files are closed, and control is returned to the driver program. A sample CONSXX file for the beam parameters B1Ø, B2Ø and TØ follows:

```
12. 30. 2. (beam parameters)
```

The Analyzer--Nonrepeatable Part

The INITPRC procedure file (described above in the section on the driver program) transmits the TONOSNR procedure file to the CDC 6600 to execute the nonrepeatable part of the analysis. The nonrepeatable SPAR runstream (NRRS) is appended to the TONOSNR file for transmittal to the CDC 6600. NRRS is
copied to a local file and SPAR is then executed using NRRS as input. The results are saved on a SPAR library file (NRLA) for later use in the repeatable part of the analysis. A file named TNREPT is returned to the PRIME indicating that the nonrepeatable analysis has completed execution. A listing of TONOSNR follows.

```plaintext
JOB,T100,CMFLX.
USER,USERNO,PASSWRD.
CHARGE,CHARGENO,LRC.
DELIVER,$UFD>SUBUFD>TNREPT
MAP,OFF.
COPYCR,INPUT,NRRS.
REPLACE,NRRS.
.*
.* THE PROCEDURE CREATES A SPAR LIBRARY
.* FROM THE NON-REPEATABLE PART
.*
GET,SPAR=SPAR14I,DCU=DCU14I.
GET,NRRS.
RFL,FLX.
REDUCE,-.
SPAR,NRRS,NSPROUT.
REPLACE,SPARLA=NRLA.
.*
.* TEST TO SEE IF GRADIENTS ARE REQUIRED
.*
IFE,(NROPT.EQ.13.OR.NROPT.EQ.23),GRADIENTS.
GET,INPT=INPTXX.
GET,EDIT1,EDIT2,BLDELDB.
REWIND,NRRS.
.*
.* EDIT OUT ALL BUT ELD INPUT IN RUNSTREAM
.*
EDIT,NRRS,EDIT1,EDOUT.
REWIND,NRRS.
.*
.* CREATE SPAR RUNSREAM TO FIND DERIVATIVES
.*
BLDELDB,INPT,NRRS,RSOUT.
REWIND,RSOUT.
EDIT,RSOUT,EDIT2,EDOUT.
REWIND,RSOUT,SPARLA.
.*
.* EXECUTE SPAR AGAIN TO FIND DERIVATIVES OF
.* THE STIFFNESS MATRIX WITH RESPECT TO
.* THE DESIGN VARIABLES
.*
SPAR,RSOUT,NSPROUT.
RETURN,INPT,EDIT1,EDIT2,BLDELDB,EDOUT.
RETURN,RSOUT,TAPE21,TAPE22,NSPROUT.
REPLACE,SPARLB=NRLA.
ENDIF,GRADIENTS.
RETURN,SPARLB=NRLA.
ENDIF,GRADIENTS.
RETURN,SPAR,DCU,SPARLA,NRRS.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
EXIT.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
```

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An example of a non-repeatable SPAR runstream (NRRS) is as follows:

```
$XQT TAB
START 80, 5$ ROTATIONS ABOUT Y EXCLUDED
TITLE" FUSELAGE MODEL, FSPAR1"
TEXT
" MEMBRANE-ROD-BEAM FUSELAGE MODEL
"NONREPEATABLE PART
JLOC$ FUSELAGE DIA. 800. CM., LENGTH=800. CM.
FORMAT=2$ CYLINDRICAL COORDINATES
1 400. 0. 0. 400. 337.5 0. 16 1 5
16 400. 0. 800. 400. 337.5 800.
MREF
FORMAT=2
1 -2 0. 0. 10000000.
2 1 0. 0. 10000000.
MATC
1 .72+6 0.3 .0028 22.-6$ AL-ALLOY, METRIC UNITS
E23 SECTION PROPERTIES $ROD ELEMENTS
1 4.168$ AREA OF THE RODS
E21 SECTION PROPERTIES $BEAM ELEMENTS
DSY 1 16804. 0. 1262.7 0. 108. 144. 0. 6.0784 0. 0.
0. 0. 0. -8.7778 17. 3.2222 17. 3.2222 -17. -8.7778 -17.
SHELL SECTION PROPERTIES
1 0.1$ SKIN THICKNESS
CONSTRAINT CASE 1
ZERO 1,2,3;1,16$ CANTILEVER THE FUSELAGE
$XQT ELD
$START
E23$ROD ELEMENTS
NSECT=1$
NREF=2
1 17 1 4 3 1$
4 20$
5 21$
6 22$
52 68$
53 69$
54 70$
7 23 1 4 10 1$
$END
$START
F21
NSECT=1$
NREF=1
1 2 2 16 2 16$
49 50 2 16 2 16$
33 34$
34 35$
39 40$
40 41$
$END
$START
F41$ MEMBRANE PANELS
NSECT=1$
1 17 18 2 2 16 1$
49 65 66 50 2 16 1$
17 33 34 18 1 1 2 2 16$
23 39 40 24 1 1 9 2 16$
32 48 33 17$
48 64 49 33$
$END
$XQT DCU
TOC 1
$XQT EXIT
```
The Analyzer--Repeatable Part

The SENDPRC procedure file transmits the TONOS procedure file (both files discussed in the above section on the driver program) to the CDC 6600 to execute the analysis (SPAR) and end processor (EPXXXX) programs. The SPFPOUT file created by the front processor is appended to the TONOS file for transmittal to the CDC 6600. The SPAR library file (SPARNAME) containing data created during the nonrepeatable analysis and the repeatable SPAR runstream file (RUNSTREAM) both reside as permanent files in the CDC 6600 disk storage. SPFPOUT is copied onto a temporary file on the CDC 6600 and merged into RUNSTREAM file using a file named MERGFP consisting of CDC TEXT EDITOR (ref. 12) commands. SPAR is then executed using the RUNSTREAM and SPARNAME files as input. The objective function and stresses are computed in SPAR and saved on a SPAR library file (SPARLD). This file is then used as input to the end processor. A listing of the MERGFP file is as follows:

```
MERGE:/SPFPOUT/,/$ MERGE NEW;/
R
RS:/E+/,+;/*
RS:/E-/,-;/*
END
```
An example of a repeatable SPAR runstream without analytical gradients (RRSNG) is as follows:

```
xqt tab
  title=fuselage model
  text
  "membrane rod beam fuselage model"
  "repeatable part without gradients"
  update=1
  $ merge new properties here.
  update=0
  xqt topo
  xqt e
  xqt eks
  xqt k
  xqt inv
  xqt m
  reset g=991.
  xqt aus
  sysvec; applied forces 1
  i=1; j=65; 69; 77; 10000. -20000. 20000.
  sysvec; unit vec
  i=1; j=1; 80; 1.0
  define wt=dem diag 0 0
  define un=unit vec
  objfun=xty(un, wt)
  xqt dcu
  print 1 objfun
  xqt ssol
  xqt gsf
  xqt psf
  xqt vprt
  print appl forc 1 1
  print stat disp 1 1
  xqt dcu
  print 1 stat disp 1 1
  print 1 strs e21 1 1
  print 1 strs e23 1 1
  print 1 strs e41 1 1
  toc 1
  copy 1,4 objf aus 1 1
  copy 1,4 strs e21 1 1
  copy 1,4 strs e23 1 1
  copy 1,4 strs e41 1 1
  toc 4
  xqt exit
```
The End Processor

The end processor, EPFUS, is also executed on the CDC 6600. The objective function and stress data saved on the SPAR library file, SPARLD, are input to the end processor using FORTRAN-callable subroutines from SPAR (ref. 13). Another file, ENDINXX, is stored on the CDC 6600 in NAMELIST form and input to the end processor. This file contains the number of each different type of element used in the model and the limits imposed on the behavior variables in constraint function evaluation. The format of the ENDINXX file is determined by the user because the user writes the end processor program dependent upon what elements are used in the finite-element model. The end processor then computes the constraints and outputs the objective function and constraints in a suitable format for input to the optimizer. The output is placed on file CNMNIO and transmitted to the PRIME on file TCMNIO. An example of an end processor program is listed in Appendix D. A sample of an ENDINXX file is as follows:

```
$EPIN
E23AL=2000.,
E21AL=2000.,
E41AL=2000.,
NSE23=58,
NSE21=76,
NSE41=56,
$END
```

Gradients

Options 1.3 and 2.3 have the capability for calculating gradients analytically. There are three problem independent programs used
to compute the analytical gradients. The first, BLDELDS, builds a file for input into the analysis program to calculate the derivatives for the mass and stiffness matrices with respect to the design variables in the nonrepeatable part. A listing of BLDELDS is in Appendix E. The program is stored on the CDC 6600 and is called by the TONOSNR (described in the section on the nonrepeatable analysis) sent to the CDC 6600 from the PRIME. The file containing the nonrepeatable SPAR runstream NRNS, is edited using the CDC Text Editor (ref. 12) commands from file EDIT1 to remove all but the element connectivity data. A listing of EDIT1 follows:

```
F:/[XQT ELD/
F:/[XQT/;2
D;*
R
F:/[XQT ELD/
E;*
R
D;*
R
ADD
$
END
```
Another file, INPT, stored on the CDC 6600 and created by the user is input to BLDELDS along with the edited NRNS file. The INPT file contains two card types. The first type (only one card) has the format ((6(1X,I4),1X,A4)) and contains the following variables:

- **NOLC** - number of load cases
- **NODV** - number of design variables
- **ISNOLC** - new starting number for load cases with derivatives
- **JOINTS** - number of joints in the model
- **NDF** - number of degrees of freedom
- **NOEL** - number of different elements
- **VORB** - a four character word to determine the type of analysis (e.g., STAT, VIBR, BUCK)

The second type has the format (6(1X,A3,1X,I3,1X,I3)) consists of one or more cards, and contains the following variables (one set for each element):

- **EL** - element type (e.g., E21, E43)
- **NSECT** - largest section property number used for that element type
- **NODVPE** - number of design variables for that element type

A sample listing of INPT follows.

```
1 3 100 80 5 3 STAT
E23 1 1 E21 1 1 E41 1 1
```

BLDELDS creates a SPAR runstream and outputs it on file RSOUT. File RSOUT is then edited using the CDC Text Editor and commands from file EDIT2 to remove any extraneous blanks or characters before being input to SPAR. SPAR is then executed using RSOUT as input. The results are saved on a SPAR library file (NRRA) for later use in the repeatable part of the analysis.
A listing of the EDIT2 file follows:

```
RS: / / /;*
RS: / / /;*
A:/TOPO/;*
>RESET MAXSUB=2500>
END
```

The other two gradient programs, GRDXXXX and DRVXXXX, are used in the repeatable part of the analysis. Listings of GRDXXXX and DRVXXXX are in Appendices F and G, respectively. Two procedure files SENDPRCG and TONOSG (similar to the SENDPRC and TONOS files previously described) are used to execute these programs in conjunction with the SPAR analysis program on the CDC 6600. The first part of the repeatable analysis with analytical gradients is identical to repeatable analysis described above. The CNMNI0 file created by the optimizer is appended to the TONOSG file by SENDPRCG before it is transmitted to the CDC 6600. The GRDXXXX, DRVXXXX, INPTXX, CONSXX, and EDGRDS files are all stored on the CDC 6600. The contents of the INPTXX and CONSXX have already been described. Each of the GRDXXXX, DRVXXXX, INPTXX, and CONSXX general file names are replaced by specific names from the NAMEij file before execution. GRDXXXX uses the repeatable SPAR runstream (RRSG) as with analytical gradients to create a runstream to calculate the derivatives of the stiffness and the mass matrices with respect to the design variables when an element (such as a beam or plate) has more than one contributing factor. The program calls user supplied subroutine(s) with any of the following names Dkdve21, Dkdve22, Dkdve33, and/or Dkdve43. These subroutines compute the derivatives of the stiffness matrix with respect to a design variable for a particular element type in SPAR (ex. E21 or E43). The name(s) used depend
upon the elements used in the finite-element model. If a subroutine is not used, it remains as an unsatisfied external. Two integer parameters used in naming the created data sets are passed to each subroutine. The first is the counter for the design variable and the second is the number of unconstrained degrees of freedom (from 1 to 6). A listing of a sample DKDVE21 subroutine is shown in Appendix H. The subroutine card for DKDVE21 is as follows:

SUBROUTINE DKDVE21(NDVJIM,NDF)

where

NDVJIM - the number of the design variables (first, second, third, etc.)
NDF  - number of degrees of freedom per joint squared

A listing of the SENDPRCG file follows.

SAVE TEMP
DELETE UPDATE
APPEND SENDFILE SPFPOUT
APPEND SENDFILE CNMNIO
DELETE CNMNIO
RJSEND SENDFILE CDC
DELETE SPFPOUT
R TEMP
A listing of the TONOSG file follows.

```
JOB,T100,CM100000.
USER,USERND,PSWHRD.
CHARGE,CHARGENO,LRC.
DELIVER,SUBFD>TCMNIO.
RFL,100000.
REDUCE(-).
MAP,OFF.
COPYCR,INPUT,SPFPDUT.
REWIND,SPFPDUT.
GET,MERGFP/UN=753437N.
GET,UNSTREAM.
EDIT,UNSTREAM,.MERGFP,EDOUT.
REWIND,UNSTREAM.
GET,SPARLA=SPAR14I,DCU=DCU14I/UN=750756N.
GET,SPARLA=SPARNAME.
SPAR,UNSTREAM,SPAROUT.
RETURN,UNSTREAM,SPFPDUT,MERGFP,EDOUT.
REWIND,SPARLA,SPARLD.
GET,SPARLIB/UN=319925N.
GET,GRDXXXX,DRVXXXX,INPTXX,CONSXX.
GET,EDGRDS/UN=753437N.
COPYCR,INPUT,CMNIO.
REWIND,CMNIO.
GRDXXXX,INPTXX,CONSXX,CMNIO,RSOUT.
REWIND,RSOUT.
EDIT,RSOUT,EDGRDS,EDOUT.
REWIND,RSOUT.
SPAR,RSOUT,SPAROUT.
RETURN,EDGRDS,EDOUT,GRDXXXX.
IFE,(NSUBS,NEO),DERIV.
REWIND,SPARLA,SPARLD,SPARLC,CMNIO,CONSXX,INPTXX.
LDSET(LIB=SPARLIB,PRESET=ZERO)
DRVXXXX,INPTXX,CONSXX,CMNIO.
RETURN,DRVXXXX,INPTXX,CONSXX,SPARLA,SPARLC.
ENDIF,DERIV.
REWIND,SPARLD,SPARLIB,CMNIO.
GET,EPXXXX,ENDINXX.
LDSET(LIB=SPARLIB,PRESET=ZERO)
EPXXXX,ENDINXX,CMNIO,BLK.
RETURN,SPARLD,EPXXXX,ENDINXX,SPARLIB.
REPLACE,SPAROUT=DUMOUT,CMNIO=DUMIO.
REWIND,BLK,CMNIO.
COPYSBF,BLK,OUTPUT.
COPYSBF,CMNIO,OUTPUT.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
EXIT.
DAYFILE(L=DISOUT)
REPLACE,DISOUT.
```

25
An example of a repeatable SPAR runstream with analytical gradients (RRSG) follows.

```
EXQT TAB
  TITLE"FUSELAGE MODEL"
TEXT
  "MEMBRANE ROD BEAM FUSELAGE MODEL"
  "REPEATABLE PART WITH GRADIENTS"
  UPDATE=1
  "$ MERGE NEW PROPERTIES HERE."
  UPDATE=0
EXQT E
EXQT EKS
EXQT TOPO
EXQT K
EXQT INV
EXQT M
RES S T G=981.
EXQT AUS
  SY SVEC;APPLIED FORCES 1
    I=1; J=65; 69; 77; 10000, -20000, 20000.
  SYSVEC;UNIT VEC
    I=1; J=1,80; 1.0
DEFINE WT*DEM DIAG 0 0
DEFINE UN=UNIT VEC
OBJF AUS 1 1=XTY(UN,WT)
EXQT DCU
  PRINT 1 OBJF AUS 1 1
EXQT SSOL
EXQT GSF
EXQT PSF
EXQT VPRT
  PRINT APPL FORC 1 1
  PRINT STAT DISP 1 1
EXQT DCU
  CHANGE 1, STRS E21 1 1,FAMS E21 1 1
  TOC 1
COPY 1,4 OBJF AUS 1 1
COPY 1,4 FAMS E21 1 1
COPY 1,4 STRS E23 1 1
COPY 1,4 STRS E41 1 1
TOC 4
EXQT EXIT
```
The SPAR runstream is output on file RSOUT. A file, EDGRDS, containing CDC Text Editor commands is used to remove any extraneous blanks or characters from RSOUT. SPAR is executed to compute the derivatives using RSOUT as input. The output data from SPAR, including stresses, stress derivatives, forces and moments, and derivatives of forces and moments are output on a SPAR library file, SPARLD. A listing of EDGRDS follows.

```
RS:/E+/,+/*
RS:/.
RS:/.
RS:/.
RS:/ /, /;*
RS:/E-/-,/-;*
RS:/ /, /;*
RS:/ , , ;*
RS: W, /, W;*
RS: G, /, G;*
RS: W, /, W;*
RS: F, /, F;*
RS: /, L, L;*
END
```

Program DRVXXXX is called if there is a need to convert forces and moments, and derivatives of forces and moments to stresses and stress derivatives. The program computes stresses and stress derivatives using a user supplied subroutine named BMSTRS (for beams) or PLTSTRS (for plates). As before, if a name is not used it remains an unsatisfied external. Four integer parameters are passed to BMSTRS. They are (1) a switch, (2) a counter so
certain computations can be skipped if they are not needed, (3) a block counter for accessing an array, and (4) another switch to determine if the beam is the contributing factor to the stress derivative. The first three parameters are also passed to PLTSTRS. A listing of a sample BMSTRS subroutine is provided in Appendix I. The subroutine for BMSTRS is as follows:

SUBROUTINE BMSTRS (ISW,KCNT,JCNT,IBEAM)

where

ISW,KCNT - a switch and a counter used to store certain beam data (ex. moments of inertia) and make certain computations (ex. derivatives of Y with respect to the design variables) only on the first time BMSTRS is called from DRVXXXX

JCNT - a counter to find the location in blank common for various data times, depends on the number of beam elements

IBEAM - 1 if beam is a contributing factor to stress derivatives - 0 otherwise

This program also uses FORTRAN-callable SPAR subroutines (ref. 13) to input and output this data to and from the SPAR library, SPARLD. After DRVXXXX completes execution the end processor is executed before control is returned to the PRIME.

EXAMINING THE INTERMEDIATE RESULTS

One of the key features in the distributed PROSSS is the capability for the user to examine the intermediate results. Because of this feature, the user does not have to wait until the end of the complete optimization process to determine whether or not the model, variables, and/or process are behaving as expected. The user, after examining the intermediate results, can let the
process continue; stop the process; or temporarily stop the process, make some changes to the optimization parameters or design variables, and restart the process. This gives the user much more control over the flow of the problem and should significantly reduce the total time required to reach the optimal solution.

All examining of intermediate results is done on the PRIME because of the faster transmission rate (9600 BAUD) to the interactive terminals. Two files, CONOUTHOLD, and PLTDATA, created by the CONMIN driver program are essential for examining these results. The CONOUTHOLD contains a cumulative listing of all information output from CONMIN. This information is originally output on file CONOUT. At the end of the CNMNPRC1 procedure file, CONOUT is appended to CONOUTHOLD to create the cumulative listing. It is best to examine the CONOUTHOLD file with the PRIME editor (ref. 14). The user is usually interested in seeing the progress of the objective function and design variables. Also of interest are the active and violated constraints. It is useful to check for errors and warning messages issued by CONMIN so that the process can be stopped at this point.

If the user desires to see a graphical display of the optimization data, the PLTDATA file should be used in conjunction with program plots. The program plots either the objective function, design variables, or constraints versus the iteration number. The capability of listing these values in tabular form is also available. The user makes a choice from a menu displayed on the screen (figure 3). The user can also decide whether or not the objective function and design variables are to be normalized. Examples of each type of plot are shown in figures 4-6.
RESTARTING PROSSS

The user may wish to restart PROSSS for a particular point in the process because the computers go down, there is an error in the system, or the examination of the intermediate results revealed a change in the system, or the examination of the intermediate results revealed a change is needed in the model or optimization parameters. To restart PROSSS is quite simple. All of the necessary files required for restarting are saved by the procedure file CNMNPRL. The user edits the first line of the NAMEij file to restart. The NRSTRT variable is set to 1. The NAMES variable is changed to create a unique name. The COUNT variable may or may not be updated depending upon whether or not the user has need of keeping track of the number of iterations through the system. Other names may be changed in the NAMEij file as needed. After these changes have been made, the user restarts PROSSS. After initialization, processing begins at CONMIN.

SAMPLE PROBLEM

Each option was executed to determine the final objective function (minimum mass, kg) of the finite-element model of the fuselage shown in figure 7 using the NAMEij input files. The model is composed of 80 joints, 58 rods, 76 beams, and 56 membranes. There are 352 degrees of freedom. The three design variables are (1) the cross-sectional area of the transverse stringers (beams), (2) the cross-sectional area of the longitudinal stringers (rods), and (3) the thickness of the panels (membranes). The design variables are handled by the optimizer in reciprocal form to improve the convergence. Their initial reciprocal starting values are 0.05 cm$^2$, 1.0 cm$^2$, 4.0 cm, respectively. The initial objective function is 5460.12 kg. Figure 8 shows the results for each option. All final objective functions are within
reasonable limits, even though some of the design variables differ significantly. The piecewise linear approach is 50 to 75 percent less expensive to execute than the nonlinear approach. Reference 6 describes, in detail, the results of this test compared to the results from an identical model tested on the mainframe-only version of PROSSS. The comparison is done in terms of accuracy, cost, CPU time, and total time.
REFERENCES


<table>
<thead>
<tr>
<th>METHOD</th>
<th>IN OPTIMIZER BY</th>
<th>EXTERNAL TO OPTIMIZER BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONLINEAR PROGRAMMING</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>PIECEWISE LINEAR PROGRAMMING</td>
<td>N/A</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**TABLE I.**- OPTIONS FOR OPTIMIZATION.
FIGURE 1.- FLOWCHART OF A DISTRIBUTED OPTIMIZATION SOFTWARE SYSTEM.
FIGURE 2.- FLOWCHART OF A TYPICAL OPTIMIZATION OPTION.
INPUT NUMBER CORRESPONDING TO TYPE OF PLOT DESIRED

1 - PLOT ITERATIONS VS OBJECTIVE FUNCTION
2 - PLOT ITERATIONS VS DESIGN VARIABLES
3 - PLOT ITERATIONS VS CONSTRAINTS
4 - PRINT NUMERICAL RESULTS
5 - END

FIGURE 3. MENU FOR PLOTTING PROGRAM.
FIGURE 4. - CHANGE IN OBJECTIVE FUNCTION FOR THE FUSELAGE MODEL.
FIGURE 5.- CHANGE IN DESIGN VARIABLES (RECIROCALS) FOR THE FUSELAGE MODEL.
FIGURE 6.- ACTIVE AND VIOLATED CONSTRAINTS FOR THE FUSELAGE MODEL.
FIGURE 7. - 352 DOF FUSELAGE MODEL USED FOR TESTING.
### FIGURE 8.—COMPARISON OF DESIGN VARIABLES.

<table>
<thead>
<tr>
<th>OPTION</th>
<th>M/O</th>
<th>D</th>
<th>M/O</th>
<th>D</th>
<th>M/O</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>1.6332</td>
<td>1.6292</td>
<td>4.7341</td>
<td>5.0582</td>
<td>.1000</td>
<td>.1000</td>
</tr>
<tr>
<td>1.2</td>
<td>1.5713</td>
<td>1.5681</td>
<td>8.4175</td>
<td>8.3682</td>
<td>.1000</td>
<td>.1000</td>
</tr>
<tr>
<td>1.3</td>
<td>1.5458</td>
<td>1.5175</td>
<td>10.6723</td>
<td>11.0132</td>
<td>.1042</td>
<td>.1083</td>
</tr>
<tr>
<td>2.2</td>
<td>1.5659</td>
<td>1.5149</td>
<td>1.1770</td>
<td>8.7796</td>
<td>.1746</td>
<td>.2158</td>
</tr>
<tr>
<td>2.3</td>
<td>1.6215</td>
<td>1.6134</td>
<td>1.6722</td>
<td>2.8777</td>
<td>.1000</td>
<td>.1000</td>
</tr>
</tbody>
</table>

M/O = MAINFRAME-ONLY SYSTEM  
D = DISTRIBUTED SYSTEM
APPENDIX A. - LISTING OF OPTION 1.1 DRIVER PROGRAM AND GENERAL SUBROUTINES.

C DISTRIBUTED PROSSS OPT11

INTEGER*4 COUNT,NAMES
INTEGER*2 STAT,SW,ERROR,NRSTRT
SW = 0

C SET UP INITIALIZATION PROCEDURE

CALL SRCH$$,(,'NAME11',6,1,0,ICODE)
READ(5,2) NRSTRT,ICR,NR,NOPT,NAMES,COUNT
2 FORMAT(3(11,1X),12,1X,A4,1X,I3)
IF(NRSTRT.EQ.0) CALL INIT(NR,ICR,NAMES,NOPT)
COUNT = COUNT-1

C SET UP FOR RESTART IF NRSTRT = 1

IF(NRSTRT.EQ.0) GO TO 4
CALL SRCH$$,(,'NAME11',6,1,0,ICODE)
CALL RSTRT(NOPT,NAMES)
CALL COMI$$('RSTRTPRC',8,6,ICODE)
CALL EXIT
CALL SRCH$$,(,'RSTRTPRC',8,1,0,ICODE)
GO TO 6

C INITIALIZATION PROCEDURE FILE

4 CALL SRCH$$,(,'NAME11',6,1,0,ICODE)
CALL COMI$$('INITPRC',7,5,ICODE)
CALL EXIT
CALL SRCH$$,(,'INITPRC',7,1,0,ICODE)
CALL SRCH$$,(,'INITPRC',7,1,0,ICODE)

C SKIP IF NONREPEATABLE PART NOT REQUIRED

C IF(NR.EQ.0) GO TO 5

C CHECK STATUS OF RETURNED FILE

CALL STCHEK(STAT,1)
CALL SRCH$$,(,'TNREPT',6,1,0,ICODE)
IF(STAT.EQ.0) GO TO 5
ERROR = 2
GO TO 40
CONMIN PROCEDURE FILE

5  COUNT = COUNT+1
   IF(COUNT,LT.999) GO TO 6
   ERROR = 1
   GO TO 40
   6  CALL COMI$$('CNMNPRC', 8, 6, ICODE)
      CALL EXIT

FRONT PROCESSOR PROCEDURE FILE

CALL COMI$$('TFRTPRC', 7, 6, ICODE)
CALL EXIT

SUBROUTINE TO UPDATE SEND FILE NAME (UNIQUELY)

CALL UPDSF(COUNT, SW, INFO)
   SW = SW+1

UPDATE NAME PROCEDURE FILE

CALL COMI$$('UPDTE', 5, 6, ICODE)
CALL EXIT

SEND TO NOS PROCEDURE FILE

CALL COMI$$('TSENDPRC', 8, 6, ICODE)
CALL EXIT

CHECK STATUS OF RETURNED FILE

CALL STCHK(STAT, 0)
   IF(STAT.GT.0) GO TO 35
   ERROR = 2
   GO TO 40

TEST FOR SYSTEM TERMINATION

35 CALL SRCH$$('GONOGO', 6, 1, 0, ICODE)
   IF(ICODE.EQ.0) GO TO 100

EDIT CNMNIO FILE RETURNED FROM NOS PROCEDURE FILE

CALL COMI$$('EDPRC', 5, 6, ICODE)
CALL EXIT
   GO TO 5

PRINT ERROR MESSAGE AND STOP PROGRAM

40  CALL ERRMSG(ERROR)

STOP

END
SUBROUTINE INIT(NR, ICR, NAME1, NOPT)
C CREATES A PROCEDURE FILE (INITPRC) FOR INITIALIZING FILES
C
INTEGER*4 NAME, NAME1, NAME2, STARTX, CONPAR, UFD, SUBUFD
INTEGER*4 SPLA, USERNO, PASSW, CHARGE, INPT, CONS
DIMENSION NAME(Z), STARTX(Z), CONPAR(Z), UFD(Z), SUBUFD(Z), SPLA(Z)
DIMENSION USERNO(Z), CHARGE(Z), INPT(Z), CONS(Z)
C OPEN PROCEDURE FILE
C CALL SRCH$$(Z,'INITPRC',7,Z,0,ICODE)
WRITE(6,7)
7 FORMAT('SAVE TEMP'/'OPEN CONOUTHOLD 1 2'/'C 1')
C SET UP TEMPORARY FILES FOR CNMNIO, CONREST, AND BLK
C IF(NOPT.EQ.11.OR. NOPT.EQ.12. OR. NOPT.EQ.13) WRITE(6,8)
8 FORMAT('ED'/'X'/'FIL CNMNIO'/'ED'/'X'/'FIL CONREST')
IF(NOPT.EQ.22. OR. NOPT.EQ.23) WRITE(6,9)
9 FORMAT('ED'/'X'/'FIL BLK')
C INITIALIZE PASS, GONOGO, AND CNT
WRITE(6,10)
10 FORMAT('ED'/1'/'FIL PASS')
   IF(NOPT.EQ.12.OR.NOPT.EQ.22.OR.NOPT.EQ.23) WRITE(6,16)
16 FORMAT('ED'/ 1.0E 00 1.0E 00 1.0E 00 0.5E-01 ' 1 '/'FIL CNT')

C INITIALIZE SENDPRC
C
   IF(NOPT.EQ.11.OR.NOPT.EQ.12.OR.NOPT.EQ.22) WRITE(6,45)
45 FORMAT('ED SENDPRC')
   IF(NOPT.EQ.13.OR.NOPT.EQ.23) WRITE(6,46)
46 FORMAT('ED SENDPRC G')
   WRITE(6,61) NAME1
61 FORMAT('C/SENDFILE/',A4,'/100'/'FIL TSENDPRC')

C STORE NAMES FOR STARTX AND CONPAR
C
   READ(5,30) STARTX
30 FORMAT(2A4)
   WRITE(6,40) STARTX
40 FORMAT('ED ',2A4,'/FIL STARTX')
   READ(5,30) CONPAR
   WRITE(6,43) CONPAR
43 FORMAT('ED ',2A4,'/FIL CONP AR')

C INITIALIZE FRONT PROCESSOR
C
   READ(5,30) CONS
30 FORMAT(2A4)
   WRITE(6,44) CONS
44 FORMAT('ED FRONTPRC '/C/CONSXX/',2A4,'/100'/'FIL TFRTPRC')

C INITIALIZE TONOS
C
   READ(5,30) NAME
50 FORMAT(2A4)
   IF(NOPT.EQ.11.OR.NOPT.EQ.12.OR.NOPT.EQ.22) WRITE(6,65) NAME
65 FORMAT('ED TONOS'/C/RUNSTREAM/',2A4,'/100'/'T')
   IF(NOPT.EQ.23) WRITE(6,64) NAME
64 FORMAT('ED TONOS G'/C/RUNSTREAM/',2A4,'/100'/'T')
   IF(NOPT.NE.13) GO TO 644
   WRITE(6,640) NAME
640 FORMAT('ED TONOS13'/C/RSGRAD/',2A4,'/100'/'T')
   READ(5,30) NAME
50 FORMAT(2A4)
   WRITE(6,641) NAME
641 FORMAT('C/RSGRAD/',2A4,'/100'/'T')
   READ(5,30) NAME
50 FORMAT(2A4)
   WRITE(6,642) NAME
642 FORMAT('C/EPYYYY/',2A4,'/100'/'T')
644 READ(5,30) UFD
   WRITE(6,66) UFD
66 FORMAT('C/UFDF/','2A4,/'100,/'T')
READ(5,30) SUBUFD
WRITE(6,67) SUBUFD
67 FORMAT('C/SUBUFD/','2A4,/'100,/'T')
READ(5,30) NAME
WRITE(6,68) NAME
68 FORMAT('C/DUMOUT/','2A4,/'100,/'T')
READ(5,30) NAME
WRITE(6,69) NAME
69 FORMAT('C/DUMIO/','2A4,/'100,/'T')
READ(5,30) SPLA
WRITE(6,70) SPLA
70 FORMAT('C/SPARNAM/','2A4,/'100,/'T')
WRITE(6,71) NAME
71 FORMAT('C/JOB/','A4,/'100,/'T')
READ(5,30) USERNO
WRITE(6,72) USERNO
72 FORMAT('C/USERNO/','2A4,/'100,/'T')
READ(5,30) PASSW
WRITE(6,73) PASSW
73 FORMAT('C/CHARG/','2A4,/'100,/'T')
READ(5,30) CHARGNO
WRITE(6,74) NAME
74 FORMAT('C/NSUBS/','2A4,/'100,/'T')
READ(5,30) NAME
WRITE(6,75) NAME
75 FORMAT('C/INPTXX/','2A4,/'100,/'T')
READ(5,79) NSUBS
76 FORMAT('C/CONSXX/','2A4,/'100,/'T')
WRITE(6,752) NSUBS
77 FORMAT('C/INPTXX/','2A4,/'100,/'T')
WRITE(6,753) INPT
78 FORMAT('C/CONSXX/','2A4,/'100,/'T')
REMOVE EXTRANEOUS BLANKS

```
WRITE(6,76)
76 FORMAT('C/ //100'/ 'T'/ 'C/ //100'/ 'T'/ 'C/ //100')
WRITE(6,77) NAME1
77 FORMAT('T'/ 'C/ //100'/ 'T'/ 'C/ //100'/ 'FIL ',A4)
```

INITIALIZE STATIN

```
WRITE(6,78) NAME1
78 FORMAT('ED'/ 'A4//' 'FIL STATIN')
```

IF NOCR EQ 0 JUST CHANGE NAMES FOR PROGRAMS

IF NOCR NE 0 EDIT FILES TO COMPILe PROGRAMS

FRONT PROCESSOR

```
READ(5,115) NAME, NOCR
115 FORMAT(2A4, 1X, I1)
   IF (NOCR.NE.0) WRITE(6,80) NAME
80 FORMAT('ED CRFPROC'/ 'C/ FPXXXX'/ '2A4'/ '1234'/ 'FIL TCRFPROC')
   IF (NOCR.NE.0) WRITE(6,120)
120 FORMAT('CO TCRFPROC 6'/ 'C 6'/ 'DELETE TCRFPROC')
   IF (NOCR.EQ.0) WRITE(6,800) NAME
800 FORMAT('CN *', 2A4, ' *FPROCESSOR')
```

EVAL

```
IF (NOPT.EQ.11 OR NOPT.EQ.13) GO TO 860
READ(5,115) NAME, NOCR
IF (NOCR.NE.0) WRITE(6,85) NAME
85 FORMAT('ED CREVAL'/ 'C/ EVALXXX'/ '2A4'/ '1234'/ 'FIL TCREVAL')
   IF ((NOPT.EQ.12 OR NOPT.EQ.22 OR NOPT.EQ.23) AND NOCR.NE.0)
1 WRITE(6,140)
140 FORMAT('C 6'/ 'CO TCREVAL'/ 'C 6'/ 'DELETE TCREVAL')
   IF (NOCR.EQ.0) WRITE(6,850) NAME
850 FORMAT('CN *', 2A4, ' EVAL')
```

CONMIN

```
860 READ(5,115) NAME, NOCR
   IF (NOCR.NE.0) WRITE(6,90) NAME
   IF (NOCR.NE.0) WRITE(6,130)
130 FORMAT('C 6'/ 'CO TCRCONMIN '/ 'C 6'/ 'DELETE TCRCONMIN')
   IF (NOCR.EQ.0) WRITE(6,900) NAME
900 FORMAT('CN *', 2A4, ' CONMIN')
```
IF(NOPT.NE.12) GO TO 960

SELECTS

READ(5,115) NAME,NOCR
IF(NOCR.NE.0) WRITE(6,950)
950 FORMAT('CO CRRITE 6'/'C 6')
GO TO 145

TEST TO DETERMINE IF MODEL CREATED WITH DATA GENERATOR
145 IF(ICR.NE.0) CALL CRSNPT

TEST TO DETERMINE IF NONREPEATABLE PART IS TO BE DONE

IF(NR.NE.0) CALL NONRPT(NR,SPLA,INPT,USERNO,PASSW,CHARGE,
1 UFD,SUBUFD,NOPT)
WRITE(6,150)
150 FORMAT('R TEMP')
CALL SRCH$(4,'INITPRC',7,2,0,ICODE)
RETURN
END

SUBROUTINE RSTRTCNOPT,NAMES)

THIS SUBROUTINE SETS UP A PROCEDURE FILE FOR
RESTARTING THE PROGRAM

INTEGER*4 NAMES,NAMERS,NAMOLD
DIMENSION NAMERS(2)
CALL SRCH$(2,'RSTRTPRC',8,2,0,ICODE)
WRITE(6,10)
10 FORMAT('SAVE TEMP*)
IF(NOPT.EQ.11.OR.NOPT.EQ.12.OR.NOPT.EQ.13) GO TO 20
IF(NOPT.EQ.22.OR.NOPT.EQ.23) GO TO 60

SET UP FILES FOR OPTIONS 1.1, 1.2, AND 1.3

20 WRITE(6,30)
30 FORMAT('DELETE PASS'/'CN SPASS PASS')
WRITE(6,40)
40 FORMAT('DELETE CNMNIO'/'CN SCNMNIO CNMNIO')
WRITE(6,50)
50 FORMAT('DELETE CONREST'/'CN SCONREST CONREST')
GO TO 100
C SET UP FILES FOR OPTIONS 2.2 AND 2.3
C
60 WRITE(6,70)
70 FORMAT('DELETE CNT'/CN SCNT CNT')
WRITE(6,80)
80 FORMAT('DELETE BLK'/CN SBLK BLK')
WRITE(6,90)
90 FORMAT('DELETE STARTX'/CN SSTARTX STARTX')
C REINITIALIZE SENDPRC
C
100 WRITE(6,101)
101 FORMAT('DELETE TSENDPRC')
IF(NOPT.EQ.11.OR.NOPT.EQ.12.OR.NOPT.EQ.22) WRITE(6,102)
102 FORMAT('ED SENDPRC')
IF(NOPT.EQ.13.OR.NOPT.EQ.23) WRITE(6,103)
103 FORMAT('ED SENDPRC')
WRITE(6,107) NAMES
107 FORMAT('C/SENDFILE/',A4,'/100'/FIL TSENDPRC')
C REINITIALIZE STATIN
C
CALL SRCH$$ (1,'STATIN',6,1,0,ICODE)
READ(5,110) NAMOLD
110 FORMAT(A4)
CALL SRCH$$ (4,'STATIN',6,1,0,ICODE)
WRITE(6,115) NAMOLD,NAMES
115 FORMAT(C,'CN ',A4,1X,A4)
WRITE(6,120) NAMES
120 FORMAT('DELETE STATIN'/ED'/A4'/FIL STATIN')
WRITE(6,130)
130 FORMAT('R TEMP')
CALL SRCH$$ (4,'RSTRTPRC',8,2,0,ICODE)
RETURN
END
SUBROUTINE NONRPT(NR,SPLA,INPT,USERNO,PASSW,CHARGE,UFD,SUBUFD,
1 NOPT)
C CREATES PROCEDURE FILE TO SEND TO CYBER FOR NONREPEATABLE PART
C OF ANALYSIS
C
INTEGER*4 NAME,INPT,SPLA,NROPT,NRRS,USERNO,CHARGE,UFD,SUBUFD,PASSW
1 ,TNREPT
DIMENSION NRRS(2),SPLA(2),INPT(2),NAME(2),USERNO(2),CHARGE(2)
1 ,UFD(2),SUBUFD(2)
CALL SRCH$$ (1,'NAMENR',6,3,0,ICODE)
WRITE(6,10)
C EDITS FILE CREATED BY DATA GENERATOR AND LOADS IN FILE CONTAINING
C PROBLEM DEPENDENT DATA
C
DIMENSION FNAME(2),LNAME(2)
INTEGER*4 NDV,LNAME,FNAME
CALL SRCHS$ (4,'NAMECRRS',6,3,0,ICODE)
END
C READ IN NUMBER OF DESIGN VARIABLES
READ(5,1) NDV
1 FORMAT(I3)
C READ IN NAME OF FILE CREATED BY DATA GENERATOR
READ(5,2) FNAME
2 FORMAT(2A4)
WRITE(6,3) FNAME
3 FORMAT(*ED*,2A4,*L JLOC*/'N'*D'/*L CMD*)
WRITE(6,4)
4 FORMAT(*D*/'L CMD*/'C/CMD/*XQT/*/C>5/13>*//$START*/)
NDVM1 = NDV-1
IF(NDVM1.EQ.0) GO TO 8
DO 7 I = 1, NDVM1
WRITE(6,6)
6 FORMAT(*L E*/'N-1*/$END*/$START*/)
7 CONTINUE
8 WRITE(6,9)
9 FORMAT(*L CMD*/'D*/'N-1*/$END*/[XQT EXIT/*/T*)
C READ IN FILE NAME CONTAINING PROBLEM DEPENDENT DATA TO BE LOADED
IN AT THE TOP OF THE FILE
READ(5,2) LNAME
WRITE(6,10) LNAME
10 FORMAT(ZAZ)
CALL SRCH$(4,'NAMECRS',8,3,0,ICODE)
RETURN
END
SUBROUTINE UPDSF(CNT,SW,INFO)
C THIS SUBROUTINE CREATES A PROCEDURE FILE (UPDTE)
C TO CREATE UNIQUE JOB NAMES TO SEND TO NOS
C INTEGER*2 NME(2),SW
INTEGER*4 CNT,CNTM1
C MODIFY STATIN
CALL SRCH$(1,'STATIN',6,1,0,ICODE)
READ(5,10) NME
10 FORMAT(2A2)
CALL SRCH$(4,'STATIN',6,1,0,ICODE)
CALL SRCH$(2,'UPDTE',5,2,0,ICODE)
WRITE(6,20) NME,NME,CNT
20 FORMAT(*SAVE TEMP*/'ED STATIN*/'N'*C/*/2A2,*/,2A2,I3)
WRITE(6, 30)
30 FORMAT('C/ ///'C/ ///'C/ ///'FIL TSTATIN')
CNTM1 = CNT - 1

CHECK FOR FIRST TIME THROUGH
IF(SW.EQ.0) GO TO 41

MODIFY SENDPRC DEPENDING UPON PASS COUNTER
IF(CNT.LT.10) WRITE(6, 35) NME, CNTM1, NME, CNT
35 FORMAT('ED TSENDPRC'/'C/', 2A2, I1, '/', 2A2, I1, '/100'/ 'T')
IF(CNT.EQ.10) WRITE(6, 360) NME, CNTM1, NME, CNT
360 FORMAT('ED TSENDPRC'/'C/', 2A2, I2, '/', 2A2, I2, '/100'/ 'T')
IF(CNT.GT.10.AND.CNT.LT.100) WRITE(6, 36) NME, CNTM1, NME, CNT
36 FORMAT('ED TSENDPRC'/'C/', 2A2, I3, '/', 2A2, I3, '/100'/ 'T')
IF(CNT.GE.100.AND.CNT.LT.1000) WRITE(6, 37) NME, CNTM1, NME, CNT
37 FORMAT('ED TSENDPRC'/'C/', 2A2, I3, '/', 2A2, I3, '/100'/ 'T')
WRITE(6, 38) NME, CNTM1
38 FORMAT('OEL'/ 'OElETE', 2A2, I3)
IF(SW.NE.1) WRITE(6, 39)
39 FORMAT('N'/ 'D'/ 'T')
IF(SW.EQ.1) WRITE(6, 40)
40 FORMAT('T')
GO TO 49
41 WRITE(6, 45) NME, NME, CNT
45 FORMAT('ED TSENDPRC'/'C/', 2A2, '/2A2', '/2A2', '?/100'/ 'T')
49 WRITE(6, 50) NME, NME, NME, NME
50 FORMAT('C/2A2', '/2A2', '/99'/ 'T'/'C/2A2, ' '2A2', '/99', '/T')
WRITE(6, 60) NME, NME
60 FORMAT('C/', 2A2, ' ', 2A2, '/99', '/FIL TSENDPRC')

MODIFY FILE TO BE SENT TO NOS
IF(CNT.LT.10) WRITE(6, 70) NME, NME, NME, CNT, INFO, NME, CNT
70 FORMAT('ED '2A2/ 'N'/ 'C/2A2, '2A2, I1, '/100'/ 'T'/ 'C/INFO/ 'I1', '/100'/ 'FIL ', 2A2, I1)
IF(CNT.GE.10.AND.CNT.LT.100) WRITE(6, 80) NME, NME, NME, CNT,
1 INFO, NME, CNT
80 FORMAT('ED '2A2/ 'N'/ 'C/2A2, '2A2, I2, '/100'/ 'T'/ 'C/INFO/ 'I1, '/100'/ 'FIL ', 2A2, I2)
IF(CNT.GE.100.AND.CNT.LT.1000) WRITE(6, 90) NME, NME, NME, CNT,
1 INFO, NME, CNT
90 FORMAT('ED '2A2/ 'N'/ 'C/2A2, '2A2, I3, '/100'/ 'T'/ 'C/INFO/ 'I1, '/100'/ 'FIL ', 2A2, I3)
WRITE(6, 100)
100 FORMAT('R TEMP')
CALL SRCH$(4, 'UPDATE', 5, 2, 0, ICODE)
RETURN
SUBROUTINE ERMSG(ERROR)
    CALL SRCH$(2,'ERRFILE',7,2,0,ICODE)
    IF(ERROR.NE.1) GO TO 15
    WRITE(6,10)
10 FORMAT(' MORE THAN 999 ITERATIONS. STOP PROGRAM. ')
    GO TO 100
15 IF(ERROR.NE.2) GO TO 100
    WRITE(6,20)
20 FORMAT(' CANNOT FIND COMET. STOP PROGRAM. ')
    GO TO 100
100 CALL SRCH$(4,'ERRFILE',7,2,0,ICODE)
    RETURN
END

SUBROUTINE STCHEK(STAT,ICHK)
C
C THIS SUBROUTINE CHECKS STATUS UNTIL FILE IS RETURNED
C FROM NOS
C
INTEGER*2 SNAME(3),RNAME(3),UFD(3),STAT
INTEGER*4 TIMER,CNTR
TIMER = 120000
CNTR = 0
C
PUT JOB TO SLEEP FOR TWO MINUTES
C
CALL SLEEP$(TIMER)
C
Determine file name for nonrepeatable part
C
IF(ICHK.EQ.0) GO TO 5
    CALL SRCH$(1,'NRSTAT',6,1,0,ICODE)
    READ(5,10) SNAME
    CALL SRCH$(4,'NRSTAT',6,1,0,ICODE)
    CALL SRCH$(5,'NRSTAT',6,1,0,ICODE)
    GO TO 20
C
Determine file name for repeatable part
C
5 CALL SRCH$(1,'TSTATIN',7,1,0,ICODE)
    READ(5,10) SNAME
10 FORMAT(3A2)
    CALL SRCH$(4,'TSTATIN',7,1,0,ICODE)
C
CHECK STATUS UNTIL STAT NE 0
C
20 CALL COMSTA(SNAME,RNAME,UFD,STAT)
    IF(STAT.NE.0) GO TO 30
    CALL SLEEP$(TIMER)
INCREASE SLEEP PERIOD EVERY 5 ITERATIONS

```c
CNTR = CNTR+1
IF(CNTR.LT.5) GO TO 20
CNTR = 0
TIMER = TIMER*2
GO TO 20
30 RETURN
END
```

SUBROUTINE COMSTAT(SNAME,RNAME,UFD,STAT)

COMSTAT -COMET STATUS. RETURNS STATUS OF FILE TRANSMITTED TO THE HOST CDC COMPUTER.

CALLING SEQUENCE:

- SNAME -THREE WORD ARRAY IN CALLING PROGRAM CONTAINING NAME OF FILE SENT TO HOST. LEFT JUSTIFIED, BLANK FILL.
- RNAME -THREE WORD ARRAY IN CALLING PROGRAM WHERE NAME OF FILE RETURNED FROM HOST IS STORED. LEFT JUSTIFIED, BLANK FILL.
- UFD -THREE WORD ARRAY IN CALLING PROGRAM WHERE UFD OF RETURNED FILE IS STORED THE CALLER'S LOGIN UFD, OTHERWISE, COMET. 6 CHARACTERS LEFT JUSTIFIED, BLANK FILL.
- STAT -STATUS OF FILE SENT TO HOST. ONE WORD INTEGER IN CALLING PROGRAM.
  - 1 = ERROR HAS OCCURRED. STATUS CANNOT BE DETERMINED. THE CONTENTS OF RNAME AND UFD ARE NOT VALID.
  - 0 = FILE HAS NOT BEEN RETURNED. THE CONTENTS OF RNAME AND UFD ARE NOT VALID.
  - 1 = FILE HAS BEEN RETURNED. THE CONTENTS OF RNAME AND UFD ARE VALID.

INTEGER*2 SNAME(3),RNAME(3),UFD(3),RJDATA(30),ERR
INTEGER*2 STAT,CODE,RNW,COMUFD(3),BLANKS(3)
INTEGER*4 POS,EOFPOS
$INSERT SYS.COM>KEYS.F
LOGICAL NAMEQV,FOUND
DATA FOUND/.FALSE./
DATA COMUFD/'COMET'/
DATA BLANKS/''/
ATTACH TO UFD COMET
CALL ATTACH(COMUFD,INTS(:100000),BLANKS,0,$900)
CALL TNOUC'ATT TO COM',10)
WRITE(1,777)STAT
```
777 FORMAT(*STAT = ',I5)
C TRY TO OPEN STATUS FILE ON UNIT 12
5 CALL OPRDWT('STATUS',12,CODE)
   IF(CODE.NE.0) GO TO 950
C OPRDWT CYCLES UNTIL 'STATUS' IS UPDATED DURING RE-WRITE
C CALL TNOU('OPEN STATUS',11)
C SET POS TO EOF AND THEN
C REWIND SO WE CAN HAVE
C A VALID EOF POSITION
C CALL PRWF$$CK$POSN,12,LOC(0),EOF,10000000,RNW,CODE)
C CALL PRWF$$CK$RPOS,12,LOC(0),EOF,EOFPOS,RNW,CODE)
C READ A STATUS ENTRY AND LOOK FOR MATCH WITH SNAME
10 CALL PRWF$$CK$RPOS,12,LOC(0),EOF,EOFPOS,RNW,CODE)
   IF(CODE.NE.0) GO TO 100
   IF(EOFPOS.GE.EOFPOS) GO TO 100
   CALL ISAD07(12,RJDATA,30)
   IF(.NOT.(NAMEQV(SNAME(1),RJDATA(1)))) GO TO 10
C NAME FOUND, CHECK STATUS
C CALL TNOU('FOUND NAME',10)
   FOUND=.TRUE.
   WRITE(1,444) RJDATA(30)
   IF(RJDATA(30).LE.0)GO TO 800
444 FORMAT('RJDATA 30 = ',15)
C CHECK FILE NAME FOR T$ PREFIX, IF PREFIX NOT
C PRESENT, AN ERROR HAS OCCURRED.
C
C IF(RJDATA(17).NE.'T$')GO TO 800
C CHECK FOR REPEATABLE NAME TCMNIO
C
C IF(RJDATA(17).EQ.'TC' .AND. RJDATA(18).EQ.'MN' .AND. 
   RJDATA(19).EQ.'10') GO TO 19
C CHECK FOR NONREPEATABLE NAME TNREPT
C
C IF(RJDATA(17).EQ.'TN' .AND. RJDATA(18).EQ.'RE' .AND. 
   RJDATA(19).EQ.'PT') GO TO 19
C GO TO 800
C FILE HAS BEEN RETURNED, COPY NAME TO RNAME.
19 DO 20 I=1,3
   RNAME(I)=RJDATA(I+16)
20 CONTINUE
C GET UFO STATUS
IF(RJDATA(30).EQ.1)GO TO 50
DO 25 I=1,3
   UFD(I)=COMUFD(I)
25 CONTINUE
GO TO 60
50 DO 55 I=1,3
   UFD(I)=RJDATA(I+6)
55 CONTINUE
60 CONTINUE
C SET RETURN STATUS TO FOUND
STAT = 1
GO TO 10
100 CONTINUE
IF(FOUND) STAT=1
CALL ATTACH(0,0,0,0,0)
CALL SEARCH(4,0,12)
RETURN
800 CONTINUE
C SNAME NOT FOUND, SET STATUS AND RETURN
STAT = 0
DO 810 I=1,3
   RNAME(I)=BLANKS(I)
   UFD(I)=BLANKS(I)
810 CONTINUE
CALL TNOUT('NAME NOT FOUND',14)
FOUND=.FALSE.
GO TO 100
900 CONTINUE
C CANNOT FIND COMET, SET ERROR STATUS AND RETURN
STAT = -1
GO TO 100
950 CONTINUE
C CANNOT OPEN STATUS, IF BUSY, TRY AGAIN.
CALL GETERR(ERR,1)
IF(ERR.EQ.'SI')GO TO 5
C FILE NOT FOUND MEANS NOT RETURNED YET.
CALL TNOUT('CAN'T OPEN STATUS',17)
GO TO 900
END
C OPRDWT->OPEN READ AND WAIT
SUBROUTINE OPRDWT(NAME,UNIT,RCODE)
C
INTEGER*2 NAME(3),UNIT,TYPE,CODE,I,RCODE
C$INSERT SYS.COM>KEYS.F
DATA I/O/
RCODE=0
CALL SRCH$(K$EXIST,'T$0001',6,1,0,CODE)

IF T$0001 DOES EXIST THEN STATUS IS BEING RE-WRITTEN
SO LOOP UNTIL THRU WITH UPDATE FUNCTION

IF(CDDE.EQ.O) GO TO 999

DO 200 I=1,25 /*KEEP TRYING*/
CALL SRCH$(K$READ,NAME,6,UNIT,TYPE,CODE)
IF(CODE.EQ.0) RETURN /*SUCCESSFUL*/
IF(CODE.EQ.4.OR.COD,5) GO TO 100
RCODE=1
RETURN

CALL SLEEP$(INTL(5000))

SLEEP FOR 5 SECONDS

CONTINUE
RCODE=1
RETURN

CALL SLEEP$(INTL(5000))
GO TO 10
END
APPENDIX B.- LISTING OF MAIN PROGRAM FOR CONMIN.

C PROGRAM CONMS1(INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT, TAPE7, TAPE8, TAPE9, TAPE10, TAPE11)
C NEW CONMIN SUBROUTINE
COMMON/CNMIN1/DELFUN, DABFUN, FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN,
1ALPHAX, ABOBJ, THETA, OBJ, NDV, NCON, NSIDE, IPRINT, NFDG, NSCAL,
2LINOBJ, ITMAX, ITRM, ICNDIR, IGOTO, NAC, INFO, INF0G, ITER
COMMON/CNMIN2/RDUM(50), IDUM(25)
COMMON X(20), VLB(20), VUB(20), G(200), SCAL(20), DF(20),
1A(20,100), S(20), G1(200), G2(200), B(100,100), C(100), ISC(200),
2IC(100), MS1(200)
COMMON/CONSAV/RSAV(50), ISAV(25)
DIMENSION KSC(200), SAVX(20), SAVG(200)
INTEGER*2 ICODE
C REAOC1, PASSAGE)
REAOC1, 10) NPASS
10 FORMAT(11)
C FIRST PASS, NPASS=1, SUBSEQUENTLY NPASS=2.
GO TO(100, 200), NPASS
100 CONTINUE
C READ(10, CONPAR)
READ(10,*) IPRINT, NDV, ITMAX, NCON, NFDG, NSIDE, ICNDIR,
1NSCAL, LINOBJ, ITRM, FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN,
2THETA, PHI, DELFUN, DABFUN, JSC, N1, N2, N3, N4, N5,
3ALPHAX,ABOBJ1,IGOTO,(VLB(I),I=1,NDV),(VUB(I),I=1,NDV)
JITER = 0
MSC = 0
IF(JSC.LT.0) MSC = 1
DO 15 I = 1,NCON
ISC(I) = MSC
15 CONTINUE
IF(JSC.EQ.0.OR.JSC.EQ.-999) GO TO 13
MSC = 1
IF(JSC.LT.0) MSC = 0
IF(JSC.LT.0) JSC = JSC*-1
CALL SRCH$(INTS(1), 'ISCFILE', INTS(7), INTS(4), INTS(0), ICODE)
READ(8,12) (KSC(I),I=1,JSC)
12 FORMAT(10I4)
CALL SRCH$(INTS(4), 'ISCFILE', INTS(7), INTS(4), INTS(0), ICODE)
DO 11 I = 1,YSC
ITEMP = KSC(I)
ISC(ITEMP) = MSC
11 CONTINUE
13 REWIND 13
WRITE(13,14) JITER,NDV,NCON,(ISC(I),I=1,NCON)
14 FORMAT(20I5)
C READ(8,STARTX)
CALL SRCH$(INTS(1), 'STARTX', INTS(6), INTS(4), INTS(0), ICODE)
READ(8,30) NDV,(X(I),I=1,NDV)
30 FORMAT(I5/(6E13.5))
CALL SRCH$(INTS(4), 'STARTX', INTS(6), INTS(4), INTS(0), ICODE)
GO TO 201
200 CONTINUE
C READ(7,SAVE)
READ(7) IPRINT,NDV,ITMAX,NCON,NSIDE,ICNDIR,NSCAL,NFDG,
1FDCH,FODCH,CT,CTMIN,CTL,CTLMIN,THETA,PHI,NAC,DELFUN,DABFUN,
2LINOBJ,ITRM,ITER,INFOG,IGOTO,INFO,OBJ,
3RDUM,IDXUM,
4X,OF,G,ISC,IC,A,S,G1,G2,C,MS1,B,VLB,VUB,SCAL,RSAV,ISAV,NCOUNT
5,N1,N2,N3,N4,N5,ALPHAX,ABOBJ1
REWIND 7
C READ(9,LINKE)
READ(9,40) OBJ,G
40 FORMAT(E13.5/(6E13.5))
ITERSV = ITER
DO 41 I = 1,NCON
SAVG(I) = G(I)
41 CONTINUE
DO 42 I = 1,NDV
SAVX(I) = X(I)
42 CONTINUE
SAVOBJ = OBJ
SAVC = CT
SAVCTL = CTL
REWIND 13
READ(13,14) JITER, NDV, NCON, (ISC(I), I=1, NCON)
JITER = JITER + 1

201 CONTINUE
NPASS = 2
REWIND 11
C WRITE(10, PASSAGE)
WRITE(11, 10) NPASS
C SOLVE OPTIMIZATION
CALL CONMINX(VLB, VUB, GL, G2, B, C,
* ISC, IC, MS1, N1, N2, N3, N4, N5)
IF(JITER.EQ.0) GO TO 48
IF(JITER.EQ.1) GO TO 47
IF(JITER.EQ.IERSV) GO TO 48
47 IERSV = ITER
REWIND 13
WRITE(13, 14) JITER, NDV, NCON, (ISC(I), I=1, NCON)
REWIND 14
WRITE(14, 45) SAVOBJ, (SAVX(I), I=1, NDV), SAVCT, SAVCTL
1, (SAVG(I), I=1, NCON)
45 FORMAT(6E13.5)
C FUNCTION AND CONSTRAINT VALUES
C WRITE(7, SAVE)
48 WRITE(7) IPRINT, NDV, ITMAX, NCON, NSIDE, ICNDR, NSCAL, NFDG,
1FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN, THETA, PHI, NAC, DELFUN, DABFUN,
2LNOBJ, ITRM, ITER, INFG, IGOTO, INFO, OBJ,
3RDUM, IDUM,
4X DF, G, ISC, IC, A, S, G1, G2, B, MS1, B, VLB, VUB, SCAL, R sav, ISAV, NCOUNT
5, N1, N2, N3, N4, N5, ALPHAX, ABOBJ1
C WRITE(9, LINKF)
REWIND 9
WRITE(9, 50) NDV, (X(I), I=1, NDV)
50 FORMAT(15/(6E13.5))
C WRITE CONTROL CARD STORED IN PROCFILE GONOGO.
101 FORMAT('1')
IF(IGOTO.NE.0) GO TO 301
CALL SRCH$$(INTS(2), 'GONOGO', INTS(6), INTS(8), INTS(0), ICODE)
WRITE(12, 101)
CALL SRCH$$(INTS(4), 'GONOGO', INTS(6), INTS(8), INTS(0), ICODE)
C WRITE ON TAPE8 IF GRADIENTS ARE REQUIRED
REWIND 13
JITER = JITER + 1
WRITE(13, 14) JITER, NDV, NCON, (ISC(I), I=1, NCON)
WRITE(14, 45) OBJ, (X(I), I=1, NDV), CT, CTL, (G(I), I=1, NCON)
301 IF(INFO.NE.2) GO TO 303
CALL SRCH$$(INTS(2), 'STARTX', INTS(6), INTS(4), INTS(0), ICODE)
WRITE(8, 30) NDV, (X(I), I=1, NDV)
CALL SRCH$$(INTS(4), 'STARTX', INTS(6), INTS(4), INTS(0), ICODE)
303 CALL SRCH$$(INTS(2), 'INFO', INTS(4), INTS(4), INTS(0), ICODE)
WRITE(8, 304) INFO
304 FORMAT(11)
CALL SRCH$$(INTS(4), 'INFO', INTS(4), INTS(4), INTS(0), ICODE)
STOP
END
APPENDIX C.- LISTING OF FRONT PROCESSOR.

C PROGRAM FPFGS1(INPUT,OUTPUT,TAPE7,TAPE5=INPUT,TAPE6=OUTPUT)
C SPAR FRONT PROCESSOR READS DESIGN VARIABLES AND
C PRINTS THEM IN SPAR SECTION PROPERTY FORMAT
C FUSELAGE MADE OF ROD BEAM MEMBRANE ELEMENTS
C DIMENSION X(50)
C NAMELIST/LINKF/NDV,X
C NDV=NUMBER OF DESIGN VARIABLES
C X(NDV)=DESIGN VARIABLES
C DV'S ARE X(1)=SECTIONAL AREA OF STRINGER RODS
C X(2)=NONDIMENSIONAL AREA OF BEAM
C X(3)=THICKNESS OF MEMBRANE PANEL
READ(7,10) B10,B20,T0
10 FORMAT(3F10.3)
C READ(5,LINKF)
READ(5,15) NDV,(X(I),I=1,NDV)
15 FORMAT(I5/(6E13.5))
XIN1=1./X(1)
XIN2=1./X(2)
XIN3=1./X(3)
C WRITE E23 ELEMENTS
WRITE(6,200)
200 FORMAT(' E23 SECTION PROPERTIES')
WRITE(6,201) XIN1
201 FORMAT(' 1 ,F8.3)
C COMPUTE VALUES FOR DSY CARDS
C WRITE E21 ELEMENTS
WRITE(6,202)
202 FORMAT(' E21 SECTION PROPERTIES')
AREA0=(2.*B10+B20)*T0
AREA=AREA0*XIN2
SCALE=SQRT(AREA/AREA0)
B1=B10*SCALE
B2=B20*SCALE
T=T0*SCALE
ALPHA1=0.
C=(B2+2.*T)**3/12.+2.*T*B1*(B1/2.-C)**2
C=C/AREA
EI2=2.*T*B1**3/12.+2.*T*B1*(B1/2.-C)**2
ALPHA2=0.
F1=0.
Z2=0.
THETA=0.
Q1=0.
Q2=0.
Q3=0.
Y11=-(B1-C)
Y12=5*B2+T
Y21=C
Y22=5*B2+T
Y31=C
Y32=-(.5*B2+T)
Y41=-(B1-C)
Y42=-(.5*B2+T)
J=1
WRITE(6,103) J,E11,ALPHA1,E12,ALPHA2,AREA
WRITE(6,1003) F,F1,Z1,Z2,THETA
103 FORMAT(9DSY*,12,F12.4,3Z*')
1003 FORMAT(1X,5F13.5)
WRITE(6,104) A1,Q2,Q3,Y11,Y12,Y21
104 FORMAT(1X,6F12.4,3Z*')
WRITE(6,1004) Y22,Y31,Y32,Y41,Y42
1004 FORMAT(1X,5F12.4)
C WRITE(6,300) XIN3
300 FORMAT(' SHELL SECTION PROPERTIES/* 1',F8.3)
WRITE(6,301)
301 FORMAT('*@*)
STOP
END
APPENDIX D.- LISTING OF END PROCESSOR.

PROGRAM EPFUS(INPUT,OUTPUT,TAPEB,TAPE5=INPUT,TAPE6=OUTPUT)
DIMENSION A(4500),B(1400)
DIMENSION A1(400),B1(400),C1(400)
DIMENSION G(400)
NAMELIST/EPIN/E23AL,E21AL,E41AL,NSE23,NSE21,NSE41
NAMELIST/LINKE/OBJ,G
READ(5,EPIN)
CALL DAL(4,11,A(1),0,IEA,KADR,IERR,NWDS,NE,LB,ITYPE,
14HOBJF,3HAUS,1,1)
OBJ=A(1)
CALL DAL(4,11,A(1),0,IEA,KADR,IERR,NWDS,NE,LB,ITYPE,
14HSTRS,3HE23,1,1)
INL=6*NSE23
DO 2 IN=6,INL,6
I=IN
A1(I)=A(IN)
G(I)=ABS(A1(IN))/E23AL-1.
I=I+1
2 CONTINUE
CALL DAL(4,11,A(1),0,IEA,KADR,IERR,NWDS,NE,LB,ITYPE,
14HSTRS,3HE21,1,1)
J1=1
KNL1=(NSE21-1)*52 + 6
DO 4 IM=5,KNL1,52
B1(J1)=ABS(A(IM))
A1(J1)=ABS(A(IM+1))
I=I+J1-1
GNUM=B1(J1)
IF(A1(J1).GT.B1(J1))GNUM=A1(J1)
G(I)=GNUM/E21AL-1.
J1=J1+1
4 CONTINUE
CALL DAL(4,11,A(1),0,IEA,KADR,IERR,NWDS,NE,LB,ITYPE,
14HSTRS,3HE41,1,1)
K1=1
LNL1=(NSE41*23)
DO 10 NP=21,LNL1,23
C1(K1)=A(NP)
B1(K1)=A(NP+1)
A1(K1)=A(NP+2)
I=I+J1+K1-2
GNUM=SQRT(C1(K1)**2+B1(K1)**2-C1(K1)*B1(K1)+3.*A1(K1)**2)
G(I)=GNUM/E41AL-1.
K1=K1+1
10 CONTINUE
CALL FIN(0,0)
REWIND 6
C
WRITE(6,LINKE)
WRITE(6,232) OBJ,G
232 FORMAT(*BEGIN CNMNI0*/E13.5/(6E13.5))
WRITE(6,233)
233 FORMAT(*END CNMNI0*)
STOP
END
APPENDIX E.- LISTING OF BLDELDs.

PROGRAM BLDELDs (TAPE5, TAPE23, TAPE20, TAPE21, TAPE22, OUTPUT)

C THIS PROGRAM CREATES A RUNSTREAM THAT WILL CREATE
C DMDV AND DMDV FOR PARTICULAR ELEMENTS USED DESIGN VARIABLES
C
DIMENSION EL(999), NSECT(999), TNAME1(8), TNAME2(8), FOR(9)
DIMENSION NODVPE(999)
DATA E21, E22, E23, E41, E43, E44, 3HE21, 3HE22, 3HE23, 3HE41, 3HE43, 3HE44/
DATA E31, E33, 3HE31, 3HE33/
DATA TNAME1/4HDEF, 4HGD, 4HTIT, 4HDIR, 4HNS, 3*4HELTS/
DATA TNAME2/5*4H, 4HNAME, 4HNOD, 4HISCT/
DATA START, END, XNSECT/4$STA, 4$END, 4HNSEC/
DATA YNSECT/3HNSE/

C CALL SUBROUTINE TO REMOVE BEGINNING BLANKS
C
C CALL REMOVE

C READ INPUT
C
NOEL=NUMBER OF ELEMENTS
NODV=NUMBER OF DESIGN VARIABLE ELEMENTS
VORB=TYPE OF ANALYSIS (EX. BUCKLING)
NDF=NUMBER OF DEGREES OF FREEDOM PER JOINT
EL = ELEMENT NAMES CONTAINING DESIGN VARIABLES
(EX. E21)
C NSECT - LAST SECTION NUMBER USED FOR EACH DESIGN VARIABLE
C NODVPE - NUMBER OF DESIGN VARIABLES PER ELEMENT

READ(5,5) NOLC,NODV,ISNOLC,JJOINTS,NDF,NOEL,VORB
 5 FORMAT(6(I1X,I4),1X,A4)
READ(5,6) (EL(I),NSECT(I),NODVPE(I),I=1,NOEL)
 6 FORMAT(6(I1X,A3,1X,I3,1X,A3))
NDF=NDF*NDF
WRITE(20,2)
 2 FORMAT(*[XQT TAB** UPDATE=1*)

C LOOP ON NUMBER OF ELEMENTS
DO 30 I = 1,NOEL
C CALL SUBROUTINE TO UPDATE TAB BY SETTING DESIGN VARIABLES TO UNITY.
C KCNT RETURNS THE NUMBER OF POSSIBLE DESIGN VARIABLES FOR A PARTICULAR ELEMENT.
C KCNT=99 MEANS THE ELEMENT NAME IS BAD
C CALL TABINPUT(EL(I),NSECT(I),KCNT)
IF(KCNT.NE.99) GO TO 30
WRITE(20,31)
 29 FORMAT(* ELEMENT NAME *,A3,* DOES NOT EXIST*)
GO TO 190
30 CONTINUE
C CONCLUDE UPDATE AND SET UP DISABLES
WRITE(20,31)
 31 FORMAT(* UPDATE=0*)
WRITE(20,32)
 32 FORMAT(*[XQT DCU** COPY 1,2*)
DO 35 I = 1,8
   IF(I.GT.4) GO TO 33
   DO 37 J = 1,NOEL
      TNAME2(J)=EL(J)
   WRITE(20,34) TNAME1(I),TNAME2(I)
 37 CONTINUE
GO TO 35
WRITE(20,34) TNAME1(I),TNAME2(I)
 33 FORMAT(* DISABLE 1,*,A4,1X,A4)
34 CONTINUE
C SET COUNTER FOR TOTAL NUMBER OF DESIGN VARIABLES
IELCNT = 0
ICNTDV = 1

66
ISW=0
ISAVCNT = 0
C
C READ IN RUNSTREAM AND CHECK FOR START OF A DESIGN VARIABLE
C
39 JCNT = 0
40 READ(21,50) (FOR(J),J=1,9)
50 FORMAT(A4,A6,7A10)
   IF(EOF(21)) 170,60
60 IF(FOR(1).EQ.START) GO TO 70
   WRITE(20,50) (FOR(J),J=1,9)
   GO TO 40
70 IF(ISW.EQ.1) WRITE(20,75)
75 FORMAT(*[,XLQ*E])
   ISW=1
   READ(21,80) (FOR(J),J=1,9)
80 FORMAT(A3,A7,7A10)
C
C SET ICNT = NUMBER OF POSSIBLE DESIGN VARIABLES FOR AN ELEMENT
C
   ICNT=99
C
C DETERMINE POSSIBLE NUMBER OF DESIGN VARIABLES PER ELEMENT
C
   IF(FOR(1).EQ.E23. OR. FOR(1).EQ.E41. OR. FOR(1).EQ.E44) ICNT=1
   IF(FOR(1).EQ.E31) ICNT=1
   IF(FOR(1).EQ.E21) ICNT=4
   IF(FOR(1).EQ.E43. OR. FOR(1).EQ.E33) ICNT=12
   IF(FOR(1).EQ.E22) ICNT=21
   TNAME=FOR(1)
   IF(ICNT.EQ.99) TNAME=SAVNAM
   JCNT = JCNT+1
   IF(ICNT.NE.99) IELCNT=IELCNT+1
C
C SET UNIT = 20 IF ONLY ONE DESIGN VARIABLE PER ELEMENT
C OTHERWISE SET UNIT = 22 (SCRATCH UNIT)
C
   IUNIT=22
   REWIND 22
   IF(ICNT.EQ.1) IUNIT=20
   IF(ICNT.EQ.99. AND. ISAVCNT.EQ.1) IUNIT=20
C
C CHECK FOR REPEAT OF ELEMENT NAME
C
   IF(ICNT.NE.99) GO TO 86
   WRITE(IUNIT,85) SAVNAM
85 FORMAT(A3,77X)
   GO TO 860
C
67
READ DATA FROM UNIT 21 AND WRITE DATA ON UNIT 20 OR 22 DEPENDING UPON VALUE OF ICNT

WRITE(IUNIT,50) (FOR(J),J=1,9)
SAVNAME=FOR(I)
ISAVCNT=ICNT
GO TO 87

ICNT = ISAVCNT
GO TO 870

READ(21,50) (FOR(J),J=1,9)
IF(FOR(1).EQ.XNSEC. OR.FOR(1).EQ.YNSEC) GO TO 88
IF(FOR(1).EQ.END) GO TO 110
WRITE(IUNIT,50) (FOR(J),J=1,9)
GO TO 87

ICNT. ISAVCNT
GO TO 870

READ(21,50) (FOR(J),J=1,9)
IF(FOR(1).EQ.XNSEC. OR.FOR(1).EQ.YNSEC) GO TO 88
IF(FOR(1).EQ.END) GO TO 110
WRITE(IUNIT,50) (FOR(J),J=1,9)
GO TO 100

IF(ICNT.NE.IJ GO TO 120

CALL SUBROUTINE TO CREATE REMAINDER OF RUNSTREAM

CALL CRRS(ICNTDV,O,O,TNAME,NDF,NODVPE(IELCNT))
ICNTDV = ICNTDV+NODVPE(IELCNT)
GO TO 39

LOOP ON POSSIBLE NUMBER OF DESIGN VARIABLES PER ELEMENT READ FROM UNIT 22

WRITE ON UNIT 20

DO 160 I = 1,ICNT
IF(I.NE.1) WRITE(20,75)
REWRITE 22
READ(22,50) (FOR(J),J=1,9)
IF(EOF(22)) 150,140
IF(FOR(1).EQ.XNSEC. OR.FOR(1).EQ.YNSEC) GO TO 141
WRITE(20,50) (FOR(J),J=1,9)
GO TO 130
141 WRITE(20,90) IP1
GO TO 130

CALL SUBROUTINE TO CREATE REMAINDER OF RUNSTREAM
C
150 CALL CRRS(ICNTDV, ICNT, I, TNAME, NDF, NODVPE(IELCNT))
   IP1 = IP1 + 1
160 CONTINUE
   ICNTDV = ICNTDV + NODVPE(IELCNT)
   GO TO 39
170 WRITE(20, 180)
180 FORMAT(* TOC 2**EXQT EXIT*)
190 STOP
   END
C
SUBROUTINE TABINPUT(ELNAME, NSCT, ICNT)
C
THIS SUBROUTINE CREATES TAB PROCESSOR INPUT FOR A RUNSTREAM
DEPENDING UPON ELEMENTS USED.
ALL DESIGN VARIABLES ARE SET TO UNITY.
ICNT = NUMBER OF DESIGN VARIABLES FOR A PARTICULAR ELEMENT
ICNT = 99 MEANS THE ELEMENT NAME IS BAD
C
DIMENSION ELEMENT(21)
DATA E21, E22, E23, E41, E43, E44, 3HE21, 3HE22, 3HE23, 3HE41, 3HE43, 3HE44/
DATA E31, E33, 3HE31, 3HE33/
DATA BA, BB, BC, SA, SB, 2HBA, 2HBB, 2HBC, 2HSA, 2HSB/
IF(ELNAME.EQ.E21) ELID = BA
IF(ELNAME.EQ.E22) ELID = BB
IF(ELNAME.EQ.E23) ELID = BC
IF(ELNAME.EQ.E41 .OR. ELNAME.EQ.E43 .OR. ELNAME.EQ.E31 .OR. 
  1 ELNAME.EQ.E33) ELID = SA
IF(ELNAME.EQ.E44) ELID = SB
WRITE(20, 10) ELID
10 FORMAT(2X, A2)
   ICNT = 99
   IF(ELNAME.EQ.E23 .OR. ELNAME.EQ.E41 .OR. ELNAME.EQ.E44) GO TO 30
   IF(ELNAME.EQ.E31) GO TO 30
   IF(ELNAME.EQ.E21) GO TO 50
   IF(ELNAME.EQ.E43 .OR. ELNAME.EQ.E33) GO TO 100
   IF(ELNAME.EQ.E22) GO TO 150
   PRINT 20, ELNAME
   WRITE(20, 20) ELNAME
   GO TO 210
C
ELEMENT NAMES E23, E31, E41, E44
ICNT = 1
C
30 K = NSCT + 1
   WRITE(20, 40) K
40 FORMAT(1X, I3, *, 1.0*)
   ICNT = 1
   GO TO 210
C ELEMENT NAME E21
C ICNT = 4

50 DO 90 I = 1,4
DO 60 J = 1,10
ELEMENT(J)=0.0
60 CONTINUE
   IF(I.EQ.1) ELEMENT(1)=1.0
   IF(I.EQ.2) ELEMENT(3)=1.0
   IF(I.EQ.3) ELEMENT(5)=1.0
   IF(I.EQ.4) ELEMENT(6)=1.0
   K=I+NSCT
   WRITE(20,70) K, (ELEMENT(J), J=1,10)
70 FORMAT(* DSY *,11,10(1X,F3.1))
   WRITE(20,80)
80 FORMAT(2X,11(*0.0 *))
90 CONTINUE
ICNT=4
GO TO 210

C ELEMENT NAMES E33, E43
C ICNT = 12

100 DO 140 I = 1,12
DO 110 J = 1,12
ELEMENT(J)=0.0
110 CONTINUE
   ELEMENT(1)=1.E-06
   ELEMENT(3)=1.E-06
   ELEMENT(6)=1.E-06
   ELEMENT(7)=1.E-06
   ELEMENT(9)=1.E-06
   ELEMENT(12)=1.E-06
   ELEMENT(I)=1.
   K=I+NSCT
   IF(I.EQ.1) WRITE(20,115)
115 FORMAT(* FORMAT=UNCOPLED*)
   WRITE(20,120) K
120 FORMAT(2X,12,1X,9(*1.0 *))
   WRITE(20,130) (ELEMENT(J), J=1,6)
130 FORMAT(1X,6(1X,E10.2))
   WRITE(20,130) (ELEMENT(J), J=7,12)
140 CONTINUE
ICNT=12
GO TO 210

C ELEMENT NAME E22
C ICNT = 21
```fortran
150 DO 200 I = 1,12
    DO 160 J = 1,21
    ELEMENT(J) = 0.0
160 CONTINUE
    K = I + NSCT
    ELEMENT(I) = 1.
    WRITE(20,170) K, ELEMENT(I)
170 FORMAT(2X,I2,1X,E10.2)
    KK = 2
    DO 190 J = 2,6
        L = KK + J - 1
        WRITE(20,180) (ELEMENT(N), N = KK, L)
180 FORMAT(ZX,6(F3.1,1X))
    KK = KK + J
190 CONTINUE
200 CONTINUE
    ICNT = 21
210 RETURN
END

SUBROUTINE CRRS(ICNTDV,ICNT,J,TNAME,NOF,NODVEL)

C THIS SUBROUTINE CREATES REMAINDER OF RUNSTREAM
C TO FIND DMDV AND DKDV.
C USE NAMES
DMDV DIAG 0 I AND
DKDV SPAR 25 I
WHERE I = 1 TO NUMBER OF POSSIBLE DESIGN VARIABLES

DIMENSION BA(4), BB(21), SAEI(12), TNAMEI(9), TNAME2(9)
DATA DK, DM, CK, CM, SK, SM/2HDK, 2HDM, 2HCK, 2HC M, 2HSM, 2HSM/
DATA DV/2HDV/
DATA BB/2H11, 2H21, 2H22, 2H31, 2H32, 2H33, 2H41, 2H42, 2H43,
1 2H44, 2H51, 2H52, 2H53, 2H54, 2H55, 2H61, 2H62, 2H63, 2H64, 2H65,
2 2H66/
DATA SAEI/2H11, 2H12, 2H22, 2H13, 2H23, 2H33, 2H44, 2H45, 2H55,
1 2H46, 2H56, 2H66/
DATA DEM/10HDDEM DIAG O/
DATA KSP/7HK SPAR /
DATA CHA/9HCHANGE 2,/
DATA COP/9HCOPY 1,2 /
DATA BA/2HI X, 2HIY, 2HDA, 2HJO /
DATA TNAMEI/4HDEF, 4HGD, 4HGTT, 4HELTS, 4HNS, 4HKMAP, 1 4HAMAP, 4HMask, 4HDIR /
DATA TNAME2/3*4H, 4HMask, 3*4H, 4HEFIL, 4H /
DATA DMDV, DKDV, SPAR/4HDMDV, 4HDKDV, 6H SPAR /
DATA DIAG/6H DIAG /
JCNTDV = ICNTDV
C
C XQT E, EKS, TOPO, K, DCU
```
WRITE(20,10)
10 FORMAT(*,XQT,E/**,XQT,EKS/**,XQT,TOPO/**,XQT,K/**,XQT,DCU*)
C
C DISABLE DATA SETS
C
DO 30 I = 1,9
IF(I.EQ.8) TNAME1(8)=TNAME
IF(I.EQ.1 OR I.EQ.2 OR I.EQ.3 OR I.EQ.9) TNAME2(I)=TNAME
WRITE(20,20) TNAME1(I), TNAME2(I)
20 FORMAT(*,DISABLE 1,*,A4,2X,A4)
30 CONTINUE
C
C SET UP ELEMENT NAMES FOR CHANGE AND COPY STATEMENTS
C
DDV=DV
DDK=DK
DDM=DM
IF(ICNT_NE.4) GO TO 31
DDV=BA(J)
GO TO 39
31 IF(ICNT_NE.12) GO TO 32
DDK=CK
DDM=CM
DDV=SAEL(J)
GO TO 39
32 IF(ICNT_NE.21) GO TO 39
DDK=SK
DDM=SM
DDV=BB(J)
39 DO 80 IJK = 1,NODVEL
WRITE(20,40) COP,DEM
40 FORMAT(A9,A10,*,0*)
WRITE(20,50) CHA,DEM,DM,DDV,DIAG,JCNTDV
50 FORMAT(A9,A10,*,0*,2A2,A6,*,0*,I3)
WRITE(20,60) COP,KSP,NDF
60 FORMAT(A9,A7,I2,*,0*)
WRITE(20,70) CHA,KSP,NDF,DDK,DDV,SPAR,NDF,JCNTDV
70 FORMAT(A9,A7,I2,*,0*,2A2,A6,I2,I4)
JCNTDV = JCNTDV+1
80 CONTINUE
RETURN
END

C THIS SUBROUTINE REMOVES THE LEADING BLANKS FROM EACH
C LINE IN THE RUNSTREAM.
C
DIMENSION DATIN(80)
DATA BLANK/1H /
REWIND 23
1 READ(23,2) (DATIN(I),I=1,80)
2 FORMAT(80A1)
   IF(EOF(23)) 7,3
3 IF(DATIN(1).NE.BLANK) GO TO 50
   DO 6 I = 2,80
      IF(DATIN(I).NE.BLANK) GO TO 60
   6 CONTINUE
60 L=I-1
   K=80-I
   DO 4 J = 1,K
      DATIN(J) = DATIN(J+L)
   4 CONTINUE
   K=K+1
   DO 5 J = K,80
      DATIN(J) = BLANK
   5 CONTINUE
50 WRITE(21,2) (DATIN(J),J=1,80)  
   GO TO 1
7 REWIND 21
RETURN
END
PROGRAM GNGRDRS(INPUT, TAPE30, TAPE31, TAPE10, TAPE5=INPUT, OUTPUT)

C THIS PROGRAM CREATES A REPEATABLE SPAR RUNSTREAM
C FOR CALCULATING DERIVATIVES WITH RESPECT TO
C DESIGN VARIABLES. THE SIZE OF THE RUNSTREAM VARIES
C WITH THE NUMBER OF LOAD CASES (NOLC) AND THE
C NUMBER OF DESIGN VARIABLES (NODV).
C
C THE RUNSTREAM IS OUTPUT ON UNIT 10
C
DIMENSION EL(999), NSECT(999), NUM(8), MFORM(5), NODVPE(999)
DATA NUM/I1H1, 1H2, 1H3, 1H4, 1H5, 1H6, 1H7, 1H8/
DATA BUCK, VIBR/4HBUCK, 4HVIBR/
DATA E21, E22, E33, E43/3HE21, 3HE22, 3HE33, 3HE43/
DATA MFORM(1)/10H(*Z11=UNIO/
DATA MFORM(4)/10H(I1, I1X,*Z*/
DATA MFORM(5)/9H(I1, I1, */)
DATA MFORM(7)/9HN(Z10, Z*/
DATA MFORM(8)/5HN(Z*/

C READ INPUT

C NOEL = NUMBER OF DIFFERENT ELEMENTS
C NUMBER OF LOAD CASES
C NODV = TOTAL NUMBER OF DESIGN VARIABLES
C ISNOLC = STARTING NUMBER FOR DERIVATIVE LOAD CASES
C NDF = NUMBER OF DEGREES OF FREEDOM PER JOINT
C NORB = TYPE OF ANALYSIS (EX. BUCKLING)
C JOINTS = NUMBER OF JOINTS IN THE MODEL
C NODVPE = NUMBER OF DESIGN VARIABLES PER ELEMENT
C EL = NAMES OF ELEMENTS CONTAINING DESIGN VARIABLES
     (EX. E21)
C
READ(5,60) NOLC,NODV,ISNOLC,JOINTS,NDF,NOEL,VORB
60 FORMAT(6(I4),1X,A4)
READ(5,61) (EL(I),NSECT(I),NODVPE(I),I=1,NOEL)
61 FORMAT(6(I3,A3,1X,I3,1X,I3))
ISNOLC=ISNOLC-1
NDF=NDF*NDF
C
C DETERMINE IF THERE IS A E21, E22, E33, OR E43 ELEMENT
C
ICNTDV = 1
DO 168 I = 1,NOEL
    JJ = NODVPE(I)
    DO 160 J = 1,JJ
        IF(EL(I).EQ.E21) GO TO 161
        IF(EL(I).EQ.E22) GO TO 163
        IF(EL(I).EQ.E43) GO TO 164
        IF(EL(I).EQ.E33) GO TO 165
    GO TO 166
160 CONTINUE
C
C CALL SUBROUTINE TO FIND DK/DV AND DM/DV FOR E21 ELEMENTS
C
161 CALL DKDVE21(ICNTDV,NDF)
     GO TO 166
C
C CALL SUBROUTINE TO FIND DK/DV AND DM/DV FOR E22 ELEMENTS
C
163 CALL DKDVE22(ICNTDV,NDF)
     GO TO 166
C
C CALL SUBROUTINE TO FIND DK/DV AND DM/DV FOR E43 ELEMENTS
C
164 CALL DKDVE43(ICNTDV,NDF)
     GO TO 166
C
C CALL SUBROUTINE TO FIND DK/DV FOR E33 ELEMENTS
C
165 CALL DKDVE33(ICNTDV,NDF)
166 ICNTDV = ICNTDV+1
160 CONTINUE
168 CONTINUE
  IF(VORB.EQ.VIBR) GO TO 320
  WRITE(10,172)
172 FORMAT(*[XQT AUS*)
C
C  FIND OBJECTIVE FUNCTIONS
C
162 WRITE(10,175) JOINTS
175 FORMAT(* SYSVEC;UNIT VEC */* I=1; J=1,*I8,*; 1.0/*
    1 * DEFINE UN=UNIT VEC*)
    DO 200 I = 1,NODV
    WRITE(10,180) I,I
200 CONTINUE
    DO 250 I = 1,NODV
    WRITE(10,220) I,I
220 CONTINUE
    DO 300 I = 1,NODV
    WRITE(10,270) I
300 CONTINUE
C
C  CALL SUBROUTINE TO CREATE RUNSTREAM FOR DERIVATIVE
C  CALCULATION
C
C  FIND APPLIED FORCES AND MOMENTS
C
   WRITE(10,2)
2 FORMAT(*[XQT AUS*/ OUTLIB=3*)
   DO 4 I = 1,NOLC
   WRITE(10,3) I,I
3 FORMAT(* DEFINE F*,I2,*=STAT DISP *,I2* 1*)
4 CONTINUE
   DO 6 I = 1,NODV
   WRITE(10,5) I,NDF,I
5 CONTINUE
   DO 10 I = 1,NOLC
   NWNOLC=I+ISNOLC
   WRITE(10,7) NWNOLC
7 FORMAT(* ALPHA; CASE TITLE *,I3)
   DO 9 J = 1,NODV
   WRITE(10,8) J,I,J
9 CONTINUE
8 FORMAT(* LOAD CASE *,I2,* DERIVATIVE 1 DESIGN VARIABLE *,
1 I I3)
CONTINUE
10 CONTINUE
IF(NO DV.NE.1) WRITE(10,2003)
2003 FORMAT(* OUTLIB=4*)
IF(NODV.EQ.1) WRITE(10,6006)
6006 FORMAT(* OUTLIB=3 *)
DO 1010 I = 1,NODV
NWNOLC=I+ISNOLC
DO 1005 J = 1,NODV
WRITE(10,1003) NWNOLC,J,J,I
1003 FORMAT(* APPL FORC *,I3,I3,** PRODUCT(-1.0 L*,I3,**1.0 F*,I2,**)
1005 CONTINUE
1010 CONTINUE
DO 15 I = 1,NODV
NWNOLC=I+ISNOLC
IF(NODV.EQ.1) GO TO 50
IF(I.EQ.1) WRITE(10,2009)
2009 FORMAT(* INLIB=4*/* OUTLIB=3*)
DO 13 J = 1,NODV
ITOP=9
ICHK=NODV-J+1
IF(ICHK.LT.9) ITOP=ICHK
DO 40 K = 1,ITOP
L=K+J-1
WRITE(10,12) K,NWNOLC,L
12 FORMAT(* DEFINE Z*,I1,**APPL FORC *,I3,I3,I1)**
40 CONTINUE
IF(ITOP.EQ.1) GO TO 41
MFORM(2)=MFORM7
IF(J.EQ.1) MFORM(2)=MFORM8
MFORM(3)=NUM(ITOP-1)
WRITE(10,MFORM) (K,K=1,ITOP)
41 IF(ITOP.EQ.1) WRITE(10,42)
42 FORMAT(*Z11=UNION(Z10,Z11)**)
WRITE(10,45)
45 FORMAT(* INLIB=3/**Z12=UNION(Z11)** DEFINE Z10=Z12**
1 * INLIB=4*)
13 CONTINUE
WRITE(10,46) NWNOLC
46 FORMAT(* APPL FORC *,I3,* 1=UNION(Z10)**)
15 CONTINUE

C FIND STRESS AND DISPLACEMENT DERIVATIVES

50 DO 32 I = 1,NODV
WRITE(10,16) NODV
16 FORMAT(*EXQT SSOL/** RESET L1=1,L2=*,I3)
NWNOLC=I+ISNOLC
WRITE(10,17) NWNOLC
SET UP RUNSTREAM FOR BUCKLING ANALYSIS

17 FORMAT(* RESET QLIB=3/* RESET SET=*,I3)
WRITE(10,18)
18 FORMAT(*VQRT VPR=LIB=3*)
WRITE(10,19) NWNOLC
19 FORMAT(* PRINT APPL FORC /*I3)
WRITE(10,20) NWNOLC
20 FORMAT(* PRINT STAT DISP */I3)
IF(VORB.EQ.BUCK) GO TO 400
WRITE(10,21) NODV
21 FORMAT(*XQT GSF/** RESET L1=1,L2=*,I3/* RESET QLIB=3*)
WRITE(10,22) NWNOLC
22 FORMAT(* RESET SET=*,I3)
WRITE(10,23) NODV
23 FORMAT(*XQT PSF/** RESET L1=1,L2=*,I3/* RESET QLIB=3*)
WRITE(10,24) NWNOLC
24 FORMAT(* RESET SET=*,I3)
GO TO 25

C
C SET UP RUNSTREAM FOR BUCKLING ANALYSIS
C
400 IDV = 0
DO 470 J = 1,NOEL
NODVEL = NODVPE(J)
DO 460 K = 1,NODVEL
IDV = IDV+1
WRITE(10,425)
425 FORMAT(*XQT GSF/** RESET EMBED=1*)
WRITE(10,430) IDV,IDV,NWNOLC
430 FORMAT(* RESET L1=*,I3,*,L2=*,I3,*,SET=*,I3,*,QLIB=3*)
WRITE(10,435)
435 FORMAT(*XQT PSF*)
WRITE(10,430) IDV,IDV,NWNOLC
WRITE(10,440)
440 FORMAT(*XQT KG*)
WRITE(10,445)
445 FORMAT(*XQT DCU*)
WRITE(10,450) NDF,NDF,IDV
450 FORMAT(* CHANGE 1,KG SPAR *,I3,* 0,DKG SPAR *,I3,I4)
WRITE(10,455) NDF,IDV
455 FORMAT(* COPY 1,3 DKG SPAR *,I3,I4)
460 CONTINUE
470 CONTINUE
25 WRITE(10,251)
251 FORMAT(*XQT DCU*)
WRITE(10,26) NWNOLC,NWNOLC
26 FORMAT(* CHANGE 3,STAT DISP *,I3,* 1,ODIS DISP *,I3,* 1*)
C
C CHANGE DATA SET NAMES
C
IDV=0
DO 31 J=1,NOEL
NOSECT = NSECT(J)
NODVEL = NODVPE(J)
DO 30 K=1,NODVEL
DO 271 LL = 1,NOSECT
IDV=IDV+1
DO 27 KK = 1,NOEL
IF(EL(KK).EQ.E21) GO TO 29
IF(EL(KK).EQ.E22) GO TO 29
IF(EL(KK).EQ.E43) GO TO 29
IF(EL(KK).EQ.E33) GO TO 29
WRITE(10,28) EL(KK),NWNOLC,IDV,EL(KK),NWNOLC,IDV
28 FORMAT(* CHANGE 3,STRS *,A3,214,*,DSTR *,A3,2I4)
WRITE(10,285) EL(KK),NWNOLC,IDV
285 FORMAT(* COPY 3,4 DSTR *,A3,2I4)
GO TO 27
C
C STORE BEAM CROSS DERIVATIVES
C
29 WRITE(10,290) EL(KK),NWNOLC,IDV,EL(KK),NWNOLC,IDV
290 FORMAT(* CHANGE 3,STRS *,A3,214,*,DFAM *,A3,2I4)
WRITE(10,292) EL(KK),NWNOLC,IDV
292 FORMAT(* COPY 3,4 DFAM *,A3,2I4)
27 CONTINUE
271 CONTINUE
30 CONTINUE
31 CONTINUE
32 CONTINUE
320 IF(VORB.EQ.WIBR) WRITE(10,260)
DO 333 I = 1,NODV
WRITE(10,332) I
332 FORMAT(* COPY 1,4 OBJF G*,I3)
333 CONTINUE
WRITE(10,33)
33 FORMAT(* TOC 3/*/ TOC 1/*/ TOC 4/*/XQT EXIT*)
STOP
END
APPENDIX G.- LISTING OF DRVXX.

PROGRAM DRVSTRS(INPUT=65,TAPE30,TAPE31,TAPE5=INPUT
1,TAPE15,TAPE16,OUTPUT=65,TAPE6=OUTPUT)

C THIS PROGRAM COMPUTES THE STRESSES AND STRESS DERIVATIVES
FOR SPAR BEAM ELEMENTS USING SPAR LIBRARIES AS INPUT.
C
C THE STRESSES ARE COMPUTED FROM SPARLA USING DATA SET
FAMS MASK I 1 WHERE I = 1 TO NOLC
C THE STRESSES ARE WRITTEN BACK ONTO SPARLA USING DATA SET
STRS MASK I 1 WHERE I = 1 TO NOLC
C
C THE STRESS DERIVATIVES ARE COMPUTED FROM SPARLC USING DATA SET
OFAM MASK I J WHERE I = ISTRTLC TO ISTRTLC+NOLC AND J = 1 TO NODV
C THE STRESS DERIVATIVES ARE WRITTEN BACK ONTO SPARLC USING DATA SET
DSTR MASK I J WHERE I = ISTRTLC TO ISTRTLC+NOLC AND J = 1 TO NODV

COMMON KORE,KEVEN,Z(1)
DIMENSION NAME1(2),NAME2(2),EL(999),NODVPE(999)
DATA E21,E22,E33,E43/3HE21,3HE22,3HE33,3HE43/
DATA NAME1/4HFAMS,4HDFAM/
DATA NAME2/4HSTRS,4HDSTR/

C READ INPUT VALUES
C
C NOEL IS THE NUMBER OF DIFFERENT ELEMENTS
C NDF IS THE DEGREES OF FREEDOM PER JOINT
C VORB IS THE TYPE OF ANALYSIS (EX. BUCKLING)
C JOINTS IS THE NUMBER OF JOINTS IN THE MODEL
C NOLC IS THE NUMBER OF LOAD CASES
C NODV IS THE NUMBER OF DESIGN VARIABLES
C ISTRTLC IS THE STARTING NUMBER FOR THE DERIVATIVE LOAD CASES
C EL = NAMES OF ELEMENTS USED AS DESIGN VARIABLES
(EX. E21)

READ(5,1) NOLC,NOOVL,ISNOLC,Joints,NDF,NOEL,VORB
1 FORMAT(6(I6),1X,A4)
READ(5,2) (EL(I),NSEC,NOOVPE(I),I=1,NOEL)
2 FORMAT(6(I6,A3,1X,I3,1X,I3))
ISTRLC=ISNOLC-1
CALL RSET(IL,0,0)

LOOP ON THE NUMBER OF LOAD CASES
DO 4 NCNTLC = 1,NOLC

LOOP ON NUMBER OF ELEMENTS
DO 10 ISTRS = 1,NOEL

CHECK FOR E21,E22,E33,E43 ELEMENT
IF(EL(ISTRS).EQ.E21.OR.EL(ISTRS).EQ.E43.OR.
1 EL(ISTRS).EQ.E22.OR.EL(ISTRS).EQ.E33) GO TO 9
GO TO 10
9 NODOVL = NODOVPE(ISTRS)

SET NUMBER OF STRESS OR STRESS DERIVATIVES TO BE WRITTEN
IF(EL(ISTRS).EQ.E21.OR.EL(ISTRS).EQ.E22) IWRDCNT = 8
IF(EL(ISTRS).EQ.E43.OR.EL(ISTRS).EQ.E33) IWRDCNT = 4

LOOP ON NUMBER OF DESIGN VARIABLES PER ELEMENT
DO 90 JK = 1,NODOVL
REWIND 15
REWIND 16

READ FAMS MASK FROM SPARLA AND COMPUTE STRS MASK
CALL RDATSET(4,NAME1(1),NCNTLC,1,NE1,1,0,EL(ISTRS))
REWIND 15
REWIND 16

CALL SUBROUTINE TO WRITE STRESSES ON SPAR LIBRARY

WRITE STRS MASK ON SPARLA
CALL WRTDATA(4,NAME2(1),NCNTLC,1,NE1,EL(ISTRS),IWRDCNT)
90 CONTINUE
10 CONTINUE
ICNTDV = 1

C LOOP ON NUMBER OF ELEMENTS
C
DO 3 ISTRS=1,NODEL
  IF (EL(ISTR) .EQ. E21 .OR. EL(ISTR) .EQ. E43) GO TO 19
  GO TO 3
19 DO 30 ICNTDV = 1,NODV
  IBEAM = 0
  NODVEL = NODVPE(ICNTDV)
C
C SET SWITCH FOR BEAM ELEMENT
C
  IF (EL(ICNTDV) .EQ. E21 .OR. EL(ICNTDV) .EQ. E22) IBEAM = 1
  N3 = NCNTLC + ISTPTLC
C
C SET NUMBER OF STRESSES AND STRESS DERIVATIVES TO BE WRITTEN
C
  IF (EL(ICNTDV) .EQ. E21) IWRDCNT = 8
  IF (EL(ICNTDV) .EQ. E43) IWRDCNT = 4
C
C LOOP ON NUMBER OF DESIGN VARIABLES PER ELEMENT
C
DO 20 JK = 1,NODVEL
C
C READ DFAM MASK FROM SPARLC AND COMPUTE DSTR MASK
C
  REWIND 15
  CALL RDATSET(4,NAME1(2),N3,ICNTDV,NE1,0,IBEAM,EL(ISTR))
  REWIND 15
C
C WRITE DSTR MASK ON SPARLC
C
  CALL WRTDATA(4,NAME2(2),N3,ICNTDV,NE1,EL(ISTR),IWRDCNT)
20 CONTINUE
30 CONTINUE
4 CONTINUE
  CALL FIN(0,0)
STOP
END

SUBROUTINE WRTDATA(NU,N1,N3,ISTR,NE1,X2,IWRDCNT)

SUBROUTINE TO WRITE STRESS AND STRESS DERIVATIVE
DATA SETS BACK INTO SPAR LIBRARIES

COMMON KORE,KEVEN,Z(1)
C SET UP BLOCK SIZES
C IF NW03 GT OPEN CORE SIZE, USE MORE THAN ONE BLOCK

NW03=NE1*WRCDCNT
LB3=NW03
IF(NW03.LT.KORE) GO TO 61
LB3=NW03/2

61 ISW=0
IF(NW03.LT.KORE) ISW=1
CALL DAL(NU,0,Z(1),KORE,1,KADR3,IERR,NW03,NE1,LB3,-1,
1 N1,X2,N3,ISTR5)

62 II=1
63 I2=I1+WRCDCNT-1
IF(I2.GT.LB3) GO TO 66

C READ STRESSES OR STRESS DERIVATIVES OFF UNIT 15
C
READ(15) (Z(I),I=I1,I2)
IF(E0F(15)) 66,65
65 II=I1+WRCDCNT
GO TO 63

C WRITE STRESSES OR STRESS DERIVATIVES ONTO SPAR LIBRARY
C
66 CALL RID(NU,10,2,KADR3,Z(1),LB3)
IF(ISW.EQ.1) GO TO 67
ISW=1
LB3=NW03-LB3
GO TO 62

67 RETURN
END

SUBROUTINE RDATSET{NU,N1,N3,ISTR5,NE1,KORE,X2)
C
C SUBROUTINE TO READ SPAR LIBRARY, STORE DATA, AND
C COMPUTE STRESSES OR STRESS DERIVATIVES
C
COMMON KORE,KEVEN,Z(1)
DATA E21,E22,E33,E43,3HE21,3HE22,3HE33,3HE43/

C SET UP BLOCK SIZE

CALL DAL(NU,10,Z(1),KORE,1,KADR1,IERR,NW01,NE1,LIB1,ITYPE,N1,
1 X2,N3,ISTR5)
N1=L1/NE1
KCNT=0
NBLK1=NW01/LB1
IF(NBLK1*LB1.NE.NW01) NBL1=NBL1+1
DO 6 J = 1,NBLK1
NLB1=LB1
IF(J.EQ.NBLK1) NLB1=NW01-(NBLK1-1)*LB1

C READ DATA FROM SPAR LIBRARY
C
CALL RID(NU,20,Z(KADR1,Z(1),NLB1)
DO 30 JCNT=1,NLB1,N1
KCNT=KCNT+1

C CALL SUBROUTINE TO COMPUTE STRESSES AND STRESS DERIVATIVES
C
IF(X2.EQ.E21.0R.X2.EQ.E22) CALL BMSTRS(ISW,KCNT,JCNT,IBEAM)
IF(X2.EQ.E43.0R.X2.EQ.E33) CALL PLTSTRS(ISW,KCNT,JCNT)
30 CONTINUE

RETURN
END
APPENDIX H.—LISTING OF DKDVE21.

SUBROUTINE DKDVE21(NDVJIM, NDF)
DIMENSION X(20)
NAMELIST/LINKF/NDV, X

THIS SUBROUTINE CREATES A SPAR RUNSTREAM TO CALCULATE

\[
\begin{align*}
  &DK &DK &DA &DK &DI &DK &DI &DK &DJ \\
  &DV &DA &DV &DI &DV &DI &DV &DJ &DV \\
  &I &I &X &I &Y &I &O &I \\
  &DV &DA &DV &DI &DV &DI &DV &DJ &DV \\
  &I &I &X &I &Y &I &O &I
\end{align*}
\]

WRITE(10,1)
1 FORMAT(*'XQT AUS*)
WRITE(10,3)NDF, NDVJIM, NDF, NDVJIM
3 FORMAT(* DEFINE A1=DKDA SPAR *,I2,I4/* DEFINE A2=DKIX*
  1 * SPAR *,I2,I4)
WRITE(10,4)NDF, NDVJIM, NDF, NDVJIM
4 FORMAT(* DEFINE A3=DKIXY SPAR *,I2,I4/* DEFINE A4=DKJO*
  1 * SPAR *,I2,I4)
WRITE(10,203)NDVJIM, NDVJIM
203 FORMAT(* DEFINE B1=DMDA DIAG 0 *,I3/* DEFINE B2=DMIX*
  1 * DIAG 0 *,I3)
WRITE(10,204)NDVJIM, NDVJIM
204 FORMAT(* DEFINE B3=DMIXY DIAG C *,I3/* DEFINE B4=DMJO*
  1 * DIAG 0 *,I3)

COMPUTE DA/DV

DADV = 1.

READ IN AND SET UP INITIALIZATION VALUES

READ IN CONSTANTS FROM UNIT 30

READ(30,5) B10, B20, TO
5 FORMAT(3F10.3)

READ IN DESIGN VARIABLES FROM UNIT 31

READ(31, LINKF)
COMPUTE FACTORS FOR $\frac{DII}{DV}$, $\frac{DII}{DV}$, $\frac{DJO}{DV}$

$$
\begin{align*}
DB1DV &= B10 \times FTR \\
DB2DV &= B20 \times FTR \\
DTDV &= T0 \times FTR \\
D11DB1 &= (B2 + 2.T) ** 3/12 - B2 ** 3/12 \\
D11DB2 &= (R2 + 2.T) ** 2 * B1 / 4 - B2 ** 2 * (B1 - T) / 4 \\
D11DT &= (B2 + 2.T) ** 2 * B1 / 2 + B2 ** 2 / 2 \\
DCDB2 &= B1 ** 2 / 2 - (B1 - T) * (B1 + T) / 2 - C * T) / AREA \\
DCDT &= (B1 ** 2 + B2 ** T - C * (2.B1 + B2)) / AREA \\
D12DB1 &= (T * B1 ** 2 / 2) + (2.T * (B1 - C) ** 2) + \\
& 1 \left(4.T * B1 * (B1 - C) * (5 - DCDB1)\right) + \\
& 2 \left(2.B2 ** T * (C - T) / 2 * DCDB1\right) \\
D12DB2 &= (-4.T * B1 * (B1 - C) * DCDB2) + (T ** 3 / 12) + \\
& 1 \left(T * (C - T) / 2 * DCDB2\right) \\
D12DT &= (B1 * (B2 / 2 - C) * T) / 2 + (2.B2 ** T * (C - T) / 2) * (DCDT - 5) \\
DJODB1 &= 2.T ** 3 / 3 \\
DJODB2 &= T ** 3 / 3 \\
DJODT &= (2.B1 + B2) * T ** 2
\end{align*}
$$

CREATE RUNSTREAM TO FIND $\frac{DK}{DV}$

$$
\begin{align*}
WRITE(10, 106) OADV, D11DV \\
WRITE(10, 107) D12DV, DJODV \\
106 FORMAT(8X, S1 = SUM(*, F13.5, 1X, A1, *E13.5, 1X, A2)) \\
107 FORMAT(8X, S2 = SUM(*, E13.5, 1X, A3, *E13.5, 1X, A4)) \\
WRITE(10, 108) NDF, NDVJIM \\
108 FORMAT(*, DKDV SPAR *, I2, I4, = SUM(S1, S2))
\end{align*}
$$

CREATE RUNSTREAM TO FIND $\frac{DM}{DV}$

$$
\begin{align*}
WRITE(10, 206) OADV, D11DV \\
WRITE(10, 207) D12DV, DJODV \\
206 FORMAT(8X, T1 = SUM(*, E13.5, 1X, B1, *E13.5, 1X, B2)) \\
207 FORMAT(8X, T2 = SUM(*, E13.5, 1X, B3, *E13.5, 1X, B4)) \\
WRITE(10, 208) NDVJIM \\
208 FORMAT(*, DMDV DIAG 0 *, I3, = SUM(T1, T2)) \\
WRITE(10, 209) \\
209 FORMAT(*, QU * DCU */* TOC 1*)
\end{align*}
$$

RETURN

END
APPENDIX I.- LISTING OF BMSTRS.

SUBROUTINE BMSTRS(ISW,KCNT,JCNT,IBEAM)
COMMON KORE,KEVEN,Z(1)
DIMENSION DY1DV(4),DY2DV(4),Y(4,2),S(8),F3(2),XM1(2),XM2(2)
DIMENSION X(20)
NAMELIST/LINKF/NDV,X
JM1 = JCNT-1
C
C STORE FORCES AND MOMENTS IF ISTRS EQ 1
C STORE DERIVATIVES OF FORCES AND MOMENTS IF ISTRS EQ 2
C
F3(1)=Z(JM1+13)
XM1(1)=Z(JM1+14)
XM2(1)=Z(JM1+15)
F3(2)=Z(JM1+19)
XM1(2)=Z(JM1+20)
XM2(2)=Z(JM1+21)
IF(KCNT.NE.1) GO TO 31
IF(ISW.NE.1) GO TO 31
C
C STORE AREA, MOMENTS OF INERTIA, AND Y VALUES IF FIRST TIME THROUGH
C
XI1=Z(JM1+25)
XI2=Z(JM1+27)
ICNT=38
DO 3 K = 1,4
DO 2 L = 1,2
ICNT=ICNT+1
Y(K+L)=Z(JM1+ICNT)
2 CONTINUE
3 CONTINUE
C
FIND DERIVATIVE OF Y VALUES IF NEEDED
C
C READ IN CONSTANT NUMBERS FROM UNIT 30
C
READ(30,10) B10,B20,TO
10 FORMAT(3F10.3)
C
C READ IN DESIGN VARIABLES FROM UNIT 31
C
READ(31,LINKF)
C
C CALCULATE DY/DV
C
AO=(2.*B10+B20)*TO
A=AO/X(2)
SCALE=SQRT(A/AO)
B1=B10*SCALE
B2=B20*SCALE
T=TO*SCALE
FTR=0.5/SQRT(A*A0)
C=C/A
DB1DV=B10*FTR
DB2DV=B20*FTR
DTDV=TO*FTR
DCDB1=(B1*(B2+2.*T)-B2*B1-2.*C*T)/A
DCDB2=(B1**2/2.-B1-T)*(B1+T)/2.-C*T)/A
DCDT=(B1**2+B2*T-C*(2.*B1+B2))/A
DCDV=(DCDB1*DB1DV)+((DCDB2*DB2DV)+(DCDT*DTDV)
DY1DV(1)=-DB1DV+DCDV
DY1DV(2)=DCDV
DY1DV(3)=DCDV
DY1DV(4)=DY1DV(1)
DY2DV(1)=0.5*DB2DV+DTDV
DY2DV(2)=DY2DV(1)
DY2DV(3)=DY2DV(1)
DY2DV(4)=DY2DV(3)
31 ICNT=0
DO 200 II = 1,2
DO 100 I = 1,4
ICNT=ICNT+1
C
C COMPUTE STRESSES OR STRESS DERIVATIVES
C
S(ICNT)=((F3(II)/A)+((XM1(II)/X11)*Y(I,2))-((XM2(II)/X12)
1 *Y(I,1))
C
C IF AREA OF BEAM IS A CONTRIBUTING FACTOR TO STRESS
C DERIVATIVES AND ISTRS EQ 1 THEN CALCULATE THE FACTOR
C AND STORE ON UNIT 16
C
IF(ISW .NE. 1) GO TO 95
DFAC = ((XM1(II)/XI1)*DY2DV(I)) - ((XM2(II)/XI2)*DY1DV(I))
WRITE(16) DFAC
GO TO 100

C IF AREA OF BEAM IS A CONTRIBUTING FACTOR TO STRESS
C DERIVATIVES AND ISTRS EQ 2 THEN READ FACTOR OFF UNIT 16
C AND ADD IT TO STRESS DERIVATIVE

95 IF(IBEAM.EQ.0) GO TO 100
READ(16) DFAC
S(ICNT) = S(ICNT) + DFAC
100 CONTINUE
200 CONTINUE

C WRITE STRESSES ON UNIT 15
C
WRITE(15) S
RETURN
END
This distributed implementation of the PROgraming Structural Synthesis System (PROSSS) combines a general purpose finite-element computer program for structural analysis, a state-of-the-art optimization program, and several user-supplied, problem-dependent computer programs. The results are flexibility of the optimization procedure organization and versatility of the formulation of constraints and design variables. The analysis-optimization process results in a minimized objective function, typically the mass. The analysis and optimization programs are executed repeatedly by looping through the system until the process is stopped by a user-defined termination criterion. However, some of the analysis, such as model definition, need only be one time and the results are saved for future use. The user must write some small, simple FORTRAN programs to interface between the analysis and optimization programs. One of these programs, the front processor, converts the design variables output from the optimizer into a suitable format for input into the analyzer. Another, the end processor, retrieves the behavior variables and, optionally, their gradients from the analysis program and evaluates the objective function and constraints and optionally their gradients. These quantities are output in a format suitable for input into the optimizer. These user-supplied programs are problem-dependent because they depend primarily upon which finite elements are being used in the model. The analysis and end processor programs are always executed on the mainframe computer because the CPU on the mainframe is much faster than that of the minicomputer. The optimization and front processor programs are always executed on the minicomputer because the optimizer requires a significant memory allocation and the minicomputer has virtual memory.

**Key Words (Suggested by Author(s))**
Optimization, Distributed Processing, Finite-Element Analysis, Minicomputer

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