VIBRATION ANALYSIS AND DESIGN OPTIMISATION STUDIES OF SPACE FRAMES - DYNAMIC ANALYSIS

VIBRATION ANALYSIS AND DESIGN OPTIMISATION STUDIES OF SPACE FRAMES

II - DYNAMIC ANALYSIS

By

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SCOPE AND CONTENT:

An oblique four bar structural model with fixed member ends, being the most general building for space frames, is analysed under free and steady-state vibrations, using discrete mass method.

Experimental techniques for measurement of free and steady-state vibrations are described.

Experimental results have been compared against analytical ones.

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ABSTRACT

This research programme has the general objective of establishing analytical techniques for analysis of indeterminate spatial frames and shells under dynamic loading. Although techniques developed should have wide applicability, emphasis will be placed, for experimental and illustrative purposes on structural configurations common to machine structures.

The present work is concerned with the dynamic analysis which is an extension of the static analysis, performed in the first stage [39] of the programme.

For the initial stage of the project a highly redundant oblique four bar space frame was selected to investigate the nature of problems involved in the optimisation of generalized space frames subject to dynamic constraints.

For establishing the inertial characteristics of the system, the discrete mass method has been used. The response of the system has been investigated under free and forced vibrations.

In the free vibration analysis six ascending computed natural frequencies were in agreement within 15 percent of the measured frequencies. The amplitudes of vibration measured at different points away from the natural frequencies, were also in agreement.

Related studies [40] will examine the optimisation problems.

INTRODUCTION

This research programme has the general objective of establishing analytical techniques for analysis of indeterminate spatial frames and shells under dynamic loading, and the design optimisation of these structures under the constraints of dynamic loading. Although the techniques developed should have wide applicability, emphasis will be placed, for experimental and illustrative purposes, on structural configurations common to machine structures.

The present work relates to the second phase of the programme in which the problem is explored by discretizing the structure into a lumped mass system, with each mass connected by springs. The first phase of this programme i.e. the static analysis has already been completed. More specifically, this thesis is concerned with dynamic analysis. The structure is studied experimentally and analytically under free vibrations. The effect of rigid body inertia is also investigated. Vibration response under steady state sinusoidal excitation is studied analytically and experimentally, with and without structural damping. Related studies will examine the optimisation problem. The following discussion reviews the overall programme.

Design synthesis essentially is an evolutionary spiral process involving a complex feed back interrelating the fields of creativity, past experience and tools of analysis. The role of the designer is to optimise the value of a synthesis on the basis of some criteria established through a balanced exploitation of the evergrowing information from all three fields. The basic techniques and the criteria of evaluation themselves need refinement from time to time in the light of achievements in the foregoing areas.

The process has been marked with rather slow progress in the field of mechanical engineering structures, mainly due to their complex nature. These have not received the intensive investigation that civil and aerospace engineering configurations have. Analysis of mechanical engineering structures has perhaps lagged behind because they are much more difficult to categorise than structures in the other fields where a few highly typical configurations can be recognised, modelled and studied in a concentrated way. In addition, the analytical tools available until lately have had their own limitations.

These methods can be broadly classified into two divisions (1) and (2).

1. Methods based on exact solution of the differential equations describing the structure.

   Apart from the difficulties in setting up and solving the equations subject often to awkward conditions, the basic assumptions regarding complex structures have proved to be too restrictive for accurate solution.

2. Approximate methods involving mathematical approximations can be subclassified into -

(a) Those based on finite difference procedures. These are unsatisfactory in their formulation of boundary conditions and convergence characteristics, and

(b) Those which approximate stress or displacement distribution by a series of analytical expressions and hence are unsuited for complex structures.

The classical analytical tools are thus incapable of providing an integrated approach even for structures of moderate complexity. Hence it is not surprising that the practical design of mechanical engineering structures has relied more on past practical experience, supported by rough analytical checks wherever possible, rather than on the analytical tools.

The need for a tool well suited to complex configurations was most acute in the aircraft industry where the designer had to work within extremely narrow margins of practical expediency [3].* Extensive efforts over the years by numerous, and often isolated workers, culminated in the finite element approach which is a major breakthrough from the past.

Based on structural as against mathematical approximation, the method essentially seeks to idealize the structure into an assembly of a finite number of discrete elements connected at a finite number of points, and then proceeds to solve for the system response on an exact mathematical basis. The basis of the technique is finite connectivity which permits a complex continuous structure to be analysed by

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* Numbers in brackets refer to references.

a system of algebraic equations. Although earlier work was restricted to the field of areonautical engineering, recently results of applications to nonaeronautical problems [4], [5], [6] and extensions to three dimensional discrete elements [7] have been reported.

It is realized that, although the finite element technique is still being developed, it provides a unified approach to the analysis of any type of structural assembly, from any field and with any combination of one, two or three dimensional elements of different characteristics [4]. It thus provides a reliable analytical tool which is prerequisite to design synthesis.

A rather limited amount of work appears to have been done on the general problem of elastic vibrations of structures and the problem of optimisation under vibrational constraints, although techniques for calculating the natural modes and frequencies of lumped mass spatial structures are fairly well established for essentially beam-like aircraft structures, and to a lesser extent the rectangular frames of civil engineering. V. H. Neubert [34], [35] investigated a symmetric foundation like structure under free and transient loadings. The significance of rigid body inertia and structural damping in spatial frames does not appear to have been studied. Archer [8], [9], has provided two useful new papers in this field and has related it to the finite element stiffness matrix technique. In an attempt to improve the accuracy of dynamic analysis as it is affected by the mass matrix; a consistent mass matrix construction is investigated that accounts for the actual distribution of mass throughout the structure in a manner similar to Rayleigh-Ritz formulation.

Another method of analysis has grown out of the well known methods of Holzer, Myklestad and Thomson [38]. It has been generalized by Pestel and Associates and is described as a method of transfer matrices. The computations require the trial values of frequency in the transfer matrices.

Another powerful method of analysis has been applied to frames by Bishop [36], [37]. This is also a trail-and-error method. Hurty [10] has developed a method for analysing complex structrual systems. In this method of analysis, the elastic and inertial properties of each component are determined seperately. And then the properties of the entire system are synthesized. Unlike Rayleigh-Ritz [38] method, the mode shapes applicable to the entire system are not defined at the outset. Instead, they are synthesized from mode shapes that are selected for the seperate elements of the system.

The concept of optimum design has registered a drastic change since the advent of high speed digital computers. Earlier, the magnitude of computation involved acted as a deterent, and a feasible solution was accepted in lieu of the optimum. With computers to handle the arithmetic, systemic design synthesis has become a reality.

Very many general techniques of optimisation appear in the literature that might be applied to structural optimisation. Most promising are the Direct Search Method first suggested by Hooke and Jeeves and further developed by Flood and Leon [11], the Method of Successive Linear Approximation due to Griffith and Stewart [12], and the Random Method of Dickinson [13].

Minimisation of weight, weight stiffness ratio, cost, volume for homogeneous structures, etc. have been suggested as criteria for optimisation of structures. But, minimisation of weight appears to have been accepted as the most satisfactory one, even though the minimum weight design is not always the minimum cost design.

The optimisation of a statically determinate truss subjected to a single loading is a problem in analysis rather than synthesis. For strength design, member cross sections are proportioned to develop maximum allowable stress for the required failure mode. For optimum stiffness design based on minimization of weight per unit stiffness, (stiffness being defined as the reciprocal of strain energy) the members should carry stresses proportional to the square root of the product of the modulus of elasticity and specific weight. The constant of proportionality is based on stiffness requirements [14].

For a given determinate truss under multiple load condition the problem essentially remains the same. All the member cross sections carry the maximum allowable stress, based on strength or stiffness design, under at least one load condition. The optimum design has come to be recognised as a fully stressed design.

In the case of indeterminate trusses, for a given configuration, applied loading and allowable stress, the cross sectional area of the members and hence the weight of the structure are functions of forces in the redundant members. Sved [15] has shown analytically that under single load conditions the minimum weight structure is always determinate.

Using the Lagrange multiplier technique, L. C. Schmidt [16] has shown that under alternate loads numerous fully stressed designs of an indeterminate truss exist. Due to the prohibitive nature of computations involved in arriving at the minimum weight he has suggested two complementary relaxation methods to arrive at a fully stressed design.

The beginning of the present decade marked a radical departure in the approach to structural optimisation. It came to be accepted as a problem in mathematical programming with Schmit [17] as the pioneer. Utilizing the joint force and displacement formulation of structural analysis as first proposed by Klein [18], he has optimised a fixed configuration three bar truss subject to three alternate loads. He treated it as a problem in nonlinear programming by adopting a modified steepest descent method designated as the method of alternate steps. On encountering an inequality constraint, which must be convex, the search moves along a constant weight plane in the feasible region until the constraint is again contacted. It then steps back halfway, and then continues to move along the steepest slope. On the basis of numerical results he concludes that in terms of design parameter space the minimum weight design need not be a fully stressed design lying at the apex of constraint hyperplanes.

Subsequently [19], [20] in collaboration with Mallett and Kicher he extended the above to the problem of selecting a suitable configuration and material for the three bar truss. Various optimum designs were compiled by changing the material or configuration, one at a time in discrete steps. The best of all these designs was chosen.

Dorn et al [21] have proposed a linear programming method which selects the optimum combination of configuration and member cross section from wide classes of admissible trusses defined by a given number of admissible joints connected in all possible ways by linear members. The optimisation is based on modified simplex method capable of handling large number of equations. The results provide an interesting study in the behaviour of optima due to change in load and the height-span ratio of the truss. The configuration remains the same for the load for a certain change in height-span ratio α, and then alters, as α continues to change. Thus a continuous spectrum is provided from which the value of α giving the absolute minimum weight truss and the configuration itself could be selected.

Best [22] has optimised a cantilever box beam by the steepest descent method. It has one unique feature. The partial derivations of stress and deflections with respect to the design parameters are calculated by the finite difference approximation using the stiffness matrix, which must be inverted to obtain the deflections. To avoid the time consuming process of inversion at every step he adopts an iterative scheme to obtain the deflections. Only the incremental stiffness matrix for a given change in design parameter is calculated which, in conjunction with the previously inverted stiffness matrix, rapidly converges to the required displacements on iterations. This feature is said to substantially reduce the calculation time. Constraints on stresses and deflections are handled by a version of the reduced gradient method. His solution is a maximum stress solution, and thus forced to be on a boundary.

The presentation of the structural synthesis as an unconstrained minimisation problem by Schmit and Fox [23] is unique. It is based on the method of solving linear simultaneous equations by minimising the sum of squares of the residuals to zero. This expression is set up for the equality constraint defining the stresses. To this is added penalty terms for violated inequality constraints, which are all simple upper and lower bounds. The actual quantity to be optimised, the weight, is treated as an inequality constraint, requiring that the weight be less than an arbitrarily defined draw down weight. The problem is now an unconstrained optimisation problem solved by a gradient method. It is repeated using progressively lower draw-down weights until the optimisation function can not be made zero. This indicates that the draw-down weight is lower than the inherent minimum weight. The method thus actually requires a series of optimisations. It does not seem too applicable to complex problems; as the constraints must be expressed explicitly in order to set up the residuals. The implicit matrix form of equality constraints are ruled out.

Razani [24] has proposed an unconventional approach using an iterative technique in which areas are changed by successive increments from an initial feasible solution so that each member is fully stressed in at least one of the several possible load conditions. This gives a feasible solution forced to be on a boundary. The true minimum may not be on a boundary if the stress is indeterminate.

The gradient projection technique has been successfully adopted by Brown and Alfredo [25] to optimise a portal frame and a two storey single bay frame. The search being at a feasible starting point until constraints are encountered. At this point the constraint hypersurfaces are approximated by hyperplanes and the gradient of the objective function is projected on the line of intersection of these planes. After a move along the indicated direction a correction is indicated due to the nonlinearity of the constraint hypersurfaces. The authors have proposed the use of only one design parameter for a member as variable, while the rest of the parameters for the same member, are expressed as functions of the selected one. As moment of inertia of the members has a predominant effect on the behaviour of the structure, other parameters are expressed as functions of moment of inertia. Inspite of this simplification the procedure seems too involved for complex structures.

Young and Christiansen [14] have provided the first known optimal structural design technique using vibrational constraints using an iterative technique. Adjustment of the member area to achieve a fully stressed design simultaneously with the required resonant frequency characteristic is the main feature. An application to pin jointed space truss is included.

THE PHYSICAL MODEL

For the first stage of project it was decided to examine a simple but highly redundant space frame with generalized characteristics. An oblique and asymmetric four bar frame was selected see Figure 1. The four bars, spaced on 24 inch centres, are welded at their base to a half inch thick aluminium plate. At the other end the bars are spaced on two and a half inch centres and welded to a half inch thick aluminium plate. To avoid deflection of the base plate (as compared to the deflection of members) it in turn was bolted to a steel plate. The structure was excited on the top plate in the three orthogonal x, y and z directions.

THEORETICAL ANALYSIS

As the stiffness matrix was obtained from the previous work [39], it was necessary to derive the mass matrix to investigate the dynamic behaviour of the structure. For deriving the mass matrix, the decision was made to gross lumping of masses. Techniques for calculating the natural modes and frequencies of complex structure by lumping the masses are well established, but the labour involved was too much.

THE MATHEMATICAL MODEL

The analytical procedure uses two mathematical models - static and dynamic. The latter is usually an extension of the previous one. Accuracy of analytical results depends upon the number of mass points selected, but it increases the labour involved. As a compromise each member was discretised into three equal lengths.

For the whole analysis, the top plate was treated as being rigid due to its relatively small size and comparatively large thickness. The plate mass was lumped at its centre and four corners. The mass of each span was lumped at its ends. The analysis was performed by considering the rigid body inertia. Thus the mass of the whole structure was lumped at thirteen discrete points, which from hereafter will be referred as nodes or stations. The various node positions are shown in Figure 1.

ANALYSIS

The analysis was restricted to motions of small amplitudes. In the theoretical analysis, the elastic and inertial properties of each element are determined seperately. Lagrange's equations are written for each component. As related to each separate component, Lagrange's equations constitute a set of independent equations of motion. However, when the components are attached to each other to form a structural system, it is necessary that the displacements of connected components be compatible at their point of connection. This compatibility requirement gives rise to a set of constraint equations which serve to relate the coordinate system. Through the use of these equations of constraints a set of system - generalized coordinates is determined. The number of system generalized coordinates is equal to the total number of component coordinates minus the number of constraint equations.

The objective of the analysis is to formulate and solve a system of equations of motion, the solution of which yields the dynamic response of the system. Written in matrix form and using the generalized coordinates, these equations appear as follows for an undamped structural system:

$$[M]\{\ddot{q}\} + [K]\{q\} = \{Q(t)\} \tag{1}$$

where:

$\{q\}$ = a column matrix of generalized displacements

$\{\ddot{q}\}$ = a column matrix of generalized accelerations

$[M]$ = a square symmetric matrix of generalized masses

$[K]$ = a square symmetric matrix of generalized stiffnesses

$\{Q(t)\}$ = a column matrix of time-dependent generalized forces

For a damped system, this matrix equation will be modified by the addition of a damping term. Two different concepts are frequently used in describing linear damping in structures, the "structural" damping concept and the "viscous" damping concept. For structural damping, Equation (1) is modified as follows:

$$[M]\{\ddot{q}\} + (1 + ig)\,[K]\{q\} = \{Q(t)\} \tag{2}$$

where:

g = structural damping factor

i = the unit imaginary number

The analysis has been classified into three categories as follows:

(1) Response of the structure to free vibrations

(2) Response of the undamped structure to steady-state sinusoidal excitation.

(3) Response of the damped structure to steady-state sinusoidal excitation.

FREE VIBRATIONS

For undamped free vibrations Equation (2) reduces to:

$$[M]\{\ddot{q}\} + [K]\{q\} = 0 \tag{2a}$$

These equations are derived from similar equations formulated for each one of the components seperately. Consider, for example, the sth component of a system. The equation for this component under free vibrations is written as follows:

$$[m]_s\{\ddot{d}\}_s + [k]_s\{d\}_s = 0 \tag{3}$$

where

$\{d\}_s$, $\{\ddot{d}\}_s$ = column matrices of time-dependent displacements and accelerations, respectively, in system coordinates

$[m]_s$, $[k]_s$ = square symmetric matrices of generalized mass and stiffness coefficients, respectively, pertaining to sth component in system coordinates

Equations similar to Equation (3) may be written for all components of the system. All of these equations may then be written compactly in the following uncoupled form for a system having an arbitrary number of components.

$$[m]\{\ddot{d}\} + [k]\{d\} = 0 \tag{4}$$

where

$$[m] = \begin{bmatrix} [m]_1 & & & & \\ & [m]_2 & & & \\ & & \ddots & & \\ & & & [m]_r & \\ & & & & \ddots \\ & & & & & [m]_s \\ & & & & & & \ddots \end{bmatrix}$$

$$[k] = \begin{bmatrix} [k]_1 & & & & \\ & [k]_2 & & & \\ & & \ddots & & \\ & & & [k]_r & \\ & & & & \ddots \\ & & & & & [k]_s \\ & & & & & & \ddots \end{bmatrix}$$

$$\{d\} = \begin{Bmatrix} \{d\}_1 \\ \{d\}_2 \\ \{d\}_r \\ \{d\}_s \end{Bmatrix} \quad \text{and} \quad \{\ddot{d}\} = \begin{Bmatrix} \{\ddot{d}\}_1 \\ \{\ddot{d}\}_2 \\ \{\ddot{d}\}_r \\ \{\ddot{d}\}_s \end{Bmatrix}$$

Equation (4) can be considered as a set of equations of motion for a group of components not connected together. These equations of motion f various members are connected to each other to form the system equations by using displacement compatibility conditions. These displacement compatibility relationships are thought of as equations which introduce kinematic constraints among the components of displacement vector {d}, so that these may no longer be regarded as generalized displacements in the connected system. If there are g components in the vector {d} and if there exists f constraint equations then there will be h = g - f equations which will be independent. In general, if each mass has 6 degrees of freedom, a system of n masses will have 6n degrees of freedom. As, the system has been discretised into thirteen masses, the vector {d} will have 78 components. However, all these displacements are not independent. So {d} and {q} can be related by a transformation matrix [B], as follows,

$$\{d\} = [B]\{q\} \tag{5}$$

Substituting Equation (5) into Equation (4) we get

$$[m][B]\{\ddot{q}\} + [k][B]\{q\} = 0$$

Premultiplying the above equation by the transpose of the transformation matrix, $[B]^T$, gives

$$[B]^T[m][B]\{\ddot{q}\} + [B]^T[k][B]\{q\} = 0$$

This equation is compared with Equation (1). The following identities are clearly shown:

$$\begin{aligned} [M] &= [B]^T[m][B] \\ [K] &= [B]^T[k][B] \end{aligned} \tag{6}$$

As already indicated, the generalized stiffness matrix was obtained from the first phase, so the generalized mass matrix was derived in this way. Since the plate is regarded as being rigid, the motion of the five plate masses are not independent of each other. Their displacements are related by an equilibrium matrix [31]. Motion of the corner masses is defined in terms of the central mass displacements.

If vector $\{d\}_p$ has displacement of any corner mass, and the vector $\{d\}_c$ has displacements of the central mass, then

$$\{d\}_p = [H]^T \{d\}_c$$

where:

$[H]^T$ = transpose of equilibrium matrix

In this way thirty displacements of five masses are represented by six displacements of the central mass. By using these constraints we derive a [B] matrix of the order of 78 x 54. So the column vector {d}, which had 78 components, reduces to column vector {q}, which has 54 components. And the transformation matrix will be of the following form:

$$[B] = \left[\begin{array}{c|c} [I] & \\ \hline & H^T \end{array}\right]$$

where

[I] = is the identity matrix.

Finally the generalized mass matrix is derived from Equation (6). The equation of motion

$$[M]\{\ddot{q}\} + [K]\{q\} = 0 \tag{7}$$

for free vibrations can also be written in an alternate form by premultiplying Equation (7) by $[\delta]$ = flexibility matrix Equation (7) reduces to:

$$[\delta][M]\{\ddot{q}\} + \{q\} = 0$$

or (8)

$$\{q\} = -[\delta][M]\{\ddot{q}\}$$

An alternate form of equation (7) can also be written as:

$$\{\ddot{q}\} = -[M]^{-1}[K]\{q\} \tag{9}$$

Assuming a solution of the form

$$\{q\} = \{U\} \sin wt, \tag{10}$$

equations (7), (8) and (9) yield alternate forms of frequency equations. Substituting Equation (10) into Equation (7) we get

$$\omega^2[M]\{U\} - [K]\{U\} = 0 \tag{11}$$

This is an eigenvalue problem. The solution for ω^2 is obtained by the JACOBI rotation method [14]. This method diagonalizes the symmetric positive definite matrix by applying successive rotations So [M] is diagonalised in the following form

$$[M] = [V][D][V]^T \tag{12}$$

where:

[D] = a diagonal matrix

[V] = modal matrix

Substituting Equation (12) in Equation (11) we obtain,

$$[K]\{U\} = \omega^2[V][D][V]^T\{U\} \tag{13}$$

Premultiplying both sides of Equation (13) by $[V]^T$, we obtain:

$$[V]^T[K]\{U\} = \omega^2[V]^T[V][D][V]^T\{U\}$$

Noting, for an orthogonal transformation

$$[V][V]^T = \text{unity},$$

so the above equation can be written as,

$$[V]^T[K][V][V]^T\{U\} = \omega^2[D][V]^T\{U\}$$

If

$$[H] = [V]^T[K][V], \text{ and}$$

$$[Y] = [V]^T\{U\} \quad \text{then}$$

$$[H]\{Y\} = \omega^2[D]\{Y\} \tag{14}$$

[D] is factorised as

$$[D] = [G][G]$$

Equation (14) reduces to,

$$[H]\{Y\} = \omega^2[G][G]\{Y\} \tag{15}$$

Premultiplying equation (15) by the inverse of matrix [G], we have

$$[G]^{-1}[H][G]^{-1}[G]\{Y\} = \omega^2[G]\{Y\}$$

If $[G]^{-1}[H][G]^{-1} = [Q]$, and

$[G]\{Y\} = \{Z\}$, then

$$[Q]\{Z\} = \omega^2\{Z\}$$

The eigenvalues so obtained are true eigenvalues but true eigenvectors are obtained from the following equation

$$\{U\} = [V][G]^{-1}\{Z\} \tag{16}$$

So in this way mode shapes and natural frequencies were obtained.

Equation (8) can also be solved, in a similar way. After substituting Equation (10) into Equation (8) we get

$$[\delta][M]\{U\} - \frac{1}{\omega^2}[I]\{U\} = 0 \tag{17}$$

If [M] is factored so $[M] = [L]^T[L]$ [39] and Equation (17) is premultiplied by [L], Equation (17) becomes

$$[L][\delta][L]^T[L]\{U\} - \frac{1}{\omega^2}\{I\}[L]\{U\} = 0$$

If we write $[L]\{U\} = \{P\}$, and $[L][\delta][L]^T = [R]$ then the problem reduces to simple eigenvalue problem;

$$[R][P] = \frac{1}{\omega^2}[P]$$

Here matrix [R] is essentially a symmtric matrix, hence can be diagonalised by JACOBI plane rotations. The diagonal elements will be the inverse of the natural frequencies. Again, natural frequencies so obtained will be true, but mode shapes have to be obtained from

$$\{U\} = [L]^{-1}\{P\}$$

Similarly the eigenvalue problem of equation (9) was solved by using library subroutine EBERVC. It is interesting to note that the time taken by the computer in three different cases was very much different. Solution of Equation (7) took 17 minutes of time, while solution of Equation (8) and Equation (9) took 6 minutes and 29 minutes respectively. The form resulting from Equation (8) is usually preferred in calculating lower frequencies [35]

STEADY-STATE ANALYSIS

Equation (1) is for an undamped structural system under steady-state excitation.

Consider again the equation

$$[M]\{\ddot{q}\} + [K]\{q\} = \{Q(t)\}$$

In analysing the system, the classical normal mode approach will be adopted and it will be referred as modal analysis. It should be observed that the excitation functions Q(t) are arbitrary functions of time. The above equation can be re-written as follows:

$$[\delta][M]\{\ddot{q}\} + \{q\} = [\delta]\{Q(t)\} \tag{18}$$

To use the modal analysis the eigenvalue problem resulting from Equation (8) will be utilized.

Again factorising $[M] = [L]^T[L]$ and on substitution in Equation (18)

$$[\delta][L]^T[L]\{\ddot{q}\} + \{q\} = [\delta]\{Q(t)\} \tag{19}$$

Premultiplying Equation (19) by [L]

$$[L][\delta][L]^T[L]\{\ddot{q}\} + [L]\{q\} = [L][\delta]\{Q(t)\} \tag{19a}$$

Substituting $[L][\delta][L]^T = [R]$

Equation (19a) becomes

$$[R]\{\ddot{Y}\} + \{Y\} = [L][\delta]\{Q(t)\} \tag{20}$$

Assuming the transformation,

$$[Y] = [V]\{\eta\}$$

where:

$[V]$ = modal matrix

$\{\eta\}$ = column matrix consisting of a set of time dependent generalised coordinates

Substituting above transformation in Equation (20)

$$[R][V]\{\ddot{\eta}\} + [V]\{\eta\} = [L][\delta]\{Q(t)\}$$

Premultiplying the above equations by $[V]^T$

$$[V]^T[R][V]\{\ddot{\eta}\} + [V]^T[V]\{\eta\} = [V]^T[L][\delta]\{Q(t)\}$$

Noting that $[V]^T[V]$ = unity,

and putting $[V]^T[L][\delta]\{Q(t)\} = \{N\}$,

the above equation reduces to

$$[V]^T[R][V]\{\ddot{\eta}\} + \{\eta\} = \{N\} \tag{21}$$

In view of its eigenvalue problem, Equation (21) can be re-written

$$\frac{1}{\omega_r^2}\{\ddot{\eta}\} + \{\eta\} = \{N\}$$

which represents a set of uncoupled differential equations of the type

$$\frac{1}{\omega_r^2}\ddot{\eta}_r(t) + \eta_r(t) = N_r(t) \qquad r = 1, 2 \ldots., n, \tag{22}$$

which have precisely the form of the differential equation describing the motion of an undamped single-degree-of-freedom system. Hence modal analysis uncouples the equations of motion by means of a linear transformation; the transformation matrix is just the modal matrix.

Assuming sinusoidal excitation

$$N(t) = N \sin \omega t$$

each equation is solved in η coordinates and then displacements are transformed to q coordinates by the following transformation

$$\{q\} = [L]^{-1}[V]\{\eta\} \tag{23}$$

The Steady-state solution of Equation (20) in original coordinates is

$$\{q\} = \frac{[L]^{-1}[V]\{N\} \sin \omega t}{[1 - (\omega/\omega_r)^2]} \tag{24}$$

where ω is frequency of excitation.

STEADY-STATE VIBRATIONS WITH STRUCTURAL DAMPING

When structural damping is considered then the equations of motion of the system are given by Equation (2), which is written below.

$$[M]\{\ddot{q}\} + (1 + ig)[K]\{q\} = \{Q(t)\} \tag{25}$$

It is customary to assume that the hysteretic damping matrix is porportional to the stiffness matrix [41], implying that all the coefficients of g have the same value.

The structural damping concept, as considered here, is valid only in dealing with steady state harmonic response. The reason for this is that the damping force is considered to be proportional in magnitude to the amplitude [38], but 90° out of phase with it. Since the damping force is 180° out of phase with velocity, this means that the concept of structural damping holds rigorously for motion in which velocity and displacement differ by 90°. This is true in harmonic motion. Therefore, one is interested in solving Equation (25) to obtain the steady state response to a harmonic exciting force

Again dividing Equation (25) by [K] and applying the linear transformation of Equation (23), it will be uncoupled into the following form.

$$\frac{1}{\omega_r^2}\ddot{\eta}_r + (1 + ig_r)\,\eta_r = N_r(t)$$

The force $N_r(t)$ is represented as follows:

$$N_r(t) = N_{or}e^{i\omega t}$$

where:

N_{or} = magnitude of force

ω = frequency of excitation

The steady-state solution is written in the following form

$$\eta_r(t) = \frac{N_{or}\ e^{i\omega t}}{[(1 - \frac{\omega^2}{\omega_r^2})^2 + g_r^2]^{1/2}} \qquad (26)$$

where the response lags behind the force by phase angle . This is given by following relationship:

$$\tan\psi = \frac{g_r}{1 - (\frac{\omega}{\omega_r})^2} \qquad (27)$$

As in the case of undamped motion, the generalized response vector {q} may be found using transformation Equation (23), from the separate responses expressed in normal coordinates as determined from Equations (26) and (27).

The following computer programmes were used in the analysis:

SUBROUTINE GMASM

This subroutine calculates the generalized mass matrix.

SUBROUTINE EVERVC

This subroutine calculates the eigenvalues and eigenvectors of a unsymmetric matrix resulted from the eigenvalue problem of Equation (9).

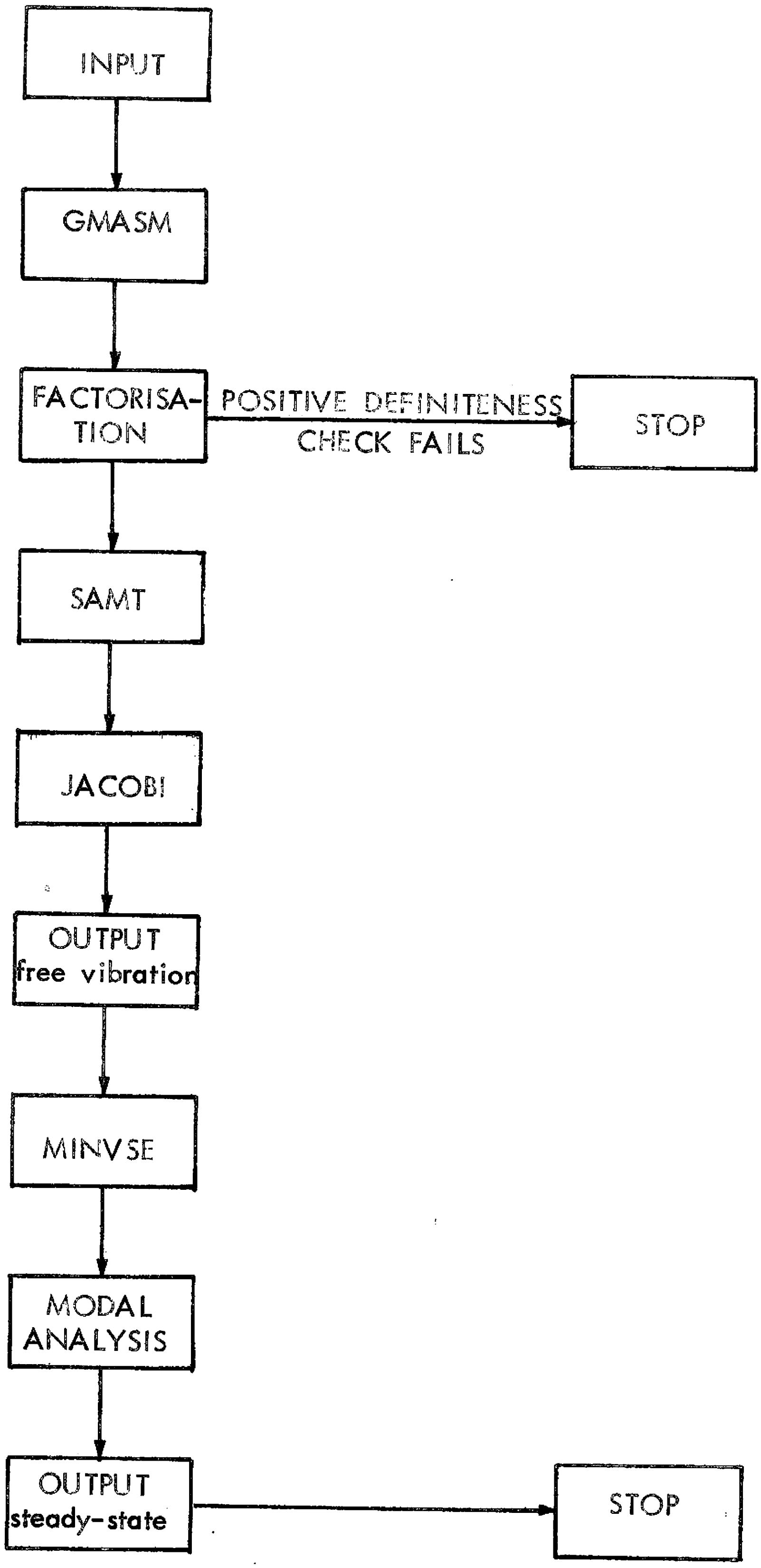
SUBROUTINE JACOBI

This subroutine was used in the eigenvalue problem of Equations (7) and (8). This diagonalizes a real symmetric and positive definite matrix.

MAIN PROGRAMME

Three different main programmes were written corresponding to Equations (7), (8) and (9) for predicting the response of system under free vibrations. However, for predicting the steady state the response with and without damping, the programme corresponding to Equation (8) was used because it was more expedient.

FLOW CHART


INPUT
GMASM
FACTORISATION
POSITIVE DEFINITENESS CHECK FAILS
STOP
SAMT
JACOBI
OUTPUT free vibration
MINVSE
MODAL ANALYSIS
OUTPUT steady-state
STOP

EXPERIMENTAL ANALYSIS

Concurrent with the theoretical analysis, the system behaviour was also investigated experimentally. Initially the structure was mounted on a square channel framework. Excitation at higher frequencies resulted in excessive vibration of the base plate. Cross stiffeners were added to the frame work to eliminate this vibration and the base plate was bolted down onto them. However, during the static test it was observed that the base plate still had some deflection. Further improvements resulted in the base being supported on two steel bars of 6" x 6" cross section.

For determining the natural frequencies of the structure it was excited by a sinusoidal force in three orthogonal x, y and z directions. A 30 pound electromagnetic vibration exciter was used as the force generator. Soft mounting was chosen. For exciting in the x and y directions, the shaker was supported on a square aluminum plate, which in turn was suspended by nylon strings from the pipe superstructure, Figures 4 and 5. For the z direction, the shaker was mounted on the tripod which carried an inflated inner tube, Figures 6 and 7.

Thirty two strain gauges were mounted on the four pipes near each node point, Figures 3 and 4. All the strain gauges were connected to a switch and balance unit. Output from the switch and balance unit was connected to a cathode ray oscilloscope. The shaker was powered through a power amplifier which in turn was connected to an R. C. generator. An ammeter was connected in series with the shaker to keep the current constant. This ensured constant amplitude of the exciting force. The amplitude and frequency of excitation was regulated on the control panel of the power amplifier. Due to the complex nature of the structure experimental determination of the mode shape was not possible.

A capacitance type proximity transducer, coupled through an oscillator and reactance converter to a cathode ray oscilloscope was adopted to measure the amplitude. The system of measurement is based on frequency modulation of a carrier wave. The transducer consists of a fixed electrode. Any flat conducting surface parallel to the fixed electrode can act as the moving electrode. The capacitance of the electrodes is in parallel with another fixed capacitance. The combination forms a series resonant circuit with an inductance. The change in distance between the electrodes, due to vibration of structure caused a change in reactance in the resonant circuit which is used to change the frequency of the signal delivered by the oscillator. The signal is amplified and detected to provide a proportional D. C. voltage which was metered on the oscilloscope. The transducer was calibrated for each setting of observations, by the integral micrometer. The calibration enabled the displacement to be evaluated. The least count of the micrometer was 0.01 mm.

The force gauge, piezoelectric type, was employed to measure the excitation amplitude. The force gauge was mounted in between the shaker and the steel rod which is bolted to the structure, Figures 8 and 9. Force applied to the Force Link is converted by the quartz crystal sensor to an electrostatic charge signal. This charge signal is proportional to the force applied along the sensitive force axis of the load cell. A charge amplifier is used to convert the electrostatic charge signal from the force link to a useful voltage signal corresponding in magnitude and polarity to the charge input. The electronics of the charge amplifier utilizes a feedback capacitor and feedback resistor to determine the time constant, frequency response, and gain characteristics of the charge amplifier. The calibration of the measuring system was accomplished by applying known static loads. The output of the charge amplifier was displayed on the screen of the cathode ray oscilloscope.

Amplitudes of vibration were recorded corresponding to two values of excitation. A force of 15.8 pounds amplitude was applied to take the observations away from the resonance. Near resonance observations were taken by applying the excitation force of 3.32 pounds amplitude. The force was kept constant by keeping the ammeter current to the required value, while changing the frequency. Amplitudes of vibration were recorded on different stations, in different directions and under varying directions of excitations. The transducer was oriented along the system axes and the observations were recorded. It was possible to measure the linear displacement only.

The effect of rotations in the measurement of linear displacements could not be accounted for. Linear displacements were measured in the coordinate directions where magnitude of rotations was comparatively small.

RESULTS AND CONCLUSIONS

A comparative study of analytically calculated and experimentally measured natural frequencies is made in Table I of Appendix I. It can be seen that theoretical and experimental values of natural frequencies are in agreement.

Table II of Appendix I shows the values of six natural frequencies in ascending order, when rigid body inertia was completely neglected and when it was included on only plate station. Comparing the values of Tables I and II of Appendix I, it can be concluded that rigid body inertia plays an important role. This is because the magnitude of angular influence coefficients was comparable to the linear ones. The values of natural frequencies when rigid body inertia was considered on (a) all stations, (b) on plate only, (c) neglected all together, are in ascending order.

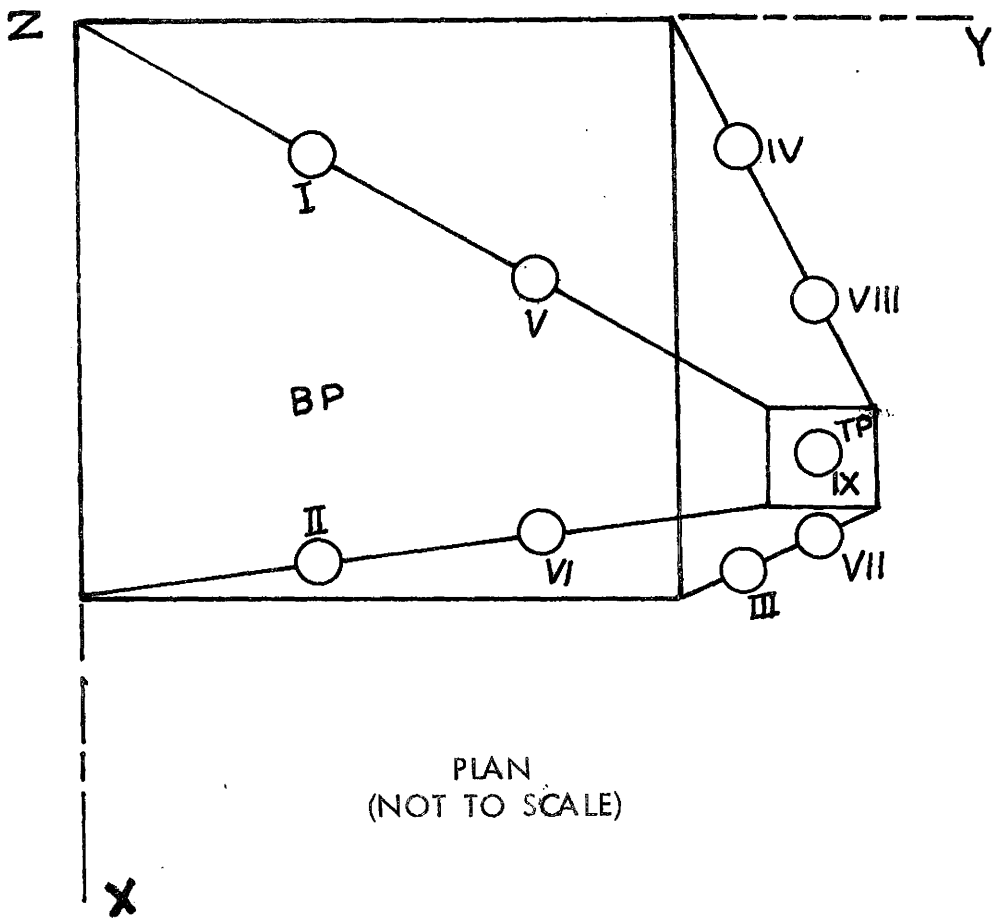
The graphs (see Appendix II) are plotted to study the steady-state response of the structure. Each graph illustrates the theoretical and experimental response of undamped and damped structure.

It can be observed that, away from resonance, the theoretically calculated and experimentally measured values of amplitude are very close. But, at the resonance no fixed pattern is observed. At some points experimental values are higher than the theoretical values, (see Graphs 5, 7, 12). And at other points the experimental values are lower than the theoretical values. The reason could be that near resonance angular displacements are comparable in magnitude to linear ones. It is interesting to note that in all graphs there is no peak corresponding to second natural frequency. This is because the first and second natural frequencies are very close and the system response overlaps considerably.

The graphs also show the response of the damped structure. The value of the damping coefficient was assumed to be .01. Away from the resonance, the effect of damping is negligible, so the response of undamped and damped structure overlaps, except near the resonance. It can be seen (Graphs 1 through 12) that at and near the resonance experimental and theoretical values of vibration amplitudes do not follow any fixed pattern. In some of the graphs (nos. 4, 10, 11) the experimental values of the amplitudes of oscillation are lower than corresponding values of the amplitude of damped oscillation, while in others they are higher. This is because of the unpredictable behaviour of angular displacements, due to their random nature of variations and the actual value of damping is not known.

It is concluded that the discrete lumping of masses gives satisfactory results. Due to the obliquity and assymetry of the structure the rigid body inertia played an important role. Away from the resonance, experimental and theoretical values of the amplitude of oscillation are in agreement.

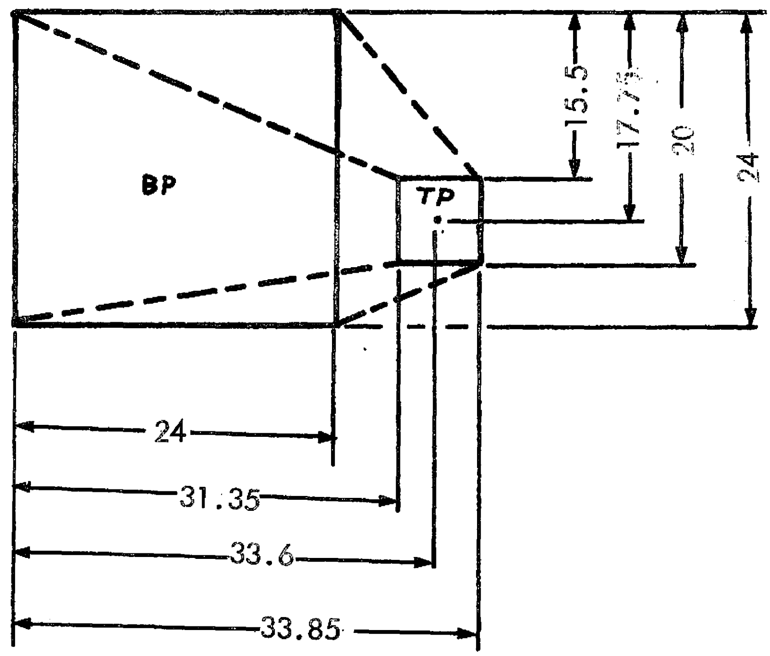
FIGURES



PLAN
(NOT TO SCALE)

FIGURE 1 DISCRETISED MATHEMATICAL MODEL

I ETC - NODE POINTS
TP - TOP PLATE
BP - BOTTOM PLATE
XYZ - SYSTEM COORDINATE AXES



PLAN
(NOT TO SCALE)

ALL DIMENSIONS IN INCHES

FIGURE 2

MODEL DIMENSIONS AND MATERIAL PROPERTIES

OUTER DIA. OF ELEMENTS	1.03 IN.
INNER DIA. OF ELEMENTS	0.824 IN.
AREA OF CROSS SECTION OF ELEMENTS	0.326 SQ. IN.
MOMENT OF INERTIA OF ELEMENT CROSS SECTION	0.03636 $IN.^4$
POLAR MOMENT OF INERTIA OF ELEMENT CROSS SECTION	0.07272 $IN.^4$
MODULUS OF ELASTICITY	10,300,000 $LBS/IN.^2$
MODULUS OF RIGIDITY	3,850,000 $LBS./IN.^2$

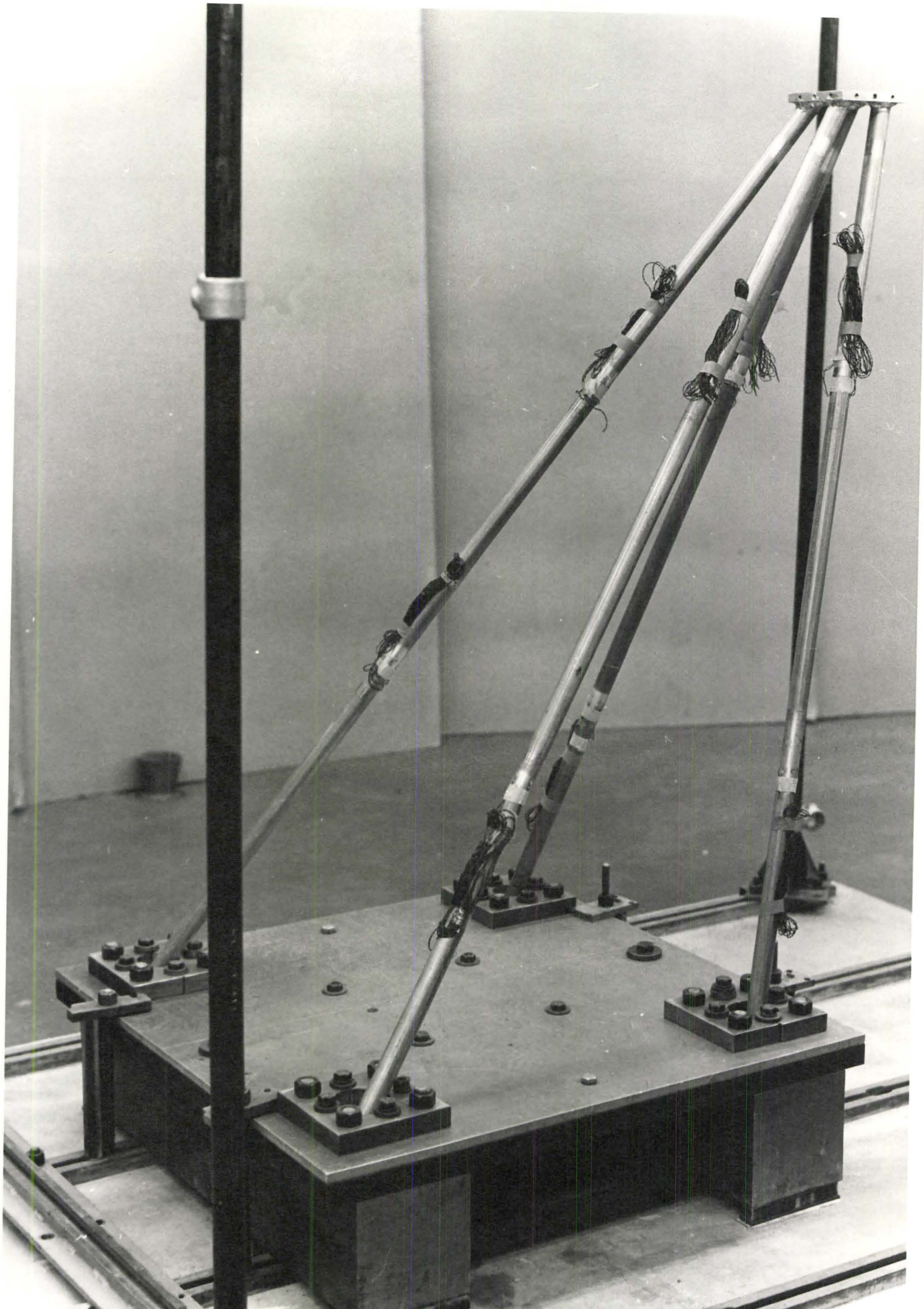


FIGURE 3. OVERALL PICTURE OF SET UP

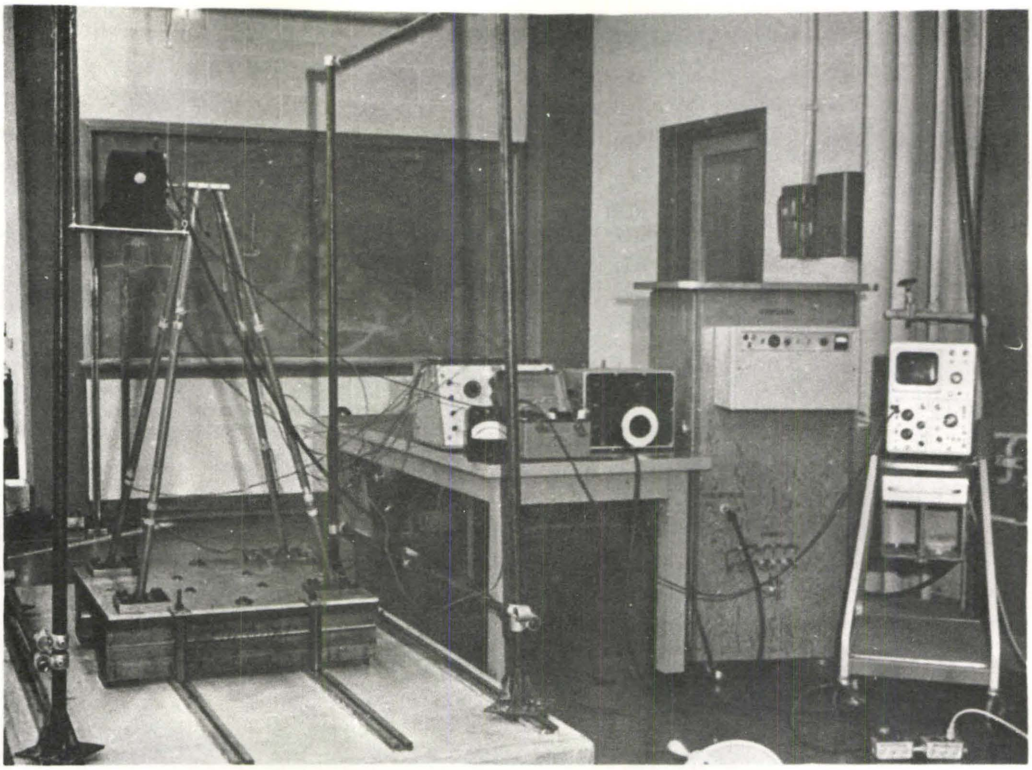


Figure 4. General View of Horizontal Excitation

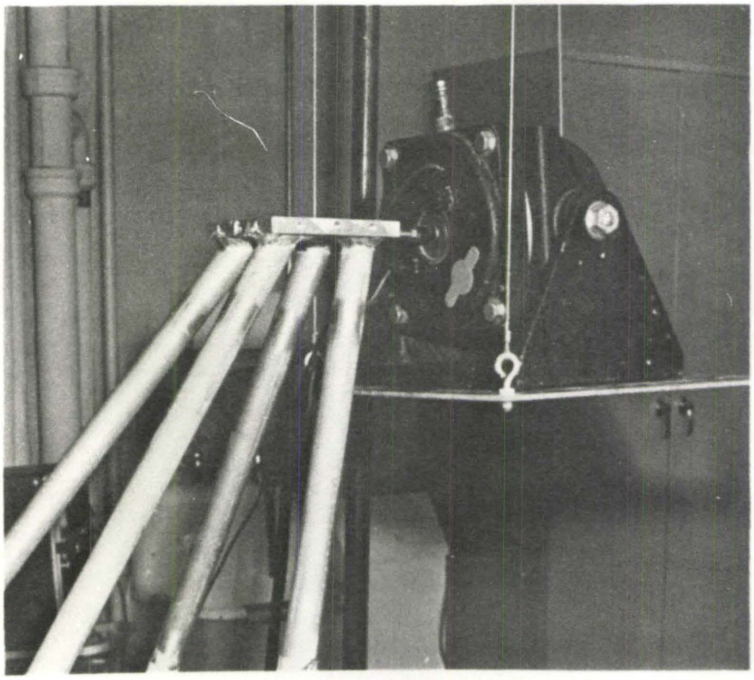


Figure 5. Detail of Horizontal Excitation

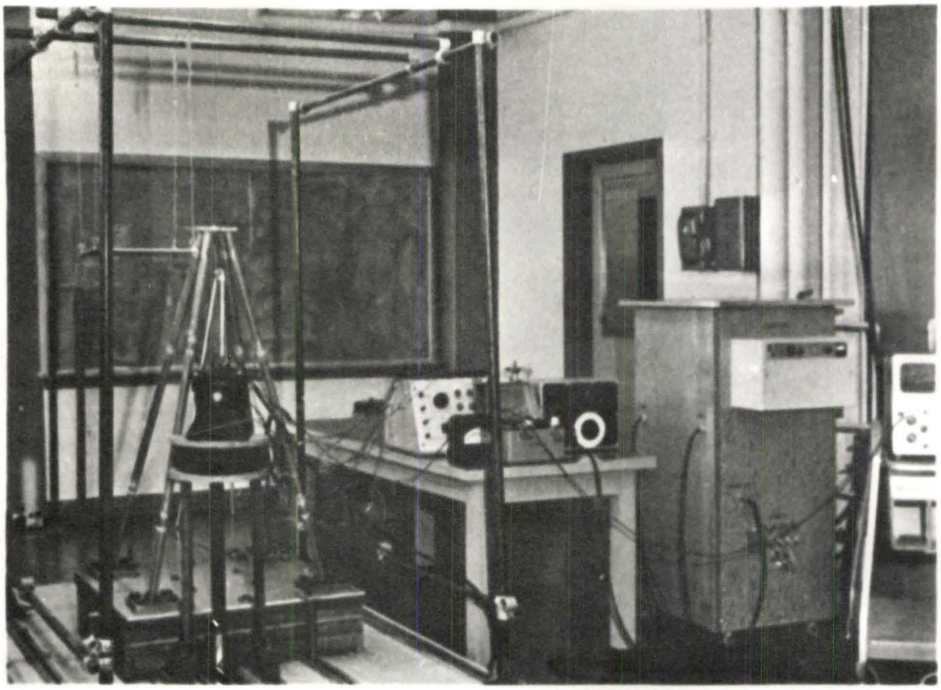


Figure 6. General View of Vertical Excitation

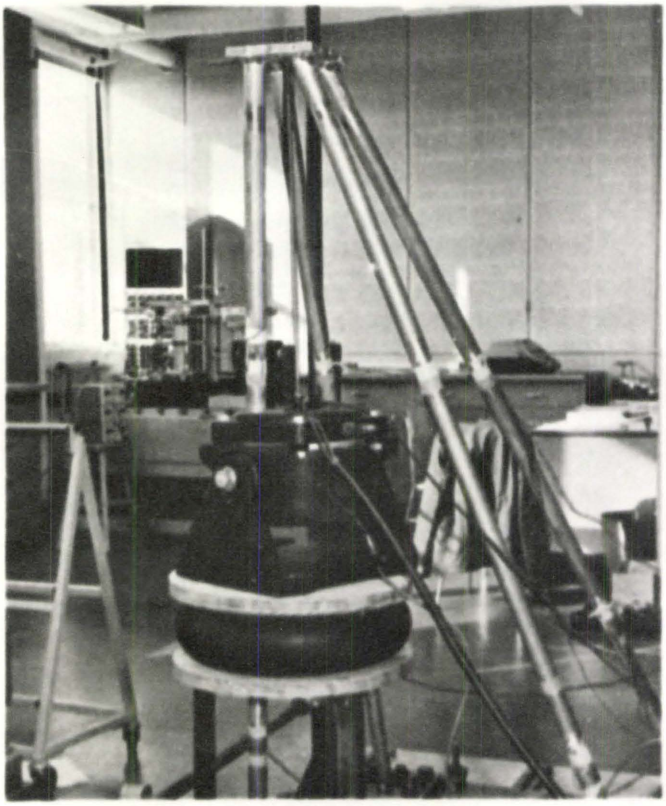


Figure 7. Detail of Vertical Excitation

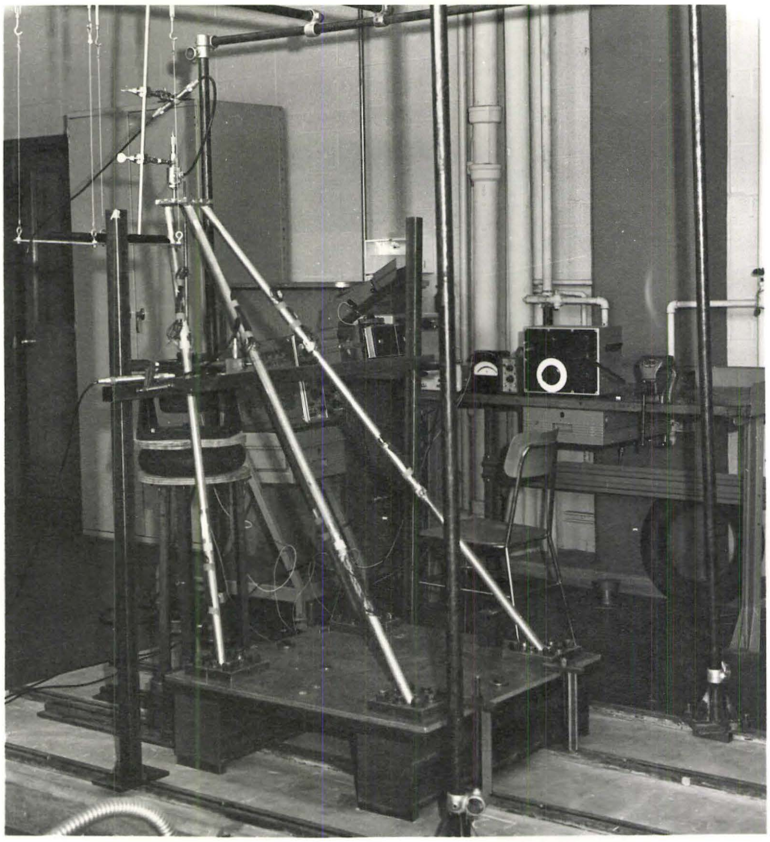


FIGURE 8. GENERAL VIEW OF AMPLITUDE MEASUREMENT

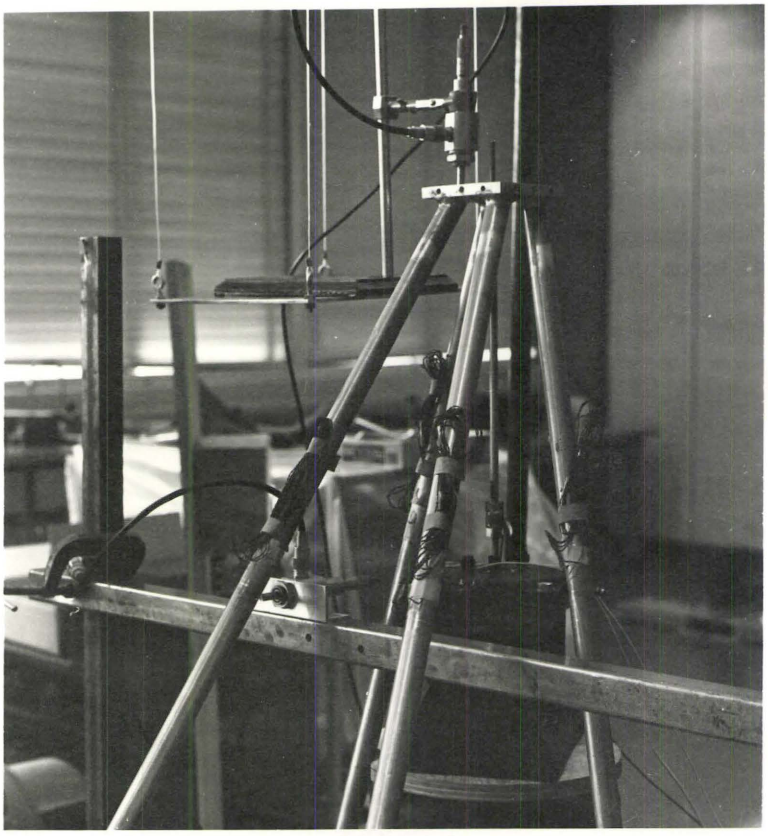


FIGURE 9. DETAIL OF AMPLITUDE MEASUREMENT

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APPENDIX - I

(RESULTS OF FREE VIBRATIONS)

FREQUENCIES

MODE	1	2	3	4	5	6	7
THEORETICAL NATURAL FREQUENCIES C.P.S.	41.74	49.3	58.3	61.68	73.4	77.2	84.9
EXPERIMENTAL NATRUAL FREQUENCIES C.P.S.	42.1	43.2	62.6	66.5	73.5	77.5	88.0

TABLE 1

FREQUENCIES

NEGLECTING RIGID BODY INERTIA ON ALL NODES C.P.S.	76.0	89.0	91.0	119.0	120.0	131.0
CONSIDERING RIGID BODY INERTIA ONLY ON PLATE NODE C.P.S.	58.3	64.8	85.0	89.5	102.5	110.8

TABLE 2

FREQUENCY 0.41744E 02 CPS

MODE SHAPE

-0.13579E-01	0.26833E 00	-0.17292E 00
-0.12466E 00	-0.53947E-02	0.67088E-02
-0.30869E-01	0.22509E 00	-0.12248E 00
-0.10205E 00	-0.84863E-02	-0.28636E-02
0.55876E-02	0.13943E 00	-0.30762E-01
-0.60417E-01	0.24969E-02	-0.36266E-02
0.62526E-02	0.16785E 00	-0.39750E-01
-0.72107E-01	0.30183E-02	0.48513E-02
-0.22673E-01	0.43720E 00	-0.28122E 00
0.31039E-01	0.14259E-02	-0.92712E-03
-0.42715E-01	0.38248E 00	-0.20791E 00
0.18758E-01	0.42474E-02	-0.43679E-02
0.10735E-01	0.27262E 00	-0.60480E-01
-0.40571E-02	0.19323E-03	-0.44285E-02
0.12296E-01	0.31865E 00	-0.75697E-01
-0.10968E-02	0.15106E-03	0.10763E-02
0.16900E-06	0.23473E 00	-0.11277E 00
0.16967E 00	-0.94354E-03	-0.21967E-01

FREQUENCY 0.49308E 02 CPS

MODE SHAPE

-0.17828E 00	0.86999E-01	0.37595E-02
-0.26070E-01	-0.67890E-01	-0.61301E-03
-0.56084E 00	-0.12601E 00	0.27907E-01
0.48832E-01	-0.14524E 00	0.83102E-02
0.23689E-01	-0.60912E-01	0.13896E-01
0.26153E-01	0.10247E-01	-0.87330E-02
0.26852E-01	0.41545E-01	-0.15879E-01
-0.17062E-01	0.11197E-01	-0.89481E-02
-0.24664E 00	0.12285E 00	0.48241E-02
0.13118E-01	0.32955E-01	-0.23435E-01
-0.64770E 00	-0.18508E 00	0.52369E-01
-0.13880E-01	0.11365E 00	-0.32555E-01
0.46574E-01	-0.11116E 00	0.26345E-01
0.31258E-03	0.11425E-02	-0.17601E-01
0.50374E-01	0.72732E-01	-0.28021E-01
0.15898E-02	0.69233E-03	-0.18434E-01
0.35899E-05	-0.34791E-01	0.27631E-02
-0.17135E-01	0.18449E-01	-0.13153E 00

FREQUENCY 0.58365E 02 CPS

MODE SHAPE

0.34749E 00	-0.27062E 00	0.65050E-01

0.85529E-01	0.11889E 00	-0.72860E-02
-0.34442E 00	0.23195E 00	-0.14904E 00
-0.97679E-01	-0.75198E-01	0.17367E-01
-0.61079E-01	0.72713E-01	-0.23193E-01
-0.30279E-01	-0.24012E-01	0.87200E-02
-0.74712E-01	-0.51654E-01	0.36373E-01
0.22057E-01	-0.30925E-01	0.86414E-02
0.39194E 00	-0.30517E 00	0.73897E-01
-0.70797E-01	-0.96472E-01	0.32512E-01
-0.28596E 00	0.29257E 00	-0.17768E 00
0.61174E-01	0.97156E-01	0.97618E-02
-0.10229E 00	0.12251E 00	-0.38873E-01
0.39894E-02	0.52419E-02	0.17263E-01
-0.11704E 00	-0.80856E-01	0.57207E-01
-0.69316E-02	0.10497E-01	0.18005E-01
0.42710E-06	0.34925E-01	-0.23142E-02
0.13737E-01	0.19019E-01	0.12262E 00

FREQUENCY 0.61681E 02 CPS

MODE SHAPE

-0.47954E 00	-0.17362E 00	0.27817E 00
0.94912E-01	-0.15707E 00	0.18468E-01
0.40367E-01	0.24651E 00	-0.13172E 00
-0.94757E-01	0.88588E-02	0.21541E-02
-0.61148E-01	0.44505E-01	-0.18669E-01
-0.18996E-01	-0.24126E-01	0.41437E-02
-0.77720E-01	-0.27724E-02	0.29502E-01
0.39072E-02	-0.31219E-01	0.49515E-02
-0.48483E 00	-0.17599E 00	0.28452E 00
-0.92568E-01	0.15638E 00	-0.26045E-02
0.32871E-01	0.28099E 00	-0.15309E 00
0.73548E-01	-0.10031E-01	0.11743E-01
-0.94877E-01	0.73681E-01	-0.32355E-01
0.39702E-02	0.85763E-02	0.66923E-02
-0.11303E 00	-0.57936E-02	0.43036E-01
-0.30882E-02	0.14434E-01	0.70075E-02
0.23504E-05	0.28786E-01	-0.79275E-02
0.13883E-01	0.43377E-01	0.45635E-01

FREQUENCY 0.73416E 02 CPS

MODE SHAPE

-0.71575E-01	0.31874E 00	-0.18981E 00
-0.99264E-01	-0.17732E-01	0.16967E-01
-0.53744E-01	0.36626E-01	-0.25887E-01
-0.14725E-01	-0.73856E-02	0.12227E-01
-0.15779E 00	-0.16081E-01	-0.15736E-01

0.46867E-02	-0.58406E-01	0.12073E-01
-0.26418E 00	-0.37389E 00	0.17245E 00
0.13817E 00	-0.96265E-01	0.41195E-02
-0.41582E-01	0.20623E 00	-0.11827E 00
0.15704E 00	0.33047E-01	0.88670E-02
-0.10708E-01	0.28954E-01	-0.20656E-01
0.13093E-01	0.23384E-01	0.19811E-01
-0.21687E 00	-0.25505E-01	-0.21155E-01
-0.31515E-02	0.31683E-01	0.16059E-01
-0.32686E 00	-0.46467E 00	0.21593E 00
-0.94022E-01	0.67221E-01	0.19707E-01
0.17094E-05	-0.63001E-01	0.43999E-01
-0.49807E-01	0.50768E-01	0.12138E 00

FREQUENCY 0.84933E 02 CPS

MODE SHAPE

0.83411E-01	0.11542E-01	-0.34565E-01
-0.59865E-02	0.16903E-01	-0.80721E-02
0.77625E-01	0.13885E 00	-0.71215E-01
-0.35530E-01	0.76437E-02	-0.71658E-02
0.80081E-01	-0.39141E 00	0.94285E-01
0.13192E 00	0.23885E-01	-0.27033E-03
-0.38381E 00	0.29375E 00	0.65473E-01
-0.83023E-01	-0.12608E 00	0.30694E-02
0.23645E-01	0.44903E-02	-0.10321E-01
0.18677E-01	-0.42303E-01	-0.83642E-02
-0.17612E-02	0.58399E-01	-0.35080E-01
0.77234E-01	-0.32519E-01	-0.72140E-02
0.88735E-01	-0.45311E 00	0.10760E 00
-0.10438E 00	-0.21944E-01	-0.12344E-01
-0.37270E 00	0.28326E 00	0.65781E-01
0.87229E-01	0.13190E 00	-0.21360E-01
0.83112E-06	-0.67183E-01	0.23037E-01
-0.34911E-01	0.14295E-01	-0.78170E-01

FREQUENCY 0.77202E 02 CPS

MODE SHAPE

-0.86997E-04	0.87355E-01	-0.61987E-01
-0.26044E-01	-0.86487E-03	-0.59802E-02
0.50709E-02	0.34215E 00	-0.18379E 00
-0.10585E 00	0.23108E-02	-0.92471E-02
0.15845E 00	-0.26856E 00	0.78229E-01
0.97982E-01	0.56350E-01	-0.53943E-02
0.32519E 00	-0.22610E 00	-0.61551E-01
0.68758E-01	0.11358E 00	-0.15332E-01
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0.37389E 00	-0.26171E 00	-0.70401E-01
-0.53359E-01	-0.93584E-01	-0.19110E-02
-0.16919E-05	-0.10912E 00	0.41996E-01
-0.62306E-01	-0.46972E-01	-0.70432E-01

FREQUENCY 0.89666E 02 CPS

MODE SHAPE

-0.32321E-01	-0.30391E-01	0.30046E-01
0.76567E-02	-0.65577E-02	-0.76944E-04
-0.31713E-01	-0.17223E-01	0.90293E-02
0.54079E-02	-0.26397E-02	-0.34401E-02
0.58259E 00	0.19528E 00	0.25735E-01
-0.59068E-01	0.18805E 00	-0.10399E-01
-0.19648E 00	-0.13969E 00	0.94147E-01
0.47262E-01	-0.62125E-01	0.44375E-04
-0.71856E-02	-0.33869E-02	0.48616E-02
-0.24045E-01	0.13428E-01	-0.14267E-02
0.34646E-02	-0.33793E-02	0.55001E-02
-0.92930E-02	0.78708E-02	-0.28162E-02
0.60445E 00	0.20761E 00	0.27407E-01
0.55274E-01	-0.17658E 00	0.67797E-02
-0.17197E 00	-0.12048E 00	0.79563E-01
-0.56720E-01	0.72075E-01	-0.20603E-03
-0.11198E-05	0.19155E-01	-0.96453E-02
0.12804E-01	-0.35046E-01	-0.11180E-01

FREQUENCY 0.12422E 03 CPS

MODE SHAPE

-0.31201E-01	-0.33300E 00	0.23662E 00
-0.22255E-01	0.33024E-02	0.46966E-02
-0.19351E 00	-0.30921E 00	0.16306E 00
0.93921E-02	0.27709E-01	-0.33433E-02
-0.33374E-02	-0.34282E 00	0.65720E-01
0.72127E-01	0.22968E-02	0.72463E-02
-0.63504E-03	-0.26298E 00	0.58728E-01
0.45194E-01	-0.20527E-02	0.16511E-02
0.21477E-01	0.24337E 00	-0.16407E 00
-0.20861E 00	0.20505E-01	0.15203E-01
0.18226E 00	0.18475E 00	-0.77609E-01
-0.20200E 00	0.40776E-01	-0.30777E-02
-0.49844E-02	-0.90381E-01	0.14697E-01

-0.18035E 00	-0.13619E-03	0.24924E-02
-0.12029E-01	-0.78445E-02	-0.49602E-02
-0.15078E 00	0.40212E-02	0.89431E-02
-0.38121E-06	0.32408E 00	-0.15420E 00
0.17020E 00	-0.13441E-01	0.27220E-01

FREQUENCY 0.12026E 03 CPS

MODE SHAPE

0.18939E 00	-0.20599E 00	0.79871E-01
0.25831E-02	-0.43364E-02	-0.12042E-01
0.62877E 00	0.18294E-01	0.33285E-01
0.42816E-02	-0.72675E-01	-0.92683E-02
-0.52107E-01	0.21473E-01	-0.14224E-01
-0.42875E-02	-0.11288E-01	-0.13278E-01
-0.40857E-01	-0.19347E 00	0.59350E-01
0.37624E-01	-0.12882E-01	-0.15390E-01
-0.11167E 00	0.13870E 00	-0.43598E-01
-0.11242E 00	-0.10086E 00	-0.11287E-01
-0.56411E 00	-0.15143E-01	-0.39695E-01
0.10629E-01	-0.15201E 00	-0.89365E-02
-0.13877E-01	0.95424E-02	-0.13696E-01
0.11205E-01	0.28420E-01	-0.27978E-01
-0.14023E-02	-0.29583E-01	0.76044E-02
-0.10785E 00	0.22999E-01	-0.20466E-01
0.12764E-05	0.69400E-01	-0.54116E-01
0.45091E-01	0.38727E-01	-0.19486E 00

FREQUENCY 0.13923E 03 CPS

MODE SHAPE

-0.41740E 00	0.27027E 00	-0.35353E-01
0.30167E-01	0.71354E-01	0.13982E-01
0.25870E 00	-0.25453E 00	0.15765E 00
-0.29356E-01	-0.60627E-01	0.31521E-01
0.11609E 00	-0.15920E 00	0.49455E-01
0.25915E-01	0.17006E-01	0.18590E-01
0.10440E 00	0.89941E-01	-0.57143E-01
-0.11609E-01	0.11731E-01	0.21621E-01
0.37950E 00	-0.25062E 00	0.31866E-01
0.98106E-01	0.15642E 00	0.17534E-01
-0.29678E 00	0.21122E 00	-0.13095E 00
-0.15364E 00	0.64552E-02	0.42074E-01
-0.56453E-02	0.77314E-03	-0.60096E-03
-0.98587E-01	-0.63050E-01	0.37712E-01
-0.32930E-01	-0.21083E-01	0.65263E-02
0.57629E-01	-0.65800E-01	0.37217E-01
-0.16403E-06	0.84196E-01	-0.12491E-01

0.26819E-01	0.14172E-01	0.25729E 00

FREQUENCY 0.14800E 03 CPS

MODE SHAPE

0.47421E 00	0.20148E 00	-0.28498E 00
0.75975E-01	-0.11531E 00	0.25776E-01
-0.15011E-01	-0.28640E 00	0.15265E 00
-0.52770E-01	0.10749E-01	0.13659E-01
0.94856E-01	-0.74013E-01	0.23070E-01
0.11585E-01	0.10821E-01	0.10969E-01
0.92560E-01	0.79619E-02	-0.29966E-01
0.10819E-02	0.81854E-02	0.13198E-01
-0.46528E 00	-0.19096E 00	0.29350E 00
0.72330E-01	-0.11441E 00	0.23335E-01
0.14376E-01	0.26808E 00	-0.14289E 00
-0.13636E 00	-0.70816E-02	0.16474E-01
-0.10086E-01	0.74086E-03	-0.10692E-01
-0.48947E-01	-0.48737E-01	0.11101E-01
-0.28527E-01	-0.33491E-02	0.16268E-01
0.38195E-02	-0.52941E-01	0.13559E-01
0.75948E-06	0.75097E-01	-0.23089E-01
0.31101E-01	0.81135E-01	0.86585E-01

FREQUENCY 0.17129E 03 CPS

MODE SHAPE

-0.10505E 00	0.31233E 00	-0.16523E 00
0.17904E 00	0.61994E-01	-0.27299E-01
-0.45420E-01	0.73061E-01	-0.39152E-01
0.38460E-01	0.48431E-01	-0.30354E-01
-0.16097E 00	-0.52015E-01	-0.12236E-01
0.38441E-02	-0.30213E-02	-0.19501E-01
-0.24182E 00	-0.42115E 00	0.16612E 00
-0.37301E-01	0.75215E-02	-0.13839E-01
0.10289E 00	-0.30840E 00	0.17739E 00
-0.93151E-01	-0.40274E-01	-0.38598E-01
0.46259E-01	-0.71269E-01	0.54289E-01
0.15440E-01	-0.37998E-01	-0.44015E-01
0.86774E-01	0.27635E-01	0.42569E-03
-0.26355E-01	0.87506E-01	-0.34993E-01
0.17922E 00	0.31323E 00	-0.14294E 00
-0.20172E 00	0.10827E 00	-0.30549E-01
-0.47198E-06	0.20116E 00	-0.12219E 00
0.97064E-01	-0.67467E-01	-0.25604E 00

FREQUENCY 0.19890E 03 CPS

MODE SHAPE

-0.78445E-01	-0.13580E-02	0.28322E-01
-0.33457E-01	0.94340E-01	-0.29451E-01
-0.42762E-01	-0.10062E 00	0.46549E-01
-0.97569E-01	0.58198E-01	-0.26350E-01
0.12619E-01	0.23800E 00	-0.42671E-01
0.11371E-02	0.28224E-02	-0.17766E-01
0.49068E 00	-0.32917E 00	-0.76183E-01
-0.53455E-01	-0.11821E 00	0.28807E-04
0.60207E-01	-0.14316E-01	-0.11597E-01
0.35723E-01	-0.72729E-01	-0.16290E-01
0.44403E-01	0.78830E-01	-0.39542E-01
0.79652E-01	-0.54421E-01	-0.12314E-01
-0.14378E-01	-0.21042E 00	0.46359E-01
0.12405E 00	-0.79171E-02	-0.17076E-01
-0.47668E 00	0.33705E 00	0.97698E-01
-0.79196E-01	-0.12130E 00	0.35112E-02
0.64678E-06	-0.14073E 00	0.47942E-01
-0.23330E-01	0.79617E-01	-0.17606E 00

FREQUENCY 0.17849E 03 CPS

MODE SHAPE

0.66773E-01	0.48231E-01	-0.48228E-01
0.41062E-01	-0.36522E-01	0.17155E-01
0.35446E-01	0.37084E 00	-0.19605E 00
0.18063E 00	-0.43305E-01	0.30431E-01
0.18983E 00	-0.30001E 00	0.77463E-01
-0.65785E-02	-0.17732E-01	0.19209E-01
0.29018E 00	-0.80825E-01	-0.79804E-01
-0.12561E-01	-0.28329E-01	0.21959E-01
-0.59346E-01	-0.24314E-01	0.60374E-01
-0.29174E-01	0.12398E-01	0.35039E-01
-0.29543E-01	-0.37494E 00	0.19593E 00
-0.78139E-01	0.37403E-01	0.39430E-01
-0.11357E 00	0.19805E 00	-0.71470E-01
-0.17619E 00	-0.90157E-01	0.35793E-01
-0.25064E 00	0.78170E-01	0.60382E-01
-0.41168E-01	-0.14001E 00	0.46985E-01
0.56209E-06	0.27652E 00	-0.89996E-01
0.78788E-01	0.85755E-01	0.22985E 00

FREQUENCY 0.22919E 03 CPS

MODE SHAPE

-0.14165E 00	-0.52268E-01	0.87920E-01
-0.24612E 00	0.42140E 00	-0.46710E-01

-0.37108E-01	-0.74845E-01	0.31440E-01
-0.15858E 00	0.10621E 00	-0.88800E-02
-0.41862E-01	-0.37450E 00	0.68153E-01
-0.11533E 00	0.21033E-01	0.51568E-03
-0.14984E-03	0.71285E-02	0.23109E-01
0.28103E-02	0.11612E-01	-0.27171E-02
-0.10367E 00	-0.29849E-01	0.69301E-01
0.26913E 00	-0.45128E 00	0.23469E-01
-0.58045E-03	0.91766E-03	0.26314E-02
0.15454E 00	-0.10991E 00	0.17730E-01
0.41352E-01	0.38642E 00	-0.78275E-01
-0.50024E-01	0.59904E-02	-0.59815E-02
0.93310E-02	0.30775E-02	0.27200E-02
0.91653E-02	-0.99374E-02	-0.52757E-02
0.36604E-06	-0.12453E 00	0.59006E-01
-0.40291E-01	0.46726E-01	-0.10649E 00

FREQUENCY 0.22207E 03 CPS

MODE SHAPE

0.13596E 00	-0.16721E 00	0.56005E-01
-0.39555E 00	-0.30283E 00	0.75648E-01
0.63321E-01	0.19524E-02	-0.51760E-03
0.13250E-01	-0.15108E 00	0.32890E-01
-0.21250E 00	-0.10259E 00	0.25214E-01
-0.37126E-01	0.57541E-01	0.22665E-01
-0.48780E-01	-0.27370E 00	0.62093E-01
-0.13907E 00	0.23947E-01	0.28541E-01
0.11464E-01	-0.56787E-01	0.19445E-01
0.41932E 00	0.29662E 00	-0.18933E-01
-0.15255E-01	0.36851E-02	-0.43248E-03
-0.74955E-02	0.15217E 00	-0.22833E-02
0.20887E 00	0.10235E 00	0.23382E-01
-0.10962E-01	0.38941E-01	0.22017E-01
0.39052E-01	0.27339E 00	-0.74784E-01
0.38169E-01	0.14004E-02	0.26154E-01
-0.51863E-06	-0.12499E 00	0.81181E-01
-0.32230E-01	-0.75102E-01	0.20976E 00

FREQUENCY 0.26758E 03 CPS

MODE SHAPE

0.20189E-01	0.29769E-01	-0.11939E-01
-0.23935E 00	-0.12495E 00	-0.34505E-01
0.10894E-01	0.64485E-02	-0.32518E-01
0.37751E 00	-0.22760E 00	-0.45595E-01
0.15322E 00	-0.17738E 00	0.69305E-01
-0.13039E 00	-0.11272E 00	-0.30331E-01

0.10185E 00	0.12980E 00	-0.56000E-01
0.16877E 00	-0.15553E 00	-0.62168E-01
0.90211E-01	-0.13217E 00	0.38807E-01
-0.18353E-01	0.14921E 00	-0.12071E 00
0.93154E-01	0.14597E 00	-0.97189E-01
-0.15459E 00	0.92549E-01	-0.83225E-01
-0.15834E 00	0.16512E 00	-0.31696E-01
0.90161E-01	0.48293E-01	-0.98758E-01
-0.57979E-01	-0.94959E-01	0.32457E-01
-0.13816E 00	0.11836E 00	-0.69151E-01
-0.68465E-07	-0.14581E 00	0.15006E-01
0.69664E-01	-0.48161E-01	-0.50295E 00

FREQUENCY 0.24352E 03 CPS

MODE SHAPE

-0.61186E-01	0.35024E-01	-0.64601E-02
0.98060E-01	0.22040E 00	-0.14355E-01
0.16409E 00	-0.22201E-01	0.18929E-01
-0.55643E-01	-0.59407E 00	0.79508E-01
-0.14673E-01	0.40894E-01	0.92568E-03
-0.60901E-02	-0.31747E-02	-0.68921E-03
-0.12027E-01	-0.45312E-01	-0.21757E-04
-0.29558E-01	-0.41597E-02	-0.16337E-02
-0.93661E-01	0.50163E-01	0.28997E-02
-0.11629E 00	-0.24836E 00	0.57893E-01
0.12661E 00	-0.75960E-02	0.41465E-02
0.59719E-01	0.64101E 00	-0.67338E-01
0.16145E-01	-0.55691E-01	0.21637E-01
0.32904E-01	0.74533E-02	0.22494E-01
0.12425E-01	0.44162E-01	-0.12117E-02
0.13107E-01	0.10017E-01	0.15649E-02
-0.28600E-06	-0.27238E-01	0.10364E-01
0.58550E-02	-0.38451E-01	0.79210E-01

FREQUENCY 0.21308E 03 CPS

MODE SHAPE

-0.77499E-02	-0.64416E-01	0.42600E-01
-0.10488E 00	0.21019E-01	0.49779E-02
-0.49094E-02	-0.16101E-01	0.16667E-01
-0.44548E-01	0.11051E-01	0.68683E-02
0.58285E 00	0.92986E-01	0.45232E-01
0.44125E-02	-0.11441E 00	0.15391E-01
-0.20186E 00	-0.20361E 00	0.11839E 00
-0.81262E-01	0.72869E-01	0.28167E-02
-0.33766E-03	0.21467E-01	-0.11438E-01
0.12213E 00	-0.20435E-01	0.10420E-01

0.36374E-02	0.54057E-03	0.32929E-02
0.39892E-01	-0.95587E-02	0.83148E-02
-0.56562E 00	-0.90276E-01	-0.43881E-01
0.39866E-01	-0.16786E 00	0.17817E-01
0.22385E 00	0.21513E 00	-0.10402E 00
-0.58703E-02	0.19559E-01	-0.35185E-04
0.44650E-06	-0.91917E-01	0.47612E-01
-0.37038E-01	0.73923E-01	0.69442E-01

FREQUENCY 0.32782E 03 CPS

MODE SHAPE

-0.59681E-02	-0.53319E-02	0.49139E-02
-0.12743E-01	-0.25843E-01	-0.67396E-01
-0.11445E-02	0.63646E-03	-0.50563E-02
-0.11140E-01	-0.32584E-01	-0.63284E-01
0.27767E-01	0.88314E-02	-0.32186E-01
0.19552E-01	0.10271E-01	-0.49336E-01
0.12477E-01	-0.15356E 00	-0.13124E-02
-0.57344E 00	0.78021E-02	0.49022E-02
0.25330E-01	-0.26526E-01	0.97014E-02
0.59072E-01	0.64412E-02	-0.68760E-01
0.25682E-01	0.96082E-02	-0.57216E-02
-0.29844E-01	0.26494E-01	-0.74202E-01
-0.45813E-01	0.20307E-01	-0.10660E-01
-0.65990E-01	-0.22669E-01	-0.39437E-01
-0.54701E-01	-0.25010E 00	0.30001E-01
0.61833E 00	-0.24100E-01	-0.10750E 00
0.62052E-07	0.21677E 00	-0.91986E-01
0.13586E-02	-0.73535E-02	-0.29801E 00

FREQUENCY 0.23811E 03 CPS

MODE SHAPE

-0.83660E-01	-0.59933E-01	0.65803E-01
-0.24763E 00	0.25716E 00	-0.26546E-02
-0.84536E-02	0.15829E 00	-0.97123E-01
0.42138E 00	0.35958E-01	0.19107E-01
-0.54763E-01	0.28180E 00	-0.79060E-01
0.98635E-01	0.15485E-01	0.10503E-02
-0.35630E-01	0.34763E-01	0.14532E-01
0.26901E-01	0.10537E-01	0.16766E-01
-0.83545E-01	-0.63253E-01	0.66260E-01
0.29167E 00	-0.28125E 00	0.37746E-01
-0.10060E-01	0.66351E-01	-0.36539E-01
-0.45441E 00	-0.39057E-01	0.30569E-01
0.75505E-01	-0.28913E 00	0.57280E-01
0.35429E-02	0.17539E-01	0.17991E-01

0.54140E-01	-0.26323E-01	-0.10416E-01
-0.21068E-01	0.10056E-01	0.13224E-01
0.84104E-07	0.18005E 00	-0.91219E-01
0.15661E-01	0.17930E-01	0.81744E-01

FREQUENCY 0.25863E 03 CPS

MODE SHAPE

-0.14884E-01	0.26216E-01	-0.22239E-01
0.31748E 00	0.52946E-01	0.17698E-01
-0.12413E-01	0.57616E-01	-0.41600E-01
0.36672E 00	0.67248E-01	0.32014E-01
-0.63413E-01	-0.15312E 00	0.59225E-01
-0.83908E-01	0.52361E-01	-0.21733E-03
-0.36562E-01	-0.17762E 00	0.70941E-01
-0.19624E 00	0.85354E-01	0.32449E-01
-0.39932E-01	0.12826E 00	-0.11782E 00
-0.24229E 00	-0.62437E-01	0.63555E-01
-0.26149E-01	0.12895E 00	-0.10729E 00
-0.32233E 00	-0.73799E-01	0.50089E-01
0.41444E-01	0.15483E 00	0.24751E-01
0.58455E-01	-0.33873E-01	0.39795E-01
0.20436E-01	0.13227E 00	-0.39783E-02
0.16207E 00	-0.69294E-01	0.35601E-01
0.13365E-06	-0.47445E 00	0.24999E 00
-0.28954E-01	0.28554E-01	0.11281E 00

FREQUENCY 0.31385E 03 CPS

MODE SHAPE

0.11967E-03	-0.18262E-02	0.70989E-02
-0.28250E-01	-0.32823E-01	-0.27668E-01
0.33922E-02	-0.18065E-02	-0.19300E-02
0.73616E-02	-0.46844E-01	-0.20375E-01
0.84722E-02	0.84702E-02	-0.12566E-01
0.44402E-02	-0.47890E-01	-0.13304E-02
-0.21033E 00	0.59893E-01	0.56155E-01
0.82740E-01	0.64833E 00	-0.54474E-01
0.43113E-01	-0.24791E-01	0.47542E-02
0.36001E-01	0.45133E-01	-0.27441E-01
0.36056E-01	0.10800E-01	-0.68283E-02
-0.16104E-01	0.54898E-01	-0.33846E-01
0.34593E-01	0.12259E-02	0.72057E-02
-0.28709E-02	0.58541E-01	-0.26942E-01
-0.16513E 00	0.85164E-03	0.56985E-01
-0.79338E-01	-0.63132E 00	0.57386E-02
0.33661E-06	0.15286E-01	-0.10648E-01
-0.10750E-02	0.13420E 00	-0.19812E 00

FREQUENCY 0.29366E 03 CPS

MODE SHAPE

0.15364E 00	-0.27445E-01	-0.41060E-01
0.12704E-02	0.70769E 00	-0.91391E-01
0.47069E-02	0.58390E-02	-0.19598E-02
0.26063E-02	-0.10354E-02	-0.58370E-03
-0.56631E-02	0.31585E-02	0.11301E-03
0.58559E-03	-0.95629E-04	-0.43537E-03
-0.74082E-02	-0.10746E-01	0.24524E-02
-0.93228E-02	-0.18859E-03	-0.55175E-03
-0.18738E 00	0.13585E-01	0.15156E-01
-0.40076E-02	0.64688E 00	-0.99954E-01
-0.10679E-01	-0.78226E-02	0.27914E-02
0.20355E-02	-0.20657E-02	-0.11280E-02
0.51483E-02	-0.40613E-02	0.28923E-03
0.15821E-02	0.24744E-02	-0.94089E-03
0.32561E-02	0.10194E-01	-0.30983E-02
0.46660E-02	0.31349E-02	-0.12069E-02
-0.17096E-06	0.74364E-03	-0.74062E-03
0.11020E-02	-0.49337E-03	-0.30823E-02

FREQUENCY 0.34648E 03 CPS

MODE SHAPE

-0.19290E-04	0.40689E-03	-0.13029E-02
0.13582E-01	-0.14686E-03	0.66420E-02
-0.46242E-02	0.53710E-02	0.50713E-02
0.69564E-02	0.21636E-01	0.88618E-02
-0.73436E-02	-0.20240E 00	-0.14642E-01
-0.65080E 00	0.16277E-01	-0.13788E-04
-0.13666E-01	-0.28137E-05	0.10332E-01
-0.26318E-01	0.24754E-01	0.97035E-02
0.63662E-02	0.29739E-01	0.12652E-01
-0.14331E-01	0.31989E-02	0.17794E-01
-0.83776E-02	0.73502E-02	-0.37887E-02
-0.71257E-02	-0.22438E-01	0.14186E-01
0.13986E-01	-0.19554E 00	-0.46868E-02
0.59857E 00	-0.13961E-01	0.12570E-01
-0.31206E-02	-0.86679E-02	-0.27257E-01
0.25099E-01	-0.22240E-01	0.12040E-01
-0.25069E-07	0.24844E 00	-0.11029E 00
-0.21482E 00	0.60765E-03	0.10308E 00

FREQUENCY 0.29503E 03 CPS

MODE SHAPE

0.71812E-02	-0.12464E 00	0.81832E-01
0.67261E 00	-0.38702E-01	-0.58525E-01
0.24735E-02	-0.25708E-02	0.13919E-01
0.56750E-01	-0.39839E-01	-0.17278E-01
0.25019E-01	-0.34518E-01	0.97268E-02
-0.10221E-01	-0.28836E-01	-0.75514E-03
0.25299E-01	0.29123E-01	-0.10856E-01
0.77914E-01	-0.44500E-01	-0.18880E-01
0.22023E-01	0.12835E 00	-0.76816E-01
0.65755E 00	0.29867E-01	-0.87742E-01
0.21048E-01	0.33555E-01	-0.11849E-01
-0.80904E-02	0.45080E-01	-0.28755E-01
-0.20004E-01	0.50090E-01	-0.33415E-02
-0.88121E-02	0.21962E-01	-0.22295E-01
-0.72303E-02	0.95877E-02	-0.16599E-02
-0.81067E-01	0.38824E-01	-0.18708E-01
-0.60852E-07	0.56834E-01	-0.33731E-01
-0.28804E-01	-0.20028E-01	-0.12491E 00

FREQUENCY 0.31177E 03 CPS

MODE SHAPE

0.11557E-01	-0.32570E-02	-0.15307E-02
-0.27316E-01	-0.11128E-01	-0.21684E-02
0.11314E 00	0.60581E-02	-0.62111E-02
0.45519E-01	0.69807E 00	-0.10570E 00
0.15303E-01	-0.17290E-01	0.77001E-02
-0.13641E-01	-0.13488E-02	-0.29646E-02
0.95317E-02	0.14168E-01	-0.76766E-02
0.18147E-01	-0.10429E-01	-0.70325E-02
-0.15766E-01	-0.86223E-02	-0.10586E-02
-0.52465E-02	0.39389E-02	-0.11000E-01
-0.12541E 00	0.86329E-02	-0.68460E-02
-0.15360E-01	0.66522E 00	-0.11560E 00
-0.27048E-01	0.14444E-01	-0.42826E-02
0.11234E-01	-0.73042E-02	-0.11890E-01
-0.21008E-01	-0.44690E-02	-0.18181E-02
-0.16181E-01	0.45274E-02	-0.78561E-02
-0.21199E-06	-0.20688E-01	0.29660E-02
0.65850E-02	-0.80873E-01	-0.48661E-01

FREQUENCY 0.83353E 03 CPS

MODE SHAPE

0.60812E-02	0.64640E-02	-0.12414E-02
-0.26433E-01	-0.77736E-01	-0.73573E 00
0.96237E-03	-0.52916E-03	-0.39473E-03

0.32368E-02	0.12677E-02	-0.80035E-02
-0.22373E-02	-0.37827E-02	-0.93369E-03
-0.55233E-03	-0.73629E-02	0.52491E-03
-0.16872E-02	-0.10518E-02	-0.17591E-02
0.11176E-01	-0.13595E-01	-0.45089E-02
-0.25154E-02	-0.21899E-02	0.53471E-02
0.32359E-01	0.81705E-01	0.66465E 00
-0.26657E-02	0.16300E-02	-0.15133E-02
-0.57824E-02	-0.22608E-02	-0.81041E-02
0.71670E-02	0.21983E-02	0.22955E-02
-0.23423E-02	0.89155E-02	-0.57906E-02
0.99791E-02	0.64388E-02	-0.51738E-02
-0.14140E-01	0.14666E-01	-0.39800E-02
-0.10669E-07	-0.44339E-02	0.24505E-02
-0.19035E-02	-0.15925E-02	-0.30605E-01

FREQUENCY 0.17680E 04 CPS

MODE SHAPE

0.26899E 00	0.53072E 00	0.80258E 00
0.84490E-03	0.39810E-02	0.50788E-02
-0.13477E-02	0.28389E-02	-0.10256E-02
-0.73019E-03	0.34489E-03	0.35549E-04
-0.16980E-02	0.55995E-02	-0.33459E-03
-0.11447E-04	0.29547E-03	0.22431E-04
-0.19898E-02	-0.33724E-02	0.13278E-03
-0.51540E-02	0.56648E-03	0.45515E-04
-0.10392E-01	-0.13350E-01	-0.32290E-01
0.20300E-02	0.37454E-02	0.28777E-03
0.25839E-02	-0.17924E-02	0.15940E-02
0.24806E-02	0.83379E-03	0.74112E-04
0.34853E-02	-0.47072E-02	0.11663E-02
0.29160E-02	0.68519E-03	0.30169E-03
0.38250E-02	0.33875E-03	-0.54575E-03
0.60079E-02	0.61374E-03	0.79174E-04
-0.53005E-07	-0.66148E-02	0.33852E-02
-0.27545E-02	-0.55727E-02	0.12060E-01

FREQUENCY 0.59430E 03 CPS

MODE SHAPE

0.21760E-02	0.29373E-02	-0.64831E-03
-0.57057E-02	-0.93746E-02	-0.18336E-01
0.95746E-03	-0.67317E-03	-0.22315E-02
0.78128E-02	-0.31260E-02	-0.20251E-01
-0.31589E-02	0.33755E-02	-0.59915E-02
-0.37532E-02	-0.13546E-02	0.70160E 00
0.70878E-02	0.55839E-02	-0.19198E-03

-0.72407E-02	-0.86643E-02	-0.40602E-02
0.38561E-02	-0.26491E-02	0.31183E-03
-0.53807E-02	0.53757E-02	-0.23926E-01
0.86589E-03	0.13074E-02	-0.33187E-02
0.39186E-02	-0.11175E-02	-0.23221E-01
0.43608E-02	-0.42872E-03	0.46584E-02
0.66331E-02	0.53167E-02	0.69529E 00
-0.13782E-02	-0.10813E-01	-0.16921E-02
0.60139E-02	0.74212E-02	-0.16150E-01
0.53740E-08	0.68843E-02	-0.74030E-02
0.37889E-02	-0.64013E-02	-0.14526E 00

FREQUENCY 0.41671E 03 CPS

MODE SHAPE

0.54851E-02	0.12695E-01	-0.35024E-02
-0.15949E-01	-0.98747E-02	-0.12411E-02
0.28710E-02	0.72074E-02	0.26968E-01
0.43984E-01	-0.22095E-01	-0.63506E-02
0.42098E-02	0.12499E-01	-0.68106E-02
0.16146E 00	-0.11022E-01	0.65797E-04
0.62525E-02	-0.24828E-01	-0.27231E-01
0.37742E-01	-0.21104E-01	-0.84580E-02
0.40170E-01	0.10529E 00	0.68898E-01
-0.10102E 00	0.17678E-01	-0.10692E-01
0.44443E-02	0.12211E 00	0.43187E-01
-0.79817E-01	0.23395E-01	-0.12219E-01
0.96648E-02	0.12222E 00	-0.12034E 00
-0.16299E 00	0.12372E-01	-0.77685E-02
-0.32603E-01	0.73995E-01	-0.99059E-01
-0.46710E-01	0.16199E-01	-0.65802E-02
-0.33415E-07	0.13074E 00	-0.36517E-01
-0.90394E 00	-0.15241E-02	-0.61965E-01

FREQUENCY 0.22744E 04 CPS

MODE SHAPE

-0.76625E-03	0.26000E-02	-0.18281E-02
-0.16119E-01	0.11808E-02	-0.88780E-03
-0.58546E-01	0.47388E 00	0.86914E 00
0.10784E-01	0.10346E-02	-0.16976E-02
-0.41086E-02	-0.17895E-03	0.44482E-02
0.26082E-02	-0.18651E-03	0.25088E-03
0.51653E-02	0.57347E-02	0.34380E-02
-0.25383E-02	-0.21497E-02	-0.11710E-03
-0.15059E-02	-0.75946E-02	0.34849E-02
0.53586E-03	-0.28991E-02	-0.10586E-02
0.75632E-02	-0.55337E-01	-0.10922E 00

-0.66897E-02	0.98255E-02	-0.74290E-03
-0.11427E-03	0.42646E-02	0.68754E-02
0.68337E-02	0.20178E-02	-0.81762E-03
-0.52578E-02	-0.51782E-02	0.21995E-02
-0.44323E-03	0.70682E-03	-0.11841E-02
0.29104E-07	-0.78422E-02	0.12489E-01
0.15238E-01	0.50428E-03	-0.13986E-01

FREQUENCY 0.56293E 03 CPS

MODE SHAPE

0.21357E-02	-0.19743E-02	0.29968E-02
-0.32830E-02	-0.97316E-02	-0.22219E-01
0.21016E-02	-0.39071E-02	0.58857E-03
-0.70917E-02	-0.16114E-01	-0.20522E-01
0.88692E-02	0.10744E-02	-0.73619E-02
0.29105E-02	-0.13738E-02	-0.10514E-02
-0.13901E-01	0.18379E-01	0.63255E-02
-0.51813E-02	0.12691E-02	0.69054E 00
0.50470E-02	-0.26292E-02	0.12860E-02
0.38976E-02	0.63336E-02	-0.25069E-01
0.65287E-02	-0.47693E-02	0.68183E-03
0.89133E-02	0.13679E-01	-0.27293E-01
-0.12795E-01	-0.33127E-02	0.43609E-02
-0.60156E-03	-0.13825E-02	-0.15052E-01
0.12981E-01	-0.27455E-01	-0.34495E-02
0.11128E-01	0.61423E-02	0.70238E 00
0.33380E-08	0.10885E-01	-0.82842E-02
-0.34248E-02	-0.44517E-02	-0.15550E 00

FREQUENCY 0.81669E 03 CPS

MODE SHAPE

0.29821E-02	0.16706E-02	-0.22154E-02
0.24221E-02	0.12423E-03	-0.68937E-03
0.45635E-03	-0.42296E-02	0.54178E-03
-0.72975E-03	-0.77869E-01	-0.72157E 00
-0.46961E-02	0.27287E-02	-0.47893E-03
0.20829E-03	0.42955E-03	-0.61997E-03
-0.74166E-02	-0.33117E-02	0.30562E-02
-0.13904E-02	0.15312E-02	-0.24432E-03
-0.54794E-02	0.21088E-02	0.97804E-04
-0.28702E-02	-0.28795E-02	-0.12069E-02
-0.19667E-02	-0.56358E-02	0.19316E-02
0.25886E-02	0.85023E-01	0.68211E 00
0.51039E-02	-0.58507E-02	0.13152E-02
0.22190E-02	0.24117E-02	-0.64274E-03
0.10473E-01	0.99000E-02	-0.54604E-02

-0.10729E-02	0.36491E-02	-0.74783E-03
-0.49360E-08	-0.10599E-02	-0.10944E-03
-0.11286E-03	-0.29034E-02	-0.13865E-01

FREQUENCY 0.34083E 03 CPS

MODE SHAPE

-0.77730E-04	-0.21408E-02	-0.35939E-02
0.12386E-01	0.23249E-01	0.18940E-01
-0.37459E-02	-0.87111E-02	0.68287E-02
-0.97217E-02	0.34384E-01	0.15541E-01
0.22516E 00	-0.34530E-02	0.65205E-02
-0.36779E-02	-0.65157E 00	0.38950E-01
0.20372E-01	-0.32961E-01	0.32896E-02
-0.60348E-01	-0.47032E-02	0.16495E-01
-0.34713E-01	0.13184E-01	0.42391E-03
-0.17223E-01	-0.33264E-01	0.21092E-01
-0.29326E-01	0.53160E-02	-0.21100E-02
0.88170E-02	-0.40523E-01	0.25766E-01
0.16173E 00	0.22781E-02	-0.18347E-02
0.13295E-02	0.63981E 00	-0.16441E-01
-0.37591E-01	0.43104E-02	0.13683E-01
0.61021E-01	-0.81169E-02	0.18405E-01
-0.40993E-06	-0.12033E-01	0.84339E-02
0.10423E-02	-0.22143E 00	0.13310E 00

FREQUENCY 0.31307E 03 CPS

MODE SHAPE

-0.35515E-02	0.10886E-02	-0.18590E-02
-0.21605E-02	0.24161E-01	0.98138E-02
-0.72078E-02	-0.14403E 00	0.79970E-01
0.64262E 00	0.15949E-01	-0.47548E-01
-0.11315E-01	0.25895E-01	-0.14253E-01
0.34956E-01	0.19437E-01	0.27313E-04
-0.27041E-02	-0.14908E-01	0.48654E-02
-0.36891E-01	0.30698E-01	0.12339E-01
-0.17661E-01	0.73960E-02	-0.35342E-03
-0.10281E-01	-0.27273E-01	0.29754E-01
-0.10078E-01	0.12704E 00	-0.65990E-01
0.69516E 00	-0.36570E-01	-0.42723E-01
0.11550E-01	-0.14234E-01	-0.59962E-02
-0.46672E-01	-0.18320E-01	0.18567E-01
-0.72736E-02	0.52829E-02	0.26550E-02
0.30636E-01	-0.33303E-01	0.17379E-01
0.40829E-07	0.11208E 00	-0.36933E-01
0.15431E-02	0.18638E-01	0.14922E 00

FREQUENCY 0.43769E 03 CPS

MODE SHAPE

0.69765E-02	0.23874E-02	-0.12455E-01
0.23495E-02	0.26257E-01	-0.14207E-01
-0.66177E-02	0.23428E-02	0.10594E-01
-0.14704E-02	-0.28672E-01	0.29367E-02
-0.35635E-02	0.43985E-02	-0.44834E-02
0.21795E-02	0.13130E 00	0.19516E-03
0.26148E-02	0.34459E-02	-0.97502E-02
0.20373E-01	0.92795E-01	-0.70528E-03
-0.93098E-01	-0.51719E-01	-0.53729E-01
0.13692E-02	-0.54855E-01	0.27656E-02
-0.43196E-01	0.44566E-01	0.66313E-01
-0.37975E-02	-0.97912E-01	0.11812E-01
-0.15925E 00	0.17196E-01	0.74462E-01
-0.93781E-02	-0.16291E 00	-0.30413E-03
-0.15510E 00	-0.12835E-01	-0.68702E-01
-0.19138E-01	-0.11691E 00	0.13759E-02
-0.26299E-06	0.59658E-02	0.15166E-02
-0.78328E-02	-0.91386E 00	0.13398E-01

FREQUENCY 0.19395E 04 CPS

MODE SHAPE

0.30564E-02	0.16369E-03	-0.17680E-03
0.29423E-04	-0.88647E-02	-0.27269E-02
0.46184E-02	0.26611E-02	0.33492E-02
0.54837E-02	-0.11213E-01	-0.39551E-02
0.98992E-01	-0.20030E 00	-0.97035E 00
0.16242E-01	0.35334E-02	-0.92893E-04
0.35767E-02	-0.44186E-02	-0.21316E-02
0.11878E-01	-0.89758E-02	-0.45954E-02
0.49800E-02	0.28265E-02	-0.30331E-02
-0.33715E-02	0.10956E-01	-0.87338E-02
0.25448E-02	0.53175E-02	-0.31704E-02
-0.89183E-02	0.11862E-01	-0.59701E-02
0.49768E-02	0.17216E-01	0.24525E-01
-0.35415E-01	-0.19634E-01	-0.41965E-02
0.41213E-02	0.19145E-01	-0.23040E-02
-0.15579E-01	0.89492E-02	-0.33542E-02
-0.54857E-07	-0.56647E-01	0.18036E-01
0.10667E-01	0.43358E-02	0.10908E-01

FREQUENCY 0.43508E 03 CPS

MODE SHAPE

0.25886E-02	0.14713E-02	-0.17450E-02
0.91629E-03	-0.35561E-02	0.12771E-02
0.19526E-02	0.35920E-02	-0.22127E-02
0.30249E-02	-0.26499E-02	0.28884E-02
0.16888E 00	-0.41881E-02	0.60437E-02
-0.13126E-02	0.68805E 00	0.68110E-03
0.65183E-02	0.28946E-02	-0.33588E-02
-0.96775E-03	-0.28404E-02	0.58942E-03
-0.22541E-02	-0.17169E-02	0.18133E-02
0.57834E-03	0.39766E-02	0.31481E-02
-0.16355E-02	-0.11029E-02	0.68391E-03
-0.31368E-02	0.30820E-02	0.31009E-02
-0.17658E 00	0.33945E-02	-0.57862E-02
-0.38729E-02	0.68226E 00	0.33086E-02
-0.12408E-01	-0.28085E-02	0.51603E-02
0.38167E-02	-0.48403E-02	0.34282E-02
-0.13097E-06	0.22968E-02	0.15269E-02
-0.52619E-03	0.91765E-02	0.26966E-01

FREQUENCY 0.10097E 04 CPS

MODE SHAPE

0.77469E-02	-0.30110E-02	0.35799E-03
-0.10425E-01	-0.13664E-01	-0.57647E-02
0.18648E-03	-0.25035E-02	0.11926E-02
-0.51434E-02	0.12645E-02	-0.69198E-02
0.73953E-02	-0.12588E-01	-0.33350E-04
0.48975E-03	-0.37306E-01	-0.70703E 00
-0.13665E-02	0.11909E-01	0.22581E-02
0.19190E-01	-0.10568E-02	0.12504E-02
0.29624E-03	-0.27375E-02	0.23924E-02
0.12003E-01	0.12100E-01	-0.79142E-02
-0.35160E-03	0.10707E-02	-0.13431E-02
0.59790E-03	-0.15603E-02	-0.78153E-02
-0.42134E-02	0.23994E-02	0.10107E-02
-0.50116E-02	0.34080E-01	0.70212E 00
-0.41143E-03	0.13728E-02	-0.11978E-02
-0.18739E-01	-0.57056E-03	0.38439E-03
-0.36545E-08	0.11681E-02	0.61591E-03
0.59069E-04	-0.11805E-01	-0.48935E-01

FREQUENCY 0.20324E 04 CPS

MODE SHAPE

-0.52482E-02	-0.39771E-02	0.30608E-02
0.12119E-02	0.12997E-01	0.69209E-02
-0.47073E-02	0.72973E-03	0.50523E-02
0.77080E-02	0.14323E-01	0.45050E-02

0.32947E-02	-0.89054E-02	0.43098E-02
-0.39660E-02	-0.30789E-02	0.31772E-03
-0.30347E 00	-0.19520E 00	-0.92756E 00
-0.73583E-02	-0.59327E-03	0.59606E-02
-0.55916E-02	0.20530E-02	-0.20257E-03
0.59498E-02	-0.15427E-01	0.69942E-02
-0.36944E-02	0.34770E-02	-0.37831E-02
-0.34300E-02	-0.16067E-01	0.84312E-02
-0.61051E-02	0.23531E-02	0.22930E-02
0.20104E-01	0.26715E-04	0.58845E-02
0.15371E-01	0.14785E-01	0.71884E-01
-0.32943E-01	-0.69156E-03	0.49846E-02
0.82306E-07	-0.15918E-01	0.94339E-02
0.17001E-01	0.40843E-02	-0.15979E-02

FREQUENCY 0.17104E 04 CPS

MODE SHAPE

-0.69755E-03	-0.30935E-02	0.13772E-03
0.12081E-01	-0.38122E-02	0.20317E-02
-0.22865E-02	0.35688E-02	0.45990E-02
0.94757E-02	-0.94859E-02	0.56610E-02
-0.14776E-02	-0.16194E-01	-0.19159E-01
0.36203E-01	0.37598E-01	0.17559E-03
-0.23660E-02	-0.74446E-02	0.13535E-02
-0.54053E-02	0.12925E-01	0.29940E-02
-0.11194E-02	-0.10659E-01	-0.21515E-01
0.11759E-01	0.40262E-02	0.51275E-02
0.47316E-02	0.71513E-02	0.30728E-02
-0.99743E-02	0.90638E-03	0.39181E-02
0.96683E-01	-0.19289E 00	-0.96238E 00
0.24662E-01	-0.18116E-01	0.42624E-02
-0.76575E-02	0.17761E-03	-0.27122E-02
0.10575E-01	-0.13449E-01	0.36189E-02
-0.13185E-06	-0.68327E-01	0.21761E-01
0.91969E-01	-0.85219E-01	-0.88887E-02

FREQUENCY 0.17255E 04 CPS

MODE SHAPE

0.58962E-03	-0.89188E-03	-0.10656E-03
0.22255E-02	-0.21768E-02	0.22927E-02
-0.11595E-02	0.65558E-01	0.10008E 00
0.15307E-01	-0.86590E-02	0.15777E-02
-0.17783E-02	-0.76855E-02	0.38274E-02
-0.19845E-01	-0.10464E-01	0.38272E-03
0.12524E-02	0.50126E-02	0.20570E-02
-0.72342E-02	-0.64354E-02	0.13564E-02

-0.13905E-02	-0.25348E-02	-0.45279E-02
-0.19429E-02	0.30737E-02	0.26373E-02
-0.61694E-01	0.46315E 00	0.86532E 00
-0.62232E-02	0.75751E-02	0.14842E-02
0.62780E-02	-0.52786E-02	0.12311E-01
0.23067E-01	0.11409E-01	0.20490E-02
0.87694E-02	-0.96864E-02	0.20223E-01
0.13189E-01	0.55770E-02	0.17511E-02
0.11928E-06	-0.35589E-01	0.15290E-01
0.88640E-01	0.79614E-01	-0.56135E-02

FREQUENCY 0.39865E 03 CPS

MODE SHAPE

0.18086E-02	0.13694E-02	-0.16593E-02
0.57743E-02	-0.10643E-02	-0.68107E-03
0.87056E-03	0.67335E-02	0.51311E-03
0.62683E-02	0.63640E-03	-0.24274E-03
-0.25342E-02	-0.68586E-02	0.66943E-03
0.40610E-02	0.30225E-03	-0.17793E-03
-0.10524E-01	-0.16121E 00	0.99736E-02
0.70914E 00	0.59462E-03	-0.34739E-03
-0.42345E-02	0.51881E-02	-0.19840E-02
-0.15700E-01	-0.17763E-02	-0.11934E-02
-0.24685E-02	-0.38650E-02	-0.30169E-03
-0.21365E-02	-0.17061E-02	-0.20607E-02
0.40864E-02	0.66164E-02	0.30891E-02
0.49690E-03	0.17621E-02	-0.17422E-02
0.13264E-01	0.17840E 00	-0.12705E-01
0.65844E 00	0.46379E-02	-0.18863E-02
-0.77101E-08	0.47916E-01	-0.21840E-01
0.28238E-01	-0.36896E-02	-0.31457E-01

FREQUENCY 0.39677E 03 CPS

MODE SHAPE

0.28154E-03	0.44832E-02	-0.27520E-02
-0.25849E-03	0.79477E-04	0.89058E-03
0.43412E-02	0.37427E-02	-0.20474E-02
0.18234E-02	-0.55419E-03	0.31214E-02
0.89663E-02	-0.55628E-02	0.18166E-02
-0.22207E-03	-0.11373E-02	0.60826E-04
0.16123E 00	-0.10828E-01	-0.49410E-01
-0.17952E-02	0.68426E 00	0.18820E-03
-0.97013E-03	-0.73067E-02	0.49975E-02
0.31074E-02	0.26033E-03	0.37264E-02
-0.46278E-02	-0.42143E-03	0.56153E-03
-0.36090E-02	-0.16989E-03	0.35476E-02

-0.14934E-01	0.68674E-02	-0.39893E-02
-0.24459E-02	-0.34664E-02	0.34624E-02
-0.16331E 00	0.64738E-02	0.57856E-01
0.47135E-04	0.68708E 00	0.37198E-02
-0.14068E-06	0.78890E-02	-0.26677E-02
0.38938E-03	0.94165E-02	0.16033E-01

FREQUENCY 0.49364E 03 CPS

MODE SHAPE

-0.54986E-02	0.65737E-02	-0.17024E-03
-0.39119E-01	-0.81596E-01	-0.65257E 00
0.21838E-02	-0.53985E-03	0.15068E-02
0.47001E-02	0.22563E-02	0.55640E-02
-0.12064E-01	0.54655E-02	0.99662E-02
0.15085E-02	0.19059E-02	0.35223E-03
-0.11393E-01	-0.10065E-01	-0.26642E-02
0.95336E-02	0.66681E-02	-0.54172E-02
-0.65927E-02	0.10155E-01	0.30154E-02
-0.68300E-01	-0.11288E 00	-0.70734E 00
-0.67665E-02	0.62506E-02	-0.90193E-03
-0.10618E-01	-0.14174E-02	0.72636E-02
0.14446E-01	-0.51760E-02	-0.50228E-02
0.51629E-02	0.13754E-02	0.32558E-02
0.80819E-02	0.23016E-01	0.83049E-03
-0.10904E-01	-0.21098E-02	0.96786E-02
-0.32175E-07	-0.22917E-01	0.12669E-01
0.27072E-02	0.12464E-01	0.21223E 00

FREQUENCY 0.48589E 03 CPS

MODE SHAPE

0.64815E-02	-0.21885E-02	0.19087E-02
-0.60467E-02	-0.24077E-01	-0.25245E-01
0.45530E-02	-0.17942E-01	0.78902E-02
0.46216E-01	0.92128E-01	0.66647E 00
0.26514E-02	0.78100E-02	-0.12234E-01
0.29099E-02	0.24427E-02	-0.36737E-03
-0.92283E-03	-0.31980E-02	0.72194E-02
-0.21885E-01	-0.95453E-03	0.74110E-02
0.11425E-01	-0.37379E-02	0.18979E-03
0.67802E-02	0.21931E-01	-0.24149E-01
0.37617E-02	0.93204E-02	-0.58773E-02
0.76786E-01	0.11606E 00	0.69730E 00
-0.37930E-02	-0.36025E-02	0.62674E-02
-0.66921E-02	-0.26326E-02	0.10106E-02
-0.76964E-04	-0.11671E-01	-0.58362E-02
0.17029E-01	0.15926E-03	-0.64086E-02

0.21414E-08	0.33461E-01	-0.15226E-01
-0.32331E-04	-0.82038E-02	-0.18340E 00

FREQUENCY 0.43646E 03 CPS

MODE SHAPE

-0.77872E-03	-0.95914E-03	0.66473E-03
-0.38996E-02	0.79387E-03	0.26069E-02
0.14844E-03	-0.15916E-02	-0.65830E-02
0.25730E-02	0.18590E-02	0.47393E-02
0.37196E-02	-0.16644E 00	0.18484E-01
0.67502E 00	0.25210E-02	0.10172E-03
0.84185E-02	-0.11411E-02	0.10032E-01
-0.21510E-01	0.34273E-02	0.10917E-02
0.75806E-03	-0.37158E-02	-0.46053E-03
0.83472E-02	0.82735E-03	0.77370E-02
0.15735E-03	0.84375E-03	-0.18067E-02
-0.41560E-02	-0.64047E-03	0.63548E-02
-0.85020E-02	0.16421E 00	0.78289E-02
0.69176E 00	-0.45565E-02	0.46988E-02
-0.11193E-01	-0.82139E-02	-0.15659E-02
0.11611E-01	-0.99352E-02	0.47375E-02
0.11571E-07	0.74497E-01	-0.43483E-01
0.21020E-01	0.37398E-02	0.35990E-01

FREQUENCY 0.10091E 04 CPS

MODE SHAPE

-0.22285E-02	-0.17609E-02	0.27486E-02
-0.76814E-02	0.30938E-02	-0.54505E-02
0.23670E-02	-0.77756E-02	-0.65975E-02
-0.22591E-02	-0.37856E-02	-0.75735E-02
0.76453E-03	0.75320E-02	-0.95431E-02
0.40994E-02	-0.60580E-02	-0.10425E-02
-0.93011E-03	0.73416E-02	0.18403E-02
0.18860E-01	-0.92158E-02	-0.46473E-02
-0.46588E-03	0.69262E-03	0.33143E-03
-0.24374E-02	-0.50900E-02	-0.10751E-01
0.16208E-03	0.11642E-02	-0.98111E-03
-0.19756E-03	0.29155E-02	-0.10092E-01
0.50371E-02	-0.20039E-01	-0.20427E-02
0.19277E-01	0.76274E-02	-0.92546E-02
0.10334E-01	0.50510E-02	-0.41488E-02
-0.24933E-01	0.13548E-01	-0.75536E-02
0.19502E-06	0.41794E 00	0.90374E 00
0.27329E-01	-0.41232E-02	-0.67689E-01

FREQUENCY 0.15326E 04 CPS

MODE SHAPE

0.10734E-01	0.18665E-01	0.26663E-01
-0.30158E-02	0.21407E-01	0.39492E-02
-0.89428E-03	-0.98956E-03	-0.67474E-03
0.14465E-01	0.62344E-02	-0.53313E-03
-0.48097E-02	0.54017E-02	0.22915E-02
-0.26423E-02	0.15624E-01	0.71614E-04
-0.83015E-03	0.16875E-02	0.14530E-02
-0.95373E-02	0.13028E-01	0.98094E-03
0.26325E 00	0.52245E 00	0.79185E 00
0.14858E-02	0.23786E-01	0.13411E-02
-0.14947E-02	0.40390E-02	-0.23022E-02
-0.47091E-02	-0.68496E-02	0.13099E-02
-0.74111E-02	-0.15058E-01	0.41382E-02
0.12823E-01	-0.15260E-01	0.62721E-03
-0.68245E-02	-0.97471E-02	-0.78831E-02
0.13030E-01	-0.11588E-01	0.15665E-03
-0.15238E-06	-0.54965E-01	0.22102E-01
0.11809E 00	-0.94243E-01	0.63413E-02

FREQUENCY 0.17017E 04 CPS

MODE SHAPE

0.20955E-03	-0.30723E-02	0.21633E-02
0.71237E-02	0.69013E-02	0.59816E-03
-0.19685E-02	0.25652E-03	-0.21079E-02
0.12078E-02	-0.25246E-02	0.76990E-03
0.38272E-02	0.85984E-02	0.83152E-03
-0.41817E-02	-0.17599E-01	0.10637E-03
-0.25286E-01	-0.16951E-01	-0.64266E-01
0.29872E-01	-0.31102E-02	0.87892E-03
-0.10822E-01	-0.48233E-03	-0.11962E-01
0.36436E-02	-0.10122E-01	0.18727E-02
0.96420E-03	-0.30507E-02	0.21086E-02
0.57170E-02	0.37625E-02	0.40887E-03
0.78481E-02	-0.10134E-01	0.84123E-02
0.47683E-02	0.17646E-01	0.10738E-02
-0.29559E 00	-0.18720E 00	-0.91953E 00
0.61099E-02	0.12181E-01	0.10547E-02
0.17275E-06	-0.54057E-01	0.23945E-01
0.82492E-01	0.11611E 00	0.23769E-01

FREQUENCY 0.97023E 03 CPS

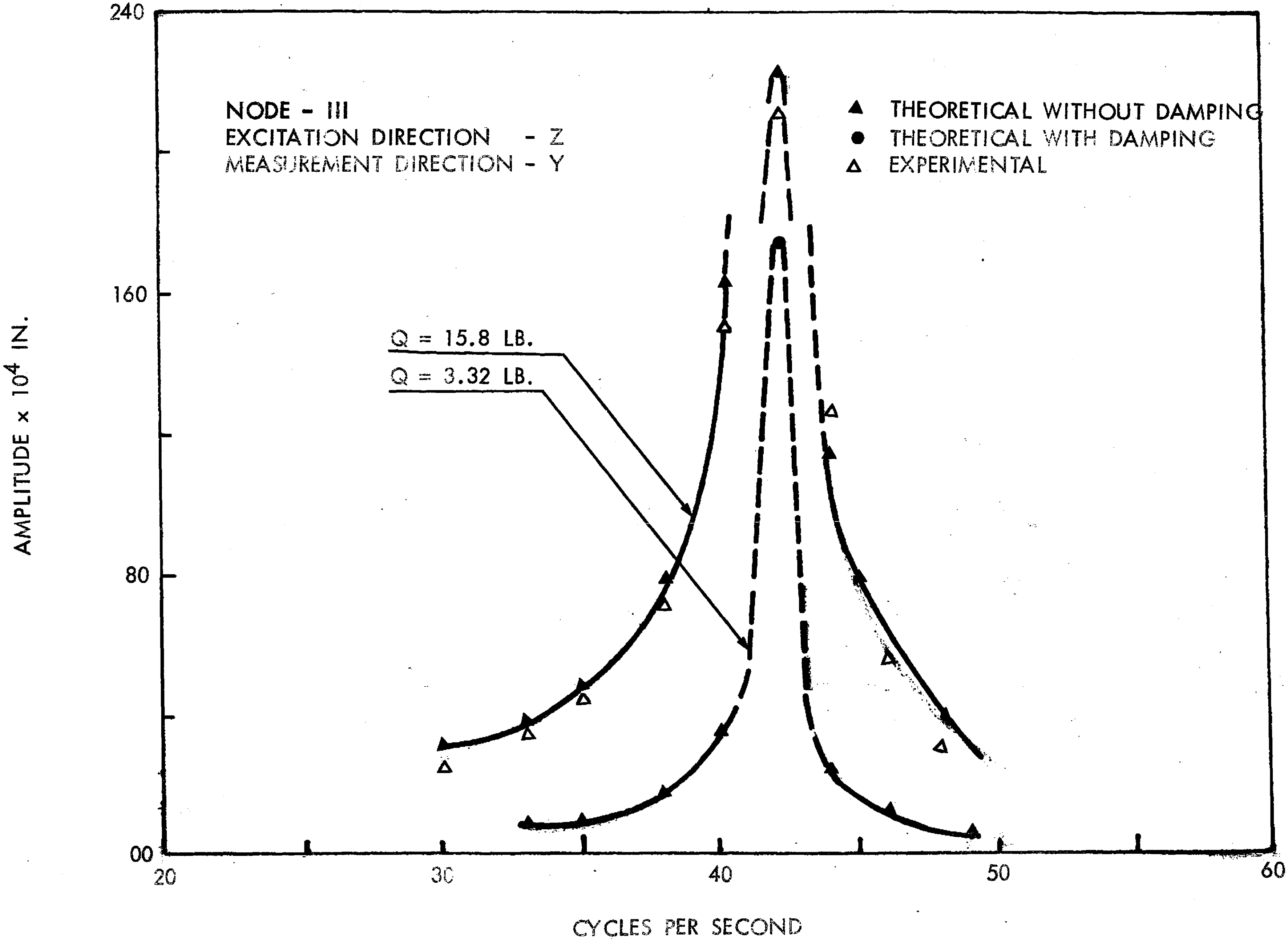
MODE SHAPE

-0.22180E-02	0.11065E-02	0.21954E-03

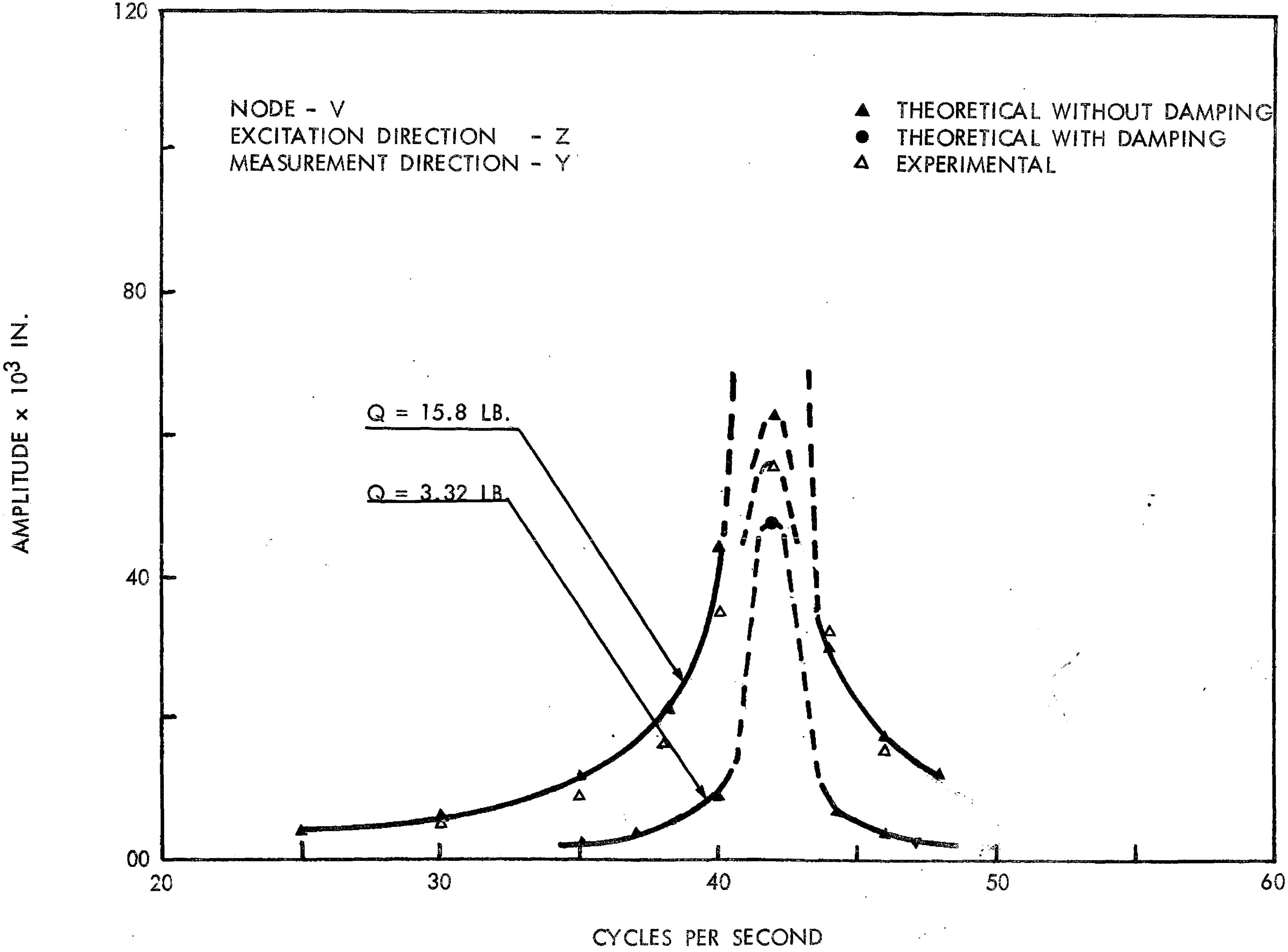
0.23969E-02	0.24823E-03	-0.15099E-02
0.85241E-03	0.33298E-02	-0.19760E-02
0.19460E-02	-0.19969E-02	-0.25533E-02
0.16583E-02	-0.38119E-02	0.22090E-02
-0.86041E-03	-0.21827E-02	-0.53051E-03
0.69865E-02	0.52486E-02	-0.48786E-03
0.51763E-01	0.31142E-01	0.71477E 00
0.42190E-02	0.18239E-02	-0.28924E-02
-0.46442E-02	0.23178E-02	0.28758E-04
0.39818E-03	0.17510E-02	-0.18396E-03
0.93522E-03	0.18248E-02	-0.46547E-04
-0.75094E-04	0.53734E-02	-0.16151E-02
0.39312E-02	0.30659E-02	-0.17893E-02
-0.67456E-02	0.40323E-02	0.44828E-02
-0.53832E-01	-0.31783E-01	-0.69249E 00
0.45936E-08	-0.13315E-01	0.52254E-02
-0.15914E-02	0.76420E-02	0.37272E-01

APPENDIX - II

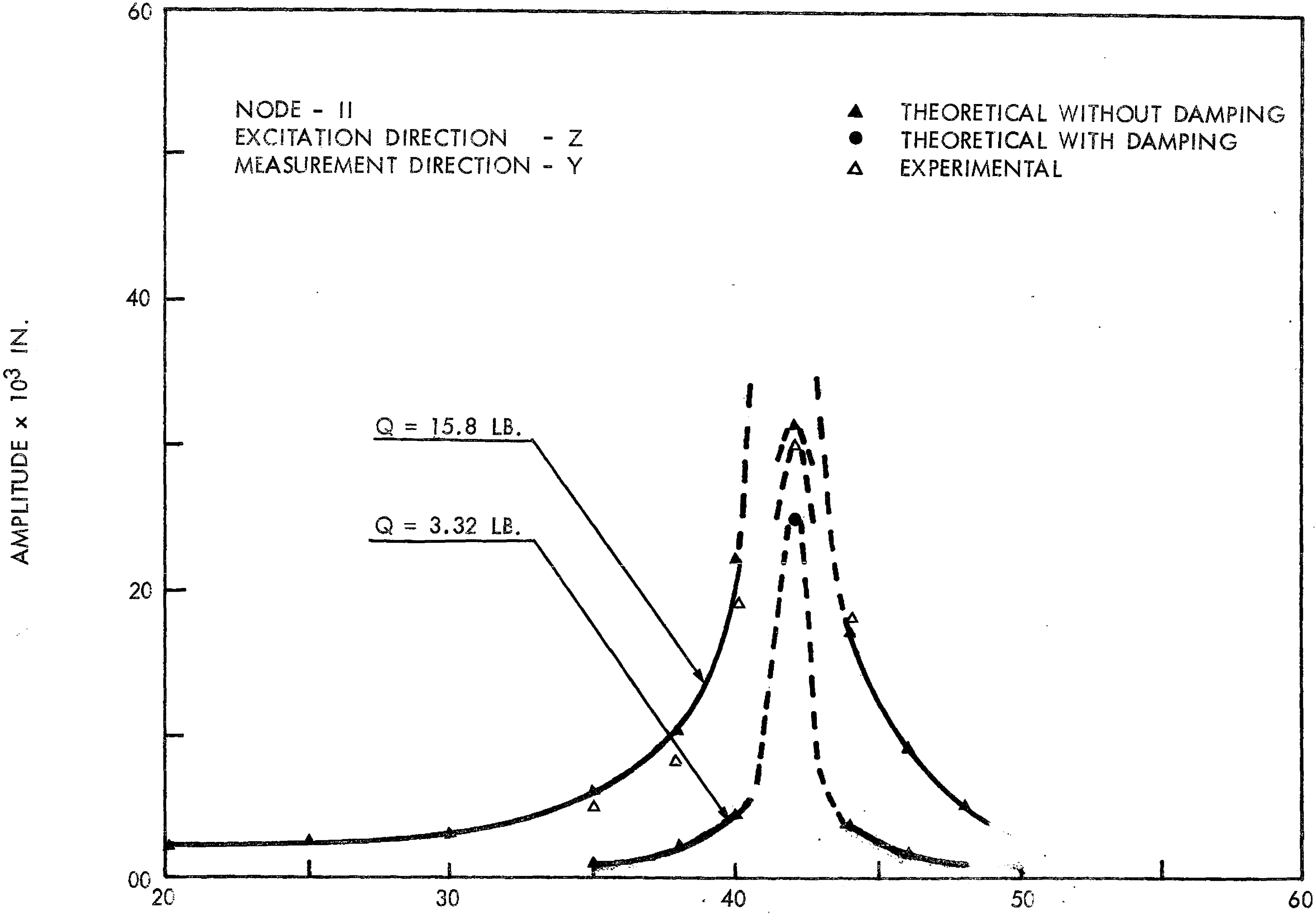
(RESULTS OF STEADY-STATE VIBRATIONS)


NODE - III
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
▲ THEORETICAL WITHOUT DAMPING
● THEORETICAL WITH DAMPING
△ EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10^4 IN.
240
160
80
00
20
30
40
50
60
CYCLES PER SECOND

GRAPH NO.1

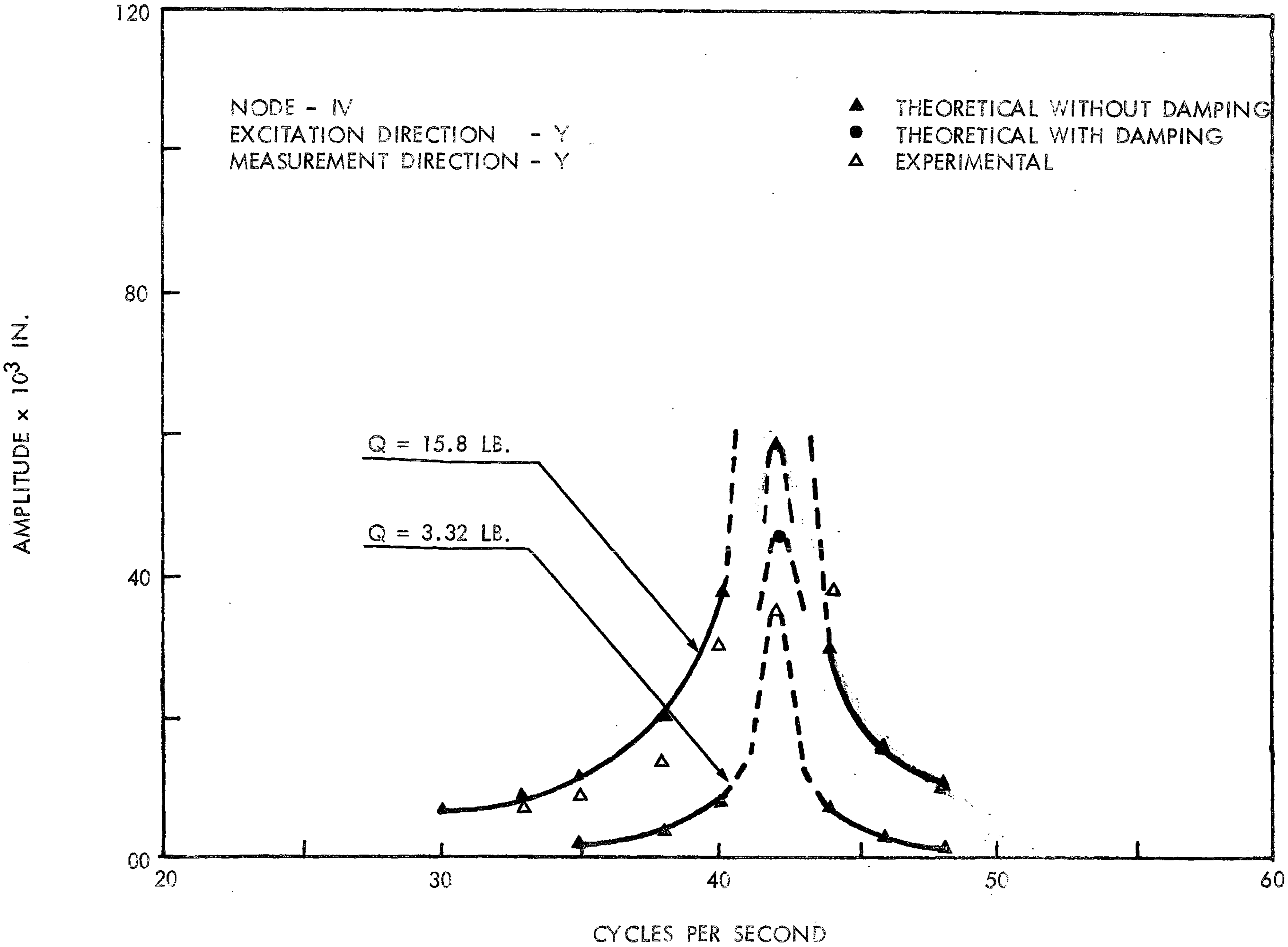

NODE - V
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE x 10^3 IN.
CYCLES PER SECOND
120
80
40
00
20
30
40
50
60

GRAPH NO. 2

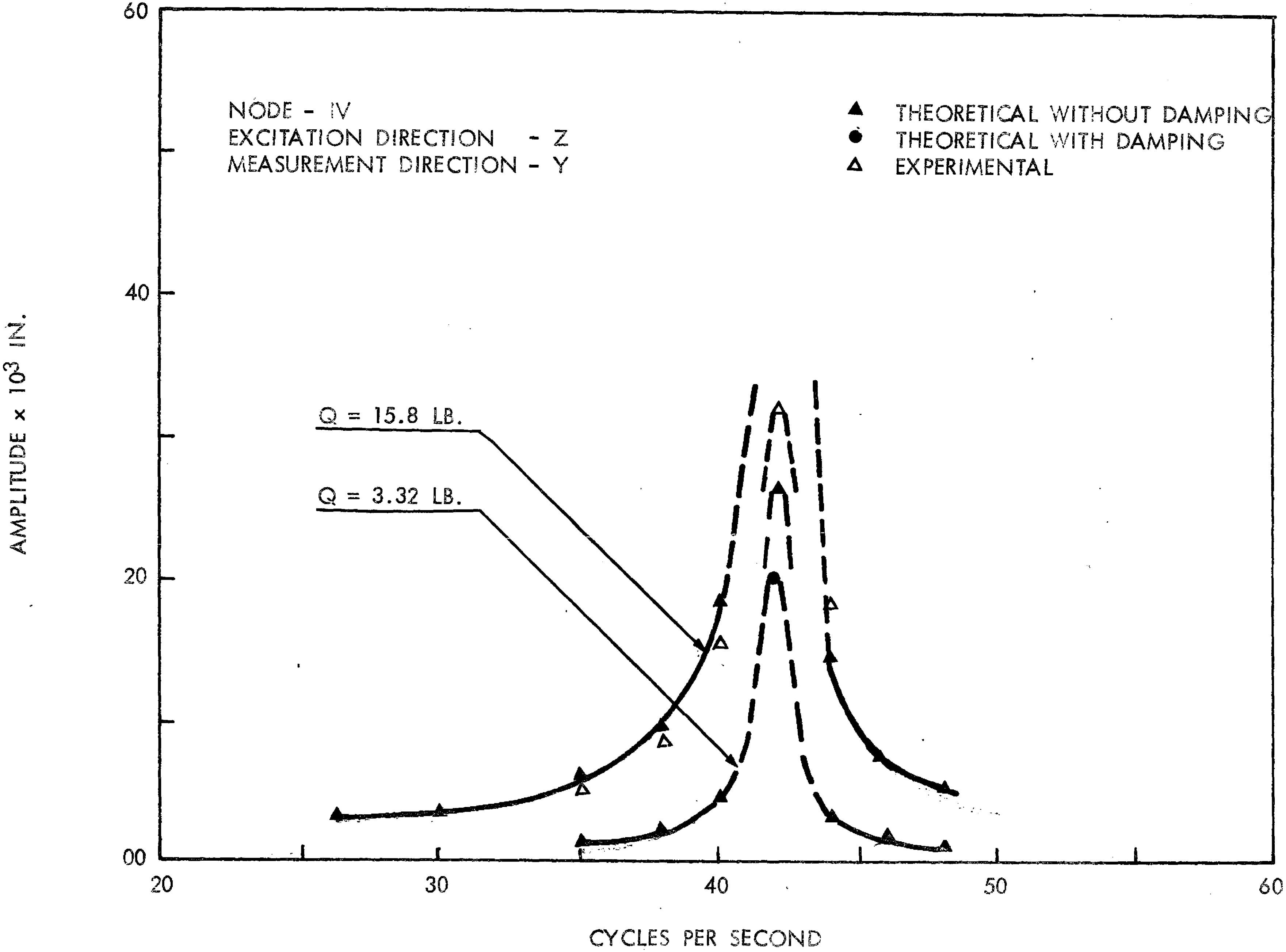


CYCLES PER SECOND

GRAPH NO. 3

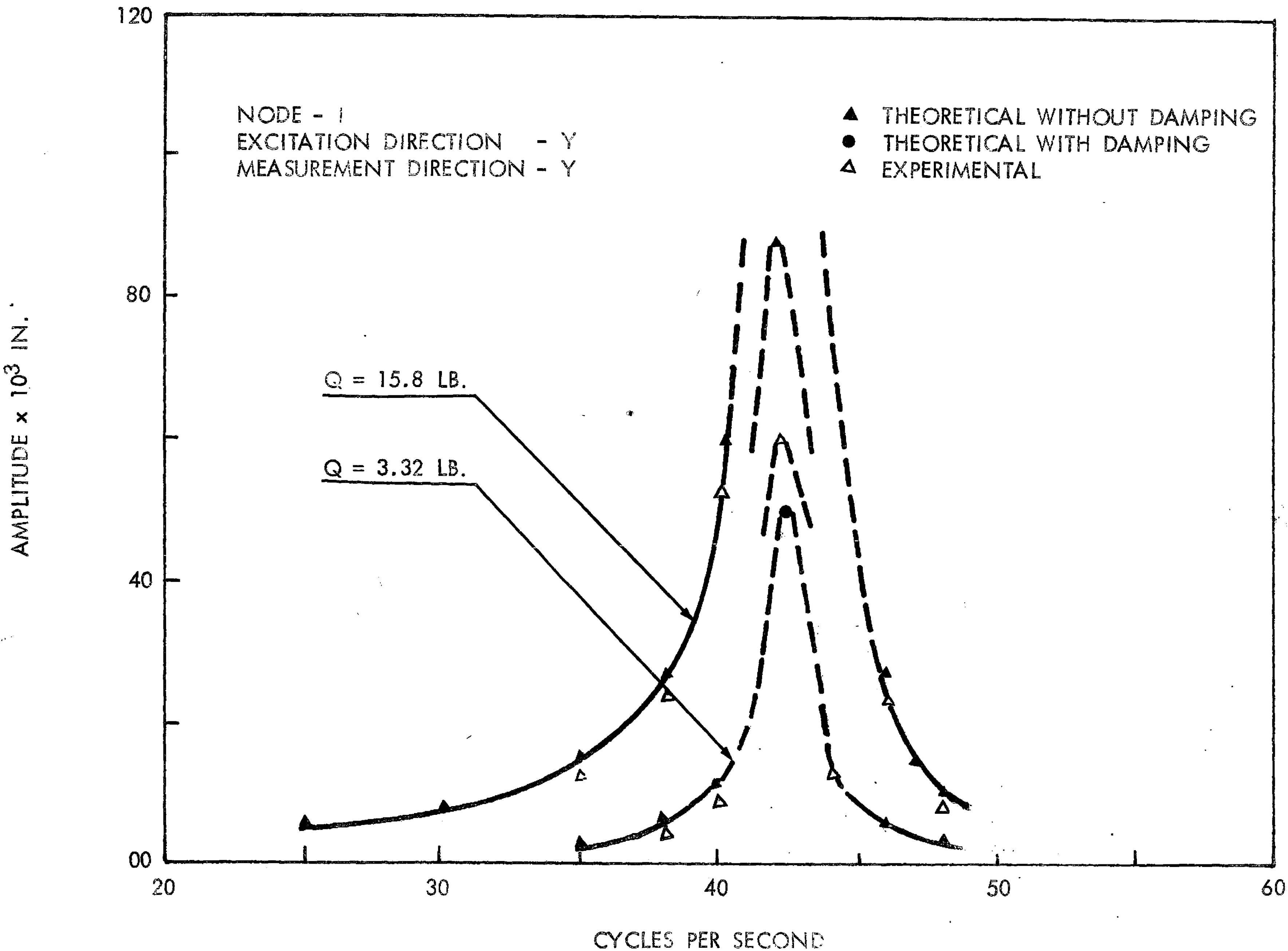

NODE - IV
EXCITATION DIRECTION - Y
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10³ IN.
120
80
40
00
20
30
40
50
60
CYCLES PER SECOND

GRAPH NO. 4



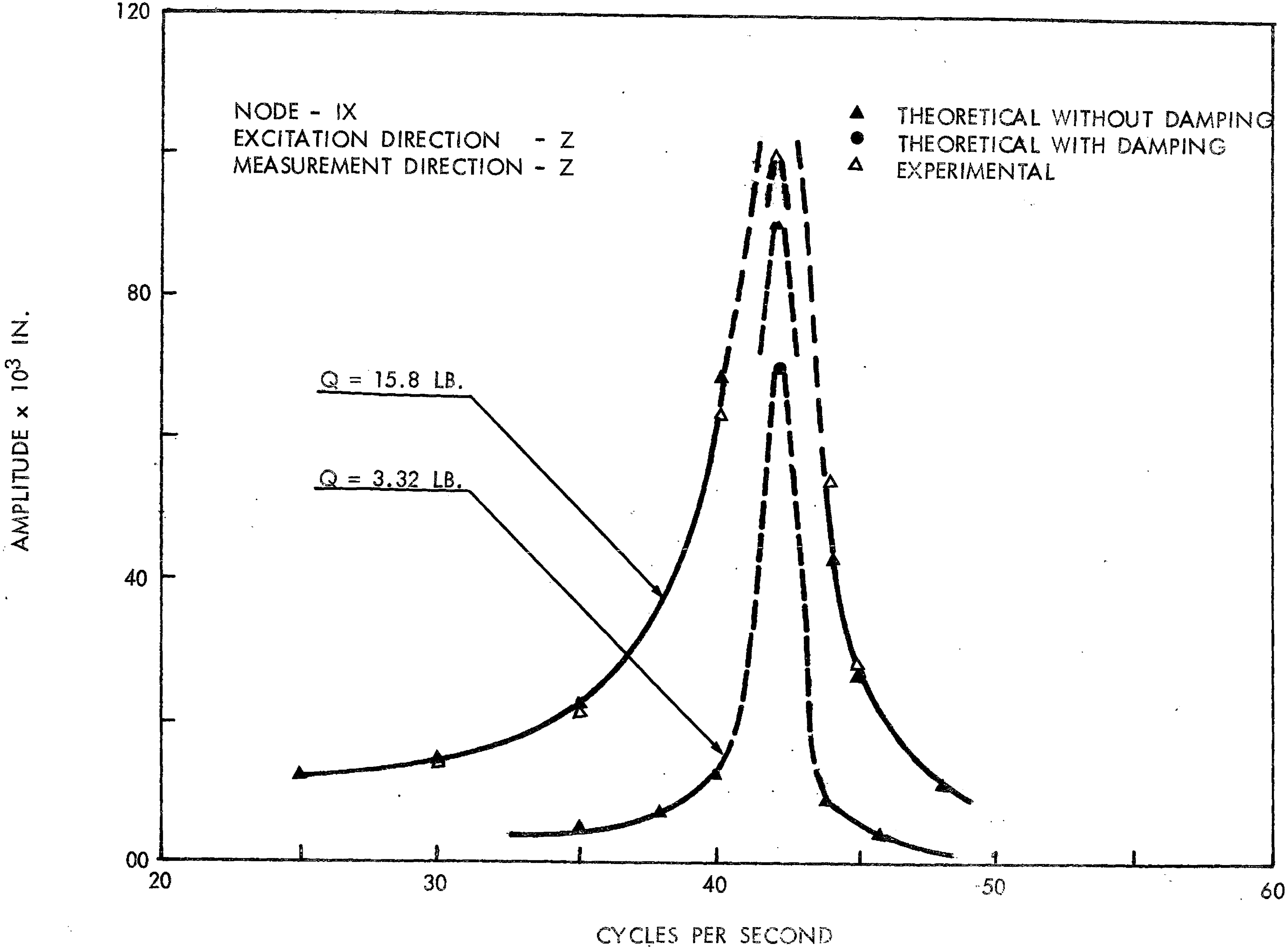
NODE - IV
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10³ IN.
60
40
20
00
20
30
40
50
60
CYCLES PER SECOND

GRAPH NO. 5

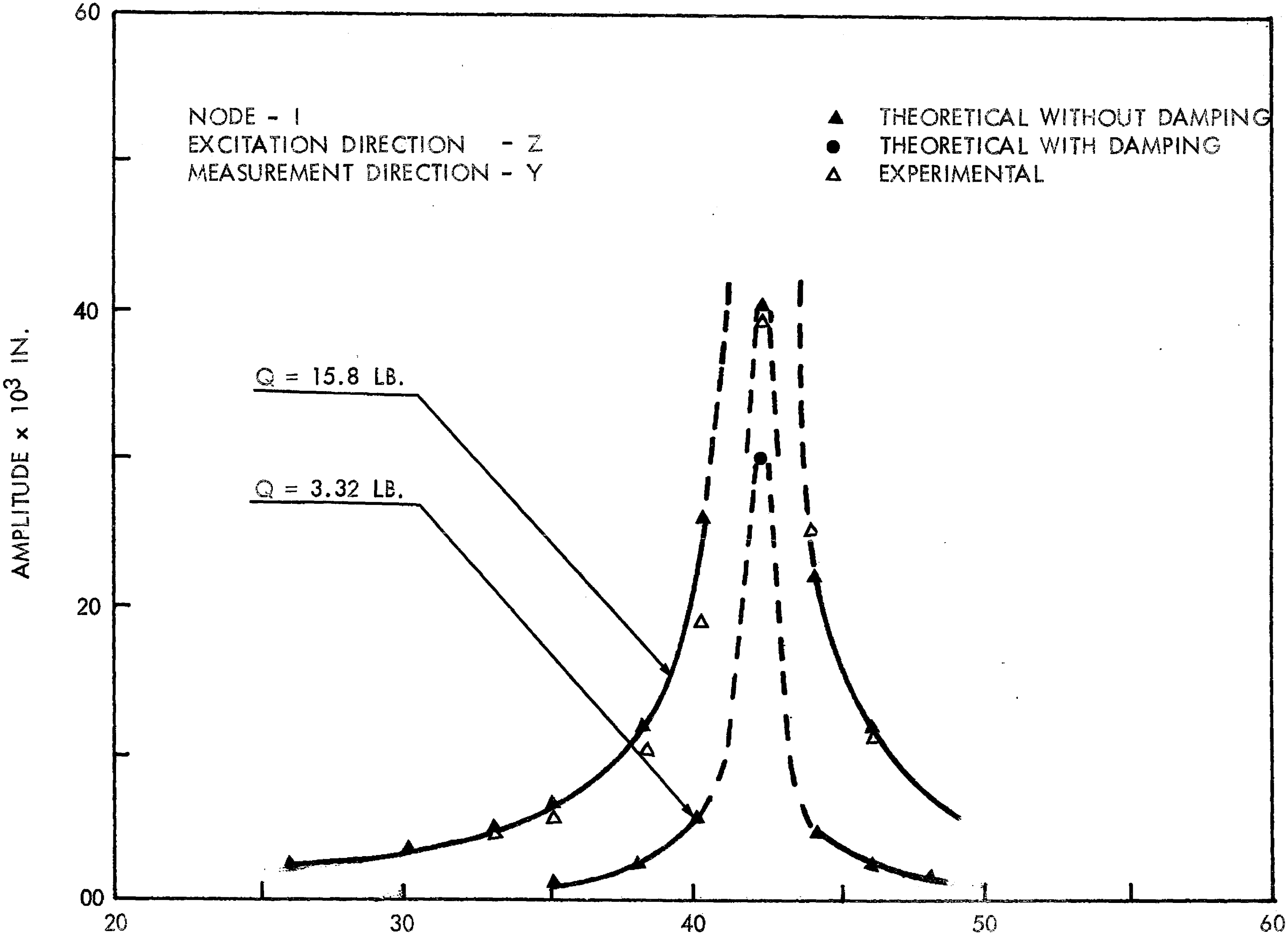


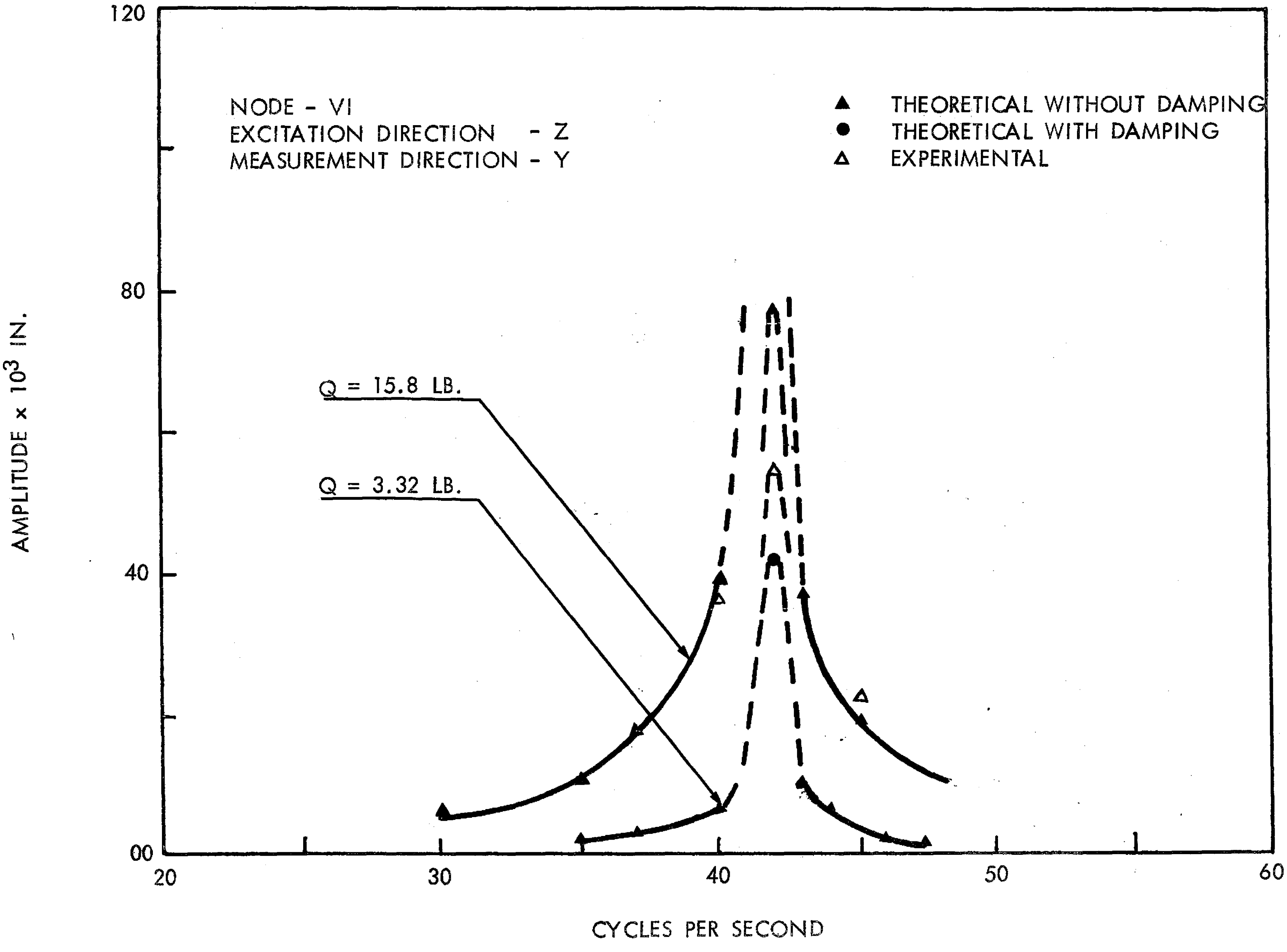
120
80
40
00
20
30
40
50
60
AMPLITUDE × 10^3 IN.
CYCLES PER SECOND
NODE - I
EXCITATION DIRECTION - Y
MEASUREMENT DIRECTION - Y
▲ THEORETICAL WITHOUT DAMPING
● THEORETICAL WITH DAMPING
△ EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.

GRAPH NO. 6

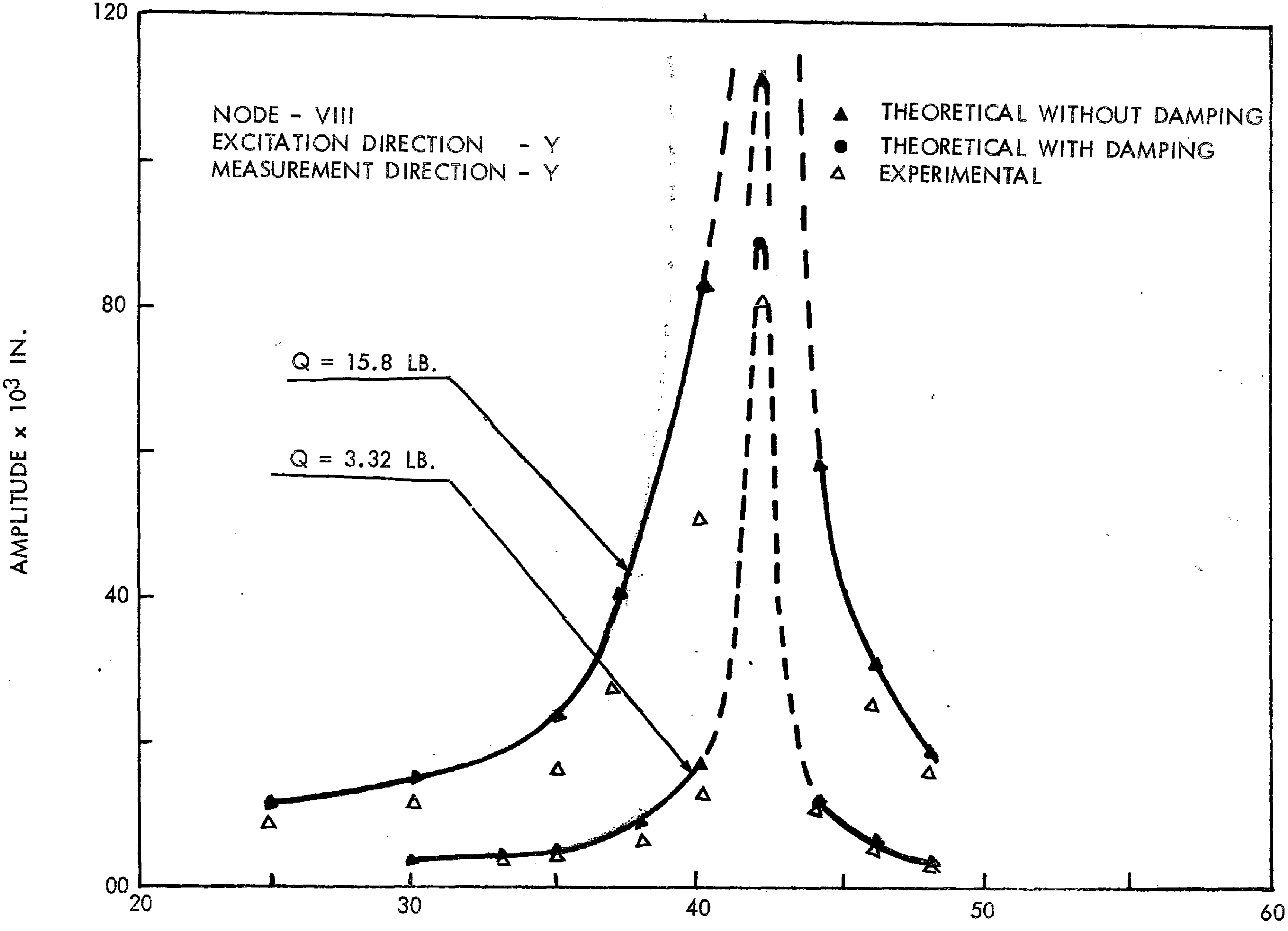

120
80
40
00
20
30
40
50
60
AMPLITUDE × 10³ IN.
CYCLES PER SECOND
NODE - IX
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Z
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.

GRAPH NO. 7


NODE - I
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10³ IN.
60
40
20
00
20
30
40
50
60
CYCLES PER SECOND
GRAPH NO. 8

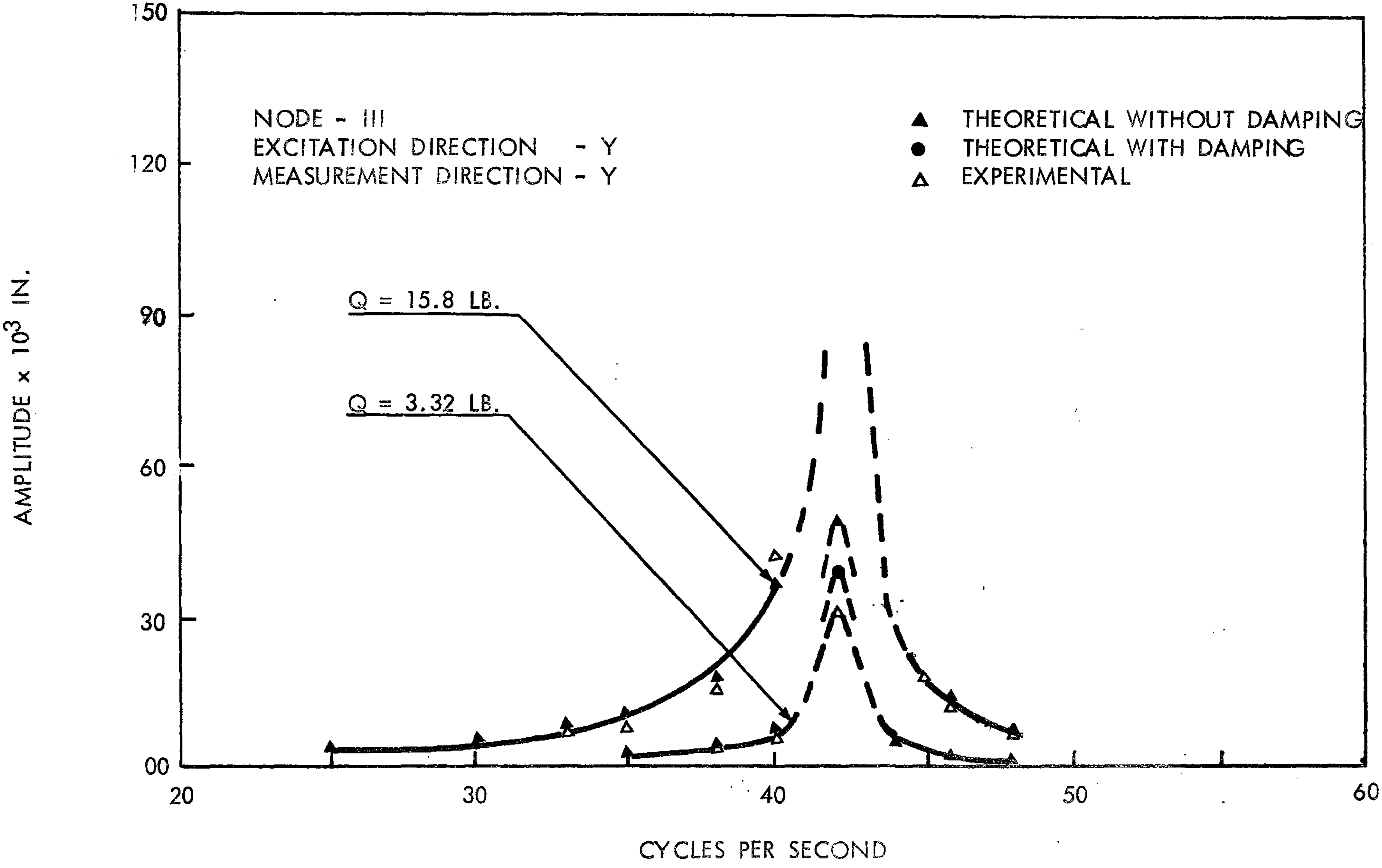

120
80
40
00
20
30
40
50
60
AMPLITUDE x 10³ IN.
CYCLES PER SECOND
NODE - VI
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
▲ THEORETICAL WITHOUT DAMPING
● THEORETICAL WITH DAMPING
△ EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.

GRAPH NO. 9

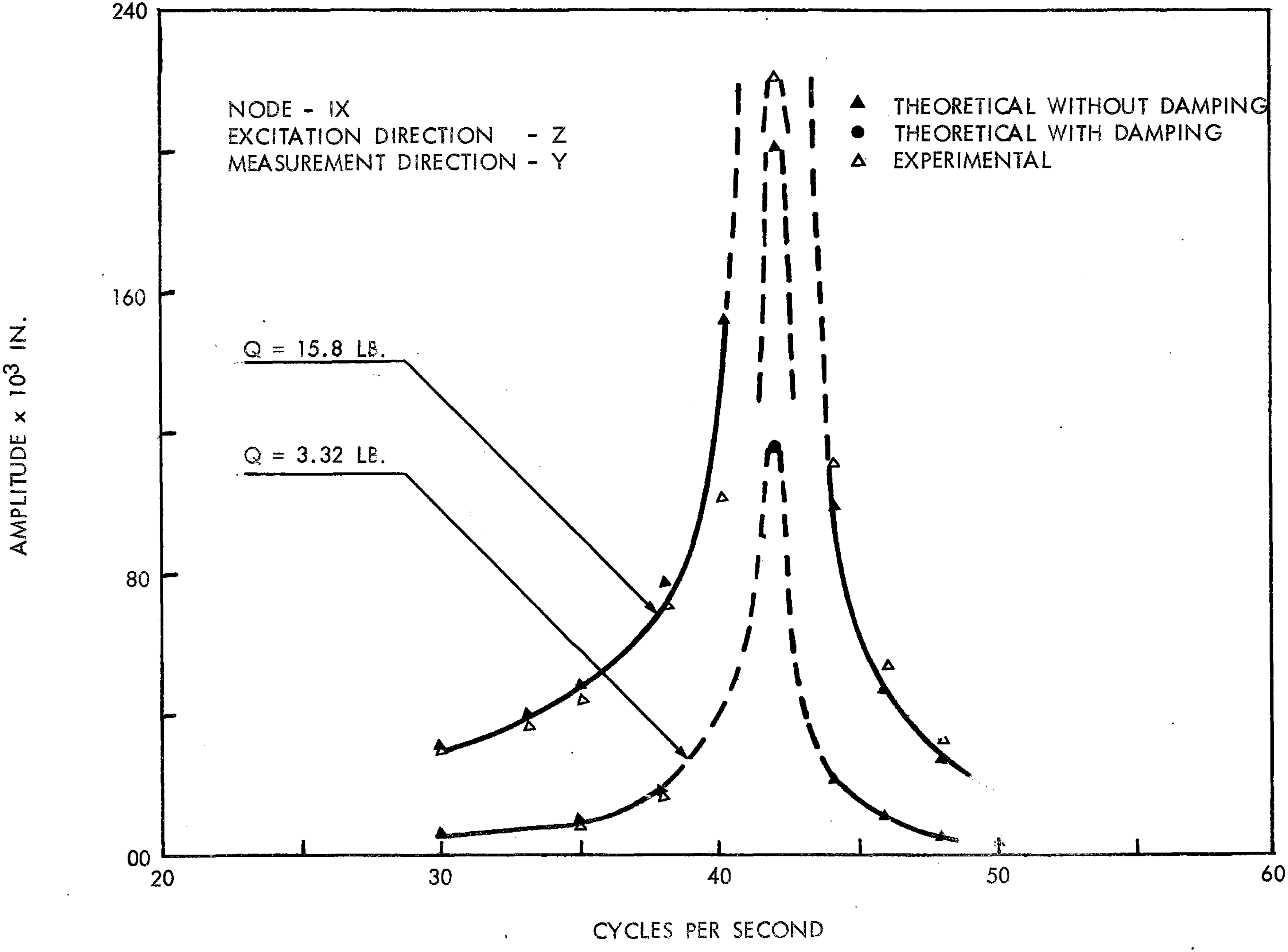


NODE - VIII
EXCITATION DIRECTION - Y
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE x 10^3 IN.
120
80
40
00
20
30
40
50
60
CYCLES PER SECOND

GRAPH NO. 10


NODE - III
EXCITATION DIRECTION - Y
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10³ IN.
150
120
90
60
30
00
20
30
40
50
60
CYCLES PER SECOND

GRAPH NO. 11


240
160
80
00
20
30
40
50
60
NODE - IX
EXCITATION DIRECTION - Z
MEASUREMENT DIRECTION - Y
THEORETICAL WITHOUT DAMPING
THEORETICAL WITH DAMPING
EXPERIMENTAL
Q = 15.8 LB.
Q = 3.32 LB.
AMPLITUDE × 10³ IN.
CYCLES PER SECOND

GRAPH NO. 12

APPENDIX - III

(COMPUTER PROGRAMMES)

C	PARAMETERS OF MAIN PROGRAMME
B	TEMPORARY STORAGE LOCATION
S	MATRIX OBTAINED FROM FACTORISATION OF GENERALISED MASS MATRIX
ST	TRANSPOSE OF MATRIX S
STP	PRODUCT OF MATRIX S FLEXIBILITY MATRIXAND MATRIX ST
V	MODAL MATRIX
Q	AMPLITUDE OF GENERALISED FORCES
QQ	FORCE AMPLITUDE IN NORMAL COORDINATES
OMEGA	FREQUENCY
ZAI	DISPLACEMENT IN NORMAL COORDINATES
IERR	MINVSE LIBRARY SUBROUTINE PARAMETER
NS	MINVSE LIBRARY SUBROUTINE PARAMETER
WORK	MINVSE LIBRARY SUBROUTINE PARAMETER
QI	DISPLACEMENT IN ORIGINAL COORDINATES
N	SIZE OF FLEXIBILITY AND MASS MATRICES
C	
C	SUBROUTINE GMASM PARAMETERS
A	TRANSPOSE OF TRANSFORMATION MATRIX
C	TEMPORARY STORAGE LOCATION
B	DISCRETE MASS MATRIX
D	TRANSFORMATION MATRIX
F	UNCOUPLED DISCRETE MASS MATRIX
TRASM	TRANSFORMATION MATRIX TO OBTAIN GENERALISED MASS MATRIX

```
$JOB              003725 RAGHAVA RS          100    010    030
$IBJOB            NODECK
$IBFTC EIG
      COMMON A(54,54),B(54,54),S(54,54),ST(54,54),V(54,54)
     1STP(54,54),QI(54),QQ(54),ZAI(54),NS(54),WORK(54)
     2F(78,78),TRASM(78,54),AUX(54,78),GM(54,54)
C     MAIN PROGRAMME
C     INPUT OF GENERALISED MASS MATRIX
C
      READ(5,1) N
      CALL GMASM(A)
C
C     NEXT 23 STATEMENTS FACTORISE THE GENERALISED
     1MASS MATRIX
C
      DO 5 I=1,N
      DO 5 J=1,N
5     S(I,J)=0.0
      S(1,1)=SQRT(A(1,1))
      DO 10 J=2,N
10    S(1,J)=A(1,J)/S(1,1)
      DO 20 I=2,N
      SUM=0.0
      LL=I-1
C
      DO 21 L=1,LL
      SUM=SUM+S(L,I)**2
      IF(SUM.GT.A(I,I))GO TO 50
21    CONTINUE
      S(I,I)=SQRT(A(I,I)-SUM)
      II=I+1
       IF(I.EQ.N) GO TO 20
C
      DO 22 J=II,N
      SUM=0.0
      KK=I-1
      DO 22 K=1,KK
      SUM=SUM+S(K,I)*S(K,J)
22    S(I,J)=(A(I,J)-SUM)/S(I,I)
20    CONTINUE
V
C     TRANSPOSE OF S MATRIX OBTAINED
C
      DO 110 I=1,N
      DO 110 J=1,N
110   ST(J,I)=S(I,J)
C
C     FLEXIBILITY MATRIX IS READ
C
      DO 150 I=1,N
150   READ(5,201)(A(I,J),J=1,I)
```

```
C
C      TRANSPOSITION OF LOWER TRIANGLE OF
      1FLEXIBILITY MATRIX
C
       DO 160 I = 1,N
       DO 160 J = 1,I
   160 A( J,I ) = A( I,J )
C
C      MATRICES S AND FLEXIBILITY MULTIPLIED
C
       DO170 I=1,N
       DO 170 J=1,N
       B(I,J)=0.0
       DO 170 K=1,N
 170   B(I,J)=B(I,J)+S(I,K)*A(K,J)
C
C      NEXT 6 STATEMENTS MULTIPLY PREVIOUS PRODUCT
C
       DO 180 I=1,N
       DO 180 J=1,N
       STP(I,J)=0.0
       DO 180 K=1,N
 180   STP(I,J)=STP(I,J)+B(I,K)*ST(K,J)
C
       CALL TO SUBROUTINE JACOBI FOR DIAGONALISATION
C
       CALL JACOBI(N,STP,1,NR,V)
       DO 190 J=1,N
 190   STP(J,J)=7.0/(44.0*SQRT(STP(J,J)))
C
       OUT PUT
C
       DO 200 I=1,N
       WRITE(7,210) STP(I,I)
C
       WRITE(7,205)
 200   WRITE(7,220)(V(J,I),J=1,N)
C
       DO 260 I=1,N
       DO 260 J=1,N
       B(I,J)=0.0
       DO 260 K=1,N
 260   B(I,J)=B(I,J)+V(K,I)*S(K,J)
       DO 270 I=1,N
       DO 270 J=1,N
       ST(I,J)=0.0
       DO 270 K=1,N
 270   ST(I,J)=ST(I,J)+B(I,K)*A(K,J)
       DO 290 I=1,N
C
```

```
C       INPUT OF GENERALISED FORCE
C
290     Q(I)=0.0
        READ(5,2) QI
        DO 280 I=1,N
        QQ(I)=0.0
C
C       NEXT 2 STATEMENRS TO OBTAIN FORCES IN NORMAL COORDINATES
C
        DO 280 K=1,N
280     QQ(I)=QQ(I)+ST(I,K)*Q(K)
C
C       CALL TO LIBRARY SUBROUTINE MINVSF TO INVERT MATRIX S
C
        CALL MINVSF(S,54,54,1.0E-08,IERR,NS,WORK)
C
C       NEXT 5 STATEMENTS ASSEMBLE TRANSFORMATION MATRIX
C
C
        DO 330 I=1,N
        DO 330 J=1,N
        A(I,J)=0.0
        DO 330 K=1,N
330     A(I,J)=A(I,J)+S(I,K)*V(K,J)
C
C       NEXT 6 STATEMENTS OBTAIN DISPLACEMENTS IN NORMAL COORDINATES
C
        OMEGA=0.0
        DO 320 I=1,90
        OMEGA=OMEGA+1.0
        DO 310 J=1,N
        ZAI(J)=QQ(J)/SQRT((1.0-(OMEGA/STP(J,J))**2)**2+(0.012**2))
310     CONTINUE
C
C       NEXT 4 STATEMENTS OBTAIN DISPLACEMENT IN ORIGINAL COORDINATES
C
        DO 340 L=1,N
        QI(L)=0.0
        DO 340 M=1,N
340     QI(L)=QI(L)+A(L,M)*ZAI(M)
C
C       OUTPUT
C
        WRITE(5,2) (QI(I),I=1,54)
320     CONTINUE
        STOP
350     FORMAT(1H0,10H AMPLITUDE/)
355     FORMAT(1X,6E18.5)
201     FORMAT(1X,6E13.5)
50      WRITE(6,6)
```

```
6       FORMAT(1X,32H MATRIX IS NOT POSITIVE DEFINITE)
1       FORMAT(I10)
2       FORMAT(6E13.5)
4       FORMAT(1X,6E20.5)
205     FORMAT(/30X,10HMODE SHAPE /)
210     FORMAT(/18X,10H FREQUENCY,E15.5,2X,4H CPS)
220     FORMAT(2X,3E20.5)
        STOP
        END
```

```
$IBFTC  JAC
C      SUBPROGRAMME FOR DIAGONALISATION OF MATRIX Q BY
      1SUCCESSIVE ROTATIONS
       SUBROUTINE JACOBI(N,Q,JVEC,M,V)
       DIMENSION Q(54,54),V(54,54),X(54),IH(54)
C
C      NEXT 8 STATEMENTS RE SETTING INITIAL VALUES OF MATRIX V
       IF(JVEC) 10,15,10
10     DO14  I=1,N
       DO 14 J=1,N
       IF(I-J) 12,11,12
11     V(I,J)=1.0
       GO TO 14
12     V(I,J)=0.0
14     CONTINUE
C
15     M=0
C      NEXT  8 STATEMENTS SCAN FOR LARGEST OFF DIAGONAL
      1ELEMENT IN EACH ROW
C      X(I) CONTAINS LARGESTS ELEM. IN ITH ROW
C      IH(I) HOLDS SECOND SUBSCRIPTS DEFINING POSITION OF ELEM.
C
17     MI=N-1
       DO 30  I=1,MI
       X(I)=0.
       MJ=I+1
       DO 30 J=MJ,N
       IF(X(I)-ABS(Q(I,J))) 20,20,30
20     X(I)=ABS(Q(I,J))
       IH(I)=J
30     CONTINUE
C
C      NEXT 7 STATEMENTS FIND FOR MAXIMUMS OF X(I)S
      1FOR PIVOT ELEMENT
C
40     DO 70 I=1,MI
       IF(I-1)60,60,45
45     IF(XMAX-X(I))60,70,70
60     XMAX=X(I)
       IP=I
       JP=IH(I)
70     CONTINUE
C
C      NEXT TWO STATEMENTS TEST FOR XMAX
       EPSI=1.E-08
       IF(XMAX-EPSI) 1000,1000,148
C
148    M=M+1
C
C      NEXT 11 STATEMENTS FOR COMPUTING TANG,SIN,COS,Q(I,I),Q(J,J)
C
```

```
      IF(Q(IP,IP)-Q(JP,JP)) 150,151,151
150   TANG=-2.0*Q(IP,JP)/(ABS(Q(IP,IP)-Q(JP,JP)) +
     1SQRT((Q(IP,IP)-Q(JP,JP))**2+4.0*Q(IP,JP)**2))
      GO TO 160
151   TANG=+2.0*Q(IP,JP)/(ABS(Q(IP,IP)-Q(JP,JP)) +
     1SQRT((Q(IP,IP)-Q(JP,JP))**2+4.0*Q(IP,JP)**2))
160   COSN=1./SQRT(1.0+TANG**2)
      SINE=TANG*COSN
      QII=Q(IP,IP)
      Q(IP,IP)=COSN**2*(QII+TANG*(2.*Q(IP,JP)+TANG*Q(JP,JP)))
      Q(JP,JP)=COSN**2*(Q(JP,JP)-TANG*(2.*Q(IP,JP)-TANG*QII))
C
      Q(IP,JP)=0.0
C     NEXT 4 ESTATEMENTS FOR PSEUDO RANK THE EIGENVALUES
C
      IF(Q(IP,IP)-Q(JP,JP)) 152 ,153,153
152   TEMP=Q(IP,IP)
      Q(IP,IP)=Q(JP,JP)
      Q(JP,JP)=TEMP
C
C     NEXT 6 STATEMENTS ADJUST SINE AND COSINE FOR
     1COMPUTATION OF Q(I,K),V(I,K)
      IF(SINE)154,155,155
154   TEMP=+COSN
      GO TO 170
 155  TEMP=-COSN
170   COSN=ABS(SINE)
      SINE=TEMP
C
153   DO 350 I=1,MI
      IF(I-IP) 210,350,200
200   IF(I-JP)210,350,210
210   IF(IH(I)-IP)230,240,230
230   IF(IH(I)-JP)350,240,350
240   K=IH(I)
250   TEMP=Q(I,K)
      Q(I,K)=0.0
      MJ=I+1
      X(I)=0.
C
C     NEXT 5 STATEMENTS SEARCH IN DEPLETED ROW FOR NEW MAXIMUM
C
      DO 320 J=MJ,N
      IF(X(I)-ABS(Q(I,J))) 300,300,320
300   X(I)=ABS(Q(I,J))
      IH(I)=J
320   CONTINUE
      Q(I,K)=TEMP
350   CONTINUE
C
```

```
      X(IP)=0.
      X(JP)=0.
C
C     NEXT 20 STATEMENTS FOR CHANDING THE OTHER ELEMENTS OF Q
C
      DO 530 I=1,N
C
      IF(I-IP)370,530,420
370   TEMP=Q(I,IP)
      Q(I,IP)=COSN*TEMP+SINE*Q(I,JP)
      IF(X(I)-ABS(Q(I,IP))) 380,390,390
380   X(I)=ABS(Q(I,IP))
      IH(I)=IP
390   Q(I,JP)=-SINE*TEMP+COSN*Q(I,JP)
      IF(X(I)-ABS(Q(I,JP)))400,530,530
400   X(I)=ABS(Q(I,JP))
      IH(I)=JP
      GO TO 530
C
420   IF(I-JP)430,530,480
430   TEMP=Q(IP,I)
      Q(IP,I)=COSN*TEMP+SINE*Q(I,JP)
      IF(X(IP)-ABS(Q(IP,I)))440,450,450
440   X(IP)=ABS(Q(IP,I))
      IH(IP)=I
450   Q(I,JP)=-SINE*TEMP+COSN*Q(I,JP)
      IF(X(I)-ABS(Q(I,JP))) 400,530,530
C
480   TEMP=Q(IP,I)
      Q(IP,I)=COSN*TEMP+SINE*Q(JP,I)
      IF(X(IP)-ABS(Q(IP,I))) 490,500,500
490   X(IP)=ABS(Q(IP,I))
      IH(IP)=I
500   Q(JP,I)=-SINE*TEMP+COSN*Q(JP,I)
      IF(X(JP)-ABS(Q(JP,I)))510,530,530
510   X(JP)=ABS(Q(JP,I))
      IH(JP)=I
530   CONTINUE
C
C     NEXT 6 STATEMENTS TEST FOR COMPUTATION OF EIGENCTORS
C
      IF(JVEC)540,40,540
540   DO 550 I=1,N
      TEMP=V(I,IP)
      V(I,IP)=COSN*TEMP+SINE*V(I,JP)
550   V(I,JP)=-SINE*TEMP+COSN*V(I,JP)
      GO TO 40
1000  RETURN
      END
$ENTRY
```

```
$IBJOB          NODECK
$IBFTC GMASM
C
C     SUBROUTINE GMASM TO CALCULATE GENERALISED MASS MATRIX
C
      COMMON A(54,54),B(54,54),S(54,54),ST(54,54),V(54,54)
     1STP(54,54),QI(54),QO(54),ZAI(54),NS(54),WORK(54)
     2F(78,78),TRASM(78,54),AUX(54,78),GM(54,54)
     1DIMENSION  A(6,6),B(6,6),C(6,6),D(6,6),E(6,6),PM(30)
C
      SUBROUTINE GMASM(GM)
C
C     INPUT
C
      DO100  I=1,78
      DO100  J=1,78
100   F(I,J)=0.0
      KK=1
      LL=6
      MM=1
      NN=6
      DO20  M=1,4
      IF(KK.EQ.61)GOTO220
C
C     READ DISCRETE MASS MATRIX, TRANSFORMATION MATRIX
C         AND ITS TRANSPOSE
C
      READ(5,2)((A(I,J),J=1,6),I=1,6), ((B(I,J),J=1,6),I=1,6)
     1((D(I,J),J=1,6),I=1,6)
C
C     NEXT 27 STATEMENTS ASSEMBLE FIRST EIGHT DISCRETE MASSES
C
      DO5  I=1,6
      DO5  J=1,6
      C(I,J)=0.0
      DO5  K=1,6
5     C(I,J)=C(I,J)+A(I,K)*B(K,J)
      DO10  I=1,6
      DO10  J=1,6
      E(I,J)=0.0
      DO10  K=1,6
10    E(I,J)=E(I,J)+C(I,K)*D(K,J)
      DO200  I=KK,LL
      II=I-KK+1
      DO200  J=MM,NN
      JJ=J-MM+1
      F(I,J)=E(II,JJ)
200   F(I+24,J+24)=E(II,JJ)
C
201   KK=KK+6
```

```
      LL=LL+6
      MM=MM+6
      NN=NN+6
20    CONTINUE
      KK=49
      MM=49
      LL=54
      NN=54
C
C     NEXT 24 STATEMENTS ASSEMBLE PLATE MASSES
C
      DO30  M=1,5
      READ(5,2)((A(I,J),J=1,6),I=1,6), ((B(I,J),J=1,6),I=1,6)
     1((D(I,J),J=1,6),I=1,6)
      DO15  I=1,6
      DO15  J=1,6
      C(I,J)=0.0
      DO15  K=1,6
15    C(I,J)=C(I,J)+A(I,K)*B(K,J)
      DO40  I=1,6
      DO40  J=1,6
      E(I,J)=0.0
C
      DO40  K=1,6
40    E(I,J)=E(I,J)+C(I,K)*D(K,J)
      DO320  I=KK,LL
      II=I-KK+1
      DO320  J=MM,NN
      JJ=J-MM+1
320   F(I,J)=E(II,JJ)
220   KK=KK+6
      LL=LL+6
      MM=MM+6
      NN=NN+6
30    CONTINUE
      READ(5,101)(PM(I),I=49,78)
      DO102  I=49,78
102   F(I,I)=F(I,I)+PM(I)
C   GENERATE  RRANSFORMATION MATRIX  TRASM
      DO210  I=1,78
      DO210  J=1,54
210   TRASM(I,J)=0.0
      DO330 I=1,48
330   TRASM(I,I)=1.0
C
C     INPUT OF EQUILIBRIUM MATRIX
C
      READ(5,230)((TRASM(I,J),J=49,54),I=49,78)
C     AUX=TRANSPOSE  OF  TRASM*MASS  MATRIX
C
```

```
C      NEXT 11 STATEMENTS CALCULATE GENERALISED MASS MATRIX
C
       DO250  I=1,54
        DO250  J=1,78
       AUX(I,J)=0.0
        DO250 K=1,78
250    AUX(I,J)=AUX(I,J)+TRASM(K,I)*F(K,J)
C      GENERATE  GENERALISED  MASS  MATRIX
       DO260  I=1,54
       DO260  J=1,54
      GM(I,J)=0.0
       DO 260 K=1,78
260    GM(I,J)=GM(I,J)+AUX(I,K)*TRASM(K,J)
       DO 340 I=1,54
340    WRITE(6,502)(GM(I,J),J=1,54)
       STOP
2      FORMAT(6F12.5)
101    FORMAT(F12.5)
230    FORMAT(6F12.5)
400    FORMAT(6E13.5)
280    FORMAT(30X,22HMATRIX  FOR  ITERATION,//)
203    FORMAT(1X,6F20.5)
306    FORMAT(1H0)
502    FORMAT(6E13.5)
       RETURN
       END
```

APPENDIX - IV

(LIST OF EQUIPMENT)

LIST OF EQUIPMENT

1. SPACE FRAME
2. Goodman's Vibration Shaker (Model V.390A/200).
3. Vibration Shaker Amplifier
4. R. C. Generator
5. Strain Gauges and Allied Equipment
6. Switch and Balance Unit (Type 20SB4-2)
7. Kistler Quartz Force Transducer (Model No. 932A, Serial No. 26452)
8. Kistler Universal Dial Calibration Charge Amplifier
9. Micrometer Proximity Transducer (Type DISA 51D11)
10. Oscillator (Type DISA 51E02 462)
11. Reactance Converter (Type DISA 51E01)
12. Strain Indicator (Type Budd Model P-350)
13. Storage Oscilloscope (Type Tektronix 564)