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PLACING THREE-DIMENSIONAL ISOPARAMETRIC ELEMENTS INTO NASTRAN

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SUMMARY

Linear (8 node), parabolic (20 node), cubic (32 node) and mixed (some edges linear, some parabolic and some cubic) have been inserted into NASTRAN, Level 15.1. First the dummy element feature was used to check out the stiffness matrix generation routines for the linear element in NASTRAN. Then, the necessary modules of NASTRAN were modified to include the new family of elements. The matrix assembly was changed so that the stiffness matrix of each isoparametric element is only generated once as the time to generate these higher order elements tends to be much longer than the other elements in NASTRAN. This paper presents some of the experiences and difficulties of inserting a new element or family of elements into NASTRAN.

INTRODUCTION

In solving many structural problems at Westinghouse, it has become apparent that in order to obtain the accuracy required, three-dimensional finite elements would be required. It also became apparent that three-dimensional finite elements based on constant strain tetrahedra like the CTETRA, CWEDGE, CHEXA1 and CHEXA2 elements in NASTRAN are too stiff to give accurate results at a reasonable cost for many problems.

Because of this, a Westinghouse proprietary program, WISEC, was developed for heat conduction and static linear elastic analysis using three dimensional isoparametric elements. Because of the large general purpose capability of NASTRAN, both for types of problems solved and for types of elements used, it was decided to place these elements into NASTRAN.

Even though three-dimensional isoparametric elements were then to be and now have been placed into NASTRAN by Dr. E. I. Field and Mr. S. E. Johnson of Universal Analytics (see Ref. 1), and are to be included in Level 16 NASTRAN now scheduled to be released in 1974, it was decided to place three-dimensional isoparametric elements into Level 15.1 NASTRAN. First we would have use of this element in NASTRAN at an earlier date than we would if we waited until Level 16 was released. Second, we would gain experience and familiarity with NASTRAN which would enable us to more easily make any future modifications which we would desire. A third benefit, which we didn't realize at the time, is the fact that the family of elements we added can have different number of grid or nodal points on the various edges as shown in figure 1. As we understand, Level 16 NASTRAN will have elements which are either linear (2 points on each edge), parabolic (3 points on each edge) or cubic (4 points on each edge). Mixed elements, like that shown in figure 1, can be used to reduce the number of degrees of freedom in portions of the structure not requiring the higher order elements without introducing incompatibilities between adjacent elements. The order of an element is taken to be that of its highest ordered edge.

As the theory of three-dimensional isoparametric elements is explained elsewhere, for instance in Refs. 1 to 4, it will not be repeated here.

At the present time, the stiffness and mass matrices have been successfully inserted and tested. The differential stiffness matrix is due to be added shortly.

The work described in this report was performed with Level 15.1 NASTRAN on an IBM 370-165. It is planned to insert the changes into Level 15.5 NASTRAN on a CDC 6600.

RECOMMENDATIONS

1. For anyone making changes in NASTRAN, an up-to-date Programmer's Manual is of great aid. Unfortunately, the latest available Programmer's Manual is not always for the latest available level of NASTRAN.

2. Many of the tables present in Level 15.1 NASTRAN are too short to permit elements with as many degrees of freedom as the isoparametric elements. These tables should be increased in length to permit easier insertion of new elements.

METHOD AND EXPERIENCES

NASTRAN is an extremely large system comprised of fifteen super links with approximately 850 subprograms whose source statements are on over 200,000 card images. NASTRAN is indeed a very large and complex program and, at first glance, a dense forest that seems too difficult to enter. As one starts to review the large NASTRAN Programmer's Manual (approximately 15 centimeters thick) and examine the materials the authors of NASTRAN have distributed, the forest does not seem as dense. This section of the paper describes our experiences in adding new elements to the NASTRAN system.

The three-dimensional isoparametric elements added presented many problems that the usual NASTRAN elements did not encounter. The tables were much larger, for example. The number of nodes that described our cubic isoparametric element varies from ten to thirty-two nodes. This number forced us to expand the Element Connection and Properties Tables and other array sizes that dealt with nodes. The concept of a variable number of nodes per element was also a departur from the usual NASTRAN practice of a constant number of nodes per element type.

For these higher order elements, the computer time necessary to create the element matrices was quite large; hence, a procedure to create the element matrices once and to save them had to be incorporated into the element level subprograms.

The release we used to incorporate the new elements was level 15.1. The computer used was an IBM 370-165 operating under the ASP system. The Programmer's Manual we had was for Level 12 which caused some difficulty but not too much. We will outline the procedure we used in adding the new elements.

First one should review the materials distributed with the Level 15 system. Figure 2 is a VTOC (Volume Table of Contents) of the distributed system. Pages 5.3-13 and 5.3-14 of the Programmer's Manual (ref. 5) describes each of the data sets of the distributed system. The data sets which are most useful to us are SOU1, the partitioned data set containing the FORTRAN source programs, SUBSYS, also a partitioned data set containing the linkage editor control cards for the fifteen super links of NASTRAN; the partitioned data set OBJ, which contains all the load modules of each individual subroutine of the system; the partitioned data set NSTNLMOD, which contain the fifteen link-edited super links which constitute the NASTRAN executable set.

The next step of the procedure should be to set up a development disk with at least two data sets which we named NEWOBJ and NADEV. NEWOBJ corresponds to OBJ, and NADEV corresponds to NSTNLMOD. It would be advisable to set up a data set corresponding to SOU1 but we elected to keep all of our new source programs in card-deck form. The IBM 370 utility program IEHMOVE or IEBCOPY can be used to move the fifteen link edited links from NSTNLMOD to the development pack. NADEV's initial allocation should be as large as possible as this data set will be modified frequently. An alternate approach, which we did not use but one that could have saved us some grief would be to set up fifteen different data sets rather than one partitioned data set with fifteen members. Then each time we needed to link-edit, we would scratch the particular data set and recreate the new link edited data set (instead of member). This procedure would keep us from using up all the extents of a partitioned data set and not having to compress the partitioned set which we had to do approximately every twenty to twenty-five re-link edits. Figure 3 is the VTOC of our development disk. The other utility that we made quite frequent use of was IEBPTPCH. With the use of this utility we can either list or punch a member of SOU1 or any of the other partitioned data sets. The JCL for PUNCHIT is given in Figure 4 and for PRINIT in Figure 5. With these two decks we can list or punch subroutines from SOU1. The punched routine could then be modified for our new element. Another utility which could have been used for modifying source decks is IEBUPDATE which we did not use. The next step in the process is to compile either a modified subprogram of the NASTRAN system or to compile one of our new subprograms. The compiled program is placed into our partitioned data set NEWOBJ. The JCL for this procedure is shown in Figure 6. When all the decks for one of the links has been compiled, the next step is to link edit this link.

The link editor allows one to specify a group of libraries of programs via the LKED.XXX DD cards. In our case, we described two libraries, OBJ which contained all the original unmodified or distributed load modules and NEWOBJ, the modified and new load modules. Each library is given a DD name, for the partitioned set OBJ the name LKED.LIB is used and for NEWOBJ we chose to use the name LKED.LIP. The overlay control cards can be punched and listed from the data set SUBSYS for this link. The control card deck is then modified to reflect the modifications made to the link. See Figure 7 for the JCL and modified control deck for the Link Edit step. The SYSLMOD DD card defines the output load module for the linkage editor and places the load module in the data set NADEV.

The next step is to run a NASTRAN problem to test the procedure implemented. Alters can be made to the DMAP program to extract contents of tables or of generated matrices. In addition, print statements can be made within the modified programs to print out calculated results. If these print statements are used, they should be activated by a specific DIAG that is not in use by the NASTRAN system. See pages 3.3-15 and 3.3-15a of the NASTRAN Programmer's Manual for DIAGS not in use by the system. Figure 8 gives an example of the use of alter statements and demonstrates the use of DIAG setting for controlling debug printing. In debugging a modified link, a dump is quite helpful on the occurrence of a system fatal error. The most important part of the dump is the save area trace which lists the routines last used when the error occurred. Usually this is sufficient and a full dump is not necessary. NASTRAN has built into the system a use of the SNAP macro which dumps only the save areas. Use of DIAG 1 will produce a full dump.

The link edit procedure for NASTRAN links is rather costly on the IBM 370-165 because of the extremely large number of segments in each of the links. Hence, whenever possible, we did as much checking of a modified module with a nonoverlayed FORTRAN run. For example, in checking out the stiffness matrix routines for the isoparametric elements we ran a simple model in NASTRAN, and with the Alter statements we printed the contents of the ECPT (Element Connection and Properties Tables). A main program which simulates SMA1 was written to supply the proper ECPT to the element stiffness matrix routines and the element matrices were generated and printed out. When we were satisfied that the routines operated properly we modified our link-edit control deck and link edited the new element stiffness matrix routines into our data set NADEV. A run of the same model would then produce the element stiffness matrices, displacements, and stresses. Figure 7 is our JCL and control deck for the insertion of stiffness matrix routines into link 3.

The procedure for the variable number of grid points for mixed elements (one that is not full) was implemented in the following manner. The connection cards for the element were left blank at positions where grid points were missing from the full element. A modification of TA1A and TA1B was made to enter a zero as the grid point number for the missing grid points. For the grid points present, the degree of freedom for that grid point (a nonzero value) was entered as the grid point number. All tables such as ECPT, EST (Element Summary Table) have nonzero values for grid points present in the element and zeros for missing grid points. The length of the grid point table is fixed for each element type, for example, twenty for CSOLID2, the quadratic isoparametric. This table is then used as a guide to all processing of the mixed element. The modifications to TA1A and TA1B were suppled to us by Carl Hennrich of MacNeal-Schwendler Company.

The procedure used for saving the element matrices and not recreating them each time they are needed was as follows: A scratch tape was assigned to be used in the element matrix subroutine. This tape had to be assigned a GINO buffer at a level where all buffers are assigned for this module. Also an array had to be assigned for record keeping of saved elements. Initilization of counters had to be done at the level where the buffer was assigned. At the element level the routine would first ask if this element had previously been encountered. This is done by a search through the table of all elements that have been saved. If found, the tape record number is extracted from the table and the tape is positioned by GINO commands to the proper record. The record is read into core and the sub matrices needed for this call are assembled from the total element matrix and given to the subroutine which is assembling the total mass or stiffness matrix. If this element has not been encountered, the element matrix is calculated, and the tape is positioned to the end of last element written, and the new element matrix is written on the scratch tape. The element number and record number is entered into the table. This procedure was suggested in the Programmers Manual, Page 4.87-1, last two sentences of paragraph 3. GINO proved very useful here in that the records saved were of variable length because of the three types of elements and because of the use of mixed elements within a type. The variable length could be stored in the record and using GINO's capability of reading and writing segmented or partial records we could read the number of words for the variable length record. To add scratch tapes to an existing module the MPL (Module Property List) had to be modified by recompiling the block data program XMPLBD, see pages 2.4-21 and 2.4-22 of the Programmers Manual.

DISCUSSION

The new Programmer's Manual for version 15.1 has an excellent chapter on adding a structural element. This was an update of a NASA Fourteenth Quarterly Report for NASTRAN, January 1970. This chapter gives a step-by-step procedure of all routines and tables that have to be modified to accommodate a new element. The Fourteenth Quarterly Report aided us greatly in getting through most of the input problems of NASTRAN.

From this step-by-step procedure, one can see that adding a new element to NASTRAN is not that difficult because of the excellent documentation and supplies that have been distributed.

ACKNOWLEDGMENTS

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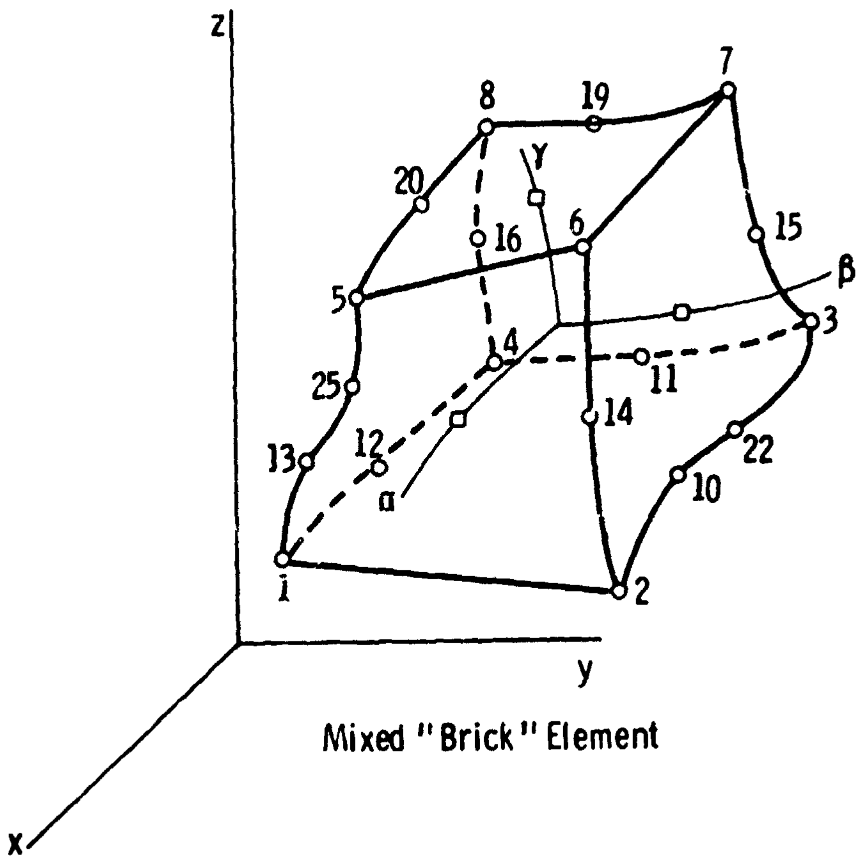
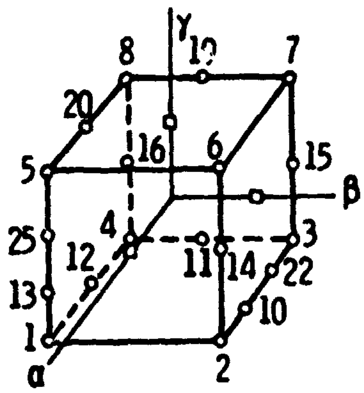


Mixed "Brick" Element



Local Coordinate System

Figure 1.- Mixed 3-D isoparametric element. Variable number of grid points.

```
VOLUME                FORMAT 4 DSCB AT     0/  2/ 1  (CC/HH/R)                      14/31/09.98    73.165

EXTENT OF VTOC   - FROM   0/  2 TO   0/  4      SEQUENCE NUMBER =  0      CODE = 01        3 TRACKS ALLOCATED
DEVICE CHARACTERISTICS               NUMBER OF LOGICAL CYLINDERS = 203
                                     NUMBER OF TRACKS PER LOGICAL CYLINDER =  20
                                     NUMBER OF BYTES PER TRACK =  7294
                                     NUMBER OF FULL DSCBS PER TRACK =  25
                                     NUMBER OF PDS DIRECTORY BLOCKS PER TRACK =  17

FORMAT 5 DSCB AT   0/  2/ 2  (CC/HH/R)            EXTENTS OF AVAILABLE SPACE

        STARTING AT RELATIVE TRACK    1 (  0/  1)  THERE ARE   0 CYLINDERS AND AN ADDITIONAL  1 TRACKS AVAILABLE
        STARTING AT RELATIVE TRACK 3368 (168/  8)  THERE ARE   1 CYLINDERS AND AN ADDITIONAL 12 TRACKS AVAILABLE
        A TOTAL OF    33 TRACKS AVAILABLE

ASTMLNCP                                 FORMAT 1 DSCB AT     0/  2/ 3  (CC/HH/R)

        NUMBER OF EXTENTS =  1           DATA SET ORGANIZATION IS  PARTITIONED                RECORD FORMAT IS  U
        BLOCKSIZE = 7294          LOGICAL RECORD LENGTH =    0
        SECONDARY ALLOCATION  -  CODE = 80            QUANTITY =   20
        THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK1027  AS RECORD NUMBER   6
        THERE ARE  5794 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
        EXTENT  1           FROM   0/  5  TO   51/ 14      SEQUENCE NUMBER =  0      CODE = 01      103C TRACKS ALLOCAT

OBJ                                      FORMAT 1 DSCB AT     0/  2/ 4  (CC/HH/R)

        NUMBER OF EXTENTS =  2           DATA SET ORGANIZATION IS  PARTITIONED                RECORD FORMAT IS  U
        BLOCKSIZE = 7294          LOGICAL RECORD LENGTH = 7294
        SECONDARY ALLOCATION  -  CODE = 80            QUANTITY =    2
        THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK 566  AS RECORD NUMBER   9
        THERE ARE  3197 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
        EXTENT  1           FROM  51/ 15  TO   80/  0      SEQUENCE NUMBER =  0      CODE = 01       566 TRACKS
        EXTENT  2           FROM  80/  1  TO   80/  2      SEQUENCE NUMBER =  1      CODE = 01         2 TRACKS
                                                                                    A TOTAL OF  568 TRACKS  ALLOCA

SOU1                                     FORMAT 1 DSCB AT     0/  2/ 5  (CC/HH/R)

        NUMBER OF EXTENTS =  1           DATA SET ORGANIZATION IS  PARTITIONED                RECORD FORMAT IS  FB
        BLOCKSIZE = 7290          LOGICAL RECORD LENGTH     80
        SECONDARY ALLOCATION  -  CODE = 40            QUANTITY =    2
        THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK2014  AS RECORD NUMBER   2
        THERE ARE  4622 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
        EXTENT  1           FROM  80/  3  TO  180/ 19      SEQUENCE NUMBER =  0      CODE = 01      2017 TRACKS ALLOCAT

SOU2                                     FORMAT 1 DSCB AT     0/  2/ 6  (CC/HH/R)

        NUMBER OF EXTENTS =  1           DATA SET ORGANIZATION IS  PARTITIONED                RECORD FORMAT IS  FB
        BLOCKSIZE = 7280          LOGICAL RECORD LENGTH =   80
        SECONDARY ALLOCATION  -  CODE = 80            QUANTITY =    1
        THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK   6  AS RECORD NUMBER   2
        THERE ARE  5000 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
```

Figure 2.- VTOC distributed system V15.

```
                                      FORMAT 1 DSCB AT      0/  2/ 7  (CC/HH/R)
SOU3                                                                                  RECORD FORMAT IS  FB
       NUMBER OF EXTENTS =  1          DATA SET ORGANIZATION IS  PARTITIONED
       BLOCKSIZE = 7280          LOGICAL RECORD LENGTH =    80
       SECONDARY ALLOCATION  -  CODE = 80           QUANTITY =      2
       THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK 109  AS RECORD NUMBER    4
       THERE ARE   2468 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
       EXTENT  1          FROM 191/ 10  TO  1?7/  0        SEQUENCE NUMBER =  0       CODE = 01        111 TRACKS ALLOCAT

                                      FORMAT 1 DSCB AT      0/  2/ 8  (CC/HH/R)
SUBSYS                                                                                RECORD FORMAT IS  FB
       NUMBER OF EXTENTS =  1          DATA SET ORGANIZATION IS  PARTITIONED
       BLOCKSIZE = 3200          LOGICAL RECORD LENGTH =    80
       SECONDARY ALLOCATION  -  CODE = 80           QUANTITY =      1
       THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK  25  AS RECORD NUMBER    2
       THERE ARE   6591 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
       EXTENT  1          FROM 187/  1  TO  188/  6        SEQUENCE NUMBER =  0       CODE = 01        26 TRACKS ALLOCAT

                                      FORMAT 1 DSCB AT      0/  2/ 9  (CC/HH/R)
UMFINDTA                                                                              RECORD FORMAT IS  FB
       NUMBER OF EXTENTS =  1          DATA SET ORGANIZATION IS  SEQUENTIAL
       BLOCKSIZE = 7280          LOGICAL RECORD LENGTH =    80
       SECONDARY ALLOCATION  -  CODE = 80           QUANTITY =      1
       THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK 140  AS RECORD NUMBER    1
       THERE ARE    769 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
       EXTENT  1          FROM 188/  7  TO  195/  7        SEQUENCE NUMBER =  0       CODE = 01        141 TRACKS ALLOCAT

                                      FORMAT 1 DSCB AT      0/  2/10  (CC/HH/R)
CENGDATA                                                                              RECORD FORMAT IS  FB
       NUMBER OF EXTENTS =  1          DATA SET ORGANIZATION IS  PARTITIONED
       BLOCKSIZE = 7280          LOGICAL RECORD LENGTH =    80
       SECONDARY ALLOCATION  -  CODE = 80           QUANTITY =      1
       THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK  43  AS RECORD NUMBER    2
       THERE ARE   4673 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
       EXTENT  1          FROM 195/  8  TO  197/ 11        SEQUENCE NUMBER =  0       CODE = 01        44 TRACKS ALLOCAT

                                      FORMAT 1 DSCB AT      0/  2/11  (CC/HH/R)
UTILMODS                                                                              RECORD FORMAT IS  [illegible]
       NUMBER OF EXTENTS =  4          DATA SET ORGANIZATION IS  PARTITIONED
       BLOCKSIZE = 7294          LOGICAL RECORD LENGTH = 7294
       SECONDARY ALLOCATION  -  CODE = 20           QUANTITY =      2
       THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK  15  AS RECORD NUMBER    3
       THERE ARE   4414 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
       EXTENT  1          FROM 197/ 12  TO  198/  1        SEQUENCE NUMBER =  0       CODE = 01        10 TRACKS
       EXTENT  2          FROM 198/  2  TO  198/  3        SEQUENCE NUMBER =  1       CODE = 01         2 TRACKS
       EXTENT  3          FROM 198/  4  TO  198/  5        SEQUENCE NUMBER =  2       CODE = 01         2 TRACKS
                                                                                  A TOTAL OF    14 TRACKS  ALLOCA
       THIS DSCB IS CHAINED TO A FORMAT 3 DSCB AT     0/  2/12  (CC/HH/R)

FORMAT 3 DSCB AT    0/  2/12  CC/HH/R)               EXTENTS CONTINUED FROM A FORMAT 1 DSCB
```

Figure 2.- Concluded.

```
VOLUME              FORMAT 4 DSCB AT     0/  1/ 1  (CC/HH/R)                       14/31/13.13    73.165

EXTENT OF VTCC   - FRCM   0/  1 TO   0/  4      SEQUENCE NUMBER =  0      CCDE = 01         4 TRACKS ALLOCATEC
DEVICE CHARACTERISTICS              NUMBER OF LOGICAL CYLINDERS = 203
                                    NUMBER OF TRACKS PER LOGICAL CYLINDER =  20
                                    NUMBER OF BYTES PER TRACK =  7294
                                    NUMBER OF FULL DSCBS PER TRACK =  25
                                    NUMBER OF PDS DIRECTORY BLOCKS PER TRACK =  17

FORMAT 5 DSCB AT    0/  1/ 2  (CC/HH/R)              EXTENTS OF AVAILABLE SPACE

         STARTING AT RELATIVE TRACK     5 (  0/  5)  THERE ARE   0 CYLINDERS AND AN ADDITIONAL 15 TRACKS AVAILABLE
         STARTING AT RELATIVE TRACK 3840 (192/  0)  THERE ARE   8 CYLINDERS AND AN ADDITIONAL  0 TRACKS AVAILABLE
         A TOTAL OF  175 TRACKS AVAILABLE

NEWOBJ                                          FORMAT 1 DSCB AT     0/  1/ 3  (CC/HH/R)

         NUMBER OF EXTENTS =  1           DATA SET ORGANIZATION IS  PARTIT:ONED              RECORD FORMAT IS  FB
         BLOCKSIZE = 3120          LOGICAL RECORD LENGTH =   80
         SECONDARY ALLOCATION  -  CODE = CO          QUANTITY =     0
         THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK 269  AS RECORD NUMBER    3
         THERE ARE  2485 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
         EXTENT  1           FROM   1/  0  TO   15/ 19      SEQUENCE NUMBER =  0      CODE = 81       300 TRACKS ALLOCAT

NADEV2                                          FORMAT 1 DSCB AT     0/  1/ 4  (CC/HH/R)

         NUMBER OF EXTENTS = 11           DATA SET ORGANIZATION IS  PARTITIONED              RECORD FORMAT IS  U
         BLOCKSIZE = 7294          LOGICAL RECORD LENGTH =    0
         SECONDARY ALLOCATION  -  CODE = CO          QUANTITY =    20
         THE LAST BLOCK WAS WRITTEN ON RELATIVE TRACK2081  AS RECORD NUMBER  15
         THERE ARE   887 BYTES REMAINING ON THAT TRACK FOLLOWING THE BLOCK
         EXTENT  1           FROM  32/  0  TO  100/ 19      SEQUENCE NUMBER =  0      CODE = 81       1330 TRACKS
         EXTENT  2           FROM 101/  0  TO  120/ 19      SEQUENCE NUMBER =  1      CODE = 81        400 TRACKS
         EXTENT  3           FROM  16/  0  TO   23/ 19      SEQUENCE NUMBER =  2      CODE = 81        160 TRACKS
                                                                                   A TOTAL OF 1940 TRACKS  ALLUC
         THIS DSCB IS CHAINED TO 1 FORMAT 3 DSCB AT     0/  1/ 5  (CC/HH/R)

FORMAT 3 DSCB AT    0/  1/ 5  CC/HH/R)              EXTENTS CONTINUED FROM A FORMAT 1 DSCB

         EXTENT  4           FROM  24/  0  TO   31/ 19      SEQUENCE NUMBER =  3      CODE = 81        160 TRACKS
         EXTENT  5           FROM 121/  0  TO  143/ 19      SEQUENCE NUMBER =  4      CODE = 81        460 TRACKS
         EXTENT  6           FROM 144/  0  TO  151/ 19      SEQUENCE NUMBER =  5      CODE = 81        160 TRACKS
         EXTENT  7           FROM 152/  0  TO  159/ 19      SEQUENCE NUMBER =  6      CODE = 81        160 TRACKS
         EXTENT  8           FROM 160/  0  TO  167/ 19      SEQUENCE NUMBER =  7      CODE = 81        160 TRACKS
         EXTENT  9           FROM 168/  0  TO  175/ 19      SEQUENCE NUMBER =  8      CODE = 81        160 TRACKS
         EXTENT 10           FROM 176/  0  TO  183/ 19      SEQUENCE NUMBER =  9      CODE = 81        160 TRACKS
         EXTENT 11           FROM 134/  0  TO  151/ 19      SEQUENCE NUMBER = 10      CODE = 81        160 TRACKS
                                                                                   A TOTAL OF 1580 TRACKS  ALLUCA
```

Figure 3.- VTOC of aevelopment system.

```
//PUNCHIT JOB (RDXXXXX,RDRD),'MBNEWMAN',REGION=100K,TIME=(,39)          JOB CARD
/*VOLREQ ID=(NASTRAN15)                                   DISTRIBUTED SYSTEM V.15
//   EXEC PGM=IEBPTPCH
//SYSPRINT DD SYSOUT=A
//SYSUT1   DD DSNAME=SOU1,UNIT=SYSDA,DISP=OLD,VOL=SER=VOLNUM,
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=7280)
//SYSUT2  DD SYSOUT=3
//SYSIN  DD  *
  PUNCH TYPORG=PO,MAXNAME=60,MAXFLDS=60
  MEMBER NAME=DS1
    RECORD FIELD=(80)
  MEMBER NAME=DS1A
    RECORD FIELD=(80)
  MEMBER NAME=DS1ABD
    RECORD FIELD=(80)
/*

     NOTE  SOU1 IS DATA SET NAME.  VOLNUM IS DISK VOLUME SERIAL NUMBER
```

Figure 4.- Punch source from SOU1.

```
//PRINIT JOB (RDXXXXX,RDRD),'MBNEWMAN',REGION=100K,TIME=(,39)           JOB CARD
/*VOLREQ ID=(NASTRAN15)                                   DISTRIBUTED SYSTEM V.15
/*FORMAT PR,DDNAME=SYSUT2,TRAIN=HN
//    EXEC PGM=IEBPTPCH
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=SYSDA,VOLUME=SER=VOLNUM,DISP=OLD,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=7280),DSN=SOU1
//SYSUT2  DD SYSOUT=A
//SYSIN  DD  *
      PRINT  TYPORG=PO,MAXFLDS=80,MAXNAME=80,MAXLINE=45
      MEMBER NAME=READ1
    RECORD FIELD=(80)
      MEMBER NAME=READ2
    RECORD FIELD=(80)
/*
```

Figure 5.- Prints source from SOU1.

```
//COMPILE JOB (RDXXXXX,RDRD),'MBNEWMAN',REGION=200K,TIME=(,39)          JOB CARD
/*VOLREQ ID=(NASTRANDEV)                                          DEVELOPMENT DISK
//      EXEC     FORTGC,PARM.FORT='NODECK'
//FORT.SYSLIN  DD  UNIT=2314,DISP=SHR,VOL=SER=VOLDEV,
//           DSN=NEWOBJ(IFX1BD)
//FORT.SYSIN  DD  *
      BLOCK DATA
CIFX1BD
      COMMON /IFPX1/ N,I1(100),I2(100),I3(100),I4(100),I5(100),I6(120),
     *           I7(64)
      DATA N/310/
      DATA I1/4HGRID,4H    ,4HGRDS,4HET  ,4HADUM,4H1   ,4HSEQG,4HP
     5        ,4HCORD,4H1R  ,4HCORD,4H1C  ,4HCORD,4H1S  ,4HCORD,4H2R
     9        ,4HCORD,4H2C  ,4HCORD,4H2S  ,4HPLOT,4HEL  ,4HSPC1,4H
     3        ,4HSPCA,4HDD  ,4HSUPO,4HRT  ,4HOMIT,4H    ,4HSPC ,4H
     7        ,4HMPC ,4H    ,4HFORC,4HE   ,4HMOME,4HNT  ,4HFORC,4HE1
     1        ,4HMOME,4HNT1 ,4HFORC,4HE2  ,4HMOME,4HNT2 ,4HPLOA,4HD
     5        ,4HSLOA,4HD   ,4HGRAV,4H    ,4HTEMP,4H    ,4HGENE,4HL
     9        ,4HPROD,4H    ,4HPTUB,4HE   ,4HPVIS,4HC   ,4HADUM,4H2
      DATA I5/4HTEMP,4HP1  ,4HTEMP,4HP2  ,4HTEMP,4HP3  ,4HTEMP,4HRB
     5        ,4HGRID,4HB   ,4HFSLI,4HST  ,4HRING,4HFL  ,4HPRES,4HPT
     9        ,4HCFLU,4HID2 ,4HCFLU,4HID3 ,4HCFLU,4HID4 ,4HAXIF,4H
C    3        ,4HBDYL,4HIST ,4HFREE,4HPT  ,4HSELE,4HCT  ,4HSELE,4HCT1
     3        ,4HBDYL,4HIST ,4HFREE,4HPT  ,4HASET,4H    ,4HASET,4H1
     7        ,4HCTET,4HRA  ,4HCWED,4HGE  ,4HCHEX,4HA1  ,4HCHEX,4HA2
     1        ,4HDMIA,4HX   ,4HFLSY,4HM   ,4HAXSL,4HOT  ,4HCAX1,4HF2
     5        ,4HCAX1,4HF3  ,4HCAX1,4HF4  ,4HCSLO,4HT3  ,4HCSLO,4HT4
     9        ,4HGRID,4HF   ,4HGRID,4HS   ,4HSLBD,4HY   ,4HCHBD,4HY
     3        ,4HQHBD,4HY   ,4HMAT4,4H    ,4HMAT5,4H    ,4HSAME,4H
C    ADD CSOLID1,CSOLID2,CSOLID3 NAMES TO DIRECTORY OF CONNECTION CARD NAMES MAN
     7        ,4HSAME,4H1   ,4HINPU,4HT    ,4HOUTP,4HUT  ,4HCSOL,4HID1
     1        ,4HCSOL,4HID2 ,4HCSOL,4HID3  ,4H****,4H****,4H****,4H****
     5        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     9        ,4H****,4H****,4H****,4H**** /
      DATA I6/4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     5        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     9        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     3        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     7        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     1        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     5        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     9        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     3        ,4H****,4H****,4H****,4H****,4H****,4H****,4H****,4H****
     7        ,4H****,4H****,4H****,4H****,4HDECO,4HMUPT,4HCPBA,4HR
     1        ,4HCPRO,4HD   ,4HCPTU,4HBE  ,4HCPQU,4HAD1 ,4HCPQU,4HAD2
     5        ,4HCPTR,4HIA1 ,4HCPTR,4HIA2 ,4HCPQD,4HPLT ,4HCPTR,4HPLT
     9        ,4HCPTR,4HBSC ,4HCOUP,4HMASS,4HGRDP,4HNT  ,4HWTMA,4HSS
     3        ,4HIRES,4H    ,4HLFRE,4HQ   ,4HMFRE,4HQ   ,4HLMOD,4HES
     7        ,4HG   ,4H    ,4HW3  ,4H    ,4HW4  ,4H    ,4HMODA,4HCC   /
      DATA I7/4HMPCS,4H    ,4HSPCS,4H    ,4HLOAD,4HS   ,4HMETH,4HODS ,
     5         4HDEFO,4HRMS ,4HTEMP,4HLDS ,4HTEMP,4HMTS ,4HICS ,4H     ,
     9         4HAOUT,4HS   ,4HLOOP,4HS   ,4HLOOP,4H1S  ,4HDLOA,4HDS   ,
     3         4HFREQ,4HS   ,4HTFS ,4H    ,4HPLOT,4HS   ,4HTSTE,4HPS   ,
     7         4HPOUT,4HS   ,4HTEMP,4HMXS ,4HDSCO,4HS   ,4HK2PP,4HS    ,
     1         4HM2PP,4HS   ,4HB2PP,4HS   ,4HCMET,4HHODS,4HSDAM,4HPS   ,
     5         4HPLCO,4HS   ,4HNLFO,4HRCES,4HXYOU,4HTS  ,4HDELE,4HTES  ,
     9         4HRAND,4HOMS ,4HAXYO,4HUTS ,4HNOLO,4HOPS ,4H****,4H****/
      END
/*
```

Figure 6.- Compiles and puts object into development data set NEWOBJ.

```
//LNKEDT JOB (RDXXXXX,RDRD),'MBNE#MAN',REGION=275K,TIME=2                JOB CARD
/*VOLREQ ID=(NASTRAN15)                                     DISTRIBUTED SYSTEM V.15
/*VOLREQ ID=(NASTRANDEV)                                           DEVELOPMENT DISK
//  EXEC FORTHL,PARM.LKED='MAP,LIST,OVLY,DC,LET,SIZE=(262K,72K)'
//LKED.SYSLIB DD DISP=SHR,DSN=SYS1.ERRPK
//             DD DISP=SHR,DSN=SYS1.FORTLIB
//LKED.SYSLMOD DD UNIT=SYSDA,DISP=SHR,VOL=SER=VOLDEV,DSN=NADEV2,
//          SPACE=(CYL,(68,8,5))
//LKED.LIP DD UNIT=SYSDA,DISP=SHR,VOL=SER=VOLDEV,DSN=NE#OBJ
//LKED.LIB DD UNIT=SYSDA,DISP=SHR,VOL=SER=VOLNUM,DSN=OBJ
//LKED.SYSIN DD *
   INCLUDE LIP(LIEN,KISOPR)                                                    00
  CHANGE EXIT(PXIT36)                                                    00000010
   INCLUDE LIB(PEXIT)                                                    00000020
   INCLUDE LIB(PXIT36)                                                   00000030
   INCLUDE LIB(LINKNSU3,XSEM3)                                           00000040
   INCLUDE LIB(CORSZ)                                                    00000050
   INCLUDE LIB(SEMDBD,RETURN,XEOT,MAPFNS,TMTOGO,CONMSG)                  00000060
   INCLUDE LIB(MESAGE,SSWTCH,GOPEN,FREAD,CLSTAB,OPNCOR,FNAME)            00000070
   INCLUDE LIB(PRELOC,WRTIRL)                                            00000080
 OVERLAY A                                                               00000090
   INCLUDE  LIB(PAGE)                                                    00000100
 OVERLAY A1                                                              00000110
   INCLUDE LIB(MSGWRT,USRMSG)                                            00000120
 OVERLAY A1                                                              00000130
   INCLUDE LIB(BTSTRP)                                                   00000140
  CHANGE NTRAN(PEXIT),LINK(PEXIT)                                        00000150
   INCLUDE LIB(ENDSYS)                                                   00000160
 OVERLAY  ENDSSS                                                         00000170
    INSERT  ENDSSS                                                       00000180
 OVERLAY A1                                                              00000190
   INCLUDE LIB(QPARAM)                                                   00000200
 OVERLAY A1                                                              00000210
   INCLUDE LIB(XSAVE)                                                    00000220
 OVERLAY A1                                                              00000230
   INCLUDE LIB(XCEI)                                                     00000240
 OVERLAY A1                                                              00000250
   INCLUDE LIB(XCHK)                                                     00000260
 OVERLAY A1                                                              00000270
   INCLUDE LIB(GNFIST,RPDABD,XSFA,XSOSGN,ACLEAN,XPUNP,XDPH)              00000280
   INCLUDE LIB(XPOLCK,XPURGE)                                            00000290
    INSERT XSFA1                                                         00000300
 OVERLAY ESFA                                                            00000310
    INSERT ESFA,OSCENT                                                   00000320
 OVERLAY A1                                                              00000330
   INCLUDE LIB(TABPT,TABPRT,MATDUM,MATPRN)                               00000340
 OVERLAY TABPRX                                                          00000350
    INSERT TABPRX                                                        00000360
 OVERLAY A1                                                              00000370
   INCLUDE LIB(PRTPRM)                                                   00000380
 OVERLAY A                                                               00000390
   INCLUDE LIP(GPTABD)                                                   00000400

   INCLUDE LIB(DELSET)                                                   00000401
   INCLUDE LIB(HMAT,BISRCH)                                              00000410
   INCLUDE LIB(GMMATD,PRETRD,INVERD,GMMATS,PREMAT)                       00000420
   INCLUDE LIB(SAXB,DAXB,SADOTB,DADOTB)                                  00000430
    INSERT GPTA1                                                         00000440
    INSERT HMTOUT                                                        00000450
    INSERT HMATDD                                                        00000460
    INSERT  MATIN,MATOUT                                                 00000470
```

Figure 7.- Link edit and puts execution module into NADEV development set.

FIGURE 7 CONTINUED

```
OVERLAY SMA1
  INCLUDE LIP(SMA1BD)
   INSERT  SMA1CL,SMA1IO,SMA1BK,SMA1ET,SMA1DP
   INSERT SMA1HT
 CHANGE KBEAM(PEXIT)
    INCLUDE LIP(SMA1A)
  INSERT SMA1SC,APLE
  INCLUDE LIB(SMA1B,DETCK)
  INCLUDE LIP(SMA1)
 CHANGE KBEAM(PEXIT)
  INCLUDE LIB(PLA1)
OVERLAY SMAEL
  INCLUDE LIB(KROD,KBAR,KTUBE,KPANEL,KELAS)
  INCLUDE LIB(KTRMEM,KQDMEM,KTRBSC,KTRPLT,KQDPLT,KTRIQD,HHBDY,HRING)
OVERLAY SMAEL
  INCLUDE LIB(KCONE,KCONEX)
OVERLAY SMAEL
  INCLUDE LIB(KTRIRG,KTRAPR,DKI,DKINT,DKK,DKM,DKJ,DKEF,DK89,DK100)
  INCLUDE LIB(DK211,DK219,DKJAB,KFAC)
OVERLAY SMAEL
  INCLUDE LIB(KTORDR,DMATRX,ROMBDK,D4K,D5K,D6K)
OVERLAY SMAEL
  INCLUDE LIB(KFLUD2,KFLUD3,KFLUD4,KSLOT,KTETRA,KSOLID,KPLIST)
OVERLAY SMAEL
  INCLUDE LIB(KDUM1,KDUM2,KDUM3,KDUM4,KDUM5,KDUM6,KDUM7,KDUM8,KDUM9)
 OVERLAY SMAEL
  INSERT K1SOPR
  INSERT DTOT,FORMTD,INV3X3,JTPTN,MATERL,MBC1A,MMAT,MULTPN,MXYZ,NSELEC
  INSERT PARTL,PARXYZ,SETCON
  INSERT SMA1PD,ELDATA,NMAT,FRONT3,PARTIL
OVERLAY SMA1
 CHANGE MBEAM(PEXIT)
 INCLUDE LIP(SMA2A)
 INCLUDE LIB(SMA2B)
 INCLUDE LIP(SMA2BD,SMA2)
  INSERT SMA2SC,MAPLE
   INSERT  SMA2CL,SMA2IO,SMA2BK,SMA2ET,SMA2DP
OVERLAY  SMAEL2
  INCLUDE LIB(MROD,MBAR,MTUBE,MASSD,BVISC,MCONMX,MCONE)
  INCLUDE LIB(MSOLID,MFLUD2,MFLUD3,MFLUD4,MFREE,MSLOT)
  INCLUDE  LIB(MASSTQ)
  INCLUDE LIB(MCBAR,MCROD,MTRBSC,MQDPLT,MTRPLT,MTRIQD)
OVERLAY  SMAEL2
  INCLUDE LIB(MTRIRG,MTRAPR,DMI,DMINT,DMK,DMM, MJ,DMEF,DM89,DM100)
  INCLUDE LIB(MFAC,DMJAB,DM219,DM211,MTORDR)
OVERLAY SMAEL2
  INCLUDE LIB(MDUM1,MDUM2,MDUM3,MDUM4,MDUM5,MDUM6,MDUM7,MDUM8,MDUM9)
 OVERLAY SMAEL2
  INCLUDE LIP(MISOPR,MLIEN)
 INSERT SMA2PD,ELDAT2,NMAT2,FRONT2,PARTI2
OVERLAY OEND(REGION)
   INSERT SMA1X

   INSERT SMA2X
OVERLAY EJDUM2
  INCLUDE LIB(EJDUM2)
   INSERT EJDUM2
 ENTRY LINKNS03
NAME LINKNS03(R)
/*
```

Figure 7.- Concluded.

```
//ALTEX JOB (RUXXXXX,RURD),'MBNEWMAN',REGION=300K,TIME=(,59)           JOB CARD
/*VOLREQ ID=(NASTRANDEV)                                       DEVELOPMENT DISK
/*FORMAT PR,DDNAME=FT04F001,TRAIN=HN
/*FORMAT PR,DDNAME=FT06F001,TRAIN=HN
/*FORMAT PR,DDNAME=SNAPSHOT,TRAIN=HN
//S2  EXEC  F56THG
//PROG.NAME DD DSNAME=SYS1.LINKLIB(VTOCPRT),VOLUME=REF=SYSLIB1,        A
//               DISP=OLD
//GO.DD2 DD UNIT=SYSDA,DISP=OLD,VOLUME=(PRIVATE,RETAIN,SER=(VOLDEV))
//GO.SYSIN  DD  *
VOLDEV
EOJ
//   EXEC NSTMBN
//NASTRAN.STEPLIB  DD  UNIT=2314,VOL=SER=VOLDEV,DISP=SHR,DSN=NADEV2
//NASTRAN.SNAPSHOT DD UNIT=(CTC,,DEFER),DCB=BLKSIZE=882
//SYSIN DD *
NASTRAN BUFFSIZE=1800,SYSTEM(31)=4096,SYSTEM(9)=35,CONFIG=10
ID   MARV,NEWMAN
APP  DISP
SOL 1,0
TIME 5
DIAG 15
DIAG 2,8,13,14
DIAG 19,21,22
DIAG 25                                                          MBNDEBUG
ALTER 21
TABPT GPTT,,,, //$
ALTER 26
TABPT GPCT,,,, // $
TABPT ECPT,GPTT,EST,, // $
TABPT EQEXIN,GEOM2,,, // $
ALTER 111
MATPRN UG',PGG,UG,, //  $
ENDALTER
CEND
OLOAD=ALL
SPC=111
SPCF=ALL
STRESS=ALL
ELFORCE=ALL
DISP=ALL
LOAD=100
TITLE=TEST OF BODY FORCE --- 1 CSOLID2 ELEMENT
ECHO=BOTH
BEGIN BULK
GRDSET                                             456
GRID     1              1.      -1.      0.
GRID     2              1.       1.      0.
GRID     3             -1.       1.      0.
GRID     4             -1.      -1.      0.
GRID     5              1.      -1.      3.
GRID     6              1.       1.      3.
```

Figure 8.- VTOC example and use of ALTER for table and matrix printouts.

```
GRID    7                -1.     1.      3.
GRID    8                -1.     -1.     3.
GRID    9                1.      0.      0.
GRID    10               0.      1.0     0.0
GRID    11               -1.0    0.0     0.0
GRID    12               0.0     -1.0    0.0
GRID    13               1.0     -1.0    1.5
GRID    14               1.0     1.0     1.5
GRID    15               -1.0    1.0     1.5
GRID    16               -1.0    -1.0    1.5
GRID    17               1.0     0.0     3.0
GRID    18               0.0     1.0     3.0
GRID    19               -1.0    0.0     3.0
GRID    20               0.0     -1.0    3.0
CSOLID2 1       10                                                      GE1
GE1     1       2       3       4       5       6       7       8       GE2
GE2     9       10      11      12      13      14      15      16      GE3
GE3     17      18      19      20
SPC     111     5       1       -.9E-05 8       12      .9E-05
SPC     111     5       2       .9E-05  8       3       .3E-05
SPC     111     5       3       .3E-05  17      1       -.9E-05
SPC     111     6       12      -.9E-05 17      2       0.0
SPC     111     6       3       .3E-05  17      3       .15E-05
SPC     111     7       1       .9E-05  18      1       0.0
SPC     111     7       2       -.9E-05 18      2       -.9E-05
SPC     111     7       3       .30E-05
SPC     111     18      3       .15E-05
SPC     111     19      1       .9E-05
SPC     111     19      2       0.0
SPC     111     19      3       .15E-05
SPC     111     20      1       0.0
SPC     111     20      2       .9E-05
SPC     111     20      3       .15E-05
MAT1    10      1.E07           .3      4.0
GRAV    100             25.     -1.0    0.0     00.0
ENDDATA
/*
```

Figure 8.- Concluded.