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SPACE VEHICLE ACOUSTICS PREDICTION IMPROVEMENT FOR PAYLOADS

by

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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
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FOREWORD

This report presents an analytic assessment of the modal analysis method for predicting the noise environment for space vehicle payloads in the low frequency regime. Two experimental cases are used to validate the analytical results, and recommendations are made to further improve the prediction model.

This report was prepared by Wyle Laboratories, Scientific Services and Systems Group, for the George C. Marshall Space Flight Center, National Aeronautics and Space Administration. The work was performed under contract NAS8-33193 entitled "Space Vehicle Acoustics Prediction Improvement for Payloads." Administration of this study was provided under the technical direction of the Systems Dynamics Laboratory with Mr. Stan Guest serving as the technical monitor.

The author would like to express his appreciation to Mr. Stan Guest for his guidance in identifying the main problem areas to be investigated, and to Dr. Ken Plotkin, of the Wyle Research Staff, for supplying much valuable information and assistance in this study.

SUMMARY

The modal analysis method developed by Wyle [1] has been extensively modified for the prediction of space vehicle noise reduction in the payload enclosure, and this program has been adapted to the Marshall Space Flight Center IBM 360 computer. The predicted noise reduction levels for two test cases were compared with experimental results to determine the validity of the analytical model for predicting space vehicle payload noise environments in the 10 Hz to 250 Hz one-third octave-band regime. The prediction approach for the two test cases generally gave reasonable magnitudes and trends when compared with the measured noise reduction spectra. The discrepancies in the predictions could be corrected primarily by improved modeling of the vehicle structural walls and of the enclosed acoustic space to obtain a more accurate assessment of normal modes. Techniques for improving and expanding the noise prediction for a payload environment are also suggested.

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1.0 INTRODUCTION

The use of orbiting and interplanetary space vehicles to place various payloads into space has been growing, and this growth will increase sharply when the Space Shuttle becomes operational. Payload utilization will greatly increase because of the relatively low launch cost that will be available with the Space Shuttle and because of the increasing space applications for scientific research, communications, energy, and for many other areas in which the application of the space environment may be beneficial to man.

In addition to an increased number of payload launches, there will also be an increase in payload complexity. These sophisticated payloads will also be sensitive to the acoustic environments to which they will be exposed. Therefore, it will be important in the payload design stage to consider the acoustic environment surrounding the payload. Also, the definition of these acoustic environments will be needed to allow an accurate assessment of the test limits for qualification testing of the payload and its components. From these considerations, it can be seen that an accurate prediction of the payload acoustic environment will be an important factor in the success of the payload missions.

The purpose of this program is to improve the technology base for defining the acoustic environments for space vehicle payloads. One goal of the study is to improve the acoustic environment prediction accuracy in the low frequency range where considerable acoustic energy is generated by the engines at liftoff. A computer program is also desired that will efficiently compute the space vehicle internal environments for any given external excitation and payload configuration. The program should also be flexible in order to incorporate state-of-the-art techniques in noise transmission analysis.

A review of the current prediction techniques for determining the interior acoustic environment of space vehicles has been performed, and the results are discussed in Section 2.0 - Literature Survey. The survey of the literature on this subject will provide a basis for choosing the best techniques available to improve the accuracy and efficiency of payload acoustic environment predictions. Since one of the goals in the study is to improve the internal noise predictions in the lower frequency regime, a classical modal analysis approach is taken.

An analytical model using the modal analysis techniques developed by Plotkin, Kasper, and Glenn [1] was selected as a logical starting point for this study. Earlier work done by Cockburn and Jolly [2] provided the basis for the more recent development by Plotkin et al. The computer programs [1] were utilized on the present contract to provide a computational tool for predicting noise reduction levels. Incorporation of state-of-the-art improvements to provide greater efficiency and accuracy for these computer programs was also applied.

The initial step in the modal analysis formulation is to express the interior sound field and structural displacement in terms of normal acoustic and vibrational modes. To facilitate the analysis, these modes are determined by approximating the actual structural geometry with a cylindrical shell with rigid end caps. Unique features incorporated into the model include the capability of treating independent shell panel segments of the structure, such as the Shuttle payload bay doors, and the capability of accounting for payload volume by the introduction of an internal concentric cylindrical payload. Application of boundary conditions requiring compatibility of the sound field with vibration of the structure at the bounding surface allows a determination of the acoustic energy coupled into the structure and ultimately radiated into the interior. The classical approach is theoretically an exact analysis from the physical standpoint. The degree of accuracy is dependent on the approximation involved in modeling the actual configurations in terms of simple geometric forms. Section 3.0 discusses the modal analysis approach in more detail.

A major practical limitation usually associated with modal analysis calculations is that calculation time and cost become very large as frequency increases due to the large number of modes involved. The computer program used for this study incorporates an innovative summation scheme, which minimizes computation time. The program is described in Section 4.0. The calculation begins with modes nearest a frequency of interest. Summation then proceeds through a sorted list of modes, with logic subroutines selecting the next modes to be included in the series. The modal summation thus considers the most important terms first, so that convergence is achieved with a minimum of wasted time due to calculation of unimportant modes.

Three versions of the computer program were prepared to calculate noise reduction (NR) at a single excitation frequency or averaged over an arbitrary bandwidth. The basic program computes the NR from a discrete excitation frequency input. This program is used when no structural or cavity resonances occur in the frequency band of interest. To obtain a band-averaged NR with this program, the response is calculated, at sufficient frequency intervals, and summed to arrive at a band averaged value of NR. The other two versions are bandwidth programs that analytically approximate an integration factor for each resonance within the band of interest. One version of the bandwidth program applies this method to acoustic resonances only, and the second version applies it to the structural resonances only. The total NR is then obtained by combining the two bandwidth NR calculations.

Section 5.0 describes a test on the Shuttle orbiter OV-101 at Edwards Air Force Base, where two F-104s were run-up to generate a simulated launch noise source. Predictions for this test case were made and compared to the measured test results. Also, a prediction case for the introduction of a payload configuration on the change of the empty payload bay NR levels is compared with a model test case.

The conclusions of the study are arrived at in Section 6.0. The accuracy of the noise reduction predictions is discussed. The applicability of the modal analysis method to the orbiter payload acoustic environment predictions is also reviewed.

Recommendations for improving the modal analysis approach used for this investigation are given in Section 7.0. Techniques for improved analytical modeling of the structure and payload bay configurations are suggested. Modifications for improving the generality and flexibility of the computer program are also given.

Appendix A gives a complete description of the computer program. It describes the three versions of the main program (PURTON, ACOBAN and STRBAN) and their subroutines. User instructions for the imput parameters are given, and a computer program listing of a sample run is also shown.

2.0 LITERATURE SURVEY

Several methods that develop the noise transmission analysis for predicting the noise levels within an enclosure subjected to external acoustic excitation have been found in the literature. Generally, the method for computing space vehicle interior noise levels follows one of these approaches:

- Classical modal analysis
- Architectural acoustics
- Statistical energy analysis
- Finite element methods
- Empirical analysis and/or extrapolation.

Each of these approaches will be briefly discussed next while noting their respective references in the literature. Dowell [3] presents an extensive bibliography in the general area of vehicle interior noise prediction, which lists the available literature on each element of the problem.

2.1 CLASSICAL MODAL ANALYSIS

Classical modal analysis as applied to the sound field inside an enclosure, such as a Shuttle payload bay, involves modeling the response of the vehicle structure and interior sound field in terms of the structural and acoustic natural modes. To obtain tractable results, the geometry must be idealized so that the mode shapes are simple analytic functions. Application of boundary conditions requiring compatibility of the sound field with the vibration of the structure at the bounding surfaces allows a determination of the acoustic energy coupled into the structure and ultimately radiated into the interior. Apart from the approximations involved in modeling the actual configuration in terms of simpler geometric forms, the modal approach is mathematically an exact treatment. The damping factor for each mode is also critical to the accuracy of the structural and acoustic response. The modal analysis method is generally the most useful at low frequencies where the modal density is low. The applicable frequency range is where the ratio of the acoustic normal mode wavelength to its corresponding cavity dimension is from about one-third to three [4]. At higher frequencies, computer time increases greatly due to the increasing number of modes involved in the summation process.

Recent developments in modal methods of sound transmission analysis are developing along two lines. Taborrak [5] has recently advanced the variational formulation (see Cragges [6]) of the principles underlying structural-acoustic problems. The formulation is intended for use in finite element analysis of the combined structural-acoustic problem. The method is powerful and especially of value for the analysis of irregularly shaped cavities and of complicated structures. The principle limitation being the computer storage and calculation time required, which increases geometrically with the size and complexity of the problem.

The other line of development has been the extension of the method of Cockburn and Jolly [2]. Many authors have built on this model, which is based on Lagrange's equation for the structure and Green's theorem for the acoustic field [1, 7, 8]. A versatile formulation has emerged from the work of Dowell [9], Vaicaitis [10], Cragges [11], Wolf [12] and Petyt [13]. The model is based upon a knowledge of the uncoupled, "in vacuo" structural modes and the rigid wall acoustic modes of the cavity. Given these modes, the model allows for full coupling between the structural wall and the acoustic cavity. Due to the <u>component mode synthesis</u> methdology employed in this model, multiple connected cavities may be considered. Any exterior acoustic excitation is theoretically allowed, including random noise with a specific correlation function [14]. This case, however, has not yet been actually computer coded and run. The acoustic and structural modes can be determined by any method, including the finite element calculation, in that "(1) By judicious selection of components, the appropriate component modeling may already be known without further analysis or, at the least, much easier to determine than that of the overall system. (2) In the synthesis when components are combined only the essential aspects (modes) of each component need be retained. Hence, the representation of the component in the total system may be much simpler than its original representation when treated separately."[3]

<u>Component mode synthesis</u> means a component of the response system is most efficiently represented in terms of its own (natural) modes. In the context of the present problem, an obvious distinction can be drawn between structural (wall) and acoustic (cavity) components. Their uncoupled normal modes are easier to calculate separately and then combined to obtain the overall coupled behavior of the system.

2.2 ARCHITECTURAL ACOUSTIC ANALYSIS

This geometrical acoustic analysis method, commonly referred to as the architectural acoustic approach, is based on the idealized assumption that the sound field enclosed within an arbitrary volume can be represented as an assemblage of an infinite number of plane waves traveling in all possible directions. By integrating the acoustic intensity over the volume and performing an energy balance, a simple relation can be derived between the incident sound power, the total acoustic absorption, and the resulting uniformly distributed sound pressure field. Since the sound field in an enclosure approaches the diffuse field idealization at sufficiently high frequencies due to the presence of closely spaced and overlapping resonances, this simple acoustic relationship has been found useful for many applications. Since the assumption of which architectural acoustic is based requires that the sound pressure be uniform throughout the enclosed volume, the method ceases to be valid at low frequencies where individual acoustic resonances become prominent. It is, therefore, a suitable method only for the evaluation of interior noise levels at high frequencies where the ratio of normal mode acoustic wavelength to its corresponding cavity dimension is about one-third or less.[4]

2.3 STATISTICAL ENERGY ANALYSIS

Statistical energy analysis (SEA) is a technique, developed in the 1960s, that treats the interaction of coupled dynamic systems in terms of their collective modal properties. The technique is based upon the modeling of each dynamic system as a group of modes with the energy of the system within a given frequency range assumed to be uniformly distributed among the modes within that range. The time-averaged power flow between the coupled system is then determined as a function of a general coupling factor and the difference in time-averaged modal energies of the system. SEA has been used extensively to predict the response and noise reduction of complex structures excited by random pressure fields.[15-18] Many complex aerospace structures can be considered as being built up from elementary structural elements such as simply support beams, plates, etc. A typical example is a shroud and payload assembly. A study that shows the application of the SEA to predict the response of this type of assembly to a reverberant field is presented by Conticelli [19]. For more complex structures, a good estimate of the modal density can be obtained by adding the modal densities of the various elements composing the structure.

When a multimodal system is excited in a band of frequencies its modes can be divided into resonant and nonresonant frequencies within the band. The energy transmission between nonresonant frequencies and between resonant and nonresonant conditions cannot be predicted by the SEA. For energy transmission between resonant modes, however, a power balance equation is given by Conticelli and Cockburn [18]. Some recent work with the SEA method can be found in References 20 through 23.

The major advantages of this approach is that the computations are relatively simple, and fine details of the system are not required. The primary disadvantage of the technique is the inability of the formulation to account for the specific characteristics of the dynamic systems. Also, the damping value specified for each frequency band significantly affects the response of the systems. Empirical means are usually required to obtain coupling parameters between the groups of structural and acoustic modes, and it is also assumed that the resulting motions are statistically independent, with energy equally partitioned among all modes in a given group. These assumptions are not necessarily valid at low frequencies where rather distinct modal coupling exist. In general, the assumptions on which SEA is based are valid only at high modal densities, corresponding to the frequency ranges commonly used in the architectural acoustics approach.

2.4 FINITE ELEMENT ANALYSIS

Finite element analysis can be described as a systematic numerical technique by which a continuous system can be modeled as an assemblage of elementary elements, expressing the state of the system in terms of parametric values at the element connecting points. The structure and acoustic cavity must be well defined in order to obtain an accurate modeling of the system. From the standpoint of variational calculus, the approach requires expressing the element properties in terms of a functional relationship and finding a optimal solution for the total assemblage.

The computer implementation of this technique over the past ten years has reached a high level of sophistication, particularly in relation to structural analysis--as evidenced by the development of NASTRAN and other similar user-oriented computer programs. Finite acoustic elements have also been applied to the calculation of the acoustic field within ducts [24]. The generality of the basic finite element technique makes it a logical approach to consider for application to the analysis of the acoustic field within an enclosure. Applications of this technique have already been used by Wolf and Nefske [25, 26], for example, to determine approximate acoustic resonant frequencies and mode shapes for an automobile body interior. Also, the major aircraft manufacturers have developed finite element programs to analyze the structural vibration of fuselages.

Finite element analysis of a structure coupled with an interior sound field constitutes a major task in the development of the necessary equations, and the computer storage and computation time required also involves a major computational task. The finite element method, however, has been used effectively in conjunction with the modal analysis method [6, 8, 25, 27] for obtaining the normal modes of the system components, as mentioned in component mode synthesis in Section 2.1 - Classical Modal Analysis.

2.5 EMPIRICAL ANALYSIS AND/OR EXTRAPOLATION

Because of the complexities inherent in the analytical methods, considerable efforts have been made to develop empirical techniques for the prediction of vibration response [28-31]. Initial developments concentrated upon the normalized response of Tital and Jupiter space vehicles [28] to predict the induced interior noise of the vehicles. Subsequent developments [30, 31] have been limited to Saturn V-type structures, and response information has been summarized in the form of data banks. The most significant disadvantage of these empirical approaches is the fact that response data are presented for limited types of structures, and little attempt has been made to review all the vibration data with a view to deriving a generalized response prediction curve.

3.0 DISCUSSION OF THE MODAL ANALYSIS METHOD

When sound waves are transmitted through the walls of a cavity all wave motion is standing wave motion, and the acoustic energy content of the cavity is determined by the nature of its walls. For cavities with a ratio of sound wavelength-to-cavity dimension between one-third and three, it will be most convenient to analyze the acoustic response in terms of normal modes of the enclosure. This ratio corresponds to a normal mode frequency range of about 6.2 to 233 Hz for the Space Shuttle orbiter payload bay cavity. The lowest longitudinal normal mode of the empty payload bay cavity is about 9.3 Hz, and the lowest circumferential mode and radial mode are 41 Hz and 85 Hz, respectively. These normal cavity modes were based on the payload bay geometry shown in Figure 3-1.

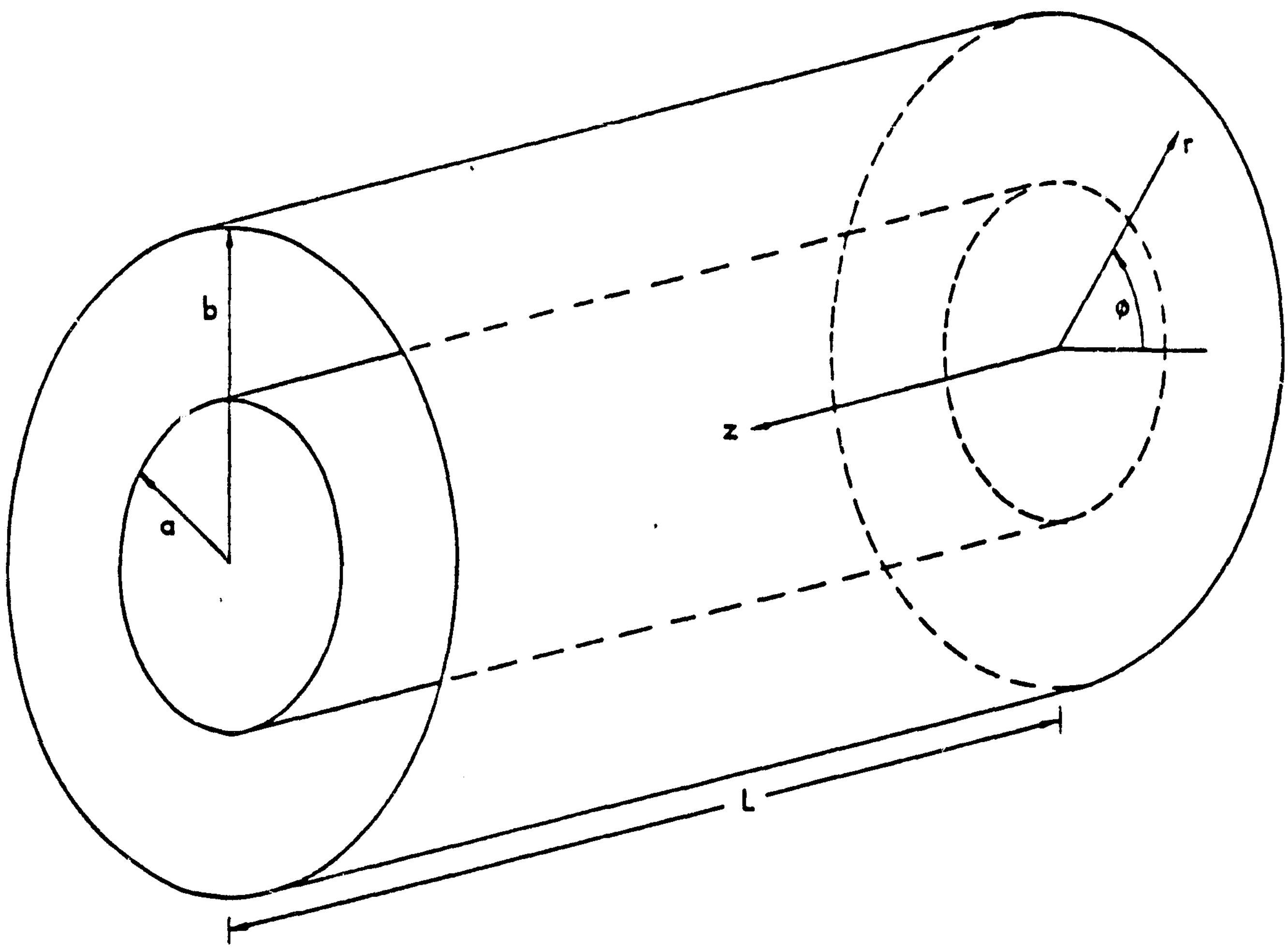

Figure 3-1. Dimensions and Coordinates of Concentric Cylindrical Cavity

Considerable external acoustic energy at these lower frequencies will be generated by the Space Shuttle engines, shown in Figure 3-2, from Reference 32, to excite the payload bay internal acoustic modes. The data in Figure 3-2 was measured at location 018 as shown in Figure 3-3. The payload bay doors will also have low frequency resonances that will couple with the external noise field to allow increased transmission of external noise into the payload bay cavity. For the case where the excitation frequency wavelength is much larger than the dimension of the cavity, the air in the enclosure can only exhibit stiffness reactance, expanding and contracting in phase, in response to the driving external pressure. This response is similar to a Helmholtz resonator condition. The introduction of payloads will also affect the lower order acoustic modes of the payload bay more than the higher order modes, because the acoustic wavelength will be smaller than the individual payload components in the higher frequency region. Therefore, the preceding factors indicate the usefulness of the normal mode analysis that allows a detailed description of the internal noise field surrounding the payload in a space vehicle.

The modal analysis approach has the advantage of permitting a detailed description of the enclosed sound field while providing a methodology for determining the interaction of the sound field with the vibrating structure. Although the modal approach is an exact analysis in the classical sense, its practical application requires that the structural shape and enclosed volume be modeled in terms of simple coordinate geometries. For application to space structures, the model is based on approximating the enclosed volume as a right circular cylinder, and the surrounding structure is consequently treated as a cylindrical shell. Apart from simplifying the overall shape of the structure, the model itself is sufficiently general to account for orthotropic structural properties as well as an arbitrary distribution of the shell surface into panels with different structural characteristics. An important feature of the model is the incorporation of a payload within the enclosed volume. In order to maintain a tractable mathematical solution, the payload geometry as shown in Figure 3-1 was taken as a circular cylinder positioned concentrically within the enclosing structure. Since the present analysis is intended for application in the low frequency range where the acoustic wavelengths will normally be large compared to individual payload components, it is not critical that full geometrical detail of the payload be

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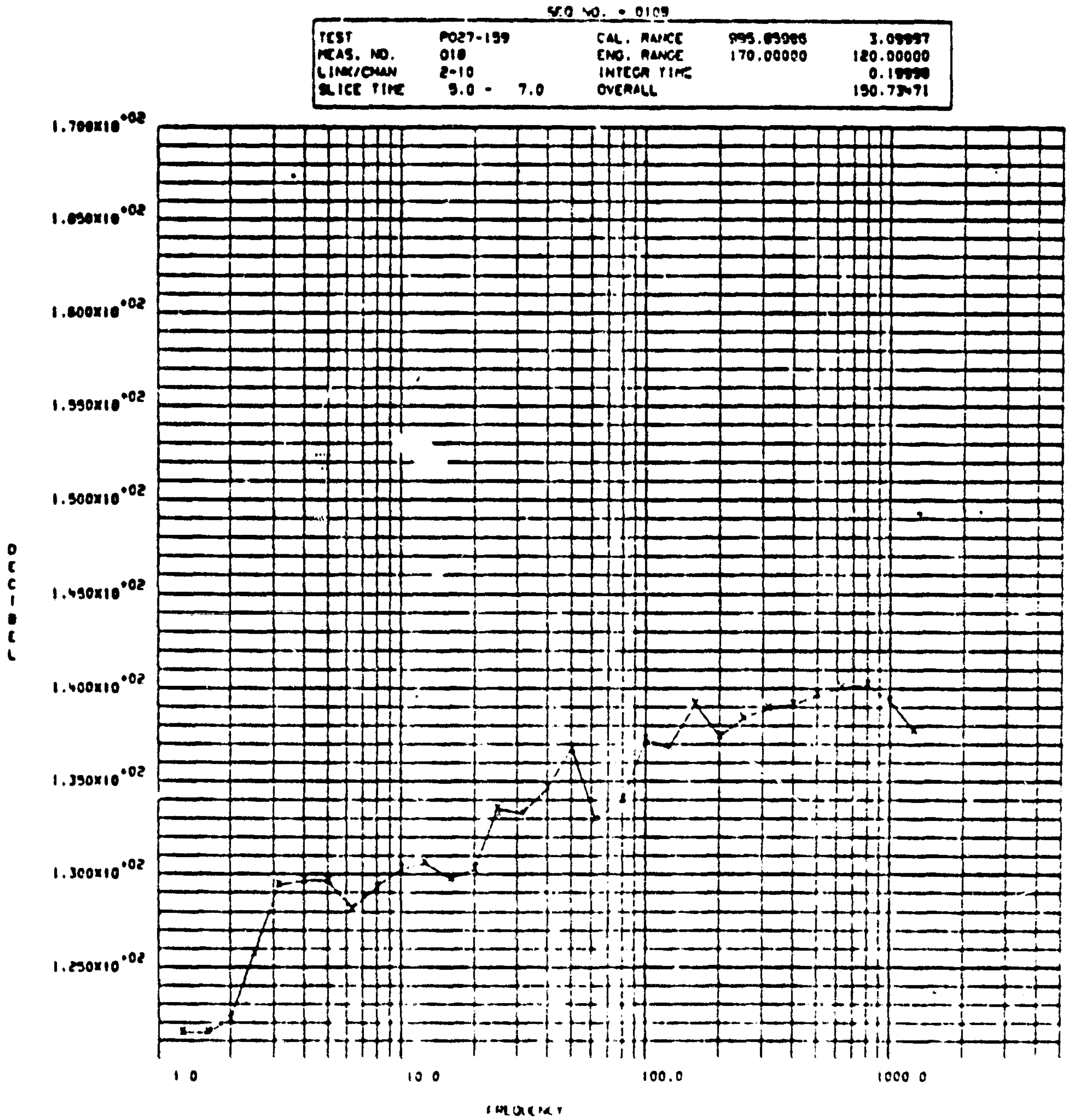


Figure 3-2. Experimental Noise Levels on Orbiter Door at 018. Taken from AMTF Test [32]

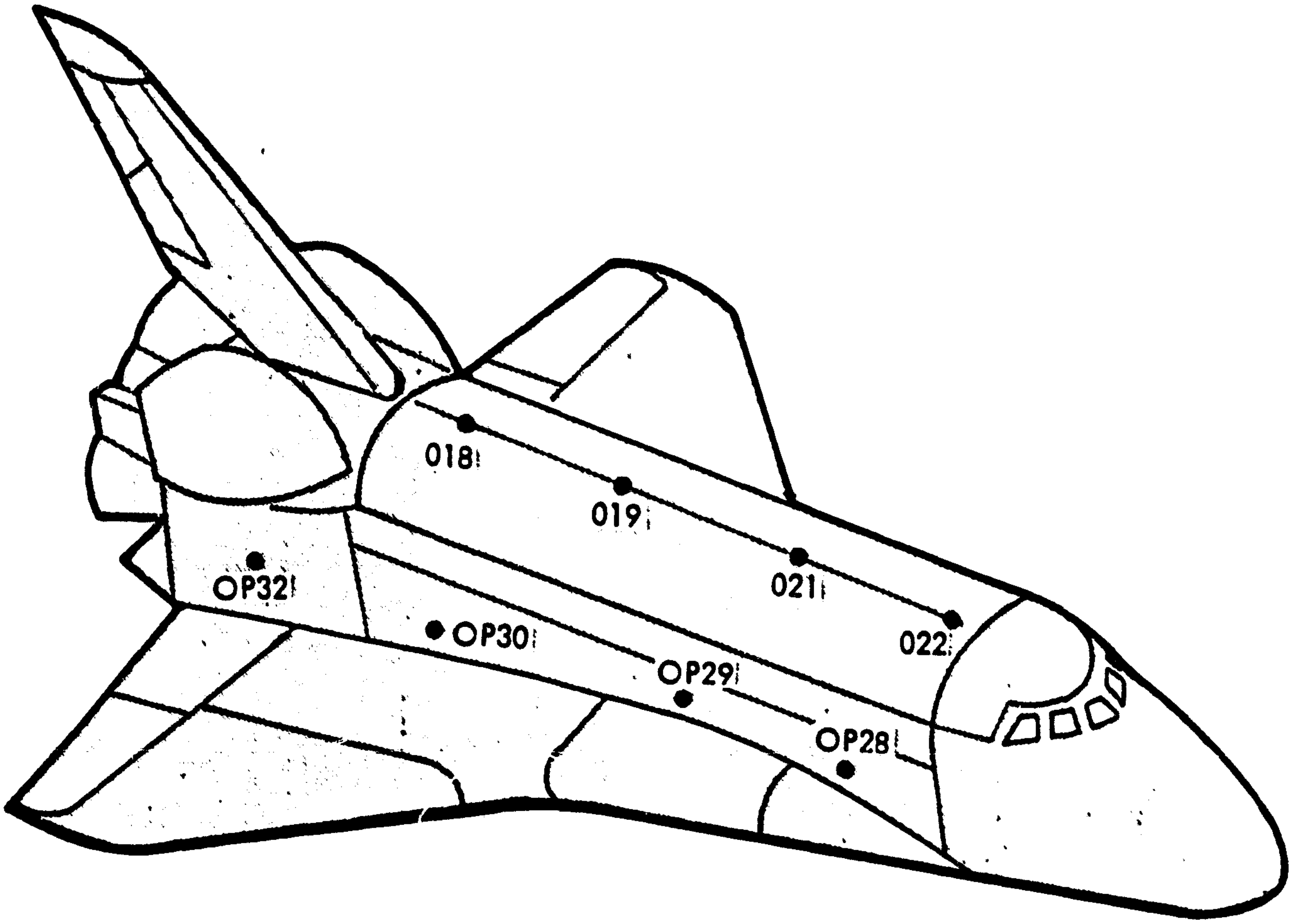


Figure 3-3. Microphone Locations on Upper and Side Surfaces of 6.4% Model [32]

included. The cylindrical model simulates the most important payload geometry factor -- the volume -- that can affect the enclosed noise field. The general treatment of the analysis is discussed in the following paragraphs.

The physical process involves the interior sound field exciting the shell, which in turn excites the interior cavity. The analytic development logically follows the inverse order, beginning with the interior sound field. Determining the interior noise field consists of finding a solution to the acoustic wave equation in terms of the normal acoustic modes of the containing volume, requiring the solution to satisfy appropriate boundary conditions at the structure wall surface [4]. Several acoustic mode shapes are shown in Figure 3-4 for typical circumferential and radial wave patterns. A corresponding circumferential structural wave pattern is also shown. The boundary conditions are that the acoustic particle velocity at the containing surface match the vibration velocity distribution

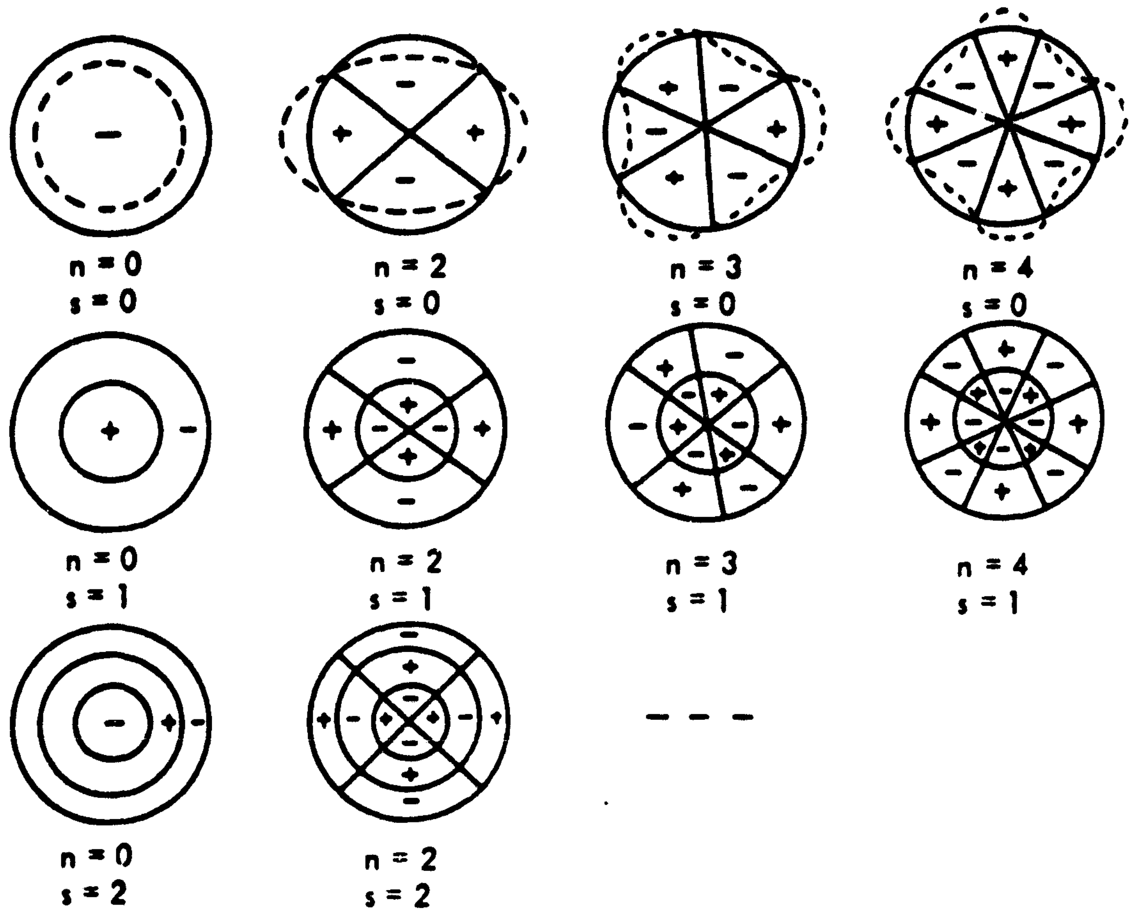


Figure 3-4. Typical Circumferential and Radial Acoustic Wave Patterns and the Corresponding Circumferential Structural Wave Patterns

of the structure. A Green's function is developed that relates the spatial distribution of the internal acoustic field to the vibrating structural surface. The acoustic response is derived for an arbitrary motion of the structure. In addition, for application to configurations containing a payload, it is required that acoustic boundary conditions be met along the surface of the payload. The payload is considered as a rigid solid that establishes the boundary condition of zero acoustic particle velocity along the surface. The effect of the boundary condition associated with the presence of the payload is to raise the resonant frequency of interior acoustic modes with radial components.

The vibration response of the space vehicle structure is then considered. The formulation begins with the equations of motion for the forced response of an orthotropic thin cylindrical shell. Solutions are developed for the response of the shell as a whole structure and for response of independent shell panel segments. Figure 3-5 illustrates the geometry of the structural model. The vehicle structure is modeled as an orthotropic thin cylindrical shell using the Donnell-Mushtari shell equation found in Leissa [33]. Figure 3-6 illustrates several examples of cylindrical shell modes. The analysis is arranged so that individual panels bounded by shear diaphragm boundary conditions along circumferential and longitudinal coordinates could be permitted to respond while the remainder is held rigid. This permits separate transmission calculations for any panel location and for panels with significantly different properties. Coupling relations between normal shell modes and the internal noise field are developed, and then the response of the coupling of the shell to an arbitrary external pressure field is derived. A weak coupling assumption is made which states that

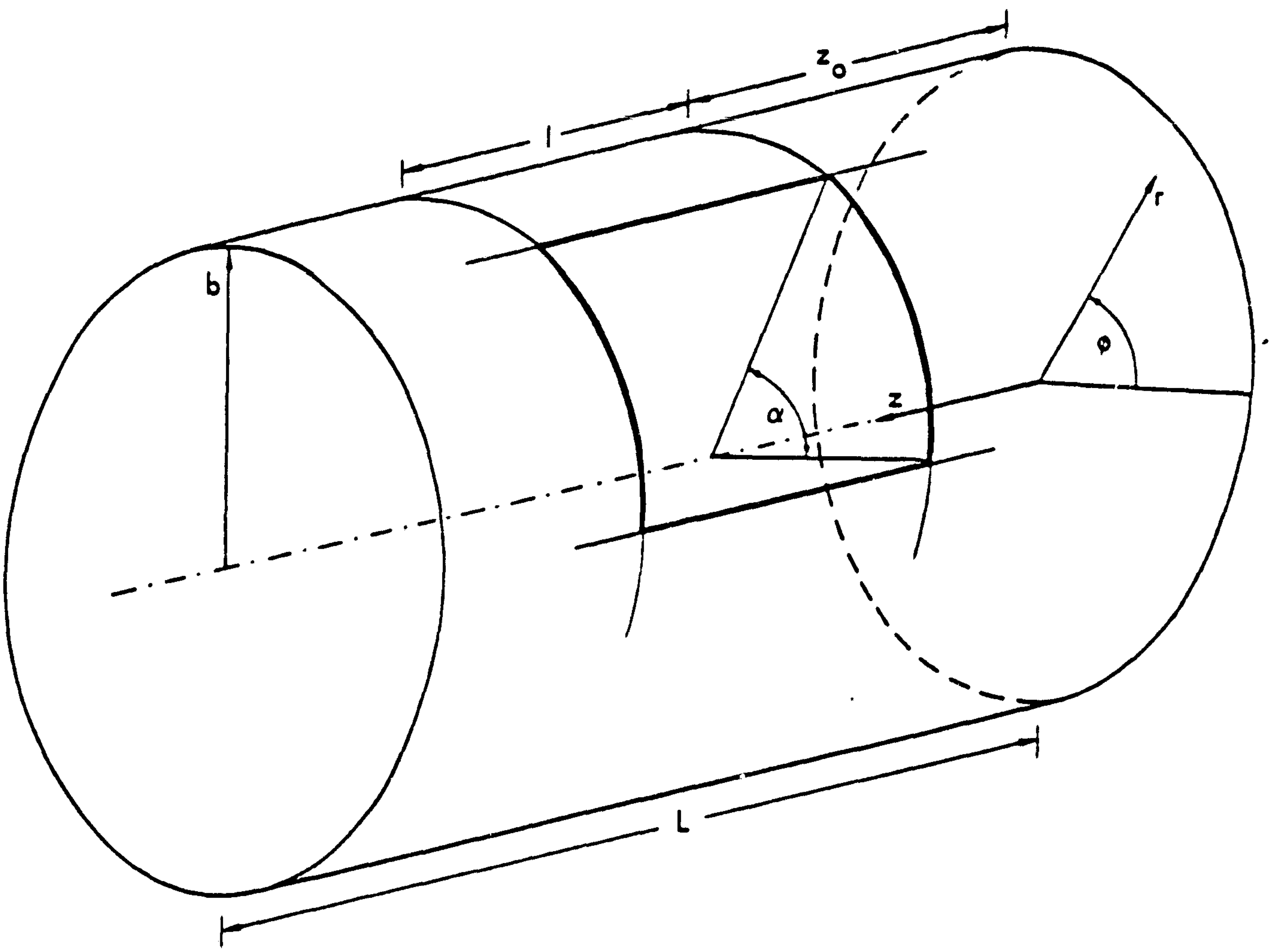
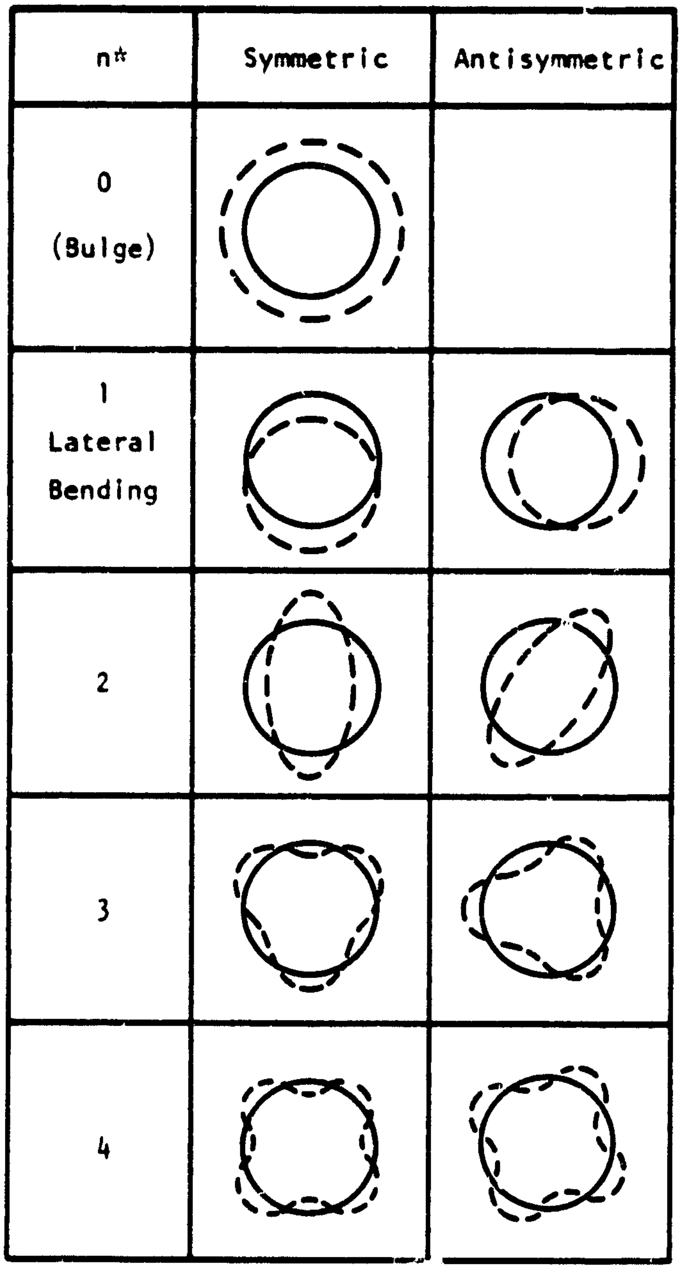
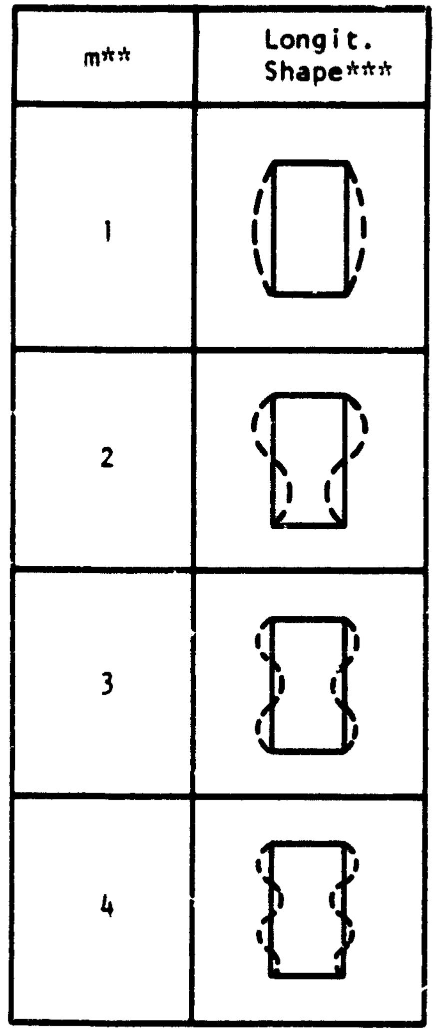


Figure 3-5. Geometry and Coordinates of Shell and Panel



a. Circumferential Modes

*n = number of full circumferential waves.



b. Longitudinal Bulge Modes

**m = number of longitudinal half waves.

***Motions shown occur at diametrically opposite points on plane of symmetry for circumferential modes in part a of this figure.

Figure 3-6. Cylindrical Shell Mode Examples (from Reference 44) interaction between the structural and acoustic response will not change the structural modes calculated in a vacuum condition, and the interaction will not affect the rigid wall acoustic modes. Therefore, coupling between the structure and cavity can be calculated using the "in vacuo" structural response and rigid wall acoustic response of the cavity. The assumption of negligible structural damping coupling is also made due to the light damping occurring in the space vehicle structure [34].

The structural excitation by random acoustic fields is developed next. It is shown that the frequency-dependent coupling between the structure and a random exterior field is described in terms of the narrow-band spatial correlation function (also called the cross-power spectral density) of the exterior noise. Coupling relations are derived for excitation by jet noise and by a reverberant field.

The spatial correlation of the exterior noise field at a given frequency is particularly important in that it determines the manner in which structural modes are excited. For example, random noise fields are correlated over distances comparable to a wavelength. The net result is that the structural modes with wavelengths comparable to the area of in-phase excitation are strongly coupled to the noise field. At higher frequencies, the area over which the pressure field is correlated becomes smaller and the structural response is characterized by the local response of individual panels or panel groups rather than that of the entire shell. It is shown in Reference 1 that this behavior results in structural modes being statistically uncorrelated for noise excitation. This provides a valuable simplification since cross terms between modes, which are important for coherent excitation, may be neglected.

4.0 COMPUTER PROGRAMS

The basic computer programs used in this study were developed by Wyle [1]. These programs have been modified to improve their efficiency, application, and accuracy to the problem of predicting payload environments. The programmed analytical model predictions were compared to test results as described in Section 5.0. This comparison was made to gain an idea of the model's accuracy and to determine feasible methods for improving the computer programs and the analytical model. Techniques for improving these noise prediction computer programs and the analytical model will be discussed in Section 7.0 - Recommendations, and a complete description of the programs is found in Appendix A. A general description of the computer program is given in this section.

The expressions derived in Reference 1 provide for the calculation of noise reduction at a single frequency, as a multiple summation over cavity acoustic modes and shell structural modes. The total expression for the ratio between interior and exterior pressure at a given frequency ω may be written in summary as

$$\frac{\left\langle \overline{p_i^2} \right\rangle}{\left\langle \overline{p_o^2} \right\rangle} = \sum_{mn} \{\ \} \left\{ \left[\sum_s Q_{ns}^2 \ (K_{ns} b) \ H_{mns}^2 \right] \left[\sum_{pq} \tilde{H}_{pq}^2 \ \gamma_{mp}^2 \ \Gamma_{nq}^2 \ I_p \ I_q \right] \right\}, \quad (4\text{-}1)$$

where the terms in { } and the summation variables are defined in Reference 1.

The amplification functions H^2 and $\tilde{H}^2$ are written in terms of modal resonant frequencies and associated constants as well as direct physical data (dimensions, material properties, etc). Calculation of noise reduction, therefore, consists of first computing these modal resonant quantities and then applying the following relationship to obtain the noise reduction in decibels:

$$NR = 10 \log_{10} \frac{\left\langle \overline{p_i^2} \right\rangle}{\left\langle \overline{p_o^2} \right\rangle} . \quad (4\text{-}2)$$

A set of computer programs has been developed that performs this calculation. The primary version of the program computes the noise reduction at a single frequency as given by Equation 4-2. This program is described in detail in Section 4.1. Of practical interest is the noise reduction of broadband sound, described in terms of octave or one-third octave bands. While the puretone response could in principle be integrated numerically, this would require calculation of response at an enormous number of frequencies -- at least several around each resonance -- to be reliable. An exact analytic integration of the NR equation (4-2) was also not practical; therefore, two alternate "bandwidth" versions of the program were prepared, which make use of an approximate analytic frequency integration. These are described in Section 4.2. The computer program's computational details, input and output parameters, and a listing of a program run case are given in Appendix A.

4.1 STRUCTURE OF PROGRAM

The greatest practical limitation to modal analysis techniques is that the number of modes grows geometrically as frequency increases. The number of terms to be included in the summation in turn grows geometrically with the number of modes. The highest frequency amenable to a modal calculation is limited by practical constraints of computer size and computation cost. For maximum practicality, a program must avoid computations that include modes not substantially contributing to the net response. Programs that deterministically compute all modes and functions within a specified range of indices have a domain of applicability that is seriously limited.

The computer program developed here was designed to avoid these limitations as much as possible. The main feature is that summation is performed in a selective manner, seeking the most important terms. The summation begins with the mode whose resonant frequency is closest to the excitation frequency. Successive terms are added by summing through an ordered list of frequencies. Summation continues until a convergence criterion is satisfied.

Figure 4-1 shows a flowchart of the program. This program is PURTON, which computes the response to a puretone. Overall, it is divided into two parts: calculation of modal frequencies, and the summation represented by Equation 4-1. To avoid repeated calculation of modal frequencies on successive runs for the same structure, all required output from the first part may be saved on a file. The option of computing or reading an existing file is separate for acoustic and structural modes.

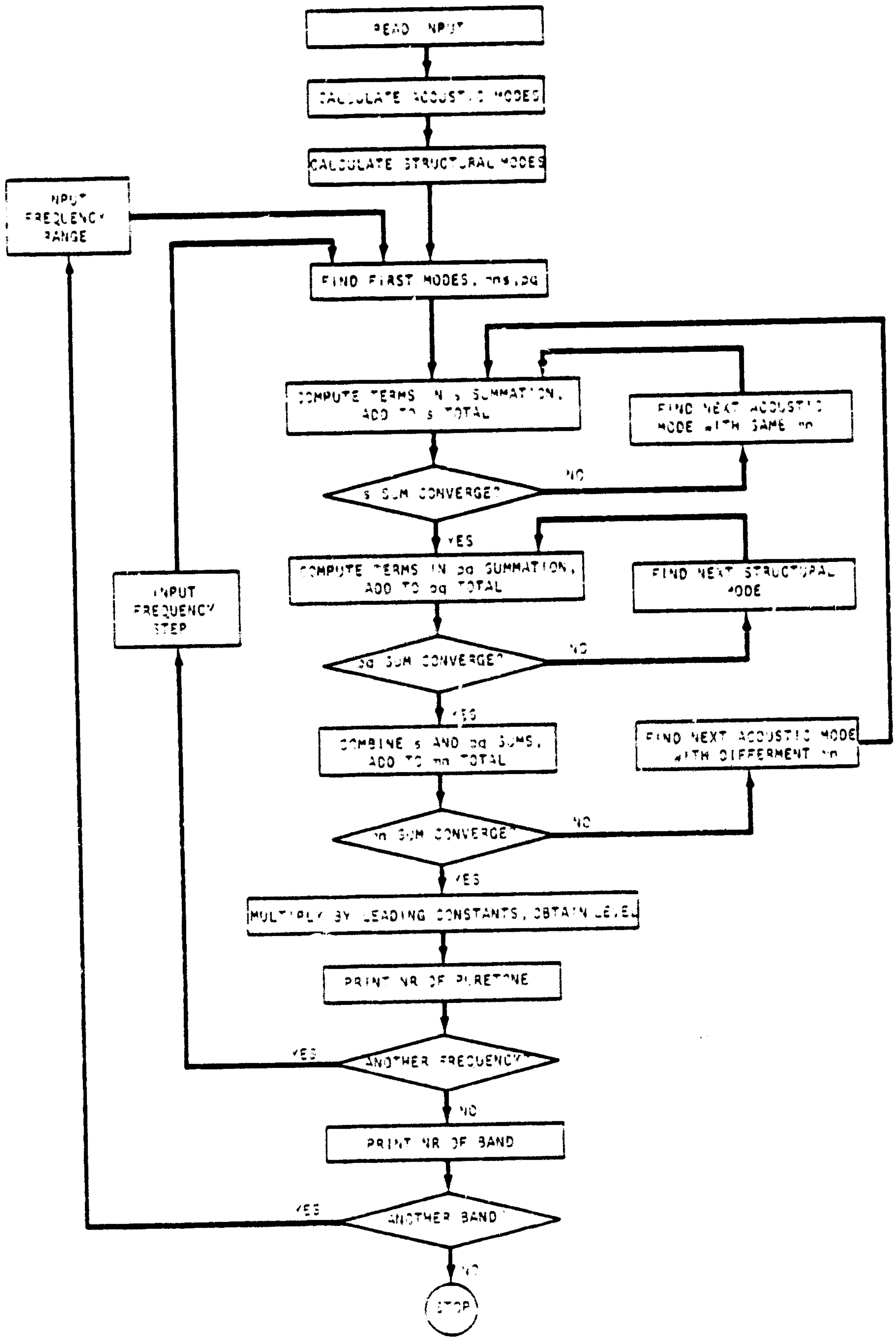


Figure 4-1. Flowchart of Main Program PURTON

The user specifies a range of modal indices for the first part of the program. The program modifies this in order to obtain a list of modes that is complete in frequency space. For example, if acoustic indices are specified from mns = 0,0,0 to M,N,S, the list of computed modes would not be complete above $\omega_{M,0,0}$. Refering to Equation 6 from Reference 1, there are modes (m,0,0) with m > M such that the frequency is less than for modes with $m \leq M$ and $n,s > 0$. To avoid skipped frequencies, the m loop is innermost, then n, then s, with the n and s loops terminated when ω_{mns} exceeds $\omega_{M,0,0}$. In addition to providing a complete frequency list, this procedure minimizes the number of roots k_{ns} that must be obtained.

A similar procedure is followed when obtaining the structural frequencies. It is complicated slightly by the fact that ω_{pq} is not monotonically increasing with q (as is ω_{mns} with each of m, n, s), and that there are three values of ω_{pq} for each pair p, q. The basic principle is the same, however.

4.2 CALCULATION OF BANDWIDTH RESPONSE

Equation 4-2 gives noise reduction at a single frequency; of practical interest is noise reduction averaged over a finite bandwidth. Numerical integration of the pure tone result would have been computationally very expensive. An exact analytic integration of a band is possible in principle, but in practice would be quite cumbersome. Each term in Equation 4-1 consists of the product of four linear oscillator terms of the form $1/[(\omega^2 - \omega_o^2)^2 + \eta^2\omega^2]$, together with polynomials in ω. Integration could be accomplished by expansion in partial fractions of the sixteenth order demoninator. Subsequent evaluation at limits corresponding to band edge frequencies would be unwieldly at best.

An approximate bandwidth result may be accomplished by noting that the strongest frequency dependence is due to the oscillator terms, and that only one at a time will be important if there is little modal overlap. Further, if the width of a resonance is small compared to the bandwidth of interest, then the integration may be taken over $\pm\infty$ rather than just over a bandwidth. It is also assumed that the remainder of the expression is approximately constant over the width of the resonant peak of interest, and may be evaluated at the resonant frequency. The linear oscillator term is thus replaced by

$$\int_{band} \frac{\omega^2 d\omega}{\left[\left(\omega_o^2 - \omega^2\right)^2 - \eta^2\omega^2\right]} \approx \int_{-\infty}^{\infty} \frac{\omega^2 d\omega}{\left[\left(\omega_o^2 - \omega^2\right)^2 - \eta^2\omega^2\right]} = \pi/\eta \ . \qquad (4\text{-}3)$$

Applying this approximate integration to each resonance within the band of interest would give the complete resonant response. There would be a possibility of error, however, in that there could be duplication in case of overlapping modes. Also, nonresonant response would be neglected.

In order to avoid (or account for) these possible errors, two separate bandwidth programs were developed and used in conjunction with the puretone model. One version applied Equation 4-3 to acoustic resonances only, so that it considered a resonant acoustic field driven by nonresonant structural response. The other version applied Equation 4-3 to structural resonances only, so that it considered a nonresonant acoustic field driven by structural resonances. These two programs are described in the following subsections.

After modal frequencies are computed, the acoustic and structural frequencies are each sorted into lists in order of size. To retain identification of modal indices, arrays containing mns and pq are sorted in parallel to the frequencies. The structural constants C_{pq} are also sorted in parallel to the structural frequency list.

The summation of Equation 4-1, the second part of the program, begins with the acoustic mode with ω_{mns} closest to the input frequency ω. Summation first takes place over s. After the first term is computed, one term with higher frequency ("up" the list) and one with lower frequency ("down" the list) is computed. The summation over s continues, adding terms up and down the frequency list until convergence is obtained in both directions. The convergence criterion is that the ratio between the newest term and the running sum be less than some small amount. The next term added may be either up or down the list, depending on which of the last up and down terms was larger. Summation proceeds in the direction of the last largest term.

The summation over p,q is then performed in a similar manner, beginning with ω_{pq} closest to the input frequency. The program does not place any distinction on which of the three ω_{pq} is used, but does keep track so that modes are not inadvertently counted more than once.

The summations over s and over p,q together with the quantity denoted {} are then multiplied together and added to the cumulative summation. The m,n summation then advances up or down the acoustic frequency list to the next mode with different m,n.

The nature of the functions γ, Γ, in the structure/cavity coupling term, and I, in the joint acceptance term, are such that many of these may be zero. Inclusion of a zero term would give a false indication of convergence. The program, therefore, tests for such zero terms, and if one is encountered, calculation advances to the next mode. To avoid errors due to rounding errors in floating point arithmetic, a zero condition is taken when the arguments of sine and cosine are terms within 0.01 radian of a zero condition.

The calculation of Equation 4-1 gives the spatially averaged noise reduction ratio. To obtain some indication of the spatial variation of the interior noise field, a parallel summing is performed where each acoustic modal coefficient is multiplied by the square of the mode shape, Equation 1 from Reference 1, evaluated at a point of interest. The program includes four such points, with location of the points specified by the user.

A third possible case is a nonresonant acoustic field driven by nonresonant structural response. This is a case readily handled by numerical integration of the pure tone program, since response in the absence of resonances would be smooth over a band.

4.2.1 Acoustic Resonance in a Band

This bandwidth program, called ACOBAN, applies Equation 4-3 to H^2_{mns} in Equation 4-1. The summation over p,q proceeds exactly as in PURTON. The summations over m, n and s are combined into a single deterministic summation over all ω_{mns} lying within the band specified by the user. The band is specified in terms of width (fraction of octave; for example, one octave, one-third octave, etc) and center frequency. At each acoustic mode in the mns summation, ω for use in other expressions is set equal to ω_{mns}. Figure 4-2 shows the flowchart for this program.

4.2.2 Resonant Structural Transmission in a Band

This bandwidth program, called STRBAN, applies Equation 4-3 to one resonator term in $\tilde{H}^2_{pq}$ in Equation 4-1. The other two resonator terms, and the numerator, are treated as weak functions of ω to be evaluated at the resonant ω_{pq}. The order of summation is changed, with the m, n and s summation performed first. These are done as in PURTON. The p,q summation is performed last, and is done as a deterministic sum over all resonant ω_{pq} in the specified band. At each structural resonance in the band, ω for use in the other terms is set equal to ω_{pq}. Figure 4-3 shows the flowchart for this program.

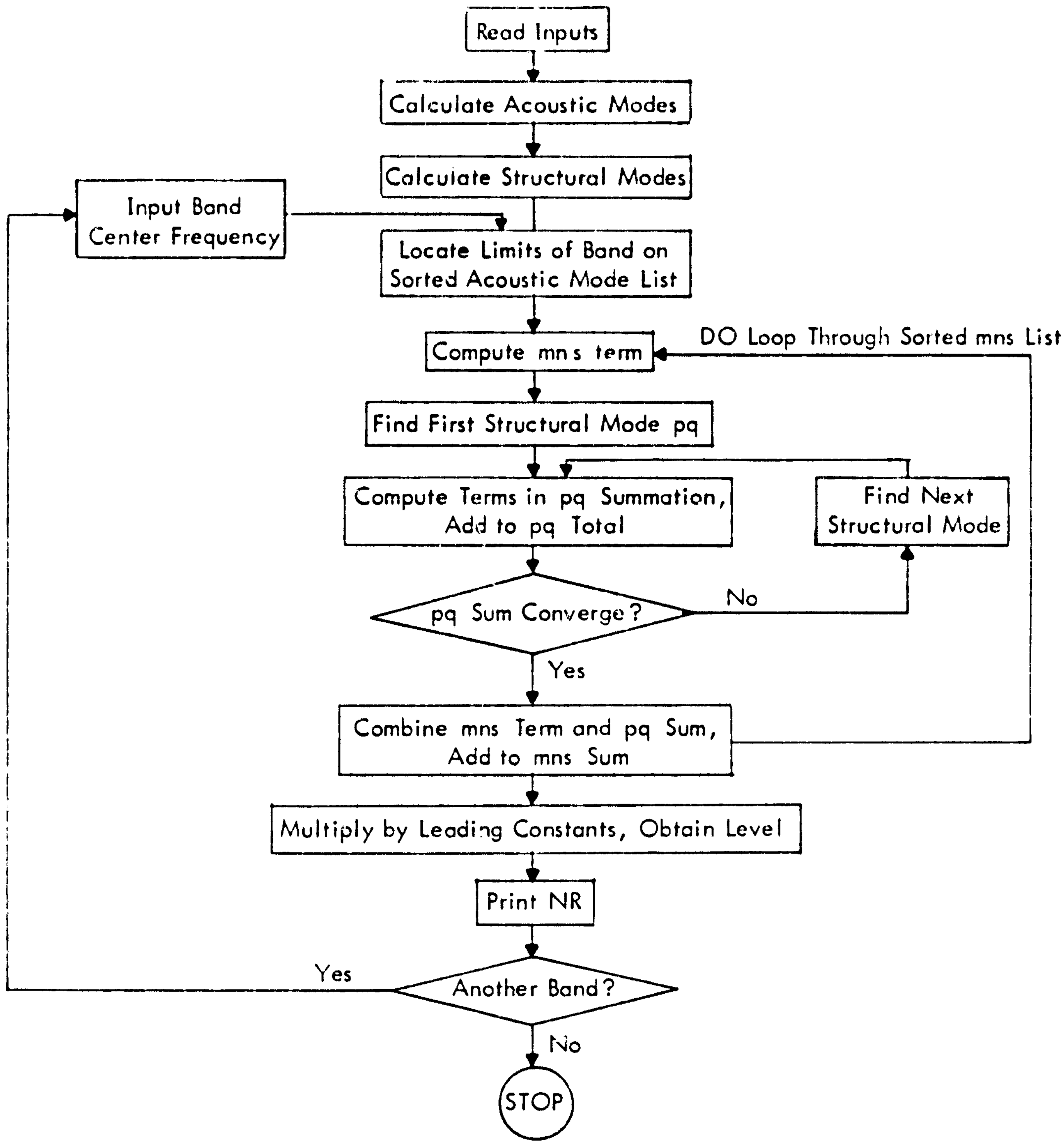


Figure 4-2. Flowchart of Main Program ACOBAN

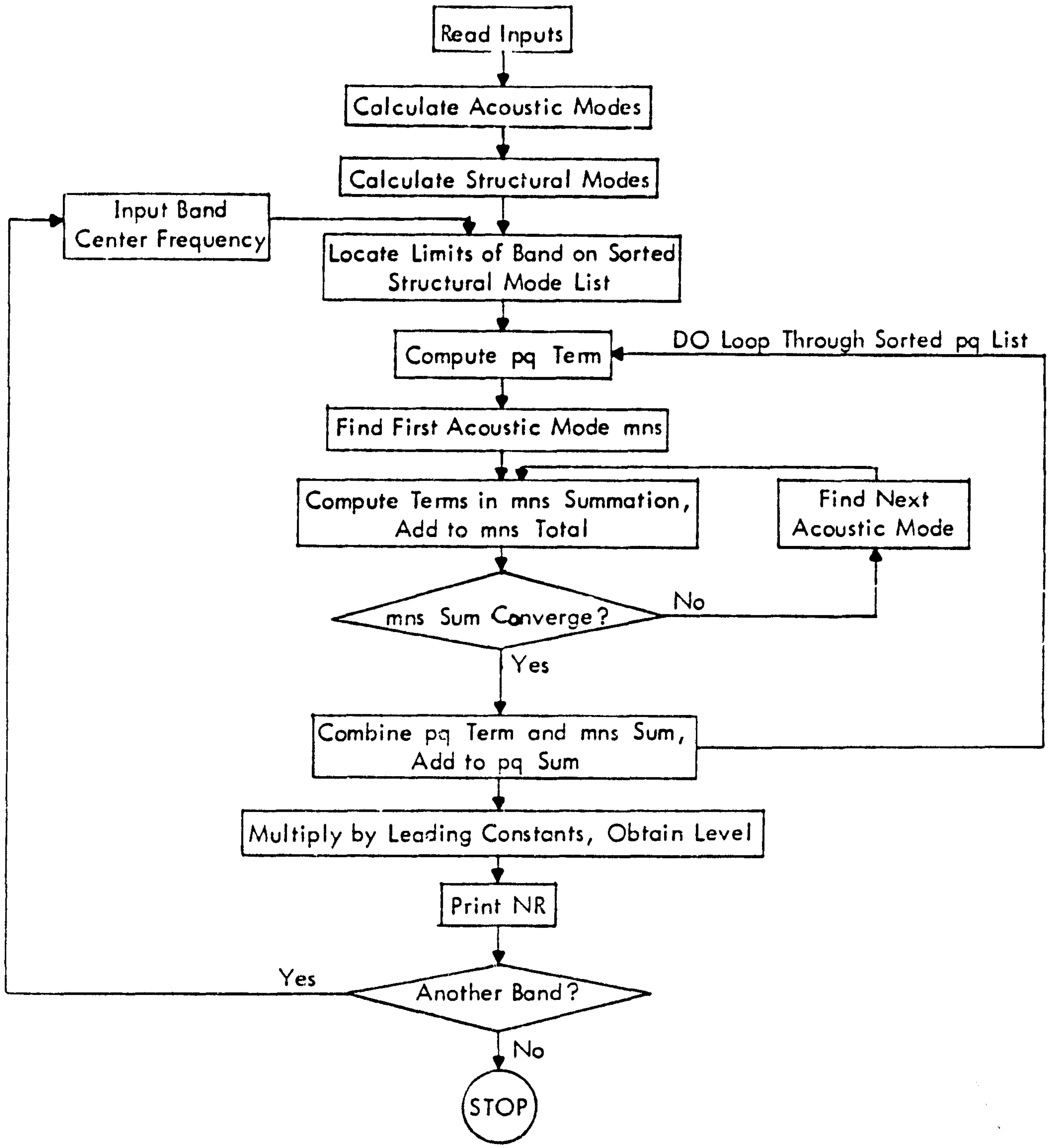


Figure 4-3. Flowchart of Main Program STRBAN

5.0 TEST CASES FOR ANALYTICAL PREDICTION MODEL

Test cases to be compared with the prediction methods were necessary to determine the validity of the analytical model, and to ascertain what improvements on the model might be necessary for better accuracy. Tests with the Space Shuttle orbiter with an empty payload bay [38] and Shuttle orbiter model tests with payload configurations [34] were used for these comparisons. Section 5.1 begins the information about the full scale acoustic test comparisons on the orbiter and Section 5.6 starts the discussion of the Shuttle model test comparisons with a payload configuration.

5.1 ACOUSTIC TESTS ON ORBITER OV-101

The acoustic tests were performed on the Space Shuttle Orbiter Vehicle (OV-101) at Edwards Air Force Base in California. Two F-104 jet aircrafts were used as the acoustic noise sources. This jet noise source provided a propagating excitation with spatial correlation characteristics similar to those expected during launch and with an intensity similar to the launch environment. Reference 38 gives the complete details and results of the tests, while the main test factors are summarized below.

5.1.1 Test Configuration

Figure 5-1 illustrates the basic test configuration at Edwards AFB. The two F-104 jet aircraft were located aft of the orbiter to generate an acoustic field similar to that anticipated during launch. Two sets of tests were performed at the two aircraft distances of 100 feet and 250 feet. The 100-foot distance for tests 2 and 3 are of concern for this study. The two tests differed only due to the microphone locations for the test measurements of the payload bay interior noise levels, as discussed in the next section.

5.1.2 Microphone Locations

The eight interior microphone locations for tests 2 and 3 are shown in Figure 5-2. The microphones in test 2, which were designated location A in Figure 5-2, were suspended on ropes that hung vertically down the payload bay centerline. In test 3 the microphones were pulled to the side, off the centerline, and into positions identified as location B, also shown in Figure 5-2. Exterior microphones were located on the orbiter surface as shown in Figure 5-3.

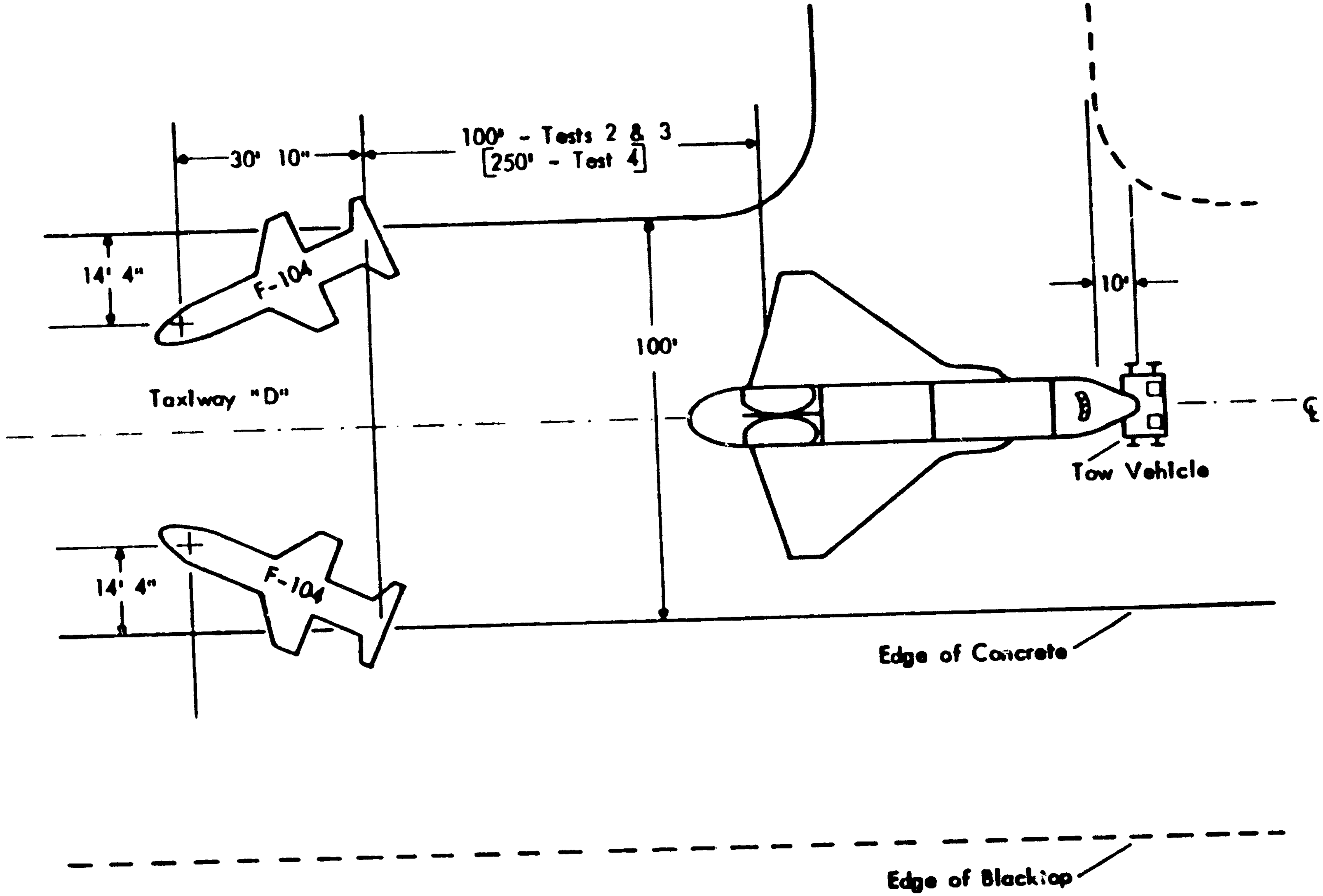


Figure 5-1. Position of F-104 Aircraft for OV-101 Acoustic Tests [38]

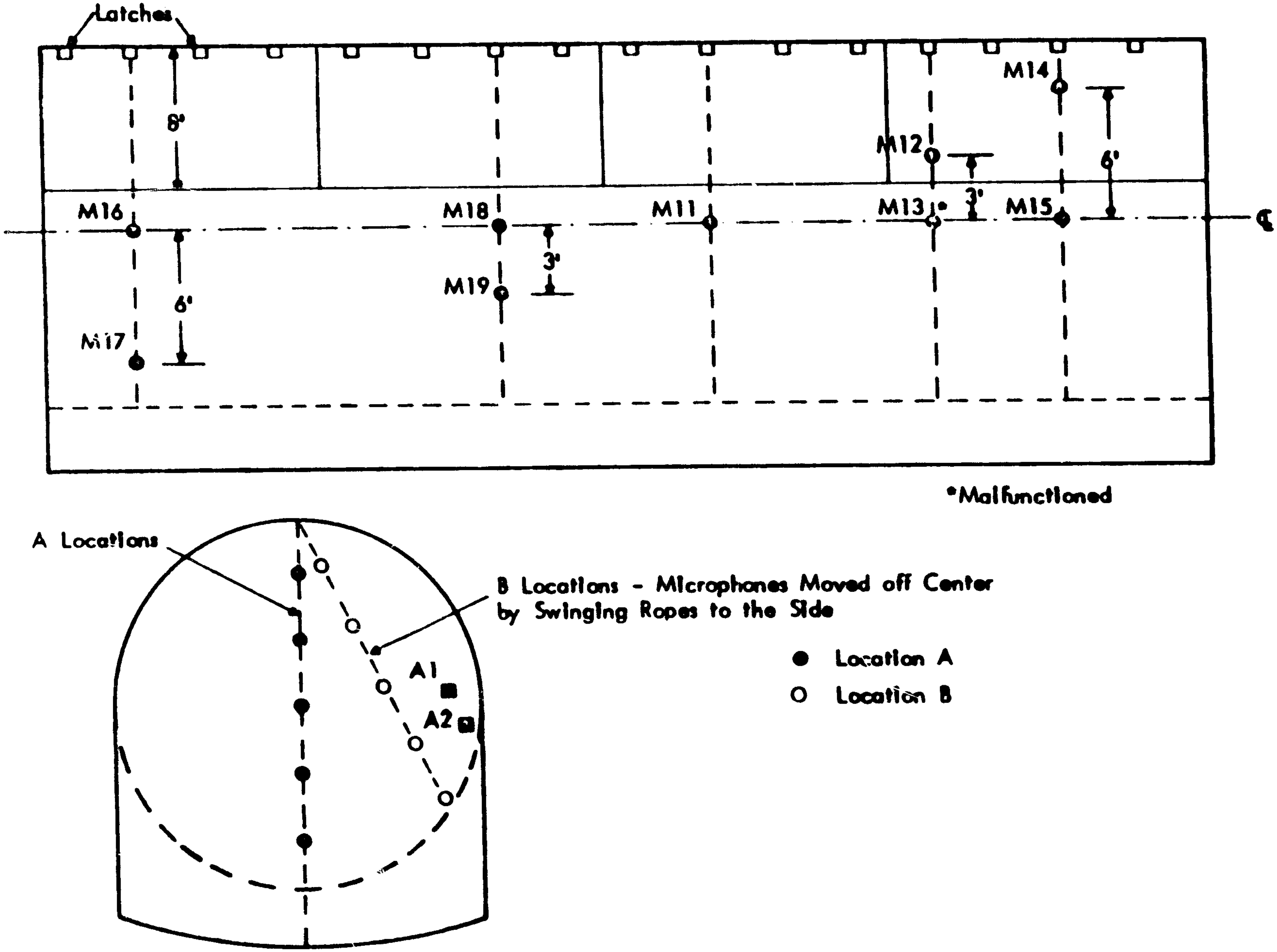


Figure 5-2. Microphone Locations Inside OV-101 Payload Bay [38]

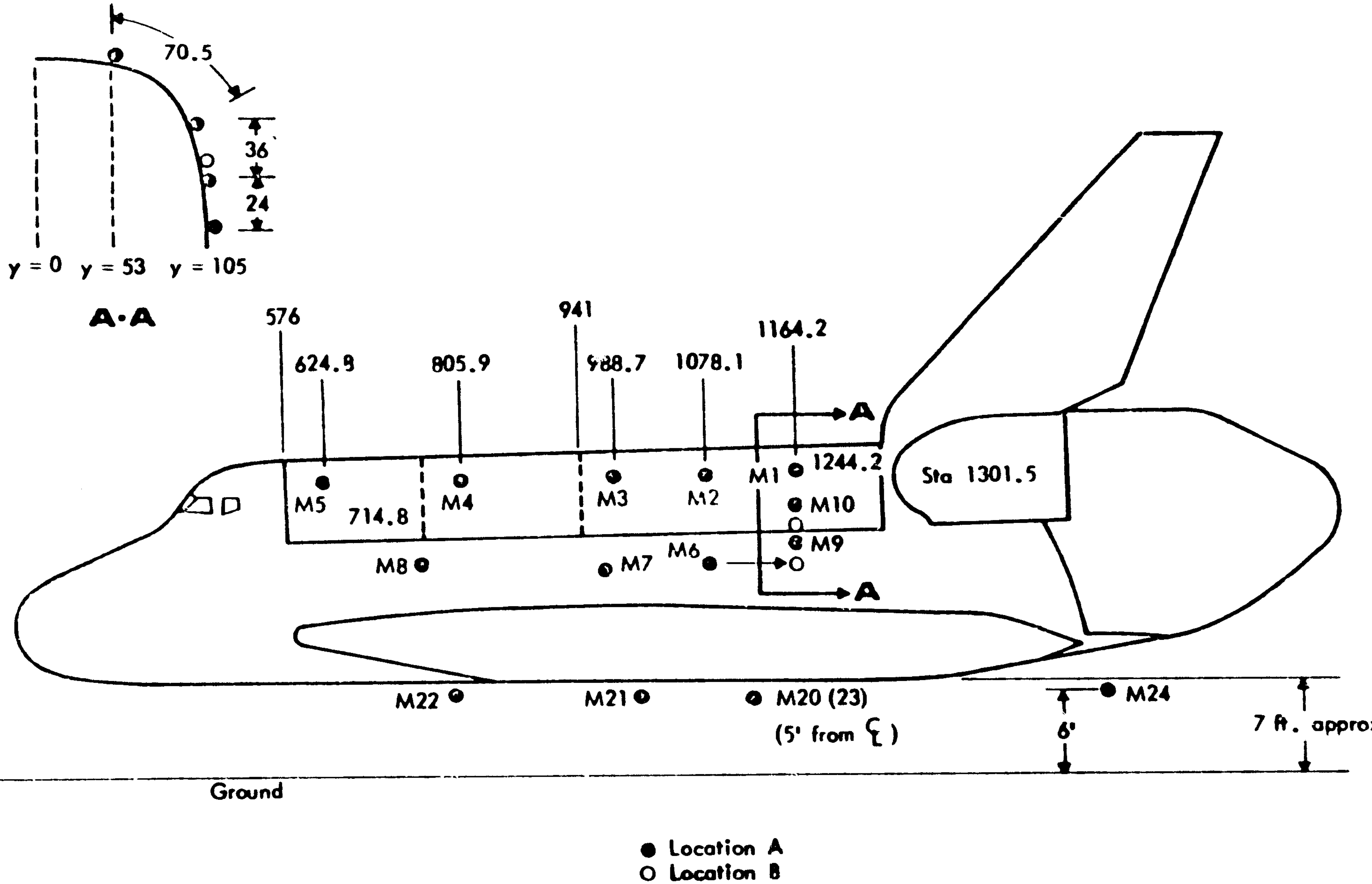


Figure 5-3. Microphone Locations Outside OV-101 Payload Bay [38]

5.1.3 Exterior Noise Source Levels

Since tests 2 and 3 were basically the same except for the location of the interior noise microphones, their exterior measurements were averaged to provide the forcing input on the structure. Noise transmission into the payload bay was primarily through the payload bay doors, especially in the low frequency range of excitation. Therefore, the test results for the doors alone will be used in the test and analytical comparison. The average exterior sound pressure levels (SPLs) measured on the doors are shown in Figure 5-4, along with a corrected door level. The corrected door levels were obtained because of a strong circumferential gradient at certain frequencies. Tables 5-1 and 5-2 list the measured one-third octave SPLs at each microphone location for test 2 and test 3, respectively.

5.1.4 External Noise Field Description

The correlation function for the convected excitation pressure field was represented by an exponentially decaying cosine function. For the longitudinal direction, it is given by

$$\rho_x(\xi, \omega) = \exp\left[-\frac{k_x}{a_x}|\xi|\right]\cos(k_x\xi) ,$$

where

$k_x = \frac{\omega}{U_x}$, wave number at frequency ω,

U_x = phase (trace) velocity over surface of vehicle,

a_x = correlation decay factor,

ξ = $x' - x$, longitudinal distance between two points on surface of vehicle.

The circumferential correlation function is of the same form as the longitudinal function:

$$\rho_y(\zeta, \omega) = \exp\left[-\frac{k_y}{a_y}|\zeta|\right]\cos(k_y\zeta) ,$$

where

k_y = wave number at frequency ω,

U_y = trace velocity in circumferential direction,

a_y = correlation decay factor,

ζ = $y' - y$, transverse distance between two points.

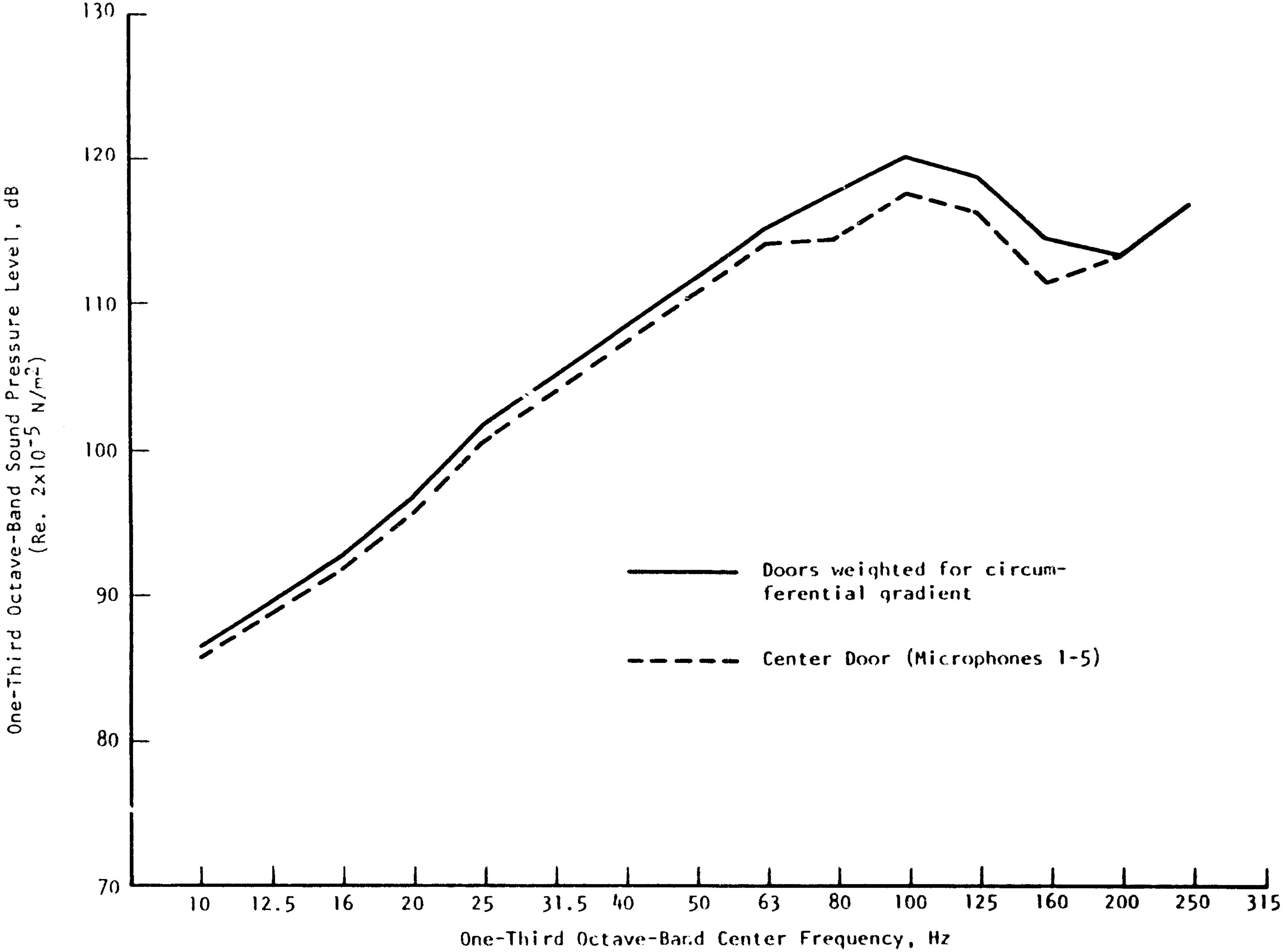


Figure 5-4. Test Measurements of Exterior Noise Levels on Orbiter

TABLE 5-1.

ONE-THIRD OCTAVE-BAND SOUND PRESSURE LEVELS ON DOOR

TEST 2 (NEAR SOURCE) 1000 RPM [34]

FREQ>	10.0	12.6	15.8	20.0	25.1	31.6	39.8	50.1	63.1	79.4
TRANSDUCER										
M1	84.8	83.7	91.4	96.7	102.2	104.6	107.0	111.5	114.1	111.8
M2	84.8	87.8	90.6	95.5	100.8	104.0	107.3	110.8	113.5	113.3
M3	84.8	87.7	90.5	94.5	100.9	103.7	106.1	110.7	112.4	114.2
M4	83.5	88.6	91.2	95.0	100.2	104.3	107.9	111.8	113.4	112.9
M5	83.6	90.1	92.7	95.6	99.7	103.6	107.3	112.1	114.5	114.1
AVG	84.3	88.7	91.4	95.5	100.8	104.1	107.2	111.4	113.6	113.3

FREQ>	100.0	125.9	158.5	199.5	251.2	316.2	398.1	501.2	631.0	794.3
TRANSDUCER										
M1	114.0	113.0	108.8	113.3	117.1	118.6	122.3	117.6	115.3	117.7
M2	118.1	113.9	109.2	113.2	116.0	118.9	123.3	119.3	116.2	116.6
M3	117.4	115.0	110.0	113.0	113.5	117.3	123.6	120.4	116.9	117.4
M4	118.7	116.0	113.6	114.2	111.4	116.0	123.0	119.6	117.9	115.2
M5	115.8	115.2	111.6	112.7	113.0	113.6	119.9	119.1	118.1	114.5
AVG	117.1	114.8	111.0	113.1	114.7	117.3	122.6	119.3	117.0	116.4

FREQ>	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3
TRANSDUCER										
M1	115.1	114.4	112.1	110.4	107.4	103.6	101.1	92.7	90.1	88.5
M2	118.2	114.9	113.5	112.8	110.3	107.4	105.5	103.4	98.3	95.8
M3	119.1	115.9	114.9	114.5	110.7	108.7	107.2	106.1	102.4	98.8
M4	118.3	118.0	115.5	114.0	112.6	110.5	107.9	107.2	102.4	99.4
M5	115.2	118.1	114.7	113.3	112.3	108.9	107.3	101.2	97.1	94.4
AVG	117.5	116.5	114.3	113.2	111.0	108.4	106.4	104.1	99.8	96.7

TABLE 5-2.

ONE-THIRD OCTAVE-BAND SOUND PRESSURE LEVELS ON DOOR

TEST 3 (NEAR SOURCE) 100% RPM [34]

FREQ>	10.0	12.6	15.8	20.0	25.1	31.6	39.8	50.1	63.1	79.4
TRANSDUCER										
M1	86.9	88.5	92.0	96.0	101.7	103.7	106.9	110.3	115.4	113.4
M2	86.1	87.3	90.9	95.0	100.7	103.2	107.3	109.8	114.4	115.4
M3	86.6	87.2	90.9	93.5	100.6	103.1	105.7	110.1	113.4	115.3
M4	86.0	88.1	91.0	94.2	100.5	103.8	107.9	110.5	114.4	114.6
M5	86.1	89.5	92.3	94.8	99.7	102.9	107.5	110.3	115.1	116.4
AVG	86.3	88.2	91.5	94.8	100.7	103.4	107.1	110.2	114.6	115.2

FREQ>	100.0	125.9	158.5	199.5	251.2	316.2	398.1	501.2	631.0	794.3
TRANSDUCER										
M1	113.8	115.1	110.1	115.2	121.0	120.2	121.5	116.6	115.5	118.7
M2	119.4	114.8	110.1	114.8	120.0	121.7	122.4	117.7	115.0	120.1
M3	118.5	118.6	111.8	112.3	118.5	120.9	122.2	116.9	116.2	120.0
M4	119.5	118.8	113.5	112.5	114.8	119.4	121.9	118.7	114.4	117.3
M5	117.0	119.2	113.5	111.0	112.1	115.8	119.4	118.0	114.7	117.9
AVG	118.1	117.4	112.1	113.5	118.3	120.0	121.6	117.7	115.2	118.9

FREQ>	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3
TRANSDUCER										
M1	113.1	113.0	110.6	109.2	104.4	101.1	97.1	95.5	93.2	92.3
M2	114.4	115.2	113.5	112.3	108.3	105.2	102.8	99.8	96.1	94.3
M3	115.7	115.9	115.1	112.8	108.6	106.1	103.3	104.0	100.5	96.6
M4	116.7	115.4	113.2	112.8	110.2	107.1	103.7	101.3	95.8	94.8
M5	114.9	114.8	113.5	111.6	109.1	105.6	102.8	101.5	98.4	97.3
AVG	115.1	115.0	113.4	111.9	108.5	105.4	102.4	101.2	97.5	95.4

The correlation decay factors and trace velocities were determined experimentally from the test between microphone pairs, and their averaged values are given below for the payload bay doors:

$$k_x = kC_o/U_x = 0.92k,$$

where $k = \omega/C_o$, and C_o = speed of sound,

$a_x = 34.4,$

$k_y = 0.26k,$

$a_y = 3.74.$

From Reference 32, the AMTF values for the longitudinal factors are

$$k_x = 0.90k,$$

$$a_x = 31.0.$$

The values of a and k were assumed to be the same for tests 2 and 3.

5.1.5 Determining the Measured Payload Bay Noise Reduction

The exterior sound pressure levels on the payload bay doors measured in tests 2 and 3 were averaged and weighted for circumferential gradient. These values are shown in Figure 5-4. Tables 5-1 and 5-2 also list the individual SPL for each microphone location and their average value at each one-third octave band. Interior SPLs measured at location A (test 2) and location B (test 3) were space-averaged by the following equation to determine the payload interior noise levels:

$$\langle SPL \rangle = 10 \log_{10}\left[0.33(10)^{L_A/10} + 0.67(10)^{L_B/10}\right],$$

where $\langle SPL \rangle$ = space averaged value of sound pressure level,

L_A = the average SPL measured for microphones at location A in test 2,

L_B = the average SPL measured for microphones at location B in test 3.

Figure 5-5 gives these space-averaged SPL results. Tables 5-3 and 5-4 give the SPL at each microphone location in the bay and also list the average one-third octave-band SPL. The SPLs at location B were weighted double those of location A

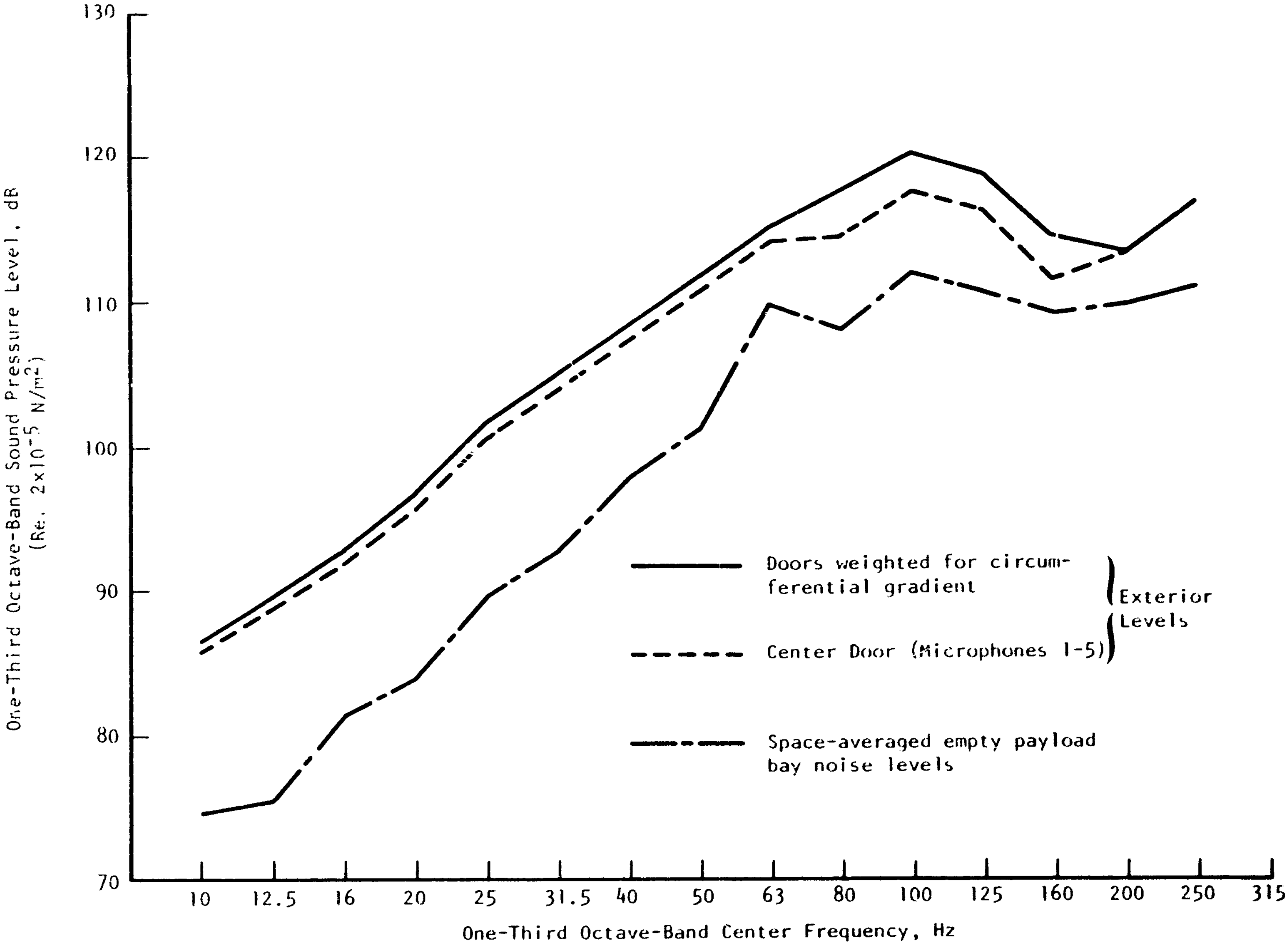


Figure 5-5. Test Measurements of Exterior and Interior Noise Levels on Orbiter

TABLE 5-3.

ONE-THIRD OCTAVE-BAND SOUND PRESSURE LEVELS INSIDE PAYLOAD BAY (ALONG CENTERLINE)

TEST 2 (NEAR SOURCE) 100% RPM [34]

FREQ> TRANSDUCER	10.0	12.6	15.8	20.0	25.1	31.6	39.8	50.1	63.1	79.4
M11	71.2	71.3	82.8	84.1	90.0	88.7	89.9	93.5	106.0	104.4
M12	74.0	73.3	75.8	76.4	87.2	86.2	90.3	89.8	101.2	104.0
M14	77.8	78.4	81.2	82.9	83.8	88.1	92.7	93.4	107.0	107.4
M15	74.6	73.9	82.0	84.7	86.6	81.1	91.7	92.9	103.9	106.3
M16	74.8	74.8	81.5	83.1	89.1	87.0	84.9	89.8	105.3	100.3
M17	77.1	77.5	82.4	84.5	89.0	92.7	92.5	97.0	109.5	107.0
M18	70.9	71.8	81.3	82.3	92.1	88.3	90.9	93.1	105.3	107.3
M19	72.3	74.4	83.0	84.0	92.9	85.9	93.0	94.7	107.0	107.6
AVG	74.7	75.1	81.6	83.3	89.7	88.2	90.7	93.6	106.2	106.1

FREQ> TRANSDUCER	100.0	125.9	158.5	199.5	251.2	316.2	398.1	501.2	631.0	794.3
M11	109.3	109.0	108.8	110.6	110.3	109.2	111.2	108.1	110.1	106.4
M12	107.8	108.7	107.3	112.1	110.6	109.0	113.2	109.5	107.8	106.6
M14	108.8	108.2	108.1	109.9	111.6	112.9	117.8	111.6	112.6	107.0
M15	110.9	105.3	110.9	109.6	110.7	110.3	113.5	109.2	111.3	106.8
M16	109.7	105.6	110.1	110.2	112.3	109.1	108.9	108.7	107.0	104.3
M17	114.3	111.2	109.7	112.1	113.[illegible]	110.6	10[illegible].4	108.9	106.2	105.5
M18	110.1	110.3	110.0	110.5	112.1	109.1	112.0	110.6	111.3	107.3
M19	110.8	1[illegible].1	108.7	112.0	112.1	109.0	112.6	110.8	110.8	107.0
AVG	110.7	108.[illegible]	109.9	111.1	111.8	110.1	11[illegible].2	109.[illegible]	110.3	106.5

FREQ> TRANSDUCER	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3
M11	105.7	104.1	102.2	97.8	91.9	92.1	88.6	84.3	80.9	80.3
M12	105.3	102.3	101.0	96.9	95.3	91.2	87.9	83.6	81.2	79.9
M14	107.8	104.9	103.6	97.0	95.2	92.6	90.3	85.2	81.9	79.4
M15	107.2	104.8	103.0	97.7	95.1	92.9	90.0	85.6	83.9	79.0
M16	103.3	102.8	99.9	96.3	91.7	90.1	86.5	82.3	79.8	79.1
M17	104.8	102.6	101.0	96.6	92.1	89.7	87.6	82.2	80.7	80.7
M18	105.4	104.9	101.4	98.8	94.5	91.8	88.5	84.7	83.0	82.4
M19	105.4	105.4	101.7	99.0	94.6	92.2	88.7	85.4	81.2	80.7
AVG	105.8	104.1	101.9	97.6	94.2	91.7	88.7	84.3	81.8	80.[illegible]

TABLE 5-4.

ONE-THIRD OCTAVE-BAND SOUND PRESSURE LEVELS INSIDE PAYLOAD BAY (OFF TO SIDE)

TEST 3 (NEAR SOURCE) 100% RPM [34]

FREQ> TRANSDUCER	10.0	12.6	15.8	20.0	25.1	31.6	39.8	50.1	63.1	79.4
M11	71.5	71.8	83.4	85.0	89.0	95.1	95.6	101.3	105.7	103.2
M12	74.5	73.9	75.7	74.9	90.1	89.2	97.1	100.3	107.6	112.2
M14	75.9	76.3	79.7	83.3	81.6	88.3	94.4	94.6	105.8	108.0
M15	73.8	73.7	82.0	86.2	84.7	89.4	97.4	98.8	103.3	108.7
M16	74.4	76.2	81.8	84.0	88.6	95.7	100.5	102.4	110.8	106.6
M17	76.4	78.6	81.7	85.2	90.3	95.9	101.7	105.1	116.0	111.4
M18	71.7	73.2	81.9	83.6	91.0	94.0	99.7	104.8	107.7	102.0
M19	73.1	75.3	83.9	85.2	91.6	94.5	101.9	105.5	113.0	109.0
AVG	74.2	75.4	81.8	84.2	89.3	93.7	99.3	102.7	110.7	108.8

FREQ> TRANSDUCER	100.0	125.9	158.5	199.5	251.2	316.2	398.1	501.2	631.0	794.3
M11	109.5	110.4	110.3	108.5	111.7	110.4	113.0	110.7	108.6	106.8
M12	112.3	112.4	104.1	103.4	106.5	111.1	113.5	112.7	107.4	106.4
M14	112.6	109.7	104.9	107.2	110.5	113.2	115.1	110.5	110.2	103.8
M15	108.0	110.0	108.4	111.9	110.3	110.7	113.2	111.2	108.3	107.7
M16	110.8	107.1	107.4	107.9	108.5	108.7	111.4	109.6	105.9	105.4
M17	110.2	112.9	111.7	111.3	112.6	109.3	110.4	110.7	110.7	105.3
M18	110.6	110.8	109.3	108.1	111.6	110.7	112.6	109.4	108.0	106.4
M19	[illegible]	112.1	[illegible]	107.9	109.6	111.1	113.0	111.4	107.7	105.8
AVG	[illegible]	110.8	[illegible]	109.2	110.5	[illegible]	113.0	110.8	108.3	106.8

FREQ> TRANSDUCER	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3
M11	106.6	104.4	101.1	97.7	94.4	91.5	88.0	83.7	81.7	83.1
M12	107.0	104.3	101.2	97.2	94.3	92.8	88.2	84.8	83.1	77.9
M14	107.2	104.4	102.4	97.5	95.3	93.0	89.5	85.1	83.4	79.8
M15	107.9	104.6	101.0	97.8	95.9	93.0	90.1	86.6	81.4	78.6
M16	105.1	101.8	100.5	96.5	93.0	89.9	87.3	82.0	80.0	80.7
M17	104.7	103.1	99.1	96.5	93.7	91.7	89.0	82.9	81.0	80.9
M18	106.7	103.7	100.4	98.7	94.6	92.9	88.7	84.4	82.5	83.1
M19	106.2	104.7	100.0	98.5	95.5	93.0	91.0	85.8	83.4	82.3
AVG	106.5	104.0	100.8	97.6	94.7	92.3	89.1	84.6	82.2	80.7

because of the payload bay symmetry. By the symmetry factor, the noise levels on the other side of the bay were assumed to have the same values as those at location B. This situation can be easily seen in Figure 5-2.

To determine the payload bay noise reduction (NR) from these one-third octave-band measured data, the space averaged interior noise levels were subtracted from the exterior door levels. Since the dominant noise transmission at these low frequencies is through the doors, little accuracy is lost on calculating the NR by considering only the transmission of the exterior noise through the doors. These noise reduction levels are plotted for each one-third octave band from 10 Hz to 250 Hz in Figure 5-6.

5.1.6 Spatial Variability of the Measured Noise Reduction

The spatial variability of the empty payload bay measurements is shown in Figure 5-7. The scatter of the 16 measurements from tests 2 and 3 are given relative to the space-averaged level. The largest variation can be seen in the 40-Hz band, where the full range is about 20 dB. For bands below 100 Hz, the data scatter becomes more prevalent as the frequency decreases. Except for the 63 Hz band, all the measurements are less than 5 dB above the space-averaged value. But since 16 measurements is a relatively small sample within the entire payload bay space, there are undoubtedly some locations where the low frequency levels exceed the space averaged levels by more than 5 dB.

5.2 INPUTS FOR THE ANALYTICAL MODEL PREDICTIONS

The following section describes the data that were used to model the Shuttle Orbiter payload bay structure, the payload bay enclosure, and the payload geometry. These inputs for the analytical representation were used with the basic computer program developed by Wyle, which is described in Section 4.0.

5.2.1 Absorption of OV-101 Payload Bay

The interior absorption of the payload bay was measured by exciting the bay with loudspeaker sources and determining the reverberation time. From the reverberation time, the volume loss factors in one-third octave bands were computed and the average wall absorption coefficients were estimated. Figure 5-8 shows the reverberation times used to compute the acoustic damping in the analytical model of the computer program.

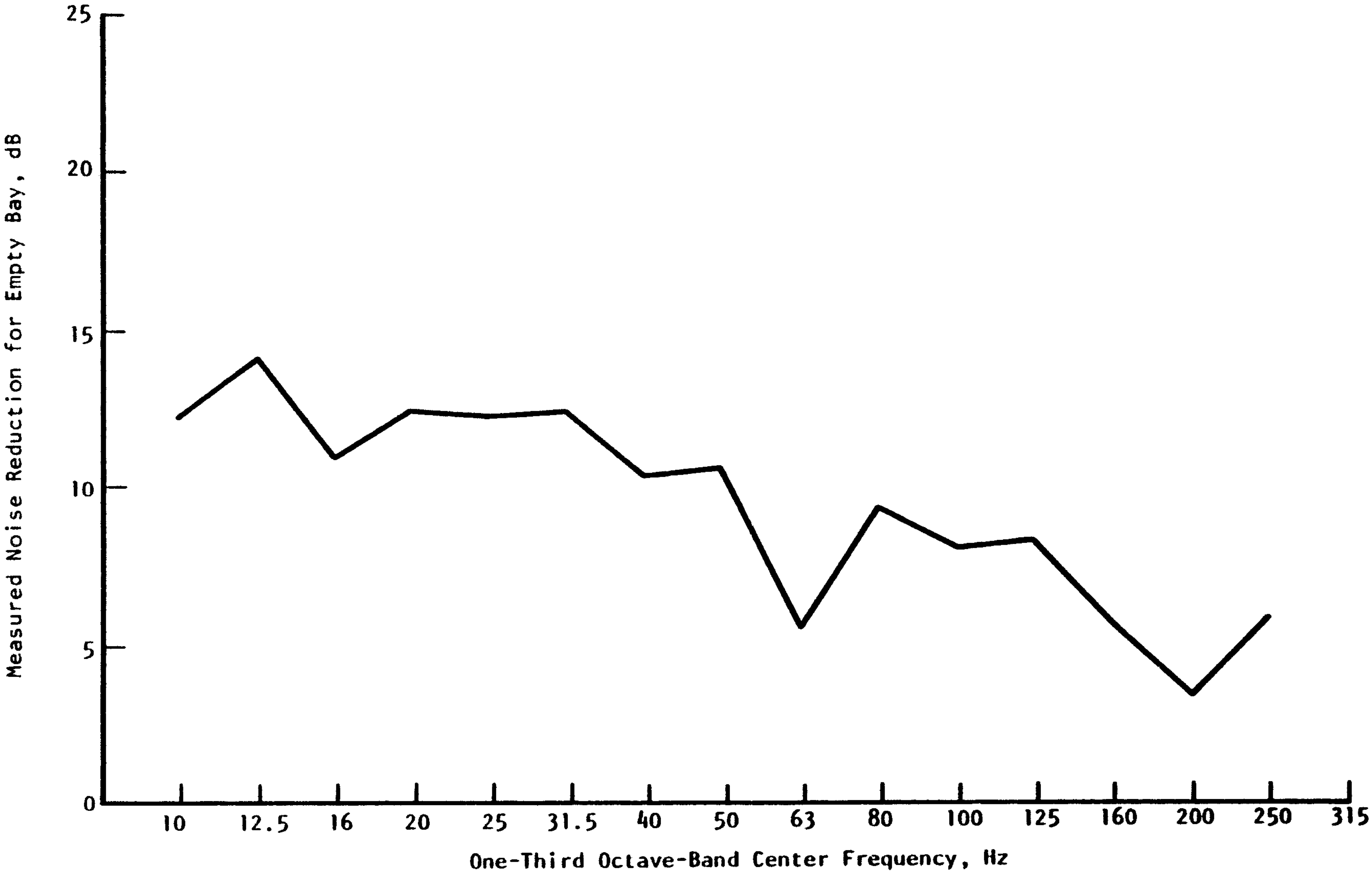


Figure 5-6. Measured Noise Reduction Levels for Empty Payload Bay

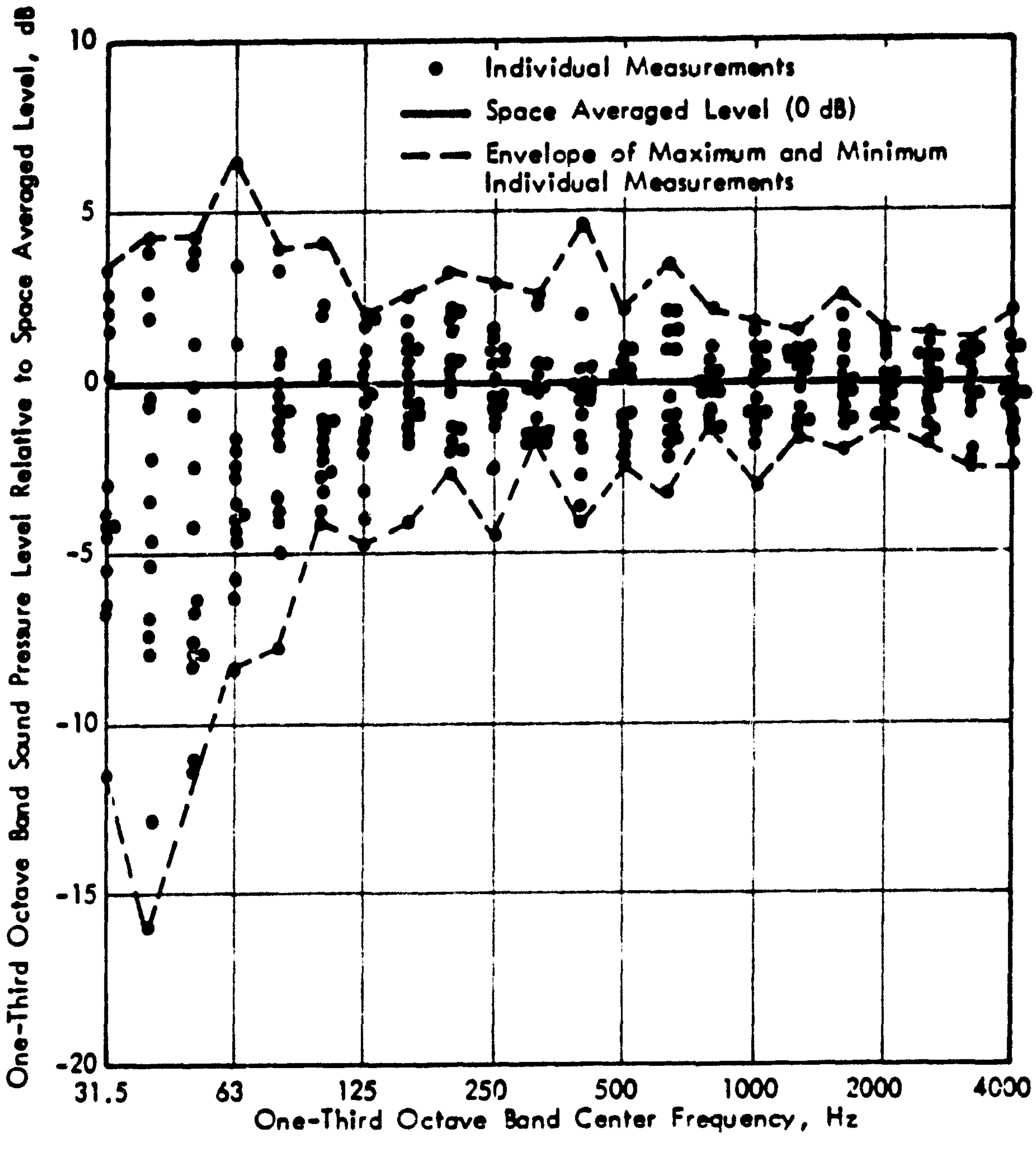


Figure 5-7. Variability of Measured Payload Bay Acoustic Levels for OV-101 Tests 1 and 2 [34]

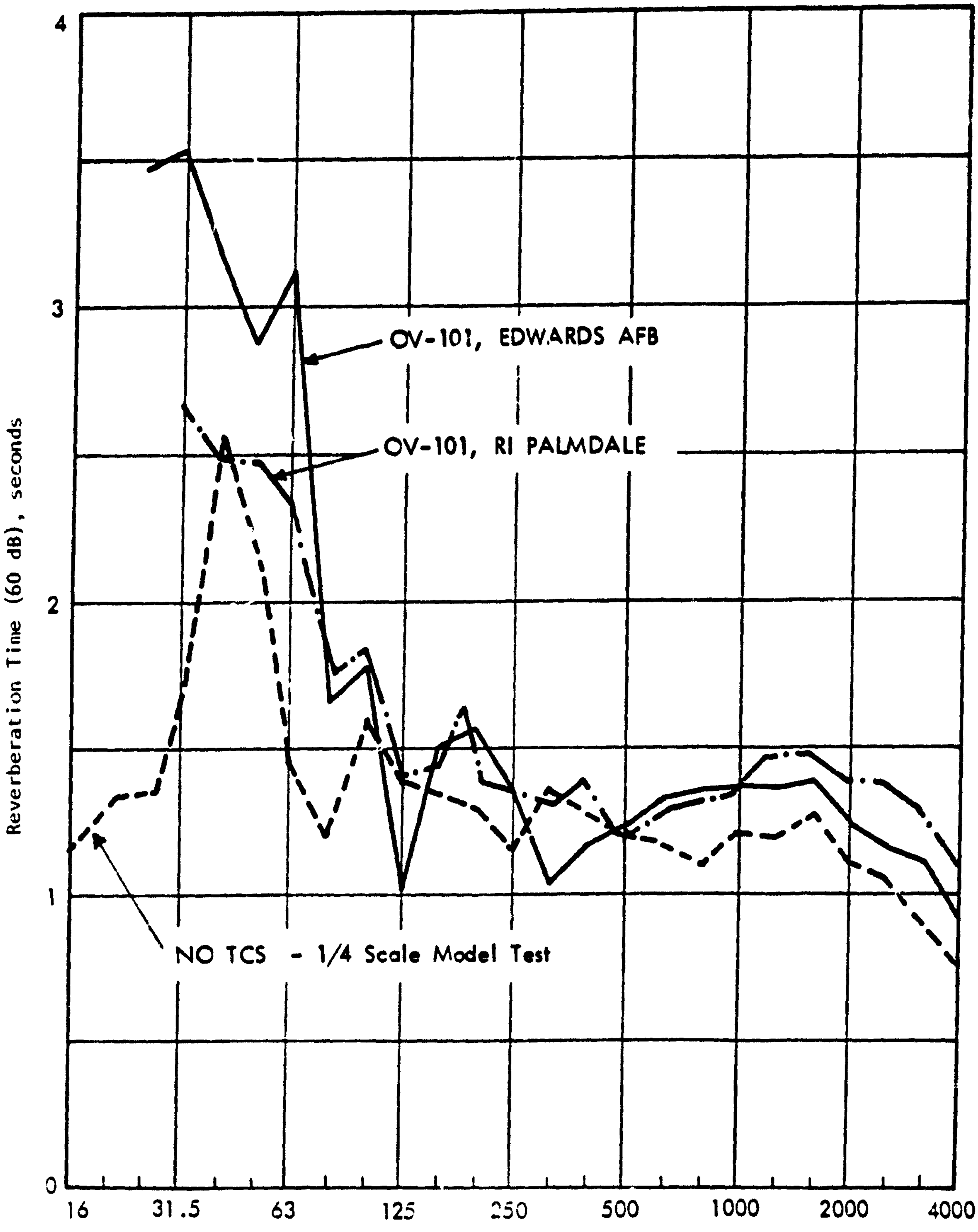


Figure 5-8. Payload Bay Reverberation Time

5.2.2 Structure of the Orbiter

Figure 5-9 shows a general view of the Space Shuttle orbiter. Figure 5-10 shows a typical cross section through the cargo bay that is approximately 60 feet long with a roughly circular usable cargo volume approximately 16 feet in diameter. The side walls and bottom are essentially flat, with truss frames (shown in Figure 5-10) at about 5-foot intervals. The doors, which have a roughly circular cross section, consist of five pairs that open in two pair of units as shown in Figure 5-11.

For the purposes of matching the orbiter structure to the cylindrical coordinate geometry of the analytic model, the payload bay structure is modeled in the following way:

- The structure is modeled as a cylinder, 16-foot diameter by 60-foot length, with rigid end walls.
- The doors are considered to comprise a 180-degree full length panel, joined to the fuselage by shear diaphragm boundary conditions.

Detailed structural and vibrational properties of the doors are discussed in Section 5.2.5.

5.2.3 Payload Bay Doors

The payload bay doors consist of five pairs, as noted above. Figure 5-11 shows the structural arrangement of one of the four main door halves. The structure consists of the skin, end frames, seven intermediate frames, a torque box at the hinge line, and a center beam. The skin is a graphite-epoxy sandwich with nomex filler. The frames are graphite-epoxy with hat-section intermediate frames. The fifth pair or doors (rearmost) is about one-eighth the length of the others, and has no intermediate frames. Not shown in Figure 5-11 are various latches, skin doublers, hardware, etc. Table 5-5 lists all components of the doors together with their weights [39]. Table 5-6 summarizes the material properties of the skin and frame materials [40]. The five door pairs are joined into two unit pairs that open and close separately. The joining is done with shear pins. When closed, the doors are latched with a combination of shear pins and latches.

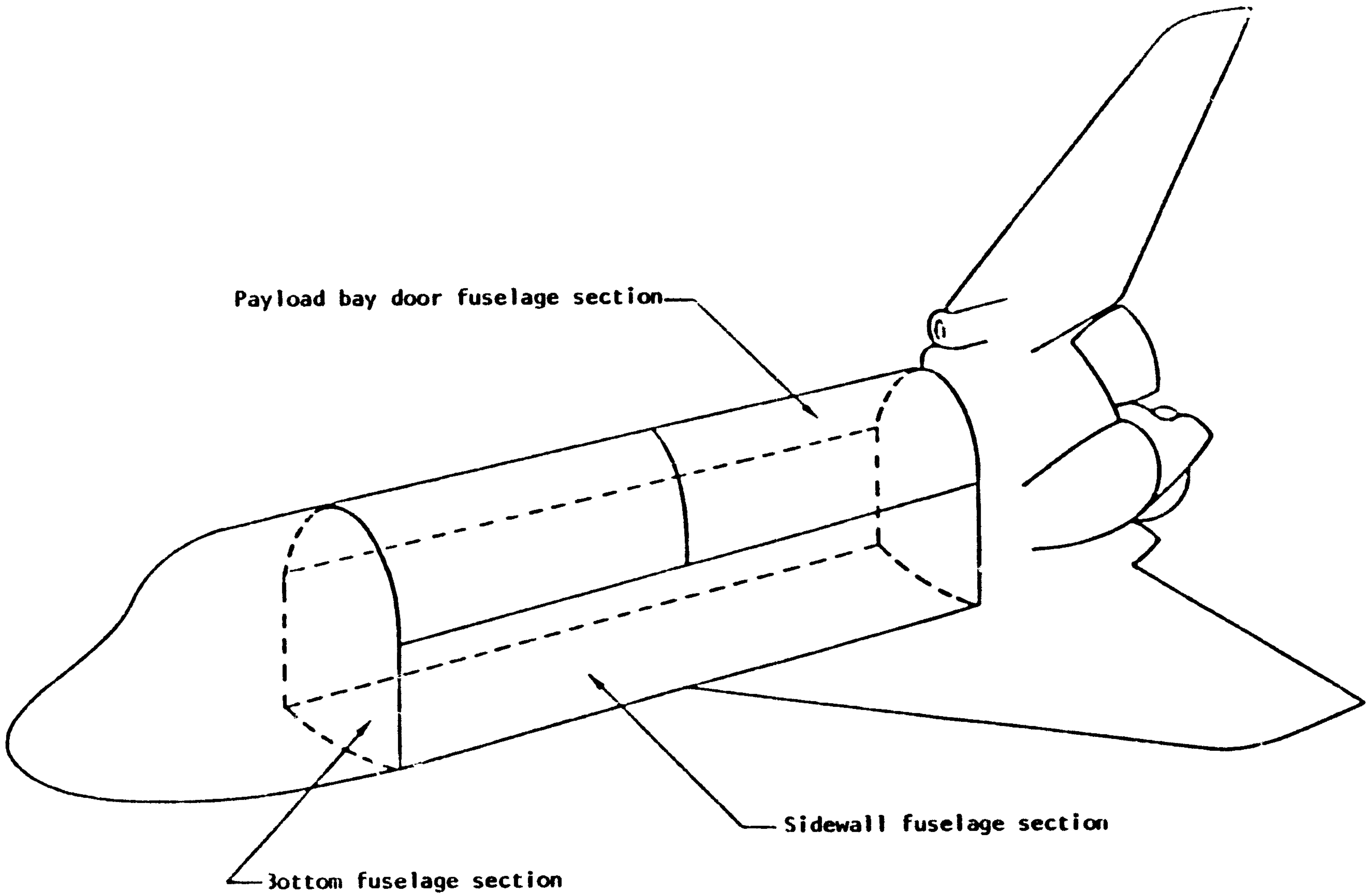


Figure 5-9. Space Shuttle Configuration

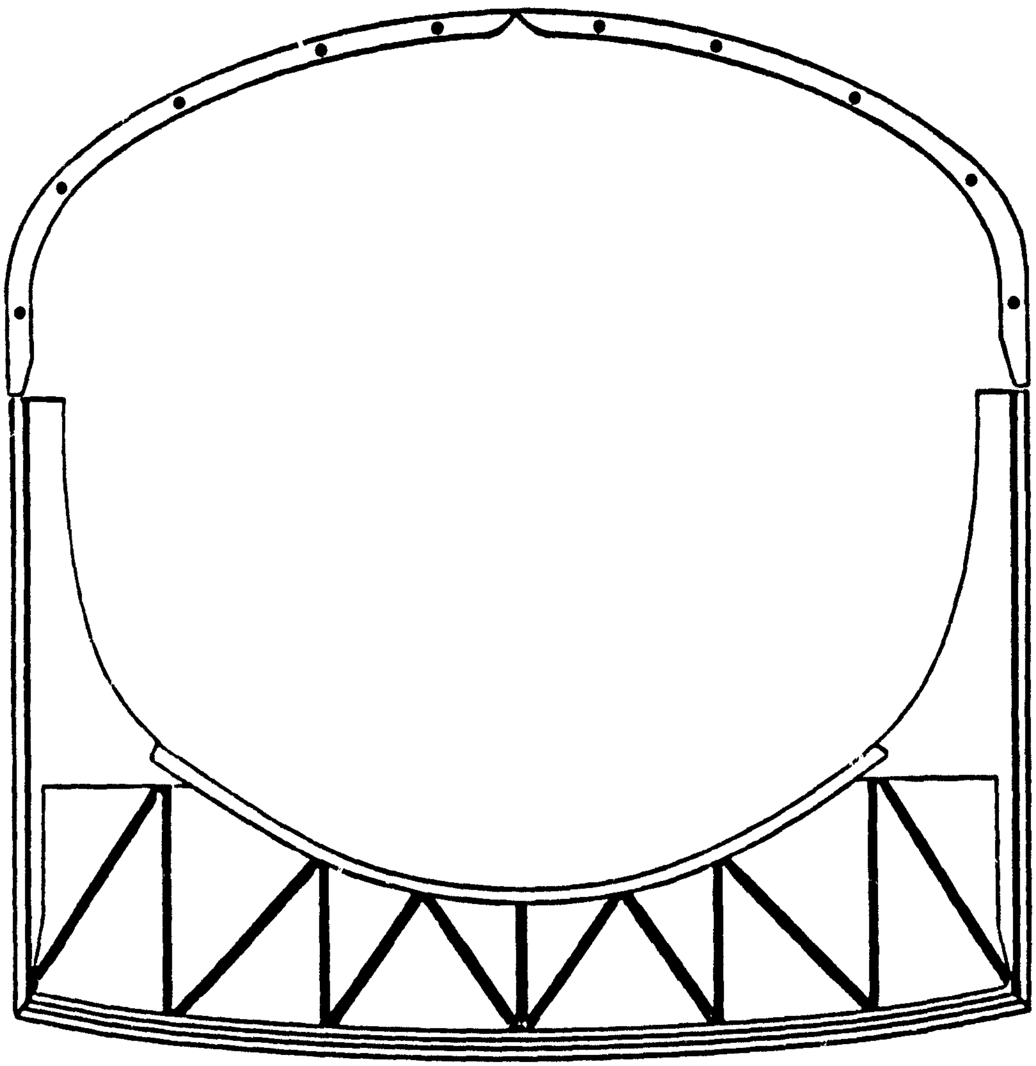


Figure 5-10. Cross Section of Space Shuttle Cargo Bay Showing Typical Truss Frame

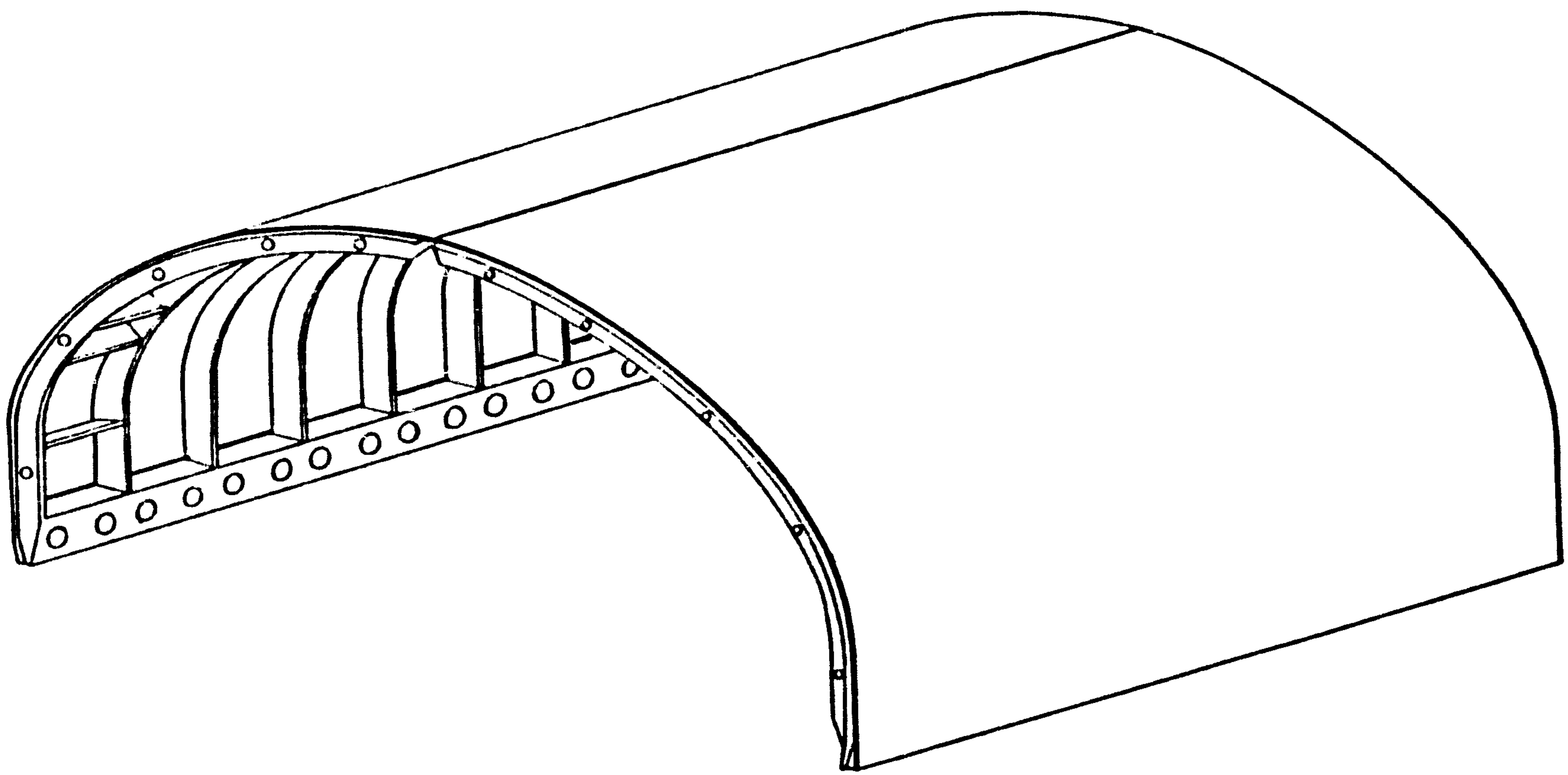


Figure 5-11. Structural Configuration of Cargo Bay Doors Showing Skins, Hinge Line Torque Box and Circumferential Frames

TABLE 5-5.

SUMMARY OF ORBITER 001 PAYLOAD BAY DOOR WEIGHTS

Component		Weight (lb.)
Forward Honeycomb Panel	Skin	373.1
	Core	87.1
	Bonding	100.2
Aft Honeycomb Panel	Skin	383.2
	Core	84.9
	Bonding	100.7
Intermediate Frames		549.5
Closeout Frames		260.0
Torque Boxes		134.6
Centerline Beams		106.4
Hingeline Closeouts		51.0
Latch Backup Structure	Right	75.8
	Left	72.8
Expansion Joints		202.9
Miscellaneous Hardware		99.1
Lightning Protection		90.9
Linkage and Hinges		58.0
Door Hinges on Door		195.4
Sealant		20.0
Seal Supports		116.4
Seals		293.0

TABLE 5-6.

PROPERTIES OF PAYLOAD BAY DOOR MATERIALS

GR/E Skin	
Thickness:	0.016" (each face sheet)
Young's Modulus:	3.5×16^6 psi (90°)
	12.8×10^6 psi (0°)
Density:	0.057 lb/in^3
Nomex Core	
Thickness:	0.6"
Cell Size:	1/8 inch
Density:	0.3 lb/ft^3

The door structure for the flight operational orbiter also includes two pairs of space radiators that open on a hinge line almost in common with the door hinges. When closed, the radiators are secured to the doors by a system of latches and ball joints. No strains from loads on the doors are transmitted to the radiators. The radiators were not installed on the OV-101 vehicle during these noise tests [38].

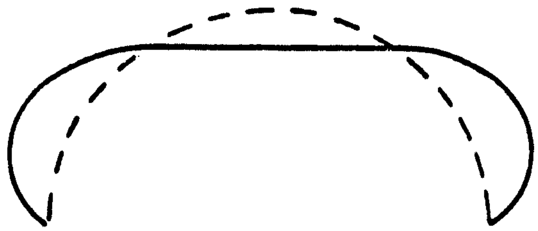
The structural properties of the doors as needed for the stiffnesses are summarized in Table 5-7. These were computed on the basis of the properties in Tables 5-5 and 5-6 and dimensions obtained from assembly drawings provided by NASA. Masses concentrated at the door/fuselage hinge line (torque boxes, hinge hardware, etc) were neglected in computing mass density because these are at a node.

Representation of the doors as a single 180° panel is not entirely satisfactory because of the pin connections between halves at the top centerline. Figure 5-12a shows the cross-sectional mode shape for $q = 3$ for the 180° homogeneous shell and the actual shape for the two-piece door with center hinge line is shown in Figure 5-12b. The true boundary conditions are not amenable to representation by an analytic expression as convenient to work with as Equation 30 from Reference 1. The main difference between Figures 5-12a and 5-12b is that b is considerably less stiff. The center hinge was, therefore, handled by reducing the

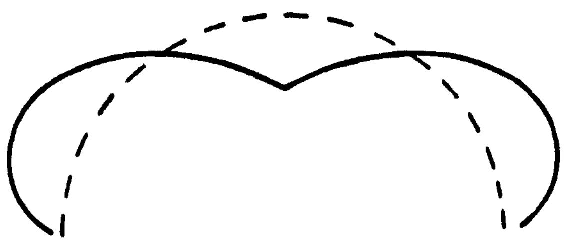
TABLE 5-7.

STRUCTURAL PROPERTIES OF PAYLOAD BAY DOORS

QUANTITY	SYMBOL	WHOLE DOOR	PANEL BETWEEN FRAMES
Length	l	60 feet	1.5 feet
Radius	b	8 feet	8 feet
Circumferential Extent	α	180°	90°
Stressed Skin Thickness (both layers)	A_{S_s}/l	0.00267 feet	0.00267 feet
Skin Filler Thickness	t_F	0.050 feet	0.050 feet
Shell Density	ρ_s	0.0989 slug/ft^2	0.0128 slug/ft^2
Longitudinal Young's Modulus	E_{S_s}	1.843x10^9 lb/ft^2	1.843x10^9 lb/ft^2
Circumferential Young's Modulus	E_{S_ϕ}	0.504x10^9 lb/ft^2	0.504x10^9 lb/ft^2
Frame Young's Modulus	E_F	1.843x10^9 lb/ft^2	---
Frame Area	A_F	0.00986 ft^2	---
Frame Moment of Inertia	I_F	0.183x10^{-3} ft^4	---
Frame Spacing	L_F	1.58 feet	---
Frame-Skin Centroid Distance	$\bar{x}$	0.109 feet	---
Poisson's Ratio	ν	0.3	0.3



a. Homogeneous Door Structure



b. Door Structure with Center Hinge

Figure 5-12. Circumferential q = 3 Mode Shape for Homogeneous and Hinged Doors

circumferential bending stiffness to compensate. For a force directed downward at the center, the split semicircle (12b) will be displaced approximately 30 times as far as the whole semicircle (12a). This was determined by applying the calculation procedure in Section 80 of Reference 41 to both cases. A relaxation factor of 30 is probably too great for the doors, however, as the driving force will not be concentrated on the centerline. For purposes of calculating low frequency vibration of the doors, the circumferential bending stiffness was divided by a factor of 20.

5.2.4 Payload Door Resonant Frequencies

Table 5-8 lists the payload bay door modal frequencies and indices through the 50 Hz one-third octave band. Table 5-9 shows the frequencies for eight of the first ten symmetric modes calculated from a finite element analysis of the door structure [42]. The finite element calculation is based on a structural description much closer to actual than the "relaxed" shell used here. The symmetric modes correspond to odd values of the circumferential modal index q. The first finite element frequency of 8.17 Hz corresponds well with the 1,3 mode of 9.3 Hz. The sequence of finite element frequencies increases in general with the

TABLE 5-8.

STRUCTURAL MODAL FREQUENCIES AND INDICES
FOR PAYLOAD BAY DOOR MODEL THROUGH 50 HZ BAND

p, q	f	p, q	f
1, 2	7.5	4, 6	39.5
1, 3	9.3	4, 3	39.8
2, 3	14.9	5, 4	40.0
1, 4	16.0	5, 6	42.5
2, 4	17.6	3, 2	43.4
1, 1	17.7	6, 5	43.9
3, 4	22.4	6, 6	46.6
2, 2	23.1	1, 7	49.6
1, 5	25.1	2, 7	49.9
2, 5	25.8	2, 1	50.5
3, 3	26.0	3, 7	50.5
3, 5	27.6	6, 4	50.7
4, 4	30.2	4, 7	51.6
4, 5	31.3	7, 6	51.8
1, 6	36.4	7, 5	52.0
2, 6	36.7	5, 7	53.4
5, 5	36.9	5, 3	54.6
3, 6	37.7	6, 7	55.9

p = number of longitudinal half waves.

q = number of circumferential full waves.

TABLE 5-9.

COMPARISON BETWEEN DOOR RESONANT FREQUENCIES FROM FINITE ELEMENT MODEL AND PRESENT MODEL SYMMETRIC MODES

PRESENT MODEL		FINITE ELEMENT MODEL
p, q	f	f
1, 3	9.3	8.17
2, 3	14.9	9.65
3, 3	26.0	10.85
4, 3	39.8	17.69
5, 3	54.6	20.04
6, 3	69.2	23.11
7, 3	50.5	26.07
8, 3	96.6	31.50

longitudinal modes p and with the odd q modes. The first and second symmetric modes are shown in Figures 5-13 and 5-14, respectively.

At high frequencies, when the wavelength is no longer large compared to the spacing between ring frames, the individual response of panels between frames must be considered. These are taken as independent panels, of circumferential extent 90 degrees and longitudinally between rings, with properties corresponding to the skin properties in Table 5-7 and supported by shear diaphragms. Table 5-10 lists the first few frequencies calculated for a typical skin panel between frames. The lowest frequency is over 400 Hz, so that these modes are of little importance for the present study.

TABLE 5-10.

RESONANT FREQUENCIES FOR DOOR PANELS BETWEEN FRAMES

MODE p, q	FREQUENCY f
1, 1	421.1
1, 2	435.5
1, 3	458.9
1, 4	490.2
1, 5	528.7
1, 6	573.4
1, 7	623.7
1. 8	679.2
1, 9	739.8
1, 10	805.5

Figure 5-13. 4 Door - Fuselage Model Modes --
Sym. TCL Constraints
Frequency = 8.17 cps
p, q = 1, 3
(from Reference 42)

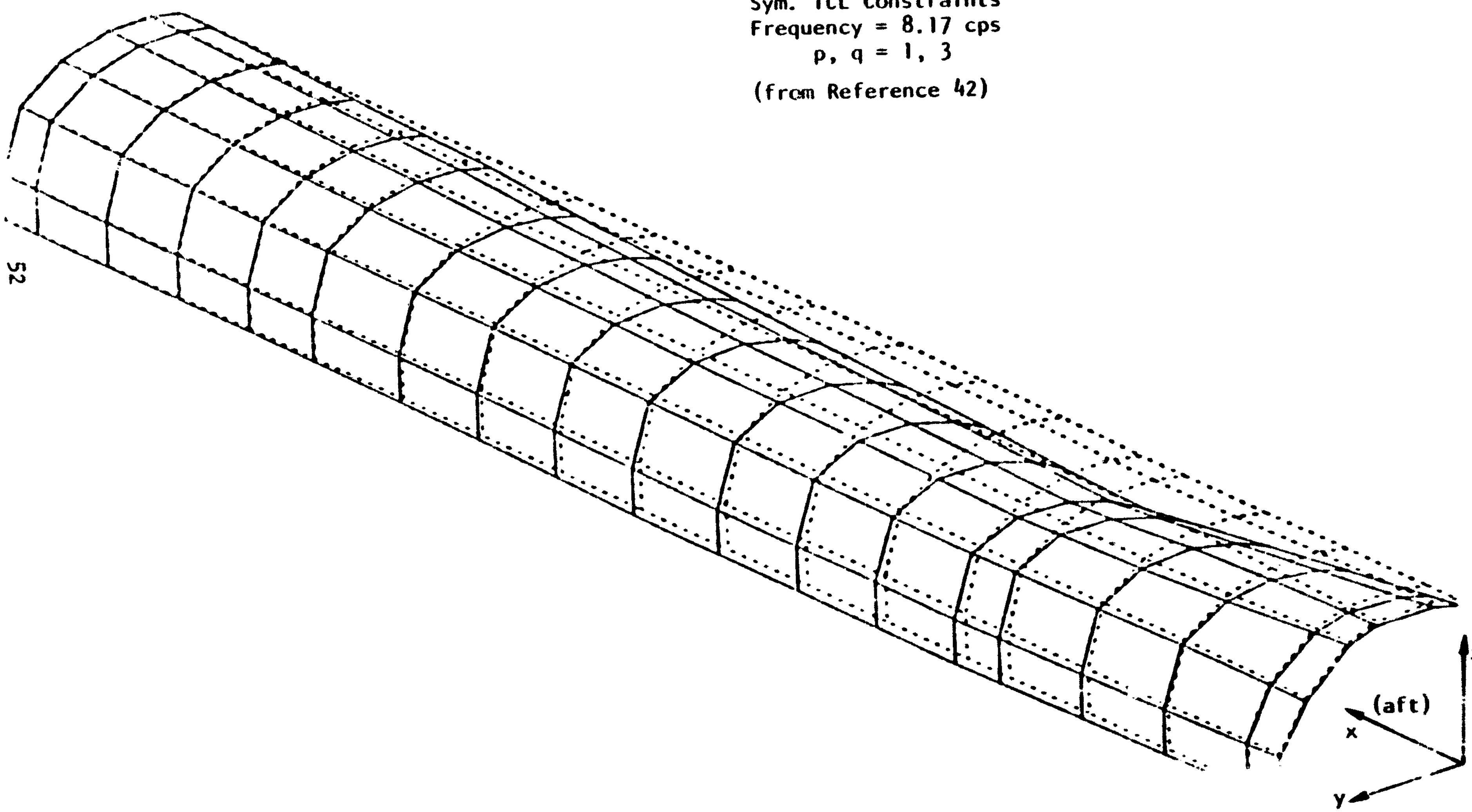
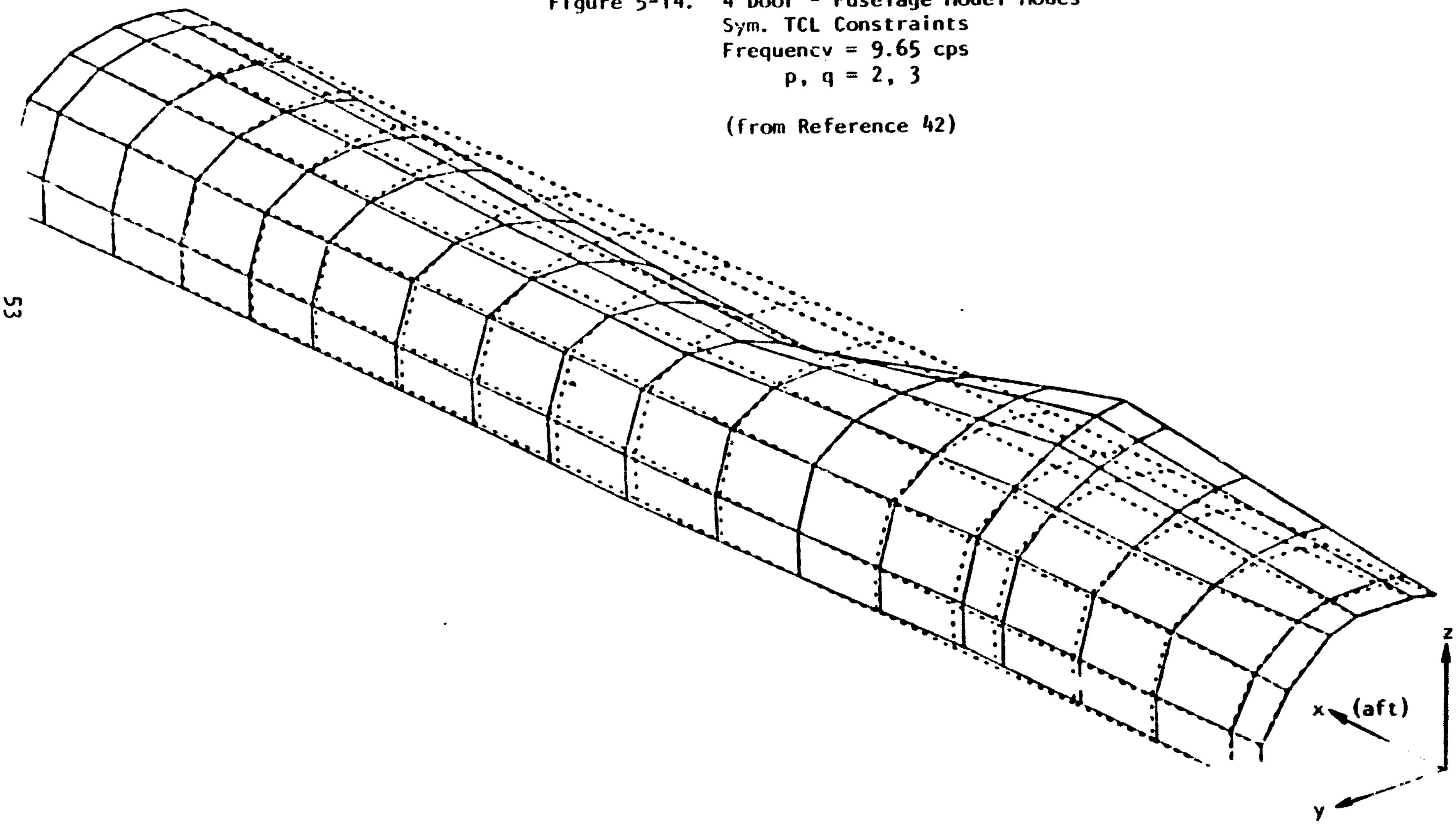


Figure 5-14. 4 Door - Fuselage Model Modes --
Sym. TCL Constraints
Frequency = 9.65 cps
p, q = 2, 3

(from Reference 42)



5.2.5 Structural Damping

The structural damping values, in terms of the loss factor $\Delta f/f$, for the payload bay doors is taken from Reference 34 to be $\eta = 2/f$, where f is in hertz.

5.2.6 Payload Bay Resonant Frequencies

The interior of the payload bay was represented as a cylindrical cavity 16 feet in diameter and 60 feet long. Payloads were modeled as a concentric inner cylinder. For this test case comparison, the noise reduction was computed only for the empty bay case. Figure 3-1 describes the bay geometry.

Table 5-11 lists acoustic modal frequencies up to 112 Hz (this is through the 100 Hz one-third octave band) together with their modal indices. The first radial mode (i.e., $s \neq 0$) occurs in the 80 Hz band, so that (except for damping and volume effects) the empty bay calculation should give the same result as would calculations with payloads. Since low frequencies are the primary interest in the present study, there is little loss of generality in considering only the empty bay.

The payload bay normal acoustic modes were also calculated with the cavity idealized by a rectangular parallelepiped with one surface deformed to represent the payload bay doors. This is a perturbation technique used in Reference 34 to model the payload bay and the geometry. The dimensions of the analytical model are shown in Figure 5-15. Table 5-12 compares the normal modes from this computation with modes calculated using the right circular cylinder idealization.

5.2.7 Acoustic Losses

There are two ways in which acoustic energy can be lost from the payload bay:

- Absorption by hardware inside the bay. This includes the effect of payloads, of frame trusses, of structural textures, etc. At low frequencies, these may all act as porous materials.
- Transmission of sound out of the bay through the structure. This is the inverse process of transmission in.

TABLE 5-11

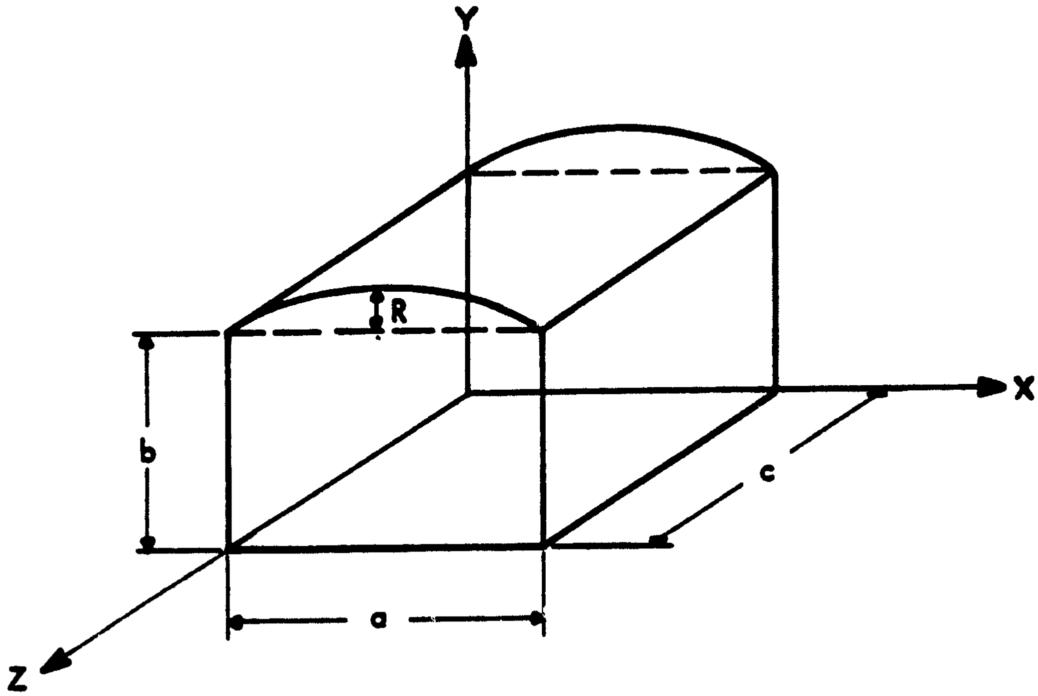
ACOUSTIC MODAL FREQUENCIES, EMPTY PAYLOAD BAY,
THROUGH 100 HZ BAND

m, n, s	f	m, n, s	f	m, n, s	f
0, 0, 0	0	2, 2, 0	70.3	1, 3, 0	93.7
1, 0, 0	9.3	3, 2, 0	73,3	7, 2, 0	94.0
2, 0, 0	18.6	8, 0, 0	74.4	2, 3, 0	95.1
3, 0, 0	27.9	7, 1, 0	76.9	5, 0, 1	97.0
4, 0, 0	37.2	4, 2, 0	77.3	3, 3, 0	97.4
0, 1, 0	40.9	5, 2, 0	82.2	4, 3, 0	100.4
1, 1, 0	41.9	9, 0, 0	83.7	8, 2, 0	100.7
2, 1, 0	44.9	8, 1, 0	85.1	10, 1, 0	101.6
5, 0, 0	46.5	0, 0, 1	85.1	6, 0, 1	101.7
3, 1, 0	49.5	1, 0, 1	85.6	11, 0, 0	102.3
4, 1, 0	55.3	2, 0, 1	87.1	5, 3, 0	104.2
6, 0, 0	55.8	6, 2, 0	87.8	7, 0, 1	107.1
5, 1, 0	61.9	3, 0, 1	89.5	9, 2, 0	107.7
7, 0, 0	65.1	4, 0, 1	92.8	6, 3, 0	108.7
0, 2, 0	67.8	10, 0, 0	93.0	11, 1, 0	110.2
1, 2, 0	68.4	9, 1, 0	93.1	12, 0, 0	111.6
6, 1, 0	69.2	0, 3, 0	93.3		

m = number of longitudinal half waves.

n = number of circumferential full waves.

s = number of radial full waves.



a = 17.50 ft; b = 12.58 ft; c = 60.42 ft; R = 4.33 ft

Figure 5-15. Deformed Parallelepiped (from Reference 34)

TABLE 5-12.

COMPARISON BETWEEN SOME ACOUSTIC MODES FROM THE PRESENT MODEL AND A PERTURBATED RECTANGULAR PARALLELEPIPED MODEL

PRESENT MODEL		PERTURBATED RECTANGULAR PARALLELEPIPED MODEL
m, n, s	f	f
0, 1, 0	40.8	27.07
1, 1, 0	41.9	28.60
2, 1, 0	44.9	32.77
3, 1, 0	49.5	38.73
4, 1, 0	55.3	45.80
5, 1, 0	61.9	53.53
0, 2, 0	67.8	61.50
1, 2, 0	68.4	62.19
6, 1, 0	69.2	61.67
2, 2, 0	70.3	64.22
3, 2, 0	73.3	67.46
7, 1, 0	76.9	70.09

The loss factor may be represented by the empty payload bay reverberation test [34] mentioned in Section 5.2.1 as

$$\eta = \frac{2.2}{fT_{60}} , \tag{1}$$

where f is in hertz and T_{60} is reverberation time from Figure 5-8.

The second factor, retransmission of sound, is explicitly neglected in the formulation of the coupling equations. It is assumed that the shell is driven by the exterior sound field alone. This is correct only if the interior sound pressure is small compared to exterior, that is, NR is large. If NR is small, the effect of interior pressure must be considered. This is equivalent to calculating the inverse problem.

Calculation of transmission from inside to out is just as complex as the outside to inside analysis treated thus far. An approximate allowance can be made, however, by noting that the process is essentially linear. The interior and exterior pressure are related by

$$\left(p_i\right)_v = A\, p_o \tag{2}$$

where $()_v$ denotes <u>in vacuo</u> shell response; that is, the effect of interior pressure is not considered. Counting interior pressure,

$$p_i = A\left[p_o - \left(p_i\right)_v\right] . \tag{3}$$

Equation 3 assumes the process is reversable. If only a single mode is considered, this is true. Since the present approximation has structural modes uncorrelated with each other, and acoustic modes are uncorrelated in the spatial average, this is a reasonable assumption. At low frequencies, there are few modes present, so that Equation 1 is reasonable from this viewpoint as well. At high frequencies, where there are many overlapping modes, an equation similar to 3 but in terms of intensity p^2 rather than pressure would be more appropriate. This is the architectural acoustics regime, however, and is not of direct interest.

The computer programs includes this second factor as an adjustment to the noise reduction calculation. The NR was calculated initially in terms of $(p_i)_v$. Equations 2 and 3 were manipulated to relate this "true" interior pressure p_i as

$$p_i = \frac{(p_i)_v}{1 + (p_i)_v / p_o} \quad . \tag{4}$$

In terms of an adjustment to noise reduction, NR = -20 log p_i/p_o,

$$NR = (NR)_v + 20 \log_{10}\left[1 + 10^{-(NR)_v/20}\right] . \tag{5}$$

The equivalent expression for the architectural acoustics case would have 10 in place of 20 in both cases.

5.3 PREDICTION OF PAYLOAD BAY NOISE REDUCTION

The inputs for analytically determining the orbiter empty payload bay noise reduction (NR) were submitted to the Wyle computer models for computation. All three versions of the computer program were required to calculate the total NR from the 10 Hz to 250 Hz one-third octave bands. The NR due to acoustic resonances was modeled by considering the nonresonant structural response of the doors driving resonant acoustic responses in the payload bay. The acoustic version of the program is called ACOBAN. When the NR was governed by the structural resonances occurring in the frequency band of interest, the response was considered to be a resonant structural response driving a nonresonant acoustic field. This program is called STRBAN. The noise reductions obtained by these programs were then added to obtain the total NR due to resonant acoustic and structural transmission by the following equation:

$$NR = -10 \log_{10}\left[\frac{1}{10^{\frac{NR_A}{10}}} + \frac{1}{10^{\frac{NR_S}{10}}}\right] ,$$

where NR_A = resonant acoustic NR,

NR_S = resonant structural NR.

If no resonance of the doors or payload bay cavity existed for a given octave band, then the PURTON version of the program was used to calculate the NR from the response of nonresonant structure driving a nonresonant condition in the payload bay cavity. The NR was computed at discrete frequencies in the desired one-third octave band and was then integrated by summing the individual NRs to obtain a total for the band.

The predicted one-third octave-band noise reduction levels are shown in Figure 5-16 for the empty payload bay case. At each one-third octave band, the values of space-averaged NR corresponding to the type of noise transmission are plotted. For example, the 10 Hz band from Figure 5-16 shows about the same noise transmission for both resonant structural and acoustic response. These two values of NR calculated by ACOBAN and STRBAN are combined to give the total one-third band level. At 10 Hz the puretone response integrated over the bandwidth by the PURTON program gives approximately the same result also.

A nonresonant condition is noted in the 12.5 Hz band since there are no structural door or payload bay resonances. This can be seen by Tables 5-8 and 5-11, respectively. Therefore, the PURTON version was used to compute the NR for single frequencies within the band and then integrated to obtain a one-third octave-band NR level.

In some frequency bands, it can be seen from Figure 5-16 that the noise transmission is dominated by either acoustic or structural resonances. For example, with the 20 Hz band, the NR is low because the noise transmission for the acoustic resonant case is very much greater than the structural resonant case due to strong acoustic responses created by the structural vibrations of the payload bay doors. This condition can be seen by looking at Tables 5-8 and 5-11. The 20 Hz band containing the 18.6 Hz acoustic longitudinal mode, where $m = 2$, can be excited by several matching structural modes with an equal wave number. These structural modes also have resonant frequencies close to the acoustic resonance. The 22.4 Hz door structural mode, on the other hand, with a longitudinal wave number $p = 3$, has only one close acoustic mode to couple with. That mode is at 27.9 Hz, which is in the 25 Hz band.

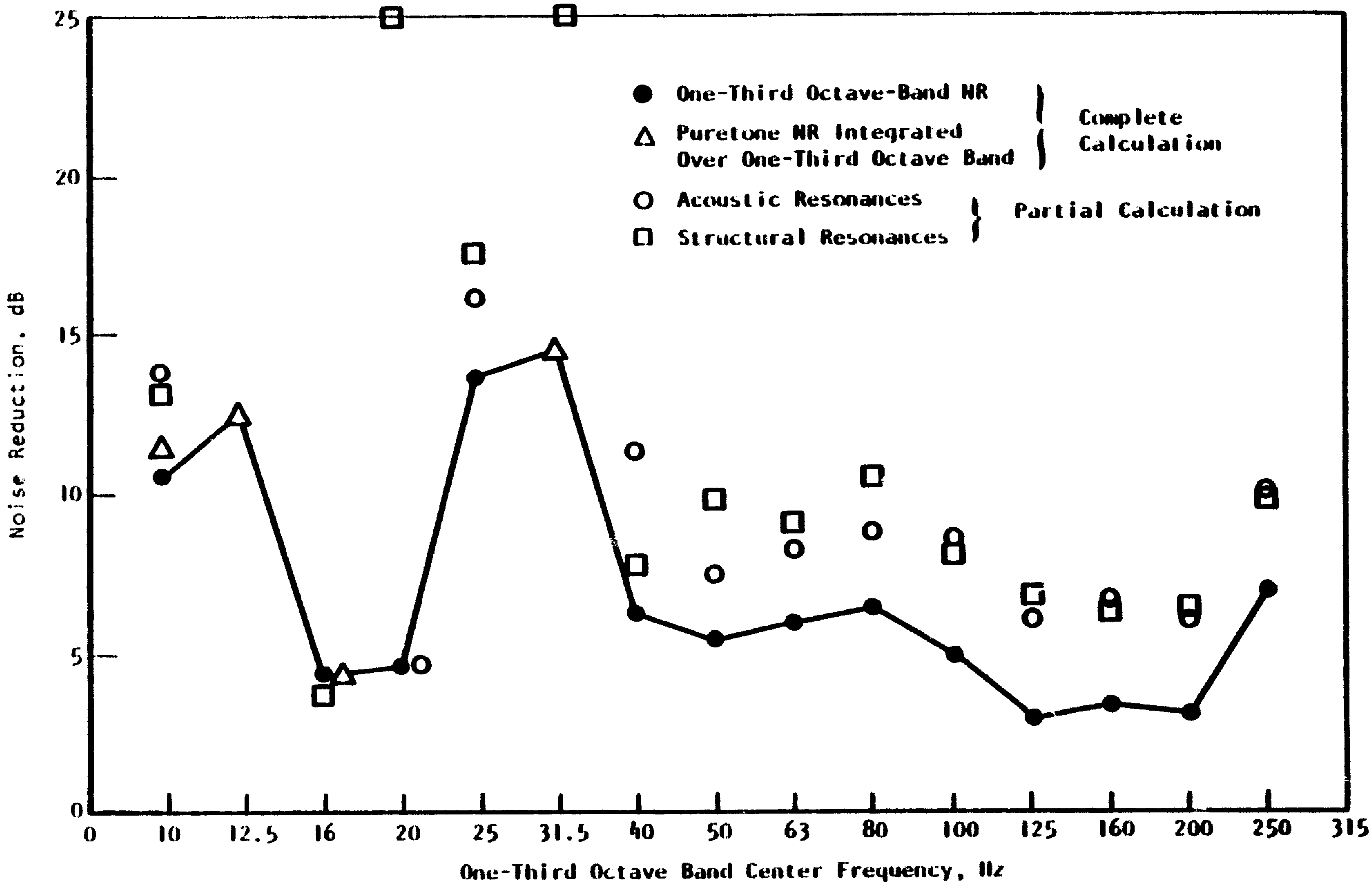


Figure 5-16. Predicted Noise Reduction for Empty Payload Bay

In the 16 Hz band in Figure 5-16, here is a case where the structural resonant response alone is responsible for the noise transmission because no payload bay acoustic modes exist. The 16 Hz door mode with a longitudinal wave number of one will couple well with the random external noise field because correlation lengths are typically comparable to acoustic wavelengths. Since the structural wavelength of the p = 1 mode is the length of the bay cavity (60 feet), and the 16 Hz acoustic excitation wavelength is about 70 feet, the payload bay door structural response is expected to be strong due to these comparable wavelengths. At the higher one-third octave bands in Figure 5-16, the noise transmission is about equally divided between the acoustic and structural resonant condition.

5.3.1 Comparison Between Measured and Predicted Noise Reduction for Empty Payload Bay

Figure 5-17 illustrates the NR curve from the measured data (Figure 5-6) plotted along with the NR predicted from the analytical model (Figure 5-16). The predicted NR curve seems to follow the measured NR trend, that of the NR decreasing with increased frequency in the 10 to 250 Hz range. Generally, the predicted NRs are fairly close to the measured levels, except at several one-third octave bands. In Figure 5-18, a plot to readily indicate the differences between the predicted and measured noise reduction levels is given. The predicted NR spectra is subtracted from the measured spectra to show these relative differences, and the 0 dB level is the measured NR used for this reference in Figure 5-17.

Approximately 87% of the predicted NR values are within 5 dB of the measured NRs, and approximately 60% are 3 dB or less from the measured levels. Bands of 10 and 12.5 Hz seem to have the best agreement with the test NRs. One important reason for this is that the door structural model modes closely match the more accurate finite element values as listed in Table 5-9. Also, the lower order longitudinal acoustic modes are easier to model at these frequencies, both in their mode shape and resonant frequency.

The worst discrepancy occurs in the 16 and 20 Hz one-third octave bands where the predicted NRs are about 6.5 and 7.5 dB less than the measured values, respectively. At 17.7 Hz, the payload bay door mode with p,q = 1,1 (from Table 5-8) would be highly correlated to the random noise field, both longitudinally and circumferentially, for the reasons mentioned in Section 5.3. Therefore, this

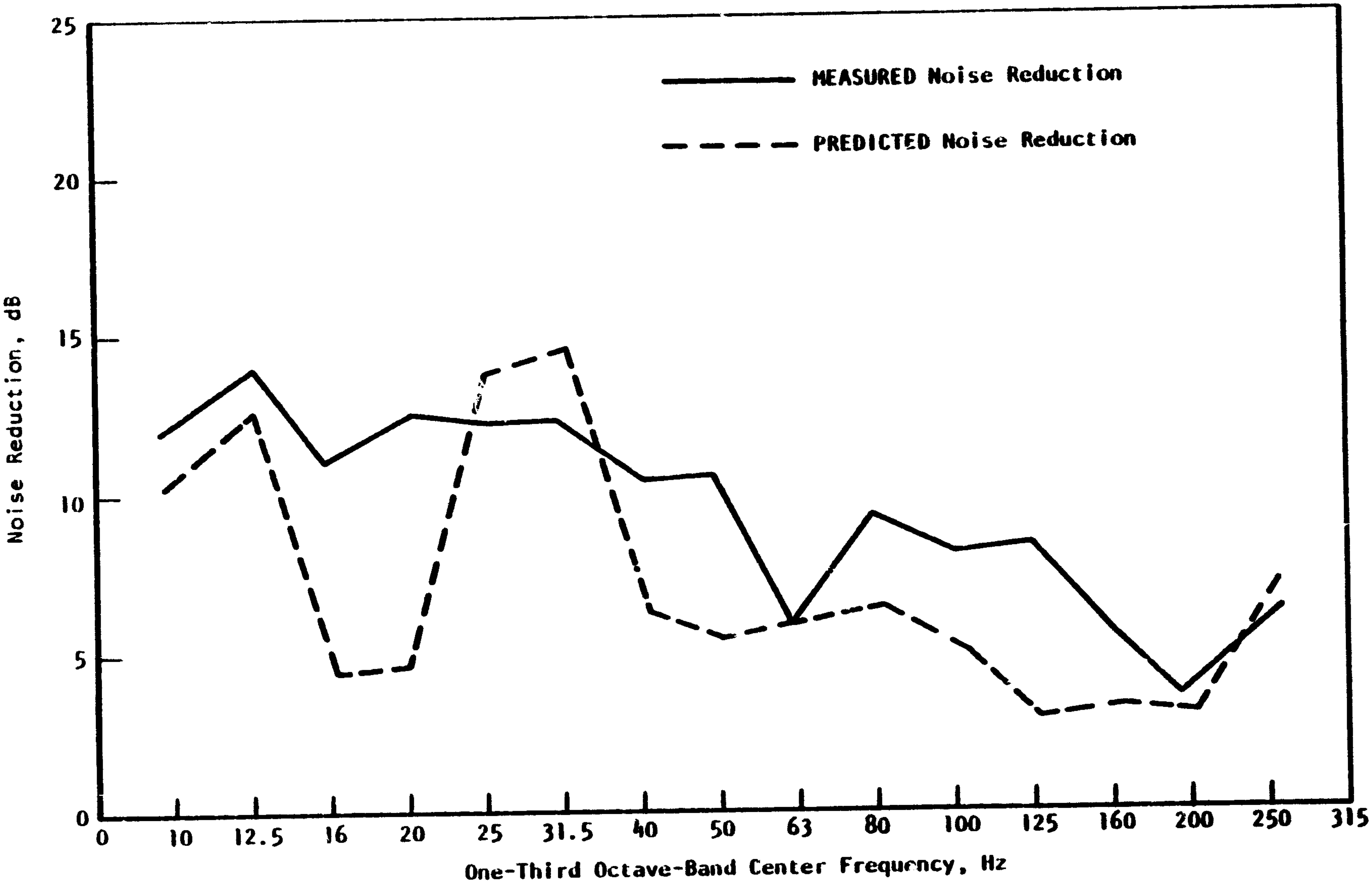


Figure 5-17. Comparison of Measured and Predicted Noise Reduction for Empty Payload Bay

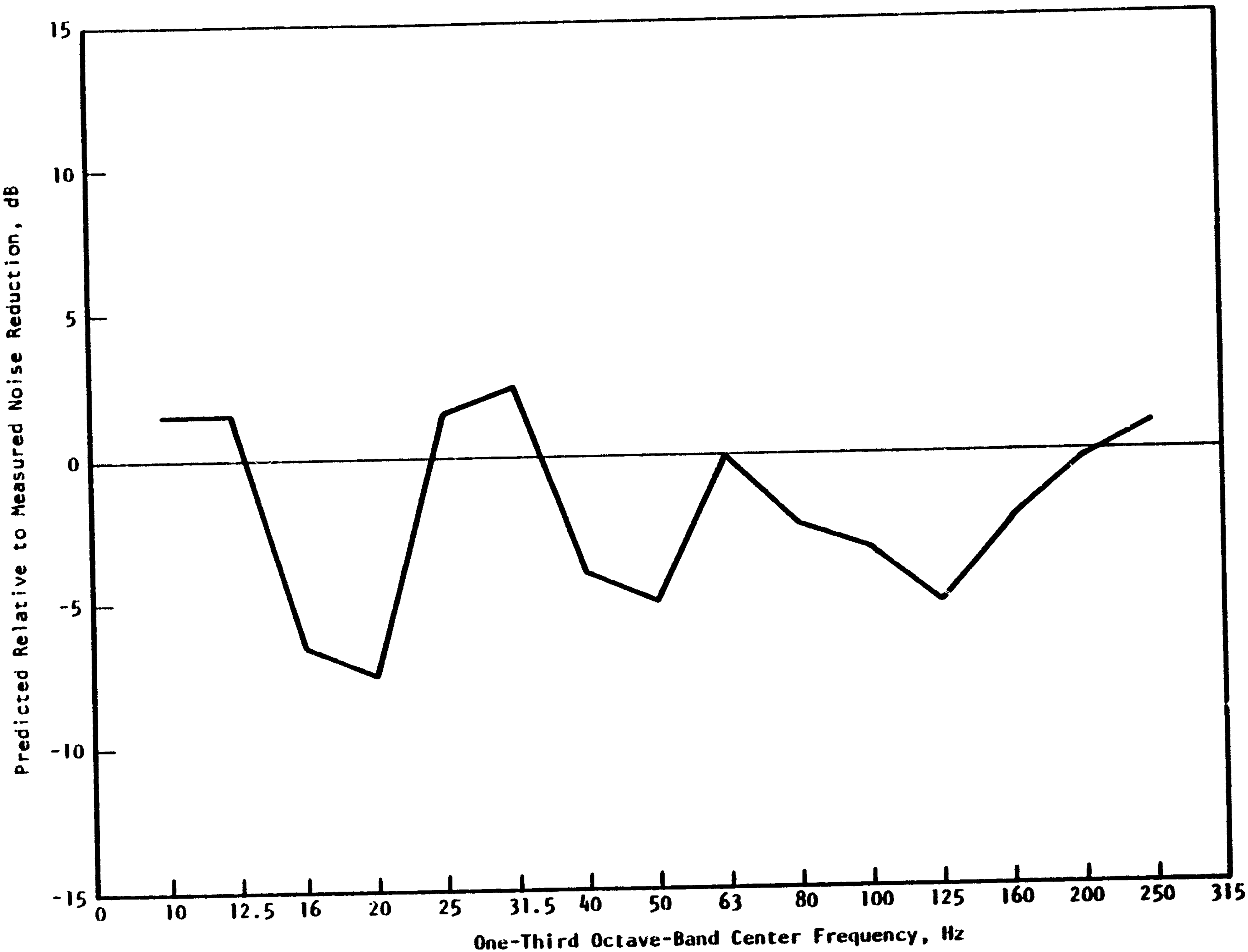


Figure 5-18. Predicted Empty Payload Bay Noise Reduction Relative to Measured Noise Reduction

predicted structural mode would couple easily with the external noise field and would transmit the noise more efficiently.

In the 20 Hz band, an acoustic resonance (18.6 Hz, m = 2) in the payload bay can be excited by several structural modes having the same longitudinal wave number and having close resonant frequencies. These low order structural modes are also well coupled to the external noise field in this frequency range. Therefore, the dominant factor, in these frequency bands of more predicted noise transmission than the test results, seems to deal with the calculated door modes. The present model of the door modes does disagree somewhat with the higher finite element modes calculated in Table 5-9.

The acoustic modes are more easily modeled at lower frequencies, so more confidence can be placed in their accuracy. The modes for the present model of a cylinder were compared to the acoustic modes calculated for a perturbated rectangular parallelepiped model of the orbiter payload bay, as shown in Figure 5-15 and Table 5-12. The longitudinal modes were found to be the same for each model, and from Table 5-12 it can be seen that the resonant frequency of the n wave number modes for the present model are greater than the parallelepiped model modes in the lower frequency bands, but they become more closely matched as the frequency increases. The mode shapes will be slightly different for the n and ℓ modes because of the different modal geometries representing the bay cross section. The m modes will have the same mode shape for each model.

Another factor that could significantly affect the prediction accuracy is the structural and acoustic damping factors. Possibly the damping values specified in the analytical model may not be entirely representative, which could easily lead to errors in the NR estimates.

5.3.2 Damping Effects on the Payload Bay Noise Reduction

The effect on the noise reduction of varying the structural damping factor can be seen in Figure 5-19. A smaller damping factor tends to reduce the noise reduction in the payload bay, and this same trend is also true for the acoustic damping factor effect on the noise reduction. Therefore, it can be observed that the damping value specified for the structural and acoustic normal modes is very important in an accurate modeling of the noise transmission problem.

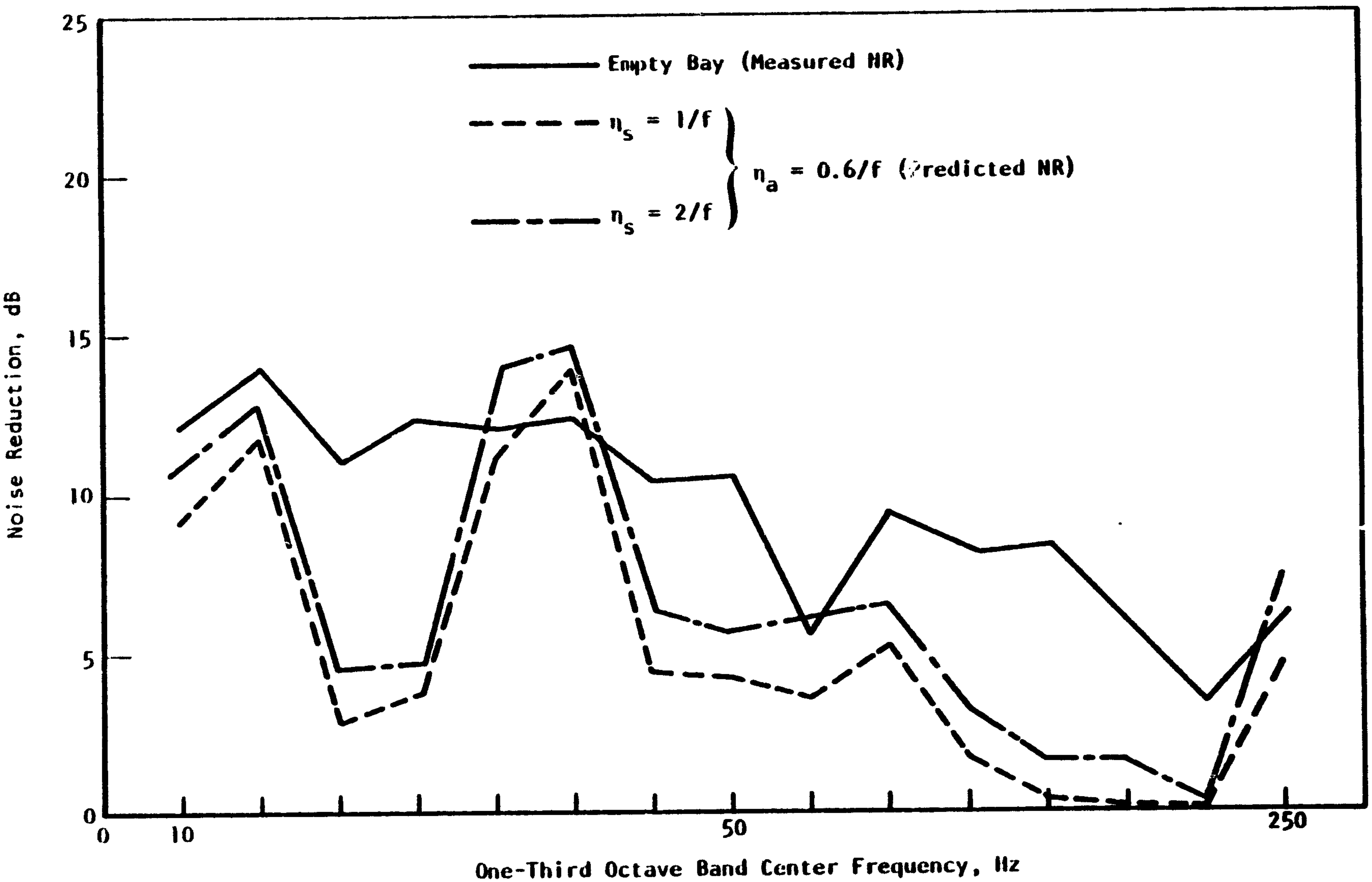


Figure 5-19. Effects of Structural Damping on the Payload Bay Noise Reduction

5.3.3 Spatial Variability of the Predicted Noise Reduction

To illustrate the spatial characteristics of the acoustic response in the payload bay, the calculated NR at one point in the bay is shown plotted in Figure 5-20. The point was taken on the centerline of the bay, 15 feet from the front of the enclosure. At this particular point, the NR varies greatly from the space-averaged value in most one-third octave bands. The NR at the point is generally larger than the average NR for the cavity. This trend can also be seen with the measured data in Figure 5-7, where the NR can vary greatly on the high side in the lower frequency bands. A node point is also noted at this location in the 20 Hz band due to a very high calculated NR. Also, the NR for some other locations can be expected to be much lower than the average value.

5.4 ACOUSTIC ENVIRONMENT FOR A PAYLOAD CONFIGURATION FROM MODEL TESTS

Acoustic tests were performed on the Rockwell International (RI) one-quarter scale flexible model of the Space Shuttle orbiter with model payload configurations [34]. A one-quarter scale model was constructed by RI for low frequency dynamic experiments related to problems such as flutter and "pogo," and was designed to represent the full scale dynamic characteristics of the orbiter. The dynamic characteristics associated with noise transmission may not be scaled with a high degree of accuracy with this model though, particularly for the payload bay doors. However, it is believed that the model is accurate enough to determine the changes in payload bay acoustic levels when payloads are introduced.

These tests involved the measurement of space-averaged sound pressure levels in the empty bay and when one of three payloads was present. The exterior noise field was generated by five loudspeakers located at the rear of the model, and the field had the properties of acoustic plane waves propagating in the forward direction. For the empty bay test, noise levels were measured at a total of 42 locations, and the data were reduced to a space-averaged one-third octave-band spectrum. When a payload was introduced in the bay, space-averaged spectra were obtained for each of the several subvolumes surrounding the payload. The differences between these spectra and that for the empty payload bay determined the effect of the payload on the bay noise levels.

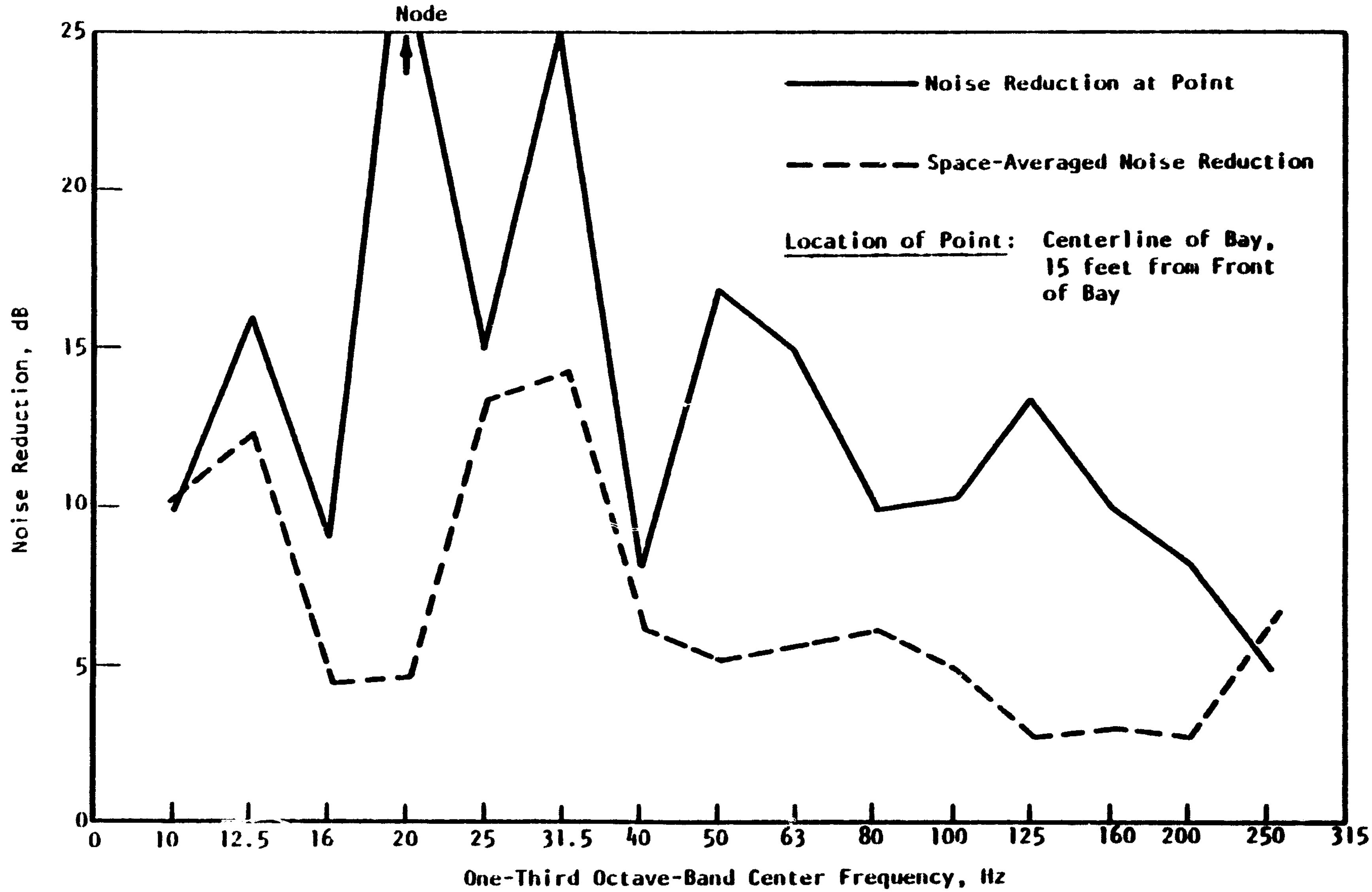


Figure 5-20. Predicted Noise Reduction at One Point in Empty Payload Bay

5.4.1 Payload Configuration

The payload configuration, designated as "Delta-D," does not simulate any real payload, but was designed as a diagnostic payload because of its creation of interesting acoustic subvolumes within the payload bay. This payload configuration consists of a series of five cylinders of different diameters plus an aft pallet. Figure 5-21 illustrates a top and side view of the payload configuration. The large diameter cylinders are of considerable interest because they have a major impact on the payload bay acoustics [34, Vol. I] and constitute a challenging situation for any analytical model.

5.4.2 Measured Data for the Delta-D Payload Effects

The space-average one-third octave-band levels for each of the seven subvolumes were subtracted from the average empty bay levels to obtain the relative effects of the payload introduction into the bay. These relative levels to the average empty bay levels are shown in Figure 5-22. From this data, it can be seen that large variations in levels occur in the low frequency range below the 31.5 Hz one-third octave band. The curves also show that empty bay levels are generally not affected significantly by the payload from the 31.5 Hz band to the 250 Hz band. The one exception is with the 95% diameter payload, where the levels above the payload are higher than the average empty bay levels.

5.5 INPUTS FOR THE ANALYTICAL MODEL OF THE PAYLOAD EFFECTS

The noise reduction results obtained with the computer program for the effects of a payload were based on the analytical model of the full scale orbiter OV-101 tested at Edwards AFB [34], as described in Section 5.1. The full scale data from the OV-101 test were used in the predictions because large differences were found to have occurred between the OV-101 and the one-quarter model noise reduction levels for an empty payload bay below the 63 Hz one-third octave-band region [34, Vol. V]. These differences demonstrated that the one-quarter scale orbiter model does not exactly represent the OV-101 acoustically. Therefore, no attempt was made to scale up the one-quarter model to predict the effects of the introduction of a payload on the empty bay noise levels. The predictions are compared to the model test data on a qualitative basis to obtain trends and relative magnitudes. The analytical inputs of one payload configuration are used in the computer programs described in Section 4.0 to obtain a space-averaged noise reduction spectrum for the entire space enclosing the payload.

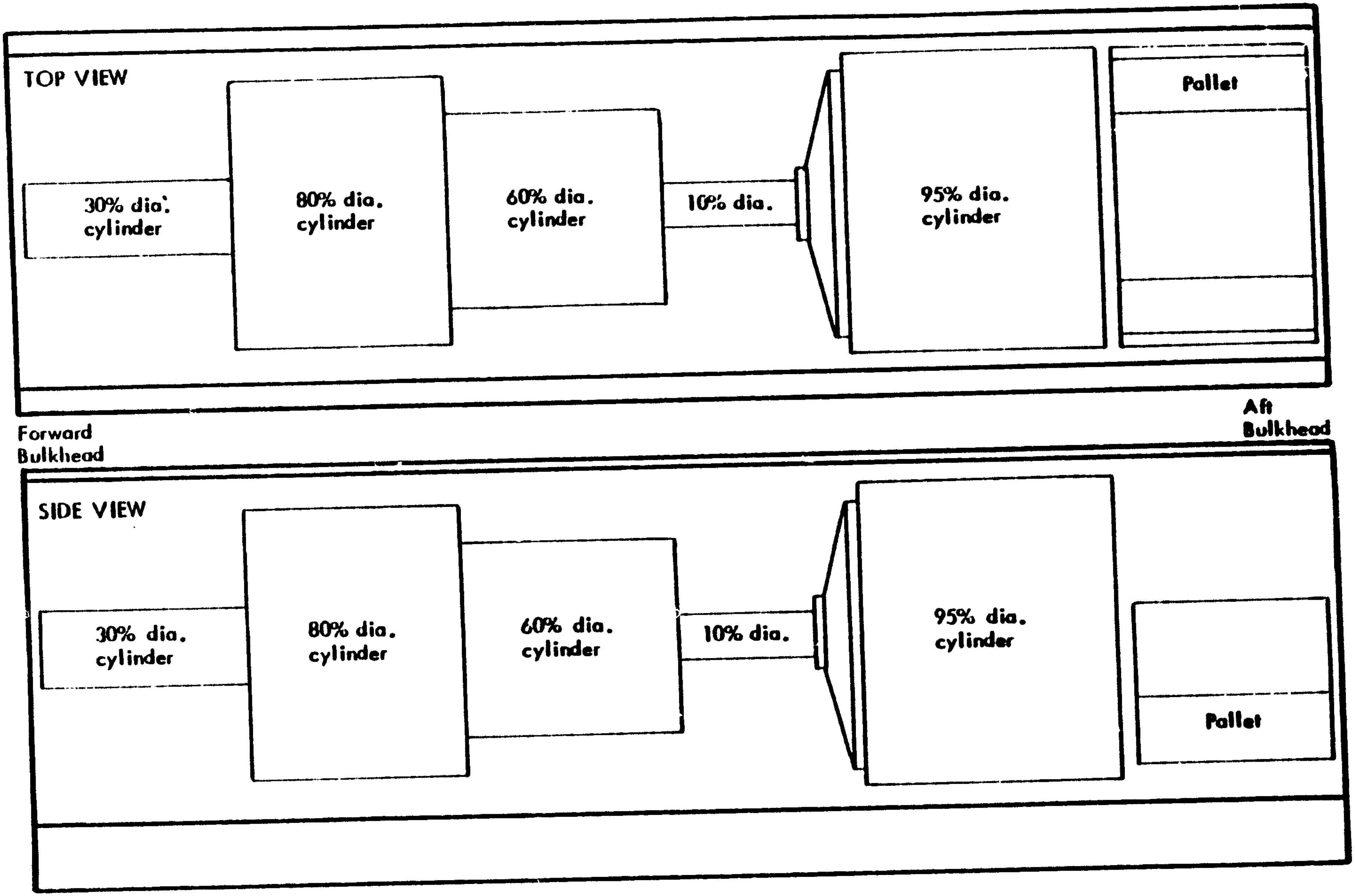


Figure 5-21. Diagram of the Delta-D Payload Model (from Reference 34)

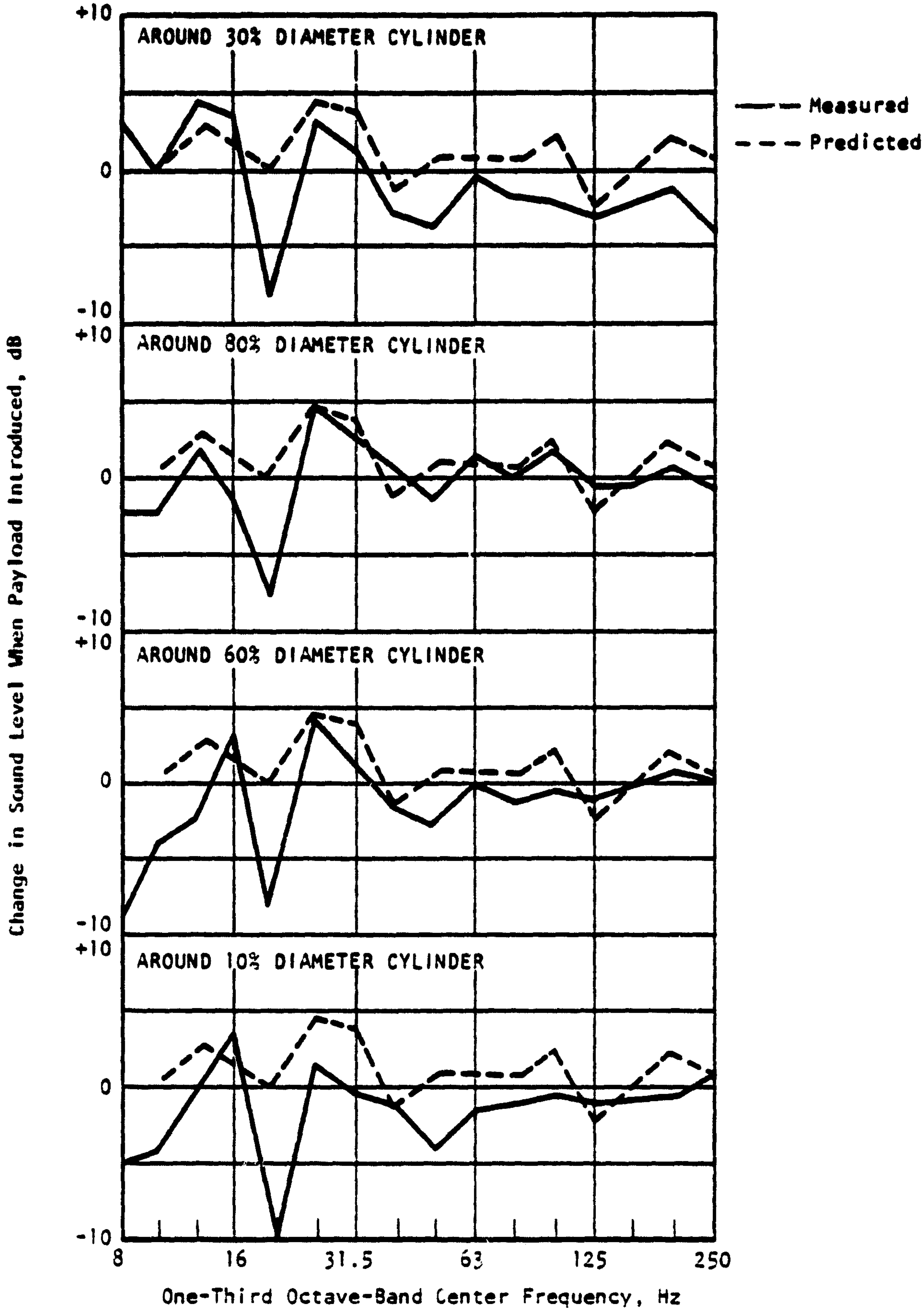


Figure 5-22. Effect of Delta-D Payload on Subvolume Space-Averaged Sound Pressure Levels

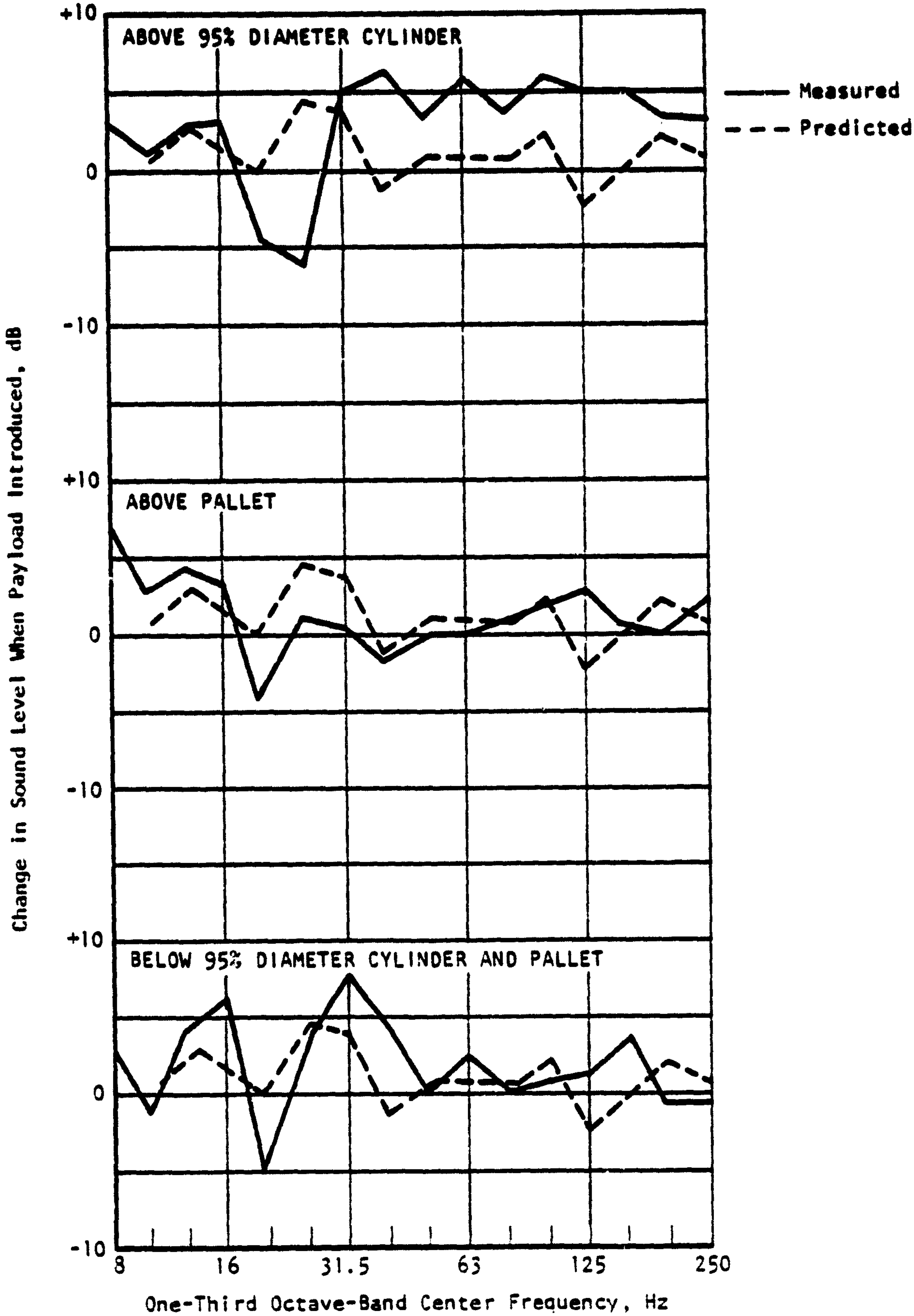


Figure 5-22. (Concluded)

5.5.1 Payload Delta-D Configuration

This payload configuration, shown in Figure 5-21, was modeled by a single cylinder placed concentrically in the cylindrical model of the empty bay (Figure 3-1), with a volume equal to the total volume of the payload. This cylindrical payload simulation had a radius of 4.82 feet, and a payload bay length of 60 feet.

5.5.2 Structure of the Orbiter

The orbiter structural properties are the same as described in Section 5.2.2 for the OV-101 used in the acoustic tests [38].

5.5.3 Payload Bay Door Resonant Frequencies and Structural Damping Factor

The introduction of a payload configuration does not change the door modes or damping factor, so the value for these inputs are the same as given in Sections 5.2.4 and 5.2.5.

5.5.4 Payload Bay Resonant Frequencies with Payload Present

For the introduction of the payload into the orbiter bay, Table 5-13 lists the bay modal frequencies and indices through the 100 Hz one-third octave band. On comparing the empty bay modes in Table 5-11 to the payload present modes, it is seen that the first three modes are the same. But the payload case brings the first circumferential mode ($n=1$) of the empty bay (40.9 Hz) down to 28.0 Hz with the introduction of the payload. The payload also increases the first radial mode ($s=1$) from 85.1 Hz of the empty bay to 177.8 Hz. Generally, the payload present case will not affect the empty bay longitudinal modes (m), but it will lower the resonant frequencies of the circumferential modes (n), and raise the resonant frequencies of the radial modes (s).

5.5.5 Acoustic Damping of OV-101 Payload Bay with Payload Present

The payload bay acoustic damping factors due to the payload being present was estimated to be greater than the empty bay values. The acoustic loss factor was based on 350 Sabins in Reference 43, and it is given by

$$\eta = \Delta f/f = 1.27/f$$

where f is in Hz.

TABLE 5-13.

ACOUSTIC MODAL FREQUENCIES FOR PAYLOAD CONFIGURATION "DELTA-D", THROUGH THE 100 HZ BAND

m, n, s	f	m, n, s	f
0, 0, 0	0	8, 1, 0	79.5
1, 0, 0	9.3	0, 3, 0	83.2
2, 0, 0	18.6	9, 0, 0	83.7
3, 0, 0	27.9	1, 3, 0	83.7
0, 1, 0	28.0	2, 3, 0	85.3
1, 1, 0	29.5	7, 2, 0	85.7
2, 1, 0	33.6	3, 3, 0	87.8
4, 0, 0	37.2	9, 1, 0	88.3
3, 1, 0	39.5	4, 3, 0	91.2
5, 0, 0	46.5	8, 2, 0	93.0
4, 1, 0	46.5	10, 0, 0	93.0
5, 1, 0	54.3	5, 3, 0	95.3
0, 2, 0	55.8	10, 1, 0	97.1
6, 0, 0	55.8	6, 3, 0	100.2
1, 2, 0	56.5	9, 2, 0	100.6
2, 2, 0	58.8	11, 0, 0	102.3
3, 2, 0	62.4	7, 3, 0	105.7
6, 1, 0	62.4	11, 1, 0	106.1
7, 0, 0	65.1	10, 2, 0	108.4
4, 2, 0	67.0	0, 4, 0	110.2
7, 1, 0	70.9	1, 4, 0	110.6
5, 2, 0	72.6	12, 0, 0	111.6
8, 0, 0	74.4	8, 3, 0	111.6
6, 2, 0	78.9	2, 4, 0	111.8

5.6 PREDICTION OF THE NOISE REDUCTION OF PAYLOAD BAY WITH A PAYLOAD PRESENT

Figure 5-23 depicts the noise reduction (NR) calculations for the Delta-D payload configuration. As with the empty payload bay NR levels, several one-third octave bands have their noise transmission governed by either structural or acoustic resonances. Reasons for this situation are discussed in Section 5.3 for the empty bay NR results. Also, as the modal densities increase with increasing one-third octave band frequencies, the structural and acoustic resonant responses share about the same amount of the noise reduction.

5.6.1 Comparison between Empty Payload Bay and a Payload Configuration

In Figure 5-24, the NR curve from Figure 5-16 for the predicted empty bay NR levels is shown with the Delta-D payload configuration NR curve. The two curves seem to follow the same NR trend with frequency. The payload introduction causes the empty bay NR levels to decrease, which means, of course, that more noise transmission has occurred and the payload acoustic environment has increased noise levels over the empty bay levels.

Figure 5-25 shows the differences in NR between the two curves from Figure 5-24 more graphically. The difference between the empty bay NR and the payload present NR is equivalent to the change in the empty bay noise level when the payload is placed in the empty bay. The 0 dB level is the empty bay space-averaged noise level in Figure 5-25. As noted in this figure, the empty bay noise in the lower frequency bands (<40 Hz) seems to be affected more by the addition of the payload. The largest change is in the 25 and 31.5 Hz one-third octave bands. A possible reason for this condition is that the payload addition causes the empty bay circumferential acoustic modes in the 40 Hz band to be reduced in frequency where they now fall into the 25 and 31.5 Hz bands. This can be seen by comparing Tables 5-11 and 5-13. For the empty bay case, no acoustic modes exist in the 31.5 Hz band, but with the addition of a payload configuration, several acoustic modes are created in this one-third octave band. These acoustic modes are then excited by structural modes, resulting in transmission of more external noise into the bay cavity than with the empty bay situation.

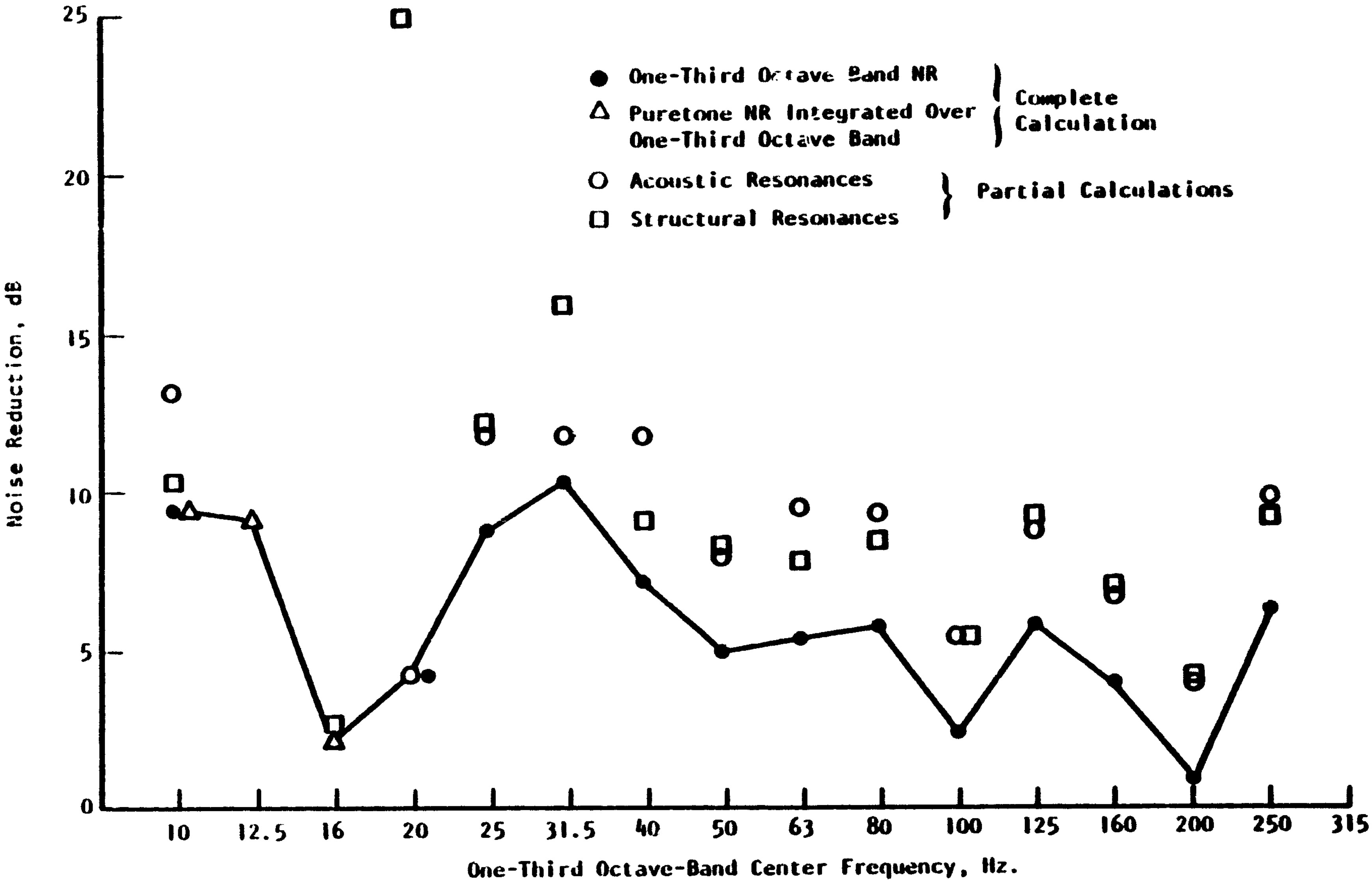


Figure 5-23. Predicted Noise Reduction for Payload Configuration Delta-D

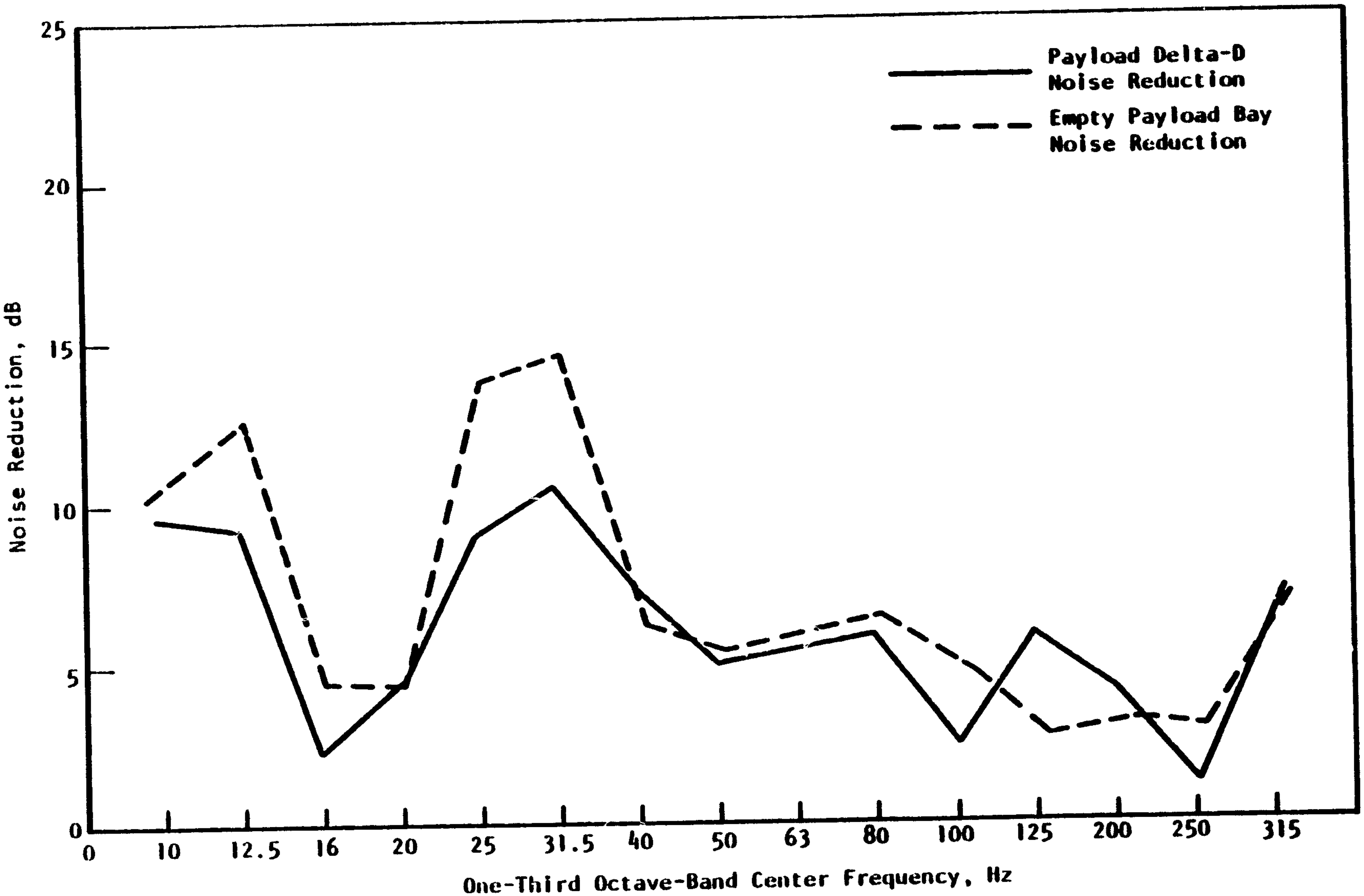


Figure 5-24. Predicted Noise Reduction for Empty Payload Bay and Payload Delta-D

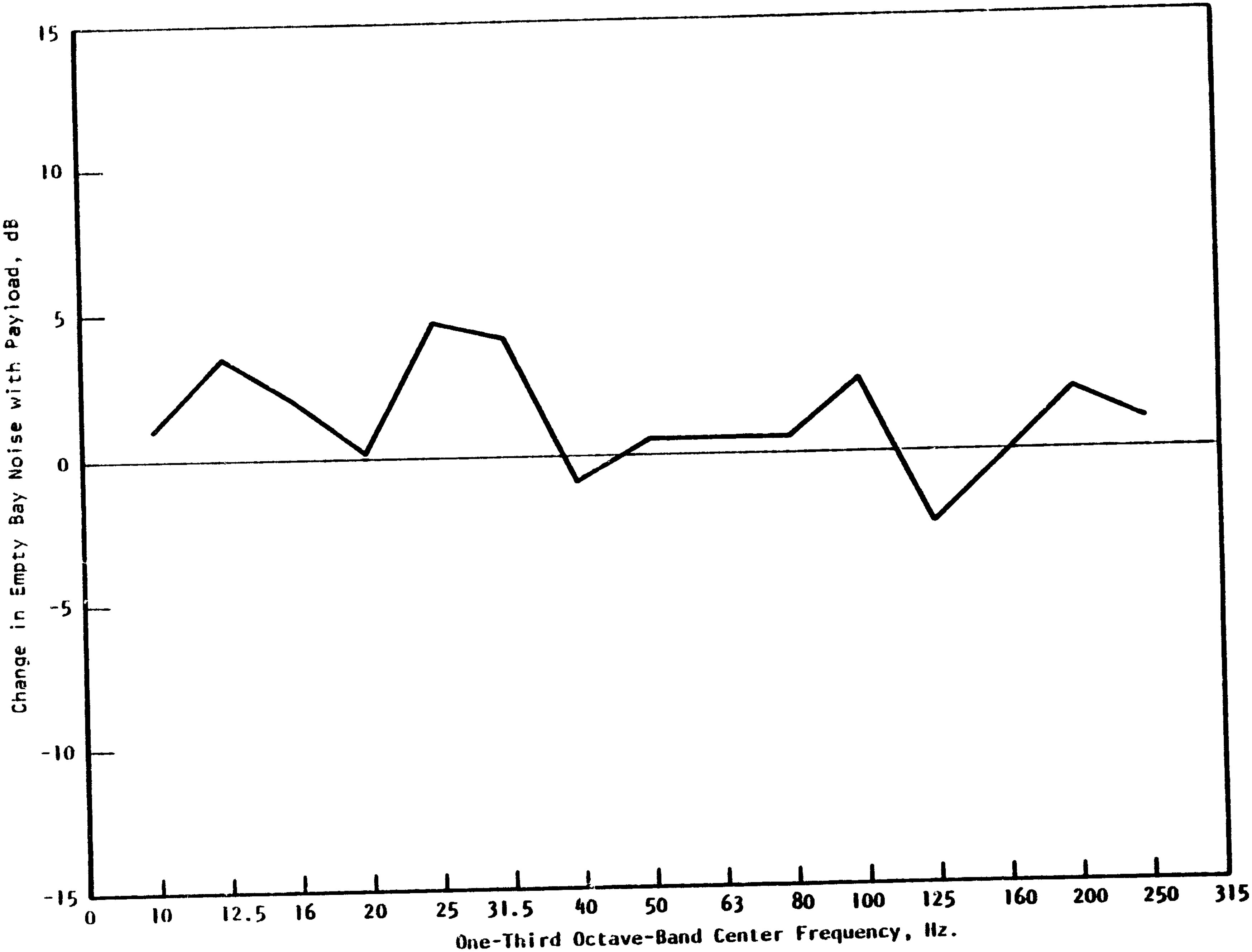


Figure 5-25. Predicted Change in Empty Bay Noise Levels with Addition of Payload Configuration Delta-D

5.6.2 Comparison of Measured and Predicted Payload Effects on Empty Bay Noise Levels

From the one-quarter scale orbiter model tests, changes in the empty payload noise levels due to the introduction of the payload configuration Delta-D are shown in Figure 5.22. Also on the same figure are the predicted values due to the payload effects. Only qualitative results should be gained from these comparisons, as explained earlier in Section 5.4.

The predicted changes seem to have about the same trends as do the measured data for most of the subvolumes surrounding each of the payload components. Even the magnitude of the changes in noise level is fairly similar for both the predicted and test cases with the 30-, 60- and 80-percent diameter cylinders. The most significant trend difference lies in the 20 Hz band with each subvolume. Although the model and the full scale OV-101 are not acoustically the same, the trend for the analytical model should probably be a little closer to the test model results at 20 Hz. In most subvolumes, the 20 Hz band for the model results is greatly affected by the payload introduction. It is likely that the normal acoustic modes of the empty bay were changed by the payload addition in such a way as to increase the noise reduction in the 20 Hz band. The measured changes above the large diameter cylinder of 95 percent show the most disagreement with the predicted results, as also noted in Section 5.4.1. Here, the measured changes are consistently higher above the 31.5 Hz band. The noise levels above the 95% cylinder, near the doors, are about 5 dB higher than the empty bay levels.

5.6.3 Spatial Variability of the Payload Noise Effects

As with the modal nature of the empty bay acoustic response, shown in Figure 5-26, the spatial variability is characteristic of the noise spectra for the subvolumes around the Delta-D payload components. The prediction method is also applicable for the payload present noise reduction computation, as demonstrated with the empty bay test case. The addition of the payload volume changes the acoustic normal modes of the empty bay. This in turn either couples or decouples their response with the structural modes, thereby changing the noise transmission characteristics relative to the empty bay levels.

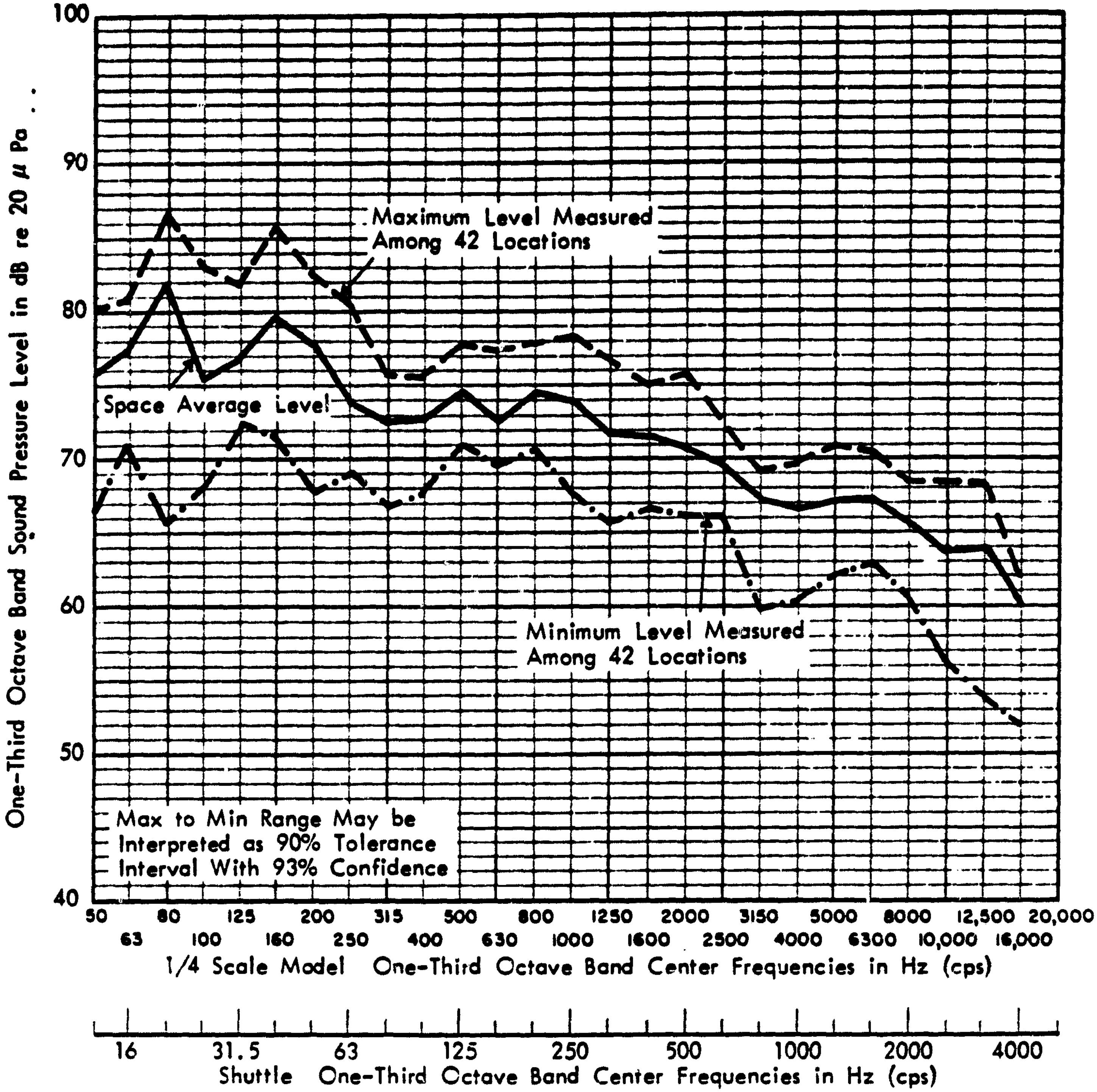


Figure 5-26. Spatial Variation of Empty Bay Interior Sound Pressure Level Measurements [34]

6.0 CONCLUSIONS

Results of the comparisons between the test cases and the predictions of the analytical models are summarized in this section to give an indication of the prediction method's applicability and accuracy for the estimation of a space vehicle's interior noise level.

The noise reduction (NR) predictions for the empty payload bay differ within ±5 dB from the measured NR levels for 87% of the one-third octave bands in the 10 Hz to 250 Hz range. About 60% of the predicted NRs are within ±3 dB of the measured levels. For most frequencies, the analytic calculations give over conservative NRs (lower NRs), as shown by Figures 5-17 and 5-18.

The greatest difference in the predicted and measured results is in the 16 and 20 Hz bands. Modeling of the payload bay door normal modes is believed to be in error for these frequency bands when compared to the finite element calculations. The questionable accuracy of the structural modes in the 100 and 125 Hz bands may also be responsible for more predicted noise transmission than measured.

Acoustic normal modes for the cylindrical model of the payload bay seem to agree fairly well with the modes calculated by a more representative payload bay shape of the rectangular parallelepiped with a curved upper surface to simulate the payload bay doors. The greatest disagreement in the model's modal characteristics occurs in the 25 Hz to 63 Hz bands. This may partially account for the discrepancy in the predictions at 40 Hz and 50 Hz one-third octave bands. The acoustic modes appear to be more closely modeled, with the exception possibly at 40 Hz and 50 Hz bands, than the door structural modes. This may be the primary reason for the discrepancies in the predictions in several of the one-third octave band mentioned above.

The modal nature of the low frequency response in the payload bay can be seen in the spatial variability characteristic of the measured noise levels. This spatial variability of the measured data for both the OV-101 acoustic tests and the model payload effects test can be seen in the experimental results. This spatial variability of the noise spectra can also be predicted by the programmed analytical model as shown in Figure 5-20. The ability to calculate the noise reduction at any given point in the payload acoustic environment may be important in certain cases where the localized noise level may greatly exceed the space-averaged value. In terms of noise reduction, this means that the noise reduction may be lower than the average noise reduction for the space surrounding the payload.

The modal characteristics of spatial variability in the payload bay noise spectra at low frequencies makes the modal analysis method well suited to determine the noise reduction. This noise reduction is primarily dependent on individual structural and interior acoustic modal responses.

The simple modeling of the Delta-D payload configuration by a concentric cylinder with an equivalent volume gives reasonable predictions around most of the payload components. Similar magnitudes and trends for the payload effects are seen from the measured model data and the full scale predicted data, although the predicted payload NR for the 20 Hz band in every case is too high. This discrepancy could be attributed either to the math model or to the one-quarter scale model not being completely similar acoustically to the full scale OV-101. The worst payload subvolume prediction is above the 95% diameter cylinder component of the payload configuration. Here, the trend in the predicted changes in noise level between the empty bay and with the payload introduction are lower.

The noise reduction prediction model is shown to give reasonable results for most frequencies and payload subvolumes for the two test cases given in the study. The main discrepancies could probably be eliminated by better modeling of the structural normal modes and, of lesser importance, by a more detailed representation of the payload acoustic cavity to obtain more accurate acoustic normal modes.

7.0 RECOMMENDATIONS

A modal analysis approach has been improved to predict the noise reduction in a space vehicle with payloads. Generally, reasonable results were obtained for most of the one-third octave bands of 10 to 250 Hz. Several additional improvements could be made in the area of modeling the structure and acoustic enclosure to obtain more accurate normal modes. Also the computer programs could be improved for more efficiency and flexibility. The following recommendations will be investigated for their feasibility and incorporation into the work on NASA contract number NAS8-33379 to further improve techniques for predicting the acoustic environment of space vehicle payloads.

The principle of component mode synthesis could be used with finite element techniques for determining the structural/acoustic system natural modes. The finite element method could be used to define the structural modal response. This method is also the most accurate analytical method available. These normal mode properties could then be incorporated into the present computer program, or possibly a finite element program could be added as a subroutine to the main program to directly compute the structural modes. The Donnell-Mushtari equations for determining the structural normal modes for the present model could also be modified to obtain another shell theory that may yield more representative normal modes of the structure walls.

The predicted acoustic resonances with the present model seem to be reasonable for the payload bay with and without a payload configuration. An improved model of the payload enclosure may be found in the perturbation technique applied to a rectangular parallelepiped where individual wall surfaces may be deformed to simulate the cavity shape. Finite element methods could also be employed to determine the mode shapes and frequencies of the payload enclosure, especially for irregular volumes. The subvolumes surrounding individual payload components may be used to determine the natural modes for their respective cavities. Then these modes could be coupled to adjacent subvolume modes until an equivalent normal mode determination for the entire cavity was obtained. This more rigorous treatment of the payload cavity might be necessary for complicated payload configurations and for large diameter payload components.

The major computational improvement for the computer program would be to combine the three versions of the present program into one program with the logic to apply the proper version to the noise reduction calculations. Also, plotting routines that would present the noise reduction as a function of frequency could be incorporated. Also, by applying the calculated noise reduction to the measured or predicted external noise spectrum, a plot of the internal noise spectrum for the payload enclosure could be generated.

The statistical energy method could be used to expand the frequency range for the noise reduction prediction program. This method would be more efficient to use in the higher frequency region than the modal analysis method because the higher modal density of the responses are more uniform over a one-third octave band and the calculations are more simplified.

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APPENDIX A

COMPUTER PROGRAM DESCRIPTION

A.1 PROGRAM STRUCTURE

The basic computational structure is that shown in flowchart form in Figures 4-1 through 4-3. Acoustic and structural modal quantities are either computed or read, then a summation is performed of the various modal combinations contributing to interior noise. Details of the summation vary among the three programs, a also shown in Figures 4-1 through 4-3.

Flow through each of the three programs is controlled by a main program. The main programs perform the following operations:

- All input (except for stored files of modal properties) is to the main progarm.
- All generally used parameters (nondimensional shell quantities, conversion factors, etc) are computed.
- Subroutines are called that calculate (or read previously computed values of) acoustic and structural modal quantities.
- The outermost loop(s) of the summation over m, n, s, p, q is controlled by the main program. Referring to Equation 4-1, the mn summation loop operates through the main program. In the two bandwidth programs, ACOBAN and STRBAN, the s and pq summations, respectively, are controlled by the main program as well.

The bulk of the calculations, including convergence testing and identifying the next mode to be considered, are performed in subroutines. Significant differences in summation logic among the three programs are handled by the main programs and specialized subroutines. This structure permits all three main programs to use the same subroutines as much as possible. Major subroutines, that is those that calculate the vibroacoustic response functions, differ among programs only with regard to whether the pure tone or bandwidth expression is of interest.

A.2 MAIN PROGRAM AND SUBROUTINE DESCRIPTIONS

Figures A-1 through A-3 show subroutine-calling heirarchy for the three programs. Each program calls the subroutines to the right of its block. The function of each program is listed below. The three main programs are described first, followed by subroutines that differ among programs.

User instructions are presented in Section A.3, and listings are presented in Section A.4. In addition to the routines described below, there is a block data subroutine.

PURTON - This is the basic main program, which calculates the noise reduction for a single frequency. It reads input data, calls routines that obtain frequency-sorted structural and acoustic modes, then computes noise reduction as described in Section 4.1. The final results are presented as the level of the interior noise relative to exterior.

ACOBAN - This main program computes band-average noise reduction for the case of a resonant interior acoustic field, as described in Section 4.2.1.

STRBAN - This main program computes band-average noise reduction for the case of resonant structural transmission, as described in Section 4.2.2.

AMODES - Computes the acoustic resonant frequencies. It first obtains the needed roots k_{ns} of Equation 3 from Reference 1, then computes resonant frequencies from Equation 6 of Reference 1. The frequencies are sorted in numerical order. Frequencies and modal indices are then saved (in double precision) on a file on logical unit 1, and printed on the main output file (unit 6). If specified by main program input, calculation is skipped and previously computed modes are read from unit 1.

BESSEL - Controls computation of Bessel and Neumann functions, following the methods described in Section 4.3.1.

BLJDEF - Computes Bessel functions from a power series.

BLYDEF - Computes Neumann functions from a power series.

CAPGAM - Computes the square of the quantity Γ_{nq} as defined in Table A-1.

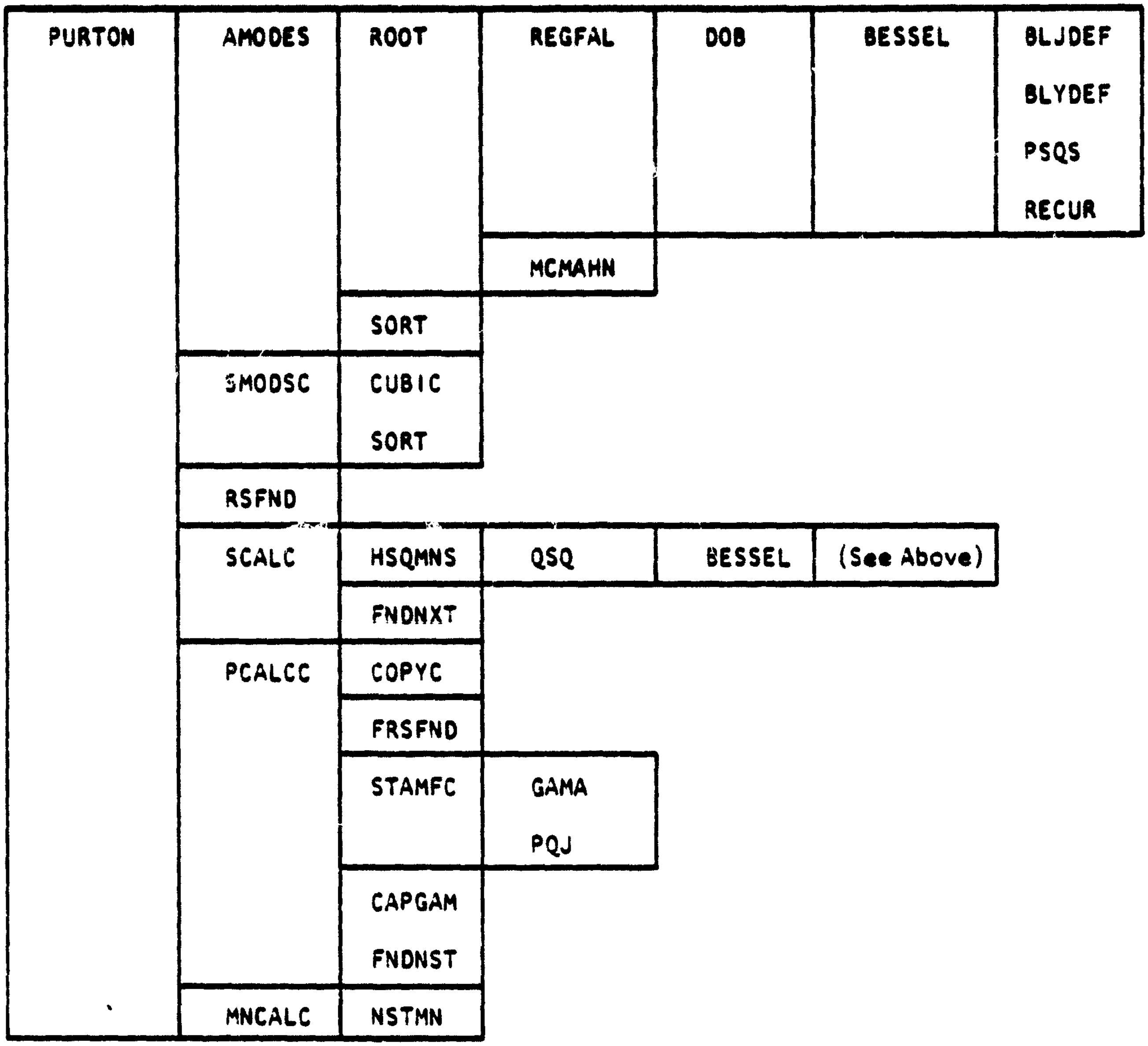

Figure A-1. Subroutine Heirarchy for PURTON

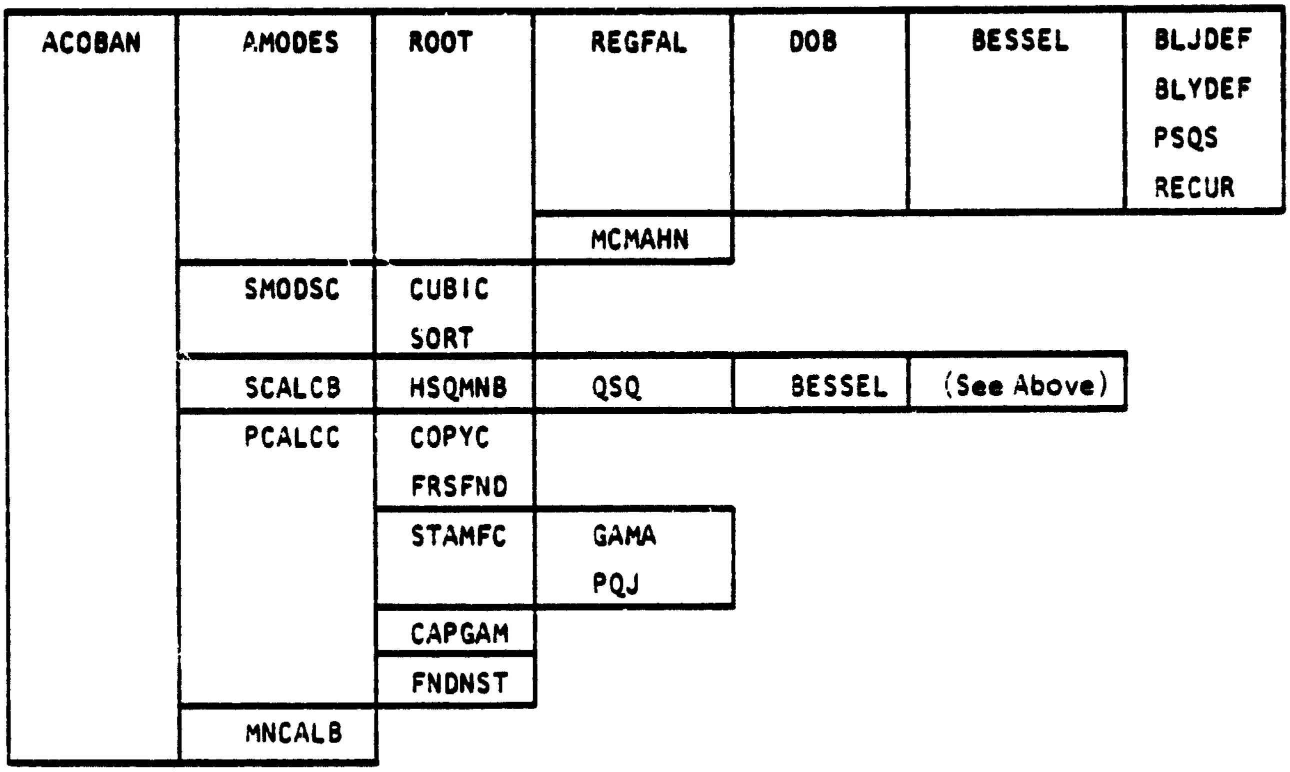

Figure A-2. Subroutine Heirarchy for ACOBAN

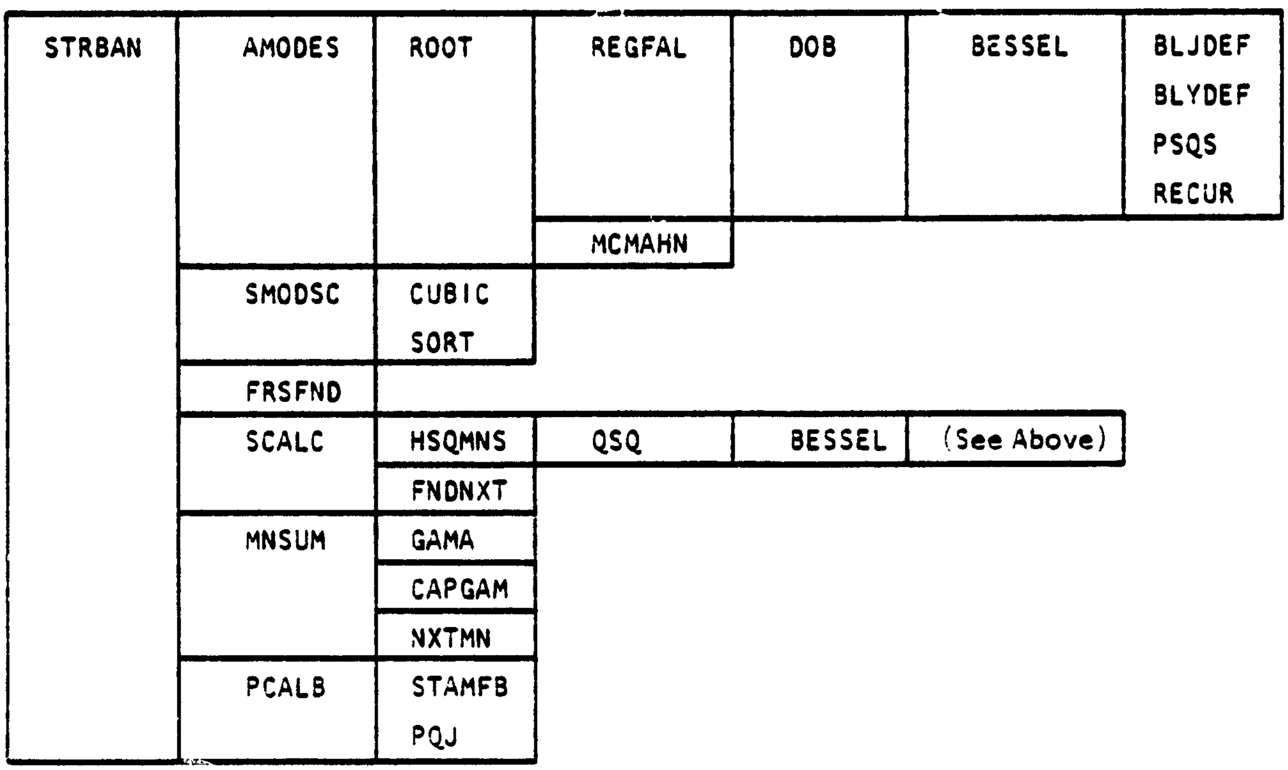

Figure A-3. Subroutine Heirarchy for STRBAN

C-2

TABLE A-1.

ACCEPTANCE BETWEEN SHELL AND CAVITY

$$g_{mn}^{pq} = \begin{cases} \dfrac{2}{\pi L \epsilon_m \epsilon_n} \; \gamma_{mp} \; \delta_{nq} \text{, whole shell case} \\ \\ \dfrac{2}{\pi L \epsilon_m \epsilon_n} \; \gamma_{mp} \; \Gamma_{nq} \text{, panel case} \end{cases}$$

where

$$\gamma_{mp} = \frac{1}{2 \frac{p\pi}{l} + \frac{m\pi}{l}} \left\{ \cos \frac{m\pi}{L} z_o - \cos \left[p\pi + \frac{m\pi}{L} (z_o + l) \right] \right\}$$

$$+ \frac{1}{2 \frac{p\pi}{l} - \frac{m\pi}{l}} \left\{ \cos \frac{m\pi}{L} z_o - \cos \left[p\pi - \frac{m\pi}{L} (z_o + l) \right] \right\} , \frac{m}{L} \neq \frac{p}{l}$$

$$\gamma_{mp} = \begin{cases} -\frac{l}{2} \; \sin \frac{p\pi}{l} z_o \; , & \frac{m}{L} = \frac{p}{l} \neq 0 \\ 0 & , \frac{m}{L} = \frac{p}{l} = 0 \end{cases}$$

$$\Gamma_{nq} = \frac{1}{2 \left(\frac{q\pi}{\alpha} + n \right)} \left\{ \cos n\phi_o - \cos \left[q\pi + n (\phi_o + \alpha) \right] \right\}$$

$$+ \frac{1}{2 \left(\frac{q\pi}{\alpha} - n \right)} \left\{ \cos n\phi_o - \cos \left[q\pi + n (\phi_o + \alpha) \right] \right\} , \; n \neq \frac{q\pi}{\alpha}$$

$$\Gamma_{nq} = -\frac{\alpha}{2} \sin n\phi_o \; , \quad n = \frac{q\pi}{\alpha}$$

$$\phi_o = \begin{cases} -\pi/2 & , \text{ q odd} \\ \\ \frac{\pi}{2n} - \frac{\alpha}{2} & , \text{ q even} \end{cases}$$

COPYC - Copies structural modal quantities into temporary working arrays.

CUBIC - Obtains the roots of a cubic algebraic equation.

DOB - Computes the quantity Q'_n; used in the solution of Equation 3 in Reference 1, by false position.

FNDNST - Searches a sorted list of modal frequencies for the next mode to be considered. See comments in the program listing for specific application.

FNDNXT - Similar to FNDNST. See comments in the program listing.

FRSFND - Searches a sorted list of modal frequencies for the one closest to a frequency of interest. Essentially selects the first term in the summation.

GAMA - Computes the quantity γ_{mp} as defined in Table A-1.

HSQMNB - Computes the acoustic response function H^2_{mns} integrated over a bandwidth, for use with main program ACOBAN.

HSQMNS - Computes the pure tone acoustic response function H^2_{mns}.

MCMAHN - Obtains roots of Equation 3 in Reference 1 using McMahon's asymptotic series.

MNCALB - Maintains the cumulative summation over mn. Used by ACOBAN.

MNCALC - Controls the summation over mn. Maintains the cumulative summation, tests for convergence, and identifies the next term. Used by PURTON.

MNSUM - Similar to MNCALC, used by STRBAN.

NXTMN - Similar to FNDNST and FNDNXT. See comments in program listing.

PCALB - Computes the joint acceptance times the bandwidth structural response function, for use with main program STRBAN.

PCALCC - Controls the summation over pq. Maintains the cumulative summation, tests for convergence, and identifies the next term.

PQJ - Computes the jet noise joint acceptance function, Equation 58 in Reference 1.

PSQS - Computes power series needed for Bessel and Neumann function asymptotic series.

QSQ - Computes $Q_n^2(k_{ns}r)$, defined by Equation 2 in Reference 1.

RECUR - Applies the recursion relations for Bessel functions, Equation 4-8.

REGFAL - Applies the method of false position in the solution of Equation 3 in Reference 1, as described in Section 4.3.2.

ROOT - Controls the solution for roots of Equation 3 in Reference 1, as described in Section 4.3.2.

SCALC - Performs and controls the summation over s of the acoustic amplification functions.

SCALCB - Used in ACOBAN to obtain the acoustic amplification function.

SMODSC - Computes the structural modal frequencies for an orthotropic circular shell segment. After computing and sorting the modes, they are written on the output file (unit 6) and saved (in double precision) on logical unit 2.

SORT - Sorts a floating point array into numerical order, and sorts a parallel integer array into the same order.

STAMFB - Computes the structural amplification function $\tilde{H}_{pq}^2$ integrated over a band. Used by STRBAN.

STAMFC - Computes the pure tone structural amplification $\tilde{H}_{pq}^2$ times the joint acceptance (Equation 58 in Reference 1) times $\gamma_{mn}^2 \Gamma_{nq}^2$.

A.2.1 Algorithms

The acoustic response of the cavity, Equation 1 in Reference 1, includes Bessel functions of the first and second kind. All arguments are real and non-negative. Also, it is necessary to solve for the roots k_{ns} of Equation 3 in Reference 1; this is a transcendental equation involving Bessel functions and their first derivatives. The Bessel function calculations are described in subsections A.2.1.1 and A.2.1.2. Subsection A.2.1.3 describes the procedures used to test for convergence in the various summations.

A.2.1.1 Bessel Functions

For arguments $x \leq 10$, Bessel functions are computed from the following series expansions:

$$J_n(x) = x^n \sum_{m=0}^{\infty} \frac{(-1)^m \, x^{2m}}{2^{2m+1} \, m! \, (n+m)!} \tag{1}$$

$$\begin{aligned} Y_n(x) = & -(x/2)^{-n} \sum_{m=0}^{n-1} \frac{(n-m-1)! \, (x^2/4)^m}{m!} + 2/\pi \, \log\,(x/2) \, J_n(x) \\ & -(x/2)^n \, 1/\pi \sum_{m=0}^{\infty} \frac{[\psi(m+1) + \psi(m+n+1)]}{m! \, (m+n)!} \, (-x^2/4)^m \end{aligned} \tag{2}$$

Values of the psi function, $\psi(k)$ are stored for $0 \leq k \leq 60$.

For arguments $x > 10$, the functions are computed from asymptotic series and recursion relations. For order $n \leq 8$, the following series are used:

$$J_n(x) = \sqrt{2/\pi x} \, [P_n(x) \cos(\arg) + Q_n(x) \sin(\arg)] , \tag{3}$$

$$Y_n(x) = \sqrt{2/\pi x} \, [P_n(x) \sin(\arg) + Q_n(x) \cos(\arg)] , \tag{4}$$

where

$$P_n(x) = 1 + \sum_{m=1}^{\infty} \frac{(-1)^m}{(2m)! \, (8x)^{2m}} \prod_{s=0}^{2m-1} [4n^2 - (2s+1)^2] ,$$

$$Q_n(x) = \sum_{m=0}^{\infty} \frac{(-1)^m}{(2m+1)! \, (8x)^{2m+1}} \prod_{s=0}^{2m} [4n^2 - (2s+1)^2] ,$$

$$\arg = x - \pi \, (n/2 + 1/4).$$

For $x > 10$ and $n > 8$, the functions are obtained from the recursion

$$B_{n+1}(x) = 2n/x\, B_n(x) - B_{n-1}(x) , \tag{5}$$

where $B_n = J_n$ or Y_n. The recursions are begun with values of B_7 and B_8 computed from the asymptotic series, Equations 3 and 4.

Derivatives of the Bessel functions are obtained from the relation

$$B_n'(x) = -B_{n+1}(x) + n/x\, B_n(x) . \tag{6}$$

Equations 1 through 6 (or equivalent alternate expressions) may be found in Chapter 9 of Reference 35 and Section 8.4 of Reference 36.

A.2.1.2 Roots of Equation 3 in Reference 1

The roots k_{ns} are required which satisfy

$$J_n'(k_{ns}a) - \frac{J'(k_{ns}b)}{Y'(k_{ns}b)} Y_n'(k_{ns}a) = 0 . \tag{7}$$

Let $x = k_{ns}a$ and $\beta = b/a$, so that $k_{ns}b = \beta x$. Then the sequence of roots x_{ns} is required which satisfy

$$J_n'(x_{ns})\, Y_n'(\beta x_{ns}) = J_n'(\beta x_{ns})\, Y_n'(x_{ns}) . \tag{8}$$

For large values of s, McMahon [37] developed the first four terms of an asymptotic series for the roots:

$$x_{ns} = \frac{s\pi}{\beta - 1} + \frac{C_1}{k} + \frac{C_2 - C_1^2}{k^3} + \frac{C_3 - 4C_1C_2 + 2C_1^3}{k^5} + \cdots \tag{9}$$

where $k = 2\pi(2n+4s-1)$, $m = 4n^2$

$$C_1 = \frac{m + 3}{8\beta}$$

$$C_2 = \frac{4(m^2 + 46m - 63)\ (\beta^3 - 1)}{3(8\beta)^3\ (\beta - 1)}$$

$$C_3 = \frac{32(m^3 + 185m^2 - 2053m + 1899)\ (\beta^5 - 1)}{5(8\beta)^5\ (\beta - 1)}$$

This expansion becomes less accurate at small values of s. The procedure used in the program is to compute the first roots by applying the method of false position to Equation 8. Roots computed from the series (9) are compared with those from false position. After both methods agree, the series method is used for higher values of s.

A.2.1.3 Convergence Tests

For a sequence of terms f_i, convergence may be defined as

$$1 - \varepsilon < \frac{f_{i+1}}{f_i} < 1 + \varepsilon \ . \qquad (10)$$

This definition of convergence (as opposed to $|f_{i+1} - f_i| < \varepsilon$) ensures that the sequence will converge to an accuracy in terms of a desired number of significant figures. For the Bessel function calculations, $\varepsilon = 0.5\times10^{-6}$, which provides six significant figures. For the main calculation of noise reduction, $\varepsilon = 0.0005$, which gives three significant figures. This provides a tolerance of about 0.002 dB, which is negligible.

Although the convergence criterion for the noise reduction calculation is quite conservative, the terms in the summation are not necessarily monotonically decreasing. An anomolously small term could give a false indication of convergence. This is somewhat unlikely, as it would have to occur simultaneously in both summation directions. Identically zero (and close to zero) terms are also appropriately handled, as discussed earlier. To check against false convergence, however, an option was incorporated into programs PURTON and ACOBAN wherein convergence would occur only when Equation 10 was satisfied a consecutive number of times. The number of times was specified as input data. Identical results were obtained with this convergence test as were found with the single test.

A.3 USER INSTRUCTIONS

A.3.1 Hardware

The programs are written in Fortran IV, and they are operational on the MSFC IBM 360 computer. The programs exist on punched cards and magnetic tape. Virtual core of 800K words is required. The following I/O devices are required·

1. A read file, 80-character records, on logical unit 5, for general data input.

2. A write file, 80 or more character records, on logical unit 6, for general output.

3. A read/write file, 80-character records, on logical unit 1, for saving calculated acoustic modal quantities.

4. A read/write file, 80-character records, on logical unit 2, for saving calculated structural modal quantities.

A.3.2 Input Data Files

The following input data cards are read from unit 5:

Card Number	Input Description
1	Title card. Format A80.
2	Bandwidth desired (ACOBAN and STRBAN only). Enter 1. for octave band 3. for one-third octave band, etc. Format F10.0 (No input card for PURTON).
3	Mode parameter. 1 = calculate new acoustic and structural modes. 2 = calculate new acoustic modes only. 3 = calculate new structural modes only. 4 = read previously calculated acoustic and structural modes from tape. Format I1.

Card Number	Input Description
4	Cylinder length L, segment length l, segment location z_o, inner radius a, outer radius b, speed of sound. Dimensions in feet, speed in feet/second. Format 6F10.0.
5	Longitudinal Young's modulus (lb/ft^2), circumferential Young's modulus (lb/ft^2), Poisson's ratio ν, thickness of stressed skin (ft), skin filler thickness (ft), area density of skin (slugs/ft^2). Format 6F10.0.
6	Frame Young's modulus E_F (lb/ft^2), frame cross-sectional area A_F (ft^2), frame moment of inertia I_F (ft^4), frame spacing (ft), displacement between skin and frame centroids (ft), circumferential extent of panel α (degrees). Format 6F10.0.
7	Radius locations of four points at which interior noise is desired, feet. Format 4F10.0.
8	Axial locations of the four interior points, feet. Format 4F10.0.
9	Coefficients a and b for $\eta_s = af^b$; coefficients a and b for $\eta_a = af^t$. Format 4F15.0.
10	Limits for modal indices n, s, m, p, q. (Lower limit followed by upper for each.) Format 10I5.
11	Relaxation factor to be applied to circumferential bending stiffness. Defined in Section 5.2.3. Format F10.0.
12.	Pressure correlation decay factors for jet noise; k_x/k, a_x, k_y/k, a_y. These factors are discussed in Section 5.1.4.
(For ACOBAN and STRBAN only.)	
13	Bandwidth center frequency (Hz). Format F10.
14	Next frequency
.	
.	
.	
N	Enter -1. to stop program.

Card Number	Input Description
(For PURTON only.)	
13	Frequency increment and upper value of frequency limit (Hz). Format 2F10.0.
14	Lower value of bandwidth frequency (Hz). Format F10.0.
15	Same as 13 for additional cards.
16	Same as 14 for additional cards.
.	
.	
.	
N	Enter -1. to stop program.

Logical units 1 and 2 may contain only files created by prior calculations from this program. For ACOBAN and STRBAN versions, the structural and acoustic parameters on cards 4, 5, 6, 10, and 11 must be the same as when the files on units 1 and 2 were created. For PURTON, cards 3, 4, 5, 9, and 10 must be the same. The program will then compute noise reduction and print the results as a level relative to the exterior noise in decibels. Values for the volume average interior noise reduction, plus approximate levels at the four specified interior points, are printed.

If structural or acoustic modes are computed, these are printed. Also, error messages (either system messages or those generated by the program) are printed with the output listing.

A.4 PROGRAM SOURCE LISTING WITH A TYPICAL RUN CASE

The following is the source listing of the program and all subroutines. Also, a sample run is included.

```
PILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  C                                                                    C
  C********************************************************************C
  C                                                                    C
  C                    ***  MAIN PROGRAM  ***                          C
  C                                                                    C
  C    THIS PROGRAM CALCULATES THE PRESSURE SQUARED RATIO BETWEEN      C
  C    THE INTERIOR AND EXTERIOR OF THE SPACE SHUTTLE PAYLOAD BAY.     C
  C    THE PROGRAM EMPLOYS MODAL ANALYSIS TECHNIQUES.  THIS IS MAIN    C
  C    PROGRAM 'PURTON', WHICH COMPUTES NOISE REDUCTION AT A           C
  C    SINGLE FREQUENCY.  THE COMPUTATION OCCURS OVER FIVE MODAL       C
  C    INDICES, THREE ACOUSTIC AND TWO STRUCTURAL.  THE PROGRAM        C
  C    SUMS OVER ALL MODES UNTIL THE CONVERGENCE CRITERIA ARE          C
  C    SATISFIED.                                                      C
  C                                                                    C
  C                            AUTHORS:  KENNETH J. PLOTKIN            C
  C                                      PATRICK K. GLENN              C
  C                                      WYLE LABORATORIES             C
  C                                      FEBRUARY 1977                 C
  C                                                                    C
  C********************************************************************C
  C                                                                    C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      REAL NRFREQ,NRSUM
      DIMENSION TITLE(10)
      COMMON /ACCEPT/ALFA
      COMMON /BESQR/B2
      COMMON /CONST/PI
      COMMON /EIGEN/BETA,BETA3,BETA5
      COMMON /FINAL/GRNDPP,GRNTOT,BIGSUM,BGSMT(4),SPGTOT(4)
      COMMON /FREQ/WSQ
      COMMON /HALT/QUIT
      COMMON /LEAD/HFTERM,BBB
      COMMON /LETTRS/A,B,C,CK,CRAT,DRAT
      COMMON /MORE/ WOLCPI,PICER
      COMMON /NORMAL/DENOM
      COMMON /RADII/RIN,ROUT
      COMMON /OTHER/ROTHR(4),ZOTHR(4),CYLNTH
      COMMON /STDAMP/STDAMA,STDAMB
      COMMON /ACDAMP/ADAMA,ADAMB
      COMMON /STOP/VCRIT,KSV
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /TERMS/RATIO,SEGLTH,PICYL,ZO,PICYLZ,FILSQ,PISEG
      COMMON /VARSQ/CSQ,PIOLLZ
      COMMON /VRBLS/PIOL4,RIN2,ACDACC
      COMMON /ACUSTK/ACMODS(3000),MNS(3000),NUMAC
      COMMON /SOLNS/SNK(400),KNS(400),NUMK
      COMMON /EPRCOF/TVXR,AXCOF,TVYR,AYCOF
      DIMENSION PANSR(4)
  C
  C
  C        INPUT VARIABLES
  C
```

ORIGINAL PAGE IS OF POOR QUALITY

```
      READ(5,3001) TITLE                                                PUR00570
      READ(5,4005) ION
 4005 FORMAT(I1)                                                        PUR00590
 3001 FORMAT(10A8)                                                      PUR00640
      WRITE(6,3002) TITLE                                               PUR00650
 3002 FORMAT(1H1,'JOB TITLE:',//,10X,10A8,10(/))                        PUR00660
      READ(5,1001)CYLNTH,SEGLTH,Z0,RIN,RCUT,SPSND                       PUR00670
      READ(5,1001)ESZ,ESTH,POISSR,SHLTHK,FILTHK,RHCH,                   PUR00680
     1EF,FA,FI,FS,FSDSPL,ALFA                                           PUR00690
 1001 FORMAT(6F10.0)                                                    PUR00700
      READ(5,1003)(ROTHR(JTR),JTR=1,4)                                  PUR00710
      READ(5,1003)(ZOTHR(JTR),JTR=1,4)                                  PUR00720
 1003 FORMAT(4F10.0)                                                    PUR00730
      WRITE(6,2000) CYLNTH,SEGLTH,Z0,RIN,RCUT,SHLTHK,FILTHK,RHCH,       PUR00740
     1      ESZ,ESTH,POISSR,SPSND                                       PUR00750
 2000 FORMAT(1X,'INPUT DATA: ',//,                                      PUR00760
     1   1X,'LENGTH OF CYLINDER = ',T48, F10.5,T59,'FEET',/,            PUR00770
     2   1X,'LENGTH OF SEGMENT = ',T48, F10.5,T59,'FEET',/,             PUR00780
     3   1X,'SEGMENT DISTANCE FROM END OF CYLINDER = ',T48, F10.5,T59,  PUR00790
     3       'FEET',/,                                                  PUR00800
     4   1X,'RADIUS OF INNER CYLINDER = ',T48, F10.5,T59,'FEET',/,      PUR00810
     5   1X,'RADIUS OF OUTER CYLINDER = ',T48, F10.5,T59,'FEET',/,      PUR00820
     6   1X,'SHELL STRUCTURAL THICKNESS = ',T48, F10.5,T59,'FEET',/,    PUR00830
     7   1X,'SHELL FILLER THICKNESS = ',T48,F10.5,T59,'FEET',/,         PUR00840
     9   1X,'SHELL DENSITY = ',T48, F10.5,T59,'SLUGS/FOOT**2'  ,/,      PUR00850
     A1X,'LONGITUDINAL YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FT**2',/,  PUR00860
     A1X,'CIRCUMFERENTIAL YOUNGS MODULUS =',T48,D10.5,T59,'LBS/FT**2',/,PUR00870
     B   1X,17HPOISSON'S RATIO = ,T48, F10.5,/,                         PUR00880
     C   1X,'SPEED OF SOUND = ',T48, F10.5,T59,'FEET/SECOND')           PUR00890
      WRITE(6,2005)FA,FI,FSDSPL,FS,EF                                   PUR00900
 2005 FORMAT(1X,'FRAME AREA = ',T48,D10.5,T59,'FEET**2',/,              PUR00910
     1 1X,'FRAME MOMENT OF INERTIA = ',T48,D10.5,T59,'FEET**2',/,       PUR00920
     2 1X,'FRAME-SKIN CENTROID DIST = ',T48,D10.5,T59,'FEET',/,         PUR00930
     3 1X,'FRAME SPACING = ',T48,D10.5,T59,'FEET',/,                    PUR00940
     4 1X,'FRAME YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FT**2')          PUR00950
 2006 FORMAT(/,1X,'ADJUST CIRCUMFERENTIAL BENDING STIFFNESS BY ',       PUR00960
     1 F10.4,/////)                                                     PUR00970
      READ(5,3010)STDAMA,STDAMB,ADAMA,ADAMB,BBB                         PUR00980
 3010 FORMAT(4F15.0,F10.0)                                              PUR00990
      READ(5,1002) NST,NEND,IST,ISEND,MST,MEND,IPST,IPEND,ICST,ICEND    PUR01000
 1002 FORMAT(10I5)                                                      PUR01010
      READ(5,1003)RELAX                                                 PUR01020
      WRITE(6,2006)RELAX                                                PUR01030
      READ(5,1003) TVXR,AXCDF,TVYR,AYCDF
      ALFA=ALFA*.01745329251994320C                                     PUR01050
  690 READ(5,1003) DELTAF,FREQL
      IF(DELTAF.LT.0.) GO TO 900
C                                                                       PUR01040
      NRFREQ=0.0
      READ(5,1501) WOMEGA                                               PUR01080
 1501 FORMAT(F10.0)                                                     PUR01090
  700 CONTINUE
      FREQ1=WOMEGA
      WOMEGA=WOMEGA*2.D0*PI                                             PUR01110
```

```
C        DEFINE MISCELLANEOUS CONSTANTS
C
      DENOM=ROUT
      BIGSUM=0.D0
      GRNTOT=0.D0
      KSV=0
      DO 40 IDX=1,4
      SPGTOT(IDX)=0.D0
   40 BGSMT(IDX)=0.D0
C        CHECK FOR THE HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) GO TO 5
      BETA=ROUT/RIN
      BETA3=BETA**3
      BETA5=BETA3*BETA*BETA
      DENOM=RIN
    5 WSQ=WOMEGA*WOMEGA
      VCRIT=.99995D0
      QUIT=1.D0-VCRIT
      CSQ=SPSND*SPSND
      PIOL2=PI*PI/(SEGLTH*SEGLTH)
      B2=ROUT**2
      B=PIOL2*B2
      SKINI=(SHLTHK**3)/48.D0+SHLTHK*((FILTHK+SHLTHK)/2.D0)**2
      RS=FA*FSDSPL/(FA+SHLTHK*FS)
      RF=FSDSPL-RS
      PNUF=1.D0-POISSR*POISSR
      C11=ESZ*SHLTHK/PNUF
      C22=(ESTH*SHLTHK+EF*FA/FS)/PNUF
      D11=SKINI*ESZ/PNUF
      D22=((SKINI+SHLTHK*RS*RS)*ESTH+EF*(FI+FA*RF*RF)/FS)/PNUF
      D22=D22*RELAX
      CRAT=C22/C11
      DRAT=D22/D11
      C=RHOH*ROUT*ROUT/C11
      CK=D22/(C22*ROUT*ROUT)
      A=(1.D0-POISSR)/2.D0
      RATIO=SEGLTH/CYLNTH
      PIOL4=PI*CYLNTH/4.D0
      RIN2=RIN**2
      HPTERM=((2.D0*ROUT*CRAT)/(PI*SEGLTH*RHOH))**2
      PICYL=PI/CYLNTH
      PIOLL2=PICYL*PICYL
      PICYLZ=PICYL*Z0
      PISEG=PI/SEGLTH
      PILSQ=1.D0/(PISEG*(2.D0/SEGLTH))
      VOLUME=PI*CYLNTH*(B2-RIN2)
C        THE FOLLOWING ARE USED IN ROUTINE PQJ
      WOLC=(SEGLTH*WOMEGA)/SPSND
      WOLCPI=WOLC/PI
      CBW=SPSND/(ROUT*WOMEGA)
      PICFR=1.D0/CBW
C
C
C        CALCULATE ACOUSTIC MODES
```

```
      IF(ION.EQ.5) GO TO 9927                                          PUR01660
      CALL AMODES (NST,NEND,IST,ISEND,MST,MEND,ION,&990)               PUR01670
      IF(ION.GT.2)GO TO 31                                             PUR01680
C        WRITE EIGENVALUES                                             PUR01690
      WRITE(6,2002)                                                    PUR01700
 2002 FORMAT(1H1,T27,'EIGENVALUE RESULTS',//,3('INDICES',4X,'EIGENVALUESPUR01710
     1',2X)//)                                                         PUR01720
      KOUNT=0                                                          PUR01730
      DO 30 I=1,NUMK,3                                                 PUR01740
      K=I+2                                                            PUR01750
      WRITE(6,2003) (KNS(J),SNK(J),J=I,K)                              PUR01760
 2003 FORMAT(1H ,3(I9,2X,D10.4,1X))                                    PUR01770
      KOUNT=KOUNT+1                                                    PUR01780
      IF(MOD(KOUNT,50) EQ.0) WRITE(6,2002) RIN,ROUT                    PUR01790
   30 CONTINUE                                                         PUR01800
   31 CONTINUE                                                         PUR01810
C        CALCULATE STRUCTURAL MODES                                    PUR01820
      CALL SMODSC (IPST,IPEND,IQST,IQEND,ION)                          PUR01830
 9927 CONTINUE                                                         PUR01840
C        INSURE OPPOSITE DIRECTION SEARCH NEXT TIME                    PUR01850
      GRNDPP=1.D70                                                     PUR01860
C FIND ACOUSTIC MODE CLOSEST TO INPUT FREQUENCY                        PUR01870
      CALL FRSFND(ACMODS,NUMAC,K)                                      PUR01880
C SAVE INDEX LOCATION                                                  PUR01890
      MNDIR=K                                                          PUR01900
      ISAVE=IABS(MNDIR)                                                PUR01910
C                                                                      PUR01920
C        MAIN LOOP                                                     PUR01930
   10 CALL SCALC (K,M,N,&990)                                          PUR01940
      CALL PCALCC (M,N,&990)                                           PUR01950
      CALL MNCALC (M,N,&10)                                            PUR01960
C        FINAL RESULT                                                  PUR01970
      RHOA = 0.002380D0                                                PUR01980
      ANSWER=((CSQ*RHOA*ROUT*WSQ)**2/(2.D0*VOLUME))*GRNTOT              PUR01990
      WOMEGA=WOMEGA/2.D0/PI                                            PUR02000
      ANSWER=10.D0*DLOG10(ANSWER)                                      PUR02010
      ABCONT=1.+10.**(ANSWER/20.)
      ANSRED=ANSWER-20.*DLOG10(ABCCNT)
      ANSNR=ANSRED+10.*DLOG10(DELTAF)
      NRFREQ=NRFREQ+(1./10.**(DABS(ANSNR/10.)))
      WRITE(6,4999)                                                    PUR02020
 4999 FORMAT(10X)                                                      PUR02030
      WRITE(6,2004) ANSWER,WOMEGA                                      PUR02040
 2004 FORMAT(2X,'***VOL AVE AMPLIFICATION = ',E10.4,' DBS FOR ',F7.1,  PUR02050
     1' HERTZ ')                                                       PUR02060
      WRITE(6,5002) ANSRED
 5002 FORMAT(1X,'VOL AVE AMP W/INTERNAL PRESSURE EFFECT = ',F6.2)
      FACTOR=(CSQ*RHOA*ROUT*WSQ)**2/2.D0                               PUR02070
      DO 50 IDX=1,4                                                    PUR02080
   50 PANSR(IDX)=10.D0*DLOG10(FACTOR*SPGTOT(IDX))                      PUR02090
      WRITE(6,5000)                                                    PUR02100
 5000 FORMAT(11X,'RADIUS(FT)',8X,'LNTH COORD(FT)',8X,'PNT AMPL(DBS)')  PUR02110
      DO 60 IDX=1,4                                                    PUR02120
      WRITE(6,5001) ROTHP(IDX),ZOTHR(IDX),PANSR(IDX)                   PUR02130
```

```
 5001 FORMAT(12X,F7.3,14X,F6.2,13X,E10.4)                              PUR02140
   60 CONTINUE                                                          PUR02150
      ION=5                                                             PUR02160
      WOMEGA=WOMEGA+DELTAF
      IF(WOMEGA.GT.FREQL) GO TO 680
      GO TO 700                                                         PUR02170
  680 NRSUM=-10.*ALOGIO(NRFREQ)
      WRITE(6,5005) NRSUM
 5005 FORMAT(1X,'1/3 OB NOISE REDUCTION WITH INTERNAL PRESSURE EFFECT =
     1',F6.2)
      GO TO 690
  800 CONTINUE                                                          PUR02180
      STOP                                                              PUR02190
C         ERROR STOP                                                    PUR02200
  900 STOP 601                                                          PUR02210
      END                                                               PUR02220
```

```
PILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
               SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
C                                                                      C
C*********************************************************************C
C                                                                      C
C                        ***  MAIN PROGRAM  ***                        C
C                                                                      C
C        THIS PROGRAM CALCULATES THE PRESSURE SQUARED RATIO BETWEEN    C
C        THE INTERIOR AND EXTERIOR OF THE SPACE SHUTTLE PAYLOAD BAY    C
C        USING MODAL ANALYSIS.  THIS IS MAIN PROGRAM 'ACOBAN', WHICH   C
C        COMPUTES NOISE TRANSMISSION INTO INTERIOR ACOUSTIC RESONANCES C
C        IN A GIVEN BAND.  THE PROGRAM SUMS OVER ALL ACOUSTIC RESO-    C
C        NANCES WITHIN THE BAND, AND SUMS OVER STRUCTURAL MODES UNTIL  C
C        CONVERGENCE IS ACHIEVED.                                      C
C                                                                      C
C                                    AUTHORS:  KENNETH J. PLOTKIN      C
C                                              PATRICK K. OLENN        C
C                                              WYLE LABORATORIES       C
C                                              FEBRUARY 1977           C
C                                                                      C
C*********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,L-Z)
      DIMENSION TITLE(10)
      COMMON /ACCEPT/ALFA
      COMMON /BESSR/B1
      COMMON /CONST/PI
      COMMON /EIGEN/BETA,BETA2,BETA5
      COMMON /FINAL/GPNOPP,GRNTOT,BIGSUM,BGSMT(4),SPOTOT(4)
      COMMON /FREQ/WSQ
      COMMON /HALT/QUIT
      COMMON /LOAD/HFTERM,BBB
      COMMON /LETTRS/A,B,C,CK,CRAT,HRAT
      COMMON /MORE/ WOLCPI,PICEP
      COMMON /NORMAL/DENOM
      COMMON /RADII/RIN,ROUT
      COMMON /OTHER/ROTHR(4),ZOTHR(4),CYLNTH
      COMMON /STDAMP/STDAMA,STDAMB
      COMMON /ACDAMP/ADAMA,ADAMB
      COMMON /STOP/VCRIT,KCV
      COMMON /TABS/ISAVE,MNDIR,F
      COMMON /TERMS/RATIO,SPGLTH,PICYL,ZC,PICYLZ,FILSQ,PISEG
      COMMON /VARSQ/CSQ,PICLL2
      COMMON /VRBLS/PICL4,RIN2,ACDAEC
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      COMMON /SOLNS/SNK(400),KNS(400),NUNK
      COMMON /EPRCUR/TVXR,AXCOF,TVYR,AYCOF
      DIMENSION PANSR(4)
C
C
      EXTERNAL SDUMP
      CALL ERRSET(207,0,0,0,SDUMP,0)
C        INPUT VARIABLES
C
```

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```
      WRITE(6,5060)                                                    ACO00500
 5060 FORMAT(1X,'ENTER 1/BANDWIDTH')                                   ACO00510
      READ(5,5061)BAND                                                 ACO00520
 5061 FORMAT(F10.0)                                                    ACO00530
      WRITE(6,5040)                                                    ACO00540
 5040 FORMAT(1X,'ENTER CONVERGENCE CRITERION')                         ACO00550
      READ(5,4005) KCV                                                 ACO00560
      WRITE(6,5052)                                                    ACO00570
 5052 FORMAT(1X,'ENTER MODE PARAMETER WHEN CODED; 1 FOR ALL NEW MODES,2 FACO00580
     1OR NEW 4 MODES,')                                                ACO00590
      WRITE(6,5053)                                                    ACO00600
 5053 FORMAT(1X,'3 FOR NEW 5 MODES, 4 FOR NO NEW MODES')               ACO00610
 5000 FORMAT(1X,'ENTER FREQUENCY ')                                    ACO00620
 5001 FORMAT(F10.0)                                                    ACO00630
      WRITE(6,2010)                                                    ACO00640
      READ(5,2001) TITLE                                               ACO00650
      READ(5,4005)ION                                                  ACO00660
 4005 FORMAT(I1)                                                       ACO00670
 2010 FORMAT(1X,'ENTER MODE PARAMETER')                                ACO00680
 2001 FORMAT(10A8)                                                     ACO00690
      WRITE(6,3002) TITLE                                              ACO00700
 3002 FORMAT(1H1,'JOB TITLE:',///,10X,10A8,////)                       ACO00710
      READ(5,1001)CYLNTH,SEGLTH,ZO,RIN,ROUT,SPSND                      ACO00720
      READ(5,1001)ESZ,ESTH,POISSR,SHLTHK,FILTHK,RHOH,                  ACO00730
     1EF,FA,FI,FS,FSDSPL,ALFAI                                         ACO00740
 1001 FORMAT(6E10.4,4F10.0)                                            ACO00760
      READ(5,1003)(ROTHP(JTR),JTR=1,4)                                 ACO00770
      READ(5,1003)(ZOTHR(JTR),JTR=1,4)                                 ACO00780
 1003 FORMAT(4F10.0)                                                   ACO00790
      WRITE(6,2000) CYLNTH,SEGLTH,ZO,RIN,ROUT,SHLTHK,FILTHK,           ACO00800
     1                   RHOH,ESZ,ESTH,POISSR,SPSND                    ACO00810
 2000 FORMAT(1X,'INPUT DATA: ',//,                                     ACO00820
     1    1X,'LENGTH OF CYLINDER = ',T48, F10.5,T59,'FEET',/,          ACO00830
     2    1X,'LENGTH OF SEGMENT = ',T48, F10.5,T59,'FEET',/,           ACO00840
     3    1X,'SEGMENT DISTANCE FROM END OF CYLINDER = ',T48, F10.5,T59,  ACO00850
     3       'FEET',/,                                                 ACO00860
     4    1X,'RADIUS OF INNER CYLINDER = ',T48, F10.5,T59,'FEET',/,    ACO00870
     5    1X,'RADIUS OF OUTER CYLINDER = ',T48, F10.5,T59,'FEET',/,    ACO00880
     6    1X,'SHELL STRUCTURAL THICKNESS = ',T48, F10.5,T59,'FEET',/,  ACO00890
     8    1X,'SHELL FILLER THICKNESS = ',T48,F10.5,T59,'FEET',/,       ACO00900
     9    1X,'SHELL DENSITY = ',T48, F10.5,T59,'SLUGS/FOOT**2'   ,/,   ACO00910
     7 1X,'LONGITUDINAL YOUNGS MODULUS = ',T48, D10.3,T59,'LBS/FOOT',/, ACO00920
     A1X,'CIRCUMFERENTIAL YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FOOT',/ ACO00930
     B   ,1X,'POISSON''S RATIO = ',T48, F10.5,/,                        ACO00940
     C    1X,'SPEED OF SOUND = ',T48, F10.5,T59,'FEET/SECOND')          ACO00950
      WRITE(6,2005)FA,FI,FSDSPL,FS,EF                                  ACO00960
 2005 FORMAT(1X,'FRAME AREA = ',T48,D10.5,T59,'FEET**2',/,             ACO00970
     1 1X,'FRAME MOMENT OF INERTIA = ',T48,D10.5,T59,'FEET**4',/,       ACO00980
     2 1X,'FRAME-SKIN CENTROID DIST = ',T48,D10.5,T59,'FEET',/,         ACO00990
     3 1X,'FRAME SPACING = ',T48,D10.5,T59,'FEET',/,                    ACO01000
     4 1X,'FRAME YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FOOT')           ACO01010
 2003 FORMAT(/,1X,'ADJUST CIRCUMFERENTIAL BENDING STIFFNESS BY ',F10.   ACO01020
     1 4,//////)                                                        ACO01030
      READ(5,3110)STDAMA,STDAMB,ADAMA,ADAMB,BBP
```


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```
 3001 FORMAT(4F15.0,F10.0)                                              ACC01040
      READ(5,1002) NST,NEND,IST,ISEND,MST,MEND,IFST,IFEND,ICST,ICEND    ACC01050
 1002 FORMAT(10I5)                                                      ACC01060
      READ(5,1003)RELAX                                                 ACC01070
      WRITE(6,3006)RELAX                                                ACC01080
      READ(5,1000) TVXF,AXCOF,TVYF,AYCOF
C                                                                       ACC01090
      WRITE(6,5551)                                                     ACC01100
 5551 FORMAT(1X,'ENTER FREQUENCY WHEN CURS. TO HALT EXECUTION ENTER NEGAACC01110
     1TIVE NUMBER')                                                     ACC01120
      ALFA=ALFAI*.0174532925199433D0                                    ACC01130
C                                                                       ACC01140
      DENOM=ROUT                                                        ACC01150
  700 WRITE(6,1500)                                                     ACC01160
      READ(5,1501)WOMEGI                                                ACC01170
      IF(WOMEGI.LT.0.0) GO TO 300                                       ACC01180
      WOMEGA=WOMEGI*2.D0*PI                                             ACC01190
      DISSUM=0.D0                                                       ACC01200
      WRATOT=0.D0                                                       ACC01210
      DO 40 IDX=1,4                                                     ACC01220
      SPGTOT(IDX)=0.D0                                                  ACC01230
   40 DGSAT(IDX)=0.D0                                                   ACC01240
C       CHECK FOR THE HOLLOW CYLINDER CASE                              ACC01250
      IF(RIN.EQ.0.D0) GO TO 5                                           ACC01260
      BETA=ROUT/RIN                                                     ACC01270
      BETA3=BETA**3                                                     ACC01280
      BETA5=BETA3*BETA*BETA                                             ACC01290
      DENOM=RIN                                                         ACC01300
    5 WSQ=WOMEGA*WOMEGA                                                 ACC01310
      VCRIT=.99995D0                                                    ACC01320
      DDIT=1.D0-VCRIT                                                   ACC01330
      CSQ=SPSND*SPSND                                                   ACC01340
      PICL2=PI*PI/(SPGLTH*SPGLTH)                                       ACC01350
      B2=ROUT**2                                                        ACC01360
      B=PICL2*B2                                                        ACC01370
      SKINI=(SHLTHK**3)/48.D0+SHLTHK*((FILTHK+SHLTHK)/2.D0)**2          ACC01380
      RS=FA*FSDSPL/(FA+SHLTHK*FS)                                       ACC01390
      RF=FSDSPL-RS                                                      ACC01400
      PNUF=1.D0-PCISSR*PCISSR                                           ACC01410
      C11=ESZ*SHLTHK/PNUF                                               ACC01420
      C22=(ESTH*SHLTHK+EF*FA/FS)/PNUF                                   ACC01430
      D11=SKINI*ESZ/PNUF                                                ACC01440
      D22=((SKINI+SHLTHK*RS*RS)*ESTH+EF*(FI+FA*RF*RF)/FS)/PNUF          ACC01450
      D22=D22*RELAX                                                     ACC01460
      CRAT=C22/C11                                                      ACC01470
      DRAT=D22/D11                                                      ACC01480
      C=RHOH*ROUT*ROUT/C11                                              ACC01490
      DK=D22/(C22*ROUT*ROUT)                                            ACC01500
      A=(1.D0-PCISSR)/2.D0                                              ACC01510
      RATIO=SPGLTH/CYLNTH                                               ACC01520
      PICL4=PI*CYLNTH/4.D0                                              ACC01530
      RIN2=RIN**2                                                       ACC01540
      HFTERM=((2.D0*ROUT*CRATT/(PI*SSGLTH*RHOH))**2                     ACC01550
      PICYL=PI/CYLNTH                                                   ACC01560
```

```
      PICCL2=PICYL*PICYL                                                ACCC1570
      PICYLZ=PICYL*2C                                                   ACCC1580
      PISEG=PI/SEGLTH                                                   ACCC1590
      PILSQ=1.DC/(PISEG*(2.DO/SEGLTH))                                  ACCC1600
      VOLUME=PI*CYLNTH*(D2-RIN2)                                        ACCC1610
C        THE FOLLOWING ARE USED IN ROUTINE POJ                          ACCC1620
      WCLC=(SEGLTH*WCYFGST/SPSND                                        ACCC1630
      WJLCPI=WCLC/PI                                                    ACCC1640
      C3W=SPSND/(RCLT*WCYFGST)                                          ACCC1650
      FICTR=1.DC/C3W                                                    ACCC1660
C                                                                       ACCC1670
C        CALCULATE ACOUSTIC MODES                                       ACCC1690
      IF(ICN.EQ.5) GO TO 9927                                           ACCC1700
      CALL AMODES (NST,NEND,IST,ISEND,MST,MEND,ICN,9927)                ACCC1710
      IF(ICN.GT.2)GO TO 31                                              ACCC1720
C        WRITE EIGENVALUES                                              ACCC1730
      WRITE(6,2002)                                                     ACCC1740
 2002 FORMAT(1H1,T27,'EIGENVALUE  RESULTS',//,3('INDICES',4X,'EIGENVALUESACCC1750
     1',2X)//)                                                          ACCC1760
      KOUNT=0                                                           ACCC1770
      DO 30 I=1,NUMM,3                                                  ACCC1780
      K=I+2                                                             ACCC1790
      WRITE(6,2003) (KNS(J),SNK(J),J=I,K)                               ACCC1800
 2003 FORMAT(1H ,3(I9,2X,E10.4,1X))                                     ACCC1810
      KOUNT=KOUNT+1                                                     ACCC1820
      IF(MOD(KOUNT,50).EQ.0) WRITE(6,2002) RIN,ROUT                     ACCC1830
   30 CONTINUE                                                          ACCC1840
   31 CONTINUE                                                          ACCC1850
C                                                                       ACCC1680
C        CALCULATE STRUCTURAL MODES                                     ACCC1860
      CALL SMODES (IPST,IPEND,IGST,IGEND,ICN)                           ACCC1870
 9927 CONTINUE                                                          ACCC1880
C        INSURE OPPOSITE DIRECTION SEARCH NEXT TIME                     ACCC1890
      GRNOPP=1.E70                                                      ACCC1900
      BANFAC=2.DC**(1.DC/BAND)                                          ACCC1910
      WSQB=WSQ/BANFAC                                                   ACCC1920
      WSQT=WSQ*BANFAC                                                   ACCC1930
      WSQC=WSQ                                                          ACCC1940
      DELTAW=DSQRT(WSQT)-DSQRT(WSQB)                                    ACCC1950
C                                                                       ACCC1960
C        MAIN LOOP                                                      ACCC1970
      KTOP=0                                                            ACCC1980
      DO 70 K=1,NUMAC                                                   ACCC1990
      IF(ACMODS(K).GE.WSQT) GO TO 70                                    ACCC2000
      IF(KTOP.EQ.0) KTOP=K                                              ACCC2010
      IF(ACMODS(K).LT.WSQB) GO TO 80                                    ACCC2020
   70 CONTINUE                                                          ACCC2030
   81 WRITE(6,9500)                                                     ACCC2040
 9500 FORMAT(1X,'NO ACOUSTIC MODES IN REQUESTED BAND')                  ACCC2050
      ICN=5                                                             ACCC2060
      GO TO 700                                                         ACCC2070
   80 KBOT=K-1                                                          ACCC2080
      IF(KBOT.LT.KTOP)GO TO 81                                          ACCC2090
      DO 90 K=KTOP,KBOT                                                 ACCC2100
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```
      WSN=ACNTOS(K)
      CALL SCALCB (M,N,N,6900)
      CALL PCALCC (M,N,6900)
   90 CALL ANCALB (M,N)
C        FINAL RESULT
      AMCA = 0.0002E00
      DUMVAR=10.00/DELTAW
      ANSWER=((CSC*RHOA*RCUT)**2/(2.00*VOLUME))*GRAD*DUMVAR
      ANSWER=10.00*ALOG10(ANSWER)
      ABCENT=1.+10.**(ANSWER/20.)
      ANSTTT=ANSWER-20.*ALOG10(ABCENT)
      WRITE(6,4999)
 4999 FORMAT(1OX)
      WRITE(6,2004) ANSWER,ACMEGI
 2004 FORMAT(2X,'***VOL AVG AMPLIFICATION = ',F10.4,' DBS FOR ',F7.1,
     1' HERTZ BAND')
      WRITE(6,5002) ANSRED
 5002 FORMAT(1X,'VOL AVG AMP W/INTERNAL PRESSURE EFFECT = ',F6.2)
      FACTOR=(CSC*RHO*RCUT)**2/2.00*DUMVAR
      DO 50 IDX=1,4
   50 PANSR(IDX)=10.00*ALOG10(FACTOR*SFCTCT(IDX))
      WRITE(6,5000)
 5000 FORMAT(11X,'RADIUS(FT)',3X,'LNTH COORD(FT)',3X,'PLT AMPL(DBS)')
      DO 60 IDX=1,4
      WRITE(6,5001)FCTR(IDX),ZCTR(IDX),PANSR(IDX)
 5001 FORMAT(12X,F7.3,14X,F6.2,15X,F10.4)
   60 CONTINUE
      ICN=5
      GO TO 700
  800 CONTINUE
      STOP
C        ERROR STOP
  900 STOP 601
      END
```

```
IPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                 SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
C                                                                      C
C**********************************************************************C
C                                                                      C
C                        ***  MAIN PROGRAM  ***                        C
C                                                                      C
C    THIS PROGRAM CALCULATES THE PRESSURE SQUARED RATIO BETWEEN        C
C    THE INTERIOR AND EXTERIOR OF THE SPACE SHUTTLE PAYLOAD BAY        C
C    USING MODAL ANALYSIS.  THIS IS MAIN PROGRAM STRBAN, WHICH         C
C    COMPUTES NOISE TRANSMISSION VIA STRUCTURAL RESONANCES IN A        C
C    GIVEN BAND.  THE PROGRAM SUMS OVER ALL STRUCTURAL MODES           C
C    WITHIN THE BAND, AND SUMS OVER ACOUSTIC MODES UNTIL CON-          C
C    VERGENCE IS ACHEIVED.                                             C
C                                                                      C
C                                  AUTHORS:  KENNETH J. PLOTKIN        C
C                                            PATRICK K. GLENN          C
C                                            WYLE LABORATORIES         C
C                                            FEBRUARY 1977             C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION TITLE(10)
      COMMON /ACCEPT/ALFA
      COMMON /BESQR/B2
      COMMON /CONST/PI
      COMMON /EIGEN/BETA,BETA3,BETA5
      COMMON /FINAL/GRNOPP,GRNTOT,BIGSUM,BGSMT(4),SPGTOT(4)
      COMMON /FREQ/WSQ
      COMMON /HALT/QUIT
      COMMON /LEAD/HFTERM,BBB
      COMMON /LETTRS/A,B,C,CK,CRAT,DRAT
      COMMON /MORE/ WOLCPI,PICER
      COMMON /NORMAL/DENOM
      COMMON /RADII/RIN,ROUT
      COMMON /OTHER/ROTHR(4),ZOTHR(4),CYLNTH
      COMMON /STDAMP/STDAMA,STDAMB
      COMMON /ACDAMP/ADAMA,ADAMB
      COMMON /STOP/VCRIT
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /TERMS/RATIO,SEGLTH,PICYL,Z0,PICYLZ,PILSQ,PISEG
      COMMON /VARSQ/CSQ,PIOLL2
      COMMON /VRBLS/PIOL4,RIN2,ACDACC
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      COMMON /SOLNS/SNK(400),KNS(400),NUMK
      COMMON /STRUCT/STMODS(1200),MPQ(1200),STMOD3(400,3),MPQ3(400),
     1          NUMST,NUM3
      COMMON /SPRCOR/TVXR,AXCOF,TVYR,AYCOF
      DIMENSION PANSR(4),POTALL(4)
C
C
      EXTERNAL SDUMP
      CALL ERRSET(207,0,0,2,SDUMP,0)
```

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```
C        INPUT VARIABLES                                                STROC500
C                                                                       STR00510
      READ(5,5061)BAND                                                  STR00540
 5061 FORMAT(F10.0)                                                     STR00550
 1501 FORMAT(F10.0)                                                     STR00640
      READ(5,3001) TITLE                                                STR00660
      READ(5,4005)ION                                                   STR00670
 4005 FORMAT(I1)                                                        STR00680
 3001 FORMAT(10A8)                                                      STR00700
      WRITE(6,3002) TITLE                                               STR00710
 3002 FORMAT(1H1,'JOB TITLE:',//,10X,10A8,////)                         STR00720
      READ(5,1001)CYLNTH,SEGLTH,ZO,RIN,ROUT,SPSND                       STR00730
      READ(5,1001)ESZ,ESTH,POISSR,SHLTHK,FILTHK,RHCH,                   STR00740
     1EF,FA,FI,FS,FSDSPL,ALFAI                                          STR00750
 1001 FORMAT(6F10.0)                                                    STR00760
      READ(5,1003)(ROTHR(JTR),JTR=1,4)                                  STR00770
      READ(5,1003)(ZOTHR(JTR),JTR=1,4)                                  STR00780
 1003 FORMAT(4F10.0)                                                    STR00790
      WRITE(6,2000) CYLNTH,SEGLTH,ZO,RIN,ROUT,SHLTHK,FILTHK,            STR00800
     1               RHOH,ESZ,ESTH,POISSR,SPSND                         STR00810
 2000 FORMAT(1X,'INPUT DATA: ',//,                                      STR00820
     1   1X,'LENGTH OF CYLINDER = ',T48, F10.5,T59,'FEET',/,            STR00830
     2   1X,'LENGTH OF SEGMENT = ',T48, F10.5,T59,'FEET',/,             STR00840
     3   1X,'SEGMENT DISTANCE FROM END OF CYLINDER = ',T48, F10.5,T59,  STR00850
     3       'FEET',/,                                                  STR00860
     4   1X,'RADIUS OF INNER CYLINDER = ',T48, F10.5,T59,'FEET',/,      STR00870
     5   1X,'RADIUS OF OUTER CYLINDER = ',T48, F10.5,T59,'FEET',/,      STR00880
     6   1X,'SHELL STRUCTURAL THICKNESS = ',T48, F10.5,T59,'FEET',/,    STR00890
     6   1X,'SHELL FILLER THICKNESS = ',T48,F10.5,T59,'FEET',/,         STR00900
     9   1X,'SHELL DENSITY = ',T48, F10.5,T59,'SLUGS/FOOT**2'  ,/,      STR00910
     A 1X,'LONGITUDINAL YOUNGS MODULUS = ',T48, D10.5,T59,'LBS/FT**2',/,STR00920
     A1X,'CIRCUMFERENTIAL YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FT**2',/STR00930
     B  ,1X,17HPOISSON'S RATIO = ,T48, F10.5,/,                         STR00940
     C   1X,'SPEED OF SOUND = ',T48, F10.5,T59,'FEET/SECOND')           STR00950
      WRITE(6,2005)FA,FI,FSDSPL,FS,EF                                   STR00960
 2005 FORMAT(1X,'FRAME AREA = ',T48,D10.5,T59,'FEET**2',/,              STR00970
     1 1X,'FRAME MOMENT OF INERTIA = ',T48,D10.5,T59,'FEET**4',/,       STR00980
     2 1X,'FRAME-SKIN CENTROID DIST = ',T48,D10.5,T59,'FEET',/,         STR00990
     3 1X,'FRAME SPACING = ',T48,D10.5,T59,'FEET',/,                    STR01000
     4 1X,'FRAME YOUNGS MODULUS = ',T48,D10.5,T59,'LBS/FT**2')          STR01010
 2006 FORMAT(/,1X,'ADJUST CIRCUMFERENTIAL BENDING STIFFNESS BY ',F10.   STR01020
     1 4,/////)                                                         STR01030
      READ(5,3010)STDAMA,STDAMB,ADAMA,ADAMB,BBB                         STR01040
 3010 FORMAT(4F15.0,F10.0)                                              STR01050
      READ(5,1002) NST,NEND,IST,ISEND,MST,MEND,IPST,IPEND,IGST,IGEND    STR01060
 1002 FORMAT(10I5)                                                      STR01070
      READ(5,1003)RELAX                                                 STR01080
      WRITE(6,2006)RELAX                                                STR01090
      READ(5,1003) TVXR,AXCDF,TVYR,AYCDF
C                                                                       STR01100
C        CONVERT TO RADIANS                                             STR01110
C        DEFINE MISCELLANEOUS CONSTANTS                                 STR01120
      ALFA=ALFAI*.0174532925199432D0                                    STR01130
C                                                                       STR01140
```

```
      DENOM=ROUT
  700 CONTINUE
      READ(5,1501)WOMEGI
      IF(WOMEGI.LE.0.0) GO TO 800
      WOMEGA=WOMEGI*2.D0*PI
      TOTALL=0.D0
      DO 40 IDX=1,4
   40 POTALL(IDX)=0.D0
C        CHECK FOR THE HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) GO TO 5
      BETA=ROUT/RIN
      BETA3=BETA**3
      BETA5=BETA3*BETA*BETA
      DENOM=RIN
    5 WSQ=WOMEGA*WOMEGA
      VCRIT=.99995D0
      QUIT=1.D0-VCRIT
      CSQ=SPSND*SPSND
      PIOL2=PI*PI/(SEGLTH*SEGLTH)
      B2=ROUT**2
      B=PIOL2*B2
      SKINI=(SHLTHK**3)/48.D0+SHLTHK*((FILTHK+SHLTHK)/2.D0)**2
      RS=FA*FSDSPL/(FA+SHLTHK*FS)
      RF=FSDSPL-RS
      PNUF=1.D0-POISSR*POISSR
      C11=ESZ*SHLTHK/PNUF
      C22=(ESTH*SHLTHK+EF*FA/FS)/PNUF
      D11=SKINI*ESZ/PNUF
      D22=((SKINI+SHLTHK*RS*RS)*ESTH+EF*(FI+FA*RF*RF)/FS)/PNUF
      D22=D22*RELAX
      CRAT=C22/C11
      DRAT=D22/D11
      C=RHOH*ROUT*ROUT/C11
      CK=D22/(C22*ROUT*ROUT)
      A=(1.D0-POISSR)/2.D0
      RATIO=SEGLTH/CYLNTH
      PIOL4=PI*CYLNTH/4.D0
      RIN2=RIN**2
      HFTERM=((2.D0*ROUT*CRAT)/(PI*SEGLTH*RHOH))**2
      PICYL=PI/CYLNTH
      PIOLL2=PICYL*PICYL
      PICYLZ=PICYL*Z0
      PISEG=PI/SEGLTH
      PILSQ=1.D0/(PISEG*(2.D0/SEGLTH))
      VOLUME=PI*CYLNTH*(B2-RIN2)
C         THE FOLLOWING ARE USED IN ROUTINE PCJ
      WOLC=(SEGLTH*WOMEGA)/SPSND
      WOLCPI=WOLC/PI
      CBW=SPSND/(ROUT*WOMEGA)
      PICER=1.D0/CBW
C
C
C         CALCULATE ACOUSTIC MODES
      IF(ION.EQ.5) GO TO 9927
```

```
      CALL AMODES (NST,NEND,IST,ISEND,MST,MEND,ION,&900)
C        WRITE EIGENVALUES
      IF(ION.NE.2.AND.ION.NE.1) GO TO 31
      WRITE(6,2002)
 2002 FORMAT(1H1,T27,'EIGENVALUE RESULTS',//,3('INDICES',4X,'EIGENVALUES
     1',2X)//)
      KOUNT=0
      DO 30 I=1,NUMK,3
      K=I+2
      WRITE(6,2003) (KNS(J),SNK(J),J=I,K)
 2003 FORMAT(1H ,3(I9,2X,D10.4,1X))
      KOUNT=KOUNT+1
      IF(MOD(KOUNT,50).EQ.0) WRITE(6,2002) RIN,ROUT
   30 CONTINUE
   31 CONTINUE
C        CALCULATE STRUCTURAL MODES
      CALL SMODSC (IPST,IPEND,IQST,IQEND,ION)
 9927 CONTINUE
C        INSURE OPPOSITE DIRECTION SEARCH NEXT TIME
      BANFAC=2.D0**(1.D0/BAND)
      WSQB=WSQ/BANFAC
      WSQT=WSQ*BANFAC
      WSQC=WSQ
      DELTAW=DSQRT(WSQT)-DSQRT(WSQB)
C
C        MAIN LOOP
      KTOP=0
      DO 70 K=1,NUMST
      IF(STMODS(K).GE.WSQT) GO TO 70
      IF(KTOP.EQ.0) KTOP=K
      IF(STMODS(K).LT.WSQB) GO TO 80
   70 CONTINUE
   80 KBOT=K-1
      IF(KBOT.LT.KTOP.OR.KTOP.EQ.0)GO TO 700
      DO 90 KS=KTOP,KBOT
      WSQ=STMODS(KS)
      IP=MOD(MPQ(KS),1000)
      IQ=MPQ(KS)/1000
      GRNOPP=1.D70
      GRNTOT=0.D0
      BIGSUM=0.D0
      DO 1 IDX=1,4
      SPGTOT(IDX)=0.D0
    1 BGSMT(IDX)=0.D0
      CALL FRSFND(ACMODS,NUMAC,K)
      MNDIR=K
      ISAVE=IABS(MNDIR)
   10 CALL SCALC(K,M,N,&900)
      CALL MNSUM(M,N,IP,IQ,&10)
   90 CALL PCALB(KS,IP,IQ,TOTALL,PCTALL)
C        FINAL RESULT
      RHOA = 0.00238D0
      DUMVAR=1.D0/DELTAW
      ANSWER=((CSQ*RHOA*ROUT)**2/(2.D0*VOLUME))*TCTALL*DUMVAR
```


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```
      IF(ANSWER.LE.0.D0)GO TO 801                                       STR02240
      ANSWER=10.D0*DLOG10(ANSWER)                                       STR02250
      ABCONT=1.+10.**(ANSWER/20.)
      ANSRED=ANSWER-20.*DLOG10(ABCONT)
      WRITE(6,4999)                                                     STR02260
 4999 FORMAT(10X)                                                       STR02270
      WRITE(6,2004) ANSWER,WOMEGI                                       STR02280
 2004 FORMAT(2X,'***VOL AVE AMPLIFICATION = ',E10.4,' DBS FOR ',F7.1,   STR02290
     1' HERTZ BAND')                                                    STR02300
      WRITE(6,5002) ANSRED
5002  FORMAT(1X,'VOL AVE AMP W/INTERNAL PRESSURE EFFECT = ',F6.2)
      FACTOR=(CSQ*RHOA*ROUT)**2/2.D0*DUMVAR                             STR02310
      DO 50 IDX=1,4                                                     STR02320
      FACPOT=FACTOR*POTALL(IDX)                                         STR02330
      IF(FACPOT.LE.0.D0)FACPOT=1.D-70                                   STR02340
   50 PANSR(IDX)=10.D0*DLOG10(FACPOT)                                   STR02350
      WRITE(6,5000)                                                     STR02360
 5000 FORMAT(11X,'RADIUS(FT)',8X,'LATH COORD(FT)',8X,'PNT AMPL(DBS)')   STR02370
      DO 60 IDX=1,4                                                     STR02380
      WRITE(6,5001) ROTHR(IDX),ZOTHR(IDX),PANSR(IDX)                    STR02390
 5001 FORMAT(12X,F7.3,14X,F6.2,15X,E10.4)                               STR02400
   60 CONTINUE                                                          STR02410
      ION=5                                                             STR02420
      GO TO 700                                                         STR02430
801   WRITE(6,805) ANSWER                                               STR02440
  805 FORMAT(' ANSWER= ',D10.4)                                         STR02450
      ION=5                                                             STR02460
      GO TO 700                                                         STR02470
  800 CONTINUE                                                          STR02480
      STOP                                                              STR02490
C        ERROR STOP                                                     STR02500
  900 STOP 601                                                          STR02510
      END                                                               STR02520
```

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PILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=56,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

```
      SUBROUTINE AMODES (NST,NEND,IST,ISEND,MST,MEND,ICN,*)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS SUBROUTINE CALCULATES THE ACOUSTIC MODAL FREQUENCIES.      C
C     EACH FREQUENCY CALCULATED HAS THREE ASSOCIATED INDICES, M,N,IS. C
C     THE FREQUENCIES SQUARED ARE CALCULATED AND PLACED IN ARRAY      C
C     ACMODS.  THE THREE INDICES ARE PACKED INTO ONE WORD AND STORED  C
C     IN ARRAY MNS WITH THE SAME SUBSCRIPT AS ACMODS.  ALTHOUGH THE   C
C     INDICES ARE PACKED IN THE ORDER M,N,IS THE CALCULATIONS ARE     C
C     PERFORMED IN NESTED LOOPS WITH M CIRCULATING FASTEST FOLLOWED   C
C     BY IS AND N. THE INDICES ALL BEGIN AT ZERO.                     C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION BUF(3),IBUF(3)
      COMMON /CONST/PI
      COMMON /NORMAL/DENOM
      COMMON /VARSQ/CSQ,PIOL2
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      COMMON /SOLNS/SNK(400),KNS(400),NUMK
      GO TO (100,100,200,200),ICN
C
C        INITIALIZE THE INCREMENT TEST VARIABLE FOR ROUTINE REGFAL.
C        THIS VALUE OF ZERO IS PASSED THROUGH ROOT TO REGFAL FOR
C        USE THE FIRST TIME REGFAL IS CALLED.
  100 XNS=0.D0
      CRITH=1.D30
      I=1
      J=1
C        LOOP OVER THREE MODAL INDICES
C
C        NOTE THAT THE DEGENERATE CASE OF M=0,N=0,IS=0 WHICH PRODUCES
C        W2MNS=0 IS ELIMINATED THROUGH THE USE OF CRITL WHICH IS
C        ALWAYS GREATER THAN ZERO.
   10 N=NST
   11 IS=IST
C        FIND THE NS TH EIGENVALUE
   12 CALL ROOT (N,IS,XNS,&50)
C        NORMALIZE THE EIGENVALUE FOR OUR USE
      XNSSQ=(XNS/DENOM)**2
      M=MST
C        CALCULATE MODAL FREQUENCY SQUARED AND CHECK IF IT WILL BE OF
C        CONSEQUENCE
   16 W2MNS=CSQ*(XNSSQ+M*M*PIOL2)
      IF(W2MNS.GT.CRITH) GO TO 21
C        SAVE FREQUENCY SQUARED AND PACKED INDICES
      ACMODS(I)=W2MNS
      IWORD=N*1000+IS
      MNS(I)=M*1000000+IWORD
      I=I+1
```

```
   20 M=M+1                                                              AM000530
      IF(M.GT.MEND) GO TO 22                                             AM000540
      GO TO 16                                                           AM000550
C        IF M=MST HERE THE NS TH EIGENVALUE WAS NCT USED AND             AM000560
C        SHOULD NOT BE SAVED                                             AM000570
   21 IF(M.EQ.MST) GO TO 26                                              AM000580
C        SAVE EIGENVALUES AND PACKED INDICES                             AM000590
   22 IF((IS.EQ.IST).AND.(N.EQ.NST))CRITH=-2MNS                          AM000600
      SNK(J)=XNS                                                         AM000610
      KNS(J)=IWORD                                                       AM000620
      J=J+1                                                              AM000630
      GO TO 27                                                           AM000640
C        REDEFINE MAXIMUM IS VALUE.  IF THE M LOOP HAS KICKED CUT CN     AM000650
C        THE FIRST VALUE OF M THEN THE VALUE CF IS AT THAT PCINT IS THE  AM000660
C        MAXIMUM VALUF OF IS WE NEED TC LOCK AT IN FURTHER ITERATICNS.   AM000670
   26 ISEND=IS                                                           AM000680
   27 IS=IS+1                                                            AM000690
      IF(IS.GT.ISEND) GO TO 30                                           AM000700
      GO TO 12                                                           AM000710
   30 N=N+1                                                              AM000720
      IF(N.GT.NEND) GO TO 31
      GO TO 11                                                           AM000740
C        NUMBER OF ACOUSTIC MODAL FREQUENCIES AND EIGENVALUES            AM000750
   31 NUMAC=I-1                                                          AM000760
      NUMK=J-1                                                           AM000770
      CALL SORT(ACMODS,MNS,NUMAC)                                        AM000780
      WRITE(1,250)NST,NEND,IST,ISEND,MST,MEND,NUMAC,NUMK                 AM000790
      NRC1=NUMAC/5                                                       AM000800
      IF(NRC1*5.LT.NUMAC)NRC1=NRC1+1                                     AM000810
      DO 60 JJJ=1,NRC1                                                   AM000820
      IND1=5*(JJJ-1)+1                                                   AM000830
      IND2=IND1+4                                                        AM000840
      IF(IND2.GT.NUMAC)IND2=NUMAC                                        AM000850
      WRITE(1,250)(MNS(III),III=IND1,IND2)                               AM000860
      WRITE(1,350)(ACMODS(III),III=IND1,IND2)                            AM000870
   60 CONTINUE                                                           AM000880
      NRC1=NUMK/5                                                        AM000890
      IF(NRC1*5.LT.NUMK)NRC1=NRC1+1                                      AM000900
      DO 61 JJJ=1,NRC1                                                   AM000910
      IND1=5*(JJJ-1)+1                                                   AM000920
      IND2=IND1+4                                                        AM000930
      IF(IND2.GT.NUMK)IND2=NUMK                                          AM000940
      WRITE(1,250)(KNS(III),III=IND1,IND2)                               AM000950
      WRITE(1,350)(SNK(III),III=IND1,IND2)                               AM000960
   61 CONTINUE                                                           AM000970
  250 FORMAT(8I10)                                                       AM000980
  350 FORMAT(5D16.10)                                                    AM000990
C        WRITE STRUCTURAL MODE FRECUENCIES                               AM001000
      TWOPI=2.D0*PI                                                      AM001010
      WRITE(6,2000)                                                      AM001020
 2000 FORMAT(1H1,T18,'ACOUSTIC MODAL FREQUENCIES AND INDICES'            AM001030
     1   ///,     3('INDICES',3X,'FREQUENCIES', 3X),//)                  AM001040
      KOUNT=0                                                            AM001050
      DO 40 I=1,NUMAC,3                                                  AM001060
```

```
      K=I+2
C        WRITE FREQUENCIES IN HERTZ
      L=1
      DO 35 J=I,K
      BUF(L)=DSQRT(ACMODS(J))/TWOPI
      IBUF(L)=MNS(J)
   35 L=L+1
      WRITE(6,2001) (IBUF(J),BUF(J),J=1,3)
 2001 FORMAT(1H ,3(I9,3X,F8.1,4X))
      KOUNT=KOUNT+1
      IF(MOD(KOUNT,50).EQ.0) WRITE(6,2000)
   40 CONTINUE
      RETURN
  200 READ(1,250)INST,NEND,IST,ISEND,MST,MEND,NUMAC,NUMK
      NRC1=NUMAC/5
      IF(NRC1*5.LT.NUMAC)NRC1=NRC1+1
      DO 70 JJJ=1,NRC1
      IND1=5*(JJJ-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUMAC)IND2=NUMAC
      READ(1,250)(MNS(III),III=IND1,IND2)
      READ(1,350)(ACMODS(III),III=IND1,IND2)
   70 CONTINUE
      NRC1=NUMK/5
      IF(NRC1*5.LT.NUMK)NRC1=NRC1+1
      DO 71 JJJ=1,NRC1
      IND1=5*(JJJ-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUMK)IND2=NUMK
      READ(1,250)(KNS(III),III=IND1,IND2)
      READ(1,350)(SNK(III),III=IND1,IND2)
   71 CONTINUE
      RETURN
   50 RETURN 1
      END
```

```
PILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE BESSEL (N,XX,BLJ,BLY)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS ROUTINE DECIDES AND CONTROLS WHICH METHOD WILL BY USED TO  C
C     CALCULATE THE BESSEL AND NEUMANN FUNCTIONS.  THE SAME CRITERIA  C
C     IS USED FOR BOTH.  FOR ARGUMENTS GREATER THAN TEN, THE          C
C     ASYMPTOTIC SERIES TECHNIQUE IS USED. THE ASYMPTOTIC SERIES IS   C
C     FOLLOWED BY A RECURSION PROCEDURE IF THE ORDER SPECIFIED IS     C
C     GREATER THAN EIGHT.  FOR SMALLER ARGUMENTS THE ACTUAL SERIES    C
C     DEFINITIONS OF THE FUNCTIONS ARE USED.  THIS TECHNIQUE IS USED  C
C     FOR ORDERS UP TO 55.  ABOVE THAT THE VALUES FOR SMALL ARGUMENTS C
C     (LESS THAN 10) ARE DEFINED TO BE ZERO AND NEGATIVE INFINITY.    C
C     THE RECURSION PROCEDURE MAY NOT WORK IF THE TECHNIQUE IS USED   C
C     TO FIND A RESULT WHICH SHOULD BE LESS THAN 1.-10 IN ABSOLUTE    C
C     VALUE DUE TO SUCCESSIVE ROUNDOFF ERRORS.                        C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /RADII/RIN,ROUT
C
C        ASYMPTOTIC SERIES EXPRESSIONS
      BSLY(TOTP,TOTQ,ARG)=DSQRT(2.D0/(PI*XX))*(TOTP*DSIN(ARG)
     1 +TOTQ*DCOS(ARG))
      BSLJ(TOTP,TOTQ,ARG)=DSQRT(2.D0/(PI*XX))*(TOTP*DCOS(ARG)
     1 -TOTQ*DSIN(ARG))
C
      IF(XX.GT.10.D0) GO TO 10
      IF(N.GT.55) GO TO 30
C        USE ACTUAL SERIES DEFINITIONS
      CALL BLJDEF(N,XX,BLJ)
C        NO NEED TO CALCULATE NEUMANN FUNCTIONS FOR HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) RETURN
      CALL BLYDEF(N,XX,BLJ,BLY)
      RETURN
   10 IF(N.GT.8) GO TO 20
C        USE ASYMPTOTIC SERIES
      CALL PSQS(N,XX,TOTP,TOTQ,ARG)
      BLJ=BSLJ(TOTP,TOTQ,ARG)
C        CHECK HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) RETURN
      BLY=BSLY(TOTP,TOTQ,ARG)
      RETURN
C        USE ASYMPTOTIC SERIES THEN RECURSION
   20 CALL PSQS(8,XX,TOTP,TOTQ,ARG)
      BLJN=BSLJ(TOTP,TOTQ,ARG)
C        CHECK HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) GO TO 25
      BLYN=BSLY(TOTP,TOTQ,ARG)
      CALL PSQS(7,XX,TOTP,TOTQ,ARG)
```

```
      BLJNM1=BSLJ(TOTP,TOTQ,ARG)
      BLYNM1=BSLY(TOTP,TOTQ,ARG)
      CALL RECUR(N,XX,BLJN,BLJNM1,BLJ)
      CALL RECUR(N,XX,BLYN,BLYNM1,BLY)
      RETURN
C        HOLLOW CYLINDER CASE HERE
   25 CALL PSQS(7,XX,TOTP,TOTQ,ARG)
      BLJNM1=BSLJ(TOTP,TOTQ,ARG)
      CALL RECUR(N,XX,BLJN,BLJNM1,BLJ)
      RETURN
   30 BLJ=0.D0
      BLY=-1.D75
      RETURN
      END
```

```
PILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=C000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE BLJDEF (N,X,BLJ)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE BESSEL FUNCTION USING THE ACTUAL     C
C     SERIES DEFINITION FOR ARGUMENTS LESS THAN OR EQUAL TO TEN.       C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONV/UP,DN
      COMMON /FCTRL/FAC(57),PSI(60)
C
      IF(X.EQ.0.D0) GO TO 30
C        WATCH LIMITS OF STORED FACTORIALS
      Z=1.D0
      M=57-N
      M=57-N
      Z=1.D0
      ZZ=X*X
      SUM=0.D0
      TOTAL=0.D0
      EJ=1.
      DO 10 I=1,M
      K=I-1
      VAR=2.D0**(2*K+N)
      TOTAL=SUM+EJ*Z/FAC(I)/FAC(I+N)/VAR
      IF(TOTAL.EQ.0.D0) GO TO 5
C        CHECK CONVERGENCE
      VAL=SUM/TOTAL
      IF(VAL.GT.DN.AND.VAL.LT.UP) GO TO 20
    5 EJ=-EJ
      Z=Z*ZZ
      SUM=TOTAL
   10 CONTINUE
   20 BLJ=X**N*TOTAL
      RETURN
   30 IF(N.GT.0) GO TO 40
      BLJ=1.D0
      RETURN
   40 BLJ=0.D0
      RETURN
      END
```

```
PILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE BLYDEF (N,X,BLJ,BLY)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS ROUTINE CALCULATES THE NEUMANN FUNCTION USING THE          C
C     ACTUAL SERIES DEFINITION FOR ARGUMENTS LESS THAN OR EQUAL TO 10 C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /CONV/UP,DN
      COMMON /FCTRL/FAC(57),PSI(60)
C
      IF(X.EQ.0.D0) GO TO 50
      TOTAL=0.D0
      CUM=0.D0
      SUM=0.D0
      Z=X*X/4.D0
      IF(N.EQ.0) GO TO 15
      ZZ=1.D0
      DO 10 I=1,N
      DIV=FAC(N-I+1)/FAC(I)
      CUM=CUM+DIV*ZZ
      ZZ=ZZ*Z
   10 CONTINUE
   15 ZZ=1.D0
      EJ=1.
      M=57-N
      DO 30 I=1,M
      DIV=ZZ/FAC(I)
      TOTAL=SUM+(PSI(I)+PSI(I+N))*EJ*DIV/FAC(I+N)
      IF(TOTAL.EQ.0.D0) GO TO 20
C        CHECK CONVERGENCE
      VAL=SUM/TOTAL
      IF(VAL.GT.DN.AND.VAL.LT.UP) GO TO 40
   20 EJ=-EJ
      ZZ=ZZ*Z
      SUM=TOTAL
   30 CONTINUE
   40 DIV=((2.D0/X)**N)/PI
      BLY=(-DIV)*CUM+(2.D0/PI)*DLOG(X/2.D0)*BLJ-(((X/2.D0)**N)/PI)*TOTAL
      RETURN
   50 BLY=-1.D75
      RETURN
   60 BLY=1.D75
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION CAPGAM (N,IQ)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     ACCEPTANCE SQUARED IN THE CIRCUMFERENTIAL DIRECTION.             C
C     THIS SUBROUTINE COMPUTES THE STRUCTURAL TO ACOUSTIC              C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ACCEPT/ALFA
      COMMON/ CONST/PI
      BN = FLOAT(N)
      QPI = PI*FLOAT(IQ)
      QPIA = QPI/ALFA
      IF(DABS(BN-QPIA).GT.1.D-2) GO TO 10
      CAPGAM=ALFA/2.D0
      GO TO 20
   10 TSTANG=QPI+ALFA*BN
      ANGUM=DMOD(TSTANG,PI*2.D0)
      IF(ANGUM.LT.1.D-2.OR.(PI*2.D0-ANGUM).LT.1.D-2)GO TO 30
      PHIO=-ALFA/2.D0
      IF((IQ/2)*2.EQ.IQ.AND.N.NE.0)PHIO=PHIO+PI/(BN*2.D0)
      IF(DABS(DMOD(BN*PHIO,PI))-PI/2.D0).LT.1.D-2)GO TO 30
      CAPGAM=(DCOS(BN*PHIO)-DCOS(QPI+BN*(PHIO+ALFA)))/(QPIA+BN)
     1       +(DCOS(BN*PHIO)-DCOS(QPI-BN*(PHIO+ALFA)))/(QPIA-BN)
      CAPGAM=CAPGAM/2.D0
   20 CAPGAM = CAPGAM**2
      RETURN
   30 CAPGAM=0.D0
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE COPYC (N)
C                                                                     C
C**********************************************************************C
C                                                                     C
C     THIS SUBROUTINE COPIES STRUCTURAL MODES STMODS AND INDICES      C
C     MPQ INTO TEMPORARY ARRAYS FROM WHICH THEY ARE CROSSED OUT AS    C
C     THEY ARE USED.  THIS ROUTINE IS USED BY MAIN PROGRAMS 'PURTCN'  C
C     AND 'ACCBAN'.                                                   C
C                                                                     C
C**********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /SAMPLE/TEMP(1200),LPQS(1200),NUMTMP
      COMMON /STRUCT/STMODS(1200),MPQ(1200),STMOD3(400,3),MPQ3(400),
     1          NUMST,NUM3
C
      DO 10 I=1,NUMST
      TEMP(I)=STMODS(I)
      LPQS(I)=MPQ(I)
   10 CONTINUE
C         NUMBER OF ELEMENTS IN TEMP ARRAY
      NUMTMP = NUMST
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                 SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE CUBIC(X,P,Q,R,*)                                      CUB00010
      IMPLICIT REAL*8(A-D,F-H,O-Z)                                     CUB00020
      DIMENSION X(3)                                                   CUB00030
      DATA PI/3.14159265358979D0/                                      CUB00040
       A=Q-P*P/3.D0                                                    CUB00050
      B=(2.D0*P**3-9.D0*P*Q+27.D0*R)/27.D0                             CUB00060
      IF((B**2/4.D0+A**3/27.D0).GT.0.D0) GO TO 10                      CUB00070
      RTA3=DSQRT(-A/3.D0)                                              CUB00080
      PHI=DARCOS(-B/(2.D0*DSQRT(-A**3/27.D0)))                         CUB00090
      X(1)=2.D0*RTA3*DCOS(PHI/3.D0)-P/3.D0                             CUB00100
      X(2)=2.D0*RTA3*DCOS(PHI/3.D0+2.D0*PI/3.D0)-P/3.D0                CUB00110
      X(3)=2.D0*RTA3*DCOS(PHI/3.D0+4.D0*PI/3.D0)-P/3.D0                CUB00120
      RETURN                                                           CUB00130
   10 WRITE(7,100)                                                     CUB00140
  100 FORMAT(1X,'IMAGINARY ROOTS')                                     CUB00150
      RETURN 1                                                         CUB00160
      END                                                              CUB00170
```

```
IMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      BLOCK DATA                                                        DAT00010
      IMPLICIT REAL*8 (A-D,F-H,O-Z)                                     DAT00020
      DIMENSION FAC1(27),FAC2(30),PSI1(30),PSI2(30)                     DAT00030
      COMMON /CONST/PI                                                  DAT00040
      COMMON /CONV/UP,DN                                                DAT00050
      COMMON /DIR/ISAME,IOPP                                            DAT00060
      COMMON /FCTRL/FAC(57),PSI(60)                                     DAT00070
      EQUIVALENCE (FAC(1),FAC1(1)),(FAC(28),FAC2(1))                    DAT00080
      EQUIVALENCE (PSI(1),PSI1(1)),(PSI(31),PSI2(1))                    DAT00090
      DATA PI/3.14159265358979300/,UP,DN/1.00000050D0,0.99999950D0/     DAT00100
      DATA ISAME,IOPP/1,-1/                                             DAT00110
C        STORED FACTORIALS                                              DAT00120
      DATA FAC1/1.0D0,.10000000D+01,.20000000D+01,                      DAT00130
     *          .6000000000000000D+01,.2400000000000000D+02,            DAT00140
     *          .1200000000000000D+03,.7200000000000000D+03,            DAT00150
     *          .5040000000000000D+04,.4032000000000000D+05,            DAT00160
     *          .3628800000000000D+06,.3628800000000000D+07,            DAT00170
     *          .3991680000000000D+08,.4790016000000000D+09,            DAT00180
     *          .6227020800000000D+10,.8717829120000000D+11,            DAT00190
     *          .1307674368000000D+13,.2092278988800000D+14,            DAT00200
     *          .3556874280960000D+15,.6402373705728000D+16,            DAT00210
     *          .1216451004088320D+18,.2432902008176640D+19,            DAT00220
     *          .5109094217170944D+20,.1124000727777608D+22,            DAT00230
     *          .2585201673888498D+23,.6204484017332394D+24,            DAT00240
     *          .1551121004333099D+26,.4032914611266056D+27/            DAT00250
      DATA FAC2/.1088886945041835D29,.3048883446117138D30,              DAT00260
     *          .8841761993739700D+31,.2652528598121910D+33,            DAT00270
     *          .8222838654177920D+34,.2631308369336934D+36,            DAT00280
     *          .8683317618811884D+37,.2952327990396040D+39,            DAT00290
     *          .1033314796638614D+41,.3719933267899011D+42,            DAT00300
     *          .1376375309122634D+44,.5230226174666010D+45,            DAT00310
     *          .2039788208119743D+47,.8159152832478974D+48,            DAT00320
     *          .3345252661316379D+50,.1405006117752879D+52,            DAT00330
     *          .6041526306337380D+53,.2658271574788447D+55,            DAT00340
     *          .1196222208654801D+57,.5502622159812085D+58,            DAT00350
     *          .2586232415111680D+60,.1241391559253606D+62,            DAT00360
     *          .6082818640342671D+63,.3041409320171335D+65,            DAT00370
     *          .1551118753287381D+67,.8065817517094381D+68,            DAT00380
     *          .4274883284060022D+70,.2308436973392412D+72,            DAT00390
     *          .1269640335365826D+74,.7109985878048627D+75/            DAT00400
C        STORED PSI FUNCTIONS                                           DAT00410
      DATA PSI1/-.5772156649015329D00,0.4227843350984671D00,            DAT00420
     *          0.9227843350984671D+00,0.1256117668431800D+01,          DAT00430
     *          0.1506117668431800D+01,0.1706117668431800D+01,          DAT00440
     *          0.1872784335098467D+01,0.2015641477955610D+01,          DAT00450
     *          0.2140641477955610D+01,0.2251752589066720D+01,          DAT00460
     *          0.2351752589066720D+01,0.2442661679975811D+01,          DAT00470
     *          0.2525995013309144D+01,0.2602918090232221D+01,          DAT00480
     *          0.2674346661660793D+01,0.2741013328327459D+01,          DAT00490
     *          0.2803513328327459D+01,0.2862336857739224D+01,          DAT00500
     *          0.2917892413294779D+01,0.2970523992242148D+01,          DAT00510
     *          0.3020523992242147D+01,0.3068143039861195D+01,          DAT00520
```

```
     *                          0.31135975853157430D+01,0.31570758461853050D+01,  DAT00530
     *                          0.31987425128519720D+01,0.32387425128519720D+01,  DAT00540
     *                          0.32772040513135100D+01,0.3314241088353547D+01,   DAT00550
     *                          0.33499553740648330D+01,0.33844381326855220D+01/  DAT00560
      DATA PSI2/0.3417771466018855D1,0.345002953053498401,                        DAT00570
     *                          0.34812795305349840D+01,0.35115825608380150D+01,  DAT00580
     *                          0.35409943255438970D+01,0.35695657541153250D+01,  DAT00590
     *                          0.35973435318931030D+01,0.36243705589201300D+01,  DAT00600
     *                          0.36506863483938140D+01,0.36763273740348400D+01,  DAT00610
     *                          0.37013273740348400D+01,0.37257176179372780D+01,  DAT00620
     *                          0.37495271417468020D+01,0.37727829557002900D+01,  DAT00630
     *                          0.37955102284275630D+01,0.38177324506497850D+01,  DAT00640
     *                          0.38394715810845680D+01,0.38607481768292480D+01,  DAT00650
     *                          0.38815815101625820D+01,0.39019896734278880D+01,  DAT00660
     *                          0.39219896734278870D+01,0.39415975165651420D+01,  DAT00670
     *                          0.39608282857959110D+01,0.39796962103242130D+01,  DAT00680
     *                          0.39982147288427320D+01,0.40163965470245500D+01,  DAT00690
     *                          0.40342536898816930D+01,0.40517975495308150D+01,  DAT00700
     *                          0.40690389288411600D+01,0.40859880813835330D+01/  DAT00710
      END                                                                         DAT00720
```

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```
IMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION DOB (N,RK)
C                                                                      C
C*********************************************************************C
C                                                                      C
C     FUNCTION DOB EVALUATES THE EIGENVALUE EQUATION, WHICH IS THE     C
C     EQUATION OF THE CROSS PRODUCT OF THE DERIVATIVES OF THE          C
C     BESSEL AND NEUMANN FUNCTIONS.  THE SIMPLE DERIVATIVE OF J(X) IS C
C     ALSO HANDLED FOR THE HOLLOW CYLINDER CASE.                       C
C                                                                      C
C*********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /EIGEN/BETA,BETA3,BETA5
      COMMON /RADII/RIN,ROUT
C
      AKN=N/RK
C        USE THE RECURSION RELATION TO FIND THE DERIVATIVES
      CALL BESSEL (N,RK,AKJN,AKYN)
      CALL BESSEL (N+1,RK,AKJNP1,AKYNP1)
C        CHECK FOR THE HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) GO TO 10
      BK=RK*BETA
      BKN=N/BK
      CALL BESSEL (N,BK,BKJN,BKYN)
      CALL BESSEL (N+1,BK,BKJNP1,BKYNP1)
C        EVALUATE EIGENVALUE EQUATION
      DOB=(AKN*AKJN-AKJNP1)*(BKN*BKYN-BKYNP1)-(BKN*BKJN-BKJNP1)*
     1    (AKN*AKYN-AKYNP1)
      RETURN
   10 DOB=AKN*AKJN-AKJNP1
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE FNDNST (L,K,I,ISAVE,N,IA,NUM,*,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS SUBROUTINE SEARCHES THE INPUT IA ARRAY FOR THE 'NEXT'       C
C     REQUESTED VALUE. THIS NEXT VALUE MAY BE EITHER IN THE UPWARDS    C
C     (DECREASING SUBSCRIPT) OR DOWNWARDS (INCREASING SUBSCRIPT)       C
C     DIRECTION.  THE INPUT IA ARRAY IS THE ARRAY OF INDICES FOR THE   C
C     MODAL FREQUENCIES.  THIS ROUTINE IS USED IN 'PCALCC', CALLED     C
C     BY MAIN PROGRAMS 'PURTON' AND 'ACOBAN'.                          C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION IA(1)
      COMMON /ERROR/LAST
C
C        SAVE CURRENT INDEX
      LAST=I
C        L*K LESS THAN ZERO MEANS PROCEED IN DOWNWARDS DIRECTION
      IF((L*K).LT.0) GO TO 30
C        IF OPPOSITE DIRECTION, START AT INDEX LOCATION WE LAST USED
C        IN THAT DIRECTION.
      IF(L.EQ.-1) I=ISAVE
      KK=I-1
      IF(KK.LT.1) GO TO 15
C        SEARCH FOR MATCHING FIRST TWO (OR ONE) MODAL INDEX
C        IN UPWARDS DIRECTION
      DO 10 II=1,KK
      J=KK-II+1
      IF(IA(J).NE.999999) GO TO 20
   10 CONTINUE
   15 CONTINUE
      IF(KK.LT.1.AND.L.EQ.-1) ISAVE=LAST
      RETURN 2
C        IF OPPOSITE DIRECTION SAVE INDEX OF OTHER DIRECTION
   20 IF(L.EQ.-1) ISAVE=LAST
      K=J
      I=J
      RETURN 1
C        DOWNWARDS DIRECTION
   30 JJ=I+1
C        IF OPPOSITE DIRECTION START AT SAVED INDEX+1
      IF(L.EQ.-1) JJ=ISAVE+1
      IF(JJ.GT.NUM) GO TO 45
      DO 40 II=JJ,NUM
      IF(IA(II).NE.999999) GO TO 50
   40 CONTINUE
   45 CONTINUE
      IF(JJ.GT.NUM.AND.L.EQ.-1) ISAVE=LAST
      RETURN 2
   50 IF(L.EQ.-1) ISAVE=LAST
```

```
      K=-II
      I=II
      RETURN 1
      END
```

COMPILER OPTIONS - NAME= MAIN,OPT=02,LINECNT=56,SIZE=0000K,
SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

```
      SUBROUTINE FNDNXT (L,K,I,ISAVE,N,IA,NUM,*,*)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS SUBROUTINE SEARCHES THE INPUT IA ARRAY FOR THE 'NEXT'      C
C     REQUESTED VALUE. THIS NEXT VALUE MAY BE EITHER IN THE UPWARDS   C
C     (DECREASING SUBSCRIPT) OR DOWNWARDS (INCREASING SUBSCRIPT)      C
C     DIRECTION.  THE INPUT IA ARRAY IS THE ARRAY OF INDICES FOR THE  C
C     MODAL FREQUENCIES.  THIS ROUTINE IS USED BY MAIN PROGRAMS       C
C     'PURTON' AND 'ACOBAN'.                                          C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION IA(1)
      COMMON /ERROR/LAST
C
C        SAVE CURRENT INDEX
      LAST=I
C        L*K LESS THAN ZERO MEANS PROCEED IN DOWNWARDS DIRECTION
      IF((L*K).LT.0) GO TO 30
C        IF OPPOSITE DIRECTION, START AT INDEX LOCATION WE LAST USED
C        IN THAT DIRECTION.
      IF(L.EQ.-1) I=ISAVE
      KK=I-1
      IF(KK.LT.1) GO TO 15
C        SEARCH FOR MATCHING FIRST TWO (OR ONE) MODAL INDEX
C        IN UPWARDS DIRECTION
      DO 10 II=1,KK
      J=KK-II+1
      ITST=IA(J)/1000
      IF(ITST.EQ.N) GO TO 20
   10 CONTINUE
   15 CONTINUE
      IF(KK.LT.1.AND.L.EQ.-1) ISAVE=LAST
      RETURN 2
C        IF OPPOSITE DIRECTION SAVE INDEX OF OTHER DIRECTION
   20 IF(L.EQ.-1) ISAVE=LAST
      K=J
      I=J
      RETURN 1
C        DOWNWARDS DIRECTION
   30 JJ=I+1
C        IF OPPOSITE DIRECTION START AT SAVED INDEX+1
      IF(L.EQ.-1) JJ=ISAVE+1
      IF(JJ.GT.NUM) GO TO 45
      DO 40 II=JJ,NUM
      ITST=IA(II)/1000
      IF(ITST.EQ.N) GO TO 50
   40 CONTINUE
   45 CONTINUE
      IF(JJ.GT.NUM.AND.L.EQ.-1) ISAVE=LAST
```

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```
      RETURN 2
   50 IF(L.EQ.-1) ISAVE=LAST
      K=-II
      I=II
      RETURN 1
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE FRSFND (A,NSIZE,K)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE IS USED TO FIND THE MODAL FREQUENCY IN THE INPUT    C
C     ARRAY WHICH IS NUMERICALLY CLOSEST TO THE EXTERIOR EXCITATION    C
C     FREQUENCY.  THE VALUE RETURNED IS THE INDEX OF THE LOCATION      C
C     IN THE ASSOCIATED INDICIES ARRAY.  THE RETURN VALUE IS GIVEN     C
C     A NEGATIVE SIGN IF THE NEXT CLOSEST VALUE IS IN THE UPWARDS      C
C     DIRECTION (DECREASING SUBSCRIPT) OR A POSITIVE SIGN IF THE       C
C     NEXT  CLOSEST VALUE IS IN THE DOWNWARDS DIRECTION (INCREASING    C
C     SUBSCRIPT).                                                      C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION A(1)
      COMMON /FREQ/WSQ
C
C        NUM = CLOSEST EVEN NUMBER TO NSIZE
      NUM=(NSIZE/2)*2
C        SEARCH TWO AT A TIME
      DO 10 I=1,NUM,2
      IF(A(I).GT.WSQ.AND.A(I+1).GT.WSQ) GO TO 10
C        IF THE CRITERIA IS SATISFIED THE FIRST TIME START
C        AT THE TOP OF THE ARRAY
      IF(I.EQ.1) GO TO 70
C        FIND DISTANCE TO FREQUENCY (I)
      TST1=DABS(WSQ-A(I))
      IF(A(I).GT.WSQ)  GO TO 30
      GO TO 20
   10 CONTINUE
C        START AT BOTTOM OF ARRAY
      GO TO 80
C        FIND DISTANCE TO FREQUENCY BELOW
   20 TST2=DABS(WSQ-A(I-1))
      IF(TST1-TST2) 40,50,50
C        FIND DISTANCE TO FREQUENCY ABOVE
   30 TST2=DABS(WSQ-A(I+1))
      IF(TST2-TST1) 60,70,70
C        DEFINE INDEX AND SIGN
   40 K=-I
      RETURN
   50 K=I-1
      RETURN
   60 K=-(I+1)
      RETURN
   70 K=I
      RETURN
   80 K=-NSIZE
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION GAMA (M,IP)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS FUNCTION CALCULATES THE ACCEPTANCE FUNCTION BETWEEN         C
C     STRUCTURAL MODE IP AND ACOUSTIC MODE M.                          C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /TERMS/RATIO,SEGLTH,PICYL,Z0,PICYLZ,PILSC,PISEG
C
      RATM=M*RATIO
C        CHECK FOR SPECIAL CASE OF INDEX COMBINATION
      IF(DFLOAT(IP).EQ.RATM) GO TO 10
      RATMPI=RATM*PI
      F1=M*PICYL
      F2=IP*PISEG
      F1F2=F2-F1
      FRONT=1.D0/(2.D0*F1F2)
      FRNT=1.D0/(2.D0*(F1+F2))
      ARG3=F1*Z0
      ARG1=ARG3
      F3=RATMPI+ARG3
      ARG2=IP*PI-F3
      ARG4=IP*PI+F3
      TSTANG=DABS(ARG1-ARG2)
      ANGUM=DMOD(TSTANG,PI*2.D0)
      IF(ANGUM.LT.1.D-2.OR.(2.D0*PI-ANGUM).LT.1.D-2)GO TO 20
      GAMA=FRONT*(DCOS(ARG1)-DCOS(ARG2))+FRNT*(DCOS(ARG3)-DCOS(ARG4))
      RETURN
   10 ARG1=IP*PISEG*Z0
      SIND=DSIN(ARG1)
      IF(DABS(SIND).LT.1.D-2)GO TO 20
      GAMA=SEGLTH*SIND/2.D0
      RETURN
   20 GAMA=0.D0
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE HSQMNB (W2MNS,IWORD,M,N,HOTHR,H2MNS,*)
C                                                                      C
C***********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE ACOUSTICAL MODE AMPLIFICATION       C
C     FUNCTION SQUARED, INTEGRATED OVER A BANDWIDTH.  THIS ROUTINE    C
C     IS USED BY MAIN PROGRAM 'ACOBAN'.                               C
C                                                                      C
C***********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ACDAMP/ACDAMA,ACDAMB
      COMMON /BESQR/B2
      COMMON /CONST/PI
      COMMON /FREQ/WSQ
      COMMON /NORMAL/DENOM
      COMMON /RADII/RIN,ROUT
      COMMON /VRBLS/PIOL4,RIN2,ACDACO
      COMMON /SOLNS/SNK(400),KNS(400),NUMK
      COMMON /OTHER/ROTHR(4),ZOTHR(4),CYLNTH
      DIMENSION HOTHR(4)
C
C        FIND MATCHING EIGENVALUE
      NS=MOD(IWORD,1000000)
      DO 10 I=1,NUMK
      IF(KNS(I).EQ.NS) GO TO 20
   10 CONTINUE
      WRITE(6,2000)
 2000 FORMAT(1X,'MATCHING EIGENVALUE INDICES NOT FOUND FOR REQUESTED COM
     1BINATION',/)
      RETURN 1
   20 SQN=N*N
      EM=1.
      IF(IWORD.LT.1000000) EM=2.
      EN=1.
      IF(N.EQ.0) EN=2.
      SQETA=(ACDAMA**2/(2.D0*PI)**(2.D0*ACDAMB))*W2MNS**(1.D0+ACDAMB)
      TERM=DSQRT(SQETA)/PI
      SNKNOR=SNK(I)/DENOM
      IF(SNK(I).EQ.0.D0) GO TO 30
C        NORMALIZE EIGENVALUE FOR OUR USE
      QB=QSQ(N,SNKNOR,ROUT)
      DIV=SQN/(SNKNOR*SNKNOR)
C        NOTE THIS EXPRESSION TAKES CARE OF ITSELF FOR
C        THE HOLLOW CYLINDER CASE
      AGEMO=EM*EN*PIOL4*((B2-DIV)*QB-(RIN2-DIV)*QSQ(N,SNKNOR,RIN))
      H2MNS=QB/(AGEMO*TERM)
      GO TO 50
   30 AGEMO=EM*EN*PIOL4*(B2-RIN2)
C        NOTE CANCELLATION OF THE QSQ(0) TERM
      H2MNS=1.D0/(AGEMO*TERM)
   50 DO 60 IDX=1,4
```

```
      R=ROTHR(IDX)
      Z=ZOTHR(IDX)
      HOTHR(IDX)=H2MNS*(DCOS(PI*M*Z/CYLNTH))**2
     1/AGEMO
      IF(SNK(I).NE.0.D0)HOTHR(IDX)=HOTHR(IDX)*QSQ(N,SNKNOR,R)
   60 CONTINUE
      RETURN
      END
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                 SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE HSQMNS (W2MNS,IWORD,M,N,HOTHR,H2MNS,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE ACOUSTICAL MODE AMPLIFICATION        C
C     FUNCTION SQUARED.  THIS ROUTINE IS USED BY MAIN PROGRAMS         C
C     'PURTON' AND 'STRBAN'.                                           C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ACDAMP/ACDAMA,ACDAMB
      COMMON /BESQR/B2
      COMMON /CONST/PI
      COMMON /FREQ/WSQ
      COMMON /NORMAL/DENOM
      COMMON /RADII/RIN,ROUT
      COMMON /VRBLS/PIOL4,RIN2,ACDACC
      COMMON /SOLNS/SNK(400),KNS(400),NUMK
      COMMON /OTHER/ROTHR(4),ZOTHR(4),CYLNTH
      DIMENSION HOTHR(4)
C
C        FIND MATCHING EIGENVALUE
      NS=MOD(IWORD,1000000)
      DO 10 I=1,NUMK
      IF(KNS(I).EQ.NS) GO TO 20
   10 CONTINUE
      WRITE(6,2000)
 2000 FORMAT(1X,'MATCHING EIGENVALUE INDICES NOT FOUND FOR REQUESTED COM
     1BINATION',/)
      RETURN 1
   20 SQN=N*N
      EM=1.
      IF(IWORD.LT.1000000) EM=2.
      EN=1.
      IF(N.EQ.0) EN=2.
      SQETA=0.D0
      IF(W2MNS.EQ.0.D0) GO TO 40
      SQETA=(ACDAMA**2/(2.D0*PI)**(2.D0*ACDAMB))*W2MNS**(1.D0+ACDAMB)
   40 TERM=(W2MNS-WSQ)**2+SQETA*WSQ
      SNKNOR=SNK(I)/DENOM
      IF(SNK(I).EQ.0.D0) GO TO 30
C        NORMALIZE EIGENVALUE FOR OUR USE
      QB=QSQ(N,SNKNOR,ROUT)
      DIV=SQN/(SNKNOR*SNKNOR)
C        NOTE THIS EXPRESSION TAKES CARE OF ITSELF FOR
C        THE HOLLOW CYLINDER CASE
      AGEMO=EM*EN*PIOL4*((B2-DIV)*QB-(RIN2-DIV)*QSQ(N,SNKNOR,RIN))
      H2MNS=QB/(AGEMO*TERM)
      GO TO 50
   30 AGEMO=EM*EN*PIOL4*(B2-RIN2)
C        NOTE CANCELLATION OF THE QSQ(0) TERM
```

```
      H2MNS=1.D0/(AGEMO*TERM)                                          HSQ00530
   50 DO 60 IDX=1,4                                                    HSQ00540
      R=ROTHR(IDX)                                                     HSQ00550
      Z=ZOTHR(IDX)                                                     HSQ00560
      HOTHR(IDX)=H2MNS*(DCOS(PI*M*Z/CYLNTH))**2                        HSQ00570
     1/AGEMO                                                           HSQ00580
      IF(SNK(I).NE.0.D0) HOTHR(IDX)=HOTHR(IDX)*QSC(N,SNKNCF,R)         HSQ00590
   60 CONTINUE                                                         HSQ00600
      RETURN                                                           HSQ00610
      END                                                              HSQ00620
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                        SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE MCMAHN (N,NTH,XMN)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE USES THE FIRST FOUR TERMS OF THE ASYMPTOTIC         C
C     SERIES METHOD DEVELOPED BY MCMAHON TO FIND THE EIGENVALUES       C
C     OF THE DERIVATIVES OF THE CROSS PRODUCT OF THE BESSEL AND        C
C     NEUMANN FUNCTIONS.  THE SECOND HALF OF THIS ROUTINE USES THE     C
C     FIRST FOUR TERMS OF THE SERIES FOR THE DERIVATIVE OF J(X).       C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /EIGEN/BETA,BETA3,BETA5
      COMMON /RADII/RIN,ROUT
C
      IF(N.NE.0) J=NTH+1
      RM=4.D0*N*N
      RMSQ=RM**2
      RMCUB=RMSQ*RM
C        CHECK FOR THE HOLLOW CYLINDER CASE.
      IF(RIN.EQ.0.D0) GO TO 10
      RK=(NTH*PI)/(BETA-1.D0)
      C1=(RM+3.D0)/(8.D0*BETA)
      C2=4.D0*(RMSQ+46.D0*RM-63.D0)*(BETA3-1.D0)/
     1        (1536.D0*BETA3*(BETA-1.D0))
      C3=32.D0*(RMCUB+185.D0*RMSQ-2053.D0*RM+1899.D0)*(BETA5-1.D0)/
     1         (1.6384D5*BETA5*(BETA-1.D0))
      C1SQ=C1*C1
      C1CUB=C1SQ*C1
      RKCUB=RK**3
      RKFIF=RKCUB*RK*RK
      TRM3=(C2-C1SQ)/RKCUB
      TRM4=(C3-4.D0*C1*C2+2.D0*C1CUB)/RKFIF
      XMN=RK+C1/RK+TRM3+TRM4
      RETURN
   10 J=NTH
C        ZERO IS THE ZEROTH SOLUTION IN THE HOLLOW CYLINDER CASE
C        ONLY FOR N=0.  THEREFORE RE-ADJUST THE SOLUTION NUMBER.
      RK=PI*(2*N+4*J+1)/4.D0
      RKCUB=RK**3
      RKFIF=RKCUB*RK*RK
      TRM3=4.D0*(7.D0*RMSQ+82.D0*RM-9.D0)/(1536.D0*RKCUB)
      TRM4=32.D0*(83.D0*RMCUB+2075.D0*RMSQ-3039.D0*RM+3537.D0)/
     1           (4.9152D5*RKFIF)
      XMN=RK-(RM+3.D0)/(8.D0*RK)-TRM3-TRM4
      RETURN
      END
```

```
IMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE MNCALB (M,N)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS IS THE SUBROUTINE THAT KEEPS TRACK OF THE CUMULATIVE        C
C     TOTAL IN THE SUM OVER THE M AND N MODAL INDICIES.                C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /DIR/ISAME,IOPP
      COMMON /ERROR/LAST
      COMMON /FINAL/GRNOPP,GRNTOT,BIGSUM,BGSMT(4),SPGTOT(4)
      COMMON /FREQ/WSQ
      COMMON /STOP/VCRIT
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /TOTALS/STOT,PTOT,SPTOT(4)
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      DIMENSION BSPRD(4),SPCOSS(4)
C
C        COMBINE 'P' AND 'Q' SUMS
      PTYMS=PTOT*STOT*WSQ
      DO 60 IDX=1,4
   60 BSPRD(IDX)=SPTOT(IDX)*PTOT*WSQ
C        CALCULATE THE CONTRIBUTION
      COSSUM=PTYMS
      DO 70 IDX=1,4
   70 SPCOSS(IDX)=BSPRD(IDX)
      GRNTOT=BIGSUM+COSSUM
      DO 80 IDX=1,4
   80 SPGTOT(IDX)=BGSMT(IDX)+SPCOSS(IDX)
      BIGSUM=GRNTOT
      DO 90 IDX=1,4
   90 BGSMT(IDX)=SPGTOT(IDX)
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE MNCALC (M,N,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS IS THE SUBROUTINE THAT KEEPS TRACK OF THE CUMULATIVE        C
C     TOTAL IN THE SUM OVER THE M AND N MODAL INDICIES.  THIS          C
C     ROUTINE IS USED BY MAIN PROGRAM 'PLRTCN'.                        C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /DIR/ISAME,IOPP
      COMMON /ERROR/LAST
      COMMON /FINAL/GRNOPP,GRNTOT,BIGSUM,BGSMT(4),SPGTOT(4)
      COMMON /STOP/VCRIT
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /TOTALS/STOT,PTOT,SPTOT(4)
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      DIMENSION BSPRD(4),SPCOSS(4)
C
C        COMBINE 'P' AND 'Q' SUMS
      PTYMS=PTOT*STOT
      DO 60 IDX=1,4
   60 BSPRD(IDX)=SPTOT(IDX)*PTOT
C        CALCULATE THE CONTRIBUTION
      COSSUM=PTYMS
      DO 70 IDX=1,4
   70 SPCOSS(IDX)=BSPRD(IDX)
C        SUM TO GRAND TOTAL
C        IF TERM EQUALS ZERO IGNORE IT
      IF(COSSUM.EQ.0.D0) CALL NXTMN (ISAME,&40,&50)
      GRNTOT=BIGSUM+COSSUM
      DO 80 IDX=1,4
   80 SPGTOT(IDX)=BGSMT(IDX)+SPCOSS(IDX)
C        CHECK CONVERGENCE OF MN SUM IN ONE DIRECTION
      IF((BIGSUM/GRNTOT).GT.VCRIT) GO TO 20
      BIGSUM=GRNTOT
      DO 90 IDX=1,4
   90 BGSMT(IDX)=SPGTOT(IDX)
C        FIND NEXT CLOSEST 'MN' FREQUENCY SAME DIRECTION AS LAST  IF
C        THE CONTRIBUTION IS GREATER THEN THE CONTRIBUTION FROM THE
C        LAST TERM IN THE OPPOSITE DIRECTION
      IF(COSSUM.GT.GRNOPP) CALL NXTMN(ISAME,&40,&50)
C        REDEFINE OPPOSITE TERM CONTRIBUTION VALUE
      GRNOPP=COSSUM
      GO TO 30
   20 BIGSUM=GRNTOT
      DO 100 IDX=1,4
  100 BGSMT(IDX)=SPGTOT(IDX)
C        CHECK IF CONVERGENCE HAS OCCURRED IN BOTH DIRECTIONS
   25 IF(GRNOPP.EQ.-1.D0) RETURN
C        INSURE SUM WILL CONTINUE IN DIRECTION FOR WHICH
```

```
C          CONVERGENCE HAS NOT YET OCCURRED
      GRNOPP=-1.D0
C          FIND NEXT CLOSEST 'MN' FREQUENCY OPPOSITE DIRECTION FROM LAST
   30 CALL NXTMN (IOPP,&40,&50)
   40 RETURN 1
   50 CONTINUE
      GO TO 25
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE MNSUM (M,N,IP,IQ,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS IS THE SUBROUTINE THAT KEEPS TRACK OF THE CUMULATIVE        C
C     TOTAL IN THE SUM OVER THE M AND N MODAL INDICIES.  THIS          C
C     ROUTINE IS USED BY MAIN PROGRAM 'STRBAN'.                        C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /DIR/ISAME,IOPP
      COMMON /ERROR/LAST
      COMMON /FINAL/GRNOPP,GRNTOT,BIGSUM,BGSMT(4),SPGTOT(4)
      COMMON /STOP/VCRIT
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /TOTALS/STOT,PTOT,SPTOT(4)
      COMMON /ACCSTK/ACMODS(8000),MNS(8000),NUMAC
      DIMENSION BSPRD(4),SPCOSS(4)
C
C     GET ACCEPTANCES SQUARED - NOTE CAPGAM IS ALREADY SQUARED
      PTOT=(GAMA(M,IP)**2)*CAPGAM(N,IQ)
C     MULTIPLY 'S' SUM BY ACCEPTANCES SQUARED
      PTYMS=PTOT*STOT
      DO 60 IDX=1,4
   60 BSPRD(IDX)=SPTOT(IDX)*PTOT
C        CALCULATE THE CONTRIBUTION
      COSSUM=PTYMS
      DO 70 IDX=1,4
   70 SPCOSS(IDX)=BSPRD(IDX)
C        SUM TO GRAND TOTAL
C        IF TERM EQUALS ZERO IGNORE IT
      IF(COSSUM.EQ.0.D0) CALL NXTMN (ISAME,&40,&50)
      GRNTOT=BIGSUM+COSSUM
      DO 80 IDX=1,4
   80 SPGTOT(IDX)=BGSMT(IDX)+SPCOSS(IDX)
C        CHECK CONVERGENCE OF MN SUM IN ONE DIRECTION
      IF((BIGSUM/GRNTOT).GT.VCRIT) GO TO 20
      BIGSUM=GRNTOT
      DO 90 IDX=1,4
   90 BGSMT(IDX)=SPGTOT(IDX)
C        FIND NEXT CLOSEST 'MN' FREQUENCY SAME DIRECTION AS LAST IF
C        THE CONTRIBUTION IS GREATER THEN THE CONTRIBUTION FROM THE
C        LAST TERM IN THE OPPOSITE DIRECTION
      IF(COSSUM.GT.GRNOPP) CALL NXTMN(ISAME,&40,&50)
C        REDEFINE OPPOSITE TERM CONTRIBUTION VALUE
      GRNOPP=COSSUM
      GO TO 30
   20 BIGSUM=GRNTOT
      DO 100 IDX=1,4
  100 BGSMT(IDX)=SPGTOT(IDX)
C        CHECK IF CONVERGENCE HAS OCCURRED IN BOTH DIRECTIONS
```


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```
   25 IF(GRNOPP.EQ.-1.D0) RETURN
C        INSURE SUM WILL CONTINUE IN DIRECTION FOR WHICH
C        CONVERGENCE HAS NOT YET OCCURRED
      GRNOPP=-1.D0
C        FIND NEXT CLOSEST 'MN' FREQUENCY OPPOSITE DIRECTION FROM LAST
   30 CALL NXTMN (IOPP,&40,&50)
   40 RETURN 1
   50 CONTINUE
      GO TO 25
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=50,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE NXTMN (L,*,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS SUBROUTINE SEARCHES THE ACOUSTIC MODE INDICES ARRAY         C
C     FOR THE 'NEXT' CLOSEST VALUE TO THE EXTERIOR EXCITATION          C
C     FREQUENCY THAN WAS FOUND THE PREVIOUS TIME THIS SUBROUTINE       C
C     WAS CALLED.  THE INPUT PARAMETER L IS NEGATIVE IF THE            C
C     SEARCH IS TO PROCEED IN A DIRECTION IN THE ARRAY OPPOSITE        C
C     FROM THE DIRECTION SEARCHED THE LAST TIME THE SUBROUTINE WAS     C
C     CALLED.  L IS POSITIVE IF THE SAME DIRECTION SHOULD BE SEARCHED  C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ERROR/LAST
      COMMON /TABS/ISAVE,MNDIR,K
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
C
C        SAVE CURRENT INDEX
      LAST=IABS(MNDIR)
C        LESS THAN ZERO MEANS PROCEED IN THE DOWNWARDS DIRECTION
      IF(L*MNDIR) 30,30,5
C        OPPOSITE DIRECTION ?
    5 IF(L.EQ.-1) GO TO 10
C        SINCE ARRAY IS SORTED THE NEXT CLOSEST IS THE PREVIOUS
C        ELEMENT IN THE ARRAY
      K=MNDIR-1
      GO TO 20
   10 K=ISAVE-1
C        SAVE LAST INDEX BEFORE DIRECTION CHANGE
      ISAVE=LAST
C        K MUST BE POSITIVE HERE SINCE WE ARE PROCEEDING UPWARDS
   20 MNDIR=K
      IF(K.GT.0) RETURN 1
      RETURN 2
   30 IF(L.EQ.-1) GO TO 40
C        NEXT FREQUENCY IS NEXT ELEMENT IN THE ARRAY
      K=-(IABS(MNDIR)+1)
      GO TO 50
   40 K=-(ISAVE+1)
      ISAVE=LAST
C        SINCE K IS USED AGAIN AND MODIFIED, SAVE IT'S VALUE
   50 MNDIR=K
      IF(IABS(MNDIR).LE.NUMAC) RETURN 1
      RETURN 2
      END
```


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```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                        SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE PCALB(KS,IP,IQ,TOTALL,POTALL)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS SUBROUTINE COMPUTES THE BANDWIDTH STRUCTURAL AMPLIFI-      C
C     CATION FUNCTION TIMES THE JOINT ACCEPTANCE.  IT IS USED BY      C
C     MAIN PROGRAM 'STRBAN'.                                           C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8(A-D,F-H,O-Z)
      COMMON /FINAL/ GRNOPP,GRNTOT,BIGSUM,BGSMT(4),SPGTCT(4)
      COMMON/FREQ/WSQ
      COMMON /LEAD/ HFTERM,BBB
      DIMENSION POTALL(4)
      CALL STAMFB(KS,H2PQ,&2)
      PROD=H2PQ*PQJ(IP,IQ,BBB)*WSQ
      TOTALL=TOTALL+PROD*BIGSUM
      DO 1 IDX=1,4
    1 POTALL(IDX)=POTALL(IDX)+PROD*BGSMT(IDX)
      RETURN
    2 STOP 69
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE PCALCC (M,N,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS SUBROUTINE PERFORMS THE SUM OVER THE  STRUCTURAL MODES.     C
C     THIS ROUTINE IS USED BY MAIN PROGRAMS 'PURTON' AND 'ACOBAN'.     C
C                                                                      C
C**********************************************************************C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /DIR/ISAME,IOPP
      COMMON /INFO/INDEX
      COMMON /STOP/VCRIT,KCV
      COMMON /TOTALS/STOT,PTOT,SPTCT(4)
      COMMON /SAMPLE/TEMP(1200),LPOS(1200),NUMTMP
C
      PSUM=0.D0
      PTOT=0.D0
      KDN=0
      KUP=0
C        CREATE MINI ARRAY OF SELECTED VALUES
      CALL COPYC (N)
      IF(NUMTMP.GT.0) GO TO 100
      WRITE(6,3000) N
 3000 FORMAT(1H0,'NO MODES FOR N = ',I5)
      RETURN
C        FIND CLOSEST FREQUENCY TO THE INPUT FREQUENCY IN THIS ARRAY
  100 CALL FRSFND (TEMP,NUMTMP,K)
C        INSURE NEXT DIRECTION WILL BE OPPOSITE
      HSQOPP=1.D70
C        STRIP SIGN FROM K
      I=IABS(K)
      ISAVE=I
C        CALCULATE STRUCTURAL AMPLIFICATION FUNCTION
   10 CALL STAMFC (I,M,N,IQ,HGAMI,&50)
      HGAMI=HGAMI*CAPGAM(N,IQ)
C        IF HGAMI I.E. GAMA EQUALS ZERO IGNORE THAT TERM AND PROCEED
      IF(HGAMI.EQ.0.D0)
     1 CALL FNDNST(ISAME,K,I,ISAVE,N,LPOS,NUMTMP,&10,&40)
      PTOT=PSUM+HGAMI
C        CHECK CONVERGENCE IN ONE DIRECTION
      IF((PSUM/PTOT).GT.VCRIT) GO TO 60
      IF(K.GT.0) KUP=0
      IF(K.LT.0) KDN=0
   15 PSUM=PTOT
C        FIND NEXT FREQUENCY IN SAME DIRECTION IF THE CONTRIBUTION
C         IS GREATER THEN THE CONTRIBUTION FROM THE LAST TERM IN
C         THE OPPOSITE DIRECTION
      IF(HGAMI.GT.HSQOPP)
     1 CALL FNDNST(ISAME,K,I,ISAVE,N,LPOS,NUMTMP,&10,&40)
C        REDEFINE OPPOSITE TERM CONTRIBUTION VALUE
      HSQOPP=HGAMI
      GO TO 30
```

```
   20 PSUM=PTOT                                                          PCA00540
C        CHECK CONVERGENCE IN BOTH DIRECTIONS                            PCA00550
   25 IF(HSQOPP.EQ.-1.D0) RETURN                                         PCA00560
C        INSURE PROGRESS WILL CONTINUE IN THE DIRECTION FOR WHICH        PCA00570
C        CONVERGENCE HAS NOT OCCURRED                                    PCA00580
      HSQOPP=-1.D0                                                       PCA00590
C        FIND NEXT FREQUENCY IN OPPOSITE DIRECTION                       PCA00600
   30 CALL FNDNST(IOPP,K,I,ISAVE,N,LPOS,NUMTMP,&10,&35)                  PCA00610
   35 K=-K                                                               PCA00620
   40 CONTINUE                                                           PCA00630
      GO TO 25                                                           PCA00640
   50 WRITE(7,101)I,M,N,ISAVE,K                                          PCA00650
  101 FORMAT('ERROR RET FROM STAMFC. I=',I5,'  M,N=',2I5,' ISAVE=',      PCA00660
     1I5,'  K=',I5)                                                      PCA00670
      RETURN 1                                                           PCA00680
   60 IF(K.GT.0) GO TO 70                                                PCA00690
      KDN=KDN+1                                                          PCA00700
      IF(KDN.GE.KCV) GO TO 20                                            PCA00710
      GO TO 15                                                           PCA00720
   70 KUP=KUP+1                                                          PCA00730
      IF(KUP.GE.KCV) GO TO 20                                            PCA00740
      GO TO 15                                                           PCA00750
      END                                                                PCA00760
```

```
OMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION PQJ(IP,IQ,BB)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS SUBROUTINE COMPUTES THE JOINT ACCEPTANCE FUNCTION FOR       C
C     JET AND ROCKET NOISE.                                            C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ACCEPT/ALFA
      COMMON /CONST/PI
      COMMON /LETTRS/A,B,C,CK,CRAT,DRAT
      COMMON /MORE/WOLCPI,PICER
      COMMON /EPRCOR/TVXR,AXCDF,TVYR,AYCDF
      DIMENSION AI(3,2),DEL(2),GAM(2),ACPT(2)
      DEL(1)=TVXR/AXCDF*WOLCPI
      DEL(2)=TVYR/AYCDF*PICER*ALFA/PI
      GAM(1)=TVXR*WOLCPI
      GAM(2)=TVYR*PICER*ALFA/PI
      DO 10 I=1,2
      J = (2-I)*IP+(I-1)*IQ
      FLJ = DFLOAT(J)
      DNM1 = DEL(I)**2+(GAM(I)+FLJ)**2
      DNM2 = DEL(I)**2+(GAM(I)-FLJ)**2
      DELT = DEL(I)
      GAMY = GAM(I)
      FACT = DEXP(-DELT*PI)*(-1.D0)**J
      SNFT = FACT*DSIN(GAMY*PI)
      CSFT = FACT*DCOS(GAMY*PI)
      AI(1,I) = DELT*(1.D0-CSFT)*(1.D0/DNM1+1.D0/DNM2)
     1          +SNFT*((GAMY+FLJ)/DNM1+(GAMY-FLJ)/DNM2)
      AI(2,I) = SNFT*((GAMY+FLJ)*(PI+2.D0*DELT/DNM1)/DNM1
     1          +(GAMY-FLJ)*(PI+2.D0*DELT/DNM2)/DNM2)
     2          -CSFT*((PI*DELT+(DELT**2-(GAMY+FLJ)**2)/DNM1)/DNM1
     3          +(PI*DELT+(DELT**2-(GAMY-FLJ)**2)/DNM2)/DNM2)
     4          +(DELT**2-(GAMY+FLJ)**2)/(DNM1**2)
     5          +(DELT**2-(GAMY-FLJ)**2)/(DNM2**2)
      AI(3,I) = DELT*SNFT*(1.D0/DNM2-1.D0/DNM1)
     1          +CSFT*((GAMY-FLJ)/DNM2-(GAMY+FLJ)/DNM1)
     2          +(GAMY+FLJ)/DNM1-(GAMY-FLJ)/DNM2
      ACPT(I) = (PI*AI(1,I)-AI(2,I)+AI(3,I)/FLJ)/2.D0
   10 CONTINUE
      PQJ = 4.*ACPT(1)*ACPT(2)/B
      PQJ = (ALFA/PI)**2*ACPT(1)*ACPT(2)/B
      RETURN
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE PSQS (N,X,TOTP,TOTQ,ARG)
C                                                                      C
C***********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE P AND Q SERIES WHEN USING THE        C
C     ASYMPTOTIC SERIES METHOD FOR BESSEL AND NEUMANN FUNCTIONS.       C
C     NOTE:  THIS P AND Q SERIES IS NOT THE SAME AS THE MODAL          C
C     P AND Q  INDICES.                                                C
C                                                                      C
C***********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /CONV/UP,DN
      COMMON /FCTRL/FAC(57),PSI(60)
C
      U=4.D0*N*N
      ATEX=8.D0*X
      EJ=-1.
      TRMP=1.D0
      SUMP=1.D0
      SUMQ=0.D0
      RJ=1.D0
C        CALCULATE 'P' AND 'Q' SERIES SIMULTANEOUSLY
      DO 10 M=2,56,2
      RK=RJ+2.D0
      TRMQ=TRMP*(U-RJ*RJ)/ATEX
      TRMP=TRMQ*(U-RK*RK)/ATEX
      TOTP=SUMP+EJ*TRMP/FAC(M+1)
      EJ=-EJ
      TOTQ=SUMQ+EJ*TRMQ/FAC(M)
      IF(TOTQ.EQ.0.D0) GO TO 5
C        IF 'Q' SERIES HAS CONVERGED THEN THE 'P' SERIES HAS
C        ALSO CONVERGED SINCE ONE MORE 'P' TERM HAS BEEN CALCULATED
      VAL=SUMQ/TOTQ
      IF(VAL.GT.DN.AND.VAL.LT.UP) GO TO 20
    5 SUMQ=TOTQ
      SUMP=TOTP
      RJ=RK+2.D0
   10 CONTINUE
C        TERM USED IN ASYMPTOTIC SERIES EXPRESSION FOR BESSEL FUNCTIONS
   20 ARG=X-PI*(N/2.D0+0.25D0)
      RETURN
      END
```

[redacted]

```
OMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION QSQ(N,XNS,R)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS FUNCTION CALCULATES THE 'Q' FUNCTION SQUARED. THE          C
C     FUNCTION IS A TERM IS THE ACOUSTIC AMPLIFICATION FUNCTION       C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /RADII/RIN,ROUT
C
      RKNS=R*XNS
C        CALCULATE DERIVATIVE USING RECURRENCE RELATION
      CALL BESSEL (N,RKNS,BJRN,BYRN)
C        TAKE CARE OF THE HOLLOW CYLINDER CASE
      IF(RIN.EQ.0.D0) GO TO 10
      BKNS=ROUT*XNS
      DIVN=N/BKNS
      CALL BESSEL (N,BKNS,BJBN,BYBN)
      CALL BESSEL (N+1,BKNS,BJBNP1,BYBNP1)
      Q=BJRN-(DIVN*BJBN-BJBNP1)*BYRN/(DIVN*BYBN-BYBNP1)
      QSQ=Q*Q
      RETURN
   10 QSQ=BJRN**2
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE RECUR (N,X,BSLN,BSLNM1,BSL)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE USES THE RECURSION RELATION FOR BESSEL AND          C
C     NEUMANN FUNCTIONS TO FIND VALUES OF HIGH ORDER.                  C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
C
      QTNT=2.D0/X
      K=N-1
C         START RECURRENCE TO FIND ORDER 9 SINCE 8 AND 7 ARE KNOWN
      DO 10 I=8,K
      BSLNP1=QTNT*I*BSLN-BSLNM1
      BSLNM1=BSLN
      BSLN=BSLNP1
   10 CONTINUE
      BSL=BSLN
      RETURN
      END
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                 SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE REGFAL (N,XL,*)
C                                                                       C
C***********************************************************************C
C                                                                       C
C     THIS SUBROUTINE USES THE REGULA FALSI (FALSE POSITION)            C
C     TECHNIQUE TO FIND THE EIGENVALUES OF THE CROSS PRODUCT OF         C
C     THE DERIVATIVES OF THE BESSEL AND NEUMANN FUNCTIONS.  IN THE      C
C     HOLLOW CYLINDER CASE FUNCTION DOB IS THE DERIVATIVE OF J(X)       C
C                                                                       C
C***********************************************************************C
C                                                                       C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /HALT/QUIT
      DATA I/0/
      IF(I.EQ.N) GO TO 5
C         START OVER AGAIN FOR NEW ORDER OF FUNCTION
      I=N
      XL=0.D0
C        STEPSIZE IS 0.1
    5 XL=XL+0.1D0
      VLFT=DOB(N,XL)
   10 XR=XL+0.1D0
      VRT=DOB(N,XR)
      IF(VLFT*VRT) 40,30,20
   20 VLFT=VRT
      XL=XR
      GO TO 10
   30 IF(DABS(VLFT).LE.QUIT) RETURN
      XL=XR
      RETURN
C        CLOSE IN ON ZERO VALUE
   40 DO 80 J=1,20
      XTST=(XL*VRT-XR*VLFT)/(VRT-VLFT)
      VLTST=DOB(N,XTST)
      IF(DABS(VLTST).LE.QUIT) GO TO 60
      IF((VLTST*VLFT).LT.0.D0) GO TO 70
      XL=XTST
      VLFT=VLTST
      GO TO 80
   60 XL=XTST
      RETURN
   70 XR=XTST
      VRT=VLTST
   80 CONTINUE
      RETURN 1
      END
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                 SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE ROOT (N,NTH,XNS,*)
C                                                                      C
C***********************************************************************C
C                                                                      C
C     THIS SUBROUTINE TESTS AND DECIDES WHICH METHOD (REGULA FALSI      C
C     OR ASYMPTOTIC SERIES) WILL BE USED TO FIND THE NEXT EIGENVALUE   C
C     FOR THE DERIVATIVES OF THE CROSS PRODUCT OF THE BESSEL           C
C     AND NEUMANN FUNCTIONS.  THE DERIVATIVE OF J(X) IS ALSO HANDLED   C
C     IN THE HOLLOW CYLINDER CASE.                                     C
C                                                                      C
C***********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      LOGICAL*1 L/.FALSE./
      COMMON /RADII/RIN,ROUT
      COMMON /STOP/VCRIT
      DATA BIG/1.00005D0/,I/0/
C
      IF(I.EQ.N) GO TO 5
      I=N
      L=.FALSE.
    5 IF(NTH.EQ.0) GO TO 25
      IF (L) GO TO 10
    7 CALL REGFAL (N,XNS,&30)
C        MAKE SURE MCMAHN DOES NOT GET A VALUE OF 'NTH' EQUAL TO ZERO
   10 IF(NTH.LE.1) RETURN
      J=NTH
C        SINCE ZERO IS THE ZEROTH SOLUTION ADJUST SOLUTION NUMBER FOR
C        N NOT EQUAL TO ZERO.  N=0 BEHAVES DIFFERENTLY
      CALL MCMAHN (N,J,XMN)
      IF (L) GO TO 21
C        USE REGULA FALSI UNTIL THE MCMAHON SERIES PROVIDES GOOD
C        AGREEMENT, THEN USE THE SERIES ALONE FOR THE REMAINING ROOTS
C        FOR THIS ORDER OF THE FUNCTION
      DIV=XNS/XMN
      IF(DIV.GT.VCRIT.AND.DIV.LT.BIG) GO TO 20
C        RETURN EIGENVALUES
      RETURN
   20 L=.TRUE.
   21 XNS=XMN
      RETURN
C        CHECK FOR HOLLOW CYLINDER CASE
   25 IF(N.NE.0) GO TO 7
      XNS=0.D0
      RETURN
   30 WRITE(6,2000)
 2000 FORMAT(1X,'NO CONVERGENCE WHILE USING REGULA FALSI PROCEDURE',/)
      RETURN 1
      END
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE SCALC (K,M,N,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE PERFORMS THE SUM OVER THE IS ACOUSTIC MODE INDEX.   C
C     IT IS USED BY MAIN PROGRAMS 'PURTCN' AND 'STRBAN'.               C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /DIR/ISAME,IOPP
      COMMON /ERROR/LAST
      COMMON /STOP/VCRIT
      COMMON /TOTALS/STOT,PTOT,SPTOT(4)
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      DIMENSION HOTHR(4),SPSUM(4)
C
C         INSURE NEXT TERM WILL BE FROM OPPOSITE DIRECTION
      HSQOPP=1.D70
      SSUM=0.D0
      STOT=0.D0
      DO 100 IDX=1,4
      SPSUM(IDX) = 0.D0
  100 SPTOT(IDX)=0.D0
C         STRIP SIGN OF K
      I=IABS(K)
      ISAVE=I
C         UNPACK ACOUSTIC MODAL INDICES AND COMBINATIONS
      NS=MOD(MNS(I),1000000)
      N=NS/1000
      MN=MNS(I)/1000
      M=MN/1000
C         CALCULATE ACOUSTIC AMPLIFICATION FUNCTION
   10 CALL HSQMNS (ACMODS(I),MNS(I),M,N,HOTHR,H2MNS,&50)
C         CHECK FOR ZERO CASE
      IF(H2MNS.EQ.0.D0)
     1 CALL FNDNXT(ISAME,K,I,ISAVE,MN,MNS,NUMAC,&10,&40)
      STOT=SSUM+H2MNS
      DO 200 IDX=1,4
  200 SPTOT(IDX)=SPSUM(IDX)+HOTHR(IDX)
C         CHECK CONVERGENCE IN ONE DIRECTION
      IF((SSUM/STOT).GT.VCRIT) GO TO 20
      SSUM=STOT
      DO 300 IDX=1,4
  300 SPSUM(IDX)=SPTOT(IDX)
C         FIND NEXT FREQUENCY IN SAME DIRECTION IF THE LAST CONTRIBUTION
C         FROM THIS DIRECTION IS GREATER THEN THE CONTRIBUTION FROM
C         THE PREVIOUS TERM IN THE OPPOSITE DIRECTION
      IF(H2MNS.GT.HSQOPP)
     1 CALL FNDNXT(ISAME,K,I,ISAVE,MN,MNS,NUMAC,&10,&40)
C         REDEFINE OPPOSITE TERM VALUE
      HSQOPP=H2MNS
```

```
      GO TO 30
   20 SSUM=STOT
      DO 400 IDX=1,4
  400 SPSUM(IDX)=SPTOT(IDX)
C         CHECK CONVERGENCE IN BOTH DIRECTIONS
   25 IF(HSQOPP.EQ.-1.D0) RETURN
C         INSURE CONTINUED PROGRESS IN THE OPPOSITE DIRECTION
      HSQOPP=-1.D0
C         FIND NEXT FREQUENCY IN OPPOSITE DIRECTION
   30 CALL FNDNXT (IOPP,K,I,ISAVE,MN,MNS,NUMAC,&10,&35)
   35 K=-K
   40 CONTINUE
      GO TO 25
   50 RETURN 1
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE SCALCB (K,M,N,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE OBTAINS THE BANDWIDTH ACCUSTICAL AMPLIFICATION      C
C     FUNCTION.  IT IS USED BY MAIN PROGRAM 'ACOBAN'                   C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /ERROR/LAST
      COMMON /STOP/VCRIT
      COMMON /TOTALS/STOT,PTOT,SPTOT(4)
      COMMON /ACUSTK/ACMODS(8000),MNS(8000),NUMAC
      DIMENSION HOTHR(4),SPSUM(4)
C
      I=K
      STOT=0.D0
      DO 100 IDX=1,4
  100 SPTOT(IDX)=0.D0
C         UNPACK ACOUSTIC MODAL INDICES AND COMBINATIONS
      NS=MOD(MNS(I),1000000)
      N=NS/1000
      MN=MNS(I)/1000
      M=MN/1000
C         CALCULATE ACOUSTIC AMPLIFICATION FUNCTION
   10 CALL HSQMNB (ACMODS(I),MNS(I),M,N,HOTHR,H2MNS,&50)
C         CHECK FOR ZERO CASE
      STOT=H2MNS
      DO 200 IDX=1,4
  200 SPTOT(IDX)=HOTHR(IDX)
      RETURN
   50 RETURN 1
      END
```

```
MPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE SMODSC (IPST,IPEND,IQST,IQEND,ICN)                        SM000010
C                                                                   C     SM000020
C*******************************************************************C     SM000030
C                                                                   C     SM000040
C     THIS SUBROUTINE CALCULATES THE STRUCTURAL MODAL FREQUENCIES    C     SM000050
C     FOR AN ORTHOTROPIC SHELL SEGMENT STIFFENED BY RINGS.  THE      C     SM000060
C     CALCULATION IS PERFORMED OVER TWO MODAL INDICIES, IP AND IQ.   C     SM000070
C     EACH COMBINATION OF IP AND IQ HAS THREE ASSOCIATED MODAL       C     SM000080
C     FREQUENCIES.  THE INDICIES ARE PACKED INTO ARRAY MPQ IN THE    C     SM000090
C     ORDER IQ AND IP.  THE FREQUENCIES SQUARED ARE STORED IN        C     SM000100
C     ARRAY STMODS.  IN ADDITION, THE THREE ASSOCIATED CONSTANTS     C     SM000110
C     NEEDED FOR THE AMPLITUDE FUNCTION FOR EACH MODE ARE CALCULATED C     SM000120
C     AND THE SQUARES STORED IN ARRAY STMCD3, THE INDICIES (SAME     C     SM000130
C     AS FOR THE THREE FREQUENCIES) ARE STORED IN ARRAY MPC3.        C     SM000140
C                                                                   C     SM000150
C*******************************************************************C     SM000160
C                                                                   C     SM000170
      IMPLICIT REAL*8 (A-D,F-H,O-Z)                                       SM000180
      DIMENSION BUF(3),IBUF(3),X(3)                                       SM000190
      COMMON/ACCEPT/ALFA                                                  SM000200
      COMMON /CONST/PI                                                    SM000210
      COMMON /LETTRS/A,B,C,CK,CRAT,DRAT                                   SM000220
      COMMON /STRUCT/STMODS(1200),MPQ(1200),STMCD3(400,3),MPC3(400),      SM000230
     1       NUMST,NUM3                                                   SM000240
      PNU=1.D0-2.D0*A                                                     SM000250
C                                                                         SM000260
      GO TO (100,200,100,200),ICN                                         SM000270
  100 J=1                                                                 SM000280
      K=1                                                                 SM000290
      FLAST = 1.D30                                                       SM000300
      FLAST1=FLAST                                                        SM000310
C        LOOP OVER P AND Q STRUCTURAL MODES                               SM000320
      DO 20 IP=IPST,IPEND                                                 SM000330
      RP2=IP*IP                                                           SM000340
      P2B=B*RP2                                                           SM000350
   10 IQ=IQST                                                             SM000360
   11 RQ2=(IQ*PI/ALFA)**2                                                 SM000370
      TER1=P2B*P2B+2.D0*P2B*RQ2+DRAT*RQ2*RQ2                              SM000380
      TER2=(1.D0+A)*P2B+(CRAT+A)*RQ2                                      SM000390
      TER3=P2B*P2B+(CRAT-PNU)*RQ2*P2B/A+CRAT*RQ2*RQ2                      SM000400
      COF2=CRAT+CK*TER1+TER2                                              SM000410
      COF1=CRAT*((1.D0+A-PNU*PNU/CRAT)*P2B+A*RQ2)+CK*TER2*TER1+A*TER3     SM000420
      COF0=A*(CK*TER3*TER1+(CRAT-PNU*PNU)*P2B*P2B)                        SM000430
      COF2=(-1.D0)*COF2                                                   SM000440
      COF0=(-1.D0)*COF0                                                   SM000450
      CALL CUBIC(X,COF2,COF1,COF0,&500)                                   SM000460
      STMODS(J)=X(1)/C                                                    SM000470
      IWORD = IQ*1000+IP                                                  SM000480
      MPQ(J)=IWORD                                                        SM000490
      J=J+1                                                               SM000500
      STMODS(J)=X(2)/C                                                    SM000510
      MPQ(J)= IWORD                                                       SM000520
```

```
      J=J+1
      STMODS(J)=X(3)/C
      MPQ(J)=IWORD
      J=J+1
      STMOD3(K,1)=(P2B+A*RQ2)/C
      STMOD3(K,2)=(A*P2B+RQ2*CRAT)/C
      STMOD3(K,3)=((P2B*RQ2)*(1.DO-A)**2)/C
      MPQ3(K)=IWORD
      K=K+1
      FLAST2=FLAST1
      FLAST1=DMIN1(STMODS(J-3),STMODS(J-2),STMODS(J-1))
      IF(IQ.EQ.IQST)FLAST2=FLAST1
      IF((FLAST1.GE.FLAST).AND.(FLAST1.GT.FLAST2)) GO TO 16
   15 IQ=IQ+1
      IF(IQ.GT.IQEND) GO TO 16
      GO TO 11
   16 IF(IP.EQ.IPST)FLAST=FLAST1
   20 CONTINUE
C        NUMBER OF STRUCTURAL MODES
      NUMST=J-1
      NUM3=K-1
      CALL SORT(STMODS,MPQ,NUMST)
      WRITE(2,250)IPST,IPEND,IQST,IQEND,NUMST,NUM3
  250 FORMAT(8I10)
      NREC=NUMST/5
      IF(NREC*5.LT.NUMST)NREC=NREC+1
      DO 60 III=1,NREC
      IND1=5*(III-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUMST)IND2=NUMST
      WRITE(2,250)(MPQ(JJJ),JJJ=IND1,IND2)
      WRITE(2,350)(STMODS(JJJ),JJJ=IND1,IND2)
   60 CONTINUE
      NREC=NUM3/5
      IF(NREC*5.LT.NUM3)NREC=NREC+1
      DO 61 III=1,NREC
      IND1=5*(III-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUM3)IND2=NUM3
      WRITE(2,250)(MPQ3(JJJ),JJJ=IND1,IND2)
      DO 611 KKK=1,3
      WRITE(2,350)(STMOD3(JJJ,KKK),JJJ=IND1,IND2)
  611 CONTINUE
   61 CONTINUE
  350 FORMAT(5D16.10)
      TWOPI=2.DO*PI
      WRITE(6,2000)
 2000 FORMAT(1H1,T16,'STRUCTURAL MODAL FREQUENCIES AND INDICES',
     1 ///,     3('INDICES',3X,'FREQUENCIES', 3X),//)
      KOUNT=0
      DO 30 I=1,NUMST,3
      K=I+2
C        WRITE FREQUENCIES IN HERTZ
      L=1
```

```
      DO 25 J=I,K
      BUF(L)=DSQRT(STMODS(J))/TWOPI
      IBUF(L)=MPQ(J)
   25 L=L+1
      WRITE(6,2001) (IBUF(J),BUF(J),J=1,3)
 2001 FORMAT(1H ,3(I9,3X,F8.1,4X))
      KOUNT=KOUNT+1
      IF(MOD(KOUNT,50).EQ.0) WRITE(6,2000)
   30 CONTINUE
      DO 6111 KKK=1,3
      WRITE(6,2002)KKK
 2002 FORMAT(1H1,T11,' STRUCTURAL CONSTANTS C',I1,' AND INCICIES'
     1,///,    3('INDICES',3X,'CONSTANTS', 3X),//)
      KOUNT=0
      DO 40 I=1,NUM3,3
      K=I+2
      L=1
      DO 35 J=I,K
      BUF(L)=DSQRT(STMOD3(J,KKK))/TWOPI
      IBUF(L)=MPQ3(J)
   35 L=L+1
      WRITE(6,2001) (IBUF(J),BUF(J),J=1,3)
      KOUNT=KOUNT+1
      IF(MOD(KOUNT,50).EQ.0) WRITE(6,2002)
   40 CONTINUE
 6111 CONTINUE
      WRITE(6,2003)
 2003 FORMAT(1H1)
      RETURN
  200 READ(2,250)IPST,IPEND,IQST,IQEND,NUMST,NUM3
      NREC=NUMST/5
      IF(NREC*5.LT.NUMST)NREC=NREC+1
      DO 70 III=1,NREC
      IND1=5*(III-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUMST)IND2=NUMST
      READ(2,250)(MPQ(JJJ),JJJ=IND1,IND2)
      READ(2,350)(STMODS(JJJ),JJJ=IND1,IND2)
   70 CONTINUE
      NREC=NUM3/5
      IF(5*NREC.LT.NUM3)NREC=NREC+1
      DO 71 III=1,NREC
      IND1=5*(III-1)+1
      IND2=IND1+4
      IF(IND2.GT.NUM3)IND2=NUM3
      READ(2,250)(MPQ3(JJJ),JJJ=IND1,IND2)
      DO 711 KKK=1,3
      READ(2,350)(STMOD3(JJJ,KKK),JJJ=IND1,IND2)
  711 CONTINUE
   71 CONTINUE
      RETURN
  500 STOP 699
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE SORT (RA,IA,NUM)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE PERFORMS A NUMERICAL SORT ON INPUT ARRAY RA AND     C
C     SORTS THE CONTENTS OF ARRAY IA IN THE SAME ORDER.                C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION IA(1),RA(1)
C
      IF(NUM.EQ.1) RETURN
      JK=NUM-1
      DO 10 I=1,JK
      KK=I+1
      DO 10 J=KK,NUM
      IF(RA(I).GT.RA(J)) GO TO 10
      XX=RA(I)
      RA(I)=RA(J)
      RA(J)=XX
      II=IA(I)
      IA(I)=IA(J)
      IA(J)=II
   10 CONTINUE
      RETURN
      END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE STAMFB (I,H2PQ,*)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE STRUCTURAL AMPLIFICATION FUNCTION    C
C     INTEGRATED OVER A BAND.  THIS IS USED BY MAIN PROGRAM 'STRBAN'.  C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /STDAMP/STDAMA,STDAMB
      COMMON/CONST/PI
      COMMON /FREQ/WSQ
      COMMON /INFO/INDEX
      COMMON /LEAD/HFTERM,BBB
      COMMON /STRUCT/STMODS(1200),MPQ(1200),STMOD3(400,3),MPQ3(400),
     1            NUMST,NUM3
C
C        FIND INDEX FOR CONSTANTS
      DO 10 J=1,NUM3
      IF(MPQ3(J).EQ.MPQ(I)) GO TO 20
   10 CONTINUE
      WRITE(7,2000) I
 2000 FORMAT(1X,'CONSTANTS NOT FOUND FOR MODAL INDEX ',I9,/)
      WRITE(6,2002)
 2002 FORMAT(1H0,'INDEX',5X,'   MPQ    ',5X,'STMODS',/)
      DO 3000 JJJ=1,NUMST
      WRITE(6,2003)JJJ,MPQ(JJJ),STMODS(JJJ)
 2003 FORMAT(1H ,I5,5X,I9,5X,D10.4)
 3000 CONTINUE
      RETURN 1
C        FIND SECOND FREQUENCY AND DESTROY ITS INDICES SO THAT IT WILL
C        NOT BE USED AGAIN AS A FIRST FREQUENCY BY MISTAKE
   20 ITST=MPQ(I)
      W2PQ1=STMODS(I)
      DO 30 JK=1,NUMST
      IF(MPQ(JK).EQ.ITST.AND.I.NE.JK) GO TO 40
   30 CONTINUE
      WRITE(7,2001)
 2001 FORMAT(1X,'SECOND FREQUENCY NOT FOUND')
      RETURN 1
   40 W2PQ2=STMODS(JK)
C         INDEX IS USED IN THE ERROR MESSAGE INDICATING MODE EXHAUSTION
      JKKK=JK+1
      DO 70 JKK=JKKK,NUMST
      IF(MPQ(JKK).EQ.ITST.AND.I.NE.JKK) GO TO 80
   70 CONTINUE
      WRITE(7,2004)
 2004 FORMAT(1X,'THIRD FREQUENCY NOT FOUND')
      RETURN 1
   80 W2PQ3 = STMODS(JKK)
      INDEX = MPQ(JKK)
```

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```
C           STRUCTURAL AMPLIFICATICN FUNCTICN                          STA00530
      AFACT=STDAMA/((2.D0*PI)**STDAMB)                                 STA00540
      AFACT=AFACT*AFACT                                                STA00550
      BFACT=1.D0+STDAMB                                                STA00560
      SQETA1=AFACT*W2PQ1**BFACT                                        STA00570
      SQETA2=AFACT*W2PQ2**BFACT                                        STA00580
      SQETA3=AFACT*W2PQ3**BFACT                                        STA00590
      H2PQ = HFTERM*((WSQ-STMOD3(J,1))*(WSQ-STMOD3(J,2))               STA00600
     1          -STMOD3(J,3))**2                                       STA00610
      H2PQ = H2PQ/((DSQRT(SQETA1)/PI)                                  STA00620
     1          *((W2PQ2-WSQ)**2+SQETA2*WSQ)                           STA00630
     2          *((W2PQ3-WSQ)**2+SQETA3*WSQ))                          STA00640
      RETURN                                                           STA00650
      END                                                              STA00660
```

```
OMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE STAMFC (I,M,N,IQ,HGAMI,*)
C                                                                     C
C*********************************************************************C
C                                                                     C
C     THIS ROUTINE CALCULATES THE STRUCTURAL AMPLIFICATION FUNCTION   C
C     SQUARED TIMES THE ACCEPTANCE FUNCTION FOR STRUCTURAL MODES      C
C     SQUARED TIMES THE ACCEPTANCE FUNCTION BETWEEN THE EXTERNAL      C
C     PRESSURE FIELD AND STRUCTURAL MODES.  THIS IS THE TERM WHICH    C
C     COMPRISES THE SUM OVER THE IP STRUCTURAL MODE INDICES.  THIS    C
C     ROUTINE IS USED BY MAIN PROGRAMS 'PURTON' AND 'ACCBAN'.         C
C                                                                     C
C*********************************************************************C
C                                                                     C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /STDAMP/STDAMA,STDAMB
      COMMON/CONST/PI
      COMMON /FREQ/WSQ
      COMMON /INFO/INDEX
      COMMON /LEAD/HFTERM,BBB
      COMMON /SAMPLE/TEMP(1200),LPQS(1200),NUMTMP
      COMMON /STRUCT/STMODS(1200),MPQ(1200),STMOD3(400,3),MPQ3(400),
     1         NUMST,NUM3
C
C        FIND ASSOCIATED THIRD FREQUENCY
      DO 10 J=1,NUM3
      IF(MPQ3(J).EQ.LPQS(I)) GO TO 20
   10 CONTINUE
      WRITE(7,2000) I
 2000 FORMAT(1X,'CONSTANTS NOT FOUND FOR MODAL INDEX ',I9,/)
      WRITE(6,2002)
 2002 FORMAT(1H0,'INDEX',5X,'   LPQS   ',5X,'TEMP',/)
      DO 3000 JJJ=1,NUMTMP
      WRITE(6,2003)JJJ,LPQS(JJJ),TEMP(JJJ)
 2003 FORMAT(1H ,I5,5X,I9,5X,D10.4)
 3000 CONTINUE
      RETURN 1
C        FIND SECOND FREQUENCY AND DESTROY ITS INDICES SO THAT IT WILL
C        NOT BE USED AGAIN AS A FIRST FREQUENCY BY MISTAKE
   20 ITST=LPQS(I)
C        UNPACK THE IP INDEX
      IQ = LPQS(I)/1000
      IP=MOD(LPQS(I),1000)
      LPQS(I)=999999
      W2PQ1=TEMP(I)
      DO 30 JK=1,NUMTMP
      IF(LPQS(JK).EQ.ITST) GO TO 40
   30 CONTINUE
      WRITE(7,2001)
 2001 FORMAT(1X,'SECOND FREQUENCY NOT FOUND')
      RETURN 1
   40 W2PQ2=TEMP(JK)
C        INDEX IS USED IN THE ERROR MESSAGE INDICATING MODE EXHAUSTION
```

```
      LPQS(JK)=999999                                                   STA00530
      DO 70 JKK=JK,NUMTMP                                               STA00540
      IF(LPQS(JKK).EQ.ITST) GO TO 80                                    STA00550
   70 CONTINUE                                                          STA00560
      WRITE(7,2004)                                                     STA00570
 2004 FORMAT(1X,'THIRD FREQUENCY NOT FOUND')                            STA00580
      RETURN 1                                                          STA00590
   80 W2PQ3 = TEMP(JKK)                                                 STA00600
      INDEX = LPQS(JKK)                                                 STA00610
      LPQS(JKK) = 999999                                                STA00620
C        CHECK FOR ZERO CASE                                            STA00630
      AMAG=GAMA(M,IP)                                                   STA00640
      IF(AMAG.EQ.0.D0) GO TO 50                                         STA00650
C        STRUCTURAL AMPLIFICATION FUNCTION                              STA00660
      AFACT=STDAMA/((2.D0*PI)**STDAMB)                                  STA00670
      AFACT=AFACT*AFACT                                                 STA00680
      BFACT=1.D0+STDAMB                                                 STA00690
      SQETA1=AFACT*W2PQ1**BFACT                                         STA00700
      SQETA2=AFACT*W2PQ2**BFACT                                         STA00710
      SQETA3=AFACT*W2PQ3**BFACT                                         STA00720
      H2PQ = HFTERM*((WSQ-STMOD3(J,1))*(WSQ-STMOD3(J,2))                STA00730
     1          -STMOD3(J,3))**2                                        STA00740
      H2PQ = H2PQ/(((W2PQ1-WSQ)**2+SQETA1*WSQ)                          STA00750
     1          *((W2PQ2-WSQ)**2+SQETA2*WSQ)                            STA00760
     2          *((W2PQ3-WSQ)**2+SQETA3*WSQ))                           STA00770
      DUMMY=PQJ(IP,IQ,BBB)                                              STA00780
      HGAMI=H2PQ*AMAG**2*DUMMY                                          STA00790
      RETURN                                                            STA00800
   50 HGAMI=0.D0                                                        STA00810
      RETURN                                                            STA00820
      END                                                               STA00830
```

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```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      FUNCTION PPN (N,IP)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS FUNCTION CALCULATES THE ACCEPTANCE BETWEEN THE EXTERNAL     C
C     PRESSURE FIELD AND THE STRUCTURAL MODES.                         C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      COMMON /CONST/PI
      COMMON /FREQ/WSQ
      COMMON /MORE/PFRONT,WOLC,WOLCPI,RECIP,CBW,PICER,PICEPI,
     1              WOLCOS,PICCOS,QCTERM
C
      PPI=IP*PI
      ZONE=WOLC+PPI
      ZTWO=WOLC-PPI
C        EVALUATE THE SI AND CIN FUNCTIONS FOR THE 'P' TERM
      CALL SINCOS(ZONE,SINONE,COSONE)
      CALL SINCOS(ZTWO,SINTWO,COSTWO)
      DJ=1.D0
      IIP=IP
C        CHECK IF IIP IS EVEN OR ODD
      IF(MOD(IIP,2).NE.0) DJ=-1.D0
      PTERM=PFRONT*((PI/2.D0)*(SINONE+SINTWO)+(COSONE-COSTWO)/(2.D0*IP))
C        CHECK FOR SPECIAL CASE
      IF((WOLCPI-IP*IP*RECIP).NE.0.D0) PTERM=PTERM-PFRONT*
     1((1.D0-DJ*WOLCOS)/(WOLCPI-IP*IP*RECIP))
      IF(N.EQ.0) GO TO 10
      PPI=2.D0*PI*N
      ZONE=PICEPI+PPI
      ZTWO=PICEPI-PPI
C        EVALUATE THE SI AND CIN FUNCTIONS FOR THE 'Q' TERM
      CALL SINCOS(ZONE,SINONE,COSONE)
      CALL SINCOS(ZTWO,SINTWO,COSTWO)
      QTERM=CBW*(PI*(SINONE+SINTWO)-(COSONE-COSTWO)/(2.D0*N))
      IF((PICER-N*N*CBW).NE.0.D0)QTERM=QTERM-CBW*(1.D0-PICCOS)/
     1                                 (PICER-N*N*CBW)
      PPN=PTERM*QTERM
      RETURN
C        USE LIMITING FORM OF 'Q' TERM
   10 PPN=PTERM*QCTERM
      RETURN
      END
```

```
OMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=56,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE SINCOS (Z,SININT,COSINT)
C                                                                      C
C**********************************************************************C
C                                                                      C
C     THIS ROUTINE CALCULATES THE VALUE OF THE SINE AND COSINE         C
C     INTEGRAL FUNCTIONS.  THE COSINE FUNCTION EVALUATED IS ACTUALLY   C
C     THE CIN FUNCTION.  SERIES TECHNIQUES ARE USED FOR ARGUMENTS      C
C     LESS THAN ONE.  RATIONAL APPROXIMATIONS ARE OTHERWISE USED.      C
C                                                                      C
C**********************************************************************C
C                                                                      C
      IMPLICIT REAL*8 (A-D,F-H,O-Z)
      DIMENSION FAX(4),FBX(4),GAX(4),GBX(4)
      COMMON /CONST/PI
      COMMON /CONV/UP,DN
      COMMON /FCTRL/FAC(57),PSI(60)
      DATA FAX/38.027264,265.187033,335.67732,38.102495/
      DATA FBX/40.021433,322.624911,570.236280,157.105423/
      DATA GAX/42.242855,302.757865,352.018498,21.821899/
      DATA GBX/48.196927,482.485984,1114.978885,449.690326/
C
      IF(Z.EQ.0.D0) GO TO 40
      IF(DABS(Z).GE.1.D0) GO TO 30
      XX=Z
      EJ=1.
      SUMSIN=0.D0
      SUMCOS=0.D0
      DO 10 I=1,57
      K=2*I-1
      L=K+1
      TOTSIN=SUMSIN+(EJ*XX)/(K*FAC(L))
      EJ=-EJ
      XX=XX*Z
      K=2*I
      L=K+1
      TOTCOS=SUMCOS+(EJ*XX)/(K*FAC(L))
      IF(TOTSIN.EQ.0.D0) GO TO 5
C        IF THE SIN SERIES HAS CONVERGED THEN THE CIN SERIES
C        HAS ALSO CONVERGED
      VAL=SUMSIN/TOTSIN
      IF(VAL.GT.DN.AND.VAL.LT.UP) GO TO 20
    5 XX=XX*Z
      SUMCOS=TOTCOS
      SUMSIN=TOTSIN
   10 CONTINUE
   20 SININT=TOTSIN
      COSINT=-TOTCOS
      RETURN
   30 Z2=Z*Z
      Z4=Z2*Z2
      Z6=Z4*Z2
      Z8=Z6*Z2
```

```
C        RATIONAL APPROXIMATION                                          SIN00530
      FOFZ=(1.D0/Z)*((Z8+FAX(1)*Z6+FAX(2)*Z4+FAX(3)*Z2+FAX(4))/          SIN00540
     1              (Z8+FBX(1)*Z6+FBX(2)*Z4+FBX(3)*Z2+FBX(4)))           SIN00550
      GOFZ=(1.D0/Z2)*((Z8+GAX(1)*Z6+GAX(2)*Z4+GAX(3)*Z2+GAX(4))/         SIN00560
     1              (Z8+GBX(1)*Z6+GBX(2)*Z4+GBX(3)*Z2+GBX(4)))           SIN00570
      SININT=PI/2.D0-FOFZ*DCOS(Z)-GOFZ*DSIN(Z)                           SIN00580
      CIOFZ=FOFZ*DSIN(Z)-GOFZ*DCOS(Z)                                    SIN00590
C        PSI(1) IS NEGATIVE EULER'S CONSTANT                             SIN00600
      COSINT=-CIOFZ+DLOG(DABS(Z))-PSI(1)                                 SIN00610
      RETURN                                                             SIN00620
   40 SININT=0.D0                                                        SIN00630
      COSINT=0.D0                                                        SIN00640
      RETURN                                                             SIN00650
      END                                                                SIN00660
```

F88-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED MAP,LET,LIST
DEFAULT OPTION(S) USED - SIZE=(131072,32768)

MODULE MAP

CONTROL SECTION			ENTRY			
NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION
MAIN	00	167A				
AMCDES	1680	82C				
BESSEL	2180	508				
BLJDEF	2788	2A6				
BLYDEF	2A30	396				
CAPGAM	2DC8	3A0				
COPYC	3168	13E				
CUBIC	32A8	364				
CONST	3610	8				
CCNV	3618	10				
DIR	3628	8				
FCTRL	3630	3A8				
DOB	39D8	2D0				
FNDNST	3CA8	2D8				
FNDNXT	3F80	30E				
FRSFND	4290	236				
GAMA	44C8	3AC				
HSQMNB	4878	5FA				
HSQMNS	4E78	60A				
MCMAHN	5488	4A0				
MNCALB	5928	1EA				
MNCALC	5B18	2F8				
MNSUM	5E10	3AE				
NXTMN	61C0	19C				
PCALB	6360	21C				
PCALCC	6580	480				
PQJ	6A00	56C				
PSQS	6F70	314				
QSQ	7288	262				
RECUR	74F0	1BE				
REGFAL	76B0	29A				
ROCT	7950	276				
SCALC	7BC8	432				
SCALCB	8000	254				
SMODSC	8258	F74				
SORT	91D0	206				
STAMFB	93D8	5EC				
STAMFC	99C8	71E				
PPN	A0E8	3AE				
SINCOS	A498	55E				
IHCLSCN *	A9F8	26C				
			DCOS	A9F8	DSIN	AA12
IHCLLOG *	AC68	200				
			DLOG10	AC68	DLOG	AC80

NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION	
IHCLSQRT*	AE68	158	DSQRT	AE68			
IHCFCPT *	AFC8	3C4	ERRSET	AFC8	ERRSAV	B1C2	[illegible]
IHCFDXPD*	B2D0	1A0	FDXPD#	B2D0			
IHCFDXPI*	B470	140	FDXPI#	B470			
IHCECOMH*	B5C0	F61	IBCOM#	B5C0	FDIOCS#	B67C	[illegible]
IHCCOMH2*	C528	65D	SEQDASD	C8A0			
SDUMP *	CB88	1E					
IHCFCVTH*	CBA8	1185	ADCON#	CBA8	FCVACUTP	CC52	[illegible]
			FCVIOUTP	D1E8	FCVECLTP	D6FC	[illegible]
IHCEFNTH*	DD60	542	ARITH#	DD60	ADJSWTCH	E0FC	
IHCLASCN*	E2A8	24F	DARCOS	E2A8	DARSIN	E2C0	
IHCLEXP *	E4F8	288	DEXP	E4F8			
IHCEFIOS*	E780	F28	FIOCS#	E780	FIOCSBEP	E786	
IHCFIOS2*	F6A8	52E					
IHCERRM *	FBD8	5CC	ERRMON	FBD8	IHCERRE	FBF0	
IHCUOPT *	10188	3A0					
IHCETRCH*	10558	28E	IHCTRCH	10558	ERRTRA	10560	
IHCUATBL*	107E8	638					
ACCEPT	10E20	8					
BESCR	10E28	8					
EIGEN	10E30	18					
FINAL	10E48	58					
FREQ	10EA0	8					
HALT	10EA8	8					
LEAD	10EB0	10					
LETTRS	10EC0	30					
MORE	10EF0	50					
NORMAL	10F40	8					
RADII	10F48	10					
OTHER	10F58	48					
STCAMP	10FA0	10					
ACCAMP	10FB0	10					
STOP	10FC0	C					
TABS	10FD0	C					
TERMS	10FE0	38					
VARSQ	11018	10					
VRBLS	11028	18					
ACUSTK	11040	17704					
SCLNS	28748	12C4					

NAME	ORIGIN	LENGTH	NAME	LOCATION	NAME	LOCATION
STRUCT	29A10	6408				
ERROR	2FE18	20				
SAMPLE	2FE38	3844				
ERROR	33680	4				
TOTALS	33688	30				
INFO	33688	4				

ENTRY ADDRESS 00
TOTAL LENGTH 336C0

****MAIN DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET

```
JOB TITLE:

           BBN TEST NO. 2 AND 3

INPUT DATA:

   LENGTH OF CYLINDER =                                60.00000 FEET
   LENGTH OF SEGMENT =                                 60.00000 FEET
   SEGMENT DISTANCE FROM END OF CYLINDER =              0.0     FEET
   RADIUS OF INNER CYLINDER =                           0.0     FEET
   RADIUS OF OUTER CYLINDER =                           8.00000 FEET
   SHELL STRUCTURAL THICKNESS =                         0.00400 FEET
   SHELL FILLER THICKNESS =                             0.05000 FEET
   SHELL DENSITY =                                      0.09890 SLUGS/FOOT**2
   LONGITUDINAL YOUNGS MODULUS =                      .18432E 10 LBS/FT**2
   CIRCUMFERENTIAL YOUNGS MODULUS =                   .50400E 09 LBS/FT**2
   POISSON'S RATIO =                                    0.30000
   SPEED OF SOUND =                                  1116.00000 FEET/SECOND
   FRAME AREA =                                       .58610D-02 FEET**2
   FRAME MOMENT OF INERTIA =                          .18300D-03 FEET**4
   FRAME-SKIN CENTROID DIST =                         .10900D 00 FEET
   FRAME SPACING =                                    .15800D 01 FEET
   FRAME YOUNGS MODULUS =                             .18432E 10 LBS/FT**2

   ADJUST CIRCUMFERENTIAL BENDING STIFFNESS BY      0.0500
```

ACOUSTIC MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
30000000	279.0	22001002	278.9	24006003	278.5
23003001	278.2	29002000	278.1	19008000	277.7
20004001	277.6	27001001	277.6	18002002	277.5
27004000	277.5	10010000	277.4	16005001	276.9
19006001	276.6	28003000	276.6	25002001	276.1
10001003	276.0	15009000	275.7	17000003	275.7
12003002	275.5	9010000	274.4	28000001	273.9
9006001	273.7	9001003	273.0	29001000	272.8
21007000	272.8	25005000	272.7	24000002	272.2
21001002	272.1	15005001	272.1	17002002	272.0
11003002	271.9	18008000	271.8	8010000	271.7
19004001	271.5	22003001	271.2	14009000	271.1
23006000	271.1	8006001	271.0	16000003	270.5
8001003	270.3	29000000	269.7	7010000	269.3
26001001	269.2	28002000	269.1	26004000	269.1
7006001	268.6	10003002	268.5	24002001	268.3
7001003	267.9	27003000	267.9	14005001	267.4
6010000	267.2	13009000	266.8	16002002	266.7
6006001	266.4	17008000	266.2	23007000	266.2
6001003	265.8	20001002	265.5	18004001	265.5
15000003	265.5	9003002	265.5	5010000	265.4
27000001	265.1	24005000	264.8	5006001	264.7
23000002	264.6	21003001	264.2	5001003	264.0
4010000	264.0	22006000	263.8	28001000	263.6
4006001	263.2	13005001	263.0	3010000	262.8
12009000	262.7	8003002	262.7	4001003	262.5
3006001	262.0	2010000	262.0	15002002	261.6
1010000	261.5	3001003	261.4	10000	261.3
2006001	261.2	25001001	260.9	16008000	260.8
25004000	260.8	14000003	260.7	1006001	260.7
23002001	260.6	2001003	260.6	6001	260.5
28000000	260.4	7003002	260.2	27002000	260.1
1001003	260.1	1003	259.9	19007000	259.8
17004001	259.7	26003000	259.2	19001002	259.1
11009000	258.9	12005001	258.9	6003002	258.0
20003001	257.4	22000002	257.1	23005000	257.0
14002002	256.8	21006000	256.7	26000001	256.3
13000003	256.2	5003002	256.2	15008000	255.6
10009000	255.4	11005001	255.0	4003002	254.6
27001000	254.4	16004001	254.2	18007000	253.6
3003002	253.4	22002001	253.0	18001002	252.9
24001001	252.6	2003002	252.6	24004000	252.5
13002002	252.2	9009000	252.1	1003002	252.1
12000003	251.9	3002	251.9	10005001	251.4
26002000	251.1	27000000	251.1	19003001	250.8
14008000	250.7	25003000	250.5	21000002	249.8
20006000	249.7	22005000	249.3	8009000	249.2
15004001	248.9	9005001	248.1	11000003	248.0
12002002	247.9	25000001	247.6	17007000	247.5
17001002	246.8	7009000	246.6	13008000	245.9

ACOUSTIC MODAL FREQUENCIES AND INDICES

NCICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
21002001	245.6	26001000	245.2	8005001	245.1
23001001	244.5	18003001	244.3	23004000	244.3
6009000	244.3	10000003	244.3	11002002	243.8
14004001	243.8	19006000	242.8	20000002	242.6
7005001	242.5	5009000	242.3	25002000	242.2
24003000	241.9	26000000	241.8	21005000	241.7
16007000	241.7	12008000	241.5	16001002	241.0
9000003	240.9	4009000	240.7	6005001	240.1
10002002	240.1	3009000	239.4	13004001	238.9
24000001	238.9	2009000	238.5	20002001	238.3
5005001	238.1	17003001	238.0	1009000	238.0
9000	237.8	8000003	237.8	11008000	237.4
9002002	236.6	4005001	236.5	22001001	236.4
22004000	236.2	18006000	236.1	25001000	236.1
15007000	236.1	19000002	235.6	15001002	235.3
3005001	235.2	7000003	235.1	12004001	234.4
2005001	234.3	20005000	234.3	1005001	233.7
5001	233.6	8002002	233.5	10008000	233.5
23003000	233.4	24002000	233.3	6000003	232.7
25000000	232.5	16003001	232.0	19002001	231.1
7002002	230.7	14007000	230.7	5000003	230.6
23000001	230.2	11004001	230.1	9008000	230.0
14001002	229.9	17006000	229.6	4000003	228.9
18000002	228.7	21001001	228.4	6002002	228.3
21004000	228.2	3000003	227.6	19005000	227.0
24001000	226.9	8008000	226.7	2000003	226.6
5002002	226.2	15003001	226.1	10004001	226.1
1000003	226.1	3	225.9	13007000	225.6
22003000	224.9	13001002	224.8	4002002	224.4
23002000	224.4	18002001	224.0	7008000	223.9
16006000	223.3	24000000	223.2	3002002	223.1
9004001	222.4	2002002	222.1	17000002	221.9
22000001	221.6	1002002	221.5	2002	221.3
6008000	221.3	12007000	220.7	14003001	220.5
20001001	220.5	20004000	220.3	12001002	219.9
18005000	219.8	5008000	219.2	8004001	219.1
23001000	217.8	4008000	217.4	15006000	217.2
17002001	217.2	21003000	216.4	11007000	216.2
7004001	216.1	3008000	216.0	22002000	215.5
16000002	215.4	11001002	215.4	13003001	215.1
2008000	215.0	1008000	214.4	8000	214.2
23000000	213.9	6004001	213.5	21000001	213.0
17005000	212.8	19001001	212.7	19004000	212.5
10007000	211.9	14006000	211.4	5004001	211.3
10001002	211.1	16002001	210.5	12003001	210.1
4004001	209.4	15000002	209.1	22001000	208.6
20003000	208.1	9007000	208.0	3004001	208.0
9001002	207.2	2004001	206.9	21002000	206.7
1004001	206.3	4001	206.1	16005000	206.0
13006000	205.8	11003001	205.3	18001001	205.0

ACOUSTIC MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
18004000	204.8	22000000	204.6	20000001	204.5
8007000	204.5	15002001	204.0	8001002	203.6
14000002	203.0	7007000	201.3	10003001	200.8
12006000	200.5	7001002	200.4	19003000	199.8
21001000	199.5	15005000	199.4	6007000	198.4
20002000	198.0	14002001	197.8	6001002	197.6
17001001	197.5	17004000	197.3	13000002	197.2
9003001	196.7	19000001	196.1	5007000	196.0
11006000	195.5	21000000	195.3	5001002	195.1
4007000	194.0	4001002	193.1	14005000	193.0
8003001	192.9	3007000	192.5	13002001	191.8
18003000	191.6	12000002	191.6	3001002	191.6
2007000	191.3	13006000	190.8	1007000	190.7
20001000	190.4	7000	190.4	2001002	190.4
16001001	190.1	16004000	189.9	1001002	189.8
1002	189.5	7003001	189.5	19002000	189.3
18000001	187.8	13005000	186.8	6003001	186.5
9006000	186.4	11000002	186.4	12002001	186.1
20000000	186.0	5003001	183.9	17003000	183.6
15001001	183.0	15004000	182.7	8006000	182.4
4003001	181.8	10000002	181.4	19001000	181.4
12005000	180.9	11002001	180.7	18002000	180.6
3003001	180.1	17000001	179.5	2003001	178.9
7006000	178.8	1003001	178.2	3001	178.0
9000002	176.8	19000000	176.7	14001001	176.0
14004000	175.8	6006000	175.6	16003000	175.6
10002001	175.6	11005000	175.4	5006000	172.9
8000002	172.6	18001000	172.3	17002000	172.0
16000001	171.4	9002001	170.8	4006000	170.6
10005000	170.1	13001001	169.2	13004000	169.0
3006000	168.9	7000002	168.8	15003000	167.8
2006000	167.6	18000000	167.4	1006000	166.8
6000	166.5	8002001	166.4	6000002	165.5
9005000	165.2	16002000	163.5	15000001	163.4
17001000	163.3	12001001	162.7	5000002	162.6
7002001	162.5	12004000	162.5	8005000	160.7
14003000	160.2	4000002	160.1	6002001	159.0
3000002	158.2	17000000	158.1	2000002	156.9
7005000	156.6	11001001	156.5	11004000	156.2
1000002	156.0	5002001	156.0	2	155.8
14000001	155.5	15002000	155.1	16001000	154.3
4002001	153.5	6005000	153.0	13003000	152.7
3002001	151.5	10001001	150.5	10004000	150.3
2002001	150.1	5005000	149.8	1002001	149.2
2001	148.9	16000000	148.8	13000001	147.8
4005000	147.2	14002000	146.8	12003000	145.4
15001000	145.4	3005000	145.1	9001001	145.0
9004000	144.7	2005000	143.6	1005000	142.7
5000	142.4	12000001	140.3	8001001	139.8
8004000	139.5	15000000	139.5	13002000	138.6

ACOUSTIC MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
11003000	138.4	14001000	136.5	7001001	135.1
7004000	134.8	11000001	133.1	10003000	131.7
6001001	130.9	12002000	130.6	6004000	130.6
14000000	130.2	13001000	127.6	5001001	127.2
5004000	126.9	10000001	126.0	9003000	125.3
4001001	124.1	4004000	123.8	11002000	122.7
3001001	121.6	3004000	121.3	13000000	120.9
2001001	119.8	2004000	119.5	9000001	119.3
8003000	119.2	12001000	118.9	1001001	118.7
1004000	118.4	1001	118.4	4000	118.1
10002000	115.1	7003000	113.7	8000001	113.0
12000000	111.6	11001000	110.2	6003000	108.7
9002000	107.7	7000001	107.1	5003000	104.2
11000000	102.3	6000001	101.7	10001000	101.6
8002000	100.7	4003000	100.4	3003000	97.4
5000001	97.0	2003000	95.1	7002000	94.0
1003000	93.7	3000	93.3	9001000	93.1
10000000	93.0	4000001	92.8	3000001	89.5
6002000	87.8	2000001	87.1	1000001	85.6
1	85.1	8001000	[illegible].9	9000000	83.7
5002000	82.2	4002000	77.3	7001000	76.9
8000000	74.4	3002000	73.3	2002000	70.3
6001000	69.2	1002000	68.4	2000	67.8
7000000	65.1	5001000	61.9	6000000	55.8
4001000	55.3	3001000	49.5	5000000	46.5
2001000	44.9	1001000	41.9	1000	40.9
4000000	37.2	3000000	27.9	2000000	18.6
1000000	9.3	0	0.0	*********	********

EIGENVALUE RESULTS

NDICES	EIGENVALUES	INDICES	EIGENVALUES	INDICES	EIGENVALUES
0	0.0	1	0.3832D 01	2	0.7016D 01
3	0.1017D 02	1000	0.1841D 01	1001	0.5332D 01
1002	0.8536D 01	1003	0.1171D 02	2000	0.3054D 01
2001	0.6706D 01	2002	0.9970D 01	3000	0.4201D 01
3001	0.8015D 01	3002	0.1135D 02	4000	0.5317D 01
4001	0.9282D 01	5000	0.6415D 01	5001	0.1052D 02
6000	0.7501D 01	6001	0.1173D 02	7000	0.8578D 01
8000	0.9647D 01	9000	0.1371D 02	10000	0.1177D 02

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
20020	5031.0	20019	5016.5	20018	5002.7
20017	4989.7	20016	4977.5	20015	4966.0
20014	4955.2	20013	4945.2	20012	4936.0
20011	4927.5	20010	4919.7	20009	4912.7
20008	4906.4	200[illegible]	4900.9	20006	4896.1
20005	4892.0	20004	4888.7	20003	4886.1
20002	4884.3	20001	4863.2	19020	4795.2
19019	4780.0	19018	4765.5	19017	4751.8
19016	4738.9	19015	4726.8	19014	4715.5
19013	4705.0	19012	4695.3	19011	4686.3
19010	4678.1	19009	4670.8	19008	4664.1
19007	4658.3	19006	4653.3	19005	4649.0
19004	4645.5	19003	4642.8	19002	4640.9
19001	4639.7	18020	4560.4	18019	4544.3
18018	4529.0	18017	4514.6	18016	4501.0
18015	4488.2	18014	4476.3	18013	4465.2
18012	4454.9	18011	4445.4	18010	4436.8
18009	4429.0	18008	4422.0	18007	4415.9
18006	4410.6	18005	4406.1	18004	4402.4
18003	4399.5	18002	4397.5	18001	4396.2
17020	4326.7	17019	4309.6	17018	4293.4
17017	4278.1	17016	4263.7	17015	4250.2
17014	4237.5	17013	4225.8	17012	4214.9
17011	4204.9	17010	4195.8	17009	4187.5
17008	4180.1	17007	4173.6	17006	4168.0
17005	4163.2	17004	4159.3	17003	4156.3
17002	4154.1	17001	4152.8	16020	4094.2
16019	4076.1	16018	4058.8	16017	4042.6
16016	4027.2	16015	4012.9	16014	3999.4
16013	3986.9	16012	3975.4	16011	3964.8
16010	3955.1	16009	3946.3	16008	3938.5
16007	3931.5	16006	3925.6	16005	3920.5
16004	3916.4	16003	3913.1	16002	3910.8
16001	3909.5	15020	3863.3	15019	3843.9
15018	3825.5	15017	3808.1	15016	3791.8
15015	3776.4	15014	3762.1	15013	3748.8
15012	3736.4	15011	3725.1	15010	3714.8
15009	3705.4	15008	3697.1	15007	3689.7
15006	3683.3	15005	3677.9	15004	3673.5
15003	3670.1	15002	3667.6	15001	3666.2
14020	3634.2	14019	3613.4	14018	3593.6
14017	3575.0	14016	3557.5	14015	3541.0
14014	3525.7	14013	3511.4	14012	3498.2
14011	3486.1	14010	3475.0	14009	3465.0
14008	3456.0	14007	3448.1	14006	3441.3
14005	3435.5	14004	3430.8	14003	3427.1
14002	3424.5	14001	3422.9	13020	3407.4
13019	3384.9	13018	3363.6	13017	3343.6
13016	3324.7	13015	3307.0	13014	3290.4
13013	3275.0	13012	3260.8	13011	3247.7

STRUCTURAL MODAL FREQUENCIES AND INDICES

INDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
13010	3235.8	13009	3225.0	13008	3215.4
13007	3206.9	13006	3199.6	13005	3193.3
13004	3188.3	13003	3184.3	12020	3183.4
13002	3181.5	13001	3179.8	12019	3159.0
12018	3135.9	12017	3114.2	12016	3093.7
12015	3074.5	12014	3056.5	12013	3039.9
12012	3024.5	12011	3010.3	12010	2997.4
12009	2985.7	12008	2975.3	12007	2966.1
11020	2963.0	12006	2958.2	12005	2951.4
12004	2945.9	12003	2941.7	12002	2938.6
12001	2936.8	11019	2936.4	11018	2911.2
11017	2887.4	11016	2865.0	11015	2844.0
11014	2824.5	11013	2806.3	11012	2789.4
11011	2774.0	11010	2759.9	10020	2747.4
11009	2747.2	11008	2735.9	11007	2725.9
10019	2718.0	11006	2717.2	11005	2709.9
11004	2703.9	11003	2699.2	11002	2695.9
11001	2693.9	10018	2690.3	10017	2664.0
10016	2639.4	10015	2616.3	10014	2594.7
10013	2574.7	10012	2556.2	10011	2539.2
9020	2538.1	10010	2523.7	10009	2509.8
9019	2505.4	10008	2497.3	10007	2486.3
20020	2478.3	10006	2476.8	9018	2474.4
10005	2468.8	10004	2462.2	10003	2457.1
10002	2453.4	10001	2451.3	20019	2447.1
9017	2445.2	9016	2417.7	20018	2417.0
9015	2392.0	20017	2388.1	19020	2386.8
9014	2368.0	20016	2360.5	19019	2354.5
9013	2345.8	8020	2337.3	20015	2334.1
9012	2325.2	19018	2323.3	20014	2309.1
9011	2306.4	8019	2300.4	18020	2296.4
19017	2293.3	9010	2289.2	20013	2285.5
9009	2273.7	8018	2265.5	19016	2264.5
20012	2263.4	18019	2263.0	9008	2259.8
9007	2247.7	20011	2242.8	9006	2237.1
19015	2237.1	8017	2232.6	18018	2230.6
9005	2228.2	20010	2223.8	9004	2220.9
9003	2215.3	9002	2211.3	19014	2211.0
9001	2208.8	17020	2207.4	20009	2206.5
8016	2201.6	18017	2199.5	20008	2190.8
19013	2186.4	20007	2176.9	17019	2172.7
8015	2172.6	18016	2169.6	20006	2164.7
19012	2163.4	20005	2154.3	7020	2148.3
20004	2145.8	8014	2145.6	19011	2141.8
18015	2141.0	17018	2139.2	20003	2139.1
20002	2134.4	20001	2131.5	19010	2122.0
8013	2120.5	16020	2119.8	18014	2113.8
17017	2106.8	7019	2106.3	19009	2103.8
8012	2097.4	18013	2088.1	19008	2087.3
16019	2083.9	8011	2076.2	17016	2075.7

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
19007	2072.7	7018	2066.4	18012	2064.0
19006	2059.9	8010	2056.9	16018	2049.1
19005	2049.0	17015	2045.9	18011	2041.4
19004	2040.1	8009	2039.5	15020	2033.7
19003	2033.1	7017	2028.7	19002	2028.0
19001	2025.0	8008	2023.9	18010	2020.6
17014	2017.5	16017	2015.4	8007	2010.3
18009	2001.5	8006	1998.5	15019	1996.6
7016	1993.3	17013	1990.6	8005	1988.5
18008	1984.2	16016	1983.0	8004	1980.3
6020	1975.9	8003	1974.0	8002	1969.5
18007	1968.8	8001	1966.8	17012	1965.3
15018	1960.4	7015	1960.1	18006	1955.4
16015	1951.9	14020	1949.3	18005	1943.9
17011	1941.6	18004	1934.4	7014	1929.1
6019	1927.6	18003	1927.0	15017	1925.4
16014	1922.2	18002	1921.7	17010	1919.7
18001	1918.6	14019	1910.9	7013	1900.4
17009	1899.7	16013	1894.0	15016	1891.6
17008	1881.5	6018	1881.5	7012	1874.0
14018	1873.4	16012	1867.5	13020	1866.8
17007	1865.2	15015	1859.1	17006	1851.0
7011	1849.7	16011	1842.6	17005	1838.9
6017	1837.7	14017	1837.0	17004	1828.9
15014	1828.1	7010	1827.7	13019	1827.1
5020	1826.1	17003	1821.1	16010	1819.6
17002	1815.5	17001	1812.1	7009	1807.9
14016	1801.8	15013	1798.5	16009	1798.4
6016	1796.5	7008	1790.2	13018	1788.3
12020	1786.1	16008	1779.2	7007	1774.6
15012	1770.6	5019	1770.4	14015	1767.9
16007	1762.0	7006	1761.2	6015	1757.7
13017	1750.4	7005	1749.8	16006	1746.9
12019	1745.2	15011	1744.4	7004	1740.6
14014	1735.2	16005	1734.1	7003	1733.4
7002	1728.3	7001	1725.2	16004	1723.5
6014	1721.6	15010	1720.1	5018	1716.9
16003	1715.2	13016	1713.7	16002	1709.2
11020	1707.4	16001	1705.6	12018	1705.0
4020	1704.7	14013	1704.3	15009	1697.7
6013	1688.1	13015	1678.2	15008	1677.4
14012	1674.9	12017	1665.8	5017	1665.7
11019	1665.4	15007	1659.2	6012	1657.2
14011	1647.3	13014	1644.1	15006	1643.2
4019	1641.8	10020	1631.5	15005	1629.5
6011	1628.9	12016	1627.5	11018	1623.9
14010	1621.6	15004	1618.2	5016	1617.0
3020	1614.7	13013	1611.5	15003	1609.4
6010	1603.2	15002	1603.0	15001	1599.2
14009	1597.8	12015	1590.5	10019	1587.5

STRUCTURAL MODAL FREQUENCIES AND INDICES

INDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
11017	1583.3	13012	1580.5	4018	1580.4
6009	1580.1	14008	1576.2	5015	1571.0
6008	1559.6	14007	1556.8	9020	1555.1
12014	1554.7	2020	1554.5	13011	1551.3
3019	1545.8	10018	1545.3	11016	1543.5
6007	1541.5	14006	1539.8	5014	1527.8
6006	1525.9	14005	1525.2	13010	1524.0
4017	1520.8	1020	1520.5	12013	1520.4
14004	1513.1	6005	1512.8	9019	1511.5
11015	1504.8	14003	1503.7	10017	1503.0
6004	1502.1	13009	1498.8	14002	1496.9
6003	1493.8	14001	1492.8	6002	1487.9
12012	1487.7	5013	1487.7	6001	1484.4
2019	1481.8	8020	1480.4	3018	1477.8
13008	1475.8	9018	1468.1	11014	1467.4
4016	1463.4	10016	1461.8	12011	1456.8
13007	1455.1	5012	1450.7	1019	1445.7
13006	1436.9	8019	1436.6	11013	1431.3
12010	1427.8	9017	1425.1	10015	1421.5
13005	1421.2	5011	1416.7	3017	1410.8
2018	1409.3	4015	1408.4	13004	1408.3
7020	1403.1	12009	1400.9	13003	1398.1
11012	1396.7	8018	1392.9	13002	1390.8
13001	1386.3	5010	1386.0	9016	1382.6
10014	1382.3	12008	1376.3	1018	1371.0
11011	1363.9	7019	1361.9	5009	1358.3
4014	1356.2	12007	1354.1	8017	1349.2
3016	1345.1	10013	1344.4	9015	1340.8
2017	1337.3	12006	1334.5	5008	1333.8
11010	1333.1	6020	1327.2	7018	1318.4
12005	1317.7	5007	1312.3	10012	1307.9
4013	1307.1	8016	1305.7	11009	1304.3
12004	1303.7	9014	1299.9	1017	1296.4
5006	1293.8	12003	1292.7	6019	1285.3
12002	1284.7	3015	1280.9	12001	1279.9
5005	1278.3	11008	1277.9	7017	1274.6
10011	1273.1	2016	1265.8	5004	1265.7
8015	1262.7	4012	1261.4	9013	1260.1
5003	1255.9	11007	1254.0	5002	1246.9
5001	1244.7	5020	1243.9	6018	1242.8
10010	1240.2	11006	1232.9	7016	1230.8
1016	1222.0	9012	1221.6	8014	1220.3
4011	1219.3	3014	1218.7	11005	1214.6
10009	1209.4	5019	1203.9	6017	1199.9
11004	1199.4	2015	1194.9	11003	1187.4
7015	1187.0	9011	1184.6	4010	1181.0
10008	1180.9	11002	1178.8	8013	1178.7
11001	1173.6	5018	1163.4	3013	1158.8
6016	1156.5	10007	1155.1	4020	1154.1
9010	1149.5	1015	1147.6	4009	1146.6

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
7014	1143.5	8012	1138.2	10006	1132.1
2014	1124.9	5017	1122.2	9009	1116.4
4008	1116.2	4019	1115.6	6015	1112.8
10005	1112.2	3012	1101.8	7013	1100.4
8011	1099.1	10004	1095.6	4007	1089.6
9008	1085.7	10003	1082.5	5016	1080.5
4018	1077.0	1014	1073.5	10002	1073.0
6014	1068.9	10001	1067.2	4006	1066.9
8010	1061.6	3020	1061.4	7012	1058.1
9007	1057.7	2013	1055.8	3011	1048.2
4005	1047.8	4017	1038.0	5015	1038.0
9006	1032.6	4004	1032.4	8009	1026.0
6013	1025.0	3019	1022.9	4003	1020.5
7011	1016.8	4002	1012.1	9005	1010.7
4001	1007.0	1013	999.5	4016	998.6
3010	998.6	5014	995.0	8008	992.7
9004	992.4	2012	988.1	3018	984.7
6012	981.4	9003	977.8	7010	976.9
2020	976.6	9002	967.3	8007	962.1
9001	960.9	4015	958.6	3009	953.6
5013	951.4	3017	946.6	7009	938.7
6011	938.3	2019	936.1	8006	934.5
1012	925.9	2011	922.2	4014	917.9
1020	915.2	3008	913.6	8005	910.4
3016	908.6	5012	907.4	7008	902.6
6010	896.1	2018	895.9	8004	890.0
3007	878.8	4013	876.3	8003	873.7
1019	871.9	3015	870.6	7007	869.1
5011	863.4	8002	861.9	2010	858.7
2017	856.2	6009	855.2	8001	854.6
1011	852.6	3006	849.2	7006	838.6
4012	833.8	3014	832.4	1018	828.8
3005	824.7	5010	819.6	2016	816.9
6008	816.1	7005	811.6	3004	805.0
2009	798.6	3013	793.9	4011	790.5
3003	790.0	7004	788.7	1017	785.8
1010	779.9	3002	779.4	6007	779.4
2015	778.0	5009	776.4	3001	773.2
7003	770.2	7002	756.7	3012	754.7
7001	748.5	4010	746.6	6006	745.5
1016	743.2	2008	743.1	2014	739.7
5008	734.4	6005	715.1	3011	714.6
1009	708.0	4009	702.3	2013	701.8
1015	700.8	5007	694.1	2007	693.5
6004	689.0	3010	673.3	6003	667.8
2012	664.4	1014	658.8	4009	658.1
5006	656.4	6002	652.1	2006	651.0
6001	642.4	1008	637.4	3009	630.7
2011	627.3	5005	622.0	1013	617.3
2005	616.3	4007	614.8	5004	591.8

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
2010	590.2	2004	589.3	3008	586.9
1012	576.5	4006	573.0	2003	569.4
1007	568.8	5003	566.9	2002	555.8
2009	552.6	5002	548.2	2001	547.8
3007	542.2	5001	536.6	1011	536.4
4005	533.9	2008	513.8	1006	504.1
4004	498.7	1010	497.4	3006	497.4
2007	473.1	4003	468.8	1009	459.8
3005	453.6	1005	446.6	4002	445.7
20020	441.6	20019	438.2	20018	434.9
20017	431.9	4001	431.1	2006	429.9
20016	429.1	20015	426.4	20014	424.0
1008	423.7	20013	421.7	20012	419.6
20011	417.8	20010	416.0	20009	414.5
20008	413.1	3004	412.3	20007	411.9
20006	410.9	20005	410.0	20004	409.3
20003	408.7	20002	408.3	20001	408.1
19020	402.2	1004	401.9	19019	398.7
19018	395.4	19017	392.3	1007	389.5
19016	389.4	19015	386.7	2005	384.3
19014	384.3	19013	382.[illegible]	19012	379.9
19011	378.0	19010	376.2	3003	375.6
19009	374.7	19008	373.3	1003	372.7
19007	372.1	19006	371.0	19005	370.2
19004	369.5	19003	368.9	19002	368.5
19001	368.3	18020	364.8	18019	361.3
18018	357.9	1006	356.3	1002	356.0
18017	354.8	18016	351.9	18015	349.1
1001	347.5	18014	346.6	3002	346.0
18013	344.3	18012	342.2	18011	340.2
18010	338.5	2004	337.8	18009	336.9
18008	335.5	18007	334.3	18006	333.3
18005	332.4	18004	331.7	18003	331.1
18002	33[illegible].7	18001	330.5	17020	329.7
3001	326.5	17019	326.0	17018	322.6
1005	321.6	17017	319.4	17016	316.4
17015	313.6	17014	311.1	17013	308.7
17012	306.5	17011	304.6	17010	302.8
17009	301.2	17008	299.8	17007	298.6
17006	297.5	16020	296.8	17005	296.6
17004	295.9	17003	295.4	17002	295.0
17001	294.7	16019	293.0	2003	292.8
16018	289.5	16017	286.2	16016	283.1
1004	280.6	16015	280.3	16014	277.6
16013	275.2	16012	273.0	16011	271.0
16010	269.2	16009	267.5	15020	266.2
16008	266.1	16007	264.9	16006	263.8
16005	262.9	15019	262.3	16004	262.2
16003	261.7	16002	261.3	16001	261.[illegible]
15018	258.6	15017	255.2	2002	253.0

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
15016	252.0	15015	249.1	15014	246.3
15013	243.8	15012	241.5	15011	239.5
14020	238.1	15010	237.6	15009	236.0
1020	235.0	15008	234.5	14019	234.0
1019	233.3	15007	233.3	15006	232.2
1018	231.5	15005	231.3	1003	231.3
15004	230.6	14018	230.1	15003	230.0
1017	229.7	15002	229.6	15001	229.4
1016	227.7	14017	226.6	1015	225.5
2001	224.0	14016	223.2	1014	223.1
1013	220.1	14015	220.1	14014	217.2
2020	216.7	1012	216.6	14013	214.6
2019	213.2	13020	212.6	14012	212.2
1011	212.2	14011	210.1	2018	209.4
13019	208.3	14010	208.2	1010	206.6
14009	206.5	2017	205.3	14008	205.0
13018	204.2	14007	203.7	14006	202.6
14005	201.7	14004	200.9	2016	200.8
14003	200.4	13017	200.4	14002	200.0
14001	199.8	1009	199.4	13016	196.8
2015	195.9	3020	194.3	13015	193.5
13014	190.5	2014	190.3	12020	190.0
1008	189.8	3019	189.1	13013	187.7
12019	185.3	13012	185.2	2013	183.9
3018	183.7	13011	182.9	12018	181.0
13010	180.9	13009	179.1	1002	178.1
3017	177.9	13008	177.5	1007	177.1
12017	176.8	2012	176.6	13007	176.2
13006	175.0	13005	174.1	13004	173.4
4020	173.1	12016	173.0	13003	172.8
13002	172.4	13001	172.2	3016	171.6
11020	170.6	12015	169.4	2011	168.2
4019	166.9	12014	166.1	11019	165.6
3015	164.8	12013	163.1	11018	160.8
1006	160.5	4018	160.4	12012	160.4
2010	158.5	12011	157.9	3014	157.4
11017	156.4	5020	155.9	12010	155.7
10020	155.1	12009	153.8	4017	153.6
12008	152.2	11016	152.1	12007	150.8
10019	149.6	12006	149.6	3013	149.4
5019	149.1	12005	148.6	11015	148.2
12004	147.9	2009	147.4	12003	147.3
12002	146.9	12001	146.6	4016	146.5
11014	144.5	10018	144.4	9020	144.0
6020	144.0	5018	142.2	11013	141.2
3012	140.6	10017	139.4	1005	139.3
4015	138.9	11012	138.1	8020	138.1
9019	138.0	7020	138.0	6019	137.1
11011	135.4	5017	135.0	10016	134.7
2008	134.5	11010	133.0	9018	132.3

STRUCTURAL MODAL FREQUENCIES AND INDICES

NDICES	FREQUENCIES	INDICES	FREQUENCIES	INDICES	FREQUENCIES
8019	131.7	7019	131.2	3011	131.0
4014	130.9	11009	130.8	10015	130.2
6018	130.1	1001	130.0	11008	129.0
5016	127.6	11007	127.5	9017	126.7
11006	126.2	10014	126.1	8018	125.4
11005	125.2	7018	124.5	11004	124.4
11003	123.8	11002	123.4	11001	123.2
6017	123.0	4013	122.5	10013	122.2
9016	121.3	3010	120.5	5015	120.0
2007	119.8	8017	119.2	10012	118.7
7017	117.7	9015	116.2	6016	115.8
10011	115.5	4012	113.6	1004	113.6
8016	113.1	10010	112.7	5014	112.1
9014	111.4	7016	111.0	10009	110.3
3009	109.0	6015	108.5	10008	108.2
8015	107.2	9013	106.9	10007	106.4
10006	105.0	7015	104.4	4011	104.1
5013	104.0	10005	103.8	2006	103.2
10004	103.0	9012	102.7	10003	102.4
10002	101.9	10001	101.7	8014	101.6
6014	101.1	9011	98.8	7014	97.8
3008	96.6	8013	96.1	5012	95.6
9010	95.4	4010	94.2	6013	93.7
9009	92.4	7013	91.3	8012	91.0
9008	89.8	9007	87.7	5011	87.0
6012	86.2	8011	86.2	9006	86.0
7012	85.0	2005	84.7	9005	84.6
4009	83.8	9004	83.7	1003	83.6
3007	83.3	9003	83.0	9002	82.5
9001	82.3	8010	81.8	7011	79.0
6011	78.8	5010	78.2	8009	77.9
8008	74.5	7010	73.3	4008	73.0
8007	71.7	6010	71.5	8006	69.4
5009	69.3	3006	69.2	7009	68.0
8005	67.7	8004	66.5	8003	65.7
8002	65.2	8001	64.9	2004	64.5
6009	64.5	7008	63.3	4007	61.9
5008	60.5	7007	59.2	6008	57.9
7006	55.9	3005	54.6	7005	53.4
5007	52.0	6007	51.8	7004	51.6
4006	50.7	7003	50.5	1002	50.5
7002	49.9	7001	49.6	6006	46.6
5006	43.9	2003	43.4	6005	42.5
4005	42.0	3004	39.8	6004	39.5
6003	37.7	5005	36.9	6002	36.7
6001	36.4	5004	31.3	4004	30.2
5003	27.6	3003	26.0	5002	25.8
5001	25.1	2002	23.1	4003	22.4
1001	17.7	4002	17.6	4001	16.0
3002	14.9	3001	9.3	2001	7.5

STRUCTURAL CONSTANTS C1 AND INDICIES

NDICES	CONSTANTS	INDICES	CONSTANTS	INDICES	CONSTANTS
1001	130.5	2001	226.0	3001	328.4
4001	432.7	5001	538.0	6001	643.6
7001	749.5	8001	855.6	9001	961.7
10001	1067.9	11001	1174.2	12001	1280.6
13001	1386.9	14001	1493.3	15001	1599.7
16001	1706.1	17001	1812.5	18001	1919.0
19001	2025.4	20001	2131.9	1002	184.7
2002	261.1	3002	353.4	4002	452.0
5002	553.6	6002	656.7	7002	760.8
8002	865.5	9002	970.5	10002	1075.9
11002	1181.5	12002	1287.2	13002	1393.0
14002	1499.0	15002	1605.0	16002	1711.1
17002	1817.2	18002	1923.4	19002	2029.6
20002	2135.9	1003	250.1	2003	310.8
3003	391.6	4003	482.5	5003	578.7
6003	678.0	7003	779.3	8003	881.7
9003	985.1	10003	1089.0	11003	1193.4
12003	1298.2	13003	1403.2	14003	1508.5
15003	1613.9	16003	1719.4	17003	1825.0
18003	1930.8	19003	2036.6	20003	2142.5
1004	320.0	2004	369.3	3004	439.5
4004	522.1	5004	612.1	6004	706.8
7004	804.4	8004	904.0	9004	1005.1
10004	1107.2	11004	1210.0	12004	1313.4
13004	1417.3	14004	1521.6	15004	1626.1
16004	1730.9	17004	1835.9	18004	1941.1
19004	2046.4	20004	2151.8	1005	391.9
2005	433.1	3005	494.3	4005	569.0
5005	652.6	6005	742.1	7005	835.6
8005	931.9	9005	1030.3	10005	1130.1
11005	1231.0	12005	1332.8	13005	1435.3
14005	1538.3	15005	1641.8	16005	1745.7
17005	1849.8	18005	1954.2	19005	2058.9
20005	2163.7	1006	464.9	2006	500.2
3006	554.0	4006	621.6	5006	698.9
6006	783.2	7006	872.3	8006	964.9
9006	1060.2	10006	1157.4	11006	1256.2
12006	1356.1	13006	1456.9	14006	1558.5
15006	1660.8	16006	1763.5	17006	1866.7
18006	1970.2	19006	2074.5	20006	2178.1
1007	538.6	2007	569.3	3007	617.2
4007	676.5	5007	750.0	6007	829.0
7007	913.7	8007	1002.5	9007	1094.5
10007	1188.9	11007	1285.3	12007	1383.1
13007	1482.1	14007	1382.1	15007	1682.9
16007	1784.3	17007	1886.4	18007	1988.9
19007	2091.8	20007	2195.0	1008	612.7
2008	639.9	3008	682.8	4008	738.7
5008	804.9	6008	879.0	7008	959.2
8008	1044.2	9008	1132.8	10008	1224.3

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STRUCTURAL CONSTANTS C

11008	1318.0	12008	1413.6	13008	1510.6
14008	1608.8	15008	1708.0	16008	1808.1
17008	1908.8	18008	2010.2	19008	2112.1
20008	2214.3	1009	687.1	2009	711.5
3009	750.3	4009	801.5	5009	862.8
6009	932.4	7009	1008.4	8009	1089.5
9009	1174.7	10009	1263.2	11009	1354.2
12009	1447.4	13009	1542.3	14009	1638.6
15009	1736.1	16009	1834.6	17009	1934.0
18009	2034.1	19009	2134.8	20009	2236.1
1010	761.7	2010	783.8	3010	819.2
4010	866.3	5010	923.4	6010	988.6
7010	1060.6	8010	1138.1	9010	1219.9
10010	1305.3	11010	1393.6	12010	1484.3
13010	1576.9	14010	1671.3	15010	1767.0
16010	1863.9	17010	1961.8	18010	2060.5
19010	2160.0	20010	2260.1	1011	836.5
2011	856.6	3011	889.1	4011	932.7
5011	985.9	6011	1047.3	7011	1115.5
8011	1189.4	9011	1267.9	10011	1350.2
11011	1435.8	12011	1524.0	13011	1614.4
14011	1706.6	15011	1800.5	16011	1895.6
17011	1992.0	18011	2089.3	19011	2187.5
20011	2286.4	1012	911.3	2012	929.8
3012	959.9	4012	1003.4	5012	1050.2
6012	1108.0	7012	1172.7	8012	1243.2
9012	1318.5	10012	1397.9	11012	1480.7
12012	1566.3	13012	1654.4	14012	1744.5
15012	1836.4	16012	1929.9	17012	2024.6
18012	2120.4	19012	2217.2	20012	2314.8
1013	986.3	2013	1003.4	3013	1031.3
4013	1069.1	5013	1115.9	6013	1170.5
7013	1231.9	8013	1299.1	9013	1371.4
10013	1447.8	11013	1527.9	12013	1611.1
13013	1696.8	14013	1784.8	15013	1874.8
16013	1966.4	17013	2059.4	18013	2153.7
19013	2249.0	20013	2345.4	1014	1061.3
2014	1077.2	3014	1103.3	4014	1138.7
5014	1182.7	6014	1234.3	7014	1292.7
8014	1356.9	9014	1426.3	10014	1499.9
11014	1577.4	12014	1658.1	13014	1741.5
14014	1827.4	15014	1915.3	16014	2005.0
17014	2096.3	18014	2189.0	19014	2282.9
20014	2377.9	1015	1136.4	2015	1151.3
3015	1175.6	4015	1209.0	5015	1250.5
6015	1299.4	7015	1355.0	8015	1416.4
9015	1483.0	10015	1554.0	11015	1628.8
12015	1707.1	13015	1788.3	14015	1872.0
15015	1957.9	16015	2045.8	17015	2135.3
18015	2226.4	19015	2318.8	20015	2412.3

STRUCTURAL CONSTANTS C

1016	1211.5	2016	1225.5	3016	1248.4
4016	1279.8	5016	1319.1	6016	1365.6
7016	1418.6	8016	1477.4	9016	1541.3
10016	1609.7	11016	1682.1	12016	1758.0
13016	1836.9	14016	1918.5	15016	2002.4
16016	2088.4	17016	2176.2	18016	2265.6
19016	2356.5	20016	2448.6	1017	1286.6
2017	1299.8	3017	1321.5	4017	1351.2
5017	1388.5	6017	1432.7	7017	1483.3
8017	1539.6	9017	1601.0	10017	1667.0
11017	1737.0	12017	1810.6	13017	1887.3
14017	1966.8	15017	2048.8	16017	2132.9
17017	2218.9	18017	2306.7	19017	2396.0
20017	2486.6	1018	1361.8	2018	1374.3
3018	1394.8	4018	1423.0	5018	1458.4
6018	1500.6	7018	1549.0	8018	1603.0
9018	1662.1	10018	1725.7	11018	1793.4
12018	1864.8	13018	1939.3	14018	2016.8
15018	2096.8	16018	2179.1	17018	2263.4
18018	2349.5	19018	2437.2	20018	2526.4
1019	1437.0	2019	1448.8	3019	1468.3
4019	1495.1	5019	1528.9	6019	1569.2
7019	1615.5	8019	1667.3	9019	1724.2
10019	1785.6	11019	1851.2	12019	1920.4
13019	1992.9	14019	2068.3	15019	2146.4
16019	2226.8	17019	2309.4	18019	2393.8
19019	2480.0	20019	2567.7	1020	1512.3
2020	1523.5	3020	1542.0	4020	1567.5
5020	1599.8	6020	1638.3	7020	1682.7
8020	1732.6	9020	1787.4	10020	1846.7
11020	1910.2	12020	1977.3	13020	2047.8
14020	2121.3	15020	2197.5	16020	2276.1
17020	2356.9	18020	2439.7	19020	2524.3
20020	2610.5	1200	247.9	400	489.7

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STRUCTURAL CONSTANTS C2 AND INDICIES

NDICES	CONSTANTS	INDICES	CONSTANTS	INDICES	CONSTANTS
1001	247.9	2001	489.7	3001	732.9
4001	976.4	5001	1220.0	6001	1463.7
7001	1707.4	8001	1951.2	9001	2195.0
10001	2438.7	11001	2682.5	12001	2926.3
13001	3170.2	14001	3414.0	15001	3657.8
16001	3901.6	17001	4145.4	18001	4389.2
19001	4633.1	20001	4876.9	1002	259.7
2002	495.8	3002	736.9	4002	979.4
5002	1222.4	6002	1465.7	7002	1709.2
8002	1952.7	9002	2196.3	10002	2440.0
11002	2683.7	12002	2927.4	13002	3171.1
14002	3414.8	15002	3658.6	16002	3902.4
17002	4146.1	18002	4389.9	19002	4633.7
20002	4877.5	1003	278.2	2003	505.7
3003	743.7	4003	984.5	5003	1226.5
6003	1469.1	7003	1712.1	8003	1955.3
9003	2198.6	10003	2442.0	11003	2685.5
12003	2929.1	13003	3172.7	14003	3416.3
15003	3660.0	16003	3903.6	17003	4147.3
18003	4391.1	19003	4634.8	20003	4878.5
1004	302.2	2004	519.3	3004	753.0
4004	991.5	5004	1232.2	6004	1473.9
7004	1716.1	8004	1958.8	9004	2201.8
10004	2444.9	11004	2688.1	12004	2931.4
13004	3174.9	14004	3418.3	15004	3661.9
16004	3905.4	17004	4149.0	18004	4392.6
19004	4636.3	20004	4879.9	1005	330.5
2005	536.3	3005	764.8	4005	1000.5
5005	1239.4	6005	1479.9	7005	1721.4
8005	1963.4	9005	2205.8	10005	2448.5
11005	2691.4	12005	2934.5	13005	3177.7
14005	3421.0	15005	3664.3	16005	3907.7
17005	4151.2	18005	4394.7	19005	4638.2
20005	4881.8	1006	362.1	2006	556.3
3006	779.0	4006	1011.4	5006	1248.2
6006	1487.3	7006	1727.7	8006	1969.0
9006	2210.8	10006	2453.0	11006	2695.5
12006	2938.2	13006	3181.1	14006	3424.2
15006	3667.3	16006	3910.5	17006	4153.8
18006	4397.2	19006	4640.6	20006	4884.0
1007	396.3	2007	579.1	3007	795.4
4007	1024.1	5007	1258.5	6007	1496.0
7007	1735.2	8007	1975.5	9007	2216.6
10007	2458.3	11007	2700.3	12007	2942.6
13007	3185.2	14007	3427.9	15007	3670.8
16007	3913.8	17007	4156.9	18007	4400.1
19007	4643.4	20007	4886.7	1008	432.3
2008	604.4	3008	814.0	4008	1038.6
5008	1270.4	6008	1505.9	7008	1743.8
8008	1983.1	9008	2223.4	10008	2464.3

STRUCTURAL CONSTANTS C

11008	2705.8	12008	2947.7	13008	3189.9
14008	3432.3	15008	3674.9	16008	3917.6
17008	4160.5	18008	4403.5	19008	4646.6
20008	4889.7	1009	469.8	2009	631.7
3009	834.5	4009	1054.8	5009	1283.6
6009	1517.1	7009	1753.4	8009	1991.6
9009	2231.0	10009	2471.2	11009	2712.1
12009	2953.4	13009	3195.2	14009	3437.2
15009	3679.5	16009	3922.0	17009	4164.6
18009	4407.3	19009	4650.2	20009	4893.2
1010	508.5	2010	661.0	3010	856.9
4010	1072.6	5010	1298.3	6010	1529.5
7010	1764.2	8010	2001.1	9010	2239.4
10010	2478.8	11010	2719.0	12010	2959.8
13010	3201.1	14010	3442.7	15010	3684.6
16010	3926.8	17010	4169.1	18010	4411.6
19010	4654.3	20010	4897.1	1011	548.1
2011	691.9	3011	880.9	4011	1091.9
5011	1314.3	6011	1543.1	7011	1776.0
8011	2011.5	9011	2248.7	10011	2487.3
11011	2726.7	12011	2966.9	13011	3207.6
14011	3448.8	15011	3690.3	16011	3932.1
17011	4174.1	18011	4416.4	19011	4658.8
20011	4901.3	1012	588.4	2012	724.3
3012	906.5	4012	1112.7	5012	1331.6
6012	1557.9	7012	1788.9	8012	2022.8
9012	2258.9	10012	2496.4	11012	2735.1
12012	2974.6	13012	3214.8	14012	3455.4
15012	3696.5	16012	3937.9	17012	4179.6
18012	4421.6	19012	4663.7	20012	4906.0
1013	629.3	2013	757.8	3013	933.6
4013	1134.8	5013	1350.1	6013	1573.8
7013	1802.7	8013	2035.1	9013	2269.9
10013	2506.4	11013	2744.2	12013	2983.0
13013	3222.5	14013	3462.6	15013	3703.2
16013	3944.2	17013	4185.6	18013	4427.2
19013	4669.0	20013	4911.1	1014	670.6
2014	792.5	3014	962.0	4014	1158.2
5014	1369.9	6014	1590.8	7014	1817.6
8014	2048.3	9014	2281.7	10014	2517.1
11014	2754.0	12014	2992.0	13014	3230.8
14014	3470.4	15014	3710.5	16014	3951.0
17014	4192.0	18014	4433.2	19014	4674.8
20014	4916.5	1015	712.4	2015	828.1
3015	991.5	4015	1182.9	5015	1390.8
6015	1608.8	7015	1833.4	8015	2062.3
9015	2294.3	10015	2528.5	11015	2764.4
12015	3001.6	13015	3239.7	14015	3478.7
15015	3718.3	16015	3958.3	17015	4198.9
18015	4439.8	19015	4680.9	20015	4922.4

STRUCTURAL CONSTANTS C

1016	754.4	2016	864.6	3016	1022.2
4016	1208.7	5016	1412.8	6016	1627.9
7016	1850.1	8016	2077.2	9016	2307.7
10016	2540.7	11016	2775.6	12016	3011.9
13016	3249.3	14016	3487.5	15016	3726.5
16016	3966.1	17016	4206.2	18016	4446.7
19016	4687.5	20016	4928.7	1017	796.8
2017	901.8	3017	1053.8	4017	1235.6
5017	1435.9	6017	1648.0	7017	1867.8
8017	2093.0	9017	2321.9	10017	2553.6
11017	2787.4	12017	3022.7	13017	3259.3
14017	3496.9	15017	3735.3	16017	3974.4
17017	4214.0	18017	4454.1	19017	4694.5
20017	4935.3	1018	839.4	2018	939.7
3018	1086.4	4018	1263.5	5018	1460.0
6018	1669.0	7018	1886.4	8018	2109.6
9018	2336.9	10018	2567.2	11018	2799.9
12018	3034.2	13018	3270.0	14018	3506.9
15018	3744.7	16018	3983.2	17018	4222.3
18018	4461.9	19018	4702.0	20018	4942.4
1019	882.2	2019	978.1	3019	1119.8
4019	1292.3	5019	1485.0	6019	1690.9
7019	1905.8	8019	2127.0	9019	2352.6
10019	2581.5	11019	2813.0	12019	3046.4
13019	3281.3	14019	3517.4	15019	3754.5
16019	3992.4	17019	4231.0	18019	4470.1
19019	4709.8	20019	4949.8	1020	925.2
2020	1017.0	3020	1153.9	4020	1322.0
5020	1512.9	6020	1713.7	7020	1926.1
8020	2145.1	9020	2369.0	10020	2596.5
11020	2826.7	12020	3059.1	13020	3293.1
14020	3528.4	15020	3764.8	16020	4002.1
17020	4240.2	18020	4478.8	19020	4718.0
20020	4957.7	1200	49.0	400	98.1

STRUCTURAL CONSTANTS C3 AND INDICIES

NDICES	CONSTANTS	INDICES	CONSTANTS	INDICES	CCNSTANTS
1001	49.0	2001	98.1	3001	147.1
4001	196.1	5001	245.1	6001	294.2
7001	343.2	8001	392.2	9001	441.2
10001	490.3	11001	539.3	12001	588.3
13001	637.3	14001	686.4	15001	735.4
16001	784.4	17001	833.4	18001	882.5
19001	931.5	20001	980.5	1002	98.1
2002	196.1	3002	294.2	4002	392.2
5002	490.3	6002	588.3	7002	686.4
8002	784.4	9002	882.5	10002	980.5
11002	1078.6	12002	1176.6	13002	1274.7
14002	1372.7	15002	1470.8	16002	1568.8
17002	1666.9	18002	1764.9	19002	1863.0
20002	1961.1	1003	147.1	2003	294.2
3003	441.2	4003	588.3	5003	735.4
6003	882.5	7003	1029.6	8003	1176.6
9003	1323.7	10003	1470.8	11003	1617.9
12003	1764.9	13003	1912.0	14003	2059.1
15003	2206.2	16003	2353.3	17003	2500.3
18003	2647.4	19003	2794.5	20003	2941.6
1004	196.1	2004	392.2	3004	588.3
4004	784.4	5004	980.5	6004	1176.6
7004	1372.7	8004	1568.8	9004	1764.9
10004	1961.1	11004	2157.2	12004	2353.3
13004	2549.4	14004	2745.5	15004	2941.6
16004	3137.7	17004	3333.8	18004	3529.9
19004	3726.0	20004	3922.1	1005	245.1
2005	490.3	3005	735.4	4005	980.5
5005	1225.7	6005	1470.8	7005	1715.9
8005	1961.1	9005	2206.2	10005	2451.3
11005	2696.4	12005	2941.6	13005	3186.7
14005	3431.8	15005	3677.0	16005	3922.1
17005	4167.2	18005	4412.4	19005	4657.5
20005	4902.6	1006	294.2	2006	588.3
3006	882.5	4006	1176.6	5006	1470.8
6006	1764.9	7006	2059.1	8006	2353.3
9006	2647.4	10006	2941.6	11006	3235.7
12006	3529.9	13006	3824.1	14006	4118.2
15006	4412.4	16006	4706.5	17006	5000.7
18006	5294.8	19006	5589.0	20006	5883.2
1007	343.2	2007	686.4	3007	1029.6
4007	1372.7	5007	1715.9	6007	2059.1
7007	2402.3	8007	2745.5	9007	3088.7
10007	3431.8	11007	3775.0	12007	4118.2
13007	4461.4	14007	4804.6	15007	5147.8
16007	5491.0	17007	5834.1	18007	6177.3
19007	6520.5	20007	6863.7	1008	392.2
2008	784.4	3008	1176.6	4008	1568.8
5008	1961.1	6008	2353.3	7008	2745.5
8008	3137.7	9008	3529.9	10008	3922.1

STRUCTURAL CONSTANTS C

11008	4314.3	12008	4706.5	13008	5098.7
14008	5491.0	15008	5883.2	16008	6275.4
17008	6667.6	18008	7059.8	19008	7452.0
20008	7844.2	1009	441.2	2009	882.5
3009	1323.7	4009	1764.9	5009	2206.2
6009	2647.4	7009	3088.7	8009	3529.9
9009	3971.1	10009	4412.4	11009	4853.6
12009	5294.8	13009	5736.1	14009	6177.3
15009	6618.6	16009	7059.8	17009	7501.0
18009	7942.3	19009	8383.5	20009	8824.7
1010	490.3	2010	980.5	3010	1470.8
4010	1961.1	5010	2451.3	6010	2941.6
7010	3431.8	8010	3922.1	9010	4412.4
10010	4902.6	11010	5392.9	12010	5883.2
13010	6373.4	14010	6863.7	15010	7354.0
16010	7844.2	17010	8334.5	18010	8824.7
19010	9315.0	20010	9805.3	1011	539.3
2011	1078.6	3011	1617.9	4011	2157.2
5011	2696.4	6011	3235.7	7011	3775.0
8011	4314.3	9011	4853.6	10011	5392.9
11011	5932.2	12011	6471.5	13011	7010.8
14011	7550.1	15011	8089.3	16011	8628.6
17011	9167.9	18011	9707.2	19011	10246.5
20011	10785.8	1012	588.3	2012	1176.6
3012	1764.9	4012	2353.3	5012	2941.6
6012	3529.9	7012	4118.2	8012	4706.5
9012	5294.8	10012	5883.2	11012	6471.5
12012	7059.8	13012	7648.1	14012	8236.4
15012	8824.7	16012	9413.1	17012	10001.4
18012	10589.7	19012	11178.0	20012	11766.3
1013	637.3	2013	1274.7	3013	1912.0
4013	2549.4	5013	3186.7	6013	3824.1
7013	4461.4	8013	5098.7	9013	5736.1
10013	6373.4	11013	7010.8	12013	7648.1
13013	8285.5	14013	8922.8	15013	9560.1
16013	10197.5	17013	10834.8	18013	11472.2
19013	12109.5	20013	12746.8	1014	686.4
2014	1372.7	3014	2059.1	4014	2745.5
5014	3431.8	6014	4118.2	7014	4804.6
8014	5491.0	9014	6177.3	10014	6863.7
11014	7550.1	12014	8236.4	13014	8922.8
14014	9609.2	15014	10295.5	16014	10981.9
17014	11668.3	18014	12354.6	19014	13041.0
20014	13727.4	1015	735.4	2015	1470.8
3015	2206.2	4015	2941.6	5015	3677.0
6015	4412.4	7015	5147.8	8015	5883.2
9015	6618.6	10015	7354.0	11015	8089.3
12015	8824.7	13015	9560.1	14015	10295.5
15015	11030.9	16015	11766.3	17015	12501.7
18015	13237.1	19015	13972.5	20015	14707.9

STRUCTURAL CONSTANTS C

1016	784.4	2016	1568.8	3016	2353.3
4016	3137.7	5016	3922.1	6016	4706.5
7016	5491.0	8016	6275.4	9016	7059.8
10016	7844.2	11016	8628.6	12016	9413.1
13016	10197.5	14016	10981.9	15016	11766.3
16016	12550.7	17016	13335.2	18016	14119.6
19016	14904.0	20016	15688.4	1017	833.4
2017	1666.9	3017	2500.3	4017	3333.8
5017	4167.2	6017	5000.7	7017	5834.1
8017	6667.6	9017	7501.0	10017	8334.5
11017	9167.9	12017	10001.4	13017	10834.8
14017	11668.3	15017	12501.7	16017	13335.2
17017	14168.6	18017	15002.1	19017	15835.5
20017	16669.0	1018	882.5	2018	1764.9
3018	2647.4	4018	3529.9	5018	4412.4
6018	5294.8	7018	6177.3	8018	7059.8
9018	7942.3	10018	8824.7	11018	9707.2
12018	10589.7	13018	11472.2	14018	12354.6
15018	13237.1	16018	14119.6	17018	15002.1
18018	15884.5	19018	16767.0	20018	17649.5
1019	931.5	2019	1863.0	3019	2794.5
4019	3726.0	5019	4657.5	6019	5589.0
7019	6520.5	8019	7452.0	9019	8383.5
10019	9315.0	11019	10246.5	12019	11178.0
13019	12109.5	14019	13041.0	15019	13972.5
16019	14904.0	17019	15835.5	18019	16767.0
19019	17698.5	20019	18630.0	1020	980.5
2020	1961.1	3020	2941.6	4020	3922.1
5020	4902.6	6020	5883.2	7020	6863.7
8020	7844.2	9020	8824.7	10020	9805.3
11020	10785.8	12020	11766.3	13020	12746.8
14020	13727.4	15020	14707.9	16020	15688.4
17020	16669.0	18020	17649.5	19020	18630.0
20020	19610.5	1200	0.0	400	0.0

***VOL AVE AMPLIFICATION = -.7967D 01 DBS FOR 10.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -10.89

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.8071D 01
0.0	30.00	-.7855D 01
7.000	15.00	-.8075D 01
7.000	30.00	-.7861D 01

***VOL AVE AMPLIFICATION = 0.8231D 01 DBS FOR 16.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -2.85

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.3770D 01
0.0	30.00	0.1107D 02
7.000	15.00	-.3812D 01
7.000	30.00	0.1107D 02

***VOL AVE AMPLIFICATION = -.3719D 02 DBS FOR 20.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -37.31

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.7000D 03
0.0	30.00	-.7000D 03
7.000	15.00	-.3588D 02
7.000	30.00	-.3000D 02

***VOL AVE AMPLIFICATION = -.1297D 02 DBS FOR 25.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -14.73

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.1746D 02
0.0	30.00	-.1177D 02
7.000	15.00	-.1438D 02
7.000	30.00	-.1105D 02

***VOL AVE AMPLIFICATION = -.2164D 02 DBS FOR 31.5 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -22.33

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.2194D 02
0.0	30.00	-.3172D 03
7.000	15.00	-.2102D 02
7.000	30.00	-.3165D 03

***VOL AVE AMPLIFICATION = -.3062D 00 DBS FOR 40.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -6.18

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.3409D 01
0.0	30.00	-.3684D 01
7.000	15.00	-.1989D 01
7.000	30.00	0.6068D 01

***VOL AVE AMPLIFICATION = -.3379D 01 DBS FOR 50.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -7.87

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.1673D 02
0.0	30.00	-.4391D 01
7.000	15.00	-.1052D 01
7.000	30.00	-.3654D 01

***VOL AVE AMPLIFICATION = -.2317D 01 DBS FOR 63.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -7.26

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)

0.0	15.00	-.1551D 02
0.0	30.00	-.2438D 02
7.000	15.00	0.2604D 01
7.000	30.00	-.1308D 02

***VOL AVE AMPLIFICATION = -.4300D 01 DBS FOR 80.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -8.43

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.8204D 01
0.0	30.00	-.1913D 01
7.000	15.00	-.6388D 00
7.000	30.00	0.2526D 01

***VOL AVE AMPLIFICATION = 0.3231D 01 DBS FOR 100.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -4.55

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.4485D 01
0.0	30.00	-.7332D 01
7.000	15.00	0.2011D 01
7.000	30.00	0.1076D 02

***VOL AVE AMPLIFICATION = 0.6128D 01 DBS FOR 125.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -3.49

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.1059D 02
0.0	30.00	-.1308D 02
7.000	15.00	0.1132D 02
7.000	30.00	0.1357D 02

***VOL AVE AMPLIFICATION = 0.6778D 01 DBS FOR 160.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -3.28

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.7026D 01
0.0	30.00	-.7301D 01
7.000	15.00	0.1223D 02
7.000	30.00	0.7956D 01

***VOL AVE AMPLIFICATION = 0.1151D 02 DBS FOR 200.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -2.05

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	-.3522D 01
0.0	30.00	-.4267D 01
7.000	15.00	0.1592D 02
7.000	30.00	0.7724D 01

***VOL AVE AMPLIFICATION = -.3280D 01 DBS FOR 250.0 HERTZ BAND
VOL AVE AMP W/INTERNAL PRESSURE EFFECT = -7.81

RADIUS(FT)	LNTH COORD(FT)	PNT AMPL(DBS)
0.0	15.00	0.5222D 01
0.0	30.00	-.6970D 00
7.000	15.00	-.6061D 01
7.000	30.00	-.8958D 01