METHOD OF FAN SOUND MODE STRUCTURE DETERMINATION
COMPUTER PROGRAM USER'S MANUAL
MOD/L CALCULATION PROGRAM

by

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This computer user's manual describes the operation and the essential features of the Modal Calculation Program, the second of two programs developed under the Method of Fan Sound Structure Determination Program, NAS3-20047. Jointly the two programs are used to determine the coherent modal structures of inlet sound fields. The purpose of the Modal Calculation Program is to calculate the amplitude and phase of modal structures by means of acoustic pressure measurements obtained from microphones placed at selected locations within the fan inlet duct. These locations are determined by the first of the two programs. In addition, the Modal Calculation Program also calculates the first-order errors in the modal coefficients that are due to tolerances in microphone location coordinates and inaccuracies in the acoustic pressure measurements.
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1.0 SUMMARY

This computer user's manual describes the operation and the essential features of the Modal Calculation Program, the second of two programs developed under the Method of Fan Sound Structure Determination Program, NAS3-20047. Jointly the two programs are used to determine the coherent modal structures of inlet sound fields. The purpose of the Modal Calculation Program is to calculate the amplitude and phase of modal structures by means of acoustic pressure measurements obtained from microphones placed at selected locations within the fan inlet duct. These locations are determined by the first of the two programs. In addition, the Modal Calculation Program also calculates the first-order errors in the modal coefficients that are due to tolerances in microphone location coordinates and inaccuracies in the acoustic pressure measurements.

2.0 INTRODUCTION

New fan designs for modern high bypass ratio commercial engines utilize blade-vane interaction theory to the extent possible for controlling the propagation of interaction noise. Currently, this theory defines the modes that can propagate, but has not been developed to the extent that it can reliably predict the strengths of the propagating modes.

Further noise reduction could be achieved if the propagating modal structure were quantified. Once the modal structure were defined, an analytical system for acoustic-treatment design could be utilized to optimize treatment for a given modal structure, to produce more efficient schemes. In addition, the modal structure could be employed to verify developing theories of fan noise generation. To provide this capability by means of measured data the Method of Fan Sound Mode Structure Determination Program (NAS3-20047) was undertaken. The method would be utilized until a valid fan noise generation model on a model basis becomes available.

The theory upon which fan spinning mode theory is founded was presented in 1961 by Tyler and Sofrin (ref. 1), following extensive analytical and experimental studies. Later, Sofrin and McCann (ref. 2) derived the general form of a coherent acoustic wave in an infinitely long cylindrical duct which extended the theory to include effects of axial flow. This equation expresses the coherent acoustic pressure at locations in the duct as a function of the amplitude and phase of the propagating modes comprising the sound field. These purely coherent signals, which are due to the contributions of the constituent modes, are extracted from the overall signal by enhancement techniques adapted at Pratt & Whitney Aircraft — the advantages of utilizing signal enhancement is discussed by Posey in reference 3.
Both the analytical expression derived for a general coherent acoustic wave and a signal enhancement technique form the basis for developing a method to determine fan sound mode structures. The method, in principle, is capable of determining the amplitude and phase of all modes that can propagate at a given frequency. In practice, the number of modes that can be determined is limited by the storage capacity and the running time of the computer and by measurement and location accuracy.

The method for determining fan sound mode structure (ref. 4) requires two computer programs: a Microphone Location Program (MLP) and a Modal Calculation Program (MCP). This User's Manual describes the MCP; the MLP is presented in a companion Manual.

The MLP identifies microphone locations in the duct for measuring acoustic pressures for input to the MCP that will insure a numerically stable solution. The MCP calculates modal structures from acoustic pressure measurements and calculates coefficients that can be used to determine the sensitivity of the modal calculation procedure to first-order errors in acoustic pressure measurements and microphone placement.

In the following sections, the algorithm for the modal calculations and the program elements—such as subroutines, functional elements, and principal element interrelationships—are discussed. A description of the input parameters is included. The output format is also described and illustrated by a sample case. Finally, a listing of the program code is provided in Appendix B.
3.0 PROGRAM DESCRIPTION

3.1 ALGORITHM

The Modal Calculation Program is an algorithm for calculating the modal structure from input data comprising acoustic pressure measurements and a finite set of modes. The general form of any coherent acoustic wave in an infinitely long cylindrical duct having uniform axial flow can be written as the real part of

\[ P(x, r, \theta; t) = \sum_{m} A_m, \mu E(k_m^\sigma r)e^{i(k x_n + m \theta_n - \omega t + \Phi_m, \mu)} \]

and

\[ k_x = \frac{Mx(\omega/c) \pm \sqrt{(\omega/c)^2 - (1 - Mx^2) k_m^\sigma^2}}{1 - Mx^2} \]

where the notation is consistent with reference 1.

Equation 1 can be written in matrix form where the measured pressures are obtained from microphone locations identified by the MLP. The equation system is solved in the usual manner by matrix inversion. The output from this procedure is the amplitude and phase of the coherent acoustic duct modes comprising the inlet sound field.

The input to the program consists of: the sound field in the duct comprising N acoustic duct modes, the geometric parameters (e.g. duct radius, hub-tip ratio), test parameters (e.g. frequency, axial Mach number, speed of sound), and measured acoustic pressure amplitude and phase at locations identified by the MLP. The characteristic numbers that include the eigen value \( k_m^\sigma, \mu \), the axial wave number \( k_x \), and the value of the eigen function \( E(k_m^\sigma r) \) are calculated.

In addition, this equation requires the input of acoustic pressure measurements, the number of which exactly equal the number of specific modes. A set of equations can then be established with the number of equations equaling the number of acoustic measurements. This set was written in matrix form with the matrix coefficients a function of the particular modes comprising the sound field and the microphone locations.

If the determinant of the equation system is non-zero, a set of independent equations exists. This equation system in principle can be inverted in the usual way to solve for the unknown amplitude and phase of the particular modes comprising the sound field. A Gaussian elimination procedure is used to reduce the equation system to a triangularized matrix for solution of the complex modal coefficients. The overall pressure at any location in the duct can be calculated from the information in the modal structure.
Once the modal structure has been determined, a set of influence coefficients (ref. 4) is calculated. These coefficients can be used to determine the errors in modal amplitudes and phases that are the results of first-order inaccuracies in measured pressures and the tolerances in microphone placement.

As an option, the MCP can also calculate the resultant sound field at any specified duct location based on a given modal structure. This modal structure is supplied by the user either arbitrarily or as output from an analytical prediction deck.

3.2 PROGRAM OVERVIEW

The Modal Calculation Program comprises six major sections which are utilized in part or whole to accomplish the objectives of the two possible modes of operation. These six major sections are:

1) Input - The input of all data is by the NAMELIST specification, and the internal parameters are initiated for program execution.

2) Characteristic Number Calculation - The characteristic numbers $K^\sigma$, and $Q^\sigma$, are calculated using the procedure described in Appendix A.

3) Mode Amplitude and Phase Calculation - The coherent acoustic wave equation system, e.g. (1), in an infinitely long cylindrical duct with uniform axial flow is solved using a Gaussian elimination procedure for the modal amplitude and phase.

4) Sensitivity Coefficient Calculation - Standard deviations due to the first-order independent errors in the measurement of both the acoustic pressures and the microphone coordinates are obtained for the error in the modal amplitudes and phases.

5) Overall Pressure Calculation - Resultant pressure amplitude and phase are calculated at the desired prediction locations using the amplitude and phase of the constituent modes comprising the sound field.

6) Output - All results from the program calculations are printed.

The interrelationships between the six major sections and their utility for each option is illustrated in Figure 1. As input, both options require a specific mode group, inlet geometry, and test condition to calculate characteristic numbers. One option, "A", requires additional input in the form of acoustic pressure signals at selected duct locations to calculate the modal structure comprising the sound field. Additionally, influence coefficients, which are functions of the modal structure, are calculated. The other option, "B", requires that the modal structure be specified as input. In both options, the amplitude and phase of the constituent modes are utilized to calculate the overall acoustic pressure at any duct location. The results from both options are printed by the output section.
3.3 PROGRAM SUBROUTINES AND FUNCTIONS DESCRIPTION

The subroutines and functions used in the six program sections presented in Section 3.2 are listed below; the purpose of each subroutine or function is described. Also as appropriate, principal-element diagrams of the more complicated sections are presented and discussed.
Input Section

The NAMELIST format is used to input data for execution of the computer program. This form of input is described in Section 3.4.1. The input variable names are listed in Section 3.4.2, including a description of their purpose. All input is read into the program by the following subroutine:

INPUT – This subroutine inputs data for each case and sets up the necessary internal parameters.

Characteristic Number Calculation Section

Expressions are derived in Appendix A for solving two simultaneous equations that define the characteristic numbers $k_{m\mu}^\sigma$ and $Q_{m\mu}^\sigma$. A principal-element diagram is presented in Figure 2 to illustrate the functional elements that lead to a determination of these numbers. Initially, the order of the Bessel functions is determined from the circumferential order of a particular mode. The $J_m$ and $Y_m$ Bessel functions are evaluated, as appropriate, depending on the value of the duct hub-tip ratio. Finally, the characteristic numbers are calculated by solving the simultaneous equations comprising the Bessel functions. The subroutines and functions utilized in this section are:

KQCAL – This subroutine calculates the characteristic numbers $k_{m\mu}^\sigma$ and $Q_{m\mu}^\sigma$.

KMUCAL – This subroutine is used by KQCAL to calculate the characteristic number $k_{m\mu}^\sigma$.

EMUCAL – This subroutine calculates characteristic E-function values for a particular radial value, $t^* - r/b$.

FALZIP – This function solves for a root of a given function using a combination of false position and bisection techniques.

BESL1 – This function is used by KMUCAL to calculate values of $K_{m\mu}^\sigma$ for the equation which defines the system of differential equations.

\[ \frac{d}{dr} \left[ J_m \left( K_{m\mu}^\sigma \right) \right] + Q_{m\mu}^\sigma \frac{d}{dr} \left[ Y_m \left( K_{m\mu}^\sigma \right) \right] = 0 \]

\[ \frac{d}{dr} \left[ J_m \left( \sigma K_{m\mu}^\sigma \right) \right] + Q_{m\mu}^\sigma \frac{d}{dr} \left[ Y_m \left( \sigma K_{m\mu}^\sigma \right) \right] = 0 \]

for a hub-tip ratio not equal to zero.

BESL2 – This function is used by KMUCAL to calculate values of $k_{m\mu}^\sigma$ for the equation which defines the above system of differential equations for a hub-tip ratio equal to zero.

BESJ – This subroutine calculates values of the Bessel function of the first kind.

BESY – This subroutine calculates values of the Bessel function of the second kind.
Figure 2  Principal-Element Diagram – Characteristic Number Calculation Section
Mode Amplitude and Phase Calculation

The modal amplitude and phase are solved by matrix inversion techniques from data that includes pressure measurements at selected microphone locations. The equations that define the matrix coefficients and a description of the procedure for fan sound mode determination was presented in Section 3.1 - Algorithm. To illustrate the functional elements that lead to a solution of the modal coefficients, a principal-element diagram is presented in Figure 3. Initially, the matrix coefficients, which are functions of the particular modes comprising the sound field and the microphone locations, are calculated. This equation system is solved by a Gaussian elimination method for the modal coefficients. The mode amplitude and phase are then extracted from these complex pressure vectors. The subroutines used in the calculation procedure are:

SOLVE: This subroutine set ups and using SIMECQ solves the acoustic wave equation matrix for the modal amplitude and phase.

SIMECQ: This subroutine solves a N x N system of simultaneous equations having complex coefficients, using a Gaussian elimination method.

Sensitivity Coefficient Calculation

The Sensitivity Coefficient Calculation procedure is illustrated in the principal-element diagram presented in Figure 4.

An important element in this procedure is the calculation of influence coefficients, which reflect the sensitivity of mode amplitude and phase calculations to first-order errors in pressure measurements and microphone placement — the derivation of the influence coefficient is provided in reference 4, Section 3.4.

Because the inverse-matrix element is a common term in each expression, the procedure is initiated by calculating the inverse matrix. The influence coefficients are calculated next as a function of the modal structure and pressure measurements. The specific error in the modal amplitude and phase due to one of the five possible measurement errors is calculated from the product of the error in the measured quality and the root-sum-square of the influence coefficients. Finally, the error in a particular mode amplitude and phase is obtained as the combined effect of each measurement error.

The subroutines utilized in the Sensitivity Coefficient Calculation procedure are:

SENSTY: This subroutine calculates the standard deviations of the modal amplitude and phase for errors associated with pressure measurement and microphone location.

INVERT: This subroutine inverts a complex N x N matrix.
Figure 3  Principal-Element Diagram - Mode Amplitude and Phase Calculation

START

CALCULATE E-FUNCTION VALUE

CALCULATE MATRIX COEFFICIENTS

INTERCHANGE ROWS AND NORMALIZE

SOLVE FOR MODEL COEFFICIENTS

CALCULATE MODAL AMPLITUDE AND PHASE

STOP

ORIGINAL PAGE IS OF POOR QUALITY
Figure 4  Principal-Element Diagram – Sensitivity Coefficient Calculation
Overall Pressure Calculation

The overall pressure at any location in the duct is obtained from the modal structure. The procedure for overall pressure calculation is illustrated in the principal-element diagram shown in Figure 5. The procedure summarizes the pressure contribution of each mode at a location in a duct defined by the user. The resultant amplitude and phase are then extracted from the complex pressure vector. Since this calculation is performed in the MAIN routine there are no subroutines or functions to list.

Output Section

The output format and the variables from the Modal Calculation Program are discussed in Section 3.5.1 and a sample case for three propagating modes is providing in Section 3.5.2. Both Sections 3.5.1 and 3.5.2 address the two possible modes of operation that can be executed with the program. Results from the computations are printed by the subroutines listed below after all angles are converted to within the range of 0° to 360°.

PRINT — This subroutine prints input and resultant values.

ANGPOS — This subroutine converts negative angles to positive angles in the range 0° to 360° for printing.
DETERMINE LOCATION WITH RESPECT TO REFERENCE LOCATION

CALCULATE E-FUNCTION VALUE

SUMMARIZE PRESSURE FROM ALL MODES

CALCULATE RESULTANT AMPLITUDE AND PHASE AT LOCATION

STOP

Figure 5  Principal-Element Diagram – Overall Pressure Calculation

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3.4 INPUT DESCRIPTION

3.4.1 Input Format

The NAMELIST format is used to input data into the Modal Calculation Program and consists of a list of parameter names grouped under an identifying name: &INDATA. The parameter names correspond to variables - single variables and matrix elements - used in the program. These variables are set by specifying both the parameter name and its value. A feature of this type of input is that all associated parameters need not be specified. Any parameter not specified in the input retains its value from the preceding case or the default value if the input is for the first case.

NAMELIST input for each case is identified by the characters &INDATA in Columns 2-7 of the first input card. Beginning in Column 9, parameters may be set using the format:

Parameter Name = Constant

The constant may be either a real or integer value and must be followed immediately by a comma. Parameter names, assigned values, or necessary commas must not extend beyond Column 72; and names of values cannot be continued on a subsequent card. Embedded blanks are not permitted in either the parameter name or constant value. Parameter names and their associated values may be specified in any order. The characters &END signify the end of the input for a particular case. If additional cards are required, parameters names must begin in Column 2.

A sample of this form of input for three microphones is presented in Figure 6.

3.4.2 Input Parameters

A sign convention was adopted for assigning positive or negative values to the input parameters. Any input parameter not addressed in this discussion is a positive value. The sign convention is formulated with respect to a cylindrical coordinate system that is consistent with the derivation of the coherent acoustic wave propagation model. Its unit vectors are designated by the directions: axial - x, circumferential - θ, radial - r.

A constant radius, annular duct is aligned with respect to this coordinate system in such a way that the positive axial unit vector is in a direction opposite to the flow. Thus, the Mach number of a uniform axial flow is always designated by a negative value to denote the axial flow rate in the negative axial direction. A positive circumferential unit vector projects in the direction that the rotor spins, and a negative vector projects in the counterrotating direction. Finally, the radial axis projects perpendicular to the centerline of the duct; thus, radial values are positive.

Each mode is characterized by three parameters which represent the circumferential and radial pressure distribution and its propagation direction. A specific mode is uniquely defined by the parenthetical notation (M, μ). The M defines a periodic circumferential pressure distribution with M number of lobes. Positive integers represent a corotating M-circumferential
lob. pattern with respect to the rotor direction, and negative $M$ integers refer to counterrotating modes. The radial mode index $\mu$ corresponds to the radial pressure distribution. These values are always non-negative integer numbers with high integer values indicating large pressure variations with respect to the radius.

The modal propagation direction in an inlet or discharge duct can be either an incident wave propagating from the fan or a reflected wave propagating towards the fan. Wave propagation in a moving medium is similarly effected by the flow rate for modes that are propagating with or against the flow direction. Hence, the input variable IDIR designates wave propagation with respect to the flow direction. Positive values denote waves propagating in the opposite direction with respect to the flow such as incident waves in the inlet duct and reflected waves in the discharge duct. Modes that propagate in the same direction as the flow are designated by a negative value for the input parameter IDIR.

Assigning of values to the input parameters will now be considered.

Since a determinative equation system is required, the number of mode indices, wave direction indicators, microphone coordinates, and measured pressures must be equal. When option B is utilized, the number of mode indices, wave direction indicators, and modal amplitude and phase values must correlate. These input parameters are listed in several tables at the end of this section. Each parameter has a corresponding description that is sufficient for assigning a value to these input parameters. However, assigning a value to the coefficient parameters for the standard deviation in measurement errors is not as straightforward as the previous parameters. The following discussion is provided to assist the user when assigning values to these variables.

The deviation coefficients for microphone location errors are the tolerances in the three coordinates: axial - x, radial - r, and circumferential - $\theta$. These errors are related to the tolerance of a measurement — such as a micrometer — for determining the location of a microphone. Specifically, a user can estimate the microphone location standard deviation by assuming a high confidence level — such as ninety-five percent — to be associated with the number of significant digits used to define the pressure measuring coordinates. The standard deviation coefficients can then be computed from this information. For example, if a 95 percent confidence level is assigned to an axial measurement accuracy of 0.005 centimeter, the standard deviation (68.3 percent confidence level) is about $2.5 \times 10^{-3}$ centimeter.

The error deviation coefficients for acoustic pressures include the two components amplitude and phase which correspond to the measured resultant pressure at any duct location. Two mechanisms can generate errors that affect the measurement of resultant pressure. One type of error is due to both response characteristics of the measuring device and repeatability of the coherent signal. The second type of error is caused by measuring contributions from modes not included in the calculation for determining the modal structure. A user can estimate the former pressure measurement error in a similar manner as previously presented for microphone location measurement errors.
A standard deviation can be computed by assuming a high confidence level to be associated with the combined inaccuracy of both pressure amplitude calibration errors and an error attributed to the repeatability of enhanced pressure signals during a period of time. In practice, however, this category of errors is small and can be minimized by requiring reasonable experimental procedures.

The second mechanism that can generate pressure measurement errors was not encountered in the previous category of location measurement errors. Ideally, the contribution from modes that are unlikely to control the duct sound field will not hinder the determination of fan sound mode structures. In practice, however, these modes have to be anticipated and their impact quantified if a meaningful standard deviation for the modal coefficients is to be calculated. This mechanism, which can be perceived as a measured pressure error, is difficult to assess prior to an experimental program. A general expression for this standard deviation is presented in Appendix E of reference 4. The actual value for the standard deviation used as input to the modal calculation program should be obtained from that general expression.

A description of the input variables for operating the Modal Calculation Program is provided in Tables I, II, and III: Table I – General Parameters; Table II – Test Geometry and Condition Parameters; Table III – Error Deviation Coefficient Parameters. Under the column heading “Variable Type”: the letter “R” indicates that the number is real and contains a decimal point; the letter “I” indicates the number is an integer and does not have a decimal point. “Default Values” are also delineated and indicate the value of the parameter that is internally initialized prior to the program execution. Parameters not specified in the input for the first case retain this value. Although the default values are expressed in units of the English System, the computer program can be executed with data in any consistent system of units.

3.5 OUTPUT DESCRIPTION

3.5.1 Output Format

The output from the Modal Calculation Program is organized into four sections: Input Variables, Modal Amplitude and Phase Calculation, Sensitivity Coefficient Calculation, and Characteristic E-Function Values. All four sections are included as output when either option is requested by the input. The printout for a sample case is provided in Appendix C to illustrate the output format.

The Input Variable Section includes the value of the various parameters supplied by the user. The parameters that define the modal structure – the circumferential and radial order, and the wave-direction indicator – are listed. The reference pressure for converting the modal amplitude and resultant amplitude to decibels is also output in this section. The test geometry and conditions subsection lists various parameters that define the fan duct geometry and operating conditions observed during the experimental program. These parameters include the duct radius, duct hub-tip ratio, axial Mach number, and frequency.

The Modal Amplitude and Phase Calculation section includes both parameters that were provided by the user and the results from the calculation procedure. In this section, the user obtains the modal amplitude in units of pressure and decibels and the modal phase in units.
<table>
<thead>
<tr>
<th>Input Name</th>
<th>Variable Type</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCM</td>
<td>I</td>
<td>2</td>
<td>Number of microphones or modes. (Less than or equal to fifty).</td>
</tr>
<tr>
<td>LOCP</td>
<td>I</td>
<td>2</td>
<td>Number of prediction locations. (Less than or equal to fifty).</td>
</tr>
<tr>
<td>IEMU</td>
<td>I</td>
<td>0</td>
<td>Print indicator for characteristic E-function value.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = No print</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = Print</td>
</tr>
<tr>
<td>PRES</td>
<td>R</td>
<td>2.9 x 10^{-9}</td>
<td>Reference pressure to convert pressure to decibels.</td>
</tr>
<tr>
<td>X0^a)</td>
<td>R</td>
<td>0.0</td>
<td>Axial coordinate of the reference location.</td>
</tr>
<tr>
<td>TH0^b)</td>
<td>R</td>
<td>0.0</td>
<td>Circumferential coordinate of the reference location. (degrees)</td>
</tr>
<tr>
<td>M(1)</td>
<td>I</td>
<td>-2</td>
<td>Circumferential mode index. (Input NLOC values)</td>
</tr>
<tr>
<td>M(2)</td>
<td></td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>M(3)</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>M(50)</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>MUS(1)</td>
<td>I</td>
<td>0</td>
<td>Radial mode index. (Input NLOC values)</td>
</tr>
<tr>
<td>MUS(2)</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MUS(3)</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>MUS(50)</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IDIR(1)</td>
<td>I</td>
<td>1</td>
<td>Mode propagation direction indicator. (Input NLOC values)</td>
</tr>
<tr>
<td>IDIR(2)</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>IDIR(3)</td>
<td></td>
<td>0</td>
<td>1 = opposite flow direction</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>...</td>
<td>1 = with flow direction</td>
</tr>
<tr>
<td>IDIR(50)</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Note a): Final character is a zero.
TABLE II
TEST GEOMETRY AND CONDITION INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Input Name</th>
<th>Variable Type</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTR</td>
<td>R</td>
<td>0.44</td>
<td>Hub-tip ratio.</td>
</tr>
<tr>
<td>OR</td>
<td>R</td>
<td>5.0</td>
<td>Outer radius of duct.</td>
</tr>
<tr>
<td>EMX</td>
<td>R</td>
<td>0.07</td>
<td>Axial Mach number (always positive).</td>
</tr>
<tr>
<td>FREQ</td>
<td>R</td>
<td>3100</td>
<td>Test frequency (Hertz)</td>
</tr>
<tr>
<td>SPEED</td>
<td>R</td>
<td>13566</td>
<td>Speed of sound</td>
</tr>
<tr>
<td>X(1)</td>
<td>R</td>
<td>9.568</td>
<td>Axial coordinates of the measurement microphone locations. (Input LOC value)</td>
</tr>
<tr>
<td>X(2)</td>
<td>R</td>
<td>6.582</td>
<td></td>
</tr>
<tr>
<td>X(3)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>X(50)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>R(1)</td>
<td>R</td>
<td>5.0</td>
<td>Radial coordinates of the measurement microphone locations. (Input NLOC value)</td>
</tr>
<tr>
<td>R(2)</td>
<td>R</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>R(3)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>R(50)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>THM(1)</td>
<td>R</td>
<td>0.0</td>
<td>Circumferential coordinates of the measurement microphone locations (degrees). (Input NLOC value)</td>
</tr>
<tr>
<td>THM(2)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>THM(3)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>THM(50)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>P1 AM(1)</td>
<td>R</td>
<td>0.03136</td>
<td>Pressure amplitude at the measurement microphone locations. (Input NLOC value)</td>
</tr>
<tr>
<td>P2 AM(2)</td>
<td>R</td>
<td>0.02097</td>
<td></td>
</tr>
<tr>
<td>BETAM(3)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>BETAM(50)</td>
<td>R</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Input Name</td>
<td>Variable</td>
<td>Default (a)</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>PSIM(1)</td>
<td>R</td>
<td>97.8</td>
<td>Pressure phase at the measurement microphone locations (degrees). (Input NLOC values)</td>
</tr>
<tr>
<td>PSIM(2)</td>
<td></td>
<td>215.6</td>
<td></td>
</tr>
<tr>
<td>PSIM(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSIM(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>PX(1)</td>
<td>R</td>
<td>5.788</td>
<td>Axial coordinates of the prediction microphone locations. (Input LOCP values)</td>
</tr>
<tr>
<td>PX(2)</td>
<td></td>
<td>2.513</td>
<td></td>
</tr>
<tr>
<td>PX(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PX(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>PR(1)</td>
<td>R</td>
<td>5.0</td>
<td>Radial coordinates of the prediction microphone locations. (Input LOCP values)</td>
</tr>
<tr>
<td>PR(2)</td>
<td></td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>PR(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>THP(1)</td>
<td>R</td>
<td>0.0</td>
<td>Circumferential coordinates of the prediction microphone locations (degrees). (Input LOCP values)</td>
</tr>
<tr>
<td>THP(2)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>THP(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THP(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>ICHK</td>
<td>I</td>
<td>0</td>
<td>Mode amplitude and phase indicator.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = Calculated from measured pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = Input values</td>
</tr>
<tr>
<td>AM(1)</td>
<td>R</td>
<td>0.0</td>
<td>Mode amplitude. (If ICHK = 1, input NLOC values)</td>
</tr>
<tr>
<td>AM(2)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>AM(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE II (Cont’d.)

<table>
<thead>
<tr>
<th>Input Name</th>
<th>Variable Type</th>
<th>Default&lt;sup&gt;(a)&lt;/sup&gt; Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHI(1)</td>
<td>R</td>
<td>0.0</td>
<td>Mode phase (degrees). (If ICHK = 1, input NLOC values)</td>
</tr>
<tr>
<td>PHI(2)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>PHI(3)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>PHI(50)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Note: (a) Default values shown in table are in units of the English System. The program, however, is designed to be executed with data in any consistent system of units.

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**ORIGINAL PAGE IS OF POOR QUALITY**
TABLE III
ERROR DEVIATION COEFFICIENT INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Input Name</th>
<th>Variable Type</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGX</td>
<td>R</td>
<td>0.0</td>
<td>Standard deviation of the axial coordinate error.</td>
</tr>
<tr>
<td>SIGR</td>
<td>R</td>
<td>0.0</td>
<td>Standard deviation of the radial coordinate error.</td>
</tr>
<tr>
<td>SIGT</td>
<td>R</td>
<td>0.0</td>
<td>Standard deviation of the circumferential coordinate error (degrees).</td>
</tr>
<tr>
<td>SIGB</td>
<td>R</td>
<td>0.0</td>
<td>Standard deviation of the pressure amplitude error.</td>
</tr>
<tr>
<td>SIGP</td>
<td>R</td>
<td>0.0</td>
<td>Standard deviation of the pressure phase error (degrees).</td>
</tr>
</tbody>
</table>
of degrees. The corresponding mode indices, axial wave number in units of degrees-per-length, and eigen value \( k_{\text{mllo}} \) are delineated.

Additional input parameters listed in this section include the reference location usually corresponding to the fan face where the modal phases are calculated. Coordinates of the input measurement locations and resultant prediction locations are listed adjacent to the respective acoustic pressure values. The input pressure values are supplied by the user in pressure units for the amplitude and degrees for the phase. The resultant pressure is calculated by the program and output is provided in units of decibels for the amplitude and degrees for the phase.

The Sensitivity Coefficient Calculation portion of the output comprises a number of sections, the primary output of which is the total normalized amplitude and the total phase deviation for each mode. These expressions represent the modal amplitude and phase error caused by a specified set of independent errors associated with the measurement of acoustic pressure and the tolerance of pressure measuring coordinates. The amplitude standard deviation of a specific mode is expressed as both the normalized quantity with respect to the mode amplitude and the mode amplitude error in decibels. The total phase deviation is expressed in degrees for each mode.

The contribution to the total amplitude and phase deviation assuming zero errors for the other error sources is provided under the heading "Normalized Standard Deviation Components". The amplitude deviation was normalized with respect to the mode amplitude. The total phase deviation in degrees for each error source is also provided under the heading. When these values are root-sum-squared, the previous expression for the total modal deviation is obtained. A user will benefit from the error deviation components by identifying which of the errors is controlling the total modal error.

The standard deviation components are also normalized with respect to their respective error. These parameters – referred to as the root-sum-square of the influence coefficients – enhance the combined variance of the influence coefficients at each microphone location. Thus, these parameters are the previous standard deviation components with respect to a unit measurement error in pressures or microphone coordinates. The root-sum-square of the influence coefficients is a convenient expression for assessing the probability of successfully tracking modes. A future user could examine these parameters to determine if the accuracy of experimental measurements made during an earlier test is sufficient to provide a desired confidence level in the mode amplitude and phase.

The influence coefficients are the partial derivatives of the mode amplitude and phase with respect to an error at each pressure measurement location that provides input for calculating the modal coefficients. These expressions allow a future user to evaluate the effect of non-uniform errors at the microphone locations. For example, an amplitude measurement error may be known to be significantly larger at one microphone location (e.g., inaccurate calibration). The user could then evaluate the impact of this error on the overall modal structure calculation.
The final section, Characteristic E-Functions, includes the value of E-functions, $E(h^Q_{\mu \nu}, \tau)$, at the measurement and prediction locations corresponding to each mode. This final section is provided as output only if it has been requested by the user.

3.5.2 Sample Cases

Two cases are presented in the sample printout, to illustrate the two options: 1) calculating mode amplitude and phase values from acoustic pressure signals and 2) specifying these values either arbitrarily or as output from an analytical prediction deck. These sample cases demonstrate the execution of each option with data listed in Figure 6. The length units in the printout are in centimeters; the time units, in seconds; the force units, in dynes.

The first sample case illustrates the option of calculating the mode amplitude and phase for a situation where three modes are propagating in a half-meter diameter annular duct. Three coherent acoustic pressure amplitude and phase values are specified at three microphone locations on the duct wall. These acoustic signals are at a frequency of 6200-Hertz, and are used to determine the modal structure of the $(-4,0)$, $(-4,1)$ and $(-4,2)$ modes.

The output for this sample case reveals that the amplitudes of the above modes are 137.4, 142.8, and 138.5 decibels, respectively; the modal phases are, respectively, 126.9, 160.0, and 229.2 degrees. Once the modal structure has been determined, the resultant sound field can be calculated at other duct locations. The resultant amplitude and phase — expressed in the same units as the modal coefficients — are requested at three microphone coordinates. The resultant amplitude at these locations are, respectively, 121.1, 115.7, and 115.1 decibels. The resultant phases are, respectively, 90.1, 357.8, and 67.2 degrees.

The sensitivity coefficient calculation portion of the program calculates the accuracy of the mode amplitude and phase values based on inaccuracies in the measured acoustic pressures and the microphone coordinates. Errors in the five measured quantities are expressed as standard deviations with zero mean. For this sample case they are axial - $2 \times 10^{-3}$ cm, radial - $2 \times 10^{-3}$ cm, circumferential - $2 \times 10^{-2}$ degree, amplitude - 25 dynes, and phase - 1.5 degrees. The combined effects of the error source deviations multiplied by the influence coefficients yields the modal amplitude and phase deviation. These calculated values for the $(-4,0)$, $(-4,1)$, and $(-4,2)$ modes are, respectively, 0.89, 0.84, and 0.87 decibel for the modal amplitude and 3.6, 2.5, and 1.7 degrees for the modal phase.

The second sample case illustrates the option to input the amplitudes and phases for the propagating modes to calculate the resultant acoustic pressure at specified locations. This case is similar to the first sample case because the $(-4,0)$, $(-4,1)$, and $(-4,2)$ modes are propagating at 6200-Hertz in a half-meter diameter annular duct. The amplitude of all the modes is 121.9 decibels and the phases of these modes are, respectively, 325, 250, and 100 degrees. Output from the Modal Calculation Program comprises the resultant sound field at three microphone locations. The value of the resultant sound field is 115.8, 120.0, and 120.0 decibels for the resultant amplitude and 36.4, 345.0, and 298.2 degrees for the resultant phase.
3.6 MACHINE REQUIREMENTS

The Modal Calculation Program can be compiled, linkage edited, and executed in 512 bytes of core storage.

The following mathematical functions and procedure are required:

- **CMPLX**: Expresses two real arguments in complex form.
- **CABS**: Modulus of a complex argument.
- **CEXP**: Exponentiation of a complex argument.
- **AIMAG**: Obtain imaginary part of a complex argument.
- **REAL**: Obtain real part of a complex argument.
- **FLOAT**: Conversion from integer to real.
- **IFIX**: Conversion from real to integer.
- **ABS**: Absolute value of a real number.
- **IABS**: Absolute value of an integer.
- **SORT**: Square root of a real value.
- **MAXO**: Obtain maximum value of input integers.
- **ALOG**: Natural logarithm of a real positive argument.
- **SIN**: Sine of a real argument.
- **COS**: Cosine of a real argument.
- **ATAN2**: Arc tangent of two real arguments.

3.7 RESOURCE ESTIMATES

The central-processor-unit (CPU) time required to process a particular case depends on the number of modes input which determines the size of the matrix to be inverted. The average estimate of CPU time per mode is 0.15 second.
REFERENCES


5. Subroutines BESJ, BESY, and INVERT were adapted from the IBM Scientific Sub-routine Package.
APPENDIX A

Calculation of the Characteristic Numbers

The characteristic numbers $K'_{m\mu}$ and $Q'_{m\mu}$ are defined to be the paired roots of the simultaneous equations

\[
\left[ -\frac{d}{dr'} J_m (K'_{m\mu} r') + Q'_{m\mu} \frac{d}{dr'} Y_m (K'_{m\mu} r') \right] r' = 1 = 0
\]  

(1)

\[
\left[ -\frac{d}{dr'} J_m (\sigma K'_{m\mu} r') + Q'_{m\mu} \frac{d}{dr'} Y_m (\sigma K'_{m\mu} r') \right] r' = 1 = 0
\]  

(2)

For a given circumferential mode number, $m$, radial order, $\mu$, and hub/tip ratio, $\sigma$ (where $\sigma$ is not equal to zero); $J_m$ and $Y_m$ are the Bessel functions of the first and second kinds of order $m$.

The following relations are used in the formulation of a solution

\[
\frac{d}{dr'} J_m (x) = J_m (x) \frac{dx}{dr'}
\]  

(3)

\[
\frac{d}{dr'} Y_m (x) = Y_m (x) \frac{dx}{dr'}
\]  

(4)

\[
J_{m+1} (x) = \frac{2m}{x} J_m (x) - J_{m-1} (x)
\]  

(5)

\[
J_m' (x) = \frac{1}{2} [J_{m-1} (x) - J_{m+1} (x)]
\]  

(6)

\[
= \frac{1}{2} [J_{m-1} (x) - \frac{2m}{x} J_m (x) + J_{m-1} (x)]
\]

\[
= J_{m-1} (x) - \frac{m}{x} J_m (x)
\]
\[
Y_m'(x) = \frac{2}{\pi x J_m(x)} + J_m'(x) \frac{Y_m(x)}{J_m(x)} \\
= \frac{2}{\pi x J_m(x)} + [J_{m-1}(x) - \frac{m}{x} J_m(x)] \frac{Y_m(x)}{J_m(x)}
\]

(7)

Letting \( K = K' \frac{\sigma}{m\mu} \) and \( Q = Q' \frac{\sigma}{m\mu} \), and evaluating at \( r' = 1 \); (1) and (2) become

\[
J_m'(K) K + Q Y_m'(K) K = 0
\]

(8)

\[
J_m'(\sigma K) \sigma K + Q Y_m'(\sigma K) \sigma K = 0
\]

(9)

From (8), \( Q = \frac{-J_m'(K) K}{Y_m'(K) K} \) substituting into (9) yields

\[
J_m'(\sigma K) \sigma K - \frac{J_m'(K) K}{Y_m'(K) K} Y_m'(\sigma K) \sigma K = 0
\]

(10)

Let \( f(K) = J_m'(\sigma K) Y_m'(K) \sigma K^2 - J_m'(K) Y_m'(\sigma K) \sigma K^2 = 0 \)

(11)

Using the expressions in (5), (6), (7), and (11) then:

\[
f(K) = \sigma K^2 \left\{ \frac{2}{\pi K J_m(K)} + \left[ J_{m-1}(K) - \frac{m}{K} J_m(K) \right] \frac{Y_m(K)}{J_m(K)} \right\}
\]

(12)

\[
f(K) = \sigma K \left\{ \frac{2}{\pi K J_m(K)} - \frac{m}{K} J_m(K) \right\} - \frac{2}{\pi K J_m(K)} \left[ J_{m-1}(K) - \frac{m}{K} J_m(K) \right] \frac{Y_m(K)}{J_m(K)} \]
Equation (13) is evaluated for values of $K_i = M + 3(i-1)$; $i = 1, 2, 3, \ldots$ until $f(K_j) < f(K_{j-1}) < 0$ for some $j$. A procedure employing a combination of false position and bisection techniques is then used to obtain a value of $K_{\text{int}}$ in the interval $[K_{j-1}, K_j]$.

Having calculated a value of $K = K_{\text{int}}$, the corresponding value of $Q = Q_{\text{int}}$ can be calculated. Combining (8) and (9) yields.

$$[J_m(K) + J_m'(sK)\sigma] K + Q [Y_m(K) + Y_m'(sK)\sigma] K = 0$$

Equation (18) is evaluated for values of $K_i = M + 3(i-1); i = 1, 2, 3, \ldots$ until $f(K_j) f(K_{j-1}) < 0$ for some value of $j$. A procedure employing a combination of false position and bisection techniques is then used to obtain a value of $K_{\text{int}}$ in the interval $[K_{j-1}, K_j]$.
APPENDIX B

MODAL CALCULATION PROGRAM

PROGRAM LISTING
COMMON /PREDICT/ XP(50), RP(50), THETAP(50)
COMMON /APRIORI/ AMP(50), PHIMU(50), ICHECK
COMMON /REFCOR/ REFPRI
COMMON /EMUS/ EMU(50,50), EMUP(50,50), EMUPRN(50,50), IEMPRT
COMMON /CNSTNT/ NMEAS, NPRED, NMOCUE, SIGMA, B, MX, FREQ, A
1 OMEGA
COMMON /KNU/ KNU(50), QMU(50)
COMMON /HULES/ MODI(50), MU(50), IAVE(50)
COMMON /ANGLES/ DEGRAD, RADDEG
COMMON /OUTPUT/ AMPR(50), PHASER(50)
COMMON /WAVE/ WAVE(50)
COMMON /REF/ XREF, RREF, THREF
REAL KNU, MX
COMPLEX XX, EXPNT, SUM, Q(50,50)
DIMENSION EMUDKM(50)

C INPUT DATA FOR THIS CASE
20 CALL INPUT(IEND)
   IF (IEND .LT. 0) GO TO 9999
   IF (IEND .LT. 0) GO TO 9999
C CALCULATE THE CHARACTERISTIC NUMBERS KNU AND QMU FOR EACH SET OF
C CIRCUMFERENTIAL MODE NUMBER AND RADIAL ORDER
C CALL KQCAL
C CALCULATE AXIAL WAVE NUMBER
   FLOW = OMEGA / A
   AMACH = 1. - MX * MX
   DO 40 I=1,NMOCUE
   RADICL = FLOW ** 2 - AMACH * (KNU(I) / B) ** 2
   IF (RADICL .LT. 0) GO TO 40
   25 XX(I) = CMPLX( -MX * FLOW / AMACH, IAVE(I) )
   1   SQRT( ABS( RADICL ) ) / AMACH
   GO TO 40
   30 XX(I) = CMPLX( ( -MX * FLOW + IAVE(I) ) * SQRT( RADICL ) )
   GO TO 40
   40 CONTINUE
C IF THIS IS A CHECK RUN, AMU AND PHIMU HAVE BEEN INPUT. THERE IS
C NO NEED TO CALCULATE THEM.
   IF (ICHECK .LT. 0) GO TO 60
   IF (ICHECK .LT. 0) GO TO 60
C SET UP AND SOLVE THE EQUATION SYSTEM ASSOCIATED WITH THE MEASUREMENT
C LOCATIONS
C CALL SOLVE
C CALCULATE SENSITIVITY COEFFICIENTS
C CALL SENSTY(Q, NMODES)
C CALCULATE SUM OF MODAL AMPLITUDES AND PHASES FOR EACH PREDICTION
C LOCATION
C
60 DO 120 J=1,NPRED
   RPRIME = RP(J) / B
C CALCULATE CHARACTERISTIC E-FUNCTIONS FOR RPRIME
C CALL EMUCAL(RPRIME, EMUP(J,J), EMUDUM, 0)
C DXP = XP(J) - XREF
   DTHEP = THETA(J) - THREF
   SUM1 = CMPLX(0., 0.)
   DO 100 I=1,NMODES
      EXPNT = CMPLX(0., REAL(KX(I)) * DXP * NODE(I) * DTHETP+1)
      SUM1 = ANU(I) * EMUP(I,J) * CEXPI(EXPNT) + EXP(-DXP * I)
   AIMG(I) = SUM1
100 CONTINUE
C AMPR(J) = CABS(SUM1)
C PHASER(J) = ATAN2(AIMG(SUM1), REAL(SUM1))
120 CONTINUE
C PRINT RESULTS OF THIS CASE
C CALL PRINT
C RECYCLE FOR NEXT CASE
C
9999 STOP
END
SUBROUTINE ANGPOS(ANGLE, NUMBER)
C
C THIS SUBROUTINE CONVERTS NEGATIVE ANGLES TO CORRESPONDING POSITIVE
C ANGLES
C
DIMENSION ANGLE(11)
DATA DEGREE / 360. /
C
DO 80 I=1,NUMBER
   IF ( ANGLL(I) ) 20, 80, 80
20 DO 40 J=1,10
   DELTA = J * DEGREE
     80 CONTINUE
FUNCTION BESLI( X )

C THIS FUNCTION CALCULATES VALUES OF THE EQUATION DEFINING THE SYSTEM OF DIFFERENTIAL EQUATIONS FOR A NON-ZERO HUB/TIP RATIO

COMMON /BESSL/ ISIGN, JSIGN, DELMNU, TOL, M, PI
COMMON /CNSINT/ DUM1(3), SIGMA, DUM2(5)

C X1 = X * SIGMA
CALL BESJ( X1, M-JSIGN, EMJ1, TOL, IER1 )
CALL BESJ( X1, M, EMJX1, TOL, IER2 )
CALL BESJ( X, M, EMJ, TOL, IER3 )
CALL BESJ( X, M-JSIGN, EMJP1, TOL, IER4 )
CALL BESJ( X, M, EMYX, IER5 )
CALL BESJ( X1, M, EMYX1, IER6 )

C EMJM1 = JSIGN * ISIGN * EMJM1
EMJX1 = ISIGN * EMJX1
EMJ = ISIGN * EMJ
EMJP1 = JSIGN * ISIGN * EMJP1
EMYX = ISIGN * EMYX
EMYX1 = ISIGN * EMYX1

C A1 = EMJM1 - ( M + JSIGN / X1 ) * EMJX1
A2 = EMJP1 - ( M + JSIGN / X ) * EMJ
A3 = 2. * A1 / ( PI * X * EMJ )
A4 = 2. * A2 / ( PI * X1 * EMJX1 )
A5 = A1 + A2 * ( EMYX / EMJ - EMYX1 / EMJX1 )

C BESLI = X1 * X * ( A3 - A4 * A5 )
RETURN

END

FUNCTION BESL2( X )

C THIS FUNCTION CALCULATES VALUES OF THE EQUATION DEFINING THE SYSTEM OF DIFFERENTIAL EQUATIONS FOR A HUB/TIP RATIO OF ZERO

COMMON /BESL2/ ISIGN, JSIGN, DELMNU, TOL, M, PI
COMMON /CNSINT/ DUM1(3), SIGMA, DUM2(5)

C CALL BESJ( X, M-JSIGN, EMJ1, TOL, IER1 )
CALL BESJ( X, M, EMJ, TOL, IER2 )

C EMJM1 = JSIGN * ISIGN * EMJM1
EMJ = ISIGN * EMJ
BESL2 = X * EMJM1 - M * JSIGN * EMJ
RETURN
SUBROUTINE BESJ(X, N, BJ, D, IER)

C THIS SUBROUTINE CALCULATES THE J BESSEL FUNCTION FOR A GIVEN ARGUMENT.
C X, AND ORDER N. THIS SUBROUTINE WAS TAKEN FROM THE IBM SCIENTIFIC
C PACKAGE

C

BJ = 0.0
IF (N .GE. 0) GO TO 20

20 IF (X) GO TO 9999
40, 30, 60

30 IF (N .GT. 0)
BJ = 1.0
GO TO 9999

C ERROR - NEGATIVE ORDER. SET ERROR INDICATOR TO 1 AND RETURN
IER = 1
GO TO 9999

C ERROR - ARGUMENT ZERO OF NEGATIVE. SET ERROR INDICATOR TO 2 AND RETURN
IER = 2
GO TO 9999

C CALCULATE MAXIMUM ORDER NUMBER THAT CAN BE PROCESSED FOR X.
IF X .LE. 15, N MUST BE LESS THAN 20 + 10*X - X**2/3.
IF X .GT. 15, N MUST BE LESS THAN 90 + X/2

60 IF (X - 15) 80, 80, 100
90 NTST = 20 + 10. • X - X ** 2 / 3.
GO TO 120

100 NTST = 90. • X / 2.
120 IF (N .LT. NTST) GO TO 140

C ERROR - ORDER RANGE COMPARED TO X IS NOT CORRECT. SET ERROR INDICATOR
TO 3 AND RETURN.
IER = 3
GO TO 9999

C COMPUTE STARTING VALUE OF N
IER = 0
N1 = N + 1
BPREV = 0.0

C COMPUTE STARTING VALUE OF M
160 MA = X + 6.
GO TO 200

180 MA = 1.4 • X + 60 / X
GO TO 200

200 MB = N + IFIX(X) / 4 + 2
NZERO = MAX0(MA, MB)

C SET UPPER LIMIT OF M

THE END OF THE PAGE IS POOR QUALITY.
C  MMAX    = NTEST
C  220  DO 320 M=ZERO,MMAX,3
C  C  SET FM(1), FM(-1)
C
C  FM1   = 1.0E-20
C  FM    = 0.0
C  ALPHA = 0.0
C  JT    = 1
C  IFI( M/2 ) * 2. <EQ. M )  JT = -1
C  M2    = M - 2
C  DO 280 K=1,M2
C  MK    = M - K
C  Bmk   = 2. * FLOAT( MK ) * FM1 / X - FM
C  FM    = FM1
C  FM1   = Bmk
C  IFI MK - N - 1 )  260, 240, 260
C  240 BJ = Bmk
C  260 JT = -JT
C  S     = 1 + JT
C  ALPHA = ALPHA + BMK * S
C  280 CONTINUE
C
C  BMK   = 2. * FM1 / X - FM
C  IFI N <EQ. 0 )  BJ = BMK
C  ALPHA = ALPHA + BMK
C  BJ    = BJ / ALPHA
C  IFI( ABS( BJ - BPREV ) - ABS( D * BJ ) )  9999, 9999, 300
C  300 BPREV = BJ
C  320 CONTINUE
C
C  C  ERROR - REQUIRED TOLERANCE NOT OBTAINED. SET ERROR INDICATOR TO 3 AND RETURN
C  C  IER    = 3
C  9999 RETURN
C  C  END
C
C  C  SUBROUTINE BESY1( X, N, BY, IER )
C
C  C  THIS SUBROUTINE CALCULATES THE Y BESSEL FUNCTION FOR A GIVEN ARGUMENT.
C  C  X, AND ORDER N.  THIS SUBROUTINE WAS TAKEN FROM THE IBM SCIENTIFIC
C  C  SUBROUTINE PACKAGE
C
C  C  IER    = 0
C  IFI N <GE. 0 )  GO TO 20
C
C  C  ERROR - NEGATIVE ORDER. SET ERROR INDICATOR TO 1 AND RETURN
C  C  IER    = 1
C  20 IFI X )
C  40, 40, 60
C
C
C  ERROR - ARGUMENT ZERO OR NEGATIVE. SET ERROR INDICATOR TO 2 AND RETURN. 00244
C
40 IER = 2
GO TO 9999
C
C BRANCH IF X IS LESS THAN OR EQUAL TO 4.
C
60 IFI X = 4. ) 100, 100, 80
C
C CALCULATE Y0 AND Y1 FOR X GREATER THAN 4.
C
80 T1 = X / X
T2 = T1 * T1
PO = ( X ( -.0000037043 * T2 + .0000173546 ) ) * T2 - .0000000012
1  .00000487613 ) * T2 + .000173546 ) * T2 - .0001735462 ) 00277
2  1 * T2 + .3989423
Q0 = ( X ( -.0000000032132 * T2 - -.0000142078 ) ) * T2 +
1  .00000436234 ) * T2 - -.01244694
2  .0000580759 ) * T2 - -.00023203 ) T2 +
Q1 = ( X ( -.00000036594 * T2 + -.00001622 ) ) * T2 -
1  .0000398708 ) * T2 + .0001064741 ) * T2 -
2  .00043904 ) * T2 + .03740084
A = 2. / SQRT(X )
B = A * T1
C = X - .7953982
Y0 = A * PO * SIN( C ) + B * QQ + COSI C )
Y1 = -.A * PI * COSI C ) + B * Q1 + SINI C )
GO TO 160
C
C CALCULATE Y0 AND Y1 FOR X LESS THAN OR EQUAL TO 4.
C
100 XX = X - X
XX = XX * XX
T = ALOG1 XX ) + .5772157
SUM = 0.0
TERM = T
YO = Y
DO 120 L=1,15
IF ( L .NE. 1 ) SUM = 1. / FLOAT( L-1 ) * SUM
FL = L
TS = T - SUM
TERM = L2 * TERM / ( FL + 2 ) ) * ( 1. - 1. / ( FL + 1 )
YO = TERM + YO
1  CONTINUE
DO 140 L=2,16
TER = XX * ( T - S )
SUM = 0.0
Y1 = TERM
DO 140 L=2,16
SUM = 1. / FLOAT( L-1 ) * SUM

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SC.PAML18.L4

VER 9.0 07/25/77 12.50.00

FL = L
FL1 = FL - 1
TS = T - SUM
TERM = ( -X2 * TERM / ( FL * FL1 ) ) * ( ( TS - .5 / FL )
1 / ( TS + .5 / FL1 )

Y1 = TERM * Y1

140 CONTINUE

P12 = .6366198
YO = P12 * YO
V1 = P12 * ( Y1 - 1.0 / X )

C CHECK IF ONLY YO OR Y1 IS DESIRED

160 IF( N .GT. 1 ) GO TO 180

C RETURN YO OR Y1 AS REQUIRED

BY = YO
F1( N .EQ. 1 ) BY = Y1

GO TO 9999

C PERFORM RECURRENCE OPERATIONS TO FIND Y(n)

180 YA = YO
YB = Y1
K = 1

200 T = FLOAT( 2*K ) / X
YC = T - YB - YA
IF( ABS( YC ) .LE. 1.0E70 )

240, 240, 220

C ERROR = .BY HAS EXCEEDED MAGNITUDE OF 10**70. SET ERROR INDICATOR TO 3

C AND RETURN

220 IER = 3

GO TO 9999

240 IF( K .EQ. N ) GO TO 260

YA = YB
YB = YC

GO TO 200

260 BY = YC

GO TO 9999 RETURN

END

BLOCK DATA
COMMON /DEFAULT/ LOCN, LOCNP, HTOR, OR, EMX, FRO, XO, RO,
THO, X(SO), R(SO), TNS(SO), BETAM(SO), PSIM(SO),
PX(SO), PR(SO), THP(SO), M(SO), MUS(SO),
10IR(SO), PREF, AM(SO), PHI(SO), ICMK,
4 SIUX, SIGR, SIGT, SIGB, SIGP, EMU, SPEED

C CONSTANT DEFAULT VALUES

C

LOCN = NUMBER OF MEASUREMENT LOCATIONS

C

38
| C   | LTCP - NUMBER OF PREDICTION LOCATIONS | 00370 |
| C   | HTR - MUb / TIP RATIO                | 00371 |
| C   | OR - OUTER RADIUS                   | 00372 |
| C   | EMX - AXIAL MACH NUMBER             | 00373 |
| C   | FNU - TEST FREQUENCY                | 00374 |
| C   | SPEED - SPEED OF SOUND              | 00375 |
| C   | DATA LOCy / 2 / LUC'y / 2 / HTr / 0.44 / Or / 5.0 / |
| C   | EMX / -0.07 / FNU / 3100. / SPEED / 13566.24 / |
| C   | REFEREnCE LOCATION VALUES           | 00377 |
| C   | XO - AXIAL COMPONENT OF REFERENCE LOCATION | 00378 |
| C   | RO - RADIAL COMPONENT OF REFERENCE LOCATION | 00379 |
| C   | THO - ANGULAR COMPONENT OF REFERENCE LOCATION (DEG) | 00380 |
| C   | DATA XO / 0.0 / RO / 0.0 / THO / 0.0 / |
| C   | MEASSUREMENT LOCATION VALUES        | 00381 |
| C   | X - AXIAL COMPONENT OF MEASUREMENT LOCATION | 00382 |
| C   | R - RADIAL COMPONENT OF MEASUREMENT LOCATION | 00383 |
| C   | THM - ANGULAR COMPONENT OF MEASUREMENT LOCATION (DEG) | 00384 |
| C   | BETAM - AMPLITUDE OF MEASURED VALUE | 00385 |
| C   | PSIM - PHASE ANGLE OF MEASURED VALUE (DEG) | 00386 |
| C   | DATA X / 9.558 / 6.502 / 4800.0 / R / 285.0 / 4800.0 / |
| C   | 1 THM / 50.0 / BETAM / 0.03136 / 0.05097 / 4800.0 / |
| C   | 2 PSIM / 57.0 / 125.0 / 4800.0 / |
| C   | PREDDICTION LOCATION VALUES         | 00387 |
| C   | PX - AXIAL COMPONENT OF PREDICTION LOCATION | 00388 |
| C   | PR - RADIAL COMPONENT OF PREDICTION LOCATION | 00389 |
| C   | THP - ANGULAR COMPONENT OF PREDICTION LOCATION (DEG) | 00390 |
| C   | DATA PX / 5.788 / 2.513 / 4800.0 / PR / 285.0 / 4800.0 / |
| C   | 1 THP / 50.0 / 0 / |
| C   | MODE VALUES                         | 00391 |
| C   | M - CIRCUMFERENTIAL MODE NUMBER     | 00392 |
| C   | NUS - RADIAL ORDER                  | 00393 |
| C   | IDIR - INCIDENT OR REFLECTED WAVE INDICATOR | 00394 |
| C   | DATA N / -2 / -2 / 4800 / NUS / 0 / 1 / 4800 / IDIR / 1 / 1 / 4800 / |
| C   | REFERENCE CONSTANTS                 | 00395 |
| C   | PREF - REFERENCE PRESSURE           | 00396 |
| C   | DATA PReF / 2.9E-9 / |

**ORIGINAL PAGE IS OF POOR QUALITY**
PRATT & WHITNEY AIRCRAFT DIVISION
SC.PAWLIN.L4
VER 9.0 07/25/77 12:50:00
C RESULTANT AMPLITUDE AND PHASE VALUES
C
C AM - AMPLITUDE
C PHI - PHASE ANGLE (DEG)
C ICHK - CHECK CASE INDICATOR
C
DATA AM / 50*0.0 / PHI / 50*0.0 / ICHK / 0 /
C BESSEL FUNCTION VALUES
C
COMMON /BESSL/, DUM2(2), DELKMU, TOL, MM, PI
DATA DELKMU / 3. / TOL / .0001 / PI / 3.141593 /
C ANGULAR CONVERSION FACTORS
C
C DEGRAD - DEGREES TO RADIANS
C RADDEG - RADIANS TO DEGREES
C
COMMON / ANGLES/, DEGRAD, RADDEG
DATA DEGRAD / 0.0174533 /, RADDEG / 57.29578 /
C ERROR DEVIATION COEFFICIENTS
C
C SIGX - AXIAL COEFFICIENT
C SIGR - RADIAL COEFFICIENT
C SIGT - ANGULAR COEFFICIENT
C SIGP - AMPLITUDE COEFFICIENT
C SIG - PHASE COEFFICIENT
C
DATA SIGX / 0.0 /, SIGR / 0.0 /, SIGT / 0.0 /, SIGP / 0.0 /,
1, SIGB / 0.0 /, 0
END
SUBROUTINE EMUCAL4(RPRIME, EMU, EMUPRM, IDERIV)
C
C THIS SUBROUTINE CALCULATES NModes CHARACTERISTIC E-FUNCTION VALUES FOR
C A PARTICULAR RADIAL VALUE, RPRIME.
C
DIMENSION EMU(11), EMUPRM(11)
COMMON / CNSTH/, NMAS, NPHED, NModes, DUM11(6)
COMMON / KMUS/ KMUS(530), KMUS(530)
COMMON / MODES/, MUS(530), DUM(1100)
COMMON / BESSL/, ISIGN, JSIGN, DELKMU, TOL, M, PI
REAL KMUS, JPRIME
C
DO 40 I=1,NModes
M = IAUS( MODE(I) )
IF ( M .NE. 0 ) GO TO 10
ISIGN = 1
JSIGN = -1
10 ISIGN = MODE(I) / M GO TO 20

40
C CALCULATE BESSEL FUNCTIONS OF FIRST AND SECOND KIND FOR KMU(I)*PRIME

C CALL BESJ( CONST, M, ENJ, TOL, IER1 )
C CALL BESY( CONST, M, ENY, IER2 )
C CALL BESI( CONST, M-JSIGN, ENI1, TOL, IER3 )
ENI1 = ISIGN * JSIGN * ENI
ENJ = ISIGN * ENJ
ENY = ISIGN * ENY
C C CALCULATE CHARACTERISTIC E-FUNCTION
C EMU(I) = EMJ + KMU(I) * EMV
IFI ( IDERIV .LT. 0 ) GO TO 40
IFI ( KMU(I) ) 30, 25, 30
C 10,0) CASE. SET DERIVATIVE TO 0.0
C 25 EMUPRM(I) = 0.0 GO TO 40
C C CALCULATE DERIVATIVE OF CHARACTERISTIC E-FUNCTION
C 30 JPRIME = ENI1 - MODE(I) * EMJ / CONST
YPRIME = 2. / ( PI * CONST * EMJ ) * JPRIME * ENY / EMJ
EMUPRM(I) = KMU(I) * ( JPRIME + KMU(I) * YPRIME )
40 CONTINUE
9999 RETURN
END

FUNCTION FALZIP (FUNCT, AL, BR, TOL, ROOT, ITER, YY)

C CORRESPONDS TO OLD VERSION (FALSIE) ARGUMENT LIST AS FOLLOWS (THIS IS
C FOR INTERNAL PURPOSES ONLY, IN USE THE TWO ARE INTERCHANGEABLE).
C FUNCTION FALSIE (AXR, XXL, XXR, TOL, ROOT, ITER, YY)
C C THIS ROUTINE USES A COMBINATION OF FALSE POSITION AND BISECTION
C TECHNIQUES TO SOLVE FOR A ROOT ('ROOT') OF A GIVEN FUNCTION
C ('FUNCT') WHICH HAS ONE ARGUMENT (THE INDEPENDENT VARIABLE).
C *AL, BR* DEFINES THE INTERVAL TO BE SEACHED.
C THE VALUE RETURNED BY THE FUNCTION IS FALZIP. FALZIP(FALZIP) = ROOT
C THE SEARCH CONTINUES UNTIL TWO SUBSEQUENT GUESSES ARE WITHIN 'TOL' OF EACH OTHER, OR UNTIL 'ITER' ITERATIONS HAVE TAKEN PLACE.
C 'YY' IS RETURNED AS FUNCTIONAL VALUE AND SHOULD BE CLOSE TO 'ROOT'.
C THE TECHNIQUE WAS ADAPTED FROM AN ALGOL ROUTINE APPEARING IN THE
C WITH ENSYMTRIC A AND B BY G. PETERS & J.H. WILKINSON
C
C EXTERNAL FUNCTION
C REAL INTPK
C
C J IS COUNT OF ITERATIONS.
C 1 J = 0
C A = AL
C B = BK
C
C EVALUATE FUNCTION AT LEFT (A) AND RIGHT (B) BRACKETS.
C AF = FUNCTION (A)
C BF = FUNCTION (B)
C
C THE FOLLOWING (THROUGH STATEMENT 3I DETERMINES IF THE FUNCTION IS OF
C OPPOSITE SIGN AT THE ENDPOINTS GIVEN.
C ISW = 1
C IF (BF - ROOT) 2, 75, 3
C 2 ISW = -1
C 3 IF (AF - ROOT) * ISW 50, 90, 85
C
C STATEMENT 5 INCREMENTS THE COUNTER J1 FIRST TIME THROUGH GO TO 50.
C 5 J = J + 1
C
C IF LEFT BRACKET HAS 'SAME' FUNCTION VALUE AS RIGHT, USE BISECTION.
C OTHERWISE, SET UP INTERPOLATED POINT FOR POSSIBLE USE.
C IF (ABS(AF - BF)/BF) - 1.E-5) 10, 10, 15
C 10 INTPK = BISECT
C GO TO 20
C 15 INTPK = (A*BF - B*AF + (B-A)*ROOT) / (BF-AF)
C
C IF WITHIN A TOLERANCE OF THE BRACKET B, MOVE THE INTERPOLATED POINT
C ONE TOLERANCE AWAY.
C 20 IF (ABS(INTPK-D)/ABS(INTPK*B1) -2.*TOL) 22, 23, 23
C 22 INTPK = B + (C - B) / ABS (C - B) * TOL
C
C SET A=B (B IS ALWAYS THE POINT WITH SMALLEST (ABS) VALUE OF FUNCTION).
C 23 A = B
C AF = BF
C
C USE POINT CLOSEST TO B (INTERP OR BISECT) AS NEW B AND EVALUATE BF.
C IF ((INTERP - BISECT) + (B - INTERP)) 30, 25, 25
C 25 B = INTERP
C GO TO 35
C 30 B = BISECT
C 35 BF = FUNCTION (B)
CIF CF IS ON THE SAME SIDE OF THE ROOT AS BF, LET POINT C = POINT A.

40 IF (C = ROOT) B = BF

50 C = A

CF = AF

C IF CF IS CLOSER (ABS) TO ROOT THAN BF, SWITCH POINTS B AND C.

C IN ANY CASE, B AND C ARE THE TWO BRACKETS. ALSO BF IS CLOSER TO THE ROOT THAN CF IS.

55 IF (ABS(BF - ROOT) - ABS(CF - ROOT)) 60, 60, 57

57 A = B

AF = BF

B = CF

C = A

CF = AF

C SET UP BISECTION POINT. IF CLOSE ENOUGH, FINISH UP. OTHERWISE GO ON.

60 BISECT = (B + C) / 2.

65 IF (ABS(BISECT - B) / ABS(BISECT + B) - 2.TOL) 75, 65, 65

70 WRITE(16,1000)A,B,CF,BF,C

1000 FORMAT (11H10// 3X, *IN FALZIP. AFTER*, I4, * ITERATIONS* //

1 LUX, *BRACKET 1 = *, G15.8, 5X, *FUNCTION = *, G15.8/

2 LUX, *BRACKET 2 = *, G15.8, 5X, *FUNCTION = *, G15.8/

3 5X, *BRACKET 1 WAS RETURNED AS RESULT.*)

75 FALZIP = B

YY = BF

RETURN

80 FALZIP = A

YY = AF

RETURN

85 WRITE(16,1100)ROOT,A,AF,B,BF

1100 FORMAT (*000** IN FALZIP, ROOT GIVEN (*#), G15.8, *) DIDN'T FALL BETWEEN VALUES OF FUNCTION AT BRACKETS GIVEN***/

2 LUX, *BRACKET 1 = *, G15.8, 5X, *FUNCTION = *, G15.8/

3 LUX, *BRACKET 2 = *, G15.8, 5X, *FUNCTION = *, G15.8/ 

4 40X, *TERMINATING RUN* )

STOP

END

SUBROUTINE INPUT ( IEND )

C THIS SUBROUTINE INPUTS THE DATA REQUIRED FOR THE EXECUTION OF A CASE

C

COMM /DFault/ LOC1, LOC2, HTR, OR, EMX, FRQ, XD, RD,

1 INO, X1(50), X1(50), THM(50), TMAP(50), BETA(50), PSEP(50),

2 PX(50), PW(50), THP(50), M(50), N(50),

3 101R(50), PH(50), PHI(50), ICHR,

4 SLO, SIG, SIGT, SIGB, SLOU, IEMU, SPEED

COMM /CMSTNT/ NM, AS, NFR, NMODE, SIGMA, B, M, FRQ, A,

1 OMEGA

ORIGINAL PAGE IS OF POOR QUALITY.
COMMON /REFS/ XREF, RREF, TTHREF
COMMON /MEASUR/ XM(50), RM(50), THETA(50), BETA(50), PSI(50)
COMMON /PRECUR/ XP(50), RP(50), THETA(50)
COMMON /MULES/ MU(50), MU(50), EIGEN(50)
COMMON /DESSL/ DUM(5), PI
COMMON /REFRAIN/ RFRPS
COMMON /ANGLES/ DEGRAD, RADDEG
COMMON /PHIMUS/ AMU(50), PHIMU(50), ICHECK
COMMON /EMUS/ EMU(50), EMU(50), EMUPR(50,50), EMUPRT
COMMON /UVINUS/ SIGMA, SIGMAR, SIGMAT, SIGMAP, DUMZ(150)
1
1DOV

NAMELIST /INDATA/ LUCN, LOCP, HR, OR, EMX, FRQ, XO,
1
THU, X, R, THM, BETAM, PSI, PX, PR, THP, Mn
2
MU5, IDIR, PREF, VREF, AM, PHI, ICHECK
3
SIGX, SIGR, SIGT, SIGB, SIGP, IEMU, SPEED

REAL MX, LAEF

C
C IEND = 0
READ(15,INDATA, END=9999)
C
C SET UP INTERNAL PARAMETERS
C
NMEAS = LOCN
NPRED = LOCN
NMOLES = LOCN
SIGMA = HR
MX = EMX
FREQ = FRQ
RFRPS = PREF
ICHECK = ICHECK
XREF = XO
RREF = RO
TTHREF = THM * DEGRAD
B = OR
A = SPEED
IMPRK = IEMU
SIGMAX = SIGA
SIGMAR = SIGR
SIGMAT = SIGT
SIGMA = SIGB
SIGMAP = SIGP
C
DO 20 I=1,NMEAS
XM(1) = X(I)
RM(1) = R(I)
THETAM(1) = THM(1) * DEGRAD
PSI(1) = PSI(1) * DEGRAD
BETA(1) = BETA(1)
20 CONTINUE
C
DO 40 I=1,NPRED
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XP(I) = PX(I)
RP(I) = PR(I)
THETA(I) = THP(I) * DEGRAD

DO CONTINUE

DO 60 I=1, NMDES
MODE(I) = M(I)
NUI(I) = MUS(I)
HAML(I) = IDIR(I)
AMU(I) = AM(I)
PHIMU(I) = PHII(I) * DEGRAD
60 CONTINUE

DO 80 J=1, 20
EML(I,J) = 0.0
EMUP(I,J) = 0.0
80 CONTINUE

CALCULATE WIDIAN FREQUENCY

OMEGA = 2. * PI * FREQ

SET INDICATOR FOR ERROR SOURCE STANDARD DEVIATIONS

IF (SIGMAX) 200, 100, 200
100 IF (SIGMAR) 200, 120, 200
120 IF (SIGMAT) 200, 140, 200
140 IF (SIGMB) 200, 160, 200
160 IF (SIGMAP) 200, 180, 200
160 IDEV = 0
200 IDEV = 1
GO TO 9999
GO TO 9999

END OF DATA SET

9998 IEND = 1
9999 RETURN

SUBROUTINE KNUCAL(N, VALUE, DELTA, KMU, RIGHT)

THIS SUBROUTINE CALCULATES THE CHARACTERISTIC NUMBER, KMU

EXTERNAL BESL1, BESL2
COMMUN/CNSTNOT, DUM1(31), SIGMA, DUM2(5)
REAL KMU, LEFT
30 IMPLUS = 0
35 IF (SIGMA) 50, 40, 50

ORIGINAL PAGE 12
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C DETERNINE IF LEFT AND RIGHT BRACKETS HAVE BEEN FOUND.
C 90 IF IPLUS .EQ. 1 .AND. MINUS .EQ. 1 ) GO TO 100
C BRACKETS NOT FOUND. RECYCLE.
C VALUSV = VALUE
VALUE = DELTA + VALUE GO TO 35
C BRACKETS FOUND, CALCULATE KMU
C 100 LEFT = VALUSV
RIGHT = VALUE
IF SIGMA ) 110, 120, 110
110 KMU = FALZI( BESL1, LEFT, RIGHT, .001, 0.0, 50, YY )
GO TO 130
120 KMU = FALZI( BESL2, LEFT, RIGHT, .001, 0.0, 50, YY )
130 RETURN
KMU 00771
SUBROUTINE KQCAL
C THIS SUBROUTINE CALCULATES THE CHARACTERISTIC NUMBERS KMU AND QMU
C COMMON /MODES/ MODE(50), MH(50), IMAVE(50)
COMMON /KMU/ KMU(50) , QMU(50)
COMMON /BESL/ ISIGN, JSIGN, DELKMU, TOL, M, PI
COMMON /CNSTN/ DUM1(2), NMODES, SIGMA, DUM2(5)
REAL KMU, KMUPRM
C DO 100 I=1,NMODES
C CALCULATE ORDER FOR BESSEL FUNCTION EVALUATION
C M = IABS( MODE(I) )
IF( M .NE. 0 ) GO TO 10
ISIGN = 1
JSIGN = -1
BRXTL = .1 GO TO 20
10 ISIGN = MODE(I) / M
JSIGN = ISIGN
This page contains a piece of computer code written in Fortran. The code is likely associated with solving a specific mathematical problem, possibly involving Bessel functions or similar mathematical operations. The code includes conditional statements, loops, and mathematical calculations, typical of scientific computing problems. The specific context or application is not clear from the code snippet alone.
END

SUBROUTINE PRINT

C THIS SUBROUTINE PRINTS INPUT AND CALCULATED VALUES

C

COMMON /CNSTM/ NMEAS, NPRDS, NMODES, SIGMA, B, RX, FREQ, A,
1 OMEGA
COMMON /REFS/ XREF, YREF, ZREF
COMMON /MEASUR/ XM(50), RM(50), THETAM(50), BETA(50), PSI(50)
COMMON /PRDCT/ XP(50), RP(50), THETAP(50)
COMMON /MODES/ MODE(50), MU(50), INAVE(50)
COMMON /ENUS/ ENU(50,50), EMUP(50,50), EMUPAM(50,50), IEMPAT
COMMON /ANGLES/ DELRAD, RAGDEG
COMMON /OUTPUT/ AMPI(50), PHASI(50)
COMMON /REFCONS/ REFPERS
COMMON /AVENUS/ VX(50)
COMMON /KMU/ KMU(50), QMU(50)
COMMON /APHMUS/ AMU(50), PHIMU(50), ICHECK
COMMON /AVIATE/ SIUMAX, SIGMAR, SIGMA, SIGMAI, SIGMAI, SIGMAX(50)
1 SIGT(50), SIGAMC(50), IDEV
COMMON /DERSUM/ ARNSUM(50), PNSUM(50), AXNSUM(50), PXNSUM(50)
1 ATNSUM(50), PTNSUM(50), AHNNSUM(50), PHNNSUM(50)
2 APNSUM(50), PPNSUM(50)
COMMON /DERIVS/ DAMDN(50,50), DAMNS(50,50), DPHDN(50,50), DPHNS(50,50)
1 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
2 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
3 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
4 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
5 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
6 DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50), DPHHRN(50,50)
COMMON /MCOMP/ XALOMP(50), RACOMP(50), TACOMP(50), BACOMP(50)
1 PACOMP(50), XPCOMP(50), RPCOMP(50), TPCOMP(50)
2 BPCOMP(50), PPLCOMP(50)

DIMENSION AMUDB(50), DEVOB(50)

COMPLEX RX
REAL KMU, RX

C CONVERT INTERNAL UNITS TO OUTPUT UNITS

C

THREF = RADDEG * THREF

DO 20 I=1,NMEAS
THETAM(I) = RADDEG * THETAM(I)
PSI(I) = RADDEG * PSI(I)
20 CONTINUE

DO 25 I=1,NPRDS
THETAP(I) = RADDEG * THETAP(I)
PHASE(I) = RADDEG * PHASE(I)
ANPI(I) = 20. * ALOG10 (AMPI(I) / REFPERS)
25 CONTINUE

DO 30 I=1,NMODES
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KX(I) = RADDEG * KX(I)
30 CONTINUE

C

DO 35 I=1,NMODES
PHIMU(I) = RADDEG * PHIMU(I)
AMU(I) = 20. * ALOG10(AMU(I) / REFPS)
35 CONTINUE

C

IF( IDEV .LE. 0 ) GO TO 50
DO 40 I=1,NMODES
DEVU(I) = 20. * ALOG10(1. * SIGAM(I) / AMU(I))
40 CONTINUE

C

DO 45 I=1,NMODES
DIVSOR = 1. / AMU(I)
XACOMP(I) = DIVSOR * SORT( XACOMP(I))
YACOMP(I) = DIVSOR * SORT( YACOMP(I))
TACOMP(I) = DIVSOR * SORT( TACOMP(I))
BACOMP(I) = DIVSOR * SORT( BACOMP(I))
PACOMP(I) = DIVSOR * SORT( PACOMP(I))
XPCOMP(I) = SORT( XPCOMP(I))
RPCOMP(I) = SORT( RPCOMP(I))
TPCOMP(I) = SORT( TPCOMP(I))
EPCOMP(I) = SORT( EPCOMP(I))
PPCOMP(I) = SORT( PPCOMP(I))
45 CONTINUE

C

DO 55 I=1,NMODES
DIVSOR = 1.0 / AMU(I)
ARNSUM(I) = DIVSOR * SORT( ARNSUM(I))
AXNSUM(I) = DIVSOR * SORT( AXNSUM(I))
ATNSUM(I) = DIVSOR * SORT( ATNSUM(I))
ANNSUM(I) = DIVSOR * SORT( ANNSUM(I))
APNSUM(I) = DIVSOR * SORT( APNSUM(I))
PRNSUM(I) = SORT( PRNSUM(I))
PXNSUM(I) = SORT( PXNSUM(I))
PTNSUM(I) = SORT( PTNSUM(I))
PFNSUM(I) = SORT( PFNSUM(I))
PPNSUM(I) = SORT( PPNSUM(I))
55 CONTINUE

C

C CONVrERT ANY NEGATIVE ANGLES TO POSITIVE ANGLES FOR PRINTING

C

CALL ANGPOS(PHIMU,NMODES)
CALL ANGPOS(PHASER,NPRED)

C

C PRINT INPUT VARIABLES

C

WRITE(6,9000)
9000 FORMAT(1H1, 1H4, 999 MODAL CALCULATION COMPUTER PROGRAM **** 100949
WRITE(6,9001) NMEAS, NPRED, NModes
9001 FORMAT(1H4, 956, 999 INPUT VARIABLES ... /, 15, 151, 'NUMBER OF MEAS=00951
18UREMENT LOCATIONS = ', 1Z, T51, 'NUMBER OF PREDICTION LOCATIONS =00952

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2, 12, T96, 'NUMBER OF (MODE,MU) SETS = 9, 12
WRITE(4,9002) 00953
00954

9002 FORMAT( //, 1X, '... INPUT MODES ...', //, T5, 'MODE', T14,
1' CircuMFERENTIAL', T34, 'RADIAL', T47, 'WAVE', // T16, 'MODE NUMBER=00956
2X, T34, 'ORDER', T45, 'INDICATOR'
00957
UD 60 L=1,NNODES 00958
WRITE(4,9003) L, MODE(1), MU(1), I WAVE(1) 00959
9003 FORMAT( 5X, 12, 11X, 1X, 13X, 12, 11X, 12
00960
60 CONTINUE 00961
C
C PRINT REFERENCE VALUES
C
WRITE(4,9004) REFPRS 00962
9004 FORMAT( //, 1X, '... REFERENCE VALUES ...', //, T5, 'REFERENCE PRESSURE'
00963
1E9.4 ) 00964
C
C PRINT TEST GEOMETRY AND CONDITIONS
C
WRITE(4,9005) SIGMA, B, MX, FREQ, A, DMEGA 00965
9005 FORMAT( //, 1X, 'TEST GEOMETRY AND CONDITIONS ...', //, T5, 'SIGMA'
1X, 'MU', TIP RATIO = ', F8.3, T42, OUTER RADIUS OF DUCT = ', F8.2, 00973
2T84, 'AXIAL MACH NUMBER = ', F8.2, '/', T5, 'FREQUENCY = ', F8.2, 00974
3T42, 'SPEED OF SOUND = ', F8.2, 'T84, 'PHASE*, T85, 'AXIAL WAVE NUMBER''
4F10.2 ) 00975
C
C PRINT CALCULATED MODAL AMPLITUDES AND PHASES
C
WRITE(4,9006) 00976
WRITE(4,9006) 00977
9006 FORMAT( //, T45, '... MODAL AMPLITUDE AND PHASE CALCULATION ...', //, T5, 00978
1X, '... CALCULATED MODAL AMPLITUDES AND PHASES ...', //, T5, 00979
2X, 'AMPLITUDE*', T84, 'PHASE', T85, 'AXIAL WAVE NUMBER', 00980
5, T5, 'PRESSURE', T71, 'DEGREES', T82, 'DEGREES', T80, 'REAL', 00982
6T10, 'IMAGINARY', / 1
DU 80 L=1,NNODES 00983
WRITE(4,9007) 1, MODE(1), MU(1), I WAVE(1), AMU(1), AMUDD(1), 00984
1
PHI MU(I), KX(I), KMU(I) 00985
9007 FORMAT( 5X, 12, 4X, 14, 11X, 12, 8X, 12, 4X, E12.6, 3X, E12.6, 00986
14X, F10.4 ) 00987
80 CONTINUE 00988
C
C PRINT REFERENCE LOCATION VALUES
C
WRITE(4,9008) XREF, REF, REF 00989
9008 FORMAT( //, 1X, '... REFERENCE LOCATION ...', //, T10, 'X', T27, 00990
1X, T42, 'THETA', //, 4X, E12.6, 215X, E12.6 ) 00991
C
C PRINT MEASUREMENT LOCATION VALUES
C
IF (ICHEN .EQ. 0 ) GO TO 110 00992
WRITE(4,9009) 00993
C
C
50
9010 FORMAT(//; IX, 12, 3X, 315X, T12.6) 01011
100 CONTINUE 01012
C PRINT PREDICTION LOCATION VALUES C
GO 110 01013
110 WHITE(6,9011) 01014
GO 120 01016
GO 120 01020
3/ ) 01021
DO 120 1=1,NPRED 01022
WHITE(6,9011) 01023
GO 120 01025
120 CONTINUE 01026
C PRINT SENSITIVITY CALCULATION VALUES IF NOT A CHECK CASE C
GO 1140 01027
1140 IF I=1 THEN GO TO 250 01028
WHITE(6,9000) 01029
WHITE(6,9012) 01030
GO 1140 01031
C PRINT ERROR SOURCE STANDARD DEVIATION VALUES C
GO 1140 01032
1140 IF I=1 THEN GO TO 250 01033
WHITE(6,9013) 01034
9013 FORMAT(///; IX, *... ERROR SOURCE STANDARD DEVIATIONS ...*; ///; IX, TIMES, T40, R*, T55, *THETA*, T70, *AMPLITUDE*) 01036
2774, *SIGMA PSI*, 4X, E12.6, 415X,E12.6) ) 01038
GO 1140 01039
C PRINT MODAL STANDARD DEVIATIONS C
GO 1140 01040
1140 IF I=1 THEN GO TO 250 01041
WHITE(6,9014) 01042
9014 FORMAT(///; IX, *... NORMALIZED STANDARD DEVIATIONS DUE TO ALL ERRORS*; ///; IX, TIMES, T40, R*, T55, *THETA*, T70, *AMPLITUDE*) 01043
2774, *MU PSI*, 4X, E12.6, 415X,E12.6) ) 01045
GO 1140 01046
C PRINT MODAL STANDARD DEVIATION COMPONENTS C
GO 1140 01047
1140 IF I=1 THEN GO TO 250 01048
WHITE(6,9015) 01049
9015 FORMAT(///; IX, TIMES, T40, R*, T55, *THETA*, T70, *AMPLITUDE*) 01050
2774, *SIGMA PSI*, 4X, E12.6, 415X,E12.6) ) 01052
GO 1140 01053
C PRINT MODAL STANDARD DEVIATION COMPONENTS C
GO 1140 01054
WHITE(6,9016) 01055

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9016 FORMAT //, IX, "... NORMALIZED STANDARD DEVIATION COMPONENTS (ER01059)
1 RD SOURCE DEVIATION TIMES RMS SUM OF NORMALIZED INFLUENCE COEFFICIO01060
2 ENTS) ... " ) 01061
WRITE(6,9017) 01062
9017 FORMAT //, TS, "MODE", TS6, "AMPLITUDE DUE TO ERROR IN", TS2, 01063
1 PHASE DUE TO ERROR IN", /, TS5, "X", TS7, "R", TS7, "THETA", 01064
2TS1, "Y", TS2, "PSI", TS9, "X", TS9, "R", TS1, "THETA", TS15, 01065
3TS1, "X", TS6, "PSI", / ) 01066
DO 140 I=1,NMODES 01067
WRITE(6,9018) I, XACOMP(I), YACOMP(I), TACOMP(I), RACOMP(I), 01068
1 PRCOMP(I), XPCOMP(I), RPCOMP(I), YPCOMP(I), 01069
2 BPCOMP(I), PBPCOMP(I) 01070
9018 FORMAT 5X, 12, 5(I,5E11.4), 4X, 5(I,5E11.4) ) 01071
160 CONTINUE 01072
C 01073
C PRINT INFLUENCE COEFFICIENTS 01074
C 01075
180 WRITE(6,9019) 01076
9019 FORMAT //, IX, "... RMS SUM OF NORMALIZED INFLUENCE COEFFICIENTS01077
1 ... " ) 01078
WRITE(6,9017) 01079
DO 200 I=1,NMODES 01080
WRITE(6,9019) I, AXNSUM(I), ARNSUM(I), ATNSUM(I), ABNSUM(I). 01081
1 APNSUM(I), PRNSUM(I), PRNSUM(I), 01082
2 PPNSUM(I), 01083
200 CONTINUE 01084
C 01085
C PRINT PARTIAL DERIVATIVES 01086
C 01087
WRITE(6,9020) 01088
9020 FORMAT //, IX, "... INFLUENCE COEFFICIENTS (PARTIAL DERIVATIVES 01089
1 ... " ) 01090
DO 200 I=1,NMEAS 01091
WRITE(6,9021) I 01092
9021 FORMAT //, TS5, "INFLUENCE COEFFICIENTS FOR MEASUREMENT LOCATION 01093
1, J2 ) 01094
WRITE(6,9017) 01095
DO 220 J=1,NMODES 01096
WRITE(6,9018) J, DAMDNI(J), DAMDN(J), DAMTNI(J), 01097
1 DAMNI(J), DAMN(J), DAMTNI(J), 01098
2 DPHDNI(J), DPHDN(J), DPHDTNI(J), 01099
3 DPHDN(J), 01100
220 CONTINUE 01101
240 CONTINUE 01102
C 01103
C PRINT CHARACTERISTIC E-FUNCTION VALUES IF REQUESTED 01104
C 01105
250 IF (1MPRT .LE. 0 ) GO TO 9999 01106
WRITE(6,9000) 01107
WRITE(6,9022) 01108
9022 FORMAT //, TS5, "... CHARACTERISTIC E-FUNCTION VALUES FOR NODAL AD109
IMPLITUDE AND PHASE CALCULATIONS ... " ) 01110
WRITE(6,9023) I, J=1,NMODES ) 01111
9023 FORMAT //, IX, ' ... MEASUREMENT LOCATIONS ... ', IX, 'LOCATION0112
1X*, 168, 'MODES', //, 6X, 15(6X,12), / )
   DO 260 J=1,NMEAS
      WRITE(6,9024) J, ( EMUL(I,J),I=1,NUMODES )
9024 FORMAT 4X, 12, 5X, 15(1X,FT3) )
   260 CONTINUE
      WRITE(6,9025) ( I,1=1,NUMODES )
9025 FORMAT //, IX, ' ... PREDICTION LOCATIONS ... ', IX, 'LOCATION0119
1X*, 168, 'MODES', //, 6X, 15(6X,12), / )
   DO 280 J=1,NPRED
      WRITE(6,9024) J, ( EMUP(I,J),I=1,NUMODES )
280 CONTINUE
   9999 RETURN
END
SUBROUTINE SIMEQCI(A, C, NA, NB, SINGUL )

  THIS SUBROUTINE SOLVES A NA X NA SYSTEM OF SIMULTANEOUS EQUATIONS
  HAVING COMPLEX COEFFICIENTS USING GAUSSIAN ELIMINATION METHOD.

  COMPLEX A(50,1), C(1), SAVE, ZERO
  DATA ZERO / (0.0,0.0) /

  SINGUL = 0.0
   DO 240 I=1,NA

  FIND MAXIMUM ELEMENT IN JTH COLUMN, ROWS I+1 TO NA

     JZ = I + 1
     IF( I - NA ) 20   100, 20
  20 VALMX = CABT( A(I+1) )
     NZ = I
     DO 60 KZ=JZ,NA
       B = CABT( A(IKZ+1) )
       IF( VALMX < B ) 40
          20 continues
     40 VALMX = B
     NZ = KZ
     60 CONTINUE

  INTERCHANGE ROW CONTAINING MAXIMUM WITH ITH ROW

   DO 80 IK=1,NB
      SAVE = A(I,IK)
      A(I,IK) = AIMZ,IK
      AIMZ,IK = SAVE
     80 CONTINUE

  NORMALIZE ITH ROW

   100 IF( REAL( A(I,I) ) ) 160, 120, 160
   120 IF( AIMAG( A(I,I) ) ) 160, 140, 160

  ERROR - COEFFICIENT MATRIX IS SINGULAR
140 SINGUL = 1.0
GO TO 9999

160 DO 220 LZ=JZ,NB
A(LZ) = A(I,LZ) / A(I,I)
IF (JZ - NB) 180, 260, 260

170 DO 220 NZ=JZ,NA
A(NZ,LZ) = A(NZ,LZ) - A(NZ,I) * A(I,LZ)

200 CONTINUE
220 CONTINUE
260 CONTINUE

C SOLVE FOR COEFFICIENTS
C

260 DO 280 NZ=1,NA
C(NZ) = ZERO

C CONTINUE
C

280 C(INA) = A(INA,NB)
NC = NA - 1
II = 1
DO 320 IZ=1,NC
C
K = NA
LZ = NA - IZ
C(LZ) = A(LZ,NI)
DO 300 M=1,II
C(LZ) = C(LZ) - C(KK) * A(LZ,KK)

300 CONTINUE
III = II + 1
320 CONTINUE

9999 RETURN
END

SUBROUTINE SOLVE

C THIS SUBROUTINE SETS UP AND SOLVES THE EQUATION SYSTEM ASSOCIATED WITH THE
C MEASUREMENT LOCATION PARAMETERS

C

COMMON /BESSL/ DUM3(5), PI
COMMON /KREFS/ XREF, RREF, THREF
COMMON /MEASUR/ XM(50), RM(50), THETAM(50), BETAM(50), PSI(50)
COMMON /MODES/ MODE(50), DUM1(100)
COMMON /SEMS/ EMU(50,50), EMUPM(50,50)
COMMON /APHIMUS/ AMU(50,50), PHIMU(50,50), ICHECK
COMMON /CNSTNT/ NMEAS, NPRED, NMODES, SIGMA, B, DUM2(4)
COMMON /WAVEN/ KK(50)
COMMON /LMAT4/ EQ1(50,51)
COMMON /AVIATE/ DUM4(155), IDEV
COMMON /KX/ XREF, RR(50,51), ANSVER(50)

C SET UP COEFFICIENT MATRIX
C

DO 40 I=1,NMEAS
DX = XM(I) - XREF
DR = RM(I) - RREF

C

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DTHETA = THETA(N) - THREF

CALCULATE CHARACTERISTIC E-FUNCTION VALUES AND DERIVATIVES FOR A PRIME

10 RPRIME = DR / B

CALL EMLCALK RPRIME, EMU1(I), EMUPRIME(I), 1

15 DO 20 J=1,NMODES

EQ1(J) = EMU(J,1) * CEXP( EXPNT ) * CEXP(-DX * AIAG(J) )

EQ1(I,J) = EQ1(I,J)

20 CONTINUE

SET UP RIGHT HAND SIDE

EQ1(NMODES+1) = BETAI * CEXP( CMLX1 0.0, PSII )

EQ1(NMODES+1) = EQ1(NMODES+1)

40 CONTINUE

SOLVE EQUATION SYSTEM

CALL SIME ( E, ANSWER, NMEAS, NMODES+1, SINGULR )

IF( SINGULR )

60 60 60 60

ERROR - SINGULAR MATRIX. TERMINATE EXECUTION

60 NNI = NMODES + 1

WHITE(6,1000) ( I EQ1(I,J),J=1,NNI,1=1,NMEAS )

1000 FORMAT( //, 5X, 'COEFFICIENT MATRIX IS SINGULAR', /, 1X, 116U13.6 )

STOP

CALCULATE AMPLITUDE AND PHASE VALUES

80 DO 100 I=1,NMODES

AMP(I) = CABS( ANSWER(I) )

PHI(I) = ATAN2( AIMAG( ANSWER(1) ) , REAL( ANSWER(1) ) )

100 CONTINUE

RETURN

END

THIS SUBROUTINE CALCULATES THE SENSITIVITY COEFFICIENTS ASSOCIATED

WITH THE EQUATION SYSTEM

9999 RETURN

SUBROUTINE SENSITY(Q, NOIM)

DIMENSION EMUAVG(50,50), IROW(50), ICOL(50)
COMPLEX KK, EQ1, TERM, ZERO, SUM, Q(NOIM,NOIM), DET
REAL KMU
COMMON /DERIVS/ DAMDRN(50,50), DAMNS(50,50), DPHDRN(50,50),
1 DPHNS(50,50), DAMDXX(50,50), DAMNS(50,50),
2 DPHDXN(50,50), DPHXXS(50,50), DAMDXXN(50,50)

55
3  DAHMNS(50,50), DPHDTN(50,50), DPHTHS(50,50); 01271
4  DMBNBS(50,50), DMBNS(50,50), DPHDIN(50,50); 01272
5  DPHNS(50,50), DAMPN(50,50), DAMPS(50,50); 01273
6  DPHDP(50,50), DPHPS(50,50); 01274

COMMON /CERSUM/ ARNSUM(50), PRNSUM(50), ARNSUM(50), PRNSUM(50); 01275
1  ATNSUM(50), PRNSUM(50), ARNSUM(50), PRNSUM(50); 01276
2  APNSUM(50), PPNNSUM(50); 01277

COMMON /NCOMP/ XALOMP(50), XLACOMP(50), TACOMP(50), BACOMP(50); 01278
1  PACOMP(50), XPCOMP(50), RPACOMP(50), TPACOMP(50); 01279
2  UPLG(50), UPCLMP(50); 01280

COMMON /DIVIATE/ S1MAX, S1MIN, S1MAX, S1MAB, SIGMAP, SIGMAN(50); 01281
1  S1MIN(50), SIGMA(50), IDEV; 01282

COMMON /LMSTN/ RMAS, MPRED, RMISLES, SIGMA, B, DUM14; 01283

COMMON /MEASUR/ DUM2(150), BETA(150), PSI(50); 01284

COMMON /APHMNS/ AMN(50), PHHMNS(50); 01285

COMMON /EMINS/ EMU(50,50), EMUX(50,50), EMUPRX(50,50), EMUPRT(50,50); 01286

COMMON /RELFLON/ RELFLON; 01287

COMMON /AMAL/ DUM4; 01288

COMMON /KMINUS/ KMN(50), QMINUS(50); 01289

COMMON /KABAND/ KAX(50); 01290

COMMON /LMATRX/ EQI(50,50); 01291

COMMON /MULS/ MUTE(50), MU(50); 01292

DATA Z(I) / (0.0, 0.0) / 01293

C CALCULATE INVERSE OF MEASUREMENT LOCATION MATRIX
C
10 CONTINUE
DO 10 J=1,NDIM
DO 10 I=1,NDIM
(11,1) = EQ(11,1)
10 CONTINUE
CALL INVERT( Q, NDIM, DET, IROW, ICOL )
C CALCULATE AVERAGE CHARACTERISTIC E-FUNCTION VALUES
C
20 CONTINUE
DO 20 J=1,NMDOLES
DO 20 I=1,NMEAS
EMUAVG(I,J) = KMINUS(J) * EMUPRX(I,J) / ( EMU(I,J) * B )
20 CONTINUE
40 CONTINUE
C CALCULATE DERIVATIVES WITH RESPECT TO R
C
60 CONTINUE
DO 60 K=1,NMEAS
SUM = ZERO
DO 60 J=1,NMDOLES
SUM = EMUAVG(K,J) * EQ(K,J) * AMU(J) + SUM
10 CONTINUE
60 CONTINUE
DO 80 L=1,NMDOLES
TERM = QIL(K) * SUM * CEQ(K) / PHIMU(L) * TERM
10 CONTINUE
LAMN(I,K,L) = - REAL (TERM)
DAMN(1,K,L) = DAMN(1,K,L) + 2
DPhHN(1,K,L) = - AIMAG (TERM / AMU(L)) * RADDEG
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OPHNS(K,L) = OPHVRHNL4(K,L) * 2
80 CONTINUE
100 CONTINUE
C
C CALCULATE DERIVATIVES WITH RESPECT TO X
C
DU 160 K=1,NMDES
SUM = ZERO
DO 120 J=1,NMDES
SUM = EU(IK,J) * KX(J) * AMU(J) * CEXP(CMPLX(0.,
1 PHIMU(J)) ) + SUM
120 CONTINUE
DU 140 L=1,NMDES
TERM = QL(L,K) * SUM * CEXP(CMPLX(0.,-PHIMU(L)) )
DAMAX(K,L) = AIMAG(TERM )
DAMINS(K,L) = DAMAX(K,L) * 2
DPHNS(K,L) = REAL(TERM / AMU(L)) * RADDEG
PHNS(K,L) = DPHNS(K,L) * 2
140 CONTINUE
160 CONTINUE
C
C CALCULATE DERIVATIVES WITH RESPECT TO THETA
C
DU 220 K=1,NMDES
SUM = ZERO
DO 180 J=1,NMDES
SUM = EU(IK,J) * MODE(J) * AMU(J) *
1 CEXP(CMPLX(0., PHIMU(J)) ) + SUM
180 CONTINUE
DU 200 L=1,NMDES
TERM = QL(L,K) * SUM * CEXP(CMPLX(0.,-PHIMU(L)) )
LAMDNK(L) = AIMAG(TERM ) / RADDEG
DAMINS(L) = DAMINS(K,L) * 2
DPHN(L) = REAL(TERM / AMU(L))
UPHNS(L) = DPHN(L) * 2
200 CONTINUE
220 CONTINUE
C
C CALCULATE DERIVATIVES WITH RESPECT TO BN
C
DU 240 L=1,NMDES
DU 240 K=1,NMDES
TERM = QL(K) * CEXP(CMPLX(0., PSI(K) - PHIMU(L)) )
LAMDNK(L) = REAL(TERM )
DAMINS(L) = DAMINS(K,L) * 2
UPHNS(L) = AIMAG(TERM / AMU(L)) * RADDEG
UPHNS(L) = DPHN(L) * 2
240 CONTINUE
260 CONTINUE
C
C CALCULATE DERIVATIVES WITH RESPECT TO PSI
C
DU 300 L=1,NMDES
DO 280 K=1,NMEAS
TERM = Q(L,K) * DETA(I) * CEXP( CNPLX( 0., PSI(K) )
1
PHI(MU(L)))
DAMPNI(K,L) = - AIMAG( TERM ) / RADDEG
DAMPNS(K,L) = DAMPNI(K,L) ** 2
(DHDPNI(K,L) = REAL( TERM / AMU(L))
DHDPNS(K,L) = DHDPNI(K,L) ** 2
280 CONTINUE
300 CONTINUE
C C CALCULATE SUMS OF DERIVATIVES C
C DO 340 J=1,NMODES
SUMM = 0.0
DO 320 I=1,NMEAS
SUMM = DAMRNS(I,J) + SUMM
320 CONTINUE
ARNSUM(I,J) = SUMM
340 CONTINUE
C DO 360 J=1,NMODES
SUMM = 0.0
DO 360 I=1,NMEAS
SUMM = DPHRNS(I,J) + SUMM
360 CONTINUE
PHNSUM(I,J) = SUMM
380 CONTINUE
C DO 420 J=1,NMODES
SUMM = 0.0
DO 440 I=1,NMEAS
SUMM = DAMXNS(I,J) + SUMM
440 CONTINUE
AXNSUM(I,J) = SUMM
420 CONTINUE
C DO 460 J=1,NMODES
SUMM = 0.0
DO 460 I=1,NMEAS
SUMM = DPHXNS(I,J) + SUMM
460 CONTINUE
PXNSUM(I,J) = SUMM
460 CONTINUE
C DO 500 J=1,NMODES
SUMM = 0.0
DO 500 I=1,NMEAS
SUMM = DAMINS(I,J) + SUMM
500 CONTINUE
AXNSUM(I,J) = SUMM
500 CONTINUE
C DO 540 J=1,NMODES

SUMM = 0.0
DO 520 I=1,NNEAS
   SUMM = DPHTNS(I,J) + SUMM
520 CONTINUE
PTNSUM(J) = SUMM
540 CONTINUE
C DO 560 J=1,NMODES
   SUMM = 0.0
   DO 560 I=1,NNEAS
      SUMM = DAMPS(I,J) + SUMM
560 CONTINUE
ABNSUM(J) = SUMM
580 CONTINUE
C DO 620 J=1,NMODES
   SUMM = 0.0
   DO 620 I=1,NNEAS
      SUMM = DPMPNS(I,J) + SUMM
620 CONTINUE
APNSUM(J) = SUMM
660 CONTINUE
C DO 660 J=1,NMODES
   SUMM = 0.0
   DO 660 I=1,NNEAS
      SUMM = DAPNS(I,J) + SUMM
660 CONTINUE
APNSUM(J) = SUMM
660 CONTINUE
C DO 700 J=1,NMODES
   SUMM = 0.0
   DO 700 I=1,NNEAS
      SUMM = DPMPNS(I,J) + SUMM
700 CONTINUE
PPNSUM(J) = SUMM
700 CONTINUE
C IF I.DIF = .EQ., 0 ) GO TO 9999
1 SIGR = SIGMAR ** 2
SIGX = SIGMAX ** 2
SIGT = SIGMAT ** 2
SIGB = SIGMAB ** 2
SIGP = SIGMAP ** 2
C C CALCULATE COMPONENTS OF MODAL STANDARD DEVIATIONS
C DO 720 I=1,NMODES
   XACUMP(I) = ARNSUM(I) * SIGX
   RACMP(I) = ARNSUM(I) * SIGR
720 CONTINUE
THIS SUBROUTINE INVETS A COMPLEX MATRIX. THIS PROCEDURE WAS ADAPTED FROM THE IBM SCIENTIFIC SUBROUTINE PACKAGE.

DIMENSION L(I), M(I)
COMPLEX A(I), BIGA, HOLD, D, ONE, ZERD
DATA ZERO / (0.0,0.0) /, ONE / (1.0,0.0) /

C SEARCH FOR THE LARGEST ELEMENT

D = ONE
NK = -N
DO 380 K=1,N
NK = N + NK
L(K) = K
M(K) = K
KK = K + NK
BIGA = A(KK)
DO 60 J=K,N
IZ = N * (J - 1)
DO 60 I=K,N
IZ = IZ + J
20 IF( CABS( BIGA ) - CABS( A(IJ) ) ) LE 0.0, 60, 60
BIGA = A(IJ)
L(K) = I
M(K) = J
60 CONTINUE

C INTERCHANGE ROWS
C J = L(K)

ORIGINAL PAGE IS OF POOR QUALITY
IF ( J - K ) = K - N
      00  KI
      DO 100 I=1,N
      KI  = N + KI
      HOLD  = -A(KI)
      JI  = KI - K + J
      A(KI)  = A(JI)
      A(JI)  = HOLD
      100  CONTINUE

C
C INTERCHANGE COLUMNS

120  I  =  NIK)
     IF ( I - K )
     160  JP  = N * ( I - I )
     DO 160 J=1,N
     JK  = NK + J
     JI  = JP + J
     HOLD  = -AIJK
     AIJK)  = A(JI)
     AIJJ)  = HOLD
     160  CONTINUE

C
C DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT IS CONTAINED IN BIGA.)

180  IF ( ABS1 BIGA )
     200  D  = ZERO
     GO TO 9999
     220  DO 260 I=1,N
     IF ( I - K )
     240  IK  = NK + I
     A(IK)  = A(IK) / ( I - BIGA )
     260  CONTINUE

C
C REDUCE MATRIX

280  IF ( I - K )
     300  KJ  = IJ - I + K
     AIJJ)  = HOLD * A(KJ) + A(IJ)
     320  CONTINUE

C
C DIVIDE ROW BY PIVOT

350  KJ  = K - N
     DO 360 J=1,N
     KJ  = N + KJ

IF J - K )
340 A(KJ) = A(KJ) / B(I)
360 CONTINUE
C
C CALCULATE DETERMINANT
C
D = D * B(I)
C
C REPLACE PIVOT BY RECIPROCAL
C
A(KK) = ONE / B(I)
380 CONTINUE
C
C FINAL ROW AND COLUMN INTERCHANGE
C
K = N
400 K = K - 1
IF ( K )
420 I = L(K)
IF ( I - K )
440 JQ = N * ( K - 1 )
JR = N * ( I - 1 )
DU 460 J=1,N
JK = JQ + J
HOLD = A(JK)
J1 = JR + J
A(JK) = -A(J1)
AI(J1) = HOLD
460 CONTINUE 480 J
480 CONTINUE = M(K)
500 KI = K - N
DO 520 I=1,N
KI = N * KI
HOLD = A(KI)
J1 = KI - K + J
A(KI) = -A(J1)
AI(J1) = HOLD
520 CONTINUE GO TO 400
9999 RETURN
END

***** ABOV ACTION SATISFACTORILY COMPLETED *****
APPENDIX C
MODAL CALCULATION PROGRAM
SAMPLE CASE
### Modal Calculation Computer Program

---

#### Input Variables

- Number of Measurement Locations = 3
- Number of Prediction Locations = 3
- Number of (Mode, Nu) Sets = 3

#### Input Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Circumferential Mode Number</th>
<th>Radial Order</th>
<th>Wave Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>-4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Reference Values

- Reference Pressure = 2000E-03

#### Test Geometry and Conditions

- Mu / Tip Ratio = 0.440
- Frequency = 6200.00
- Outer Radius of Duct = 25.00
- Speed of Sound = 34345.00
- Axial Mach Number = -0.10
- Radian Frequency = 36456.75
### MODAL CALCULATION COMPUTER PROGRAM ###

--- MODAL AMPLITUDE AND PHASE CALCULATION ---

#### CALCULATED MODAL AMPLITUDES AND PHASES ####

<table>
<thead>
<tr>
<th>MODE</th>
<th>CIRCUMFERENTIAL MODE NUMBER</th>
<th>RADIAL ORDER</th>
<th>WAVE INDICATOR</th>
<th>AMPLITUDE (PRESSURE)</th>
<th>AMPLITUDE (DB)</th>
<th>PHASE (DEGREES)</th>
<th>AXIAL WAVE NUMBER</th>
<th>REAL</th>
<th>IMAGINARY</th>
<th>RPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-3</td>
<td>0</td>
<td>1</td>
<td>0.146735E+04</td>
<td>0.137428E+03</td>
<td>126.9814</td>
<td></td>
<td></td>
<td></td>
<td>5.2510</td>
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<tr>
<td>2</td>
<td>-4</td>
<td>1</td>
<td>1</td>
<td>0.276110E+04</td>
<td>0.142601E+03</td>
<td>160.0302</td>
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<td></td>
<td></td>
<td>8.7800</td>
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<tr>
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<td>-4</td>
<td>2</td>
<td>1</td>
<td>0.169032E+04</td>
<td>0.138539E+03</td>
<td>229.2115</td>
<td></td>
<td></td>
<td></td>
<td>12.9210</td>
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</table>

--- REFERENCE LOCATION ---

<table>
<thead>
<tr>
<th>X</th>
<th>R</th>
<th>THETA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

--- MEASUREMENT LOCATIONS ---

<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>X</th>
<th>R</th>
<th>THETA</th>
<th>AMPLITUDE (DB)</th>
<th>PHASE (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>25.000000</td>
<td>0.0</td>
<td>0.228700E+03</td>
<td>324.699951</td>
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<tr>
<td>2</td>
<td>14.76000</td>
<td>25.000000</td>
<td>0.0</td>
<td>0.128900E+03</td>
<td>135.400009</td>
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<tr>
<td>3</td>
<td>29.960007</td>
<td>25.600000</td>
<td>0.0</td>
<td>0.841000E+02</td>
<td>252.200073</td>
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</table>

--- PREDICTION LOCATIONS ---

<table>
<thead>
<tr>
<th>LOCATION NUMBER</th>
<th>X</th>
<th>R</th>
<th>THETA</th>
<th>AMPLITUDE (RESULTANT)</th>
<th>PHASE (RESULTANT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>25.000000</td>
<td>239.900040</td>
<td>0.121165E+03</td>
<td>90.099747</td>
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<td>2</td>
<td>13.525000</td>
<td>25.000000</td>
<td>100.666637</td>
<td>0.115699E+03</td>
<td>357.780762</td>
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<tr>
<td>3</td>
<td>20.300003</td>
<td>25.000000</td>
<td>15.900006</td>
<td>0.115084E+03</td>
<td>67.249161</td>
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</table>
### Modal Calculation Computer Program

### Sensitivity Coefficient Calculation

#### Error Source Standard Deviations

<table>
<thead>
<tr>
<th>Mode</th>
<th>Sigma X</th>
<th>Sigma F</th>
<th>Sigma Theta</th>
<th>Sigma B</th>
<th>Sigma PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.200000E-02</td>
<td>0.200000E-02</td>
<td>0.200000E-01</td>
<td>0.250000E+02</td>
<td>0.150000E+01</td>
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</tbody>
</table>

#### Normalized Standard Deviations Due to All Error Sources

<table>
<thead>
<tr>
<th>Mode</th>
<th>Cylindrical Mode Number</th>
<th>Radial Order</th>
<th>Wave Indicator</th>
<th>Normalized Amplitude Deviation</th>
<th>Amplitude Deviation (in)</th>
<th>Phase Deviation (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.107999E+00</td>
<td>0.840576E+00</td>
<td>0.360487E+01</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0.101800E+00</td>
<td>0.842055E+00</td>
<td>0.244215E+01</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0.105467E+00</td>
<td>0.874971E+00</td>
<td>0.168606E+01</td>
</tr>
</tbody>
</table>

#### Normalized Standard Deviation Components

<table>
<thead>
<tr>
<th>Mode</th>
<th>Amplitude Due to Error in X</th>
<th>Poise</th>
<th>Amplitude Due to Error in Y</th>
<th>Poise</th>
<th>Amplitude Due to Error in R</th>
<th>Poise</th>
<th>Amplitude Due to Error in THETA</th>
<th>Poise</th>
<th>Amplitude Due to Error in B</th>
<th>Poise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.74151-03</td>
<td>0.95-05</td>
<td>0.5571-03</td>
<td>0.1075E+00</td>
<td>0.1604E+03</td>
<td>0.8676E-01</td>
<td>0.8135E-04</td>
<td>0.4966E-01</td>
<td>0.3481E+01</td>
<td>0.9311E+00</td>
</tr>
<tr>
<td>2</td>
<td>0.46171-03</td>
<td>0.65-05</td>
<td>0.1666E-03</td>
<td>0.1016E+00</td>
<td>0.6815E-02</td>
<td>0.6406E-01</td>
<td>0.1140E-03</td>
<td>0.4898E-01</td>
<td>0.2335E+01</td>
<td>0.9185E+00</td>
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<tr>
<td>3</td>
<td>0.30441-03</td>
<td>0.1094-05</td>
<td>0.4717-03</td>
<td>0.1054E+00</td>
<td>0.20501-02</td>
<td>0.6200E-01</td>
<td>0.7084E-03</td>
<td>0.4885E-01</td>
<td>0.1402E+01</td>
<td>0.9347E+00</td>
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</table>
### Modal Calculation Computer Program

#### Sensitivity Coefficient Calculation

#### FSM Sum of Normalized Influence Coefficients

<table>
<thead>
<tr>
<th>Mode</th>
<th>Amplitude Due to Error in X (R, Theta)</th>
<th>Phase Due to Error in X (R, Theta)</th>
<th>B (Psi)</th>
<th>D (Psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.374e+00 0.497e-02 0.267e-01 0.630e-02 0.663e-02</td>
<td>0.433e+02 0.406e+01 0.248e+01 0.139e+00 0.620e+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.730e+00 0.477e-02 0.711e-01 0.603e-02 0.451e-02</td>
<td>0.420e+02 0.576e+01 0.244e+01 0.925e+00 0.612e+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.151e+00 0.408e-02 0.767e-01 0.429e-02 0.196e-02</td>
<td>0.410e+02 0.103e+00 0.249e+01 0.561e+00 0.623e+00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Influence Coefficients (Partial Derivatives)

Influence coefficients for measurement location 1

<table>
<thead>
<tr>
<th>Mode</th>
<th>Amplitude Due to Error in X (R, Theta, B)</th>
<th>Phase Due to Error in X (R, Theta, B)</th>
<th>D (Psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.432e+03 0.277e+01 0.250e+02 0.239e+01 0.801e+02</td>
<td>-0.286e+02 0.225e+01 0.159e+01 -0.773e-01 0.398e+00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.457e+03 0.474e+01 0.357e+02 0.357e+01 0.657e+01</td>
<td>-0.315e+02 0.463e+01 0.182e+01 -0.516e-01 0.455e+00</td>
<td></td>
</tr>
</tbody>
</table>
### Influence Coefficients for Measurement Location 2

<table>
<thead>
<tr>
<th>MCDE</th>
<th>Amplitude Due to Error in $\theta$</th>
<th>B</th>
<th>PSI</th>
<th>Phase Due to Error in $\theta$</th>
<th>B</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0.3253E+03$</td>
<td>$-0.6131E+01$</td>
<td>$-0.2075E+02$</td>
<td>$0.5216E+01$</td>
<td>$0.5167E+01$</td>
<td>$-0.3014E+02$</td>
</tr>
<tr>
<td>2</td>
<td>$0.4446E+02$</td>
<td>$-0.9217E+01$</td>
<td>$-0.2524E+02$</td>
<td>$0.7925E+01$</td>
<td>$0.7129E+01$</td>
<td>$-0.2464E+02$</td>
</tr>
<tr>
<td>3</td>
<td>$0.1588E+03$</td>
<td>$-0.6414E+01$</td>
<td>$-0.1078E+02$</td>
<td>$0.5605E+01$</td>
<td>$0.2695E+01$</td>
<td>$-0.2936E+02$</td>
</tr>
</tbody>
</table>

### Influence Coefficients for Measurement Location 3

<table>
<thead>
<tr>
<th>MCDE</th>
<th>Amplitude Due to Error in $\theta$</th>
<th>B</th>
<th>PSI</th>
<th>Phase Due to Error in $\theta$</th>
<th>B</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0.1070E+03$</td>
<td>$0.3158E+01$</td>
<td>$-0.1132E+02$</td>
<td>$0.2649E+01$</td>
<td>$0.2630E+01$</td>
<td>$-0.1226E+02$</td>
</tr>
<tr>
<td>2</td>
<td>$0.1116E+01$</td>
<td>$-0.5649E+01$</td>
<td>$-0.1174E+02$</td>
<td>$0.5724E+01$</td>
<td>$0.2811E+01$</td>
<td>$-0.1283E+02$</td>
</tr>
<tr>
<td>3</td>
<td>$-0.1967E+03$</td>
<td>$0.1467E+01$</td>
<td>$-0.1652E+02$</td>
<td>$0.2087E+01$</td>
<td>$0.1630E+01$</td>
<td>$-0.8542E+01$</td>
</tr>
</tbody>
</table>
### Measurement Locations

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.404  -0.315  0.233</td>
</tr>
<tr>
<td>2</td>
<td>0.404  -0.215  0.232</td>
</tr>
<tr>
<td>3</td>
<td>0.404  -0.315  0.733</td>
</tr>
</tbody>
</table>

### Prediction Locations

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.404  -0.215  0.733</td>
</tr>
<tr>
<td>2</td>
<td>0.404  -0.215  0.733</td>
</tr>
<tr>
<td>3</td>
<td>0.404  -0.315  0.233</td>
</tr>
</tbody>
</table>
*** MODAL CALCULATION COMPUTER PROGRAM ***

*** INPUT VARIABLES ***

NUMBER OF MEASUREMENT LOCATIONS = 3  
NUMBER OF PREDICTION LOCATIONS = 3  
NUMBER OF (MODE, MU) SETS = 3

*** INPUT MODES ***

<table>
<thead>
<tr>
<th></th>
<th>CIRCUMFERENTIAL</th>
<th>RADIAL ORDER</th>
<th>WAVE INDICATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>-4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*** REFERENCE VALUES ***

REFERENCE PRESSURE = .2000E-03

*** TEST GEOMETRY AND CONDITIONS ***

HUB / TIP RATIO = 0.440  
FREQUENCY = 1200.00  
OUTER RADIUS OF DUCT = 25.00  
SPEED OF SOUND = 34345.00  
AXIAL MACH NUMBER = -0.10  
RADIAN FREQUENCY = 38955.75
### Modal Calculation Computer Program

### Modal Amplitude and Phase Calculation

#### Calculated Modal Amplitudes and Phases

<table>
<thead>
<tr>
<th>Mode</th>
<th>Circumferential Mode Number</th>
<th>Radial Order</th>
<th>Wave Indicator</th>
<th>Amplitude (Pressure)</th>
<th>Amplitude (DB)</th>
<th>Phase (Degrees)</th>
<th>Axial Wave Number</th>
<th>Imaginary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4</td>
<td>0</td>
<td>1</td>
<td>0.256000E+03</td>
<td>0.12193E+03</td>
<td>321.6000</td>
<td>71.0845</td>
<td>0.0</td>
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<tr>
<td>2</td>
<td>-4</td>
<td>1</td>
<td>1</td>
<td>0.256000E+03</td>
<td>0.12193E+03</td>
<td>250.0001</td>
<td>69.0154</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>-4</td>
<td>2</td>
<td>1</td>
<td>0.256000E+03</td>
<td>0.12193E+03</td>
<td>106.0000</td>
<td>65.0758</td>
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</table>

#### Reference Location

<table>
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<tr>
<th>X</th>
<th>R</th>
<th>Theta</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Prediction Locations

<table>
<thead>
<tr>
<th>Location Number</th>
<th>X</th>
<th>R</th>
<th>Theta</th>
<th>Amplitude (Resultant)</th>
<th>Phase (Resultant)</th>
</tr>
</thead>
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### Modal Calculation Computer Program

### Characteristic E-Function Values for Modal Amplitude and Phase Calculations

### Measurement Locations

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### Prediction Locations

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