CONSPEC - A DMAP SYSTEM FOR CONVENTIONAL RESPONSE-SPECTRUM ANALYSIS IN MSC/NASTRAN

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ABSTRACT

This Paper describes the features of a DMAP system called CONSPEC that implements a conventional response-spectrum analysis in MSC/NASTRAN. The term "conventional" refers herein to an approach based on the relative-motion concept and on post-processing of a standard SOL-3 eigensolution. CONSPEC, unlike SOL-63, obviates the need for fictitious modelling details. It accommodates a wide range of damping representations. It can output individual-mode contributions to total response and can sort element forces/stresses. An intermediate, but optionally stand-alone, step in CONSPEC evaluates and outputs useful modal measures such as participation factors, effective masses, damping factors and mode-truncation-effectiveness matrix. In effect, CONSPEC enables the average NASTRAN-user to realize most of his practical requirements in response-spectrum analysis without any artificial model augmentation and special DMAP procedures.

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1.0 INTRODUCTION

Response Spectrum Analysis (ie., RSA) represents a popular approach to the evaluation of the dynamic response of structures subjected to base-motion excitation. MSC/NASTRAN, the widely-used finite-element program (1), offers the RSA-capability as part of its SOLUTION 63 and bases it on the Large-Mass concept. From the standpoint of the average user, the SOL-63 implementation is circumscribed by certain disadvantages as outlined below:-

(a) SOL-63, a solution sequence couched in terms of superelement and data-base logic, is less conventional and friendly than SOL-3, a Rigid Format.

(b) Even before launching on a mode-extraction analysis, the user needs to decide if RSA would be a requirement. This decision has a tangible bearing on the modelling details.

(c) If RSA is required, the model has to be augmented with certain fictitious items, viz, an RBE-type rigid element that reduces the base to a single grid-point, CMASS2-type large masses to be placed at the excited degrees of freedom and SUPORT-type restraints replacing SPC's at the excited DOF's.

(d) On the EIGR card, the MASS option becomes mandatory for eigenvector normalization.

(e) The artificial zero-frequency modes mandated by the large masses are an inconvenience. And there is the real danger of eigensolution inaccuracy if the GIV or MGIV method is employed with large masses.

(f) Replacing SPC with SUPORT leads to incorrect output for SPCFORCE reactions.

(g) SOL-63, if un-ALTERed, does not provide for the use of uniform mass damping or strain-energy-weighted Composite Damping in response computation. Nor does it output individual modal contributions to the total response. Again, SOL-63 needs an ALTER for sorting element output on the basis of magnitude.

(h) The calculation of modal parameters like participation factors, effective masses and damping factors (which are useful criteria for assessing the relative importance of modes) is unnecessarily tied to the mechanics of setting up the RSA model.

There exists, therefore, the need for an alternative set-up that would obviate the aforesaid difficulties and reduce RSA to a simple post-processing operation on the results of the traditional SOL-3 mode extraction. The present work aims to fulfill this need and thereby make MSC/NASTRAN mirror the RSA implementation of other systems like STARDYNE (2). The work presents a system named CONSPEC, consisting of two programs called CONMAIN and CONLOAD. These are written in the DMAP language of NASTRAN (3,4) and are founded on the Relative-Motion approach rather than the Large-Mass concept. Like SOL-63, CONSPEC deals only with the case of uniform motion of the base points. CONSPEC is fully documented in Reference (5).

2.0 ANALYSIS STEPS

Response Spectrum Analysis via CONSPEC is conveniently carried out in three steps as outlined below and shown in Figure 1.

2.1 STEP-A : MODE EXTRACTION

This is a conventional eigensolution run via SOL-3. The run should be Checkpointed. MPC's, SPC's and, if meaningful, SUPORT's are employed as usual. Displacement Co-ordinate Systems are assigned to grid-points as desired. In particular, the Displacement Systems associated with SPC'ed grid-points may be different from (a) one another, (b) the Basic System and (c) the System associated with the Ground Excitation that may be applied in Step-B and Step-C. No fictitious model augmentation is introduced just for the sake of RSA. As noted in Section 6.4, there is a restriction on the use of scalar points (SPOINT) in the model. The degrees of freedom at which the structure is joined to the implied Ground are placed on SPC cards. As noted in Section 3.0, certain G-set damping matrices may be generated in this step, if so desired. Coupled Mass and Generalized Dynamic Reduction are fully valid options. Eigenvectors may be normalized via any of the three methods, viz., MAX, MASS and POINT. In effect, there is little that is special about this step.

2.2 STEP-B : MAIN RESPONSE-SPECTRUM ANALYSIS

In this step, a Restart is performed from SOL-3 of Step-A into the DMAP program CONMAIN. The Restart is initiated with the OPTP and Checkpoint Dictionary of Step-A.

Damping may be changed or newly introduced as discussed in Section 3.0. A single set of output requests is entered above the

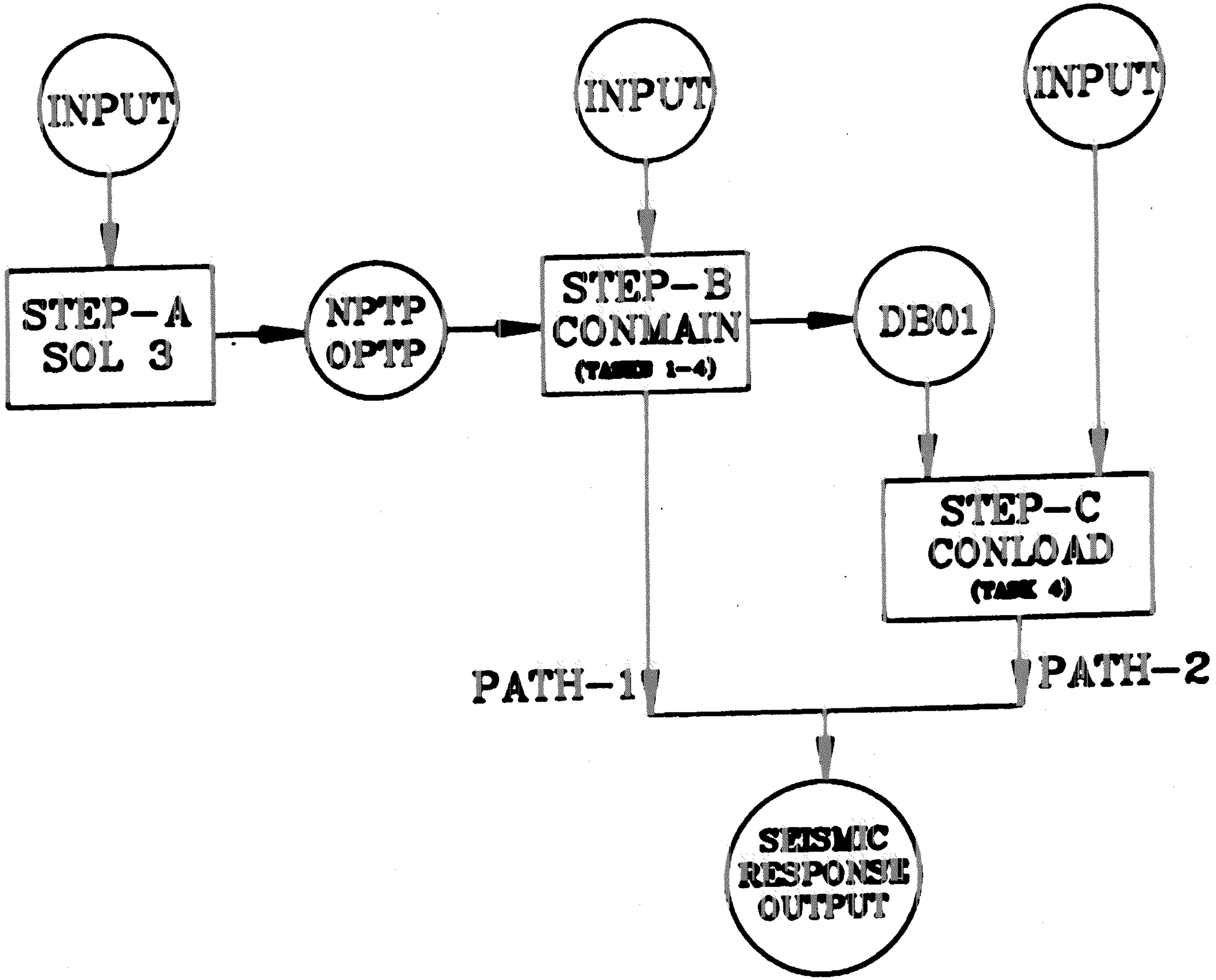


FIGURE 1 : CONSPEC ANALYSIS FLOW

Subcase-level so that it would govern both the normalized eigensolution and the seismic response. Seismic spectra are specified, the base is identified, modes are selected for response calculations and summation rules are defined.

Step-B carries out a sequence of FOUR Tasks as follows:-

Task-1: Process damping data.

Task-2: Calculate normalized values for a Master Set of node-and-element output variables, based on a selected set of eigenvectors and a set of above-Subcase case-control output requests.

Task-3: Compute the modal parameters of Section 4.0, using the selected modes and a specified Ground grid-point.

Task-4: Perform a complete Response Spectrum Analysis for a set of Subcases that define (a) Loads and/or (b) Modal Summation Rules.

The results of all but Task-4 are written to the Data-Base file DB01, for a possible restart in Step-C. The user decides which of these Tasks are to be performed in a given run and controls his input accordingly. Many independent executions of Step-B may be made using the same OPTP.

The compiled DMAP sequence of CONMAIN is listed in Appendix A.

2.3 STEP-C : DATA-BASE RESTART FOR NEW SUBCASES

This step is purely optional and represents a continuation of Step-B. It restarts from the Data-Base file DB01 created in Step-B and executes the DMAP program called CONLOAD. The latter is essentially a small subset of CONMAIN used in Step-B.

Step-C isolates Task-4 described under Step-B and executes it for additional new Subcases defining (a) new Excitation Spectra (b) new Modal Summation Rules and/or (c) altered Output Requests. There are two conditions attached to Step-C. The damping, mode-selection and modal parameters occurring in Step-B hold good in Step-C and cannot be changed. Also, a physical-response variable for which output is sought in Step-C must have already appeared in the Master Set of Step-B. Should the above conditions not be applicable in a given situation, the user may simply resort to a new Step-B execution. Conversely, when the conditions are satisfied, the user is free to perform under Step-B only its first three Tasks and then switch to one or more executions of Step-C for Task-4 processing of all of his Subcases.

The compiled DMAP sequence of CONLOAD is listed in Reference 5.

3.0 DAMPING REPRESENTATION

CONSPEC not only admits all the forms of damping catered to by SOL-63, but also provides for additional types. The full range of damping representation available in CONSPEC is summarized below. It may be noted that RSA is predicated on the implicit assumption that modal damping is uncoupled. The matrix suffixes used in the following echo those in section 1.6 of Reference (3).

3.1 TYPE (1) : ORDINARY MODAL DAMPING

The modal damping matrix $\underset{\sim}{C}$ is diagonal in this case, with the r^{th} diagonal given by,

$$c^r = 2 \zeta^r \omega^r m^r$$

where, ζ^r is the Damping Factor of the r^{th} mode as specified on SDAMP/TABDMP1 cards and m^r and ω^r are the Generalized Mass and Circular Frequency respectively.

3.2 TYPE (2) : RAYLEIGH DAMPING

The damping matrix B is assumed to be given by,

$$\underset{\sim}{B} = (G / W3) \underset{\sim}{K} + ((GMASS) \times (W3MASS)) \underset{\sim}{M}$$

where $\underset{\sim}{K}$ and $\underset{\sim}{M}$ are the stiffness and mass matrices respectively. The resulting modal damping matrix $\underset{\sim}{C}$ is diagonal, with $\underset{\sim}{C}$ defined as shown in Section 3.3.

G, W3, GMASS and W3MASS are scalar parameters specified on PARAM cards. They are discussed in Section 5.0.

This form leads to the following modal Damping Factor:-

$$\zeta^r = 1/2 \, ((G / W3) \times \omega^r + (GMASS \times W3MASS) / \omega^r)$$

ω^r is the circular frequency of the r^{th} mode.

3.3 TYPE (3) : COMPOSITE MODAL MATERIAL DAMPING

This form is specified via the following:-

```
'GE' entry on MATi cards
PARAM, W4, 1.0     card
PARAM, NOBCOM, 1   card
```

The resulting modal Damping Factor is given by

$$\zeta^r = 1/2\ c^r / (\ m^r \times \omega^r \times \omega^r\ )$$

where

m^r: Generalized Mass of r^{th} mode

ω^r: Circular Frequency of r^{th} mode

c^r: the r^{th} diagonal of matrix $\underset{\sim}{C}$

$$\underset{\sim}{C} = \underset{\sim}{Z}^T \underset{\sim}{B} \underset{\sim}{Z}$$

$$\underset{\sim}{B} = \underset{\sim}{K}^{4gg}$$

$\underset{\sim}{K}^{4gg}$: Damping Matrix based on MATi cards

$\underset{\sim}{Z}$: Modal Matrix

The parameters W4 and NOBCOM are discussed in Section 5.0.

To emphasize that this composite damping is derived by weighting element damping by the fraction of modal strain energy carried by the element, we may also express ζ^r in the following alternative form:-

$$\zeta^r = \frac{1}{2} \left(\sum_i g_i E_i^r \right) / \left(\sum_i E_i^r \right)$$

where

E_i^r : Strain Energy of the i^{th} element in the r^{th} mode.

3.4 TYPE (4) : ORDINARY MATERIAL DAMPING

This form is specified via the 'GE' entry on MATi material cards, scaled by a factor W4 entered on a PARAM card. It leads to a modal Damping Factor given by

$$\zeta^r = 1/2\ c^r / (\ m^r \times \omega^r\ )$$

where the symbols have the same meaning as in Type (3), except that matrix B is now given by,

$$\underset{\sim}{B} = \underset{\sim}{K}^{4gg} / W4$$

3.5 TYPE (5) : G-SET VISCOUS DAMPING

This type is specified via the following cards:-

CVISC, CDAMPi cards (yielding $\underset{\sim}{B}^{1gg}$ matrix)
B2GG on DMIG cards (yielding $\underset{\sim}{B}^{2gg}$ matrix)
PARAM, W4BGG card

The resulting modal Damping Factor is of the form shown under Type (4), except that matrix $\underset{\sim}{B}$ is now given by,

$$\underset{\sim}{B} = (W4BGG) \times (\underset{\sim}{B}^{1gg} + \underset{\sim}{B}^{2gg})$$

The W4BGG parameter is discussed in Section 5.0.

3.6 TYPE (6) : P-SET VISCOUS DAMPING

This type is specified as B2PP on DMIG cards, setting up a matrix $\underset{\sim}{B}^{2pp}$.

The resulting modal Damping Factor is again as shown under Type (4), except that matrix $\underset{\sim}{B}$ is now given by,

$$\underset{\sim}{B} = \underset{\sim}{B}^{2pp}$$

3.7 ADDITIONAL REMARKS ON DAMPING

Though so many different forms of damping are permitted, the user assumes the responsibility for avoiding duplication. All except Type (3) are additive when applied simultaneously. Type (3) cannot be combined with the others. Types (1), (2) and (6) can be introduced only in Step-B of the analysis.

Damping Types (3) and (4) are based on MATi material cards which are crucial to the definition of the finite-element model in Step-A itself. In view of this, CONSPEC provides for ample flexibility in regard to the stage at which damping of Types (3) and (4) may be specified. The user may specify 'GE' on MATi cards in Step-A and the resulting $\underset{\sim}{K}^{4gg}$ may be either used or discarded in Step-B at will. In another scheme, the $\underset{\sim}{K}^{4gg}$ of Step-A, <u>if any</u>, may be replaced by a new $\underset{\sim}{K}^{4gg}$ to be created in Step-B based on a revised set of MATi cards. The parameters NEWK4GG and W4 control these choices. If the MATi cards are revised in Step-B, the revision affects only material damping. Stiffness, mass, frequencies, modes and other damping are all left unaffected.

Damping Type (5) may be specified either in Step-A or Step-B. If specified in Step-A, the resulting $\mathbf{B}$-matrix may be either used or discarded in Step-B at will. In another scheme, the $\mathbf{B}$-matrix of Step-A, <u>if any</u>, may be replaced by a new $\mathbf{B}$-matrix to be created in Step-B based on a revised set of CVISC, CDAMPi and B2GG-DMIG cards. The parameters NEWBGG and W4BGG control these choices. It should be noted that $\mathbf{B}^{1gg}$ and $\mathbf{B}^{2gg}$ are considered as an integral unit for the purpose of specification, creation and manipulation. It is recommended that Type (5) damping, if required, be introduced in Step-B. In the normal course, $\mathbf{B}^{2gg}$ and $\mathbf{B}^{2pp}$ serve the same purpose and only one or the other need be employed.

While defining damping in Step-B, the user should ensure that <u>no new grid or scalar point</u> is introduced into the model.

In damping Types (4), (5) and (6), the off-diagonal terms of matrix $\mathbf{C}$ are <u>arbitrarily discarded</u> so as to suit response-spectrum analysis. In Type-(3), the off-diagonals of $\mathbf{C}$ are discarded based on a heuristic energy-related reasoning. Types (1) and (3) are the most popular forms of damping in response-spectrum calculations.

CONSPEC follows standard practice in that it ignores the contribution, if any, of damping to the effective load-vector on the right-hand side of the equations of motion. That is, Mass Participation Factors are not supplemented by any Damping Participation Factors.

4.0 <u>COMPUTED MODAL PARAMETERS</u>

An intermediate phase in CONMAIN deals with the computation of certain modal parameters. These parameters are defined below.

Let $\mathbf{M}$ be the mass matrix of size g x g. Let $\mathbf{Z}$ be the modal matrix of size g x h, where h is the number of modes for which the modal parameters are desired.

Let $\mathbf{H}$ be the h x h diagonal matrix of generalized masses, given by,

$$\mathbf{H} = \mathbf{Z}^T \mathbf{M} \mathbf{Z}$$

Let $\mathbf{D}$ be the g x 6 matrix of rigid-body motions of the structure referred to unit motions in the six degrees of freedom of a single grid-point representing the ground.

The h x 6 matrix $\underset{\sim}{Q}$ of Participation Factors is given by,

$$\underset{\sim}{Q} = \underset{\sim}{H}^{-1} (\underset{\sim}{Z}^{T} \underset{\sim}{M} \underset{\sim}{D})$$

The h x 6 matrix $\underset{\sim}{R}$ of Effective Modal Masses is given by,

$$\underset{\sim}{R} = \underset{\sim}{H} (\underset{\sim}{Q} * \underset{\sim}{Q}),$$

where '*' indicates term-by-term scalar multiplication.

If the $\underset{\sim}{D}$-matrix represents stress-free motion, it follows that the strain energy of the structure due to $\underset{\sim}{D}$ is zero. CONMAIN computes the 6 x 6 strain-energy matrix $\underset{\sim}{U}$ defined by,

$$\underset{\sim}{U} = \underset{\sim}{D}^{T} \underset{\sim}{K} \underset{\sim}{D},$$

where $\underset{\sim}{K}$ is the g x g stiffness matrix of the structure. This should normally be a (null) matrix of computational zero's. The program proceeds further regardless of the merits of $\underset{\sim}{U}$. The user is required to judge $\underset{\sim}{U}$ for himself.

In assessing whether all the important modes have been included in response evaluation, some analysts find it useful to employ a heuristic matrix-measure $\underset{\sim}{Y}$ (of size g x 6) defined by:-

$$\underset{\sim}{V} = \underset{\sim}{Z} \underset{\sim}{Q}$$

$$\underset{\sim}{Y} = \underset{\sim}{V} : \underset{\sim}{D}$$

where ':' indicates term-by-term scalar division. $\underset{\sim}{Y}$ may be loosely termed the mode-truncation-effectiveness matrix. The user compares the translational components of $\underset{\sim}{Y}$ with unity as a check on mode-truncation. CONSPEC computes $\underset{\sim}{Y}$ at user's option.

If any of the damping mechanisms of Section 3.0 are present, CONMAIN computes the resulting modal Damping Factors, ζ^{n}, for the selected modes.

5.0 INPUT PARAMETERS ON PARAM CARDS

In employing CONSPEC, the user may need to input certain real or integer parameters on PARAM cards. The meaning of these parameters is summarized herein. It is assumed that the user refrains from entering these parameters in Step-A, inasmuch as they are relevant only in Step-B and/or Step-C. Some of the parameters are borrowed from Standard MSC/NASTRAN, while others are special to CONSPEC. Unless explicitly stated otherwise, the parameters to be discussed here may be input only in the Bulk Data deck. The Tasks to which the parameters are pertinent are identified within parentheses.

(i) OPTION, CLOSE (Task-4)

These parameters control modal summation and are discussed in Reference (1). They are input in Step-B and/or Step-C and can be changed between the Steps. They may be entered in either Bulk Data or Case Control. In Case Control, they may be changed from one Subcase to another.

(ii) GROUND, NEWGRID (Task-3)

These parameters are optional and serve to identify a chosen grid-point as the base to be excited. They are explained in Section 6.0. They are input in Step-B.

(iii) HFREQ, LFREQ, LMODES (Tasks 2, 3, 4)

These parameters, together with the optional OFREQ case-control card, specify the selection of modes for response calculation. They are discussed in Reference (1). They are entered in Step-B.

(iv) G, W3, GMASS, W3MASS (Task-1)

These parameters are used in the specification of damping Type (2), i.e., Rayleigh Damping. G and W3 control uniform stiffness damping. They are discussed in Reference (3). The default value of W3 is 0.0, implying the absence of stiffness damping. GMASS and W3MASS are special to CONSPEC and they control uniform mass damping.These two parameters are real numbers and carry the default value of zero. The only purpose in specifying them as two separate parameters entering a simple product is to render GMASS dimensionless and to make mass damping look akin to stiffness damping. The four parameters of Rayleigh Damping are entered in Step-B of the analysis.

(v) NOBCOM, W4 (Task-1)

These two parameters deal with element material damping as it enters Types (3) and (4) of Section 3.0. W4 is discussed in Section 1.6 of Reference 3. NOBCOM is an integer parameter introduced in CONSPEC. The two parameters are entered in Step-B. The following are the valid options:-

(a) NOBCOM = -1 (default)
W4 = 0.0 (default)

This means that damping of Types (3) and (4) is treated as non-existent, even if the MATi cards had non-zero 'GE' entries.

(b) NOBCOM = 1
W4 = 1.0

This means that MATi damping would be treated as Type-(3), i.e., as composite modal damping.

(c) NOBCOM = -1 (default)
W4 ≠ 0.0, positive real number.

This means that MATi damping is treated as Type-(4) damping.

(vi) NEWK4GG (Task-1)

This parameter controls damping Types (3) and (4). It assumes one of two values, viz., - 1 (default) and 1. The default implies that the MATi cards of Step-A carry the correct 'GE' entries and that therefore their damping contribution, if any, need not be recomputed in Step-B. A value of '1' means that the 'GE' entries on MATi cards of Step-A are replaced by those of Step-B and that therefore MATi damping should be recomputed. This parameter is entered in Step-B. It is simply for convenience and efficiency in the context where the user wants to introduce or modify MATi damping in Step-B at will, without having perforce to go back to Step-A. Parameters NOBCOM and W4 are relevant regardless of the value of NEWK4GG.

(vii) W4BGG (Task-1)

This is a real parameter that may be entered in Step-B. It is a scale factor on Type-(5) damping, with a default value of 0.0. The default value deactivates Type-(5) damping for response analysis, regardless of whether the damping has been created in Step-A or Step-B. Thus, W4BGG plays essentially the same role in Type-(5) damping that W4 plays in Types (3) and (4).

(viii) NEWBGG (Task-1)

This integer parameter functions in the same way as NEWK4GG discussed above, except that it controls Type-(5) damping instead of Types (3) and (4).

(ix) NOIMR (Task-4)

This parameter assumes one of two values, viz., - 1 (default) and 1. The former indicates that the individual contributions of the selected modes to the total physical responses are not required as an output. A value of '1' implies that, in addition to the total responses, the individual modal contributions should also be computed separately and printed. This parameter is entered in Step-B and/or Step-C and can be changed between the two Steps. It may be input in either Bulk Data or Case Control. In Case Control, it may be changed from one Subcase to another.

(x) PRTDRUG (Task-3)

This optional parameter assumes one of two values, viz., - 1 (default) and 1. It is entered in Step-B. The default value means that the pseudo-static matrix $\underset{\sim}{D}$ of Section 4.0 (size g x 6) will not be printed. A value of '1' helps print $\underset{\sim}{D}$.

(xi) PREIGED, PREIGES (Task-4)

These integer parameters are optional and control the printing of the master set of normalized eigensolution output data-blocks created in Task-2 of Step-B and stored on DB01. They may be entered in Step-B and/or Step-C. Both have the default value of - 1, which means that the eigensolution output are not printed by CONSPEC. If PREIGED = 1, the eigensolution Displacements and SPCFORCES are printed. If PREIGES = 1, the eigensolution ELFORCES and ELSTRESSES are printed. These data must have been created in Step-B with case-control requests.

(xii) OLDF, OLDS, NEWF, NEWS, NUMF, NUMS, BIGEF, BIGES (Task-4)

These eight parameters govern the generation and printing of sorted/filtered output for ELFORCE and ELSTRESS requests. They are explained in Section 10.0. They may be entered in Step-B and/or Step-C.

(xiii) PHICARE, PHIFILT

These parameters are optional and entered in Step-B. They govern the evaluation and printing of the mode-truncation- effectiveness matrix $\underset{\sim}{Y}$ of Section 4.0.

The integer parameter PHICARE assumes one of two values, viz., -1 and 1. The former is the default and makes the program skip the computation and printing of $\underset{\sim}{Y}$. The value of '1' activates these operations.

PHIFILT is a positive real number with a default value of zero. Only those terms of $\underset{\sim}{Y}$ will be printed that are greater than or equal to PHIFILT. The user may, for example, specify a fraction approaching unity, say, 0.9.

6.0 IDENTIFICATION OF BASE

The base-excitation is visualized as acting at a single grid-point, called GROUND, representing the entire base. This grid-point serves only two purposes. First, the directions of the displacement components at GROUND identify the directions of the base-excitation components. Secondly, if rotational excitation is present, GROUND serves as the reference point about which the rotation is presumed to occur, i.e., the centre of rotation. GROUND may or may not be a part of the actual elastic structure modelled in Step-A. And, no artificial element-connectivity is needed at GROUND. The user specifies GROUND in Step-B of the analysis, using one of the options stated below.

6.1 OPTION-(i) : DEFAULT GROUND

In this option, the user accepts the program default, which identifies the Basic Origin as GROUND and the Basic Cartesian System as the System used to specify the components of Ground Excitation. Rotational excitation, if present, occurs about the Basic Axes through the Basic Origin. No user-input is needed for this option.

6.2 OPTION-(ii) : EXISTING GRID-POINT

Here, the user chooses a convenient grid-point G1 from the structure of Step-A as the GROUND. He enters the following bulk-data cards:-

```
PARAM, GROUND, G1
USET, U1, G1, 123456
```

In the above, the only variable is G1, which is the ID of an existing grid-point chosen by the user. All the other items on the above two cards must be entered as shown. The Displacement System at G1 defines the System for Ground Excitation.

6.3 OPTION-(iii) : NEW GRID-POINT

This is the most general of the available options. The user chooses to add a new grid-point G1 to the model and identifies that as the GROUND. He accomplishes this objective with the following bulk-data cards:-

```
PARAM, GROUND, G1
USET, U1, G1, 123456
PARAM, NEWGRID, 1
GRID, G1, CP, X1, X2, X3, CD
CORDij, CP, ... etc. (optional)
CORDij, CD, ... etc. (optional)
(Example of CORDij : CORD2R)
```

In the above, G1 is the ID of a new grid-point. G1 is located by the standard GRID card. CP and CD are identifiers of co-ordinate systems, which may be defined, if necessary, with new CORDij cards. CD should be the co-ordinate system associated with the Ground Excitation. The NEWGRID parameter, with a value of '1' signals to the program that a new grid-point is being added in Step-B. It should be noted that this is the only context in which a new grid-point may be entered into CONSPEC.

6.4 AN IMPLIED LIMITATION ON SCALAR POINTS

The pseudo-static $\underset{\sim}{D}$-matrix of Section 4.0 is basically created from the geometric locations of the grid-points of the Step-A model, relative to the GROUND. The effect of MPC's is also additionally accounted for. But, unlike in SOL-63, no stiffness properties are utilized. This procedure introduces a limitation on the use of SPOINT's in the Step-A model, because SPOINT's have no physical location.

The limitation is stated as follows:-

> "If an SPOINT has associated non-zero mass in the G-set mass matrix, then it must also be a degree of freedom that is either SPC'ed or rendered dependent on grid-point degrees of freedom via one or more MPC equations."

SPOINT's that have no G-set mass terms do not affect the Mass Participation matrix $\underset{\sim}{Q}$ of Section 4.0. Hence, there is no limitation on their use, though they do, in principle, render the $\underset{\sim}{D}$-matrix and the diagnostic $\underset{\sim}{U}$ and $\underset{\sim}{Y}$ matrices partially inaccurate. The SPOINT's introduced in Generalized Dynamic Reduction are free of limitation because they are associated only with zero terms in both the G-set stiffness matrix and the G-set mass matrix.

In practice, the above limitation is no more than a minor inconvenience. Many real-life models have no need at all for SPOINT's, except in the aforesaid context of Dynamic Reduction.

In most instances, SPOINT's can be replaced by grid-point degrees of freedom in the model-definition phase. It should also be noted that few finite-element programs accommodate the special concept of SPOINT's. NASTRAN is perhaps the only exception.

7.0 SPECIFICATION OF BASE-EXCITATION SPECTRA

The shock loading at the base is specified in terms of Response Spectra. CONSPEC expects that there are six excitations, one for each degree of freedom at the point 'GROUND' that implicitly represents the entire base. Loading input is valid both in Step-B and in Step-C.

A load Case is defined in the Bulk Data by a set of three card-types, viz., DLOAD, DTI-SPECSEL and TABLED1. These cards are explained in Reference (1). The card formats are symbolically stated below in free-format:-

```
DLOAD, SID, S, S1, L1, S2, L2, S3, L3, +DL1
+DL1, S4, L4, S5, L5, S6, L6
etc. etc. (additional DLOAD cards with different SID's)

DTI, SPECSEL, RECNO,, TYPE, TID1, ZETA1, TID2, ZETA2, +SP1
+SP1, TID3, ZETA3, ...etc.
etc. etc. (additional cards with different RECNO's)

TABLED1, TID1,,,,,,,,+TB1
+TB1, X1, Y1, X2, Y2, X3, Y3, X4, Y4, +TB2
+TB2, X5, Y5, etc., etc., ENDT
etc. etc. (additional cards with different TID's)
```

Each DLOAD card defines a Load Case, with a set-ID of SID. A Load Case specifies an overall Scale Factor 'S' and <u>six</u> (SI, LI) pairs corresponding to the six excitations. L1 is the RECNO of the Spectra Record to be applied as excitation at displacement component '1' of the base. (The components are ordered from 1 to 6.) S1 is the individual Scale Factor (i.e., multiplier) to be applied to the amplitudes defined by the Curves of L1. Even when there is no excitation in a certain displacement component, the associated (SI, LI) must still be entered, with SI=0.0 and LI any available Spectra Record.

Once various Load Cases have been defined in the Bulk Data, they may be selected in the Case Control via the DLOAD = SID specification. Also, by means of the Subcase structure in Case Control, many Load Cases may be solved for in one execution of Step-B or one execution of Step-C.

8.0 MODAL SUMMATION RULES

Parameters OPTION and CLOSE of Section 5.0 govern directional and modal summation and are fully explained in Reference (1). These parameters together with the NOIMR parameter introduced in this work would, for convenience, be collectively called the Modal Summation Rules. The Summation Rules are processed at the stage when Load Cases are processed. The former may be varied via both the Subcase structure in Case Control and the Step-C restart, in the same way as the latter.

9.0 OUTPUT REQUESTS

Some of the output data from the three-step analysis are automatically printed, while others are generated/printed based on user request. This section summarizes the latter.

The output requests in Step-A follow standard practice in SOL-3. They have no impact on CONSPEC, except that only those frequencies and A-set eigenvectors that are determined in Step-A (READ module) are available for response calculations in the succeeding steps.

In Step-B, one set of SORT1 output requests, known as the Master Set, is placed above the Subcase level. The items that may be requested are:- DISPLACEMENT, VELOCITY, ACCELERATION, SPCFORCE, ELFORCE, and ELSTRESS. All except Velocity and Acceleration apply to the Normalized Eigensolution as well as the Dynamic Responses under all of the Subcases. Velocity and Acceleration requests apply only to the Dynamic Responses. The printing of the Normalized Eigensolution output is controlled by the PREIGED and PREIGES parameters. The standard Dynamic Responses are of the Summed-Mode kind, with ELFORCE and ELSTRESS output presented in order of increasing element numbers. However, Individual-Mode Responses may be generated and printed by the use of the parameter NOIMR. Further, ELFORCE and ELSTRESS output in the Summed-Mode Response cases may be sorted/filtered on the basis of magnitude by the use of the options discussed in Section 10.0. The user may request printing of matrices $\underline{D}$ and $\underline{Y}$ of Section 4.0 by exercising the parameters PRTDRUG, PHICARE and PHIFILT of Section 5.0.

Step-C output requests are similar to the Step-B requests described above, with some exceptions to be stated here. The output requests in Step-C may be placed above the Subcase level or within Subcases. If within Subcases, they may be varied from one Subcase to the next. However, as noted in Section 2.3, the Step-C requests may not call for output items that were not already part of the above-Subcase Master Set of Step-B. For instance, if the ELFORCE of element 32 is required in Step-C, it must also have been requested in Step-B.

Ply-stresses in laminated composite shell elements are not, at present, available as output.

10.0 SORTING/FILTERING OF ELEMENT-RESPONSE OUTPUT

CONSPEC provides the user with the option of obtaining element-response output, viz., ELFORCE and ELSTRESS, in a sorted/filtered form. The standard unsorted form orders element output by element number. In the sorted form, element output is ordered by the descending magnitude of a response quantity. Both forms may requested in a given instance.

There are eight parameters and one DTI-table that may be specified in implementing element-output sorting. The sorting option is available in Step-B and/or Step-C. The DTI-table may appear only in the bulk-data. The parameters may be entered in the bulk-data or under case-control Subcases. The names of parameters associated with ELFORCE end with the letter 'F' and those related to ELSTRESS end with the letter 'S'. The sorting option is considered expensive for large amounts of data. ELFORCE/ELSTRESS requests must be present in case-control to provide the output data for sorting. Filtering, with or without sorting, is available as an option, so that printout may be obtained only for elements sustaining stresses (or forces) above a specified value. CONSPEC allows sorting/filtering only for summed-mode responses and not for individual-mode responses or normalized eigensolution data. The sorting/filtering takes place independently for each element-type in the model.

Parameters OLDF and OLDS control the printing of the standard unsorted form. The default value of zero prints the unsorted form, whereas a value of '-1' would suppress printing.

Parameters NEWF and NEWS control the generation and printing of the new sorted/filtered form. The default value of '-1' bypasses sorting/filtering. A value of '1' would generate and print the sorted/filtered form.

Parameters NUMF and BIGEF have the default values of '-2' and 0.0 respectively. They have the following meaning in the sorting/filtering process:-

(a) If NUMF = -2, all elements with ELFORCE $\geq$ BIGEF are printed. Thus BIGEF acts as a filter and no sorting by magnitude takes place.

(b) If NUMF = -1, sorting by magnitude occurs and all elements with ELFORCE $\geq$ BIGEF are printed in the sorted order.

(c) If NUMF = N, a positive integer, N elements at the top of the sorted order for each element-type are printed. BIGEF is irrelevant in this case.

Parameters NUMS and BIGES control ELSTRESS output in the same way as NUMF and BIGEF control ELFORCE output.

As stated above, sorting orders the element output, on the basis of the descending magnitude of a response-quantity serving as the key. There is a default key associated with each element-type in the NASTRAN element library. However, the user may change the key by entering the DTI-SORTKEY input-table in the bulk-data. The first record of the DTI-SORTKEY table specifies ELSTRESS sort-keys and the second record ELFORCE sort-keys.

11.0 SUMMARY OF INPUT DATA

A summary of the input data for each of the three steps of analysis is presented in this section. It is self-evident that Task-4 of CONSPEC may be executed only if Tasks 1-3 have been completed in Step-B.

11.1 STEP-A INPUT DATA

Step-A is a standard SOL-3 run. Hence the usual input data are applicable. Special input items are highlighted below.

(i) Executive Control
CHKPNT YES

(ii) Case Control
B2GG Damping may be selected.

(iii) Bulk Data
Some forms of damping may optionally be introduced as noted in Section 3.0. The EIGR card should generate at least as many frequencies and modes as would be needed in the response analysis.

(iv) Job Control
NPTP and Checkpoint Dictionary are saved for subsequent Restart in Step-B.

11.2 Step-B INPUT DATA

Step-B is a Restart from SOL-3 of Step-A into the CONMAIN DMAP program. The input structure is outlined below.

(i) Executive Control

CONMAIN DMAP sequence (plus REENTER card)

Restart Dictionary from Step-A

(ii) Case Control

Eigensolution/Response Output Requests, if any (Tasks 2, 4)

OFREQ Mode Selection, if any (Tasks 2, 3)

B2GG, B2PP Damping Selection, if any (Task-1)

SDAMP Damping Selection, if any (Task-1)

DLOAD Load Selections, if any (Task-4)

PARAM cards of Modal Summation Rule, if any (Task-4)

PARAM cards of element-output sorting, if any (Task-4)

All of the above except the DLOAD and PARAM cards must appear above the Subcase-level. The Output Requests are explained in Section 9.0. Subcases may be defined for various DLOAD selections and PARAM specifications.

(iii) Bulk Data

PARAM cards to define the parameters of Section 5.0.

Ground identification cards, if any (Section 6.0; Task-3).

Different forms of damping may be entered as noted in Section 3.0 (Task-1).

DLOAD cards, if any, to specify Multipliers and Record Numbers for Input Shock Spectra (Task-4).

DTI, SPECSEL cards, if any, to identify Spectra Records (Task-4).

TABLED1 cards, if any, to specify Spectra Curves (Task-4).

DTI, SORTKEY cards, if any, to specify sort-keys for element-output sorting (Section 10.0; Task-4)

(iv) Job Control

OPTP and Restart Dictionary are retrieved from Step-A. Data-Base DB01 is optionally saved for possible continuation into Step-C.

11.3 STEP-C INPUT DATA

Step-C represents a continuation of Step-B and executes only Task-4 via the CONLOAD auxiliary program. The input structure is outlined below.

(i) Executive Control

CONLOAD DMAP sequence

(ii) Case Control

Response Output Requests

DLOAD Load Selections

PARAM cards of Modal Summation Rule, if any.

PARAM cards of element-output sorting, if any.

The above may be grouped under various Subcases as desired. However, Output Requests may not exceed the ambit of the Master Set of Step-B, as explained in Section 9.0.

(iii) Bulk Data

PARAM cards of Modal Summation Rule, if any.

PARAM cards of element-output sorting, if any.

DLOAD cards.

DTI, SPECSEL cards.

TABLED1 cards.

DTI, SORTKEY cards, if any, for element-output sorting.

The above bulk data must be complete in the current deck, with no inferred association with similiar cards of Step-B.

(iv) Job Control

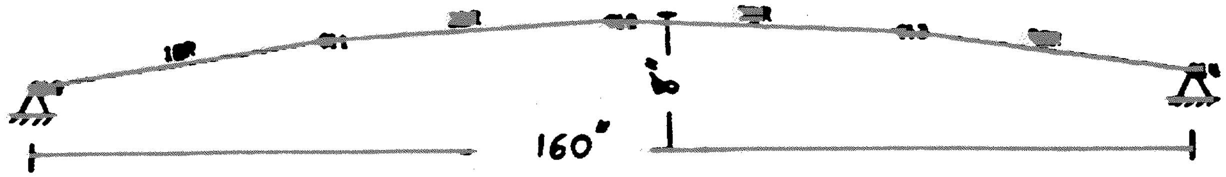
The Data-Base file DB01 must be retrieved from Step-B.

12.0 ILLUSTRATIVE ANALYSIS

A simple, parabolic arch lying in the XY-plane is taken as the basic structure to be analyzed (Figure 2). It is pinned to ground at both ends and subjected to base accelerations along X and Y. The model consists of 5 GRID-points and 4 BAR elements. Damping is taken to be of Type (3). The response analysis considers the first three modes, the natural frequencies of the latter being 11.7 Hz., 24.7 Hz. and 66.9 Hz. These modes essentially represent transverse bending only. Appendix B presents three input decks illustrating the three Steps (A, B and C) of the analysis. The example simply serves to highlight the features of CONSPEC. It does not necessarily portray a realistic situation. The following remarks supplement the comments in the decks.

12.1 DECK-1 : MODE EXTRACTION IN STEP-A

This is a Step-A SOL-3 run for mode extraction. The MATi cards happen to include material damping coefficients. The pinned-end boundary conditions are specified with the usual SPC cards (and not as SUPORT). The default lumped-mass option is accepted. For mode extraction, Generalized Dynamic Reduction is employed with six generalized co-ordinates. The MGIV method is chosen for eigensolution, along with MASS normalization. The latter is not mandatory. Four modes are determined. The OPTP and Dictionary are saved.



$A = 0.785 \text{ in.}^2$

$I_1 = 0.049 \text{ in.}^4$

$I_2 = 0.049 \text{ in.}^4$

$J = 0.098 \text{ in.}^4$

$E = 10. \times 10^6 \text{ psi}$

$\nu = 0.3$

$\rho = 2.6 \times 10^{-4} \text{ lb} - \text{sec}^2/\text{in.}^4$

FIGURE 2 : SHALLOW ARCH EXAMPLE

12.2 DECK-2 : SEISMIC RESPONSE IN STEP-B

This is a STEP-B CONMAIN run for the seismic response of the arch under X- and Y- accelerations of the base applied simultaneously as one Subcase. Type-3 material damping is employed. However, as an option, the K4GG of OPTP is discarded and a new material-damping matrix is created based on new MAT1 cards. The latter bear revised GE-entries and explicitly replace the MAT1 cards of OPTP. Revising the MAT1 cards has the sole effect of regenerating damping matrices, with no side-effect on the modes and frequencies already determined. (A similar procedure is applicable to TYPE-4 and TYPE-5 damping.)

A single group of output requests is entered above the Subcase level. This is all that Step-B allows. (There may, of course, be many Subcases for solution in Step-B.)

Deck-2 illustrates the mechanics of explicitly identifying the GROUND. Option-(iii) described in Section 6.3 is utilized. Thus, a new grid-point (ID = 99) is located and the GROUND Excitation Co-ordinate System is taken to be different from the Basic system.

Optional parameters are exercised to (a) print the pseudo-static D-matrix (b) compute and print the filtered terms of the Y-matrix (c) print normalized eigensolution output for nodes and elements and (d) compute and print the individual-mode contributions to total response.

As required, the DLOAD bulk-data card contains a multiplier for each of the six directions of excitation, though only two are non-zero. Y-excitation occurs via Record 6 calling on Tables 11 and 12. X-excitation occurs via Record 9 calling on Tables 13 and 14.

If no output requests exist in the case-control and no spectra-input is present, CONSPEC will simply execute Tasks 1 and 3 for the selected damping, modes and GROUND. Thus, the user may assess his modal parameters without performing a response analysis.

If spectra-input is withheld in Step-B, only Tasks 1, 2 and 3 are completed. The user may then conveniently enter all of his Subcases in Step-C for the execution of Task-4.

The Data-Base file DB01 may be saved for possible restarts into Step-C.

12.3 DECK 3 : SEISMIC RESPONSE IN STEP-C

This is a Step-C CONLOAD run for seismic response under two new excitation Subcases. A restart is initiated from the DB01 Data-Base file created in the Step-B run of Deck-2.

The deck illustrates the optional use of certain parameters in case-control rather than in bulk-data. Output requests are varied from one Subcase to the next. Sorting of ELFORCE and ELSTRESS output is exemplified in Subcase 2. The present choice of sorting parameters is such as to cause printing of both the unsorted and sorted forms of element output.

13.0 OUTPUT DETAILS

In this Section, we highlight the output items that are either printed automatically or printed at user's request. Output excerpts pertaining to the arch example of Section 12.0 are presented in the Tables of Appendix C.

13.1 OUTPUT OF STEP-A

Step-A being a straight-forward SOL-3 execution, there is nothing special about its output. Table-1 lists the SORT-ed echo of the bulk-data. Table-2 lists the G-set degrees of freedom and the natural frequencies of the arch. Table-3 consists of the mode shapes requested by the user.

13.2 SPECIAL INTERMEDIATE OUTPUT IN STEP-B

Some of the output in Step-B is special to Step-B and is discussed here. Output that is common to Step-B and Step-C is outlined in Section 13.3.

The SORT-ed echo of the bulk-data of Deck-2 is listed in Table-4. The echo reflects the current status of the <u>entire</u> bulk-data (including cards from OPTP and modifications).

Table-5 displays the modal damping matrix $\underset{\sim}{C}$ of Section 3.0, under the name BHH. The off-diagonal terms of $\underset{\sim}{C}$ would, of course, be ignored in response analysis.

Table-6 displays the pseudo-static $\underset{\sim}{D}$-matrix of Section 4.0, under the name DRUG. This output occurs only if PARAM,PRTDRUG is exercised. Table-7 prints matrix $\underset{\sim}{U}$ under the name RIGIDSE. The largest term in $\underset{\sim}{U}$ is listed under the name SUM. Table-8 presents the modal mass-participation factors under the name PSIT. PSIT is the transpose of $\underset{\sim}{Q}$. The effective modal masses appear as in Table-9 under the name MEFFT which is the transpose of $\underset{\sim}{R}$. Table-10 portrays the (filtered) mode-truncation-effectiveness matrix $\underset{\sim}{Y}$ under the name PHIQDF. The output of $\underset{\sim}{Y}$ is controlled by parameters PHICARE and PHIFILT. In the present instance, $\underset{\sim}{Y}$ reflects the contribution of only three modes.

13.3 SOLUTION OUTPUT IN STEP-B AND STEP-C

The main solution output resulting from Step-B and/or Step-C consists of nodal responses and element forces and stresses. Parenthetically, it may be noted that the SORT-ed echo of the bulk-data of Step-C does not include the cards of Step-A and Step-B. In this Section, solution output common to Step-B and Step-C is discussed.

If normalized eigensolution results are desired as output, the parameters PREIGED and PREIGES may be exercised. This output is of the standard form and not shown here.

Table-11 lists the frequencies and damping factors of the selected modes under the name XFN and XZETAH respectively. Table-12 presents, under the name UHVR (1), the normal-mode response-coefficients resulting from the combination of six base-excitation components. Table-13 displays excerpts of the physical responses obtained by summing the contributions of the selected modes. This Table embodies the final results of the analysis and is governed by case-control requests and parameter selections. If PARAM,NOIMR equals unity, the contribution of each mode to the summed (physical) response is printed as well, with an appropriate heading listing the mode sequence number (MODENUM), frequency and damping factor. This output is not shown here. The optional sorting of element-response output is illustrated in Table-14.

14.0 PROGRAM LIMITATIONS

There are some general limitations currently associated with CONSPEC, as outlined below:-

(a) Only uniform base-excitation is permitted. That is, the excitation spectra may not be different at different points on the base.

(b) Methods of directional and modal summation are limited to those described in Reference (1). For instance, the Double Sum and CQC techniques are not available.

(c) No facility exists for output-plotting.

(d) No simple means exists for combining the static and dynamic responses.

(e) Ply-stresses are not computed for laminated composite shell elements.

(f) There is a minor limitation on the use of Scalar Points, as noted in Section 6.4.

(g) Superelement definition is not available.

Of the above limitations, the first five are common to SOL-63 and CONSPEC.

15.0 CONCLUSION

CONSPEC offers an attractive alternative to SOL-63 for response-spectrum analysis. It retains considerable flexibility in model definition, analysis flow, damping representation, excitation specification and output requests. It provides in a standard form many useful options that a user of SOL-63 could realize only with significant DMAP-ALTER effort. The salient features of CONSPEC may be summarized as follows:-

(a) CONSPEC functions entirely within the purview of MSC/NASTRAN. Being a complete DMAP sequence rather than an ALTER packet, it is relatively immune to changes engendered by MSC/NASTRAN revisions.

(b) It uses SOL-3 (and not SOL-63) for mode extraction. It reduces Response-Spectrum Analysis to a post-processing operation on the output of SOL-3. The SOL-3 step is fairly routine and independent of whether it is to be followed by a response analysis.

(c) CONSPEC provides for six different representations of damping, including energy-weighted material damping. The user has considerable flexibility in introducing or revising damping.

(d) CONSPEC may also be employed for the sole purpose of calculating modal parameters useful in the assessment of modes. The user simply withholds excitation input.

(e) Six components of base-excitation are allowed. The specification of the Ground point and associated directions is quite general.

(f) Normalized eigensolution results may be printed.

(g) SPCFORCE's in dynamic response may be requested as meaningful output. ELFORCE/ELSTRESS results may be sorted by magnitude. The contribution of individual modes to the summed response may be printed.

(h) A convenient subcase structure exists for varying loads, summation rules, output requests and sorting options.

REFERENCES

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2. (Ed.) R.E. Ragle, STARDYNE User Information Manual, January 1984, System Development Corporation.

3. (Ed.) C.W. McCormick, MSC/NASTRAN User's Manual, May 1983, The MacNeal-Schwendler Corporation.

4. (Ed.) D.M. McLean, MSC/NASTRAN Programmer's Manual, September 1982, The MacNeal-Schwendler Corporation.

5. A. Parthasarathy, CONSPEC - A DMAP System for Conventional Response-Spectrum Analysis in MSC/NASTRAN, Report No. MA/TR-85P-01-1, October 1985, Control Data Canada, Limited.

APPENDIX A

CONMAIN DMAP SEQUENCE

```
       N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
  1   BEGIN $  DEVELOPED BY A. PARTHASARATHY, CONTROL DATA CANADA LTD.
  2   $-----------------------------------------------------------------
  2   $$ STEP-B OF RESPONSE SPECTRUM ANALYSIS $$ SEPTEMBER,1985
  2   $$ PROGRAM CONMAIN FOR DPTP-RESTART FROM SOL-3 (MSC/NASTRAN 63A)
  2   $-----------------------------------------------------------------
  2   $$ PRELIMINARY SETTINGS
  2   JUMP        LSHUT $
  3   DBFETCH     /SPECSEL,,,,/ $
  4   TABPT       SLT,ETT,EST,GEI,BPECT// $
  5   TABPT       GEOMIQ,,,,// $
  6   TABPT       GPL,EQEXIN,GPDT,CSTM,// $
  7   TABPT       BGPDT,SIL,ECT,,// $
  8   LABEL       LSHUT $
  9   PARAM       //DIAGOFF//47 $
 10   DBMGR       //0 $
 11   SETVAL      //V,N,CARDNO/0 $
 12   SETVAL      //V,N,NOBGGY/1 $
 13   PARAM       //NOP/V,Y,PHICARE=-1 $ CONTROL DIAGNOSTIC Y-MATRIX.
 14   PARAM       //NOP/V,Y,PREIGED=-1 $ PRINT EIGENSOLN. NODAL OUTPUT
 15   PARAM       //NOP/V,Y,PREIGES=-1 $ PRINT EIGENSOLN. ELEM. OUTPUT
 16   PARAM       //NOP/V,Y,PRTDRUG=-1  $ PRINT PSEUDO-STATIC D ?
 17   PARAM       //NOP/V,Y,COORID=0 $  DO NOT CHANGE IT.
 18   PARAM       //NOP/V,Y,GROUND=0 $ GROUND POINT
 19   PARAM       //NOP/V,Y,NEWGRID=-1 $ IS GROUND-PT. NEW ?
 20   PARAM       //NOP/V,Y,LOADRST=-1 $ STEP-B LOAD-RESTART * UNUSED *
 21   PARAM       //NOP/V,Y,NOIMR=-1 $ INDIVIDUAL MODE RESPONSE
 22   PARAM       //NOP/V,Y,NEWK4GG=-1 $ NEW K4GG-DAMPING
 23   PARAM       //NOP/V,Y, NEWBGG=-1 $ NEW BGG-DAMPING
 24   PARAM       //NOP/V,Y,NOBCOM=-1  $ COMPOSITE DAMPING FROM K4GG
 25   $$ PARAMETERS W4BGG, GMASS, W3MASS DEFINED SUBSEQUENTLY.
 25   $$ PARAMETERS LMODES,HFREQ,LFREQ ARE ALLOWED.
 25   $$ PARAMETERS B,W3,W4,OPTION,CLOSE ARE ALLOWED.
 25   PARAM       //NOT/V,N,NOLOAD/LOADRST $
 26   PARAM       //MPY/V,Y,GRDPNT/GROUND/1 $
 27   PARAM       //SUB/V,N,GROUND1/GROUND/1 $
 28   PARAM       //AND/V,N,NEWDAMP/NEWK4GG/NEWBGG $
 29   PARAML      BGG//PRES////V,N,OLDBGG $
 30   COND        LSKLOAD,NOLOAD $
 31   $-----------------------------------------------------------
 31   $$ TASK-1A ASSEMBLE BGGN AND K4GGN, IF NECESSARY.
 31   FILE        K4GG=APPEND $
 32   JUMP        LA1 $
 33   ADD         MGG,/K4GG/ $
 34   LABEL       LA1 $
 35   EQUIV       K4GG,K4GGN/NEWK4GG $
 36   COND        SKPDAMP,NEWDAMP $
 37   GP1        GEOM1D,GEOM2,/GPLN,EQEXINN,GPDTN,CSTMN,BGPDTN,SILN/
                  S,N,LUSET/0/S,N,NOGPDT $
 38   EQUIV       GPLN,GPL/ALWAYS/EQEXINN,EQEXIN/ALWAYS/GPDTN,GPDT/ALWAYS $
```

```
     N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
NO.
39  EQUIV      CSTMN,CSTM/ALWAYS/BGPDTN,BGPDT/ALWAYS/SILN,SIL/ALWAYS $
40  GP2       GEOM2,EQEXIN/ECTN $
41  EQUIV      ECTN,ECT/ALWAYS $
42  GP3        GEOM3,EQEXIN,GEOM2/SLTN,ETTN/0/V,N,NOGRAV/0 $
43  EQUIV      SLTN,SLT/ALWAYS/ETTN,ETT/ALWAYS $
44  TA1,       ,ECT,EPT,BGPDT,SIL,ETT,CSTM,/ESTN,,GEIN,GPECTN,/V,N,LUSET/
               -1/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
45  EQUIV      ESTN,EST/ALWAYS/GEIN,GEI/ALWAYS/GPECTN,GPECT/ALWAYS $
46  COND       LBLNOBX,NEWBGG $
47  EMG       EST,CSTM,MPT,DIT,GEOM2,,,/,,,,BELMN,BDICTN/0/0/S,N,NOBGGY $
48  COND      LEMAB,NOBGGY $
49  EMA       GPECT,BDICTN,BELMN,BGPDT,SIL,CSTM/BGGY, $
50  LABEL     LEMAB $
51  MTRXIN    CASECC,MATPOOL,EQEXIN,SIL,/,,B2GGN/LUSET/S,N,NOK2Z/
              S,N,NOM2Z/S,N,NOB2Z/1 $
52  PARAM     //AND/V,N,NOBGG/NOBGGY/NOB2Z $
53  EQUIV     BGGY,BGG/NOB2Z $
54  COND      LBLNOBX,NOB2Z $
55  ADD       BGGY,B2GGN/BGGZ/C,Y,CB1=(1.0,0.0)/C,Y,CB2=(1.0,0.0) $
56  EQUIV      BGGZ,BGG/ALWAYS $
57  LABEL     LBLNOBX $
58  COND      SKPDAMP,NEWK4GG $
59  EMG        EST,CSTM,MPT,DIT,GEOM2,,,/K4ELM,K4DICT,,,,/
               -1/0/0/S,N,NOK4GG $
60  EMA       GPECT,K4DICT,K4ELM,BGPDT,SIL,CSTM/K4GGN,/V,N,NOK4GG $
61  LABEL     SKPDAMP $
62  $  APPLY  MULTIPLIER ON BGG.
62  PARAMR     //COMPLEX//V,Y,W4BGG=0.0//V,N,C1BGG $
63  ADD        BGG,/BGGN/C1BGG $
64  $   ----------------------------------------------------
64  $$ TASK-1B REDUCE BGGN AND K4GGN TO A-SET.
64  PURGE      BAA/NEVER $
65  PARAML     BGGN//PRES////V,N,NOBGG $
66  EQUIV      BGGN,BAA/NOBGG $
67  COND      LBLSB,NOBGG $
68  EQUIV     BGGN,BAA/NOA $
69  COND      LBLSB,NOA $
70  MATREDU   BGGN,USET,GM,GOA/BAA/S,N,NOBGG $
71  LABEL     LBLSB $
72  PURGE      K4AA/NEVER $
73  PARAML     K4GGN//PRES////V,N,NOK4GG $
74  EQUIV      K4GGN,K4AA/NOK4GG $
75  COND      LNOK4,NOK4GG $
76  EQUIV     K4GGN,K4AA/NOA $
77  COND      LNOK4,NOA $
78  MATREDU   K4GGN,USET,GM,GOA/K4AA/S,N,NOK4GG $
79  LABEL     LNOK4 $
80  $-------------------------------------------------------------------
80  $$ TASK-2 ASSEMBLE PP-MATRICES AND REDUCE ALL MATRICES TO H-SET.
80  $$ TASK-2 ALSO  GENERATE MASTER OUTPUT OF EIGENSOLUTION.
```

```
    N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
  80  MTRXIN     CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/ S,N,
                 NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
  81  PARAM      //AND/V,N,MDEMA/V,N,NOUE/V,N,NOM2PP$
  82  PARAM      //AND/V,N,KDEKA/V,N,NOUE/V,N,NOK2PP$
  83  EQUIV      M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MMAA,MDD/MDEMA/ GOA,
                 GOAD/NOUE/GM,GMD/NOUE $
  84  EQUIV      KAA,KDD/KDEKA $
  85  EQUIV      BAA,BDD/NEVER $
  86  $COND       LNOGT,NOGPDT $
  86  GKAD       USETD,GM,GOA,KAA,BAA,MMAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,
                 GMD,GOAD,K2DD,M2DD,B2DD/TRAN/DISP/MODAL/C,Y,G=0.0/ C,Y,W3=0.0/
                 C,Y,W4=0.0/-1/-1/-1/1/1/1/1/-1/-1/V,N,NOKGG/1 $
  87  $LABEL      LNOGT $
  87  EQUIV      M2DD,MDD/NOMGG $
  88  $$ REDUCE  THE SYSTEM TO OFREQ SIZE.
  88  MODACC      CASECC,LAMA,PHIA,,,/LAMA1,PHIA1,,,/REIG $
  89  GKAM       USETD,PHIA1,,LAMA1,DI1,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
                 NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=1.E+30/-1/-1/-1/ S,
                 N,NONCUP/S,N,FMODE $
  90  $  INTRODUCE UNIFORM MASS DAMPING VIA GMASS,W3MASS PARAMETERS.
  90  PARAMR      //MPY/V,N,GW3MAS/V,Y,GMASS=0.0/V,Y,W3MASS=0.0  $
  91  PARAMR      //COMPLEX//GW3MAS//V,N,CGW3MAS $
  92  ADD         MHH,BHH/BHHMAS/CGW3MAS $
  93  EQUIV       BHHMAS,BHH/ALWAYS $
  94  MATPRN      BHH// $
  95  EQUIV      PHIDH,PHIAH/NOUE $
  96  COND       NOUEDRM,NOUE $
  97  UPARTN     USETD,PHIDH/PHIAH,,,/D/A/E/1 $
  98  LABEL      NOUEDRM $
  99  $  MASTER OUTPUT OF EIGENSOLUTION
  99  SDR1       USETD,,PHIAH,,,GOA,GM,,KFS,,/PHIGH,,QGH/1/REIGS $
 100  SDR2       CASECC,CSTM,MPT,DIT,EQEXIN,,,,BGPDT,LAMA1,QGH,     PHIGH,EST,
                 XYCDB/,IQG1,IPHIG1,IES1,IEF1,/REIG/S,N,NOM2 $
 101  DBSTORE     IPHIG1,IQG1,IES1,IEF1// $
 102  $---------------------------------------------------
 102  $$ TASK-3A COMPUTE (PSEUDO-STATIC) DRUG-MATRIX.
 102  $$ SEE SECTION 6.2 OF REPORT.
 102  EQUIV       EQEXIN,EQEXINX/NEWGRID/CSTM,CSTMX/NEWGRID/
                  BGPDT,BGPDTX/NEWGRID/GPDT,GPDTX/NEWGRID/
                  SIL,SILX/NEWGRID/GPL,GPLX/NEWGRID $
 103  PARAM       //MPY/V,N,LUSETX/1/LUSET $
 104  COND        LG1,NEWGRID $
 105  GP1         GEOM1,GEOM2,/GPLX,EQEXINX,GPDTX,CSTMX,BGPDTX,
                  SILX/S,N,LUSETX/0/V,N,NOGPDTX $
 106  LABEL       LG1 $
 107  VECPLOT,    ,BGPDTX,EQEXINX,CSTMX,,/DRB/GRDPNT/COORID/4 $
 108  TRNSP       DRB/DRBT $
 109  EQUIV       DRBT,DRBT/GROUND1  $
 110  COND        LRBASIC,GROUND1 $
 111  GP4        CASECC,GEOM4,EQEXINX,SILX,GPDTX,BGPDTX,CSTMX/RGN,YSBN,USETN,
```

```
     N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
                 ASETN/LUSETX/V,N,ZZ1/V,N,ZZ2/V,N,ZZ3/V,N,ZZ4/V,N,ZZ5/
                 V,N,YY1/V,N,YY2/V,N,YY3/V,N,YY4/V,N,YY5/C,Y,SUBID $
112  VEC          USETN/VRB/G/U1/COMP $
113  PARTN        DRBT,,VRB/DRBTU1,DRBCOMP,,/1 $
114  SOLVE        DRBTU1,/COEF/ $  INVERT TO GET (6X6) COEF. MATRIX.
115  MPYAD        DRBT,COEF,/DRGTX/ $
116  EQUIV        DRGTX,DRGT/NEWGRID $
117  COND         LRBASIC,NEWGRID $
118  MATGEN       EQEXINX/RIE/9/0/LUSETX $ NEW IN-EX.
119  MPYAD        RIE,VRB,/VRBE/1 $
120  MPYAD        RIE,DRGTX,/DRGTY/1 $ NEW EXT. SORT.
121  PARTN        DRGTY,,VRBE/DRGTYU1,DRGTYG,,/1 $ OLD EXT. SORT.
122  MATGEN       EQEXIN/RIEO/9/0/LUSET $ OLD IN-EX
123  MPYAD        RIEO,DRGTYG,/DRGT/ $ OLD INT. SORT.
124  JUMP         LRBASIC $
125  TABPT        GPL,CSTM,GPDT,BGPDT,SIL// $
126  LABEL        LRBASIC $
127  $$ CORRECTION OF DRGT FOR MPC-PRESENCE
127  EQUIV        DRGT,DRUG/MPCF1 $
128  COND         LSKMPC,MPCF2 $
129  UPARTN       USET,DRGT/DRUN,WRUM,,/G/N/M/1 $
130  MPYAD        GM,DRUN,/DRUM/ $
131  UMERGE       USET,DRUN,DRUM/DRUG/G/N/M $
132  LABEL        LSKMPC $
133  $$ PRINT OPTION FOR PSEUDO-STATIC D-MATRIX.
133  COND         LPDRUG,PRTDRUG $
134  MATGPR       GPL,USET,SIL,DRUG//H/G $
135  LABEL        LPDRUG $
136  $ CHECK RIGID-BODY STRAIN ENERGY.
136  MPYAD        DRUG,KGG,/DGTK/1 $
137  MPYAD        DGTK,DRUG,/RIGIDSE/ $
138  MATPRN       RIGIDSE// $
139  MATMOD       RIGIDSE,,,,,/RDUMMY,/20 $ PRINT MAX. OF RIGIDSE.
140  $-----------------------------------------------------------------------
140  $$ TASK-3B COMPUTE PART. FACTORS (PSI-MATRIX).
140  $$ TASK-3B ALSO, COMPUTE MATRICES MEFF AND Y.
140  $$ SEE SECTION 4.0 OF REPORT.
140  DIAGONAL     MHH/MIINV/SQUARE/-1.0 $
141  MPYAD        PHIGH,MGG,/ZTM/1 $
142  MPYAD        ZTM,DRUG,/PSIN/ $
143  MPYAD        MIINV,PSIN,/PSI/ $
144  TRNSP        PSI/PSIT $
145  MATPRN       PSIT// $
146  ADD          PSI,/PSIDUP/ $
147  ADD          PSIDUP,PSI/PSISQ///1 $
148  MPYAD        MHH,PSISQ,/MEFF/ $
149  TRNSP        MEFF/MEFFT $
150  MATPRN       MEFFT// $
151  $            TEST OF ((PHIG * PSI) : DRUG)
151  COND         LCARE,PHICARE $
```

```
     N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
152  MPYAD      PHIGH,PSI,/PHIGPSI/ $
153  $MATGPR     GPL,USET,SIL,PHIGPSI//H/G $
153  ADD        PHIGPSI,DRUG/PHIQD///2 $
154  MATMOD     PHIQD,,,,/PHIQDF,/2////C,Y,PHIFILT=0.0 $
155  MATGPR     GPL,USET,SIL,PHIQDF//H/G $
156  LABEL      LCARE $
157  $$ STORE FREQS. AND PART. FACTORS.
157  DIAGONAL  MHH/MDIAG/COLUMN $
158  ADD       KHH,MHH/OMEGSQ///2 $
159  DIAGONAL  OMEGSQ/OMEG/COLUMN/0.5 $
160  ADD       OMEG,/FN/.159155 $
161  DBSTORE     FN,PSI// $
162  $----------------------------------------
162  $$ TASK-3C COMPUTE ZETAH (ORDINARY OR COMPOSITE)
162  $$ SEE SECTION 3.0 OF REPORT.
162  PARAML     BHH//PRESENCE////V,N,NOBHHZ $
163  PARAM      //NOT/V,N,NOZET/NOBHHZ $
164  COND       LSKZET,NOZET $
165  ADD        FN,/ZET/(0.,0.) $
166  EQUIV      ZET,ZETAH/ALWAYS $
167  JUMP       LDBSZET $
168  LABEL      LSKZET $
169  COND       LSKBCOM,NOBCOM $
170  $EQUIV      BHHZ,BHH/NEVER $
170  DIAGONAL   OMEGSQ/WHH/SQUARE/0.5 $
171  MPYAD      MHH,WHH,/MWHH/ $
172  DIAGONAL   BHH/BHH1/SQUARE/1. $
173  DIAGONAL   KHH/KHH1/SQUARE/-1. $
174  MPYAD      KHH1,BHH1,/GHH/ $
175  MPYAD      MWHH,GHH,/BHHZ/ $
176  MODTRL     BHHZ////6 $
177  EQUIV      BHHZ,BHH/ALWAYS $
178  LABEL      LSKBCOM $
179  DIAGONAL   BHH/BDIAG/COLUMN $
180  ADD       BDIAG,OMEG/BDIAG1///2 $
181  ADD       BDIAG1,MDIAG/ZETAH/(0.5,0.)//2 $
182  LABEL      LDBSZET $
183  DBSTORE    ZETAH// $
184  $----------------------------------------
184  $$ TASK-4 SPECTRUM INTERPOLATION AND OUTPUT
184  $$ TASK-4 HAS OUTER LOOP AND INNER LOOP.
184  LABEL      LSKLOAD $
185  DBFETCH    /XFN,XPSI,XZETAH,,///1 $
186  DBFETCH    /XIPHIG1,XIQG1,XIES1,XIEF1,///1 $
187  $ OPTIONAL  PRINT OF EIGENSOLUTION MASTER OUTPUT
187  COND       LEIG1,PREIGED $  NODAL EIGEN-OUTPUT
188  OFP        XIPHIG1,XIQG1,,,,//S,N,CARDNO $
189  LABEL      LEIG1 $
190  COND       LEIG2 PREIGES $  ELEMENT EIGEN-OUTPUT
191  OFP        XIEF1 XIES1 ,,,//S,N,CARDNO $
```

```
      N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
192  LABEL      LEIG2 $
193  $$ PRINT MODAL FREQUENCIES AND DAMPINGS.
193  MATPRN      XFN,XZETAH// $
194  PARAML      SPECSEL//PRES////V,N,NOSEL $
195  DBSTORE     SPECSEL/////NOSEL $
196  COND        FINIS,NOSEL $
197  DBFETCH     /SPECSEL,,,,/ $
198  PARAM       //MPY/V,N,REPEATT/1/-1 $
199  $$ OUTER LOOP FOR SPECTRUM LOAD CASES.
199  JUMP       LBL13 $
200  LABEL      LBL13 $
201  CASE       CASECC,/CASEXX/TRAN/S,N,REPEATT/S,N,NOLOOP $
202  PARAML     CASEXX//VPS/1 $
203  INTERR     CASEXX,DIT,DYNAMICS,XZETAH,XFN,SPECSEL,XPSI/UHVR/
            V,Y,CLOSE=1.0/V,Y,OPTION=ABS $
204  PARAML     UHVR//PRESENCE////V,N,NOUHVR $
205  COND       LBL15,NOUHVR $
206  MATPRN     UHVR// $
207  DDRMM      CASEXX,UHVR,,XIPHIG1,XIQG1,XIES1,XIEF1,XYCDB/OUPV1,OQP1,DOES1,
            DOEF1, $
208  OFP        OUPV1,OQP1,,,,//S,N,CARDNO $
209  $$ -------- CONTINUE TASK 4. -------------------
209  $ SORTING AND OUTPUT OF ELEMENT FORCES AND STRESSES
209  $$ SEE SECTION 10.0 OF REPORT.
209  PARAM       //NOP/V,Y,OLDF=0 $
210  PARAM       //NOP/V,Y,OLDS=0 $
211  PARAM       //NOP/V,Y,NEWF=-1 $
212  PARAM       //NOP/V,Y,NEWS=-1 $
213  JUMP        JCODE $
214  DBFETCH     /SORTKEY,,,,/ $
215  LABEL       JCODE $
216  COND        LSOF,OLDF $
217  OFP         DOEF1,,,,,//S,N,CARDNO $
218  LABEL       LSOF $
219  COND        LSNF,NEWF $
220  STRSORT     DOEF1,SORTKEY/DOEF1Z/V,Y,NUMF=-2/V,Y,BIGEF=0.0 $
221  OFP         DOEF1Z,,,,,//S,N,CARDNO $
222  LABEL       LSNF $
223  COND        LSOS,OLDS $
224  OFP         DOES1,,,,,//S,N,CARDNO $
225  LABEL       LSOS $
226  COND        LSNS,NEWS $
227  STRSORT     DOES1,SORTKEY/DOES1Z/V,Y,NUMS=-2/V,Y,BIGES=0.0 $
228  OFP         DOES1Z,,,,,//S,N,CARDNO $
229  LABEL       LSNS $
230  $$ -------- CONTINUE TASK-4. --------------------
230  $$ INNER LOOP FOR OPTIONAL INDIVIDUAL MODAL RESPONSES
230  COND        LSKIMR,NOIMR $
231  PARAML      UHVR//TRAILER/2/V,N,NMOD $
232  SETVAL      //V,N,MODENUM/0 $
```

```
          N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
 233  JUMP       IMRTOP $
 234  LABEL      IMRTOP $
 235  PARAM      //ADD/V,N,MODENUM/MODENUM/1 $
 236  PARAM      //SUB/V,N,DMOD/NMOD/MODENUM $
 237  COND       LSKIMR,DMOD $
 238  MATGEN     ,/V/4/1/NMOD/0/1/NMOD/MODENUM $
 239  $MATPRN     V// $
 239  TRNSP      V/VT $
 240  MPYAD      V,VT,/FILT/ $
 241  MPYAD      FILT,UHVR,/UHVR1/ $
 242  DDRMM      CASEXX,UHVR1,,XIPHI01,XIQG1,XIES1,XIEF1,XYCDB/
                 OUPVA,OQPA,OESA,OEFA, $
 243  $$ IDENTIFY INDIVIDUAL MODE.
 243  PRTPARM    //0/C,N,MODENUM $
 244  SCALAR     XFN//MODENUM/1/V,N,MODEFREQ $
 245  SCALAR     XZETAH//MODENUM/1/V,N,MODEZETA $
 246  OFP        OUPVA,OQPA,OEFA,OESA,,//S,N,CARDNO $
 247  REPT       IMRTOP,100 $
 248  LABEL      LSKIMR $
 249  $$ END OF INNER LOOP FOR IMR-OUTPUT
 249  LABEL      LBL15 $
 250  COND       FINIS,REPEATT $
 251  REPT       LBL13,100 $
 252  $$ END OF OUTER LOOP FOR LOAD CASES.
 252  $$ -------- END OF TASK-4 -----------------------
 252  LABEL      FINIS $
 253  END $
```

APPENDIX B

ILLUSTRATIVE INPUT DECKS

DECK-1 : STEP-A SOL-3 MODE EXTRACTION FOR SHALLOW ARCH (A.PARTHA)

```
NASTRAN SYSTEM(20)=0
ID SHALLOW,ARCH
TIME 10
SOL 3
DIAG 8
CHKPNT YES  $ REQUIRED FOR SEISMIC RESTART
CEND
TITLE = STEP-A: SHALLOW ARCH MODE-EXTRACTION (USUAL SOL-3)
SUBTITLE = K4GG-DAMPING IS A BY-PRODUCT OF MAT1 CARDS.
ECHO = BOTH
SPC = 100
DYNRED = 100  $ GEN. DYNAMIC REDUCTION
METHOD = 33
DISP = ALL
BEGIN BULK
$ USUAL PARAMETERS
PARAM,SEQOUT,1
PARAM,AUTOSPC,YES
PARAM,USETPRT,0
PARAM,GRDPNT,0
$ USUAL MODEL DEFINITION
GRDSET,,,,,,,345
GRID,10,,0.,0.
GRID,11,,40.,6.0
GRID,12,,80.,8.0
GRID,13,,120.,6.
GRID,14,,160.,0.
CBAR,1,1,10,11,0.,1.,0.
CBAR,2,2,11,12,0.,1.,0.
CBAR,3,3,12,13,==
CBAR,4,4,13,14,==
```

DECK-1 (CONTD.) : STEP-A SOL-3 MODE EXTRACTION FOR SHALLOW ARCH

```
PBAR,1,1,.785,.049,.049,.098
PBAR,2,2,.785,.049,.049,.098
PBAR,3,3,.785,.049,.049,.098
PBAR,4,4,.785,.049,.049,.098
$ OPTIONAL GE-ENTRY ON MAT1 CARDS
MAT1,1,10.E6,,.3,2.6E-4,,,0.08
MAT1,2,10.E6,,.3,2.6E-4,,,0.02
MAT1,3,10.E6,,.3,2.6E-4,,,0.04
MAT1,4,10.E6,,.3,2.6E-4,,,0.08
$ PINNED ENDS
SPC1,100,12,10,14
$ EIGENSOLUTION
EIGR,33,MGIV,,,,4,,,+EIG
+EIG,MASS
$ GENERALIZED DYNAMIC REDUCTION
DYNRED,100,100.
SPOINT,1001,THRU,1006
QSET1,,1001,THRU,1006
ASET1,,1001,THRU,1006
ENDDATA
```

DECK-2 : STEP-B CONMAIN SEISMIC RESPONSE ANALYSIS (A.PARTHA)

```
*DECK NAST
NASTRAN SYSTEM(20)=0,FILES=(OPTP,DB01)
$ USE OPTP; CREATE DB01.
ID CONSPEC,STEPB
TIME 10
DIAG 8,14,20
$-----------------------------------------
$ INSERT DMAP-PROGRAM CONMAIN.
/READ,CONMAIN
$ INSERT RESTART DICTIONARY.
*READ DICT
$-----------------------------------------
CEND
TITLE = STEP-B : CONMAIN EXECUTION FOR SEISMIC RESPONSE
ECHO = BOTH
$ SORTED DECK INCLUDES STEP-A DATA AND NEW/REVISED DATA.
$-----------------------------------------
$ ABOVE-SUBCASE MASTER OUTPUT IN STEP-B
DISP = ALL
ACCEL = ALL
SPCFO = ALL
ELFO = ALL
ELSTRESS = ALL
$-----------------------------------------
SUBCASE 1
  DLOAD = 100  $ SPECTRUM LOADING
BEGIN BULK
$-----------------------------------------
$ NEW TYPE-3 (COMPOSITE MATERIAL) DAMPING
$ DISCARD K4GG OF OPTP, IF ANY.
PARAM,NEWK4GG,1
```

DECK-2 (CONTD.) : STEP-B CONMAIN SEISMIC RESPONSE ANALYSIS (A.PARTHA)

```
PARAM,W4,1.0
PARAM,NOBCOM,1
$ REVISE GE-DAMPING ON MATERIAL CARDS.
/,15,18
MAT1,1,10.E6,,.3,2.6E-4,,,0.02
MAT1,2,10.E6,,.3,2.6E-4,,,0.04
MAT1,3,10.E6,,.3,2.6E-4,,,0.03
MAT1,4,10.E6,,.3,2.6E-4,,,0.07
$-------------------------------------------------------------
$ SAMPLE DEFINITION OF GROUND, IF NEEDED.
$ SUPPOSE GROUND IS A NEW GRID-POINT AND
$ THE EXCITATION AXES ARE NOT THE BASIC AXES.
$ THIS IS THE MOST GENERAL OF THE AVAILABLE POSSIBILITIES.
PARAM,GROUND,99
USET,U1,99,123456
PARAM,NEWGRID,1
GRID,99,0,80.,0.,0.,9
CORD2R,9,0,80.,0.,0.,80.,0.,10.
,100.,1.,0.
$-----------------------------------------------------------------
$ PRINT PSEUDO-STATIC D-MATRIX.
PARAM,PRTDRUG,1
$ COMPUTE AND PRINT DIAGNOSTIC Y-MATRIX OF SEC. 4.
PARAM,PHICARE,1
PARAM,PHIFILT,0.75
$ PRINTING OF NORMALIZED EIGENSOLUTION OUTPUT
PARAM,PREIGED,1
PARAM,PREIGES,1
$-----------------------------------
$ SELECT MODES FOR RESPONSE ANALYSIS
PARAM,LMODES,3
```

DECK-2 (CONTD.) : STEP-B CONMAIN SEISMIC RESPONSE ANALYSIS (A.PARTHA)

```
$ MODAL SUMMATION METHOD
PARAM,OPTION,ABS
$ INDIVIDUAL-MODE RESPONSE
PARAM,NOIMR,1
$-----------------------------------------------------
$ X- AND Y-SPECTRA (ACCELERATION) LOADING
DLOAD,100,386.4,0.2,9,1.0,6,0.,6
,0.,6,0.,6,0.,6
$ SPECTRA RECORD NO. 6
DTI,SPECSEL,6,,A,11,.02,12,.10
$ TWO SPECTRA CURVES
TABLED1,11
,0.,.002,1.,.30,3.,.72,28.,.72
,70.,.32,80.,.20,100.,.20,ENDT
TABLED1,12
,0.,.001,1.,.075,3.,.18,28.,.18
,70.,.08,80.,.05,100.,.05,ENDT
$ SPECTRA RECORD NO. 9
DTI,SPECSEL,9,,A,13,.02,14,.10
$ TWO SPECTRA CURVES
TABLED1,13
,0.,.001,1.,.15,3.,.36,28.,.36
,70.,.16,80.,.10,100.,.10,ENDT
TABLED1,14
,0.,.001,1.,.15,3.,.36,28.,.36
,70.,.16,80.,.10,100.,.10,ENDT
ENDDATA
```

DECK-3 : STEP-C CONLOAD SEISMIC RESPONSE ANALYSIS (A.PARTHA)

```
NASTRAN FILES=(DB01)
ID CONSPEC,STEPC
TIME 10
DIAG 8,14,20
$ INSERT DMAP-PROGRAM CONLOAD.
/READ,CONLOAD
CEND
TITLE = STEP-C : DATA-BASE RESTART FOR NEW LOADINGS
SUBT = ILLUSTRATION OF VARIOUS OPTIONS
ECHO = BOTH
$ SORTED DECK CONTAINS ONLY NEW DATA OF THIS RUN.
$------------------------------------------------
SUBCASE 1
 DLOAD = 300  $ FIRST NEW LOADING
$ SELECTED OUTPUT
 SET 1 = 10,11,12  $ GRID-PTS
 SET 2 = 1,2  $ ELEMENTS
 DISP = 1
 ELFO = 2
$ PARAMETERS IN CASE CONTROL
 PARAM,OPTION,ABS
 PARAM,NOIMR,-1  $ NO INDIV.-MODE RESP.
$--------------------------------------------------
SUBCASE 2
 DLOAD = 400  $ SECOND NEW LOADING
$ CHANGED OUTPUT REQUEST.
 DISP = ALL
 ELFO = ALL
 ELSTRESS = ALL
 PARAM,OPTION,SRSS
 PARAM,CLOSE,0.1
```

DECK-3 (CONTD.) : STEP-C CONLOAD SEISMIC RESPONSE ANALYSIS (A.PARTHA)

```
 PARAM,NOIMR,1  $ INDIV.-MODE RESP. REQUESTED.
$ SORT ALL (SUMMED) EL-FORCES AND ALL STRESSES.
$ PRINT BEFORE AND AFTER SORTING.
$ PARAMETERS OLDF, OLDS ARE DEFAULTED.
 PARAM,NEWF,1
 PARAM,NEWS,1
 PARAM,NUMF,-1
 PARAM,NUMS,-1
$----------------------------------------------------
BEGIN BULK
$$ NEW LOADINGS
DLOAD,300,386.4,0.,1,1.,1,0.,1
,0.,1,0.,1,0.,1
DLOAD,400,386.4,0.2,1,0.8,1,0.,1
,0.,1,0.,1,0.,1
DTI,SPECSEL,1,,A,13,.02,14,.10
TABLED1,13
,0.,.001,1.,.15,3.,.36,28.,.36
,70.,.16,80.,.10,100.,.10,ENDT
TABLED1,14
,0.,.001,1.,.15,3.,.36,28.,.36
,70.,.16,80.,.10,100.,.10,ENDT
$-----------------------------------------------
$ SORT ON AXIAL FORCE AND AXIAL STRESS.
$ DTI-INPUT IS NECESSARY FOR NON-DEFAULT SORT-KEYS.
$ IREC=1 FOR ELSTRESS AND IREC=2 FOR ELFORCE.
DTI,SORTKEY,1,34,6
DTI,SORTKEY,2
ENDDATA
```

APPENDIX C

ILLUSTRATIVE OUTPUT TABLES

TABLE-1 : SORTED BULK-DATA OF DECK-1 STEP-A RUN

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	ASET1		1001	THRU	1006					
2-	CBAR	1	1	10	11	0.	1.	0.		
3-	CBAR	2	2	11	12	0.	1.	0.		
4-	CBAR	3	3	12	13	0.	1.	0.		
5-	CBAR	4	4	13	14	0.	1.	0.		
6-	DYNRED	100	100.							
7-	EIGR	33	MGIV				4			+EI0
8-	+EIG	MASS								
9-	GRDSET							345		
10-	GRID	10		0.	0.					
11-	GRID	11		40.	6.0					
12-	GRID	12		80.	8.0					
13-	GRID	13		120.	6.					
14-	GRID	14		160.	0.					
15-	MAT1	1	10.E6		.3	2.6E-4			0.08	
16-	MAT1	2	10.E6		.3	2.6E-4			0.02	
17-	MAT1	3	10.E6		.3	2.6E-4			0.04	
18-	MAT1	4	10.E6		.3	2.6E-4			0.08	
19-	PARAM	AUTOSPC	YES							
20-	PARAM	GRDPNT	0							
21-	PARAM	SEQOUT	1							
22-	PARAM	USETPRT	0							
23-	PBAR	1	1	.785	.049	.049	.098			
24-	PBAR	2	2	.785	.049	.049	.098			
25-	PBAR	3	3	.785	.049	.049	.098			
26-	PBAR	4	4	.785	.049	.049	.098			
27-	QSET1		1001	THRU	1006					
28-	SPC1	100	12	10	14					
29-	SPOINT	1001	THRU	1006						
	ENDDATA									

TOTAL COUNT= 30

TABLE-2 : O-SET DOF-S AND NATURAL FREQUENCIES IN STEP-A (SOL-3 RUN)

O DISPLACEMENT SET

	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	
1=	1001-0	1002-0	1003-0	1004-0	1005-0	1006-0	10-1	10-2	10-3	10-4 =	10
11=	10-5	10-6	11-1	11-2	11-3	11-4	11-5	11-6	12-1	12-2 =	20
21=	12-3	12-4	12-5	12-6	13-1	13-2	13-3	13-4	13-5	13-6 =	30
31=	14-1	14-2	14-3	14-4	14-5	14-6					

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	5.400060E+03	7.364801E+01	1.170506E+01	1.000000E+00	5.400060E+03
2	2	2.417474E+04	1.554823E+02	2.474577E+01	1.000000E+00	2.417474E+04
3	3	1.786018E+05	4.202401E+02	6.688330E+01	1.000000E+00	1.786018E+05
4	4	1.305706E+07	3.706035E+03	5.046004E+02	1.000000E+00	1.305700E+07
5	5	4.742082E+07	6.886011E+03	1.096000E+03	0.0	0.0
6	6	8.136526E+07	9.020260E+03	1.435620E+03	0.0	0.0

TABLE-9 : REQUESTED OUTPUT OF EIGENVECTORS IN STEP-A (SOL-9 RUN)

EIGENVALUE = 5.400000E+03   R E A L   E I G E N V E C T O R   N O .   1
CYCLES = 1.170505E+01

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	-2.000000E-01
11	G	1.154714E+00	-7.000500E+00	0.0	0.0	0.0	0.407200E-04
12	G	7.700160E-01	4.002751E-13	0.0	0.0	0.0	2.001474E-01
13	G	1.154714E+00	7.006500E+00	0.0	0.0	0.0	0.407200E-04
14	G	0.0	0.0	0.0	0.0	0.0	-2.000000E-01
1001	S	9.875170E-01	1.676126E-01	-4.840006E-08	-2.004545E-15	-3.010043E-10	1.430371E-16

EIGENVALUE = 2.417474E+04   R E A L   E I G E N V E C T O R   N O .   2
CYCLES = 2.474577E+01

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	2.044600E-01
11	G	-6.621062E-01	4.330037E+00	0.0	0.0	0.0	-2.430633E-01
12	G	4.437750E-14	-0.151754E+00	0.0	0.0	0.0	1.304110E-14
13	G	6.621062E-01	4.330037E+00	0.0	0.0	0.0	2.430633E-01
14	G	0.0	0.0	0.0	0.0	0.0	-2.044600E-01
1001	S	1.575125E-01	-0.076170E-01	-0.045570E-05	-4.447236E-16	-5.650257E-10	-2.000160E-15

EIGENVALUE = 1.766018E+05   R E A L   E I G E N V E C T O R   N O .   3
CYCLES = 6.600330E+01

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	-2.070005E-01
11	G	4.040411E-01	-6.447103E+00	0.0	0.0	0.0	-6.212706E-02
12	G	-1.350377E-14	-0.100073E+00	0.0	0.0	0.0	-5.175009E-12
13	G	-4.040411E-01	6.447103E+00	0.0	0.0	0.0	6.212706E-02
14	G	0.0	0.0	0.0	0.0	0.0	2.070005E-01
1001	S	2.000007E-01	0.640454E-01	-1.000000E+00	1.062574E-12	0.550321E-12	0.435137E-12

EIGENVALUE = 1.706706E+07   R E A L   E I G E N V E C T O R   N O .   4
CYCLES = 5.046004E+02

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	2.006300E-02
11	G	5.431006E+00	1.200010E+00	0.0	0.0	0.0	-1.100632E-02
12	G	7.754560E+00	0.111270E-12	0.0	0.0	0.0	-4.336370E-02
13	G	5.431005E+00	-1.200010E+00	0.0	0.0	0.0	-1.100645E-02
14	G	0.0	0.0	0.0	0.0	0.0	2.006200E-02
1001	S	-3.004001E-16	-2.647074E-16	-2.006300E-12	-0.006600E-01	-2.687500E-02	1.040603E-03

TABLE-4 : SORTED BULK-DATA OF DECK-2 STEP-0 CONMAIN RUN

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	ASET1		1001	THRU	1008					
2-	CBAR	1	1	10	11	0.	1.	0.		
3-	CBAR	2	2	11	12	0.	1.	0.		
4-	CBAR	3	3	12	13	0.	1.	0.		
5-	CBAR	4	4	13	14	0.	1.	0.		
6-	CORD2R	9	0	80.	0.	0.	80.	0.	10.	+000001
7-	++000001	100.	1.	0.						+000002
8-	DLOAD	100	386.4	0.2	9	1.0	6	0.	6	+000003
9-	++000003	0.	8	0.	5	0.	6			+000004
10-	DTI	SPECSEL	6		A	11	.02	12	.10	
11-	DTI	SPECSEL	9		A	13	.02	14	.10	
12-	DYNRED	100	100.							
13-	EIGR	33	MGIV				4			+EIG
14-	+EIG	MASS								
15-	GRDSET							345		
16-	GRID	10		0.	0.					
17-	GRID	11		40.	6.0					
18-	GRID	12		80.	9.0					
19-	GRID	13		120.	6.					
20-	GRID	14		160.	0.					
21-	GRID	99	0	80.	0.	0.	9			
22-	MAT1	1	10.E6		.3	2.6E-4			0.02	
23-	MAT1	2	10.E6		.3	2.6E-4			0.04	
24-	MAT1	3	10.E6		.3	2.6E-4			0.03	
25-	MAT1	4	10.E6		.3	2.6E-4			0.07	
26-	PARAM	AUTOSPC	YES							
27-	PARAM	GRDPNT	0							
28-	PARAM	GROUND	99							
29-	PARAM	LMODES	3							
30-	PARAM	NEWGRID	1							
31-	PARAM	NEWK4GG	1							
32-	PARAM	NOHCOM	1							
33-	PARAM	NOIMR	1							
34-	PARAM	OPTION	ABS							
35-	PARAM	PHICARE	1							
36-	PARAM	PHIFILT	0.75							
37-	PARAM	PREIDED	1							
38-	PARAM	PREIDES	1							
39-	PARAM	PRTDRUG	1							
40-	PARAM	SEQOUT	1							
41-	PARAM	USETPRT	0							
42-	PARAM	W4	1.0							
43-	PBAR	1	1	.785	.049	.049	.098			
44-	PBAR	2	2	.785	.049	.049	.098			
45-	PBAR	3	3	.785	.049	.049	.098			
46-	PBAR	4	4	.785	.049	.049	.098			
47-	OSET1		1001	THRU	1008					

TABLE-4 (CONTD.) ; SORTED BULK-DATA OF DECK-2 STEP-8 CONMAIN RUN

```
48-        SPC1     100      12       10       14
49-        SPOINT   1001     THRU     1006
50-        TABLED1  11                                                                  +000005
51-        ++0000050.        .002     1.       .30      3.       .72      20.      .72  +000006
52-        ++0000670.        .12      80.      .20      100.     .20      ENDT          +000007
53-        TABLED1  12                                                                  +000008
54-        ++0000080.        .001     1.       .075     3.       .18      20.      .18  +000009
55-        ++0000970.        .09      80.      .05      100.     .05      ENDT          +000010
56-        TABLED1  13                                                                  +000011
57-        ++0000110.        .001     1.       .15      3.       .36      20.      .36  +000012
58-        ++0001270.        .16      80.      .10      100.     .10      ENDT          +000013
59-        TABLED1  14                                                                  +000014
60-        ++0000140.        .001     1.       .15      3.       .36      20.      .36  +000015
61-        ++0001570.        .18      80.      .10      100.     .10      ENDT          +000016
62-        USET     U1       99       123456
           ENDDATA
     TOTAL COUNT=    63
```

TABLE-5 : PRINTOUT OF MODAL DAMPING MATRIX BHH IN STEP-8 RUN

```
0        MATRIX BHH       (GINO NAME 101  ) IS A REAL              3 COLUMN X      3 ROW SYMETRIC MATRIX.
0COLUMN        1          ROWS        1 THRU       3       ----------------------------------------------------
    ROW
      1)    2.1640E+02  1.1727E+02 -2.8406E+01             ----------------------------------------------------
0COLUMN        2          ROWS        1 THRU       3       ----------------------------------------------------
    ROW
      1)    1.1727E+02  9.3602E+02 -1.0007E+00
0COLUMN        3          ROWS        1 THRU       3       ----------------------------------------------------
    ROW
      1)   -2.8406E+01 -1.0007E+00  7.0714E+03
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =        3
0THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.
```

TABLE-6 : PRINTOUT OF PSEUDO-STATIC D-MATRIX (DRUG) IN STEP-0 RUN

```
             DRUG
       POINT       VALUE     POINT        VALUE     POINT        VALUE     POINT        VALUE     POINT        VALUE
0COLUMN   1
       10 T1  9.98752E-01    10 T2  4.99376E-02    11 T1  9.98752E-01    11 T2  4.99376E-02    12 T1  9.98752E-01
       12 T2  4.99376E-02    13 T1  9.98752E-01    13 T2  4.99376E-02    14 T1  9.98752E-01    14 T2  4.99376E-02
0COLUMN   2
       10 T1 -4.99376E-02    10 T2  9.98752E-01    11 T1 -4.99376E-02    11 T2  9.98752E-01    12 T1 -4.99376E-02
       12 T2  9.98752E-01    13 T1 -4.99376E-02    13 T2  9.98752E-01    14 T1 -4.99376E-02    14 T2  9.98752E-01
0COLUMN   3
       10 T3  1.00000E+00    11 T3  1.00000E+00    12 T3  1.00000E+00    13 T3  1.00000E+00    14 T3  1.00000E+00
0COLUMN   4
       10 T3  3.99501E+00    10 R1  9.98752E-01    10 R2  4.99376E-02    11 T3  7.99002E+00    11 R1  9.98752E-01
       11 R2  4.99376E-02    12 T3  7.99002E+00    12 R1  9.98752E-01    12 R2  4.99376E-02    13 T3  3.99501E+00
       13 R1  9.98752E-01    13 R2  4.99376E-02    14 T3 -3.99501E+00    14 R1  9.98752E-01    14 R2  4.99376E-02
0COLUMN   5
       10 T3  7.99002E+01    10 R1 -4.99376E-02    10 R2  9.98752E-01    11 T3  3.96505E+01    11 R1 -4.99376E-02
       11 R2  9.98752E-01    12 T3 -3.99501E-01    12 R1 -4.99376E-02    12 R2  9.98752E-01    13 T3 -4.02407E+01
       13 R1 -4.99376E-02    13 R2  9.98752E-01    14 T3 -7.99002E+01    14 R1 -4.99376E-02    14 R2  9.98752E-01
0COLUMN   6
       10 T2 -8.00000E+01    10 R3  1.00000E+00    11 T1 -6.00000E+00    11 T2 -4.00000E+01    11 R3  1.00000E+00
       12 T1 -8.00000E+00    12 R3  1.00000E+00    13 T1 -6.00000E+00    13 T2  4.00000E+01    13 R3  1.00000E+00
       14 T2  8.00000E+01    14 R3  1.00000E+00
```

TABLE-7 : PRINTOUT OF RIGID-BODY STRAIN-ENERGY MATRIX IN STEP-0 RUN

```
0     MATRIX RIGIDSE   (GINO NAME 101  ) IS A REAL          6 COLUMN X      6 ROW SQUARE   MATRIX.
0COLUMN      1        ROWS        1 THRU       6    ----------------------------------------------------------
  ROW
    1)   -1.3438E-09  3.4881E-10  0.            0.           0.          -2.4495E-09
0COLUMN      2        ROWS        1 THRU       6    ----------------------------------------------------------
  ROW
    1)    7.0573E-11 -1.7441E-11  0.            0.           0.          -1.5042E-10
0COLUMN      3        ROWS        3 THRU       5    ----------------------------------------------------------
  ROW
    3)   -1.8190E-12 -1.3642E-11 -1.4552E-11
0COLUMN      4        ROWS        3 THRU       5    ----------------------------------------------------------
  ROW
    3)   -8.1752E-12 -6.6855E-11 -3.1530E-10
0COLUMN      5        ROWS        3 THRU       5    ----------------------------------------------------------
  ROW
    3)    1.8621E-11 -3.5362E-10 -5.2877E-09
0COLUMN      6        ROWS        1 THRU       6    ----------------------------------------------------------
  ROW
    1)    2.5552E-09 -1.4770E-09  0.            0.           0.          -1.1742E-09
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =      3
0THE DENSITY OF THIS MATRIX IS  50.00 PERCENT.
1OUTPUT FROM MTMD20 IS AS FOLLOWS

    RIGIDSE                                                                                  SUM
  2.44948E-08    0.           0.           0.           0.           0.                2.44948E-08
```

```
         TABLE-8 : MODAL MASS-PARTICIPATION FACTORS (PSIT) IN STEP-0 RUN
         ===============================================================

0       MATRIX PSIT       (GINO NAME 101  ) IS A REAL           3 COLUMN X       6 ROW RECTANG  MATRIX.
0COLUMN       1        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)     2.5234E-02 -1.2617E-03  0.             0.         0.             4.8030E+00
0COLUMN       2        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)    -1.8242E-04 -3.6484E-09  0.             0.         0.             2.5580E-13
0COLUMN       3        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)    -7.8166E-03 -1.5633E-01  0.             0.         0.            -2.8422E-14
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =          3
0THE DENSITY OF THIS MATRIX IS  50.00 PERCENT.
?

         TABLE-9 : EFFECTIVE MODAL MASSES (MEFFT) IN STEP-0 RUN
         ======================================================

0       MATRIX MEFFT      (GINO NAME 101  ) IS A REAL           3 COLUMN X       6 ROW RECTANG  MATRIX.
0COLUMN       1        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)     6.3676E-04  1.5019E-06  0.             0.         0.             2.3060E+01
0COLUMN       2        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)     3.3270E-08  1.3311E-05  0.             0.         0.             0.5431E-26
0COLUMN       3        ROWS        1 THRU       6   ---------------------------------------------------
     ROW
       1)     6.1100E-05  2.4440E-02  0.             0.         0.             0.0770E-20
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =          3
0THE DENSITY OF THIS MATRIX IS  50.00 PERCENT.
?

         TABLE-10 : MODE-TRUNCATION-EFFECTIVENESS MATRIX (PHIODF) IN STEP-0 RUN
         ======================================================================

                  PHIODF
        POINT            VALUE      POINT          VALUE      POINT          VALUE      POINT          VALUE      POINT
   VALUE

0COLUMN       1
          11 T2 -2.80640E+00      12 T2  1.00373E+00     13 T2  4.00100E+00
0COLUMN       2
          11 T1  1.49612E+00      11 T2  1.00243E+00     12 T2  1.00373E+00     13 T1 -1.43777E+00     13 T2  0.
02982E-01
0COLUMNS      3 (        0-   ) THRU        5 (        0-   ) ARE NULL.
0COLUMN       6
          10 R3 -1.41481E+00      11 T1 -0.41898E-01     11 T2  0.41656E-01     12 R3  1.41816E+00     13 T1 -0.
41838E-01
          13 T2  0.41656E-01      14 R3 -1.41481E+00
```

```
TABLE-11 : MODAL FREQS.(XFN) AND DAMP-FACTORS(XZETAH) IN STEPS B AND C
======================================================================

0        MATRIX XFN       (GINO NAME 101 ) IS A REAL            1 COLUMN X       3 ROW RECTANG  MATRIX.
0COLUMN        1          ROWS       1 THRU       3    ------------------------------------------------
     ROW
       1)     1.1705E+01  2.4746E+01  6.6003E+01
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =        3
0THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.

0        MATRIX XZETAH    (GINO NAME 102 ) IS A REAL            1 COLUMN X       3 ROW RECTANG  MATRIX.
0COLUMN        1          ROWS       1 THRU       3    ------------------------------------------------
     ROW
       1)     2.0012E-02  1.9370E-02  2.0021E-02
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =        3
0THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.
?


TABLE-12 : MODAL RESPONSE COEFFICIENTS (UHVR) IN STEP-B RUN
======================================================================

0  SCALED SPECTRAL RESPONSE, ABS  OPTION, DLOAD =        100  CLOSE =       1.00

0        MATRIX UHVR      (GINO NAME 101 ) IS A REAL            3 COLUMN X       3 ROW SQUARE   MATRIX.
0COLUMN        1          ROWS       1 THRU       3    ------------------------------------------------
     ROW
       1)    -1.9460E-04 -4.2107E-05 -1.2010E-04
0COLUMN        2          ROWS       1 THRU       3    ------------------------------------------------
     ROW
       1)    -1.4310E-02 -6.5600E-03 -5.0506E-02
0COLUMN        3          ROWS       1 THRU       3    ------------------------------------------------
     ROW
       1)    -1.0530E+00 -1.0201E+00 -2.1225E+01
0THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =        3
0THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.
```

TABLE-19 : SUMMED-MODE PHYSICAL RESPONSES IN STEP-B RUN

STEP-B : COMMAIN EXECUTION FOR SEISMIC RESPONSE — MARCH 4, 1988 MSC/NASTRAN 11/23/88 PAGE 44

SUBCASE 1

TIME = 0.

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	9.327170E-06
11	G	3.100184E-04	2.456601E-03	0.0	0.0	0.0	1.704815E-05
12	G	1.400004E-04	1.131101E-03	0.0	0.0	0.0	5.800714E-05
13	G	3.100184E-04	2.455601E-03	0.0	0.0	0.0	1.704815E-05
14	G	0.0	0.0	0.0	0.0	0.0	9.327170E-05
1001	S	1.000000E-04	7.294850E-06	1.201003E-04	2.244510E-10	1.147000E-15	1.124350E-15

SUBCASE 1

TIME = 0.

A C C E L E R A T I O N   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	0.0	0.0	0.0	0.0	0.0	5.007100E+00
11	G	1.216500E+01	1.402750E+02	0.0	0.0	0.0	1.560515E+00
12	G	8.100352E-01	1.400053E+02	0.0	0.0	0.0	3.034223E-01
13	G	1.216500E+01	1.402750E+02	0.0	0.0	0.0	1.568515E+00
14	G	0.0	0.0	0.0	0.0	0.0	5.007100E+00
1001	S	1.200071E+00	1.175273E+00	2.122487E+01	3.053620E-11	2.027840E-10	2.002630E-10

SUBCASE 1

TIME = 0.

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10	G	1.111924E+01	1.695205E+00	0.0	0.0	0.0	0.0
14	G	1.111924E+01	1.695205E+00	0.0	0.0	0.0	0.0

SUBCASE 1

TIME = 0.

F O R C E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND MOMENT END-B PLANE 1	BEND MOMENT END-B PLANE 2	SHEAR PLANE 1	SHEAR PLANE 2	AXIAL FORCE	TORQUE
1	3.100554E-10	0.0	2.332860E+00	0.0	5.767644E-02	0.0	1.123814E+01	0.0
2	2.332868E+00	0.0	1.033010E+00	0.0	8.406463E-02	0.0	1.120462E+01	0.0
3	1.033018E+00	0.0	2.332860E+00	0.0	8.406463E-02	0.0	1.120462E+01	0.0
4	2.332868E+00	0.0	7.243730E-10	0.0	5.767644E-02	0.0	1.123814E+01	0.0

SUBCASE 1

TIME = 0.

S T R E S S E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	SA1 / SB1	SA2 / SB2	SA3 / SB3	SA4 / SB4	AXIAL STRESS	SA-MAX / SB-MAX	SA-MIN / SB-MIN	M.S.-T / M.S.-C
1	0.0	0.0	0.0	0.0	1.431610E+01	1.431610E+01	1.431610E+01	
	0.0	0.0	0.0	0.0		1.431610E+01	1.431610E+01	
2	0.0	0.0	0.0	0.0	1.427340E+01	1.427340E+01	1.427340E+01	
	0.0	0.0	0.0	0.0		1.427340E+01	1.427340E+01	
3	0.0	0.0	0.0	0.0	1.427340E+01	1.427340E+01	1.427340E+01	
	0.0	0.0	0.0	0.0		1.427340E+01	1.427340E+01	
4	0.0	0.0	0.0	0.0	1.431610E+01	1.431610E+01	1.431610E+01	
	0.0	0.0	0.0	0.0		1.431610E+01	1.431610E+01	

TABLE-14 : SORTED ELFORCE/ELSTRESS OUTPUT IN DECK-3 STEP-C RUN

STEP-C : DATA-BASE RESTART FOR NEW LOADINGS MARCH 4, 1986 MSC/NASTRAN 11/23/83 PAGE 20
ILLUSTRATION OF VARIOUS OPTIONS

SUBCASE 2

TIME = 0.

F O R C E S I N B A R E L E M E N T S (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	SHEAR PLANE 1	SHEAR PLANE 2	AXIAL FORCE	TORQUE
1	1.273346E-10	0.0	0.605670E-01	0.0	2.307100E-02	0.0	4.430500E+00	0.0
2	0.605670E-01	0.0	3.206727E-01	0.0	2.754372E-02	0.0	4.410644E+00	0.0
3	3.206727E-01	0.0	0.605670E-01	0.0	2.754372E-02	0.0	4.410644E+00	0.0
4	0.605670E-01	0.0	2.803470E-10	0.0	2.307100E-02	0.0	4.430500E+00	0.0

STEP-C : DATA-BASE RESTART FOR NEW LOADINGS MARCH 4, 1986 MSC/NASTRAN 11/23/83 PAGE 22
ILLUSTRATION OF VARIOUS OPTIONS

SUBCASE 2

TIME = 0.

F O R C E S I N B A R E L E M E N T S (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	SHEAR PLANE 1	SHEAR PLANE 2	AXIAL FORCE	TORQUE
4	0.605670E-01	0.0	2.803470E-10	0.0	2.307100E-02	0.0	4.430500E+00	0.0
1	1.273346E-10	0.0	0.605670E-01	0.0	2.307100E-02	0.0	4.430500E+00	0.0
2	0.605670E-01	0.0	3.206727E-01	0.0	2.754372E-02	0.0	4.410644E+00	0.0
3	3.206727E-01	0.0	0.605670E-01	0.0	2.754372E-02	0.0	4.410644E+00	0.0

STEP-C : DATA-BASE RESTART FOR NEW LOADINGS MARCH 4, 1986 MSC/NASTRAN 11/23/83 PAGE 24
ILLUSTRATION OF VARIOUS OPTIONS

SUBCASE 2

TIME = 0.

S T R E S S E S I N B A R E L E M E N T S (C B A R)

ELEMENT ID.	SA1 / SB1	SA2 / SB2	SA3 / SB3	SA4 / SB4	AXIAL STRESS	SA-MAX / SB-MAX	SA-MIN / SB-MIN	M.S.-T / M.S.-C
1	0.0	0.0	0.0	0.0	5.643061E+00	5.643061E+00	5.643061E+00	
	0.0	0.0	0.0	0.0		5.643061E+00	5.643061E+00	
2	0.0	0.0	0.0	0.0	5.630120E+00	5.630120E+00	5.630120E+00	
	0.0	0.0	0.0	0.0		5.630120E+00	5.630120E+00	
3	0.0	0.0	0.0	0.0	5.630120E+00	5.630120E+00	5.630120E+00	
	0.0	0.0	0.0	0.0		5.630120E+00	5.630120E+00	
4	0.0	0.0	0.0	0.0	5.643061E+00	5.643061E+00	5.643061E+00	
	0.0	0.0	0.0	0.0		5.643061E+00	5.643061E+00	

STEP-C : DATA-BASE RESTART FOR NEW LOADINGS MARCH 4, 1986 MSC/NASTRAN 11/23/83 PAGE 26
ILLUSTRATION OF VARIOUS OPTIONS

SUBCASE 2

TIME = 0.

S T R E S S E S I N B A R E L E M E N T S (C B A R)

ELEMENT ID.	SA1 / SB1	SA2 / SB2	SA3 / SB3	SA4 / SB4	AXIAL STRESS	SA-MAX / SB-MAX	SA-MIN / SB-MIN	M.S.-T / M.S.-C
4	0.0	0.0	0.0	0.0	5.643061E+00	5.643061E+00	5.643061E+00	
	0.0	0.0	0.0	0.0		5.643061E+00	5.643061E+00	
1	0.0	0.0	0.0	0.0	5.643061E+00	5.643061E+00	5.643061E+00	
	0.0	0.0	0.0	0.0		5.643061E+00	5.643061E+00	
2	0.0	0.0	0.0	0.0	5.630120E+00	5.630120E+00	5.630120E+00	
	0.0	0.0	0.0	0.0		5.630120E+00	5.630120E+00	
3	0.0	0.0	0.0	0.0	5.630120E+00	5.630120E+00	5.630120E+00	
	0.0	0.0	0.0	0.0		5.630120E+00	5.630120E+00	