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# Modal Acoustic Transmission Loss (MOATL): A Transmission-Loss Computer Program Using a Normal-Mode Model of the Acoustic Field in the Ocean

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Washington, D.C.

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A FORTRAN program which calculates coherent and incoherent acoustic transmission loss is described. The program is based on normal-mode theory of ocean acoustics. The theory models the ocean as two fluid layers, each with an arbitrary sound-speed profile, which overlay a uniform half-space. The half-space may be a fluid or a shear-supporting solid. The model incorporates losses due to acoustic absorption in all three media and losses due to roughness of the upper and lower boundaries of the upper fluid layer. An acoustic environment changing slowly with range is treated using the adiabatic approximation.

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## CONTENTS

# MODAL ACOUSTIC TRANSMISSION LOSS (MOATL): A TRANSMISSION-LOSS COMPUTER PROGRAM USING A NORMAL-MODE MODEL OF THE ACOUSTIC FIELD IN THE OCEAN

## INTRODUCTION

Investigations of acoustic transmission in shallow water typically consider propagation to ranges of 100 to 1000 times the thickness of the water column. The ocean may therefore be considered to be a thin film through which the signal is propagated. In many ocean areas the thickness of this film will show considerable variation over propagation ranges of interest. In addition, the acoustical properties of the water and the ocean bottom can depend upon range. However, these range dependences are usually slow and the acoustical properties are uniform over range intervals many times the acoustic wavelength. In contrast to the slow range-dependence, the acoustical properties of the ocean bottom and the water column frequently show rapid depth-dependence. Appreciable changes in these media occur over vertical distances comparable to the acoustic wavelength. In addition to this spatial variability, the properties of the water column are time-dependent and can change considerably over the period of a day due both to diurnal heating and cooling and to tidal flow.

The relative shallowness of the water column and the strong depth-dependence of its acoustical properties make normal-mode representations of the acoustic field more useful and reliable than the ray-tracing methods frequently used in transmission loss calculations for the deep ocean. NRL has developed a computer program that calculates transmission loss by using a normal-mode model. The subroutines which perform the normal-mode calculations have been described previously [1]. The transmission-loss calculation using the normal-mode parameters is the subject of the present report.

This transmission-loss model may be used with arbitrary depth-dependence of the sound speed in the water column and in the sediment layer. Provision is made, *via* the adiabatic approximation, for calculating loss in an environment changing slowly with range. The third source of variability mentioned above, temporal change in the water column, is not considered.

In the following section the normal-mode model of the acoustic field is described briefly. Details of this model and the associated FORTRAN programs are found in Ref. 1. Recent revisions of these programs are described in Appendix A. The transmission-loss model for the coherent and incoherent modal field sum for the perfectly stratified (range-independent) ocean is then presented. Modifications made to the calculation to incorporate an environment changing slowly with range follow.

## THEORY

### Normal-Mode Model for a Perfectly Stratified Medium

The model geometry is shown in Fig. 1. A fluid layer of thickness $H_1$ and uniform density $\rho_1$ is bounded above by a pressure-release surface and below by a second fluid layer, which has thickness $H_2$ and uniform density $\rho_2$. These layers will be referred to as the water layer and the sediment layer. The (arbitrary) sound speed profiles in the water and sediment layers are $c_1(z)$ and $c_2(z)$, respectively. Beneath the sediment layer is a homogeneous semi-infinite basement of uniform density $\rho_3$ and compressional sound speed $c_{3c}$. The basement may be modeled as a fluid or as a shear-supporting solid. In the latter case, the shear sound speed is $c_{3s}$.

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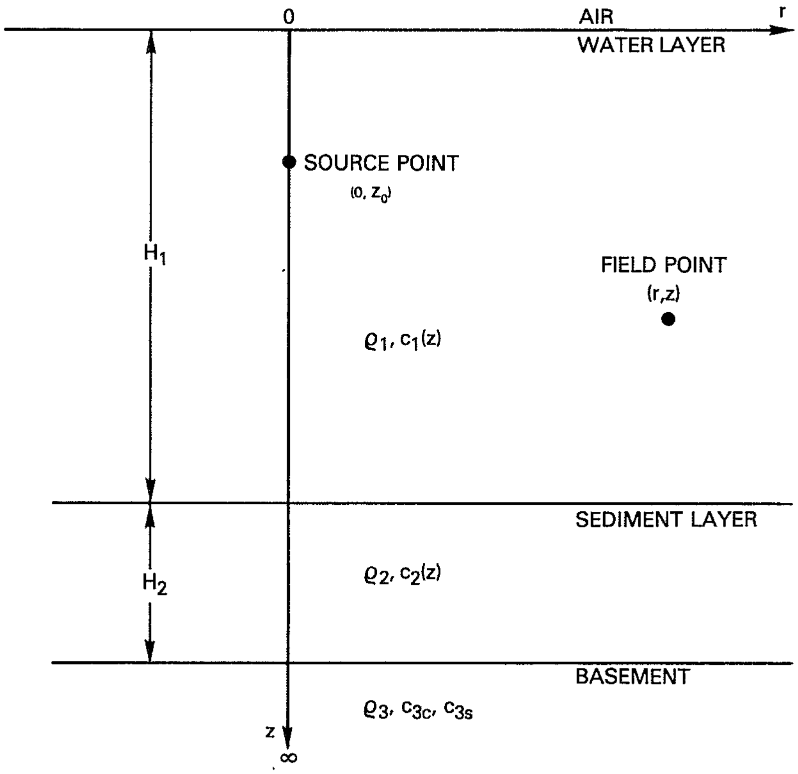



Fig. 1 — Physical model. An infinite half-space consisting of two fluid layers bounded above by air and having respective depths $H_1$ and $H_2$, densities $\rho_1$ and $\rho_2$, and a third, semi-infinite layer of density $\rho_3$, compressional velocity $c_{3c}$, and shear velocity $c_{3s}$ (if it is a solid). At the source point the $z$-axis of a cylindrical coordinate system is established perpendicular to the pressure-release surface (the $r$-axis) with increasing $z$ downward. The sound speed profile in the water and sediment layers, $c_1(z)$ and $c_2(z)$ respectively, is a function of depth.

A cylindrical coordinate system is defined so the pressure-release surface lies in the $(r, \theta)$ plane, and the $z$-axis is perpendicular to the surface with $z$ increasing downward. A harmonic point source of unit strength and angular frequency $\omega$ lies on the $z$-axis at depth $z_0$. The velocity potential $\Phi$ at any field point $(r, \theta, z)$ satisfies the wave equation:

$$\nabla^2 \Phi + \left(\frac{\omega}{c(z)}\right)^2 \Phi = -\frac{1}{r}\,\delta(r)\delta(\theta)\delta(z - z_0). \tag{1}$$

The model geometry possesses cylindrical symmetry. The boundary conditions at the media interfaces, the water depth, and $c(z)$ do not depend on $r$, so we may separate Eq. (1) into two ordinary differential equations. The resulting solution is:

$$\Phi(r, \zeta) = \frac{i}{4H_1}\,\rho(\zeta_0) \sum_{n=1}^{N} u_n(\zeta_0)\, u_n(\zeta)\, H_0^{(1)}(k_n r),$$

where $N$ is the number of discrete normal modes allowed and where we have introduced the dimensionless depth coordinate $\zeta = z/H_1$. The eigenfunctions $u_n(\zeta)$ satisify the eigenvalue equation:

$$\frac{d^2 u_n}{d\zeta^2} + H_1^2\left[\left(\frac{\omega}{c(\zeta)}\right)^2 - k_n^2\right] u_n = 0, \tag{2}$$

and in the case of a fluid basement are subject to the normalization condition

$$\int_0^\infty \rho(\zeta)\, u_n^2(\zeta)\, d\zeta = 1, \tag{3}$$

where, depending on the value of $\zeta$, $\rho = \rho_1$, $\rho_2$, or $\rho_3$ and $c = c_1$, $c_2$, or $c_3$. A similar (but more complicated) condition applies to the solid-basement model [1]. These normalized eigenfunctions are the acoustic normal modes of the given environment. At sufficiently long range the Hankel function $H_0^{(1)}(k_n r)$ may be replaced by its asymptotic form. Thus

$$\Phi(r, \zeta, t) \sim i\rho(\zeta_0)\left(\frac{1}{8\pi H_1 r}\right)^{1/2} \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{k_n^{1/2}}\, e^{i(k_n r - \omega t - \pi/4)}, \tag{4}$$

where the time dependence $e^{-i\omega t}$ has been inserted.

Each of the terms in the sum in Eq. (4) corresponds to the contribution of a single normal mode of propagation. Each of these modal contributions is propagated independently of the others. Attenuation of the signal field is introduced by allowing the wave number (eigenvalue of Eq. (2)) of each mode to become complex:

$$k_n \rightarrow k_n + i\delta_n.$$

The attenuation coefficient, $\delta_n$, assumes the form:

$$\delta_n = \epsilon_2 \gamma_n^{(2)} + \epsilon_{3c}\gamma_n^{(3c)} + \epsilon_{3s}\gamma_n^{(3s)} + S_{0,n} + S_{1,n} + \alpha_n. \tag{5}$$

Here $\epsilon_2$ is the plane-wave attenuation coefficient (imaginary part of the wavenumber) in a hypothetical infinite medium consisting of the material in the sediment layer. The quantities $\epsilon_{3c}$ and $\epsilon_{3s}$ represent the compressional and shear plane-wave attenuation coefficients of the basement. The quantities $\gamma_n^{(2)}$, $\gamma_n^{(3c)}$, $\gamma_n^{(3s)}$ measure the degree to which the $n$th mode interacts with the sediment and the basement compressional and shear wave mechanisms. If the basement is a fluid, the term $\epsilon_{3s}\gamma_n^{(3s)}$ is absent. Of the remaining terms, $S_{0,n}$ and $S_{1,n}$ represent attenuation of the modal field due to interaction of the mode with statistically rough boundaries at the pressure-release boundary and the water-sediment boundary, respectively. The rough-boundary interaction is discussed in Refs. 2 and 3. The term $\alpha_n$ represents the attenuation due to absorption by the water (see Appendix A). The inclusion of the attenuation, Eq. (5), due to rough boundaries and water and bottom absorption in Eq. (4) gives:

$$\Phi(r, \zeta, t) \sim i\rho(\zeta_0)\left(\frac{1}{8\pi H_1 r}\right)^{1/2} \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{k_n^{1/2}}\, e^{i(k_n r - \omega t - \pi/4)}\, e^{-\delta_n r}. \tag{6}$$

The (real) instantaneous pressure $p(t)$ due to a signal source of rms source pressure level $S$, referred to unit distance from the source, is:

$$p(t) = S(4\pi)^{1/2}\rho(\zeta_0) \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{(H_1 k_n r)^{1/2}} \cos(k_n r - \omega t - \pi/4)\, e^{-\delta_n r}. \tag{7}$$

Details of the results presented in this section are given in Ref. 4.

### Transmission Loss for a Perfectly Stratified Medium

To obtain transmission loss we consider the rms pressure averaged over a time $T >> \frac{2\pi}{\omega}$:

$$<p^2(t)>^{1/2} = \frac{S(4\pi)^{1/2}}{H_1}\,\rho_1 \left\{ \frac{1}{T}\int_0^T \left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{(k_n r)^{1/2}} \cos(k_n r - \omega t - \pi/4)\, e^{-\delta_n r} \right]^2 dt \right\}^{1/2}.$$

This expression, in which the summation includes the phases of the individual modal pressure contributions, is called the coherent sum. The coherent transmission loss obtained from this expression, expressed in decibels, is:

$$L_{coh} = -10 \log_{10}\left[\frac{(2\pi\rho_1^2)}{H_1^2}\left\{\left[\sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{(k_n r)^{1/2}}\, e^{-\delta_n r} \cos(k_n r)\right]^2 + \left[\sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n(\zeta)}{(k_n r)^{1/2}}\, e^{-\delta_n r} \sin(k_n r)\right]^2\right\}\right]. \tag{8}$$

When $N$ is large, loss calculated from this expression usually exhibits rapid oscillations of order 10 to 20 dB as range changes (see Fig. 2). Transmission loss measurements employing CW acoustic signals show similar oscillations (see Fig. 3). These oscillations are caused by phase interference effects among the normal modes in which the signals are propagated. Details of the interference pattern are extremely sensitive to the values of $k_n$. The values of $k_n$ are, in turn, sensitive to the sound-speed structure of the ocean bottom. In most cases of practical interest when there are more than a few modes the sound-speed structure of the ocean bottom is not known with sufficient accuracy to permit detailed agreement between calculated and measured interference patterns. Comparison of calculated and measured results is aided if the rapidly varying interference pattern is removed, leaving only a smooth curve. In treating experimental data this is accomplished by smoothing CW loss measurements over a range interval or by using broadband signals and processing techniques. The interference pattern is removed from the model calculations by performing an incoherent mode summation. That is, the energy contributions of individual modes rather than the phased pressures are added. The resulting expression for the incoherent loss is

$$L_{inc} = -10 \log_{10}\left\{\frac{(2\pi\rho_1^2)}{H_1^2} \sum_{n=1}^{N} \left[\frac{u_n(\zeta_0)\, u_n(\zeta)}{(k_n r)^{1/2}}\, e^{-\delta_n r}\right]^2\right\}. \tag{9}$$

**Treatment of Nearly Stratified Media**

In most shallow water areas of interest the assumption that the geometry and acoustical properties of the medium do not depend upon range is not valid, even over relatively short (~10 km) propagation paths. When a range-dependent medium is introduced, the acoustic wave equation (Eq. (1)) cannot be treated by the separation-of-variables technique used above. Since solutions of this generalized problem do not exist, it is necessary to employ approximation techniques. The approximation used here is that the range-dependence of the environment is sufficiently slow that the wave equation is "locally separable." By this we mean that any property of a given normal mode, say the eigenvalue $k_n$ or the attenuation coefficient $\delta_n$, in the vicinity of some point in the range-dependent medium is the same as it would be in a hypothetical range-independent medium with an environment the same as at the point of interest. In other words, the normal modes of propagation adapt to the local environment and the local properties can be calculated from the range-independent model.

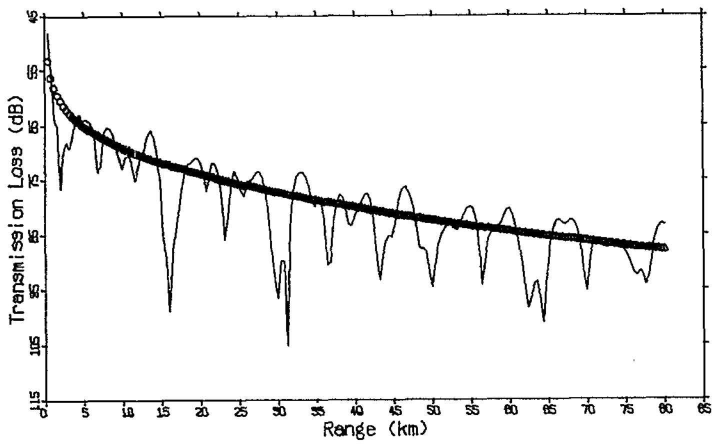
An additional approximation, that the range-dependent environment does not transfer energy from one mode to another, is made. In this approximation [5,6], called the adiabatic approximation or the conservation of mode index, energy originally propagated in a particular normal mode remains in that mode until it is removed by absorption.

The modifications [7] to Eqs. (8) and (9) necessary to employ these two approximations are:

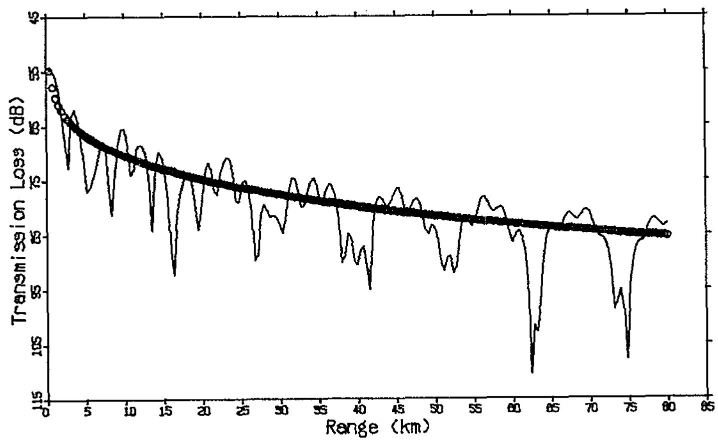
$$u_n(\zeta_0)\, u_n(\zeta) \rightarrow u_n(\zeta_0)\, u_n'(\zeta)$$

and

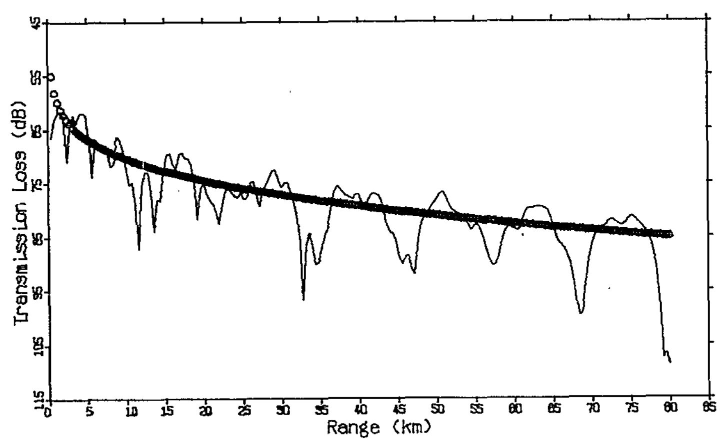
$$H_1 \rightarrow \sqrt{H_1 H_1'},$$




(a)




(b)




(c)

Fig. 2 — Calculated transmission loss. These three graphs are examples of the plotted output generated by PROGRAM MOATL. All result from the same physical environment (given as "Test Case Number 1" in the "OUTPUT" section of this report), but each corresponds to a different value of the receiver depth: (a) 70 m, (b) 200 m, and (c) 400 m. The value of $L_{coh}$ (see Eq. (8)) is plotted as a continuous line and exhibits the oscillations due to modal interference. The value of $L_{inc}$ at each range (see Eq. (9)) is plotted as a circle. The circles overlap at most of the ranges in these illustrations.

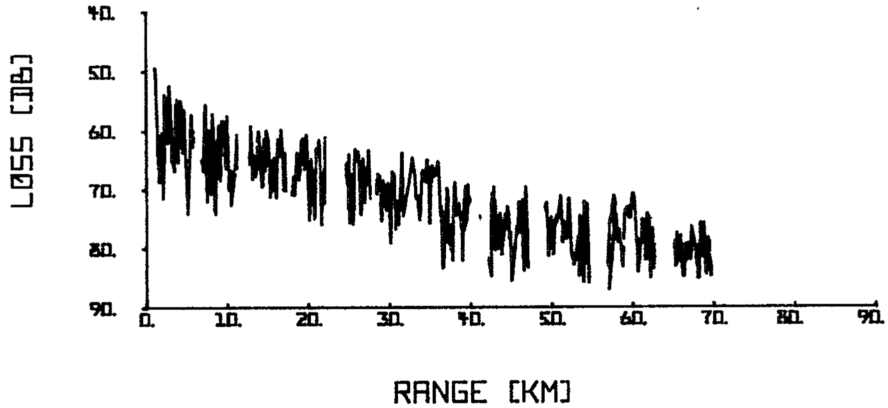



Fig. 3 — Measured CW transmission loss. Oscillations in the transmission loss are shown here for some typical measurements employing a towed CW source. The places where data are missing correspond to intervals during which the source was turned off.

where unprimed quantities $u_n$ and $H_1$ apply to the source location and primed quantities $u_n'$ and $H_1'$ apply to the field point at range $r$;

$$k_n r \rightarrow \phi_n \equiv \int_0^r k_n(r)\, dr$$

is the cumulative phase; and

$$\delta_n \rightarrow \Delta_n \equiv \frac{1}{r} \int_0^r \delta_n(r)\, dr$$

is the average attenuation coefficient. Eqs. (8) and (9) then become:

$$L_{coh} = -10 \log_{10} \left( \frac{(2\pi \rho_1^2)}{H_1 H_1'} \left\{ \left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos\phi_n \right]^2 + \left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin\phi_n \right]^2 \right\} \right) \tag{10}$$

and

$$L_{inc} = -10 \log_{10} \left\{ \frac{(2\pi \rho_1^2)}{H_1 H_1'} \sum_{n=1}^{N} \left[ \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \right]^2 \right\}. \tag{11}$$

The phase of the signal is obtained as the arctangent of the ratio:

$$\frac{\left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin\phi_n \right]}{\left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos\phi_n \right]}.$$

## ANALYSIS OF PROGRAM AND TECHNIQUES

### General Remarks

For each point source of harmonic frequency $f$ ($f = \omega/2\pi$) PROGRAM MOATL calculates the transmission loss as a function of range $r$ and depth $z$. The model described above located the source at the range origin and considered the field point associated with the receiver to be a variable. In the program code, however, source-receiver reciprocity is employed to locate the receiver at the range origin and depth $z_0$. The source is located at the point $(r,z)$. This change was made so that the program conforms to the common experimental situation in which a source is towed along a radial track extending from a fixed receiver. In model calculations for range-independent environments the location of the receiver at the origin is largely for convenience of notation. In range-dependent environments, however, locating the fixed transducer at the origin makes the calculation more economical, since $\phi_n$ and $\Delta_n$ may be evaluated over the track without repetitive integrations over range. The program described in this report may be applied to situations in which the source is fixed and the receivers are moving, if the user exchanges the variables associated with source and receiver.

In the following description and in programming Eqs. (10) and (11), $u_n(\zeta_0)$ is taken to be the $n$th modal eigenfunction calculated by using the environment found at the origin and evaluated at the (normalized) depth $\zeta_0$ associated with the receiver. The quantity $u_n'(\zeta)$ is calculated for the environment associated with range $r$ and is evaluated at the source depth $\zeta$. Note that if the water depth at the source $H_1'$ depends upon range, the normalized source depth $\zeta(r) = z/H_1'(r)$ is also range-dependent.

The needed values $u_n$ are obtained from the normal-mode representation of the sound field in an ocean consisting of a three-layer half-space, as discussed previously. To this end, the main program (MOATL) calls one of two sets of subroutines; the set FLUID, HALFF, and ITRTF assume the semi-infinite basement to be a fluid, whereas the set SOLID, HALFS, and ITRTS assume a basement capable of supporting shear. These subroutines are streamlined versions of the programs described in Ref. 1. Some improvements have been made since Ref. 1 was published; the major changes are discussed in Appendix A. Variable namelists are given in Appendix B.

When two distinct bottom layers with different properties are not required, a two-layer model may be realized. This is accomplished by giving the sediment layer (a) a small thickness and (b) physical properties identical to those either of the water layer (SOLID or FLUID) or of the basement (FLUID only). Realization of the single-medium bottom is illustrated by the first test case in the "OUTPUT" section.

Provision is made for the receiver to be located in the water or sediment layer; the source must be in the water layer.

The range points at which loss is to be calculated or the calculation ranges, as we shall sometimes call them, are assumed to be equally spaced. The user supplies the number of points and the maximum range at which calculated transmission loss is desired. The program obtains the spacing between points by division. Nevertheless, it is a simple matter to obtain results at unequally spaced range points. There are two places in the main program where the FORTRAN code must be altered slightly. These places are marked with COMMENT statements which give examples of how to make the required modifications (see the listing given in Appendix C). One word of caution: difficulties may be encountered if NMFREQ is given a value other than one; unequally spaced-calculation-range cases should be run one-at-a-time.

The user must always supply an environmental data set (including water depth, sound-speed profile, bottom properties, and other relevant parameters) at zero range. If a range-independent model is to be used, no further environmental input is required. For a range-dependent model calculation, additional environmental data sets are required. Each set may differ from the others by any arbitrary combination of the environmental parameters, subject to the constraint that the fluid-basement and solid-basement models may not both be used along the track. Such data sets may be supplied at any number of user-selected ranges (not necessarily equally spaced and not necessarily coincident with any of the ranges at which loss is to be calculated). Guidelines for the selection of spacing of environmental data sets are given in the "INPUT DATA" section below. The normal-mode parameters are calculated at each of these ranges. The modal properties are obtained at the intermediate range points (where the loss is to be calculated) by performing a linear interpolation. If loss calculations are desired out past the last data set, a linear extrapolation is performed.

With regard to this interpolation, there are four range points of interest at any given moment during the execution of the program (for a range-dependent model). The first is the range origin. Since an environmental profile is always supplied here, no range-interpolation is necessary to obtain the modal parameters at the receiver position. The second range of interest is the calculation range $r$, which together with the source depth locates the source position. Since $r$ is not usually coincident with the range of one of the user-supplied input environments, a linear interpolation between the two input ranges which bound $r$ is required in order to obtain the modal parameters at the source position. The ranges at which environmental data are supplied are the third and fourth ranges of interest. The smaller input range or any group of variables at that range will be designated hereafter by SR; the larger input range by LR. Details of the interpolation are presented below in Part 7 of the "Step-by-Step Analysis" section.

The dimensioning of many of the arrays implies an application for which the number of normal modes is less than or equal to 150. If more modes are expected, redimensioning and some minor FORTRAN code modifications are required; these are not discussed here. Knowledge of the expected number of modes is also required for determination of the input variables LI1 and LI2. For this purpose, we give the following "rule of thumb" guide:

$$N \approx \frac{2fH}{c_{\min}} \sqrt{1 - \left[\frac{c_{\min}}{c_3}\right]^2} + 1/2, \tag{12}$$

where $N$ is the total number of modes, $f$ is the frequency, $H$ is the sum of the thicknesses of the water and sediment layers, $c_{\min}$ is the minimum sound speed found in the water and sediment layers, and $c_3$ is $c_{3c}$ (FLUID case) or $c_{3s}$ (SOLID case). For an isovelocity profile and slight redefinition of variables, the expression becomes exact [8].

Before using the program, one must first inspect the two PARAMETER statements at the beginning of the main program and change them if necessary. The variables REC and SOC should be assigned values equal to or greater than the number of receiver and source depth points, respectively, at which calculated results are desired. The variable REC5 should be equal to or greater than REC and should be an integral multiple of five. This parameter is used for dimensioning the output transmission loss arrays, but the purpose of introducing it in place of REC is solely to make the printout more aesthetic; if resulting program storage requirements exceed the limitations of the given computer, the parameter may be eliminated by minor output adjustments. The variable RNG should be assigned a value equal to or greater than the number of range points at which calculations are desired. Before using the program for the first time on a given machine, the parameters MGNTD and PRCSN should be assigned appropriate values (see the COMMENT statement preceding the PARAMETER statement in the listing). They will not have to be changed subsequently.

The program was written in ASC FORTRAN for use with the Texas Instruments Advanced Scientific Computer (ASC) located at NRL. Wherever possible, however, the source code was put into standard form. Thus it should compile on most FORTRAN compilers with a minimum amount of preliminary code-changing.

The ASC has a single precision floating point word (32 bits) consisting of 1 bit for the sign, 7 bits for the exponent, and 24 bits for the fraction (precise to approximately 7 decimal digits). Some of the program variables are in DOUBLE PRECISION. A double precision word (64 bits) consists of 1 bit for the sign, 7 bits for the exponent, and 56 bits for the fraction (precise to approximately 16 decimal digits). In general, any variable involved in or affecting the calculation of an eigenvalue or eigenfunction is in DOUBLE PRECISION.

The required storage allocations for the main program, subroutines, and COMMON blocks are given in Table 1.

Table 1 — Storage Requirements

| Routines | Number of Words (in hexadecimal base) |
|---|---|
| MOATL | 4C59 |
| FLUID | 195B |
| ITRTF | 4E3 |
| HALFF | 306 |
| SOLID | 1B9E |
| ITRTS | 581 |
| HALFS | 335 |
| | TOT 91F1 |
| Common Blocks | |
| TNIH | 2 |
| TNH | 12C |
| TNI | 7 |
| TH | 1 |
| TN | 58680 |
| NIH | 968 |
| NH | 5 |
| NIFLU | 2 |
| NI | 12DB |
| IH | 2 |
| NISOL | 7 SUBT=5A409 |

GRAND TOTAL = 635FA$_{16}$ = 407034

As an aid to following the flow of control in the program when reading the code, the following types of control statements have been indented three spaces: (1) DO loop; (2) GO TO statement; (3) transfer-of-control IF statement; and (4) calls to subroutines.

The Naval Research Laboratory's computer peripherals include an 11-inch Calcomp (California Computer Products) Model 565 Drum Plotter. The on-line plotter software on NRL's ASC currently supports this plotter. PROGRAM MOATL includes an option which uses this package to plot coherent and incoherent transmission loss as functions of range. Separate plots are generated for each frequency, receiver depth, and source depth.

Input to the program is from logical unit five (card reader by convention), and printed output is to logical unit six (line printer by convention).

**Step-by-Step Analysis**

In the present discussion, we follow PROGRAM MOATL step-by-step from start to finish. The FORTRAN namelist (Appendix B) should prove useful to the reader at this time. A synopsis of the workings of the program will be sketched and, whenever appropriate, the numerical methods and programming techniques will be described. Wherever the normal-mode subroutines are mentioned, reference to Appendix A may prove useful.

The program has been broken up into 11 parts for discussion. The program listing is given in Appendix C. The parts are defined, by control statement number (CSN), as follows:

| | |
|---|---|
| Part 1: 34-58 | Part 7: 189-214 |
| Part 2: 59-66 | Part 8: 215-247 |
| Part 3: 67-120 | Part 9: 248-262 |
| Part 4: 121-141 | Part 10: 263-271 |
| Part 5: 142-146 | Part 11: 272-299 |
| Part 6: 147-188 | |

Preceding the executable code are CSNs 1-33, which set up the necessary COMMON blocks, PARAMETERs, DIMENSIONs, and FORMATs.

*Part 1: Input Data and Initialization*

The plot package is initialized and the parameters PMGTD and PPRCN are defined. These two parameters are used in the normal-mode subroutines. The transmission-loss input parameters are next read in and printed out. The variable DR is the calculation-range increment, defined by dividing the maximum range by the number of calculation-range points. The array RAN(I) contains integral multiples of DR, which are the ranges at which calculations are to be performed. If plotting is desired, parameters are now defined for this purpose.

*Part 2: Frequency and Attenuation*

The frequency loop (DO 340) marks the beginning of an actual calculation of transmission loss. A value of NMFREQ greater than one may be used, not only to obtain results for more than one frequency, but for more than one run of the program for any reason (*e.g.* different sediment thickness, different profile, *etc.*). For each case, the TITLE and frequency F are read in and printed out. The equation for EP4 converts the plane-wave absorption coefficient of the sediment, $\epsilon_2$ (EP1 in the FORTRAN), from units of dB/Hz-m into units of nepers/m, in which form it is subsequently used. Similar equations convert the basement compressional plane-wave absorption coefficient, $\epsilon_{3c}$ (EP2 in the FORTRAN), and the basement shear plane-wave absorption coefficient, $\epsilon_{3s}$ (EP3 in the FORTRAN). They become EP5 and EP6, respectively.

*Part 3: Input Data, Initialization, Receiver Parameters*

The environmental input parameters (at zero range) needed for the normal-mode calculations at the site of the receiver are first read in and printed out. The appropriate normal-mode subroutines are next called to perform modal calculations. Prior to the call to FLUID or SOLID, NMODE is set to 10 000. This is done for the following reason. In a range-dependent calculation, one of the input environments may support more modes than a previous environment, *i.e.*, one at closer range. However, the program implements conservation of mode index by excluding the higher order modes which are not present at the previous environment. For example, if only five modes exist at an input range of 10 km, then at each of the calculation ranges beyond 10 km, only the five lowest order modes will be used for a calculation of transmission loss. Additional modes allowed at ranges greater than 10 km are assumed to be cut off at 10-km range. Each time FLUID or SOLID is called at a new input range, NMODE is redefined to be the smaller of (a) the previous value of NMODE or (b) the maximum number of modes existing for the given environment. Since this test is performed even for the first call to FLUID or SOLID, NMODE must have been defined prior to the first subroutine call. Since "redefinition" is actually to be definition by criterion (b), NMODE must be preset to a large number.

Prior to the first call to FLUID or SOLID, KA is set to zero. The variable KA is a flag which when zero causes the eigenfunctions to be stored in UNRM1(IM,I) and when one causes the eigenfunctions to be stored in UNRM2(IM,I). Mode order is designated by the variable IM, depth index by the variable I.

Many of the variables defined in Part 3 have names ending with the numeral 1 or 2, for example RANGE1 and RANGE2. The reason for this (the same as for UNRM1(IM,I) and UNRM2(IM,I)) rests in the numerical technique employed to calculate the transmission loss for a range-dependent environment. Any given source range at which loss calculations are desired will fall between two ranges at which environmental input data have been supplied. Environmental and modal parameters required at the source position are approximated by a linear interpolation which uses the given input at each of the bounding ranges. (This procedure is described later.) The parameters at the smaller (*i.e.*, closer to the receiver) input range (hereafter designated SR) are stored in the variables whose names contain the trailing numeral 1. The parameters at the larger range (LR) use the trailing numeral 2. Parameters used for interpolation are: H11, H12 (water layer thickness); RANGE1, RANGE2 (range at which environmental input is supplied); CT1, CT2 (sound speed at the surface of the water layer); CB1, CB2 (sound speed at the bottom of the water layer); N11, N12 (N1 = LI1 + 1, where LI1 is the number of incremental intervals into which the water layer is broken); EIGVL1(IM), EIGVL2(IM) (the eigenvalue $k_n$); R11(IM), R12(IM) (sediment attenuation ratio $\gamma_n^{(2)}$); R21(IM), R22(IM) (basement compressional attenuation ratio $\gamma_n^{(3c)}$); R31(IM), R32(IM) (basement shear attenuation ratio $\gamma_n^{(3s)}$); RA1(IM), RA2(IM) (water absorption $\alpha_n$ — see Appendix A); RT1(IM), RT2(IM) ($\Gamma_{0,n}$ — see below); RB1(IM), RB2(IM) ($\Gamma_{1,n}$ — see below).

The quantities described above are read in and/or calculated in Part 3 for the receiver (zero range); they therefore constitute the first SR group. They are stored in the variables designated by the trailing numeral 1. They are also initially stored in the LR group, for a reason which is explained in the discussion of Part 6. The terms $S_{0,n}$ and $S_{1,n}$ appearing in Eq. (5) may be rewritten as:

$$\left.\begin{aligned} S_{0,n} &= (1 - |R_{0,n}|)\,\Gamma_{0,n} \\ S_{1,n} &= (1 - |R_{1,n}|)\,\Gamma_{1,n} \end{aligned}\right\} . \tag{13}$$

The variable $R_{0,n}$ is the plane-wave reflection coefficient at the air/water interface, and $R_{1,n}$ is the plane-wave reflection coefficient at the interface between the water and sediment layers. $\Gamma_{0,n}$ and $\Gamma_{1,n}$ are the respective scattering ratios, which are calculated in the normal-mode subroutines. (See also Ref. 1.) At the receiver site (RANGE1 = 0) these quantities are stored in the SR variables RT1(IM) and RB1(IM), respectively.

The quantities H10, RERHO1, and RERHO2 are defined as the water depth, water density, and sediment density, respectively, at the receiver. They are defined because H11, RHO1, and RHO2 will take on new values when subsequent input environments are read in; however, the values of these quantities at the receiver will be needed in the final transmission-loss calculation.

The arrays SE(IM), S1(IM), S2(IM), S3(IM), SA(IM), ST(IM), and SB(IM) will be described in Part 8. They are now initialized to zero.

The final calculations of Part 3 are to obtain the values of $u_n(\zeta_0)$, which appear in Eqs. (10) and (11). The outer DO 110 loop varies the mode-order index $n$ (programmed as IM) from 1 to NMODE. The inner DO 100 loop varies the receiver identification index (programmed as J1) from 1 to NDRE (the total number of receiver depths supplied). Each of the receiver depths corresponds to a different value of $\zeta_0 \equiv z_0/H_1$. The quantity $u_n(\zeta_0)$ is programmed as RE (J1, IM).

The eigenfunction for a given mode is calculated in the normal-mode subroutines; values of the function are defined at each of the N1 + N2 = (LI1 + 1) + (LI2 + 1) incremental depths (see Appendix A and Ref. 1). The receiver depth, however, will generally lie between two of these incremental depths. The program performs a linear interpolation, as follows, to obtain the value of $u_n(\zeta_0)$. Assume for convenience that the receiver is in the water layer; the calculations for a receiver in the sediment are similar. The program first defines A1 to contain the number, plus fraction, of incremental layers (numbered downward from the air/water surface) which corresponds to the receiver depth. For example, if the receiver is exactly in the middle of the third incremental layer, A1=2.5. The term IA1 contains the (truncated) integer value of A1; following the above example, IA1=2. Thus in general, $\zeta_{\mathrm{IA1}+1} < \zeta_0 < \zeta_{\mathrm{IA1}+2}$, where $\zeta_{\mathrm{IA1}+1}$ is the normalized depth at the top of the (IA1+1)th incremental layer; $\zeta_{\mathrm{IA1}+2}$ is defined similarly. Note that $\zeta_1 = 0$. In the above example, $\zeta_0$ is bounded by the depths at the tops of the third and fourth incremental layers. (The general procedure is illustrated in Fig. 4.) Standard linear interpolation yields the value for $u_n(\zeta_0)$:

$$u_n(\zeta_0) = u_n(\zeta_{\mathrm{IA1}+1}) + \Delta[u_n(\zeta_{\mathrm{IA1}+2}) - u_n(\zeta_{\mathrm{IA1}+1})]. \tag{14}$$

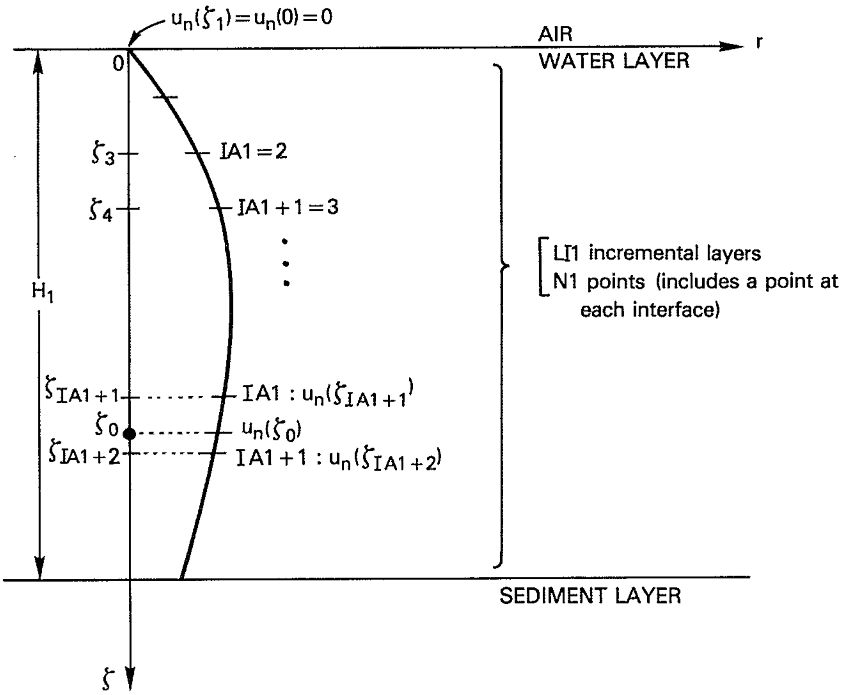



Fig. 4 — Receiver eigenfunction. The first mode (fluid-basement model) at zero range is illustrated, along with the values of the eigenfunction to be used in the interpolation of $u_n(\zeta_0)$.

The quantity $\Delta$ (programmed as DLTA1) is that fraction of a layer increment by which $\zeta_0$ exceeds $\zeta_{IA1+1}$. For a receiver in the water layer, we have:

$$\Delta = (LI1) * (\zeta_0) - IFIX[(LI1) * (\zeta_0)] = \frac{\zeta_0 - \zeta_{IA1+1}}{\zeta_{IA1+2} - \zeta_{IA1+1}}. \qquad (15)$$

For a receiver in the sediment, the calculation of $\Delta$ is performed similarly.

For a receiver depth equal to the depth of one of the incremental layer boundaries, $\Delta$ will take on the value zero or one, and the interpolation is actually a "do nothing" procedure.

*Part 4: Range-Independent Parameters*

If the calculation is to be based on a range-independent model, then the transmission-loss parameters and the calculated eigenfunctions at any given range will be the same as those already calculated at zero range for the receiver. Later calculations of the program use the terms HS, CTS, and CBS for the water-layer thickness and sound speeds at the surface and bottom of the water layer, respectively. For a range-independent calculation, these parameters and the others defined in Part 4 will not depend on the range $r$ as the calculation point moves out in range. Thus they have simple definitions. The definitions for a range-dependent calculation are given in Part 7.

The procedure for obtaining the quantities $u_n'(\zeta)$, which are the eigenfunction values at the source, is identical to the procedure described in Part 3 for the receiver. As before, there are two loops, one for the NDSO source depths $\zeta$ and one for the $n = 1, \ldots,$ NMODE modes. The variable $u_n'(\zeta)$ is programmed as SM(J2,IM), where J2 is the depth index and IM the mode-order index. The only difference in procedure between the source and receiver calculations is that the source must be in the water layer; *i.e.*, it may not be located in the sediment.

The quantities WN(IM), G1(IM), G2(IM), G3(IM), GA(IM), GT(IM), and GB(IM) have simple definitions, thus obvious meanings, for the range-independent case (see Appendix B).

*Part 5: Calculation Range Loop*

The DO 300 loop uses I as the index for the NRCALC calculation-range points, which are stored in RAN(I) one-by-one as encountered. If the calculations are to be range-independent, then the parameters of interest in Parts 6 and 7 have already been defined in Part 4, and Part 5 now transfers control to Part 8. This is programmed as: IF(NRBUF.EQ.1) GO TO 209.

If the calculations are to be range-dependent, then two more checks are made. Before calculations can be performed, we require various environmental and modal parameters, which are to be obtained for a given RAN(I) by interpolating these same parameters between their known (or subroutine-calculated) values at the SR and the LR ranges (see Part 3 for definitions and Part 7 for the technique). Prior to the first time through the DO 300 loop, only the zero-range (receiver) parameters have been obtained, and they have been stored in the SR group. The first time through the DO 300 loop (and only the first time), RANGE2 will be equal to RANGE1, which is equal to zero (see Part 3). If they are equal, then Part 5 transfers control to Part 6, where the LR group is established.

The second check is made for subsequent loops over range. If, for a given value of I, $r \equiv$ RAN(I) lies between the present values of RANGE1 and RANGE2, then an interpolation between the present SR and LR groups can and should be made; Part 5 thus transfers control to Part 7. If RAN(I), which has just been obtained by adding DR to the previous calculation range, is greater than RANGE2, then the value of RANGE2 must become the next value of RANGE1, and a new RANGE2 (and a new LR group) is needed before the calculations can proceed (see Part 6). Part 5 transfers control to Part 6. The quantity RANGE2 + (DR/2) is actually used for this check, since for RANGE2 < RAN(I) < RANGE2 + (DR/2), it is more accurate to extrapolate past the present RANGE2 than to make the redefinitions of Part 6 and interpolate between subsequent SR and LR groups. (See Fig. 5.)

Occasionally (when the option of unequally spaced calculation range points is used—see the "General Remarks" section and the COMMENT statements in the program listing following CSNs 51 and 142), RAN(I) may be larger than RMAX, the range of the last input environment. In this case, linear extrapolation is to be performed past RMAX, which is RANGE2 at this point.

The formulae for extrapolation are identical to those for interpolation and are not programmed separately. We speak below only of interpolation, but the "double usage" is intended.

*Part 6: Range-Dependent Parameters: Initialization*

As alluded to previously, this part of the program is entered only if the present value of RAN(I) lies outside the interpolation interval (RANGE1, RANGE2 + DR/2) and thus the interval must be redefined. To this end, all of the present LR group variables are stored in the SR group, *i.e.,* RANGE2 becomes the new RANGE1, and all of the LR parameters become the new SR parameters. For example, we encounter FORTRAN statements like CT1=CT2 in Part 6. Note that the previous values of the SR variables are lost. (They will no longer be needed for calculation of modal parameters at the source position.) The new RANGE2 and its environmental parameters are next read in and printed out, and the new LR group is established. Since the normal-mode subroutines have been called previously to provide the modal parameters at zero range, the initial zero value of KA is now changed to one. When either FLUID or SOLID is subsequently called to perform the modal calculations, the value KA=1 ensures that the eigenfunctions are stored in the LR array UNRM2(N,K).

In Part 3 we remarked that the receiver parameters were initially stored not only in the SR group, but also in the LR group. The reason for this now becomes apparent, in view of the procedure

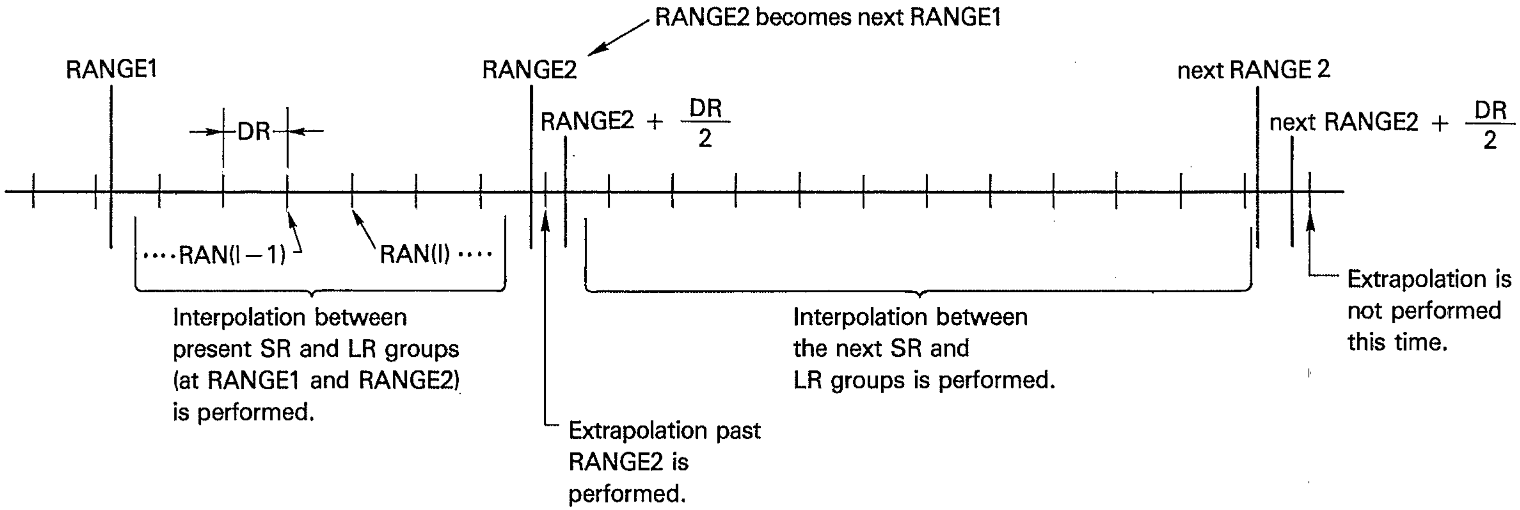



Fig. 5 — Interpolation or extrapolation at RAN(I). For the calculation range just beyond the present input RANGE2, an extrapolation is performed. If the calculation range were to lie beyond RANGE2 + (DR/2), as is the case for the next RANGE2, then RANGE2 and the present LR group would become the next RANGE1 and SR group, the next RANGE2 and LR group would be read in and/or calculated, and then an interpolation performed.

described above of shifting the values of the LR variables into the SR variables each time a new user-supplied environment is encountered. During the first pass through the DO 300 loop (I=1), the first nonzero range environment is read in. Just prior to storing it in the appropriate LR variables, however, all of the LR group is shifted into the SR group. By predefining these two groups to be identical, the receiver parameters are not lost but are still retained in the SR group. The new LR group is then established. Following the example of the last paragraph, we encounter such FORTRAN statements as CT2=C1(1) in setting up the new LR group. (The trailing numeral 1 in the array name here designates the water layer, *not* the SR group.) Storage of the eigenfunctions into the SR and LR arrays are handled in a different manner. The flag KA is set to zero to ensure that the receiver eigenfunctions are stored in UNRM1(N,K) and KA is then set to one to ensure that the eigenfunctions at the first nonzero range are stored in UNRM2(N,K). (See above and also Part 3.)

*Part 7: Range-Dependent Parameters: Calculation of Source Parameters*

Part 7 and Part 4 perform the same function and correspond to the range-dependent and range-independent cases, respectively. The quantities HS, CTS, and CBS depend on $r$ for a range-dependent calculation. For the thickness of the water layer (the other two quantities are defined similarly), standard linear interpolation requires us to put:

$$\mathrm{HS} = \mathrm{H11} + \Delta * (\mathrm{H12} - \mathrm{H11}),$$

where

$$\Delta = \frac{\mathrm{RAN\,(I)} - \mathrm{RANGE\,1}}{\mathrm{RANGE\,2} - \mathrm{RANGE\,1}}. \tag{16}$$

The quantity $\Delta$ is programmed as SCALE. For interpolation of the eigenvalues and attenuation and scattering ratios, it is more accurate to replace the numerator in Eq. (16) by [RAN (I) − (DR/2)] − RANGE1, which is effected by the FORTRAN statement:

$$\mathrm{SCALE} = \mathrm{SCALE} - \mathrm{DR}/(2.0*(\mathrm{RANGE\,2} - \mathrm{RANGE\,1})). \tag{17}$$

The reason for this, illustrated in Fig. 6, is as follows.

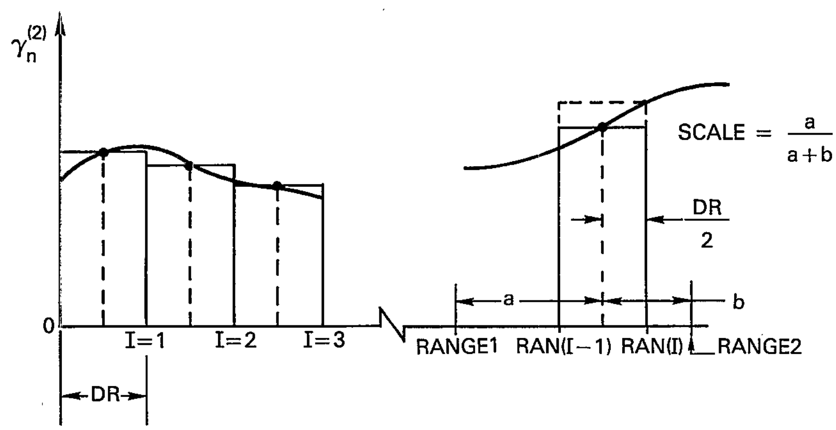



Fig. 6 — Approximation of $\int_0^r \gamma_n^{(2)}(r')dr'$. The "piece" of the integral $\int_{\mathrm{RAN(I-1)}}^{\mathrm{RAN(I)}} \gamma_n^{(2)}(r')dr'$ is approximated by DR $*\ \gamma_n^{(2)}(r'')$, where $r''$ is equal to RAN(I) − (DR/2). The result is shown with solid lines, and is more accurate than the result (shown with dashed lines) corresponding to $r''$ = RAN(I).

Equations (10) and (11) for the transmission loss each contain the term $e^{-\Delta_n r}$, where

$$\Delta_n \equiv \frac{1}{r} \int_0^r \delta_n(r')\, dr' \tag{18}$$

is the average attenuation coefficient. This integral may be broken into a number of separate integrals through use of Eq. (5). For example, one term of Eq. (18), say $\Delta_n'$, will be

$$\Delta_n' \equiv \frac{\epsilon_2}{r} \int_0^r \gamma_n^{(2)}(r')\, dr'. \tag{19}$$

At any given range $r$ = RAN(I), the integral is approximated by adding a new "piece," representing the integral from RAN(I-1) to RAN(I), to the stored value of the (approximated) integral from zero to RAN(I-1). (See Part 8.) Reference to Fig. 6 demonstrates that the appropriate value of $\gamma_n^{(2)}$ to be multiplied by DR (in order to approximate $\int_{\mathrm{RAN(I-1)}}^{\mathrm{RAN(I)}} \gamma_n^{(2)}(r')\, dr'$ by a rectangle) is the value of the function at the midpoint of the range-increment interval, *i.e.*, at RAN(I) − (DR/2). In the FORTRAN code, this value of $\gamma_n^{(2)}$ is programmed as G1(IM). Thus if we write

G1(IM) = R11(IM) + SCALE * (R12(IM) − R11(IM)),

SCALE must be given by its redefined value, Eq. (17), rather than its original value, Eq. (16).

Other variables handled in a manner identical to that of G1(IM) are: WN(IM) (the eigenvalue $k_n$), G2(IM) (compressional attenuation ratio $\gamma_n^{(3c)}$), G3(IM) (shear attenuation ratio $\gamma_n^{(3s)}$), GA(IM) (water absorption $\alpha_n$), GT(IM) (air/water scattering ratio $\Gamma_{0,n}$), and GB(IM) (water/sediment scattering ratio $\Gamma_{1,n}$).

The values of the modal eigenfunctions $u_n'(\zeta)$ at the source position are determined as follows. The normalized source depth at range RAN(I) is calculated. Then the value of the eigenfunction, XXR1, for this normalized depth at the SR range is determined by interpolating between stored values of the eigenfunction computed for the SR range (CSN 202). The method is similar to that used for the receiver eigenfunction which is given by Eqs. (14) and (15) and which is illustrated in Fig. 4. The interpolation is repeated (CSN 203) on the eigenfunction calculated at the LR range to obtain XXR2. Finally, the value of the eigenfunction at RAN(I), programmed as SM(J2,IM) is determined by a range-weighted interpolation between XXR1 and XXR2 at CSN 204 where the interpolation coefficient $\Delta$ is determined from Eq. (16). After this procedure has been applied to all the normal modes which propagate to the receiver and the loss at RAN(I) is determined, the normalized source depth at RAN(I+1) is calculated and the above procedure is repeated.

Note that, in general, XXR1 and XXR2 will change as RAN(I) moves between SR and LR. Interpolation employing the normalized depth variable has been found to be more accurate than direct interpolation using the depth variable $z$ to obtain different normalized depths at the SR and LR ranges.

*Part 8: Transmission Loss: I.*

The array PL(J1,J2,I) is used for the incoherent transmission loss or transmission-loss anomaly (see Part 9 for definition of transmission-loss anomaly) and QC(J1,J2) and QS(J1,J2) are used for the cosine and sine terms, respectively, of the coherent transmission loss or transmission-loss anomaly. These arrays are first set to zero. Note that for each new calculation-range point, they will initially contain all zeros. On the other hand, the arrays SE(IM), ... , SB(IM), were initialized to zero outside the DO 300 range loop (see Part 3). Thus they initially contain zeros only for the first range-point calculation. For each individual mode (they are subscripted for mode index), these arrays will accumulate "pieces" of the range integrals they represent (see below and also Fig. 6) as execution of the code contained in the range loop is repeated for each new calculation-range point.

As noted in the discussion of Part 7, the average attenuation coefficient $\Delta_n$ (see Eq. (18)) may be broken into a number of integrals representing the separate attenuation mechanisms. Considering only the sediment attenuation ratio $\gamma_n^{(2)}$, for example, the coefficient $\Delta_n'$ (a component of $\Delta_n$) is given by Eq. (19). Similar equations hold for the other attenuation mechanisms. The program approximates each of these integrals by dividing it into "pieces," each "piece" representing the integral over the range from RAN(I-1) to RAN(I); recall I is the index of the DO 300 range loop. The piece $\int_{\mathrm{RAN(I-1)}}^{\mathrm{RAN(I)}} \gamma_n^{(2)}(r')\,dr'$ is approximated by the area of a rectangle having sides DR and G1(IM) (see Part 7 and Fig. 6). Thus it is programmed as G1(IM) * DR. In the FORTRAN statement:

S1(IM) = S1(IM) + G1(IM) * DR,

S1(IM) on the left-hand side represents $\int_0^{\mathrm{RAN(I)}} \gamma_n^{(2)}(r')\,dr'$. On the right-hand side, S1(IM) represents the accumulated value of the integral for previous ranges, *i.e.*, it contains the approximation for $\int_0^{\mathrm{RAN(I-1)}} \gamma_n^{(2)}(r')\,dr'$.

Other variables handled in an identical manner to that of S1(IM) are: SE(IM), which represents $\phi_n = \int_0^r k_n(r')\,dr'$; S2(IM), which represents $\int_0^r \gamma_n^{(3c)}(r')\,dr'$; S3(IM), which represents $\int_0^r \gamma_n^{(3s)}(r')\,dr'$; SA(IM), which represents $\int_0^r \alpha_n(r')\,dr'$; ST(IM), which represents $\int_0^r \Gamma_{0,n}(r')\,dr'$; and SB(IM), which represents $\int_0^r \Gamma_{1,n}(r')\,dr'$.

Equations (10) and (11) for the transmission loss each contain the term $e^{-\Delta_n r}$. Using Eqs. (18) and (5), we have

$$\Delta_n r = \epsilon_4 \int_0^r \gamma_n^{(2)}(r')\,dr' + \epsilon_5 \int_0^r \gamma_n^{(3c)}(r')\,dr' + \epsilon_6 \int_0^r \gamma_n^{(3s)}(r')\,dr' + \int_0^r S_{0,n}(r')\,dr' + \int_0^r S_{1,n}(r')\,dr' + \int_0^r \alpha_n(r')\,dr', \tag{20}$$

where we have inserted $\epsilon_4$, $\epsilon_5$, and $\epsilon_6$ in place of $\epsilon_2$, $\epsilon_{3c}$, and $\epsilon_{3s}$, respectively, as discussed in Part 2. The term $\Delta_n r$ is programmed as QQ. We first encounter the definition

QQ=EP4 * S1(IM) + EP5 * S2(IM) + EP6 * S3(IM) + SA(IM),

which adds the first three terms and the last term on the right-hand side of Eq. (20). The remaining two terms of Eq. (20) are added to QQ by the two FORTRAN statements following the defining statement. The terms $S_{0,n}$ and $S_{1,n}$ may be expressed in terms of the scattering ratios $\Gamma_{0,n}$ and $\Gamma_{1,n}$, respectively; the relationship is given by Eqs. (13). The plane-wave reflection coefficients appearing there may be evaluated in terms of the rms roughnesses of the boundaries. If we let $\sigma_0$ (SIG0 in the program) be the rms wave height and $\sigma_1$ (SIG1 in the program) be the rms excursion of the water/sediment interface, then Eqs. (13) take the form [3]:

$$\left.\begin{aligned} S_{0,n} &= 2\sigma_0^2 \left[\left(\frac{\omega}{c_1(0)}\right)^2 - k_n^2\right] \Gamma_{0,n} \\ S_{1,n} &= 2\sigma_1^2 \left[\left(\frac{\omega}{c_1(H_1)}\right)^2 - k_n^2\right] \Gamma_{1,n} \end{aligned}\right\}. \tag{21}$$

If the explicit expressions for $\Gamma_{0,n}$ and $\Gamma_{1,n}$ given in Ref. 1 are inserted into Eqs. (21), the result is that of Ref. 3. The fourth term on the right-hand side in Eq. (20) may now be written

$$\int_0^r S_{0,n}(r')\,dr' = 2\sigma_0^2 \int_0^r \left[\left(\frac{\omega}{c_1(0)}\right)^2 - k_n^2(r')\right] \Gamma_{0,n}(r')\,dr'.$$

The FORTRAN statement which includes this term in QQ is:

QQ = QQ + 2.0*ST (IM)*SIG 0*SIG 0* ((6.2831853*F/CTS)** 2 − WN (IM)*WN (IM)).

The inclusion of the water/sediment scattering term follows in a similar manner.

The term $e^{-\Delta_n r}$ is programmed as Q2:

Q2 = 1.0/EXP (QQ).

If $\Delta_n r > 32.25$ for any given mode n, the term Q2 will not be included in the modal sum of Eqs. (10) and (11), and the program prints out a flag informing the user of this fact. The reason for neglecting the term is as follows. Suppose that QQ > 32.25. Then Q2 < $10^{-14}$. The largest value that Q1 can reasonably be expected to attain is of order $10^4$; thus even for the largest value of Q1, Q will always be less than $10^{-10}$ (see below for definitions of Q1 and Q). Such a small term will not make a significant contribution to the modal sum appearing in Eqs. (10) and (11), thus it is neglected. What this means physically is that at ranges for which $\Delta_n r > 32.25$, nearly all of the energy initially in the $n$th mode has been removed by attenuation.

Also appearing in the modal sums of Eqs. (10) and (11) is the term $u_n(\zeta_0)\, u_n'(\zeta)/\phi_n^{1/2}$. Except for inclusion of a factor $r^{1/2}$ in the numerator, this term is programmed as Q1: Q1 = RE(J1,IM) * SM(J2,IM) * DSQRT(RAN(I)/SE(IM)). (See Part 9 for programming of the removal of the factor $r^{1/2}$.)

The variable Q is defined as the product of Q1 and Q2. We have seen above that Q may be neglected for a particular mode if it is smaller than $10^{-10}$. This, in turn, imposes a restriction on the smallness of Q2 corresponding to the largest possible value of Q1. Alternatively, consider the largest possible value of Q2, which is one. We may therefore restrict the absolute value of Q1 to be greater than or equal to $10^{-10}$. The test for Q2 < $10^{-14}$, when fulfilled, will remove a given modal contribution for all source and receiver depths. The test for Q1 > $10^{-10}$ must be a function of mode-index, source depth, and receiver depth. The corresponding FORTRAN statement thus appears within the DO 220 source and receiver loops as well as within the DO 230 mode loop.

The inclusion of terms excluded by the two above-described tests would not invalidate the transmission-loss calculations. One reason for having the tests is to save execution time. However, a more important reason exists. The argument of the exponential function, QQ, may become quite large. If no check is made, a fatal execution error may result, due to machine limitations on the size of the argument of the EXP function. Similarly, Q2 may become very small in absolute value. This will occur, for example, if either of the depths $\zeta_0$ or $\zeta$ is such that the eigenfunction $u_n(\zeta_0)$ or $u_n'(\zeta)$ is very close to a node (for a particular mode order $n$). The resulting calculation of Q1 might yield a number smaller than $10^{-x}$, where $x$ specifies the dynamic range of a real constant (a machine-dependent parameter). This would cause a fatal error. Such a problem has never been encountered in years of using the program. On the other hand, numbers have been encountered which, when squared (as Eqs. (10) and (11) require), would have caused an execution error due to their extreme smallness. The test on Q1 eliminates the possibility of such errors.

After the definition of Q comes the FORTRAN statement QS(J1,J2)=QS(J1,J2)+Q* DSIN(SE(IM)). For each source depth and each receiver depth (for which these arrays are subscripted), QS(J1,J2) will "accumulate" NMODE terms as the DO 230 loop is executed. After the loop is finished, we have:

$$\mathrm{QS}\,(\mathrm{J\,1,J\,2}) = \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)\, r^{1/2}}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin\phi_n.$$

In a similar manner, we have:

$$\mathrm{QC}\,(\mathrm{J\,1,J\,2}) = \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)\, r^{1/2}}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos \phi_n$$

and

$$\mathrm{PL}\,(\mathrm{J\,1,J\,2,I}) = \sum_{n=1}^{N} \left[ \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \right]^2 r. \tag{22}$$

The array PL(J1,J2,I) will finally represent the incoherent transmission loss or transmission-loss anomaly (see Part 9). As presently defined by Eq. (22), however, it represents an intermediate result. The multiplicative factor $r$ has been introduced for numerical purposes and is to be removed in the final calculation.

*Part 9: Transmission Loss: II*

The array COPL(J1,J2,I) is used for coherent loss calculations and is defined initially, for each source and receiver depth (via the DO 270 loops), as the sum of the squares of QS(J1,J2) and QC(J1,J2):

$$\mathrm{COPL}\,(\mathrm{J\,1,J\,2,I}) = \left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin \phi_n \right]^2 r$$

$$+ \left[ \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos \phi_n \right]^2 r. \tag{23}$$

The phase of the signal, as defined in the "THEORY" section, is coded next.

PHASE (J 1,J 2)=ATAN 2(QS (J 1,J 2),QC (J 1,J 2))*57.295779513.

The multiplicative factor at the end converts the result of the arctangent function from radians to degrees.

The program will calculate either the transmission loss (TL) or the transmission-loss anomaly (TLA), which is the loss in addition to that caused by cylindrical spreading. The input parameter ISPRD controls this choice. If ISPRD = 0, then the TLA is calculated. If ISPRD = 1, then the TL is calculated. The relation between the two is: TL = 10 $\log_{10}$ r + TLA. We shall discuss here only the coherent and incoherent TL, which are given by Eqs. (10) and (11), respectively. The TLA is obtained in a similar manner.

To get Eq. (10) from Eq. (23), we divide by the range r=RAN(I), the water depth at the receiver H10, and the water depth at the source HS; we multiply by $2\pi\rho_1^2$; and we take the base-10 log of the result and multiply by (−10). The FORTRAN statement which does this therefore completes the evaluation of Eq. (10) and stores the final result in the array COPL(J1,J2,I). To get Eq. (11) from Eq. (22), we follow an identical procedure. The array PL(J1,J2,I) contains the final result. In writing Eqs. (10) and (11), the "normal" situation of a receiver in the water layer was assumed. In this case, we have DEPRE(J1).LE.H10 fulfilled in the FORTRAN IF statement, and Eqs. (10) and (11) are programmed with $\rho_1$ given by RERHO1. As mentioned earlier, however, the program will accommodate a receiver in the sediment. In this case, the program replaces $\rho_1$ by $\rho_2$, given in the FORTRAN by RERHO2.

*Part 10: Printed Output*

The calculated coherent transmission loss (modulus in decibels, phase in degrees) and incoherent transmission loss (in decibels) are printed out as functions of range (DO 300), source depth (DO 290), and receiver depth (DO 280). (When there is only one source and one receiver, the quantities are functions of range only, and the output is on one line per range.)

Examples are given in the "OUTPUT" section.

*Part 11: Plotted Output*

Plotting of loss *vs* range is performed separately for each source depth and receiver depth. The plots, which contain both coherent and incoherent loss, are executed in the following order, which is important to note since the plots are unlabeled:

```
     DO 340 loop for frequency
     DO 330 loop for receiver depth
     DO 330 loop for source depth
     Plot Package
330  CALL ORIGIN (XLENG +2.5, 0.)
340  CONTINUE
```

## INPUT DATA

### Explanation of Data Deck and Notes to the User

There are three groups of data input statements. The first group, containing primarily data needed for transmission-loss calculations, is read in once (in Part 1). (The various "Parts" of the program are defined in the "Step-By-Step Analysis" section.) The second group, containing primarily environmental data needed for modal calculations at the receiver site, is read in once for each frequency (in Part 3). The third group is similar to the second and is read in (only for a range-dependent calculation) NRBUF-1 times for each frequency (in Part 6). Each of the second and third groups may differ from the others by any arbitrary combination of the environmental parameters, subject to the constraint that the fluid-basement and solid-basement models may not both be used for a given track. If NMFREQ is greater than one, the procedure of reading the second and third groups is repeated.

The spacing of the user-supplied environmental data profiles for the range-dependent model is usually dictated by the bathymetry of the acoustic propagation path, and to a lesser degree, by changes in the sound speed profile with range. Since water depth at a calculation range site is approximated by a linear interpolation between the depths at two user-supplied profiles, the user should approximate the known bathymetry by linear segments, supplying input data at the ranges where these segments meet. Additional profiles may be supplied at other ranges in order to take account of the range-dependence of other environmental parameters.

There is another reason for inserting extra profiles along the track. If the number of modes which the environment will support decreases rapidly with increasing range, as will be the case for a water depth, $H_1$, which decreases rapidly, then the calculated loss may change discontinuously at an input range where there are many fewer modes than at the previous input range. This is due to conservation of mode-index, implemented in the program by excluding those higher order modes which are not present at both of the input environments between which range-interpolations are to be carried out on the eigenfunctions. Thus, for example, if three input profiles A, B, and C support 80, 50, and 20 modes, respectively, calculations at range points between A and B will use 50 modes, and those between B and C will use 20 modes. At ranges greater than B, some of the (excluded) higher order modes may initially actually yield an important contribution which decreases rapidly thereafter. By exclusion of all these modes starting at range B, a small discontinuity in the loss may be caused at range B. The problem may be avoided, however, by supplying additional profiles, perhaps one between A and B which supports approximately 65 modes and one between B and C which supports approximately 35 modes. (If the discontinuity is reduced, but not eliminated, more supplemental profiles may be necessary.)

The above-described procedure will work if enough intermediate profiles are used; however, this may substantially increase the execution time of the program. We shall briefly discuss another method of circumventing the problem which is particularly suited to those tracks along which the deep sediment structure is not important. Reference to Eq. (12) shows that the total number of modes which exists at a given range is dependent, among other things, on $H \equiv H_1 + H_2$, and not on the water depth $H_1$ alone. (It was tacitly assumed in the previous paragraph that $H_2$ is nearly constant with range so the change in the number of allowed modes was due to the decrease of $H_1$.) If deep sediment structure is unimportant, the sediment thickness $H_2$ may be assigned small values at the smaller ranges and large values at the larger ranges, thereby keeping H and consequently the total number of modes nearly constant with changing range. This procedure allows the higher order modes to accumulate large attenuation coefficients before their contributions are dropped from the modal sum in Eq. (22).

In experiments the source depth sometimes changes at one or more points along the tow track. The user of PROGRAM MOATL can incorporate source depth changes along the track by inserting the appropriate IF statement(s) between CSNs 193 and 194:

```
IF(RAN(I).GT. ·····) DEPSO(1) = ... (etc.).
```

In situations in which the water depth over part of the acoustic propagation path is less than the source depth, the change of source depth is necessary since the program requires the source to be in the water layer. This change is necessary even if the source was not towed over that part of the path in the experiment whose results are to be modeled, since the program assumes that the source is towed from the range origin in order to evaluate Eqs. (18), (19), and (20) accurately. We note for completeness that for the range-dependent or range-independent model, the source depth may be changed at any range for any other reason and all the loss calculations will be correct.

There are two other notable variations that the program will treat. First, although the program is set up to model a three-layer half-space, a two-layer model may be practically realized when the basement rock interfaces with the water (SOLID) or the sediment is so thick that deep sediment structure is not important (FLUID). Such an example for the fluid basement is given in the "OUTPUT" section. The second variation is that, although the code as programmed assumes the calculation ranges to be equally spaced, minor code alterations will allow unequally spaced ranges. Details concerning each of these two variations, along with additional information, may be found in the section "General Remarks."

Listed below are the required input data. Each line (and an indented continuation) corresponds to a single data card (or a single record of 80 characters if input is not by use of cards). If there is more than one of each type of card, the variable specifying the number of cards is printed to the left and is underlined. All of such cards appear together in the data deck. (By "NDSO ÷8" it is meant, for example, that if there are to be eleven source depths, there will be two data cards, eight values on the first and three on the second.) The three input groups described in the first paragraph of this section are separated by brackets. If there is more than one set of a group of cards, the variable specifying the number of sets is printed to the left and is underlined. These sets are clustered in the data deck. The FORMAT to be used for each card is specified in parentheses at the end of each line.

TITLE(I) (20A4)

ISPRD,NMFREQ,NRBUF,NRCALC,RMAX,EP1,EP2,
EP3,SIG0,SIG1 (4I5,F10.3,5F10.7)

NDSO,NDRE (2I5)

III (I5)

IPLOT,DBMIN,DBMAX,DY,DX (I5,2F10.3,2 F10.7)

NDSO÷8 — DEPSO(I), I=1,8 (8F10.3)

NDRE÷8 — DEPRE(I), I=1,8 (8F10.3)

NMFREQ

TITLE(I) (20A4)

F (F10.3)

MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H11,H2
(3I5,5F10.3)

EPSLN,COMP,SHEAR,RANGE1,LI1,LI2,ND1,ND2
(F10.8,3F10.3,4I5)

ND1 — Z1(I),C1(I) (2F10.3)

ND2 — Z2(I),C2(I) (2F10.3)

NRBUF−1

MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2
(3I5,5F10.3)

EPSLN,COMP,SHEAR,RANGE2,LI1,LI2,ND1,ND2
(F10.8,3F10.3,4I5)

ND1 — Z1(I),C1(I) (2F10.3)

ND2 — Z2(I),C2(I) (2F10.3)

**Description of Input Data**

We now describe the function and use of each of the input variables. They are arranged here in the same order as they are read in by the program. For determining input values further information is given in the previous section and the "General Remarks" section.

No specific units (m or km, for example) are required; however, it is necessary to see that the units chosen are consistent for all the input variables. (The only two exceptions are the density of the water, which must always be unity (see below), and DX (km/in.) and RMAX (m) when the plot package is desired.) We assume below the m-k-s system for convenience, which serves also as a useful example.

TITLE(I) — An array containing any alphanumeric label (80 characters maximum).

ISPRD — If 0, the loss anomaly (no cylindrical spreading) will be calculated. If 1, the loss (cylindrical spreading included) will be calculated. (See discussion in the section "Step-By-Step Analysis—Part 9".)

NMFREQ — The number of source frequencies (or alternatively, the number of different environmental cases for a given frequency) for which the calculations are desired. Should be set to unity when unequally spaced calculation ranges are used.

NRBUF — The number of environmental data profiles to be input. If 1, the environment is range-independent. If greater than 1, the environment is range-dependent.

NRCALC — The number of range points at which loss calculations are desired (limited by PARAMETER statement). In general, these will be equally spaced out to the maximum range specified. (See the "General Remarks" section for further discussion and limitations.)

RMAX — Maximum range (m) at which loss calculations are desired.

EP1 — Sediment layer plane-wave absorption coefficient (dB/Hz-m).

EP2 — Basement compressional plane-wave absorption coefficient (dB/Hz-m).

EP3 — Basement shear plane-wave absorption coefficient (dB/Hz-m). Set equal to 0 for a FLUID model.

SIG0 — The rms wave height (m) used for calculating attenuation due to air/water interface scattering.

SIG1 — The rms bottom roughness (m) used for calculating attenuation due to water/sediment interface scattering.

NDSO — Number of source depths. (Limited by PARAMETER statement.)

NDRE — Number of receiver depths. (Limited by PARAMETER statement.)

III — If 0, a FLUID basement is assumed. If 1, a SOLID basement is assumed. (The type of basement is fixed by III for the entire track.)

IPLOT — If 0, no plots are included in the output. If 1, plotting is executed.

DBMIN — Lower bound for transmission loss (dB) on the plotted graph's loss axis.

DBMAX — Upper bound for transmission loss (dB) on the plotted graph's loss axis.

DY — Number of decibels per inch determining the scale of the plotted graph's loss axis.

DX — Determines the scale of the plotted graph's range axis. If the units used for range are meters, DX should specify the number of kilometers per inch on the axis.

DEPSO(I) — An array storing the source depths (m). (Each of these values must be $\leqslant H_1$.)

DEPRE(I) — An array storing the receiver depths (m). (Each of these values must be $\leqslant H_1 + H_2$.)

TITLE(I) — Another arbitrary alphanumeric label (80 characters maximum).

F — Source frequency (Hz).

MDPRNT — If 0, none of the calculated mode-amplitude functions will be printed out. Otherwise, they will be printed out in accordance with the following two inputs.

INC1 — A variable containing a value one greater than the number of depth-increment values to be skipped between printed-out values of the mode-amplitude functions, in the water layer. Note: first determine LI1; then set INC1 to give the desired number of printed out values. As an example, if LI1 = 300 and INC1 = 6, then 50 values will be printed out.

INC2 — Same as INC1, but for the sediment layer. The number of output values is based on LI2.

RHO1 — The variable RHO1=1.0 always. It is the density to be used for water regardless of the units used for the rest of the data.

RHO2 — Ratio of the density of the sediment layer to that of water.

RHO3 — Ratio of the density of the basement to that of water.

H11 — The thickness (m) of the water layer at the receiver.

H12 — The thickness (m) of the water layer at any nonzero range where the environmental data are read in.

H2 — The thickness (m) of the sediment layer. (Same variable name used at all ranges.)

EPSLN — The variable EPSLN = 0.0001 always. It is the criterion for the accuracy of the calculated eigenvalues (modal wave numbers), *i.e.*, the amount by which the air/water surface value of the normalized eigenfunction may differ from the pressure-release boundary-condition requirement of being identically zero.

COMP — Compressional velocity (m/s) in the basement.

SHEAR — Shear velocity (m/s) in the basement for the SOLID model; it must exceed the minimum sound speed found in the water and sediment layers. However, for the FLUID model, set SHEAR = 0.

RANGE1 — The variable RANGE1 = 0 always. It is the receiver range, which is zero by defintion.

RANGE2 — The range (m) from the fixed receiver of the present environmental profile being read in.

LI1 — The number of incremental steps into which the water layer is to be divided for the calculations. (See "Notes" below.)

LI2 — The number of incremental steps into which the sediment layer is to be divided for the calculations. (See "Notes" below.)

Notes: The numbers of layers LI1 and LI2 help to determine the accuracy of the eigenvalues and mode-amplitude functions. The quantity LI1 should be set equal to about ten times the number of modes expected; LI2 should be set to yield approximately the same spacing. To estimate N, the total number of modes, see Eq. (12). Dimensioning of arrays requires that N be less than or equal to 150. In no event should either LI1 or LI2 be less than four, nor should their sum exceed 1200. They must each be even-valued to be consistent with the Simpson's rule integration method used in the subroutines.

ND1 — The number of sound-speed profile depths to be read in for the water layer (not to exceed 150).

ND2 — The number of sound-speed profile depths to be read in for the sediment layer (not to exceed 150).

Z1(I), C1(I) — The arrays for the depth (m) and sound speed (m/s), respectively, profile values of the water layer.

Z2(I), C2(I) — The arrays for the depth (m) and sound speed (m/s), respectively, profile values of the sediment layer.

Notes: The following conditions must be met: Z1(1) = 0; Z1(ND1) = Z2(1) = H11 (or H12, if range $r \neq 0$); Z2(ND2) = H11 + H2 (or H12 + H2). Since the program interpolates linearly for sound speeds between those given, it is sufficient to supply only the two bounding depths when there are three or more consecutive depth points having sound speed a linear function of depth.

For the user who knows only the type of material comprising the sediment, we include Table 2, as a guide in determining input values. The density of a given sediment type is suitable for the input variable RH02 as given. The velocity ratio, when multiplied by the value of C1(ND1), yields the value to be used for C2(1). If the attenuation coefficient (dB/m-kHz) is to be used for EP1 (supplied in dB/m-Hz), it must first be multiplied by $10^{-3}$.

Table 2[a] — Sediment Layer Parameters

| Sediment Type | Density ($g/cm^3$) | Porosity (%) | Velocity Ratio | Atten. Coeff. (dB/m-kHz) |
|---|---|---|---|---|
| Coarse sand | 2.034 | 38.6 | 1.201 | 0.47 |
| Fine sand | 1.957 | 44.8 | 1.147 | 0.51 |
| Very fine sand | 1.866 | 49.8 | 1.111 | 0.68 |
| Silty sand | 1.806 | 53.8 | 1.091 | 0.69 |
| Sandy silt | 1.787 | 52.5 | 1.088 | 0.76 |
| Silt | 1.767 | 54.2 | 1.062 | 0.68 |
| Sand-silt-clay | 1.583 | 67.2 | 1.033 | 0.11 |
| Clayey silt | 1.469 | 72.6 | 1.011 | 0.08 |
| Silty clay | 1.421 | 75.9 | 0.994 | 0.07 |

[a]Compiled by Anthony I. Eller and Frank Ingenito from data given in Refs. 9-12 — private communication.

## OUTPUT

Most of the input variables are also printed out, *via* WRITE statements that follow the corresponding READ statements in the code. This helps in error-checking and also serves to label the printout uniquely. The first page of printed output contains all of the input variables of group one (the three groups of input variables are discussed in the "INPUT DATA" section) except for the variable III. The value of III is reflected, however, in the inclusion or omission (on the second printed page) of the shear and Rayleigh velocities. Apart from the latter, which is a calculated quantity, the second page of output contains only the values of variables of the second input group.

Beginning on the third page are the calculated modal properties of each of the normal modes supported by the environment given on the second page. The FORTRAN WRITE commands for this output are located near the end of SUBROUTINE SOLID (or FLUID). For each mode, the mode-order and phase velocity are first printed out. Also printed is the number of iterate solutions, *i.e.*, the number of times that SUBROUTINE HALFS (or HALFF) called SUBROUTINE ITRTS (or ITRTF) in order to converge to the correct eigenvalue. Also printed on the same line is the number of times that the eigenfunction had to be scaled down, according to the technique described in Appendix A. The last two lines for a given mode contain, from left to right, the label and value for each of the following quantities: the wave number (eigenvalue $k_n$), the water absorption $\alpha_n$, the sediment-layer attenuation ratio $\gamma_n^{(2)}$, the basement compressional attenuation ratio $\gamma_n^{(3c)}$, the basement shear attenuation ratio $\gamma_n^{(3s)}$ (included only for the solid-basement model), the air/water scattering attenuation ratio $\Gamma_{0,n}$, and the water/sediment scattering attenuation ratio $\Gamma_{1,n}$.

In addition to the modal output described in the last paragraph, there are several statements which are conditionally printed for each mode. The statement "UPPER AMPLITUDES MATCHED FOR THIS MODE STARTING AT NORMALIZED DEPTH = " will be printed out (along with the appropriate value of the normalized depth $z_m$) if the eigenfunction $u_n(z)$ has been calculated for $z<z_m$ according to the procedure described in Appendix A. The remaining conditional statements are "LAYER 2 ATTEN RATIO = DEFAULT ZERO" and similar statements for the compressional and/or shear attenuation ratios. These statements are printed out only if during their calculation they were determined to be small enough to be set to zero.

After the modal parameters and flags have been printed out for each mode, and if MDPRNT = 1, the eigenfunctions are printed out. (If MDPRNT = 0, they are not printed out.) They are printed out in columnar form, twelve to a page, with depth increasing down the page. (The first column contains the values of the normalized depth for each line.)

If the problem is a range-dependent one, the second environment (*i.e.*, the one at the first nonzero input range) and the normal-mode parameters for it are next printed out in a format identical to the first (receiver) environment.

Next to be printed out are the transmission loss calculations for the output ranges which fall between the first and second environments. (For a range-independent problem, there is no second environment, and all the transmission-loss calculations follow the output for the receiver environment.) If there is a third input range, its environmental and modal parameters are printed next, followed by loss calculations at output ranges between the second and third input ranges. This procedure is repeated until the output ranges have been exhausted.

For those pages containing the calculated loss, the coherent transmission loss is printed on the left sides of the pages; the incoherent transmission loss is printed on the right sides of the pages. The format for each is as follows. The calculations for each output range are grouped together. Following the line on which the value of this range is printed is a "group" of output for each source depth, which is also printed out. This "group" will be only one line if there are five or fewer receiver depths. (If there are between six and ten receiver depths, there will be two lines, *etc.*) Each line contains the transmission loss for up to five values of the receiver depth. If there are fewer than an integral multiple of five receiver depths, the line is "filled out" with indeterminate form data (*i.e.*, a string of the letter "I"). The procedure for filling variables with indeterminate form data prior to execution is machine-dependent and is not described here. The transmission loss is not labeled with receiver depth, but the depths are in order of decreasing depth, as printed out on the first page of output.

We now include, on the following pages, the computer output (described in general above) for two dissimilar test cases. The differences, summarized in Table 3, illustrate many of the options available to the user.

Table 3 — Summary of Differences Between Test Cases 1 and 2

| Item | Test Case 1 (for Fig. 2) | Test Case 2 |
|---|---|---|
| Type of model | Range-independent environment | Range-dependent environment |
| Type of environment | 2-layer fluid-basement | 3-layer solid-basement |
| Surface and bottom scattering | No | Yes |
| No. of output ranges | 200 | 10 |
| Plots | Yes | No |
| No. of source depths | 1 | 2 |
| No. of receiver depths | 3 | 2 |
| Receiver in the sediment layer | No | Yes |
| Sound speed profile in water and sediment layers | Isovelocity | Depth-dependent |
| Frequency | 20 Hz | 100 Hz |
| No. of modes | 6 | 19, 22, 24 (3 environments) |
| Eigenfunctions printed out | Yes | No |

Note that test case 1 calls for plots of transmission loss. These plots have already been presented as Fig. 2 (see the "THEORY" section). Note also that test case 1 asks for transmission-loss calculations at 200 range points. We include only the first and last page of calculated results here. The 23 intervening pages of output have been deleted.

## ACKNOWLEDGMENTS

The authors would like to thank their colleagues, Frank Ingenito, Anthony Eller, William Kuperman, and David Nutile for the numerous helpful suggestions they made while this program was being developed.

******************************* TRANSMISSION LOSS ******************************

TEST CASE NUMBER 1 (FOR FIG. 2)

NUMBER OF FREQUENCIES = 1

| NO. PROFILES | NO. CALCULATION RANGES | MAXIMUM RANGE | EP1 | EP2 | EP3 | SIG0 | SIG1 |
|---|---|---|---|---|---|---|---|
| 1 | 200 | 80000.000 | 0.0006800 | 0.0006800 | 0.0000000 | 0.0000000 | 0.0000000 |

IPLOT = 1 DBMIN = 45.000 DBMAX = 115.000 DY =14.0000000 DX =10.0000000

1 SOURCE DEPTH(S)
100.000

3 RECEIVER DEPTH(S)
70.000
200.000
400.000

TEST CASE 1 PROFILE SOURCE FREQUENCY = 20.000

MDPRNT =1 INC1 = 2 INC2 = 1 RHO1 =1.000 RHO2 =1.870 RHO3 =1.870 H1 = 520.000 H2 = 10.000
EPSLN =0.00010000 RANGE = 0.000 LI1 =100 LI2 = 6 ND1 = 2 ND2 = 2

COMPRESSIONAL VELOCITY
1666.000

SOUND SPEED PROFILE

| DEPTH | DEPTH | VELOCITY |
|---|---|---|
| 0.000 | 0.000 | 1500.000 |
| 1.000 | 520.000 | 1500.000 |
| | | |
| 1.000 | 520.000 | 1666.000 |
| 1.019 | 530.000 | 1666.000 |

MAXIMUM NUMBER OF MODES = 6          NUMBER OF MODES CALCULATED = 6

MODE NO. = 1     PHASE VELOCITY = 0.150324980539D 04
NUMBER OF ITERATE SOLUTIONS = 15     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.835946931061D-01 | 0.5540E-08 | 0.9142E-03 | 0.8659E-03 | 0.5789E-04 | 0.5784E-04 |

MODE NO. = 2     PHASE VELOCITY = 0.151322191018D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.830438056033D-01 | 0.5548E-08 | 0.3250E-02 | 0.3240E-02 | 0.1183E-03 | 0.1179E-03 |

MODE NO. = 3     PHASE VELOCITY = 0.153054406650D 04
NUMBER OF ITERATE SOLUTIONS = 16     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.821039451879D-01 | 0.5572E-08 | 0.6217E-02 | 0.6812E-02 | 0.1827E-03 | 0.1815E-03 |

MODE NO. = 4     PHASE VELOCITY = 0.155619291574D 04
NUMBER OF ITERATE SOLUTIONS = 14     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.807507249729D-01 | 0.5617E-08 | 0.9276E-02 | 0.1189E-01 | 0.2518E-03 | 0.2492E-03 |

MODE NO. = 5     PHASE VELOCITY = 0.159149118336D 04
NUMBER OF ITERATE SOLUTIONS = 14     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.789597249784D-01 | 0.5674E-08 | 0.1232E-01 | 0.2069E-01 | 0.3254E-03 | 0.3206E-03 |

MODE NO. = 6     PHASE VELOCITY = 0.163795116220D 04
NUMBER OF ITERATE SOLUTIONS = 14     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | LAYER 3 ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|
| 0.767200567659D-01 | 0.5658E-08 | 0.1552E-01 | 0.4796E-01 | 0.3977E-03 | 0.3896E-03 |

MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF 20.000 HZ.

FIRST LAYER

| DEPTH | 1MODE AMPLITUDE | 2MODE AMPLITUDE | 3MODE AMPLITUDE | 4MODE AMPLITUDE | 5MODE AMPLITUDE | 6MODE AMPLITUDE |
|---|---|---|---|---|---|---|
| 0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | -0.0000 | 0.0000 |
| 0.0200 | 0.0774 | -0.1557 | 0.2353 | -0.3152 | 0.3939 | -0.4662 |
| 0.0400 | 0.1545 | -0.3094 | 0.4635 | -0.6135 | 0.7546 | -0.8758 |
| 0.0600 | 0.2311 | -0.4590 | 0.6779 | -0.8789 | 1.0518 | -1.1793 |
| 0.0800 | 0.3069 | -0.6026 | 0.8720 | -1.0972 | 1.2605 | -1.3397 |
| 0.1000 | 0.3817 | -0.7382 | 1.0400 | -1.2567 | 1.3630 | -1.3378 |
| 0.1200 | 0.4553 | -0.8640 | 1.1769 | -1.3489 | 1.3509 | -1.1737 |
| 0.1400 | 0.5274 | -0.9785 | 1.2785 | -1.3688 | 1.2250 | -0.8673 |
| 0.1600 | 0.5978 | -1.0801 | 1.3420 | -1.3153 | 0.9960 | -0.4557 |
| 0.1800 | 0.6662 | -1.1674 | 1.3652 | -1.1913 | 0.6832 | 0.0111 |
| 0.2000 | 0.7324 | -1.2393 | 1.3476 | -1.0035 | 0.3129 | 0.4766 |
| 0.2200 | 0.7962 | -1.2948 | 1.2897 | -0.7619 | -0.0838 | 0.8843 |
| 0.2400 | 0.8574 | -1.3333 | 1.1932 | -0.4795 | -0.4734 | 1.1848 |
| 0.2600 | 0.9158 | -1.3542 | 1.0610 | -0.1714 | -0.8232 | 1.3416 |
| 0.2800 | 0.9712 | -1.3572 | 0.8971 | 0.1459 | -1.1036 | 1.3358 |
| 0.3000 | 1.0234 | -1.3423 | 0.7063 | 0.4554 | -1.2912 | 1.1680 |
| 0.3200 | 1.0723 | -1.3097 | 0.4944 | 0.7405 | -1.3701 | 0.8587 |
| 0.3400 | 1.1177 | -1.2598 | 0.2677 | 0.9859 | -1.3337 | 0.4452 |
| 0.3600 | 1.1593 | -1.1933 | 0.0329 | 1.1784 | -1.1850 | -0.0223 |
| 0.3800 | 1.1972 | -1.1111 | -0.2028 | 1.3078 | -0.9366 | -0.4870 |
| 0.4000 | 1.2312 | -1.0142 | -0.4324 | 1.3672 | -0.6093 | -0.8927 |
| 0.4200 | 1.2611 | -0.9039 | -0.6491 | 1.3532 | -0.2307 | -1.1902 |
| 0.4400 | 1.2869 | -0.7817 | -0.8464 | 1.2668 | 0.1672 | -1.3433 |
| 0.4600 | 1.3085 | -0.6492 | -1.0184 | 1.1124 | 0.5511 | -1.3337 |
| 0.4800 | 1.3257 | -0.5081 | -1.1598 | 0.8984 | 0.8886 | -1.1623 |
| 0.5000 | 1.3387 | -0.3603 | -1.2666 | 0.6363 | 1.1514 | -0.8500 |
| 0.5200 | 1.3472 | -0.2077 | -1.3355 | 0.3401 | 1.3172 | -0.4347 |
| 0.5400 | 1.3514 | -0.0525 | -1.3644 | 0.0257 | 1.3721 | 0.0334 |
| 0.5600 | 1.3511 | 0.1035 | -1.3525 | -0.2902 | 1.3115 | 0.4974 |
| 0.5800 | 1.3463 | 0.2581 | -1.3002 | -0.5904 | 1.1406 | 0.9011 |
| 0.6000 | 1.3372 | 0.4093 | -1.2089 | -0.8590 | 0.8736 | 1.1955 |
| 0.6200 | 1.3237 | 0.5551 | -1.0814 | -1.0816 | 0.5331 | 1.3450 |
| 0.6400 | 1.3058 | 0.6936 | -0.9216 | -1.2463 | 0.1477 | 1.3315 |
| 0.6600 | 1.2837 | 0.8229 | -0.7343 | -1.3441 | -0.2501 | 1.1565 |
| 0.6800 | 1.2573 | 0.9414 | -0.5249 | -1.3699 | -0.6268 | 0.8413 |
| 0.7000 | 1.2269 | 1.0474 | -0.2999 | -1.3223 | -0.9508 | 0.4241 |
| 0.7200 | 1.1924 | 1.1397 | -0.0658 | -1.2038 | -1.1948 | -0.0445 |
| 0.7400 | 1.1540 | 1.2169 | 0.1702 | -1.0208 | -1.3382 | -0.5077 |
| 0.7600 | 1.1118 | 1.2780 | 0.4011 | -0.7831 | -1.3689 | -0.9094 |
| 0.7800 | 1.0660 | 1.3223 | 0.6200 | -0.5035 | -1.2844 | -1.2008 |
| 0.8000 | 1.0167 | 1.3491 | 0.8203 | -0.1968 | -1.0919 | -1.3466 |
| 0.8200 | 0.9640 | 1.3582 | 0.9961 | 0.1204 | -0.8074 | -1.3292 |
| 0.8400 | 0.9082 | 1.3493 | 1.1421 | 0.4311 | -0.4549 | -1.1506 |
| 0.8600 | 0.8494 | 1.3226 | 1.2540 | 0.7187 | -0.0642 | -0.8325 |
| 0.8800 | 0.7878 | 1.2785 | 1.3283 | 0.9679 | 0.3320 | -0.4135 |
| 0.9000 | 0.7237 | 1.2175 | 1.3628 | 1.1651 | 0.7002 | 0.0556 |
| 0.9200 | 0.6572 | 1.1404 | 1.3566 | 1.2999 | 1.0094 | 0.5180 |
| 0.9400 | 0.5885 | 1.0483 | 1.3098 | 1.3651 | 1.2337 | 0.9176 |
| 0.9600 | 0.5179 | 0.9424 | 1.2238 | 1.3571 | 1.3542 | 1.2060 |
| 0.9800 | 0.4456 | 0.8240 | 1.1012 | 1.2763 | 1.3607 | 1.3481 |
| 1.0000 | 0.3718 | 0.6947 | 0.9457 | 1.1272 | 1.2526 | 1.3268 |

MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF 20.000 HZ.

SECOND LAYER

| DEPTH | 1MODE AMPLITUDE | 2MODE AMPLITUDE | 3MODE AMPLITUDE | 4MODE AMPLITUDE | 5MODE AMPLITUDE | 6MODE AMPLITUDE |
|---|---|---|---|---|---|---|
| 1.0000 | 0.1988 | 0.3715 | 0.5057 | 0.6028 | 0.6698 | 0.7095 |
| 1.0032 | 0.1872 | 0.3506 | 0.4791 | 0.5745 | 0.6443 | 0.6931 |
| 1.0064 | 0.1763 | 0.3309 | 0.4539 | 0.5476 | 0.6197 | 0.6771 |
| 1.0096 | 0.1660 | 0.3123 | 0.4300 | 0.5219 | 0.5960 | 0.6615 |
| 1.0128 | 0.1564 | 0.2947 | 0.4074 | 0.4974 | 0.5733 | 0.6462 |
| 1.0160 | 0.1473 | 0.2782 | 0.3860 | 0.4741 | 0.5514 | 0.6313 |
| 1.0192 | 0.1387 | 0.2625 | 0.3657 | 0.4518 | 0.5304 | 0.6167 |

```
COHERENT TRANSMISSION LOSS
(LOSS IN DB, PHASE IN DEGREES)


RANGE(M) =   400.0

SOURCE DEPTH(M) = 100.000
( 48.13/  76.092) ( 54.51/ 163.416) ( 66.48/ 118.902) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =   800.0

SOURCE DEPTH(M) = 100.000
( 54.79/ 148.907) ( 54.80/ 241.256) ( 63.13/ 113.484) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  1200.0

SOURCE DEPTH(M) = 100.000
( 63.86/ 258.699) ( 56.18/ 330.446) ( 61.96/ 154.769) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  1600.0

SOURCE DEPTH(M) = 100.000
( 64.87/   8.078) ( 58.69/  58.893) ( 61.67/ 226.057) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  2000.0

SOURCE DEPTH(M) = 100.000
( 76.48/  96.168) ( 62.89/ 158.679) ( 62.36/ 296.950) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  2400.0

SOURCE DEPTH(M) = 100.000
( 69.76/ 282.186) ( 67.64/ 262.764) ( 70.92/  30.447) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  2800.0

SOURCE DEPTH(M) = 100.000
( 68.06/ 345.787) ( 72.57/  86.634) ( 64.88/ 194.353) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) =  3200.0

SOURCE DEPTH(M) = 100.000
```

```
INCOHERENT TRANSMISSION LOSS
LOSS IN DB


RANGE(M) =   400.0

SOURCE DEPTH(M) = 100.000
 53.14   54.72   55.00  IIIIII  IIIIII


RANGE(M) =   800.0

SOURCE DEPTH(M) = 100.000
 56.23   57.80   58.08  IIIIII  IIIIII


RANGE(M) =  1200.0

SOURCE DEPTH(M) = 100.000
 58.08   59.64   59.90  IIIIII  IIIIII


RANGE(M) =  1600.0

SOURCE DEPTH(M) = 100.000
 59.41   60.96   61.21  IIIIII  IIIIII


RANGE(M) =  2000.0

SOURCE DEPTH(M) = 100.000
 60.46   62.00   62.24  IIIIII  IIIIII


RANGE(M) =  2400.0

SOURCE DEPTH(M) = 100.000
 61.34   62.86   63.09  IIIIII  IIIIII


RANGE(M) =  2800.0

SOURCE DEPTH(M) = 100.000
 62.09   63.60   63.82  IIIIII  IIIIII


RANGE(M) =  3200.0

SOURCE DEPTH(M) = 100.000
```

```
SOURCE DEPTH(M) = 100.000
( 83.81/ 291.096) ( 83.20/ 260.794) (107.63/ 192.737) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

RANGE( M) = 79600.0

SOURCE DEPTH(M) = 100.000
( 83.06/  27.604) ( 83.62/  16.295) (106.73/ 357.067) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

RANGE(M) = 80000.0

SOURCE DEPTH(M) = 100.000
( 83.22/ 124.524) ( 83.24/ 131.807) (108.71/ 158.472) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)
```

```
SOURCE DEPTH(M) = 100.000
 87.76   85.34   84.98  IIIIII  IIIIII

RANGE(M) = 79600.0

SOURCE DEPTH(M) = 100.000
 87.82   85.38   85.03  IIIIII  IIIIII

RANGE(M) = 80000.0

SOURCE DEPTH(M) = 100.000
 87.88   85.42   85.08  IIIIII  IIIIII
```

******************************** TRANSMISSION LOSS ********************************
TEST CASE NUMBER 2

NUMBER OF FREQUENCIES = 1

| NO. PROFILES | NO. CALCULATION RANGES | MAXIMUM RANGE | EP1 | EP2 | EP3 | SIGO | SIG1 |
|---|---|---|---|---|---|---|---|
| 3 | 10 | 50000.000 | 0.0005100 | 0.0000500 | 0.0000550 | 0.3000000 | 0.1000000 |

IPLOT = 0 DBMIN = 0.000 DBMAX = 0.000 DY = 0.0000000 DX = 0.0000000

2 SOURCE DEPTH(S)
70.000
140.000

2 RECEIVER DEPTH(S)
140.000
160.000

TEST CASE 2 PROFILES SOURCE FREQUENCY = 100.000

MDPRNT =0 INC1 = 0 INC2 = 0 RHO1 =1.000 RHO2 =1.957 RHO3 =2.500 H1 = 150.000 H2 = 50.000
EPSLN =0.00010000 RANGE = 0.000 LI1 =250 LI2 = 90 ND1 = 5 ND2 = 2

| COMPRESSIONAL VELOCITY | SHEAR VELOCITY | RAYLEIGH VELOCITY |
|---|---|---|
| 3800.000 | 2194.000 | 2017.159 |

SOUND SPEED PROFILE

| DEPTH | DEPTH | VELOCITY |
|---|---|---|
| 0.000 | 0.000 | 1500.000 |
| 0.123 | 18.500 | 1500.000 |
| 0.333 | 50.000 | 1489.000 |
| 0.560 | 84.000 | 1486.000 |
| 1.000 | 150.000 | 1486.000 |
| | | |
| 1.000 | 150.000 | 1705.000 |
| 1.333 | 200.000 | 1730.000 |

MAXIMUM NUMBER OF MODES = 19        NUMBER OF MODES CALCULATED = 19

MODE NO. = 1    PHASE VELOCITY = 0.148864339686D 04
NUMBER OF ITERATE SOLUTIONS = 19    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.422074576117D 00 | 0.1373E-06 | 0.9013E-03 | 0.2063E-09 | 0.2227E-09 | 0.0000E 00 | 0.2290E-03 |

MODE NO. = 2    PHASE VELOCITY = 0.149542688226D 04
NUMBER OF ITERATE SOLUTIONS = 21    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.420159981187D 00 | 0.1376E-06 | 0.2491E-02 | 0.1591E-08 | 0.1731E-08 | 0.0000E 00 | 0.3639E-03 |

MODE NO. = 3    PHASE VELOCITY = 0.150481755142D 04
NUMBER OF ITERATE SOLUTIONS = 16    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.417538013248D 00 | 0.1380E-06 | 0.4186E-02 | 0.2300E-07 | 0.2531E-07 | 0.3662E-03 | 0.4769E-03 |

MODE NO. = 4    PHASE VELOCITY = 0.151191529830D 04
NUMBER OF ITERATE SOLUTIONS = 22    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.415577864332D 00 | 0.4106E-13 | 0.5248E 00 | 0.4597E 00 | 0.5104E 00 | 0.1494E-09 | 0.1745E-09 |

MODE NO. = 5    PHASE VELOCITY = 0.151713428349D 04
NUMBER OF ITERATE SOLUTIONS = 22    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.414148264629D 00 | 0.1398E-06 | 0.6119E-02 | 0.1149E-06 | 0.1284E-06 | 0.5684E-03 | 0.6012E-03 |

MODE NO. = 6    PHASE VELOCITY = 0.153295253623D 04
NUMBER OF ITERATE SOLUTIONS = 16    THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.409874745543D 00 | 0.1399E-06 | 0.8653E-02 | 0.2212E-07 | 0.2520E-07 | 0.7724E-03 | 0.7679E-03 |

```
MODE NO. =  7      PHASE VELOCITY =  0.155338247311D 04
NUMBER OF ITERATE SOLUTIONS = 18      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.404484112314D 00      0.1413E-06            0.1159E-01            0.2145E-07            0.2510E-07          0.9515E-03         0.9439E-03

MODE NO. =  8      PHASE VELOCITY =  0.157871738272D 04
NUMBER OF ITERATE SOLUTIONS = 16      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.397993040170D 00      0.1431E-06            0.1508E-01            0.3969E-07            0.4808E-07          0.1142E-02         0.1123E-02

MODE NO. =  9      PHASE VELOCITY =  0.160967207889D 04
NUMBER OF ITERATE SOLUTIONS = 22      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.390339460415D 00      0.1452E-06            0.1990E-01            0.1267E-06            0.1605E-06          0.1329E-02         0.1313E-02

MODE NO. = 10      PHASE VELOCITY =  0.164715836708D 04
NUMBER OF ITERATE SOLUTIONS = 18      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.381456053817D 00      0.1473E-06            0.2824E-01            0.7730E-06            0.1037E-05          0.1518E-02         0.1513E-02

MODE NO. = 11      PHASE VELOCITY =  0.169191719732D 04
NUMBER OF ITERATE SOLUTIONS = 20      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.371364823122D 00      0.1477E-06            0.5220E-01            0.1319E-04            0.1909E-04          0.1706E-02         0.1691E-02

MODE NO. = 12      PHASE VELOCITY =  0.173841860001D 04
NUMBER OF ITERATE SOLUTIONS = 24      THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER          WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO    AIR/H2O SCATTER    H2O/2ND SCATTER
0.361431090713D 00      0.7369E-07            0.5441E 00            0.2276E-02            0.3593E-02          0.9403E-03         0.9311E-03
```

MAXIMUM NUMBER OF MODES = 19        NUMBER OF MODES CALCULATED = 19

MODE NO. = 13     PHASE VELOCITY = 0.1754299187400D 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.358159278206D 00 | 0.8749E-07 | 0.4624E 00 | 0.4032E-02 | 0.6572E-02 | 0.1120E-02 | 0.1109E-02 |

MODE NO. = 14     PHASE VELOCITY = 0.1808707357800D 04
NUMBER OF ITERATE SOLUTIONS = 20     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.347385400964D 00 | 0.1223E-06 | 0.2721E 00 | 0.4694E-02 | 0.8627E-02 | 0.1714E-02 | 0.1694E-02 |

MODE NO. = 15     PHASE VELOCITY = 0.1843744530050D 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.340783942936D 00 | 0.6121E-07 | 0.6530E 00 | 0.1613E-01 | 0.3233E-01 | 0.8780E-03 | 0.8616E-03 |

MODE NO. = 16     PHASE VELOCITY = 0.1902172688020D 04
NUMBER OF ITERATE SOLUTIONS = 13     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.330316240305D 00 | 0.1476E-06 | 0.1609E 00 | 0.5296E-02 | 0.1255E-01 | 0.2261E-02 | 0.2224E-02 |

MODE NO. = 17     PHASE VELOCITY = 0.1981328131000D 04
NUMBER OF ITERATE SOLUTIONS = 16     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.317119875747D 00 | 0.9855E-07 | 0.4632E 00 | 0.1791E-01 | 0.5665E-01 | 0.1626E-02 | 0.1589E-02 |

MODE NO. = 18     PHASE VELOCITY = 0.2034538944770D 04
NUMBER OF ITERATE SOLUTIONS = 16     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.308826003225D 00 | 0.1079E-06 | 0.4093E 00 | 0.1822E-01 | 0.7451E-01 | 0.1800E-02 | 0.1759E-02 |

```
MODE NO. = 19     PHASE VELOCITY =  0.2140168491350 04
NUMBER OF ITERATE SOLUTIONS = 14     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER        WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.293583674957D 00     0.1515E-06           0.1965E 00            0.7030E-02            0.7001E-01         0.2706E-02         0.2648E-02
```

```
MDPRNT =0      INC1 = 0      INC2 = 0      RHO1 =1.000      RHO2 =1.957      RHO3 =2.500      H1 = 180.000      H2 =  50.000
EPSLN =0.00010000      RANGE = 18000.000      LI1 =250      LI2 = 90      ND1 = 6      ND2 = 2
```

| COMPRESSIONAL VELOCITY | SHEAR VELOCITY | RAYLEIGH VELOCITY |
|---|---|---|
| 3800.000 | 2194.000 | 2017.159 |

SOUND SPEED PROFILE

| DEPTH | DEPTH | VELOCITY |
|---|---|---|
| 0.000 | 0.000 | 1500.000 |
| 0.103 | 18.500 | 1500.000 |
| 0.278 | 50.000 | 1489.000 |
| 0.467 | 84.000 | 1486.000 |
| 0.833 | 150.000 | 1482.000 |
| 1.000 | 180.000 | 1482.000 |
| | | |
| 1.000 | 180.000 | 1700.000 |
| 1.278 | 230.000 | 1725.000 |

```
                    MAXIMUM NUMBER OF MODES = 22          NUMBER OF MODES CALCULATED = 19

MODE NO. =  1      PHASE VELOCITY =  0.148559946491D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.422939389491D 00      0.1373E-06            0.1150E-02            0.2411E-09           0.2593E-09          0.0000E 00          0.2534E-03

MODE NO. =  2      PHASE VELOCITY =  0.149099607821D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.421408573705D 00      0.1375E-06            0.1773E-02            0.8039E-09           0.8703E-09          0.0000E 00          0.2637E-03

MODE NO. =  3      PHASE VELOCITY =  0.149793828530D 04
NUMBER OF ITERATE SOLUTIONS = 20     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.419455552265D 00      0.1378E-06            0.2888E-02            0.4629E-08           0.5053E-08          0.0000E 00          0.3475E-03

MODE NO. =  4      PHASE VELOCITY =  0.150687063359D 04
NUMBER OF ITERATE SOLUTIONS = 20     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.416969125759D 00      0.1384E-06            0.4178E-02            0.1639E-06           0.1809E-06          0.3402E-03          0.4369E-03

MODE NO. =  5      PHASE VELOCITY =  0.150989310314D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.416134446480C 00      0.7623E-13            0.5286E 00            0.4576E 00           0.5068E 00          0.2202E-09          0.2648E-09

MODE NO. =  6      PHASE VELOCITY =  0.151790527314D 04
NUMBER OF ITERATE SOLUTIONS = 16     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)
  WAVE NUMBER         WATER ABSORPTION  LAYER 2 ATTEN RATIO   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2ND SCATTER
0.413937906294D 00      0.1391E-06            0.5607E-02            0.5452E-07           0.6097E-07          0.5059E-03          0.5309E-03
```

MODE NO. = 7 PHASE VELOCITY = 0.153154684380D 04
NUMBER OF ITERATE SOLUTIONS = 16 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.410250938951D 00 | 0.1401E-06 | 0.7411E-02 | 0.1966E-07 | 0.2237E-07 | 0.6530E-03 | 0.6494E-03 |

MODE NO. = 8 PHASE VELOCITY = 0.154842106970D 04
NUMBER OF ITERATE SOLUTIONS = 20 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.405780147928D 00 | 0.1414E-06 | 0.9463E-02 | 0.1875E-07 | 0.2180E-07 | 0.7778E-03 | 0.7736E-03 |

MODE NO. = 9 PHASE VELOCITY = 0.156872486418D 04
NUMBER OF ITERATE SOLUTIONS = 18 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.400528190166D 00 | 0.1429E-06 | 0.1178E-01 | 0.2862E-07 | 0.3419E-07 | 0.9127E-03 | 0.8964E-03 |

MODE NO. = 10 PHASE VELOCITY = 0.159278062674D 04
NUMBER OF ITERATE SOLUTIONS = 20 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.394479013726D 00 | 0.1446E-06 | 0.1476E-01 | 0.6443E-07 | 0.7962E-07 | 0.1047E-02 | 0.1027E-02 |

MODE NO. = 11 PHASE VELOCITY = 0.162109680744D 04
NUMBER OF ITERATE SOLUTIONS = 22 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.387588531316D 00 | 0.1466E-06 | 0.1906E-01 | 0.2186E-06 | 0.2816E-06 | 0.1177E-02 | 0.1165E-02 |

MODE NO. = 12 PHASE VELOCITY = 0.165422945054D 04
NUMBER OF ITERATE SOLUTIONS = 19 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.379825501542D 00 | 0.1484E-06 | 0.2669E-01 | 0.1253E-05 | 0.1701E-05 | 0.1314E-02 | 0.1305E-02 |

MAXIMUM NUMBER OF MODES = 22          NUMBER OF MODES CALCULATED = 19

MODE NO. = 13     PHASE VELOCITY = 0.169256159484D 04
NUMBER OF ITERATE SOLUTIONS = 22     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.371223435905D 00 | 0.1484E-06 | 0.4923E-01 | 0.1716E-04 | 0.2486E-04 | 0.1444E-02 | 0.1427E-02 |

MODE NO. = 14     PHASE VELOCITY = 0.173226970641D 04
NUMBER OF ITERATE SOLUTIONS = 20     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.362714032573D 00 | 0.8935E-07 | 0.4443E 00 | 0.1765E-02 | 0.2753E-02 | 0.9460E-03 | 0.9318E-03 |

MODE NO. = 15     PHASE VELOCITY = 0.174659530226D 04
NUMBER OF ITERATE SOLUTIONS = 20     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.359739047681D 00 | 0.7508E-07 | 0.5384E 00 | 0.4315E-02 | 0.6924E-02 | 0.7982E-03 | 0.7854E-03 |

MODE NO. = 16     PHASE VELOCITY = 0.179063933876D 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.350890610474D 00 | 0.1394E-06 | 0.1592E 00 | 0.2474E-02 | 0.4360E-02 | 0.1599E-02 | 0.1573E-02 |

MODE NO. = 17     PHASE VELOCITY = 0.182949463375D 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.343438302101D 00 | 0.6070E-07 | 0.6546E 00 | 0.1492E-01 | 0.2885E-01 | 0.7316E-03 | 0.7115E-03 |

MODE NO. = 18     PHASE VELOCITY = 0.186556641550D 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.336797728292D 00 | 0.1357E-06 | 0.2156E 00 | 0.6543E-02 | 0.1392E-01 | 0.1681E-02 | 0.1645E-02 |

MODE NO. = 19     PHASE VELOCITY =  0.193268729610D 04

NUMBER OF ITERATE SOLUTIONS = 15     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.325100978304D 00 | 0.1480E-06 | 0.1738E 00 | 0.6065E-02 | 0.1591E-01 | 0.1966E-02 | 0.1917E-02 |

```
COHERENT TRANSMISSION LOSS
(LOSS IN DB, PHASE IN DEGREES)


RANGE(M) =  5000.0

SOURCE DEPTH(M) =  70.000
( 59.18/ 352.366) ( 77.91/ 283.863) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 61.35/ 175.467) ( 78.42/ 183.384) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 10000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15

SOURCE DEPTH(M) =  70.000
( 65.59/ 277.299) ( 84.65/ 267.595) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 64.15/ 102.153) ( 79.51/ 114.290) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 15000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17

SOURCE DEPTH(M) =  70.000
( 67.10/ 293.924) ( 84.69/ 319.461) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 76.06/ 136.311) ( 98.88/ 195.953) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 20000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18

SOURCE DEPTH(M) =  70.000
( 71.58/  94.362) ( 97.97/ 131.717) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 78.91/  80.528) ( 91.02/ 106.087) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)
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INCOHERENT TRANSMISSION LOSS
LOSS IN DB


RANGE(M) =  5000.0

SOURCE DEPTH(M) =  70.000
 63.09   76.47  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 61.96   75.35  IIIIII  IIIIII  IIIIII


RANGE(M) = 10000.0

SOURCE DEPTH(M) =  70.000
 66.98   83.51  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 66.07   82.85  IIIIII  IIIIII  IIIIII


RANGE(M) = 15000.0

SOURCE DEPTH(M) =  70.000
 69.14   87.82  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 69.09   87.86  IIIIII  IIIIII  IIIIII


RANGE(M) = 20000.0

SOURCE DEPTH(M) =  70.000
 70.74   90.55  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 72.04   91.48  IIIIII  IIIIII  IIIIII
```

MDPRNT =0 INC1 = 0 INC2 = 0 RHO1 =1.000 RHO2 =1.957 RHO3 =2.500 H1 = 200.000 H2 = 50.000
EPSLN =0.00010000 RANGE = 50000.000 LI1 =250 LI2 = 90 ND1 = 6 ND2 = 2

| COMPRESSIONAL VELOCITY | SHEAR VELOCITY | RAYLEIGH VELOCITY |
|---|---|---|
| 3800.000 | 2194.000 | 2017.159 |

SOUND SPEED PROFILE

| DEPTH | DEPTH | VELOCITY |
|---|---|---|
| 0.000 | 0.000 | 1502.000 |
| 0.120 | 24.000 | 1500.000 |
| 0.325 | 65.000 | 1490.000 |
| 0.525 | 105.000 | 1488.000 |
| 0.750 | 150.000 | 1486.000 |
| 1.000 | 200.000 | 1486.000 |
| | | |
| 1.000 | 200.000 | 1705.000 |
| 1.250 | 250.000 | 1730.000 |

MAXIMUM NUMBER OF MODES = 24 NUMBER OF MODES CALCULATED = 19

MODE NO. = 1 PHASE VELOCITY = 0.148843484060D 04
NUMBER OF ITERATE SOLUTIONS = 21 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.422133716290D 00 | 0.1373E-06 | 0.7149E-03 | 0.1591E-09 | 0.1717E-09 | 0.0000E 00 | 0.1888E-03 |

MODE NO. = 2 PHASE VELOCITY = 0.149293230588D 04
NUMBER OF ITERATE SOLUTIONS = 17 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.420862036572D 00 | 0.1375E-06 | 0.1324E-02 | 0.5637E-09 | 0.6116E-09 | 0.0000E 00 | 0.2192E-03 |

MODE NO. = 3 PHASE VELOCITY = 0.149882389086D 04
NUMBER OF ITERATE SOLUTIONS = 18 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.419207709825D 00 | 0.1378E-06 | 0.2292E-02 | 0.2748E-08 | 0.3003E-08 | 0.0000E 00 | 0.2979E-03 |

MODE NO. = 4 PHASE VELOCITY = 0.150614970618D 04
NUMBER OF ITERATE SOLUTIONS = 22 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.417168710480D 00 | 0.1382E-06 | 0.3174E-02 | 0.2825E-07 | 0.3114E-07 | 0.3175E-03 | 0.3538E-03 |

MODE NO. = 5 PHASE VELOCITY = 0.151191529009D 04
NUMBER OF ITERATE SOLUTIONS = 19 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.415577866589D 00 | 0.7287E-13 | 0.5248E 00 | 0.4597E 00 | 0.5104E 00 | 0.2138E-09 | 0.2161E-09 |

MODE NO. = 6 PHASE VELOCITY = 0.151497029460D 04
NUMBER OF ITERATE SOLUTIONS = 22 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.414739835466D 00 | 0.1388E-06 | 0.4275E-02 | 0.2103E-06 | 0.2344E-06 | 0.4299E-03 | 0.4283E-03 |

MODE NO. = 7 PHASE VELOCITY = 0.152606436803D 04
NUMBER OF ITERATE SOLUTIONS = 21 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.411724789517D 00 | 0.1396E-06 | 0.5730E-02 | 0.2290E-07 | 0.2587E-07 | 0.5283E-03 | 0.5281E-03 |

MODE NO. = 8 PHASE VELOCITY = 0.153963198097D 04
NUMBER OF ITERATE SOLUTIONS = 18 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.408096570143D 00 | 0.1407E-06 | 0.7254E-02 | 0.1496E-07 | 0.1719E-07 | 0.6339E-03 | 0.6239E-03 |

MODE NO. = 9 PHASE VELOCITY = 0.155576272963D 04
NUMBER OF ITERATE SOLUTIONS = 20 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.403865267339D 00 | 0.1419E-06 | 0.8970E-02 | 0.1677E-07 | 0.1969E-07 | 0.7359E-03 | 0.7244E-03 |

MODE NO. = 10 PHASE VELOCITY = 0.157480952975D 04
NUMBER OF ITERATE SOLUTIONS = 20 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.398980650579D 00 | 0.1433E-06 | 0.1098E-01 | 0.2660E-07 | 0.3205E-07 | 0.8336E-03 | 0.8295E-03 |

MODE NO. = 11 PHASE VELOCITY = 0.159703277065D 04
NUMBER OF ITERATE SOLUTIONS = 20 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.393428702444D 00 | 0.1450E-06 | 0.1344E-01 | 0.5720E-07 | 0.7112E-07 | 0.9433E-03 | 0.9351E-03 |

MODE NO. = 12 PHASE VELOCITY = 0.162271187717D 04
NUMBER OF ITERATE SOLUTIONS = 22 THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.387202768130D 00 | 0.1468E-06 | 0.1686E-01 | 0.1710E-06 | 0.2209E-06 | 0.1057E-02 | 0.1046E-02 |

MAXIMUM NUMBER OF MODES = 24          NUMBER OF MODES CALCULATED = 19

MODE NO. = 13     PHASE VELOCITY = 0.1652304214850 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.380268067508C 00 | 0.1487E-06 | 0.2251E-01 | 0.7742E-06 | 0.1048E-05 | 0.1172E-02 | 0.1161E-02 |

MODE NO. = 14     PHASE VELOCITY = 0.168620059916D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.372623833150D 00 | 0.1497E-06 | 0.3558E-01 | 0.6561E-05 | 0.9400E-05 | 0.1289E-02 | 0.1269E-02 |

MODE NO. = 15     PHASE VELOCITY = 0.172393760669D 04
NUMBER OF ITERATE SOLUTIONS = 23     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.364467094563D 00 | 0.1392E-06 | 0.1237E 00 | 0.2153E-03 | 0.3304E-03 | 0.1300E-02 | 0.1274E-02 |

MODE NO. = 16     PHASE VELOCITY = 0.174594465334D 04
NUMBER OF ITERATE SOLUTIONS = 19     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.359873109102D 00 | 0.3165E-07 | 0.8095E 00 | 0.5016E-02 | 0.8039E-02 | 0.3057E-03 | 0.2965E-03 |

MODE NO. = 17     PHASE VELOCITY = 0.177266608948D 04
NUMBER OF ITERATE SOLUTIONS = 14     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.354448327548D 00 | 0.1425E-06 | 0.1286E 00 | 0.1646E-02 | 0.2789E-02 | 0.1432E-02 | 0.1402E-02 |

MODE NO. = 18     PHASE VELOCITY = 0.181772712071D 04
NUMBER OF ITERATE SOLUTIONS = 22     THE EIGENFUNCTION WAS SCALED DOWN 0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.345661636204D 00 | 0.1146E-06 | 0.3228E 00 | 0.6090E-02 | 0.1144E-01 | 0.1232E-02 | 0.1201E-02 |

MODE NO. = 19     PHASE VELOCITY =  0.1845507288840 04
NUMBER OF ITERATE SOLUTIONS = 18     THE EIGENFUNCTION WAS SCALED DOWN  0 TIME(S)

| WAVE NUMBER | WATER ABSORPTION | LAYER 2 ATTEN RATIO | COMP ATTEN RATIO | SHEAR ATTEN RATIO | AIR/H2O SCATTER | H2O/2ND SCATTER |
|---|---|---|---|---|---|---|
| 0.340458438998D 00 | 0.7817E-07 | 0.5512E 00 | 0.1384E-01 | 0.2788E-01 | 0.8535E-03 | 0.8241E-03 |

```
COHERENT TRANSMISSION LOSS
(LOSS IN DB, PHASE IN DEGREES)


RANGE(M) = 25000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18

SOURCE DEPTH(M) =  70.000
( 75.96/ 135.462) (108.38/  23.682) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 74.35/ 273.483) ( 90.41/ 273.839) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 30000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 16
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 19

SOURCE DEPTH(M) =  70.000
( 77.98/ 247.720) (100.95/ 204.795) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 84.95/ 354.092) (114.38/ 142.139) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 35000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 12
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 16
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 19

SOURCE DEPTH(M) =  70.000
( 77.49/ 288.267) (100.42/ 307.415) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 72.25/  62.076) ( 92.70/  51.892) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


RANGE(M) = 40000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
```

```
INCOHERENT TRANSMISSION LOSS
LOSS IN DB


RANGE(M) = 25000.0

SOURCE DEPTH(M) =  70.000
 72.45    92.93  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 73.73    94.01  IIIIII  IIIIII  IIIIII


RANGE(M) = 30000.0

SOURCE DEPTH(M) =  70.000
 73.84    94.82  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 75.39    96.36  IIIIII  IIIIII  IIIIII


RANGE(M) = 35000.0

SOURCE DEPTH(M) =  70.000
 75.08    96.41  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 76.79    98.37  IIIIII  IIIIII  IIIIII


RANGE(M) = 40000.0
```

```
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 12
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 13
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 16
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 19

SOURCE DEPTH(M) =  70.000                                                                 SOURCE DEPTH(M) =  70.000
( 84.36/ 354.742) (100.71/ 353.959) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  76.22   97.81  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000                                                                 SOURCE DEPTH(M) = 140.000
( 82.12/ 104.993) (105.92/  74.268) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  77.96  100.04  IIIIII  IIIIII  IIIIII


RANGE(M) = 45000.0                                                                        RANGE(M) = 45000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 12
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 13
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 16
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 19

SOURCE DEPTH(M) =  70.000                                                                 SOURCE DEPTH(M) =  70.000
( 75.46/ 316.897) ( 96.79/ 306.807) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  77.27   99.06  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000                                                                 SOURCE DEPTH(M) = 140.000
( 76.27/ 153.151) ( 99.60/ 149.173) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  78.95  101.41  IIIIII  IIIIII  IIIIII


RANGE(M) = 50000.0                                                                        RANGE(M) = 50000.0
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  4
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO.  5
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 12
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 13
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 14
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 15
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 16
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 17
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 18
EXPONENTIAL (THUS CONTRIBUTION AT ALL SOURCE/RECEIVER DEPTHS) SET TO ZERO FOR MODE NO. 19

SOURCE DEPTH(M) =  70.000                                                                 SOURCE DEPTH(M) =  70.000
( 77.97/ 254.880) ( 99.44/ 266.108) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  78.26  100.20  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000                                                                 SOURCE DEPTH(M) = 140.000
( 80.38/ 103.657) (104.49/  85.910) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)  79.80  102.52  IIIIII  IIIIII  IIIIII
```

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## Appendix A

## NORMAL-MODE SUBROUTINES

Detailed documentation [A1] is available for the normal-mode calculations. Although the complete model theory and its FORTRAN coding may be found in Ref. A1, we present here an outline of the salient features, with particular emphasis on the major changes and improvements made to the routines since the publication of Ref. A1.

For a shear-supporting solid basement, PROGRAM MOATL calls subroutines SOLID, HALFS, and ITRTS for the normal-mode calculations. (The fluid-basement case is similar, but less complicated, and will not be discussed here.) The three subroutines used in the solid-basement case correspond, respectively, to PROGRAM SOLID, SUBROUTINE HALF, and SUBROUTINE ITERATE of Ref. A1.

The normal modes of a given environment are the eigenfunctions of Eq. (A1). Application of appropriate boundary conditions will yield a set of $N$ discrete modes, with corresponding modal wave numbers, or eigenvalues $k_n$ ($n = 1, \ldots, N$). Due to the appearance of the depth-dependent $c(\zeta)$, Eq. (A1) must be replaced by a finite-difference equivalent for numerical solution; the water and sediment layers must therefore be divided into a number of intervals, or incremental steps, and these are user-specified through the input variables LI1 and LI2.

$$\frac{d^2 u_n}{d\zeta^2} + H_1^2 \left[ \left( \frac{\omega}{c(\zeta)} \right)^2 - k_n^2 \right] u_n = 0. \tag{A1}$$

Normal-mode calculations begin in SOLID with a determination of the maximum number of modes. The calculation of modal parameters follows. The mode order is designated and upper and lower bounds are set for the eigenvalue. HALFS is then called to repeatedly shorten the length of this interval, thus converging on the correct eigenvalue. For each new trial eigenvalue obtained, a call to ITRTS is made, where a set of "three-point extrapolation" equations (the finite-difference equivalent of Eq. (A1)) is used to generate, from bottom to surface, the corresponding trial eigenfunction. Depending on the value of the trial eigenfunction at the air/water surface, the trial eigenvalue becomes either the new left- or new right-hand bound of the now-smaller eigenvalue interval. Generally ten or more calls are made to ITRTS before an acceptable eigenvalue is found.

The correct eigenvalue has an eigenfunction which fulfills the boundary condition of being zero at the air/water (pressure-release) surface. Alternatively, HALFS requires that either of two criteria are met: (1) the surface value of the trial eigenfunction is less than EPLON *and* the difference between the present trial eigenvalue and either the left or the right bound of the present interval is less than $10^{-12}$; or (2) the difference between the trial eigenvalue and either bound of the interval is less than PPRCN. The variable PPRCN is defined as $10^{-\mathrm{PRCSN}}$, where PRCSN is one less than the approximate number of decimal digits associated with the mantissa of a DOUBLE PRECISION floating-point number. What this means is that for criterion (2), the eigenvalue is correct to within the limits of the machine. The machine-dependent PRCSN is adjusted by a PARAMETER statement in MOATL.

For criterion (1), EPLON is defined as the product of EPSLN (a preselected small number) and UMAX (the maximum value that the unnormalized trial eigenfunction takes on). When the correct eigenfunction is determined, control returns to SOLID, where the eigenfunction is normalized (using the Simpson's rule numerical integral technique) according to the solid-basement equivalent of Eq. (A2).

The value of EPSLN is usually selected on the assumption that the maximum value of the eigenfunction is of the order of magnitude one. Since the surface value is checked in HALFS using the unnormalized trial eigenfunction, EPSLN is redefined as EPLON, as stated above. In this way, the normalized eigenfunction will have a surface value less than the input variable EPSLN, if criterion (1) is met.

$$\int_0^\infty \rho(\zeta)\; u_n^2(\zeta)\; d\zeta = 1. \tag{A2}$$

In this connection, we mention another major change in the programming. It was found in some cases that the unnormalized eigenfunction generated in ITRTS took on very large values, sometimes larger than PMGTD, which is defined as $10^{\mathrm{MGNTD}}$. (The variable MGNTD depends on one-half the dynamic range of a real constant and, being machine-dependent, is defined for convenience by a PARAMETER statement in MOATL.) In the course of normalization of the eigenfunction, certain single-precision variables are set equal to the sum of the squares of unnormalized eigenfunction values. Thus a value larger than PMGTD, when squared, will cause a floating point overflow in the machine, with subsequent termination of execution and/or the generation of erroneous results. This problem was eliminated in the following way. During generation of the trial eigenfunction in ITRTS, whenever a value larger than PMGTD is encountered, the entire eigenfunction thus far generated is scaled down by dividing the value at each incremental depth by PMGTD. If a given value is so small that such a division would cause a floating point underflow, that value is redefined to be zero. Then the generation of the rest of the eigenfunction resumes. Whenever such a scaling of the eigenfunction takes place, a counter, IFG, is increased by one. The value of this counter is passed back to HALFS along with the trial eigenvalue and eigenfunction. In HALFS, the eigenvalue interval redefinition (described above) depends on the surface values of the trial eigenfunctions, so the scaling information must be taken into account.

There is another important change in the programming of the eigenfunction generation to be discussed. It is stated in Ref. A1 that for certain downward-refracting sound speed profiles, the lowest order eigenfunctions generated may exhibit large amplitude fluctuations near the surface. Previously, the eigenfunction was zeroed (the values at each of the incremental depths were set to zero) from this point up to the air/water surface. Recently, a method of calculating the actual, albeit small, values of the function has been implemented to replace the zeroing procedure.

The phase velocity, $c_{p,n} \equiv \omega/k_n$, increases monotonically with mode-order $n$. Consider a sound-speed profile which is strongly downward refracting near the surface, such as the deep water profile shown in Fig. A1. It may happen that the phase velocities of the lowest order eigenfunctions, although larger than $c_{\min}$ as they must be, are smaller than the surface value of the sound speed profile. (In Fig. A1, this is true of the $n$th mode, but not the $(n+1)$th mode.) Thus for some depth value $z_m$, we have

$$k_n > \frac{\omega}{c_1(z)} \quad \text{for} \quad 0 \leqslant z < z_m \, .$$

The result is that solutions of Eq. (A1) for $z < z_m$ are exponential rather than sinusoidal, and further iteration of the solution may become unstable.

The program will now calculate the values of the eigenfunctions for $z < z_m$ (rather than setting them to zero). The technique, for a given mode, is simply to start the iteration again, this time at the air/water surface, and generate the eigenfunction down to $z_m$. The two functions are then matched at $z_m$ to obtain the entire scaled eigenfunction.

To discuss this technique, it is convenient to use the symbols and notation of Ref. A1, to which the reader is referred for appropriate definitions.

The flag IZERO, which in the past controlled the zeroing procedure, now controls the matching procedure. It is set to one for the final call to SUBROUTINE ITRTS, which is the call that generates the acceptable eigenfunction. Note that when this final call is made the eigenvalue $k_n$ has already been

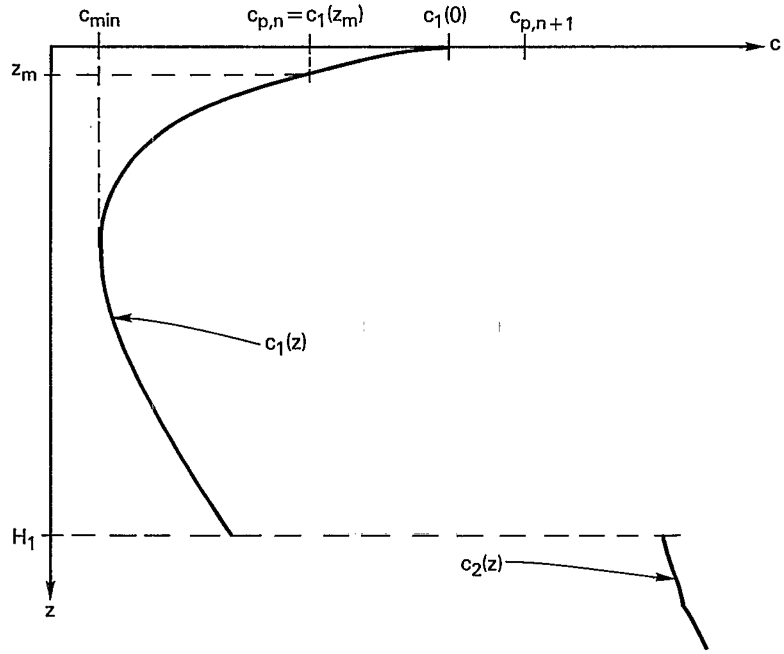


Fig. A1 — Hypothetical phase velocity configuration. For each mode order $\leqslant n$, there will be a depth $z_m$ for which $c_1(z)$ (with $z < z_m$) will be greater than the corresponding modal phase velocity. For modes of order $> n$, $z_m = 0$.

determined. The matching procedure is not used (or needed) in the eigenvalue search procedure. When IZERO = 1, the DO 6 loop is executed, which searches the water layer for $z_m$. It may also happen that $k_n > [\omega/c_1(z)]$ everywhere in the water layer. In this case, the DO 8 loop searches the sediment layer for $z_m$ ($z_m$ is always less than $H_1 + H_2$). The variable MATCH stores the number of the incremental layer corresponding to $z_m$. Then ITRTS proceeds, as usual, to generate the eigenfunction from bottom up to $z_m$. Then control transfers to statement number 131, where we begin a similar calculation from the surface downward. The flag IZERO is set to two; this instructs SOLID to print a message informing the user that the present mode has been "matched" at depth $z_m$. Next, to accomodate the pressure-release boundary condition, we set $Z_n^{(1)}(0) = 0$. We estimate the value at the next incremental depth down from the surface by using the Taylor polynomial of second order, expanded about zero:

$$Z_n^{(1)}(t_1) = Z_n^{(1)}(0) + t_1 \left.\frac{dZ_n^{(1)}}{dz}\right|_0 + \frac{t_1^2}{2!} \left.\frac{d^2Z_n^{(1)}}{dz^2}\right|_0 .$$

Until normalization, the slope of the eigenfunction is arbitrary. To avoid the problem of "exponential runaway," we therefore choose the very small value of $10^{-10}$ for $\left.\frac{dZ_n^{(1)}}{dz}\right|_0$. We can solve Eq. (A1) for $\left.\frac{d^2Z_n^{(1)}}{dz^2}\right|_0$, and the result is zero. Thus we are left without next amplitude, YOU(2):

$$Z_n^{(1)}(t_1) = t_1 \times 10^{-10}.$$

To obtain YOU(3) through YOU(N1) (or through YOU(MATCH) if MATCH < N1, *i.e.*, $z_m < H_1$) we employ the "three-point extrapolation" finite-difference equivalent of Eq. (A1). For $j = 2, \ldots,$ N1−1 we have:

$$Z_n^{(1)}(jt_1) = \left\{ Z_n^{(1)}((j-1)t_1) \left[ 24 - 10 \left( \frac{\omega^2 t_1^2}{c_1^2((j-1)t_1)} - k_n^2 t_1^2 \right) \right] \right.$$
$$\left. - Z_n^{(1)}((j-2)t_1) \left( 12 + \frac{\omega^2 t_1^2}{c_1^2((j-2)t_1)} - k_n^2 t_1^2 \right) \right\} \left( 12 + \frac{\omega^2 t_1^2}{c_1^2(jt_1)} - k_n^2 t_1^2 \right)^{-1} .$$

If MATCH > N1, the above calculation will procede all the way to the boundary value of the eigenfunction in the water at the water/sediment interface: YOU(N1) = $Z_n^{(1)}(H_1)$. From the boundary conditions, we immediately obtain the boundary value of the eigenfunction in the sediment layer: YOU(N1PLS1) = $Z_n^{(2)}(H_1) = (\rho_1/\rho_2)\, Z_n^{(1)}(H_1)$. To obtain the next point, we again use the Taylor polynomial, this time expanded about $H_1$:

$$Z_n^{(2)}(H_1 + t_2) = Z_n^{(2)}(H_1) + t_2 \left. \frac{dZ_n^{(2)}}{dz} \right|_{H_1} + \frac{t_2^2}{2!} \left. \frac{d^2 Z_n^{(2)}}{dz^2} \right|_{H_1} .$$

Now

$$\left. \frac{dZ_n^{(2)}}{dz} \right|_{H_1} = \left. \frac{dZ_n^{(1)}}{dz} \right|_{H_1} \equiv \left. \frac{dZ_n}{dz} \right|_{H_1}$$

because of the boundary conditions. We program the derivative numerically:

$$\left. \frac{dZ_n}{dz} \right|_{H_1} = (-3Z_n^{(1)}(H_1 - 2t_1) + 4Z_n^{(1)}(H_1 - t_1) - Z_n^{(1)}(H_1))/2t_1 .$$

From Eq. (A1), we have the second derivative:

$$\left. \frac{d^2 Z_n^{(2)}}{dz^2} \right|_{H_1} = - \left[ \frac{\omega^2}{c_2^2(H_1)} - k_n^2 \right] Z_n^{(2)}(H_1) .$$

Substituting these values into the Taylor polynomial, one obtains the value of $Z_n^{(2)}(H_1 + t_2)$.

From this point on, *i.e.*, for calculation of YOU(N1PLS3) through YOU(MATCH), we again make use of the finite-difference equivalent of Eq. (A1); the procedure is straightforward and we shall not repeat the details.

The quantity YOU(MATCH) is the value of the eigenfunction at $z_m$, as calculated by the original procedure of integrating upward from the bottom. The variable PPLUS1 is the same quantity, but calculated by the present procedure of starting at the top and integrating downward. It remains to "match" the solutions, which is accomplished by the DO 149 loop. Each of the values, from the surface to $z_m$, is multiplied by the factor YOU(MATCH)/PPLUS1. This ensures the continuity of the eigenfunction at $z_m$. Continuity of its first derivative follows from the condition that the correct eigenvalue has already been determined. Continuity of higher derivatives follows from Eq. (A1). This completes the task, since normalization takes place later in SOLID.

With control returned from HALFS to SOLID, the eigenfunction is normalized, as stated above. Next, the scattering ratios and the bottom attenuation ratios are determined (see Eqs. (A3) and (A4)). The quantity $\Gamma_{0,n}$ is termed AIRH2O(I) and $\Gamma_{1,n}$ is termed H2O2ND(I), where I designates the mode order. The quantity $\gamma_n^{(2)}$ is termed ATTEN2(I), $\gamma_n^{(3c)}$ is termed ATTENC(I), and $\gamma_n^{(3s)}$ is termed ATTENS(I). The values of these parameters are as defined in the old version of the program (see Ref. A1); however, the code has been modified to take into account the discussed procedure of scaling the eigenfunction. The only numerical change is in the formula used for calculating derivatives of the eigenfunction at the surface and bottom. For example, whereas we previously [A1] defined

```
DYOUA=(YOU(2)*ANORM-YOU(1)*ANORM)/DL1,
```

we now use the more accurate formula:

```
DYOUA=(-3.*YOU(1)*ANORM+4.*YOU(2)*ANORM -YOU(3)*ANORM)/2./DL1.
```

In the present version of SOLID, normalization is accomplished first, thus we have programmed YOU(J)*ANORM as UNRM1(I,J) or UNRM2(I,J), where the mode order I has been inserted.

$$\delta = \epsilon_2\gamma_n^{(2)} + \epsilon_{3c}\gamma_n^{(3c)} + \epsilon_{3s}\gamma_n^{(3s)} + S_{0,n} + S_{1,n} + \alpha_n. \tag{A3}$$

$$\left.\begin{aligned} S_{0,n} &= 2\sigma_0^2\left[\left(\frac{\omega}{c_1(0)}\right)^2 - k_n^2\right]\Gamma_{0,n} \\ S_{1,n} &= 2\sigma_1^2\left[\left(\frac{\omega}{c_1(H_1)}\right)^2 - k_n^2\right]\Gamma_{1,n} \end{aligned}\right\}. \tag{A4}$$

In many cases, attenuation of the modal field due to absorption by the water is not appreciable. In some cases, however, this loss mechanism has been found to yield a significant contribution, thus it is now included in the transmission loss calculated by MOATL *via* Eq. (A3). In a manner similar to that of the sediment layer and basement, we may write the attenuation as $\alpha_n = \epsilon_1\gamma_n^{(1)}$, where $\epsilon_1$ is the plane-wave absorption coefficient in an infinite medium of ocean water. Whereas $\epsilon_2$, $\epsilon_{3c}$, and $\epsilon_{3s}$ depend on the particular sediment and basement chosen (and are input variables), $\epsilon_1$ may by taken as constant and given empirically by [A2]:

$$\epsilon_1 = \frac{(0.1)\, f^2}{1 + f^2} + \frac{40 f^2}{4100+f^2} + 2.75 \times 10^{-4} f^2,$$

where $f$ is the frequency in kHz and $\epsilon_1$ is given in dB/kyd. The coefficient $\epsilon_1$ is termed EPW by SOLID, where it is converted to nepers/m. The quantity $\gamma_n^{(1)}$ measures the degree of interaction of the $n$th mode with the absorption mechanism and is given (in a form similar to that of $\gamma_n^{(2)}$), by:

$$\gamma_n^{(1)} = \rho_1 \frac{\omega}{k_n} \int_0^{H_1} \frac{[u_n^{(1)}(z)]^2}{c_1(z)}\, dz.$$

The superscript on the eigenfunction refers to the layer number, in this case the water layer.

## REFERENCES

A1. J.F. Miller and F. Ingenito, "Normal Mode FORTRAN Programs for Calculating Sound Propagation in the Ocean," NRL Memorandum Report 3071, June 1975.

A2. R.J. Urick, *Principles of Underwater Sound* (McGraw-Hill, New York, 1975), 2nd ed., p. 102.

## Appendix B

## FORTRAN NAMELIST OF PROGRAM MOATL VARIABLES AND SYSTEM SUBROUTINES AND FUNCTIONS

All the variables of PROGRAM MOATL are alphabetically listed below with their corresponding definitions. For the arrays in the list, the index N denotes mode-order, the index I denotes range, and the variables J1 and J2 denote receiver and source identification, respectively. Occasionally, reference is made to the "SR group" or the "LR group." For further explanation and definitions, see the section "Step-By-Step Analysis—Part 3."

Most of the variables occurring in the subroutines have been described elsewhere [B1]; some name changes and new variables are defined in Appendix A.

The computer system library functions appearing in the FORTRAN code are described at the end of this Appendix in Table B1.

The on-line plotter software includes the following subroutines, which are not discussed here: CENTRE, CNUMBR, ENDPLT, NXAXIS, NYAXIS, ORIGIN, PLOT, PLOTS, and SYMBOL.

ABSOR(N): An array containing the water absorption, $\alpha_n$, calculated in the subroutines.

AIRH2O(N): An array containing the scattering ratios $\Gamma_{0,n}$, used in calculating the attenuation due to interaction of the various modes with a statistically rough boundary at the air/water interface.

AKN(N): An array containing the eigenvalues (modal wave numbers), $k_n$, as calculated by the subroutines.

ATTENC(N): An array containing the basement compressional attenuation ratios, $\gamma_n^{(3c)}$.

ATTENS(N): An array containing the basement shear attenuation ratios, $\gamma_n^{(3s)}$.

ATTEN2(N): An array containing the sediment attenuation ratios, $\gamma_n^{(2)}$.

A1: The number plus fraction (starting at the air/water surface) of the incremental layer corresponding to the source or receiver depth.

A2: In a range-dependent model, A1 is used (as defined above) for the SR calculation and A2 (defined the same way) is used for the LR calculation.

CBS: the range-interpolated value of $c_1(H)$, the sound speed at the bottom of the water layer.

CB1: The value of $c_1(H)$ at the SR range.

CB2: The value of $c_1(H)$ at the LR range.

COMP: The compressional velocity, $c_{3c}$, of the basement.

COPL(J1,J2,I): An array containing the coherent transmission loss or transmission-loss anomaly in decibels.

CTS: The range-interpolated value of $c_1(0)$, the sound speed at the surface of the water layer.

CT1: The value of $c_1(0)$ at the SR range.

CT2: The value of $c_1(0)$ at the LR range.

C1(J): An array containing the sound-speed profile in the water layer, $c_1(z)$.

C2(J): An array containing the sound-speed profile in the sediment layer, $c_2(z)$.

DBMAX: The maximum loss (in dB) on the vertical axis of the plot.

DBMIN: The minimum loss (in dB) on the vertical axis of the plot.

DEPRE(J1): An array containing the receiver depths.

DEPSO(J2): An array containing the source depths.

DLTA1: That fraction of an incremental layer by which the source or receiver depth exceeds the depth of the nearest shallower incremental layer boundary.

DLTA2: In a range-dependent model, DLTA1 is used (as defined above) for the SR calculation and DLTA2 (defined the same way) is used for the LR calculation.

DR: The distance (increment) between ranges at which transmission loss (or loss anomaly) is calculated.

DX: The number of kilometers per inch on the horizontal (range) axis of the plot.

DY: The number of decibels per inch on the vertical (loss) axis of the plot.

EIGVL1(N): An array containing the eigenvalues, $k_n$, at the SR range.

EIGVL2(N): An array containing the eigenvalues, $k_n$, at the LR range.

EPSLN: The criterion for the accuracy of the determined eigenvalues and eigenfunctions, *i.e.*, the amount by which the air/water surface value of the normalized eigenfunction may differ from the pressure-release boundary condition requirement of being identically zero.

EP1: The plane-wave absorption coefficient of the sediment, $\epsilon_2$, expressed in dB/Hz-m.

EP2: The basement compressional plane-wave absorption coefficient, $\epsilon_{3c}$, expressed in dB/Hz-m.

EP3: The basement shear plane-wave absorption coefficient, $\epsilon_{3s}$, expressed in dB/Hz-m.

EP4: Same as EP1, expressed in nepers/m.

EP5: Same as EP2, expressed in nepers/m.

EP6: Same as EP3, expressed in nepers/m.

F: The source frequency, $f$.

GA(N): An array containing the range-interpolated values of the water absorption, $\alpha_n$.

GB(N): An array containing the range-interpolated values of the scattering ratios $\Gamma_{1,n}$.

GT(N): An array containing the range-interpolated values of the scattering ratios $\Gamma_{0,n}$.

G1(N): An array containing the range-interpolated values of the attenuation ratios $\gamma_n^{(2)}$.

G2(N): An array containing the range-interpolated values of the attenuation ratios $\gamma_n^{(3c)}$.

G3(N): An array containing the range-interpolated values of the attenuation ratios $\gamma_n^{(3s)}$.

HS: The range-interpolated value of the water layer thickness (*i.e.*, the water depth), $H_1$.

H10: The value of the water layer thickness $H_1$ at the receiver, *i.e.*, at zero range.

H11: The value of the water layer thickness $H_1$ at the SR range.

H12: The value of the water layer thickness $H_1$ at the LR range.

H2: The value of the sediment layer thickness $H_2$.

H2O2ND(N): An array containing the scattering ratios $\Gamma_{1,n}$, used in calculating the attenuation due to interaction of the various modes with a statistically rough boundary at the water/sediment interface.

I: A DO-LOOP index used primarily for the DO 300 range loop.

IA1: The truncated integer value of A1.

IA2: The truncated integer value of A2.

IFREQ: The DO 340 frequency loop index.

III: An input flag used to specify whether the basement is to be modeled as a fluid or a solid.

IM: A DO-LOOP index denoting mode-order.

INC1: A variable having a value one greater than the number of depth-increment values to be skipped between printed-out values of the eigenfunctions in the water layer.

INC2: A variable having a value one greater than the number of depth-increment values to be skipped between printed-out values of the eigenfunctions in the sediment layer.

IPLOT: An input flag used to specify whether or not plotting of transmission loss (or loss anomaly) *vs* range is to be included in the output.

ISPRD: An input flag used to specify whether transmission loss or transmission loss anomaly is to be calculated.

J: An implied DO-LOOP index used for the sound-speed profiles.

J1: A DO-LOOP index used for denoting the various receiver depths.

J2: A DO-LOOP index used for denoting the various source depths.

KA: A parameter whose value flags the normal-mode subroutines to store the calculated eigenfunctions in either the SR array UNRM1(N,K) or the LR array UNRM2(N,K).

LI1: The number of incremental steps into which the water layer is to be divided for the numerical calculations.

LI2: The number of incremental steps into which the sediment layer is to be divided for the numerical calculations.

MDPRNT: An input flag used to specify whether or not calculated normal-mode amplitude functions (eigenfunctions), $u_n(z)$, are to be printed out.

MGNTD: A machine-dependent parameter set equal to approximately half (but not larger than half) the dynamic range of a single-precision real constant.

NDRE: The number of receiver depths for which calculations are to be performed.

NDSO: The number of source depths for which calculations are to be performed.

ND1: The number of points (depths) in the water layer at which the sound speed is supplied.

ND2: The number of points (depths) in the sediment layer at which the sound speed is supplied.

NMFREQ: The number of source frequencies (or more accurately, the number of separate environmental cases) for which the entire transmission-loss calculations are to be performed.

NMODE: The total number of modes that exist and/or that are to be used in the calculations.

NRBUF: The number of range points at which environmental data are to be supplied.

NRCALC: The number of range points at which loss calculations are to be performed.

N1: LI1+1 in the subroutines.

N11: LI1+1 at the SR environmental data set.

N12: LI1+1 at the LR environmental data set.

N2: LI2+1 in the subroutines.

PHASE(J1,J2): An array containing the phase angles in degrees of the coherent transmission loss.

PL(J1,J2,I): An array containing tne incoherent transmission loss or transmission-loss anomaly in decibels.

PLTAR(K): An array used solely by the machine for buffering the execution-generated plot commands onto Calcomp plotter tape.

PMGTD: The value of ten raised to the power MGNTD.

PPRCN: The value of ten raised to the power (– PRCSN).

PRCSN: A machine-dependent parameter specifying one less than the approximate number of decimal digits associated with the mantissa of a DOUBLE PRECISION real constant.

Q: A variable containing the product of Q1 and Q2.

QC(J1,J2): An array containing the intermediate results, $\sum_{n=1}^{N'} \frac{u_n(\zeta_0)\,u_n'(\zeta)\,r^{1/2}}{\phi_n^{1/2}} e^{-\Delta_n r} \cos \phi_n$, $1 \leqslant N' \leqslant N$, which are used in calculating the coherent loss.

QQ: The average attenuation coefficient, $\Delta_n$, times the range, $r$.

QS(J1,J2): An array containing the intermediate results, $\sum_{n=1}^{N'} \frac{u_n(\zeta_0)\,u_n'(\zeta)\,r^{1/2}}{\phi_n^{1/2}} e^{-\Delta_n r} \sin \phi_n$, $1 \leqslant N' \leqslant N$, which are used in calculating the coherent loss.

Q1: The term $\frac{u_n(\zeta_0)\,u_n'(\zeta)\,r^{1/2}}{\phi_n^{1/2}}$.

Q2: The term $e^{-\Delta_n r}$.

RAN(I): An array containing the range points, $r$, at which results are to be calculated.

RANGE1: The range of the SR environmental data set.

RANGE2: The range of the LR environmental data set.

RA1(N): An array containing the water absorption, $\alpha_n$, at the SR range.

RA2(N): An array containing the water absorption, $\alpha_n$, at the LR range.

RB1(N): An array containing the scattering ratios $\Gamma_{1,n}$ at the SR range.

RB2(N): An array containing the scattering ratios $\Gamma_{1,n}$ at the LR range.

RE(J1,N): An array containing the depth-interpolated values of $u_n(\zeta_0)$, which are the eigenfunction values at the various receiver depths.

REC: A PARAMETER which specifies the maximum number of receiver depths.

REC5: A PARAMETER which is greater than or equal to REC and which is an integral multiple of five.

RERHO1: The water-layer density $\rho_1$ at the receiver, *i.e.*, at zero range.

RERHO2: The ratio of the density of the sediment layer to that of water, *i.e.*, $\rho_2$, at the receiver range.

RHO1: The water-layer density $\rho_1$ at the variable range $r$.

RHO2: The ratio of the density of the sediment layer to that of water, *i.e.*, $\rho_2$, at the variable range $r$.

RHO3: The ratio of the density of the basement to that of water, *i.e.*, $\rho_3$, at the variable range $r$.

RMAX: The range of the final input environmental data set and/or the maximum range at which calculations are desired.

RMXKM: The length, in km, of the range axis for plotted output.

RNG: A PARAMETER which specifies the maximum number of range points at which loss calculations are to be performed.

RT1(N): An array containing the scattering ratios $\Gamma_{0,n}$ at the SR range.

RT2(N): An array containing the scattering ratios $\Gamma_{0,n}$ at the LR range.

R11(N): An array containing the sediment-attenuation ratios $\gamma_n^{(2)}$ at the SR range.

R12(N): An array containing the sediment-attenuation ratios $\gamma_n^{(2)}$ at the LR range.

R21(N): An array containing the basement compressional attenuation ratios $\gamma_n^{(3c)}$ at the SR range.

R22(N): An array containing the basement compressional attenuation ratios $\gamma_n^{(3c)}$ at the LR range.

R31(N): An array containing the basement shear attenuation ratios $\gamma_n^{(3s)}$ at the SR range.

R32(N): An array containing the basement shear attenuation ratios $\gamma_n^{(3s)}$ at the LR range.

SA(N): An array containing the values of the integrals $\int_0^r \alpha_n(r)\, dr$.

SB(N): An array containing the values of the integrals $\int_0^r \Gamma_{1,n}(r)\, dr$.

SCALE: A variable which contains the interpolation factor $\Delta$ used in the linear range interpolation. (See the section "Step-By-Step Analysis—Part 7," specifically Eqs. (16) and (17).)

SE(N): An array containing the values of the integrals $\phi_n = \int_0^r k_n(r)\, dr$.

SHEAR: The shear velocity, $c_{3s}$, of the basement.

SIG0: The root-mean-square wave height $\sigma_0$, used in calculating the term $S_{0,n}$.

SIG1: The root-mean-square excursion of the water/sediment interface $\sigma_1$ , used in calculating the term $S_{1,n}$.

SM(J2,N): An array containing the depth-interpolated values of $u'_n(\zeta)$, which are the eigenfunction values at the various source depths.

SOC: A PARAMETER which specifies the maximum number of source depths.

ST(N): An array containing the values of the integrals $\int_0^r \Gamma_{0,n}(r)\, dr$.

S1(N): An array containing the values of the integrals $\int_0^r \gamma_n^{(2)}(r)\ dr$.

S2(N): An array containing the values of the integrals $\int_0^r \gamma_n^{(3c)}(r)\ dr$.

S3(N): An array containing the values of the integrals $\int_0^r \gamma_n^{(3s)}(r)\ dr$.

TH: The name of a COMMON block used for variables common to PROGRAM MOATL, SUBROUTINE HALFF, and SUBROUTINE HALFS.

TITLE(K): Any alphanumeric label used to identify the computer run.

TN: The name of a COMMON block used for variables common to PROGRAM MOATL, SUBROUTINE FLUID, and SUBROUTINE SOLID.

TNH: The name of a COMMON block used for variables common to PROGRAM MOATL, SUBROUTINE FLUID, SUBROUTINE SOLID, SUBROUTINE HALFF, and SUBROUTINE HALFS.

TNI: The name of a COMMON block used for variables common to PROGRAM MOATL, SUBROUTINE FLUID, SUBROUTINE SOLID, SUBROUTINE ITRTF, and SUBROUTINE ITRTS.

TNIH: The name of a COMMON block used for variables common to PROGRAM MOATL and all subroutines.

UNRM1(N,J2): An array containing the eigenfunctions $u_n'(z)$ at the SR range.

UNRM2(N,J2): An array containing the eigenfunctions $u_n'(z)$ at the LR range.

WN(N): An array containing the range-interpolated values of the eigenvalues $k_n$.

X: The x-coordinate of a point to be plotted on the graph.

XLENG: The to-scale length, in inches, of the range axis for the plotted output graph.

XXR1: The depth-interpolated value of the eigenfunction at the source depth, at the SR range.

XXR2: The depth-interpolated value of the eigenfunction at the source depth, at the LR range.

X2: XLENG divided by two.

Y: The y-coordinate of a point to be plotted on the graph.

YLENG: The length, in inches, of the loss axis for the plotted output graph.

Y2: YLENG divided by two.

Z1(J): An array containing the sound-speed-profile depth points in the water layer.

Z2(J): An array containing the sound-speed-profile depth points in the sediment layer.

Table B1 — System Library Functions

| Form | Definition | Mode of Argument | Mode of Result |
|---|---|---|---|
| ABS(X) | Absolute value of X | Real | Real |
| ALOG10(X) | Logarithm to base 10 of X | Real | Real |
| ATAN2(X,Y) | Arctangent† of (X divided by Y) | Real | Real |
| DCOS(D) | Cosine of D† | Double | Double |
| DSIN(D) | Sine of D† | Double | Double |
| DSQRT(D) | Square root of D | Double | Double |
| EXP(X) | *e* raised to power X | Real | Real |
| FLOAT(I) | Convert integer I to real | Integer | Real |
| IFIX(X) | Truncate real X to integer | Real | Integer |

†in radians

**REFERENCES**

B1. J.F. Miller and F. Ingenito, NRL Memorandum Report 3071, June 1975.

## Appendix C

## FORTRAN LISTING AND CROSS-REFERENCE OF PROGRAM AND SUBROUTINES

The FORTRAN code for each of the main program and subroutines is listed on the following pages. Following each listing is a cross-reference for that routine, which gives all of the variable and routine names used, in alphabetical order. Following each FORTRAN name in the cross-reference is a list of control statement numbers (CSNs) referencing the statements in which the name appears.

The following control statements are indented three spaces for ease in following the FORTRAN code: (1) DO loop, (2) GO TO statement, (3) transfer-of-control IF statement, and (4) calls to subroutines.

Each Part of PROGRAM MOATL (as subdivided for the discussion in the "Step-By-Step Analysis" section) is marked with a COMMENT.

SOURCE LISTING

```
CSN           STATEMENT

0001               PROGRAM MOATL
0002           DOUBLE PRECISION AKN,EIGVL1,EIGVL2,WN,SE
0003           COMMON/TN/Z1(150),C1(150),Z2(150),C2(150),ABSOR(150),ATTEN2(150),
              >ATTENC(150),ATTENS(150),AIRH2O(150),H2O2ND(150),UNRM1(150,1202),
              >UNRM2(150,1202),MDPRNT,INC1,INC2,H2,LI1,LI2,SHEAR,NMODE,KA,ND1,
              >ND2,N2
0004           COMMON/TH/EPSLN
0005           COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
0006           COMMON/TNH/AKN(150)
0007           COMMON/TNIH/PPRCN,PMGTD
0008           PARAMETER REC=3   ,REC5=5   ,SOC=4   ,RNG=200
         C
         C  THE FOLLOWING ARE MACHINE-DEPENDENT PARAMETERS.  MGNTD IS ROUGHLY
         C  (BUT SMALLER THAN) ONE-HALF THE DYNAMIC RANGE OF A REAL CONSTANT.
         C  PRCSN IS ONE LESS THAN THE APPROXIMATE NUMBER OF DECIMAL DIGITS TO
         C  WHICH A DOUBLE PRECISION NUMBER IS PRECISE.
         C
0009           PARAMETER MGNTD=30,PRCSN=15
0010           DIMENSION PLTAR( 500),TITLE(20),DEPRE(REC),DEPSO(SOC),RAN(RNG),
              >RE(REC,150),SM(SOC,150),QS(REC,SOC),QC(REC,SOC),PL(REC5,SOC,RNG),
              >COPL(REC5,SOC,RNG),PHASE(REC5,SOC),EIGVL1(150),EIGVL2(150),
              >R11(150),R12(150),R21(150),R22(150),R31(150),R32(150),RT1(150),
              >RT2(150),RB1(150),RB2(150),SE(150),S1(150),S2(150),
              >S3(150),WN(150),G1(150),G2(150),G3(150),ST(150),GT(150),S8(150),
              >GB(150),RA1(150),RA2(150),GA(150),SA(150)
0011      1000 FORMAT(20A4)
0012      2000 FORMAT(4I5,F10.3,5F10.7)
0013      3000 FORMAT(I5,2F10.3,2F10.7)
0014      4000 FORMAT(8F10.3)
0015      5000 FORMAT(3I5,5F10.3)
0016      6000 FORMAT(F10.8,3F10.3,4I5)
0017      7000 FORMAT(2F10.3)
0018      1001 FORMAT (1H1)
0019      2001 FORMAT (10(/),24X,27H***************************,' TRANSMISSION LO
              >SS ANOMALY ',26H**************************,/,24X,20A4,6(/),52X,'NU
              >MBER OF FREQUENCIES =',I2,///,1X,'NO. PROFILES',5X,'NO. CALCULATIO
              >N RANGES',5X,'MAXIMUM RANGE',10X,'EP1',10X,'EP2',10X,'EP3',9X,'SIG
              >0',9X,'SIG1',/,6X,I2,19X,I3,16X,F10.3,8X,5(F10.7,3X))
0020      3001 FORMAT (10(/),24X,31H*******************************,' TRANSMISSIO
              >N LOSS ',30H******************************,/,24X,20A4,6(/),52X,'NU
              >MBER OF FREQUENCIES =',I2,///,1X,'NO. PROFILES',5X,'NO. CALCULATIO
              >N RANGES',5X,'MAXIMUM RANGE',10X,'EP1',10X,'EP2',10X,'EP3',9X,'SIG
              >0',9X,'SIG1',/,6X,I2,19X,I3,16X,F10.3,8X,5(F10.7,3X))
0021      3002 FORMAT (//,24X,'IPLOT =',I2,5X,'DBMIN =',F8.3,5X,'DBMAX =',F8.3,
              >5X,'DY =',F10.7,5X,'DX =',F10.7)
0022      4001 FORMAT (///,55X,I3,1X,'SOURCE DEPTH(S)',/,50(58X,F10.3,/))
0023      5001 FORMAT (/,54X,I3,1X,'RECEIVER DEPTH(S)',/,50(58X,F10.3,/))
0024      6001 FORMAT (7(/),1X,20A4,5X,'SOURCE FREQUENCY =',F10.3)
0025      7001 FORMAT (//,1X,'MDPRNT =',I1,7X,'INC1 =',I2,8X,'INC2 =',I2,7X,
              >'RHO1 =',F5.3,6X,'RHO2 =',F5.3,6X,'RHO3 =',F5.3,6X,'H1 =',F8.3,6X,
```

```
MOATL              SOURCE LISTING

   CSN                 STATEMENT

                  >'H2 =',F8.3,/,1X,'EPSLN =',F10.8,10X,'RANGE =',F10.3,10X,
                  >'LI1 =',I3,5X,'LI2 =',I3,5X,'ND1 =',I2,5X,'ND2 =',I2)
  0026       8001 FORMAT (1H1,1X,'COHERENT TRANSMISSION LOSS ANOMALY',60X,'INCOHEREN
                  >T TRANSMISSION LOSS ANOMALY',/,1X,'(LOSS ANOMALY IN DB/ PHASE IN D
                  >EGREES)',57X,'LOSS ANOMALY IN DB')
  0027       9001 FORMAT (1H1,1X,'COHERENT TRANSMISSION LOSS',68X,
                  >'INCOHERENT TRANSMISSION LOSS',
                  >/,1X,'(LOSS IN DB, PHASE IN DEGREES)',65X,'LOSS IN DB')
  0028      10001 FORMAT (////,1X,'RANGE(M) =',F8.1,76X,'RANGE(M) =',F8.1)
  0029      11001 FORMAT(1X,'EXPONENTIAL THUS CONTRIBUTION AT ALL SOURCE/RECEIVER',
                  >' DEPTHS) SET TO ZERO FOR MODE NO.',I3)
  0030      12001 FORMAT(1X,'CONTRIBUTION SET TO ZERO FOR MODE NO.',I3,
                  >' AT SOURCE DEPTH =',F8.3,' AND RECEIVER DEPTH =',F8.3)
  0031      13001 FORMAT (/,1X,'SOURCE DEPTH(M) =',F8.3,69X,'SOURCE DEPTH(M) =',
                  >F8.3)
  0032      14001 FORMAT (1X,5('(',F6.2,'/',F8.3,')',1X),4X,5(F6.2,2X))
  0033      15001 FORMAT (/,1X,'(',F6.2,'/',F8.3,')',77X,F6.2)
            C
            C  ********** PART 1 **********
            C
  0034            CALL PLOTS (PLTAR,500,.7)
  0035            PMGTD=10.**MGNTD
  0036            PPRCN=10.**(-PRCSN)
  0037            READ(5,1000)TITLE
  0038            READ (5,2000)ISPRD,NMFREQ,NRBUF,NRCALC,RMAX,EP1,EP2,EP3,SIG0,SIG1
  0039            READ (5,2000)NDSO,NDRE
  0040            READ (5,2000)III
  0041            WRITE(6,1001)
  0042            IF (ISPRD.EQ.0) WRITE(6,2001)TITLE,NMFREQ,NRBUF,NRCALC,RMAX,EP1,
                  >EP2,EP3,SIG0,SIG1
  0043            IF (ISPRD.EQ.1) WRITE(6,3001)TITLE,NMFREQ,NRBUF,NRCALC,RMAX,EP1,
                  >EP2,EP3,SIG0,SIG1
  0044            READ (5,3000)IPLOT,DBMIN,DBMAX,DY,DX
  0045            WRITE(6,3002) IPLOT,DBMIN,DBMAX,DY,DX
  0046            READ (5,4000)(DEPSO(I),I=1,NDSO)
  0047            READ (5,4000)(DEPRE(I),I=1,NDRE)
  0048            WRITE(6,4001) NDSO,(DEPSO(I),I=1,NDSO)
  0049            WRITE(6,5001) NDRE,(DEPRE(I),I=1,NDRE)
  0050            DR=RMAX/NRCALC
  0051            RAN(1)=DR
            C
            C  THE FOLLOWING STATEMENT EXEMPLIFIES HOW THE PROGRAM MAY BE USED FOR
            C  UNEQUAL RANGE INCREMENT CALCULATIONS.
            C     DR=RAN(1)=10000.
            C
  0052               IF (IPLOT.EQ.0) GO TO 90
  0053            RMXKM=5.*(IFIX(RMAX/5000.)+1)
  0054            XLENG=RMXKM/DX
  0055            X2=XLENG/2.
  0056            YLENG=(DBMAX-DBMIN)/DY
```

```
MOATL          SOURCE LISTING

    CSN           STATEMENT

    0057             Y2=YLENG/2.
    0058          90 CONTINUE
              C
              C   ********** PART 2 **********
              C
    0059                DO 340 IFREQ=1,NMFREQ
    0060             READ(5,1000)TITLE
    0061             READ (5,4000)F
    0062             WRITE(6,1001)
    0063             WRITE(6,6001) TITLE,F
    0064             EP4=EP1*F*0.1151292546
    0065             EP5=EP2*F*0.1151292546
    0066             EP6=EP3*F*0.1151292546
              C
              C   ********** PART 3 **********
              C
    0067             READ (5,5000)MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H11,H2
    0068             READ (5,6000)EPSLN,COMP,SHEAR,RANGE1,LI1,LI2,ND1,ND2
    0069             WRITE(6,7001) MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H11,H2,EPSLN,
                    >RANGE1,LI1,LI2,ND1,ND2
    0070             RANGE2=RANGE1
    0071             H12=H11
    0072             H10=H11
    0073             RERHO1=RHO1
    0074             RERHO2=RHO2
    0075             READ (5,7000)(Z1(J),C1(J),J=1,ND1)
    0076             READ (5,7000)(Z2(J),C2(J),J=1,ND2)
    0077             CT2=C1(1)
    0078             CT1=C1(1)
    0079             CB2=C1(ND1)
    0080             CB1=C1(ND1)
    0081             KA=0
    0082             NMODE=10000
    0083                IF (III.EQ.0) CALL FLUID
    0084                IF (III.EQ.1) CALL SOLID
    0085             N11=N1
    0086             N12=N1
    0087                DO 110 IM=1,NMODE
    0088             EIGVL1(IM)=AKN(IM)
    0089             EIGVL2(IM)=AKN(IM)
    0090             R11(IM)=ATTEN2(IM)
    0091             R12(IM)=ATTEN2(IM)
    0092             R21(IM)=ATTENC(IM)
    0093             R22(IM)=ATTENC(IM)
    0094             R31(IM)=ATTENS(IM)
    0095             R32(IM)=ATTENS(IM)
    0096             RA1(IM)=ABSOR(IM)
    0097             RA2(IM)=ABSOR(IM)
    0098             RT1(IM)=AIRH2O(IM)
    0099             RT2(IM)=AIRH2O(IM)
```

```
     STATEMENT

     RB1(IM)=H2O2ND(IM)
     RB2(IM)=H2O2ND(IM)
     SE(IM)=0.0
     S1(IM)=0.0
     S2(IM)=0.0
     S3(IM)=0.0
     SA(IM)=0.0
     ST(IM)=0.0
     SB(IM)=0.0
        DO 100 J1=1,NDRE
        IF (DEPRE(J1).GT.H10) GO TO 95
     A1=(N1-1)*DEPRE(J1)/H10
     IA1=IFIX(A1)
     DLTA1=A1-IA1
        GO TO 100
  95 A1=(N2-1)*(DEPRE(J1)-H10)/H2+FLOAT(N1)
     IA1=IFIX(A1)
     DLTA1=A1-IA1
 100 RE(J1,IM)=UNRM1(IM,IA1+1)+DLTA1*(UNRM1(IM,IA1+2)-UNRM1(IM,IA1+1))
 110 CONTINUE
        IF (NRBUF.GT.1) GO TO 115
C
C  ********** PART 4 **********
C
     IF (ISPRD.EQ.0) WRITE(6,8001)
     IF (ISPRD.EQ.1) WRITE(6,9001)
     HS=H11
     CTS=CT1
     CBS=CB1
        DO 112 J2=1,NDSO
     A1=(N1-1)*DEPSO(J2)/HS
     IA1=IFIX(A1)
     DLTA1=A1-IA1
        DO 111 IM=1,NMODE
 111 SM(J2,IM)=UNRM1(IM,IA1+1)+DLTA1*(UNRM1(IM,IA1+2)-UNRM1(IM,IA1+1))
 112 CONTINUE
        DO 113 IM=1,NMODE
     WN(IM)=EIGVL1(IM)
     G1(IM)=R11(IM)
     G2(IM)=R21(IM)
     G3(IM)=R31(IM)
     GA(IM)=RA1(IM)
     GT(IM)=RT1(IM)
     GB(IM)=RB1(IM)
 113 CONTINUE
C
C  ********** PART 5 **********
C
 115    DO 300 I=1,NRCALC
C
```

MOATL SOURCE LISTING

CSN STATEMENT

```
C  THE FOLLOWING STATEMENT EXEMPLIFIES HOW THE PROGRAM MAY BE USED FOR
C  UNEQUAL RANGE INCREMENT CALCULATIONS.
C      IF (I.EQ.3) DR=2000.
C
          IF (I.GT.1) RAN(I)=RAN(I-1)+DR
             IF (NRBUF.EQ.1) GO TO 209
             IF (RANGE2-RANGE1.LT.0.00001) GO TO 125
  120        IF (RAN(I).LT.RANGE2+DR/2.0.OR.RAN(I).GE.RMAX) GO TO 160
C
C  ********** PART 6 **********
C
  125 RANGE1=RANGE2
      H11=H12
      CT1=CT2
      CB1=CB2
      N11=N12
         DO 130 IM=1,NMODE
         IF (KA.EQ.0) GO TO 129
         DO 128 IA1=1,1202
  128 UNRM1(IM,IA1)=UNRM2(IM,IA1)
  129 CONTINUE
      EIGVL1(IM)=EIGVL2(IM)
      R11(IM)=R12(IM)
      R21(IM)=R22(IM)
      R31(IM)=R32(IM)
      RA1(IM)=RA2(IM)
      RT1(IM)=RT2(IM)
      RB1(IM)=RB2(IM)
  130 CONTINUE
      READ (5,5000)MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2
      READ (5,6000)EPSLN,COMP,SHEAR,RANGE2,LI1,LI2,ND1,ND2
      WRITE(6,1001)
      WRITE(6,7001) MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2,EPSLN,
     >RANGE2,LI1,LI2,ND1,ND2
      READ (5,7000)(Z1(J),C1(J),J=1,ND1)
      READ (5,7000)(Z2(J),C2(J),J=1,ND2)
      CT2=C1(1)
      CB2=C1(ND1)
      KA=1
         IF (III.EQ.0) CALL FLUID
         IF (III.EQ.1) CALL SOLID
      IF (ISPRD.EQ.0) WRITE(6,8001)
      IF (ISPRD.EQ.1) WRITE(6,9001)
      N12=N1
         DO 150 IM=1,NMODE
      EIGVL2(IM)=AKN(IM)
      R12(IM)=ATTEN2(IM)
      R22(IM)=ATTENC(IM)
      R32(IM)=ATTENS(IM)
      RA2(IM)=ABSOR(IM)
```

MOATL SOURCE LISTING

CSN STATEMENT

```
      RT2(IM)=AIRH2O(IM)
      RB2(IM)=H2O2ND(IM)
  150 CONTINUE
         GO TO 120
C
C  ********** PART 7 **********
C
  160 SCALE=(RAN(I)-RANGE1)/(RANGE2-RANGE1)
      HS=H11+SCALE*(H12-H11)
      CTS=CT1+SCALE*(CT2-CT1)
      CBS=CB1+SCALE*(CB2-CB1)
      SCALE=SCALE-DR/(2.0*(RANGE2-RANGE1))
         DO 180 J2=1,NDSO
      A1=(N11-1)*DEPSO(J2)/HS
      IA1=IFIX(A1)
      DLTA1=A1-IA1
      A2=(N12-1)*DEPSO(J2)/HS
      IA2=IFIX(A2)
      DLTA2=A2-IA2
         DO 170 IM=1,NMODE
      XXR1=UNRM1(IM,IA1+1)+DLTA1*(UNRM1(IM,IA1+2)-UNRM1(IM,IA1+1))
      XXR2=UNRM2(IM,IA2+1)+DLTA2*(UNRM2(IM,IA2+2)-UNRM2(IM,IA2+1))
  170 SM(J2,IM)=XXR1+(SCALE+DR/(2.*(RANGE2-RANGE1)))*(XXR2-XXR1)
  180 CONTINUE
         DO 200 IM=1,NMODE
      WN(IM)=EIGVL1(IM)+SCALE*(EIGVL2(IM)-EIGVL1(IM))
      G1(IM)=R11(IM)+SCALE*(R12(IM)-R11(IM))
      G2(IM)=R21(IM)+SCALE*(R22(IM)-R21(IM))
      G3(IM)=R31(IM)+SCALE*(R32(IM)-R31(IM))
      GA(IM)=RA1(IM)+SCALE*(RA2(IM)-RA1(IM))
      GT(IM)=RT1(IM)+SCALE*(RT2(IM)-RT1(IM))
      GB(IM)=RB1(IM)+SCALE*(RB2(IM)-RB1(IM))
  200 CONTINUE
C
C  ********** PART 8 **********
C
  209    DO 210 J2=1,NDSO
         DO 210 J1=1,NDRE
      PL(J1,J2,I)=0.0
      QC(J1,J2)=0.0
  210 QS(J1,J2)=0.0
      WRITE(6,10001) RAN(I),RAN(I)
         DO 230 IM=1,NMODE
      SE(IM)=SE(IM)+WN(IM)*DR
      S1(IM)=S1(IM)+G1(IM)*DR
      S2(IM)=S2(IM)+G2(IM)*DR
      S3(IM)=S3(IM)+G3(IM)*DR
      SA(IM)=SA(IM)+GA(IM)*DR
      ST(IM)=ST(IM)+GT(IM)*DR
      SB(IM)=SB(IM)+GB(IM)*DR
```

MØATL SØURCE LISTING

```
CSN          STATEMENT

0229          QQ=EP4*S1(IM)+EP5*S2(IM)+EP6*S3(IM)+SA(IM)
0230          QQ=QQ+2.0*ST(IM)*SIG0*SIG0*((6.2831853*F/CTS)**2-WN(IM)*WN(IM))
0231          QQ=QQ+2.0*SB(IM)*SIG1*SIG1*((6.2831853*F/CBS)**2-WN(IM)*WN(IM))
0232             IF (QQ.LE.32.25) GØ TØ 215
0233          WRITE(6,11001) IM
0234             GØ TØ 230
0235      215 Q2=1.0/EXP(QQ)
0236             DØ 220 J2=1,NDSØ
0237             DØ 220 J1=1,NDRE
0238          Q1=RE(J1,IM)*SM(J2,IM)*DSQRT(RAN(I)/SE(IM))
0239             IF (ABS(Q1).GE.10.**(-10)) GØ TØ 217
0240          WRITE(6,12001) IM,DEPSØ(J2),DEPRE(J1)
0241             GØ TØ 220
0242      217 Q=Q1*Q2
0243          QS(J1,J2)=QS(J1,J2)+Q*DSIN(SE(IM))
0244          QC(J1,J2)=QC(J1,J2)+Q*DCØS(SE(IM))
0245          PL(J1,J2,I)=PL(J1,J2,I)+Q*Q
0246      220 CØNTINUE
0247      230 CØNTINUE
        C
        C  ********** PART 9 **********
        C
0248             DØ 270 J2=1,NDSØ
0249             DØ 270 J1=1,NDRE
0250          CØPL(J1,J2,I)=QS(J1,J2)*QS(J1,J2)+QC(J1,J2)*QC(J1,J2)
0251          PHASE(J1,J2)=ATAN2(QS(J1,J2),QC(J1,J2))*57.295779513
0252          IF (PHASE(J1,J2).LT.0.) PHASE(J1,J2)=360.+PHASE(J1,J2)
0253          IF  (ISPRD.EQ.0.AND.DEPRE(J1).LE.H10) CØPL(J1,J2,I)=-10.0*ALØG10(
             >6.283*CØPL(J1,J2,I)*RERHØ1*RERHØ1/(H10*HS))
0254          IF  (ISPRD.EQ.0.AND.DEPRE(J1).GT.H10) CØPL(J1,J2,I)=-10.0*ALØG10(
             >6.283*CØPL(J1,J2,I)*RERHØ2*RERHØ2/(H10*HS))
0255          IF  (ISPRD.EQ.1.AND.DEPRE(J1).LE.H10) CØPL(J1,J2,I)=-10.0*ALØG10(
             >6.283*CØPL(J1,J2,I)*RERHØ1*RERHØ1/(H10*HS*RAN(I)))
0256          IF  (ISPRD.EQ.1.AND.DEPRE(J1).GT.H10) CØPL(J1,J2,I)=-10.0*ALØG10(
             >6.283*CØPL(J1,J2,I)*RERHØ2*RERHØ2/(H10*HS*RAN(I)))
0257          IF  (ISPRD.EQ.0.AND.DEPRE(J1).LE.H10) PL(J1,J2,I)=-10.0*ALØG10(
             >6.283*PL(J1,J2,I)*RERHØ1*RERHØ1/(H10*HS))
0258          IF  (ISPRD.EQ.0.AND.DEPRE(J1).GT.H10) PL(J1,J2,I)=-10.0*ALØG10(
             >6.283*PL(J1,J2,I)*RERHØ2*RERHØ2/(H10*HS))
0259          IF  (ISPRD.EQ.1.AND.DEPRE(J1).LE.H10) PL(J1,J2,I)=-10.0*ALØG10(
             >6.283*PL(J1,J2,I)*RERHØ1*RERHØ1/(H10*HS*RAN(I)))
0260          IF  (ISPRD.EQ.1.AND.DEPRE(J1).GT.H10) PL(J1,J2,I)=-10.0*ALØG10(
             >6.283*PL(J1,J2,I)*RERHØ2*RERHØ2/(H10*HS*RAN(I)))
0261      270 CØNTINUE
0262             IF (NDRE+NDSØ.EQ.2) GØ TØ 295
        C
        C  ********** PART 10 **********
        C
0263             DØ 290 J2=1,NDSØ
0264          WRITE(6,13001) DEPSØ(J2),DEPSØ(J2)
```

```
MØATL           SOURCE LISTING

    CSN            STATEMENT

    0265              DØ 280 J1=1,NDRE,5
    0266          280 WRITE(6,14001) CØPL(J1,J2,I),PHASE(J1,J2),CØPL(J1+1,J2,I),
                     >PHASE(J1+1,J2),CØPL(J1+2,J2,I),PHASE(J1+2,J2),CØPL(J1+3,J2,I),
                     >PHASE(J1+3,J2),CØPL(J1+4,J2,I),PHASE(J1+4,J2),
                     >PL(J1,J2,I),PL(J1+1,J2,I),PL(J1+2,J2,I),PL(J1+3,J2,I),
                     >PL(J1+4,J2,I)
    0267          290 CØNTINUE
    0268              GØ TØ 300
    0269          295 WRITE(6,15001) CØPL(1,1,I),PHASE(1,1),PL(1,1,I)
    0270          300 CØNTINUE
    0271              IF (IPLØT.EQ.0) GØ TØ 340
                C
                C  ********** PART 11 **********
                C
    0272              DØ 330 J1=1,NDRE
    0273              DØ 330 J2=1,NDSØ
    0274              CALL NXAXIS (0.,0.,0.,5.,RMXKM,XLENG,-.05,.1,-1)
    0275              CALL NYAXIS (XLENG,0.,DBMAX,-10.,DBMIN,YLENG,.05,0.,-1)
    0276              CALL CNUMBR (-.1,0.,.1,DBMAX,90.,-1)
    0277              CALL NYAXIS (0.,0.,DBMAX,-10.,DBMIN,YLENG,-.05,.1,-1)
    0278              CALL NXAXIS (0.,YLENG,0.,5.,RMXKM,XLENG,.05,0.,-1)
    0279              IF (ISPRD.EQ.0) CALL CENTRE (-.3,Y2,.16,'T¢RANSMISSIØN ¢L¢ØSS ¢A¢N
                     >ØMALY ¢(¢D¢B)',90.,38)
    0280              IF (ISPRD.EQ.1) CALL CENTRE (-.3,Y2,.16,'T¢RANSMISSIØN ¢L¢ØSS ¢(¢D
                     >¢B)',90.,28)
    0281              CALL CENTRE (X2,-.46,.16,'R¢ANGE ¢(¢KM¢)',0.,14)
    0282              DØ 310 I=1,NRCALC
    0283              X=RAN(I)/(1000.*DX)
    0284              Y=YLENG-(CØPL(J1,J2,I)-DBMIN)/((DBMAX-DBMIN)/YLENG)
    0285              IF (Y.GT.YLENG) Y=YLENG
    0286              IF (Y.LT.0.0) Y=0.0
    0287              IF (I.GT.1) GØ TØ 310
    0288              CALL PLØT (X, Y, 3)
    0289          310 CALL PLØT (X, Y, 2)
    0290              DØ 320 I=1,NRCALC
    0291              X=RAN(I)/(1000.*DX)
    0292              Y=YLENG-(PL(J1,J2,I)-DBMIN)/((DBMAX-DBMIN)/YLENG)
    0293              IF (Y.GT.YLENG) Y=YLENG
    0294              IF (Y.LT.0.0) Y=0.0
    0295          320 CALL SYMBØL (X, Y, 0.08, 2, 0., 1)
    0296          330 CALL ØRIGIN (XLENG+2.5,0.)
    0297          340 CØNTINUE
    0298              CALL ENDPLT
    0299              END
```

MOATL CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | | |
|---|---|---|---|---|---|---|
| 90 | | 58 | 52 | | | |
| 95 | | 115 | 110 | | | |
| 100 | | 118 | 109 | 114 | | |
| 110 | | 119 | 87 | | | |
| 111 | | 131 | 130 | | | |
| 112 | | 132 | 126 | | | |
| 113 | | 141 | 133 | | | |
| 115 | | 142 | 120 | | | |
| 120 | | 146 | 188 | | | |
| 125 | | 147 | 145 | | | |
| 128 | | 155 | 154 | | | |
| 129 | | 156 | 153 | | | |
| 130 | | 164 | 152 | | | |
| 150 | | 187 | 179 | | | |
| 160 | | 189 | 146 | | | |
| 170 | | 204 | 201 | | | |
| 180 | | 205 | 194 | | | |
| 200 | | 214 | 206 | | | |
| 209 | | 215 | 144 | | | |
| 210 | | 219 | 215 | 216 | | |
| 215 | | 235 | 232 | | | |
| 217 | | 242 | 239 | | | |
| 220 | | 246 | 236 | 237 | 241 | |
| 230 | | 247 | 221 | 234 | | |
| 270 | | 261 | 248 | 249 | | |
| 280 | | 266 | 265 | | | |
| 290 | | 267 | 263 | | | |
| 295 | | 269 | 262 | | | |
| 300 | | 270 | 142 | 268 | | |
| 310 | | 289 | 282 | 287 | | |
| 320 | | 295 | 290 | | | |
| 330 | | 296 | 272 | 273 | | |
| 340 | | 297 | 59 | 271 | | |
| 1000 | | 11 | 37 | 60 | | |
| 1001 | | 18 | 41 | 62 | 167 | |
| 2000 | | 12 | 38 | 39 | 40 | |
| 2001 | | 19 | 42 | | | |
| 3000 | | 13 | 44 | | | |
| 3001 | | 20 | 43 | | | |
| 3002 | | 21 | 45 | | | |
| 4000 | | 14 | 46 | 47 | 61 | |
| 4001 | | 22 | 48 | | | |
| 5000 | | 15 | 67 | 165 | | |
| 5001 | | 23 | 49 | | | |
| 6000 | | 16 | 68 | 166 | | |
| 6001 | | 24 | 63 | | | |
| 7000 | | 17 | 75 | 76 | 169 | 170 |
| 7001 | | 25 | 69 | 168 | | |
| 8001 | | 26 | 121 | 176 | | |
| 9001 | | 27 | 122 | 177 | | |

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MOATL        CROSS REFERENCE LISTING

   LABEL      TYPE      DEFN      REFERENCES

   10001                  28        220
   11001                  29        233
   12001                  30        240
   13001                  31        264
   14001                  32        266
   15001                  33        269


   SYMBOL     TYPE/USAGE          REFERENCES

    ABS       R*4   IFN       239
    ABSOR     R*4   ARR         3      96      97     184
    AIRH2O    R*4   ARR         3      98      99     185
    AKN       R*8   ARR         2       6      88      89     180
    ALOG10    R*4   IFN       253     254     255     256     257     258     259     260
    ATAN2     R*4   IFN       251
    ATTENC    R*4   ARR         3      92      93     182
    ATTENS    R*4   ARR         3      94      95     183
    ATTEN2    R*4   ARR         3      90      91     181
    A1        R*4   VAR       111     112     113     115     116     117     127     128     129     195     196     197
    A2        R*4   VAR       198     199     200
    CBS       R*4   VAR       125     192     231
    CB1       R*4   VAR        80     125     150     192     192
    CB2       R*4   VAR        79     150     172     192
    CENTRE          SBR       279     280     281
    CNUMBR          SBR       276
    COMP      R*4   VAR         5      68     166
    COPL      R*4   ARR        10     250     253     253     254     254     255     255     256     256     266     266
                              266     266     266     269     284
    CTS       R*4   VAR       124     191     230
    CT1       R*4   VAR        78     124     149     191     191
    CT2       R*4   VAR        77     149     171     191
    C1        R*4   ARR         3      75      77      78      79      80     169     171     172
    C2        R*4   ARR         3      76     170
    DBMAX     R*4   VAR        44      45      56     275     276     277     284     292
    DBMIN     R*4   VAR        44      45      56     275     277     284     284     292     292
    DCOS      R*4   IFN       244
    DEPRE     R*4   ARR        10      47      49     110     111     115     240     253     254     255     256     257
                              258     259     260
    DEPSO     R*4   ARR        10      46      48     127     195     198     240     264     264
    DLTA1     R*4   VAR       113     117     118     129     131     197     202
    DLTA2     R*4   VAR       200     203
    DR        R*4   VAR        50      51     143     146     193     204     222     223     224     225     226     227
                              228
    DSIN      R*4   IFN       243
    DSQRT     R*4   IFN       238
    DX        R*4   VAR        44      45      54     283     291
    DY        R*4   VAR        44      45      56
```

MOATL CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EIGVL1 | R*8 | ARR | 2 | 10 | 88 | 134 | 157 | 207 | 207 | | | | | |
| EIGVL2 | R*8 | ARR | 2 | 10 | 89 | 157 | 180 | 207 | | | | | | |
| ENDPLT | | SBR | 298 | | | | | | | | | | | |
| EPSLN | R*4 | VAR | 4 | 68 | 69 | 166 | 168 | | | | | | | |
| EP1 | R*4 | VAR | 38 | 42 | 43 | 64 | | | | | | | | |
| EP2 | R*4 | VAR | 38 | 42 | 43 | 65 | | | | | | | | |
| EP3 | R*4 | VAR | 38 | 42 | 43 | 66 | | | | | | | | |
| EP4 | R*4 | VAR | 64 | 229 | | | | | | | | | | |
| EP5 | R*4 | VAR | 65 | 229 | | | | | | | | | | |
| EP6 | R*4 | VAR | 66 | 229 | | | | | | | | | | |
| EXP | R*4 | IFN | 235 | | | | | | | | | | | |
| F | R*4 | VAR | 5 | 61 | 63 | 64 | 65 | 66 | 230 | 231 | | | | |
| FLOAT | R*4 | IFN | 115 | | | | | | | | | | | |
| FLUID | | SBR | 83 | 174 | | | | | | | | | | |
| GA | R*4 | ARR | 10 | 138 | 211 | 226 | | | | | | | | |
| GB | R*4 | ARR | 10 | 140 | 213 | 228 | | | | | | | | |
| GT | R*4 | ARR | 10 | 139 | 212 | 227 | | | | | | | | |
| G1 | R*4 | ARR | 10 | 135 | 208 | 223 | | | | | | | | |
| G2 | R*4 | ARR | 10 | 136 | 209 | 224 | | | | | | | | |
| G3 | R*4 | ARR | 10 | 137 | 210 | 225 | | | | | | | | |
| HS | R*4 | VAR | 123 | 127 | 190 | 195 | 198 | 253 | 254 | 255 | 256 | 257 | 258 | 259 |
| | | | 260 | | | | | | | | | | | |
| H10 | R*4 | VAR | 72 | 110 | 111 | 115 | 253 | 253 | 254 | 254 | 255 | 255 | 256 | 256 |
| | | | 257 | 257 | 258 | 258 | 259 | 259 | 260 | 260 | | | | |
| H11 | R*4 | VAR | 67 | 69 | 71 | 72 | 123 | 148 | 190 | 190 | | | | |
| H12 | R*4 | VAR | 5 | 71 | 148 | 165 | 168 | 190 | | | | | | |
| H2 | R*4 | VAR | 3 | 67 | 69 | 115 | 165 | 168 | | | | | | |
| H2O2ND | R*4 | ARR | 3 | 100 | 101 | 186 | | | | | | | | |
| I | I*4 | VAR | 46 | 46 | 47 | 47 | 48 | 48 | 49 | 49 | 142 | 143 | 143 | 143 |
| | | | 146 | 146 | 189 | 217 | 220 | 220 | 238 | 245 | 245 | 250 | 253 | 253 |
| | | | 254 | 254 | 255 | 255 | 255 | 256 | 256 | 256 | 257 | 257 | 258 | 258 |
| | | | 259 | 259 | 259 | 260 | 260 | 260 | 266 | 266 | 266 | 266 | 266 | 266 |
| | | | 266 | 266 | 266 | 266 | 269 | 269 | 282 | 283 | 284 | 287 | 290 | 291 |
| | | | 292 | | | | | | | | | | | |
| IA1 | I*4 | VAR | 112 | 113 | 116 | 117 | 118 | 118 | 118 | 128 | 129 | 131 | 131 | 131 |
| | | | 154 | 155 | 155 | 196 | 197 | 202 | 202 | 202 | | | | |
| IA2 | I*4 | VAR | 199 | 200 | 203 | 203 | 203 | | | | | | | |
| IFIX | I*4 | IFN | 53 | 112 | 116 | 128 | 196 | 199 | | | | | | |
| IFREQ | I*4 | VAR | 59 | | | | | | | | | | | |
| III | I*4 | VAR | 40 | 83 | 84 | 174 | 175 | | | | | | | |
| IM | I*4 | VAR | 87 | 88 | 88 | 89 | 89 | 90 | 90 | 91 | 91 | 92 | 92 | 93 |
| | | | 93 | 94 | 94 | 95 | 95 | 96 | 96 | 97 | 97 | 98 | 98 | 99 |
| | | | 99 | 100 | 100 | 101 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 |
| | | | 118 | 118 | 118 | 118 | 130 | 131 | 131 | 131 | 131 | 133 | 134 | 134 |
| | | | 135 | 135 | 136 | 136 | 137 | 137 | 138 | 138 | 139 | 139 | 140 | 140 |
| | | | 152 | 155 | 155 | 157 | 157 | 158 | 158 | 159 | 159 | 160 | 160 | 161 |
| | | | 161 | 162 | 162 | 163 | 163 | 179 | 180 | 180 | 181 | 181 | 182 | 182 |
| | | | 183 | 183 | 184 | 184 | 185 | 185 | 186 | 186 | 201 | 202 | 202 | 202 |
| | | | 203 | 203 | 203 | 204 | 206 | 207 | 207 | 207 | 207 | 208 | 208 | 208 |
| | | | 208 | 209 | 209 | 209 | 209 | 210 | 210 | 210 | 210 | 211 | 211 | 211 |

MOATL CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 211 | 212 | 212 | 212 | 212 | 213 | 213 | 213 | 213 | 221 | 222 | 222 |
| | | | 222 | 223 | 223 | 223 | 224 | 224 | 224 | 225 | 225 | 225 | 226 | 226 |
| | | | 226 | 227 | 227 | 227 | 228 | 228 | 228 | 229 | 229 | 229 | 229 | 230 |
| | | | 230 | 230 | 231 | 231 | 231 | 233 | 238 | 238 | 238 | 240 | 243 | 244 |
| INC1 | I*4 | VAR | 3 | 67 | 69 | 165 | 168 | | | | | | | |
| INC2 | I*4 | VAR | 3 | 67 | 69 | 165 | 168 | | | | | | | |
| IPLOT | I*4 | VAR | 44 | 45 | 52 | 271 | | | | | | | | |
| ISPRD | I*4 | VAR | 38 | 42 | 43 | 121 | 122 | 176 | 177 | 253 | 254 | 255 | 256 | 257 |
| | | | 258 | 259 | 260 | 279 | 280 | | | | | | | |
| J | I*4 | VAR | 75 | 75 | 75 | 76 | 76 | 76 | 169 | 169 | 169 | 170 | 170 | 170 |
| J1 | I*4 | VAR | 109 | 110 | 111 | 115 | 118 | 216 | 217 | 218 | 219 | 237 | 238 | 240 |
| | | | 243 | 243 | 244 | 244 | 245 | 245 | 249 | 250 | 250 | 250 | 250 | 250 |
| | | | 251 | 251 | 251 | 252 | 252 | 252 | 253 | 253 | 253 | 254 | 254 | 254 |
| | | | 255 | 255 | 255 | 256 | 256 | 256 | 257 | 257 | 257 | 258 | 258 | 258 |
| | | | 259 | 259 | 259 | 260 | 260 | 260 | 265 | 266 | 266 | 266 | 266 | 266 |
| | | | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 272 | 284 |
| | | | 292 | | | | | | | | | | | |
| J2 | I*4 | VAR | 126 | 127 | 131 | 194 | 195 | 198 | 204 | 215 | 217 | 218 | 219 | 236 |
| | | | 238 | 240 | 243 | 243 | 244 | 244 | 245 | 245 | 248 | 250 | 250 | 250 |
| | | | 250 | 250 | 251 | 251 | 251 | 252 | 252 | 252 | 253 | 253 | 254 | 254 |
| | | | 255 | 255 | 256 | 256 | 257 | 257 | 258 | 258 | 259 | 259 | 260 | 260 |
| | | | 263 | 264 | 264 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | 266 |
| | | | 266 | 266 | 266 | 266 | 266 | 266 | 273 | 284 | 292 | | | |
| KA | I*4 | VAR | 3 | 81 | 153 | 173 | | | | | | | | |
| LI1 | I*4 | VAR | 3 | 68 | 69 | 166 | 168 | | | | | | | |
| LI2 | I*4 | VAR | 3 | 68 | 69 | 166 | 168 | | | | | | | |
| MDPRNT | I*4 | VAR | 3 | 67 | 69 | 165 | 168 | | | | | | | |
| MGNTD | I*4 | PAR | 9 | 35 | | | | | | | | | | |
| NDRE | I*4 | VAR | 39 | 47 | 49 | 49 | 109 | 216 | 237 | 249 | 262 | 265 | 272 | |
| NDSO | I*4 | VAR | 39 | 46 | 48 | 48 | 126 | 194 | 215 | 236 | 248 | 262 | 263 | 273 |
| ND1 | I*4 | VAR | 3 | 68 | 69 | 75 | 79 | 80 | 166 | 168 | 169 | 172 | | |
| ND2 | I*4 | VAR | 3 | 68 | 69 | 76 | 166 | 168 | 170 | | | | | |
| NMFREQ | I*4 | VAR | 38 | 42 | 43 | 59 | | | | | | | | |
| NMODE | I*4 | VAR | 3 | 82 | 87 | 130 | 133 | 152 | 179 | 201 | 206 | 221 | | |
| NRBUF | I*4 | VAR | 38 | 42 | 43 | 120 | 144 | | | | | | | |
| NRCALC | I*4 | VAR | 38 | 42 | 43 | 50 | 142 | 282 | 290 | | | | | |
| NXAXIS | | SBR | 274 | 278 | | | | | | | | | | |
| NYAXIS | | SBR | 275 | 277 | | | | | | | | | | |
| N1 | I*4 | VAR | 5 | 85 | 86 | 111 | 115 | 127 | 178 | | | | | |
| N11 | I*4 | VAR | 85 | 151 | 195 | | | | | | | | | |
| N12 | I*4 | VAR | 86 | 151 | 178 | 198 | | | | | | | | |
| N2 | I*4 | VAR | 3 | 115 | | | | | | | | | | |
| ORIGIN | | SBR | 296 | | | | | | | | | | | |
| PHASE | R*4 | ARR | 10 | 251 | 252 | 252 | 252 | 266 | 266 | 266 | 266 | 266 | 269 | |
| PL | R*4 | ARR | 10 | 217 | 245 | 245 | 257 | 257 | 258 | 258 | 259 | 259 | 260 | 260 |
| | | | 266 | 266 | 266 | 266 | 266 | 269 | 292 | | | | | |
| PLOT | | SBR | 288 | 289 | | | | | | | | | | |
| PLOTS | | SBR | 34 | | | | | | | | | | | |
| PLTAR | R*4 | ARR | 10 | 34 | | | | | | | | | | |
| PMGTD | R*4 | VAR | 7 | 35 | | | | | | | | | | |

MOATL CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPRCN | R*4 | VAR | 7 | 36 | | | | | | | | | | |
| PRCSN | I*4 | PAR | 9 | 36 | | | | | | | | | | |
| Q | R*4 | VAR | 242 | 243 | 244 | 245 | 245 | | | | | | | |
| QC | R*4 | ARR | 10 | 218 | 244 | 244 | 250 | 250 | 251 | | | | | |
| QQ | R*4 | VAR | 229 | 230 | 230 | 231 | 231 | 232 | 235 | | | | | |
| QS | R*4 | ARR | 10 | 219 | 243 | 243 | 250 | 250 | 251 | | | | | |
| Q1 | R*4 | VAR | 238 | 239 | 242 | | | | | | | | | |
| Q2 | R*4 | VAR | 235 | 242 | | | | | | | | | | |
| R$1ALA | | SBR | | | | | | | | | | | | |
| R$1AT2 | | SBR | | | | | | | | | | | | |
| R$1DCS | | SBR | | | | | | | | | | | | |
| R$1DSN | | SBR | | | | | | | | | | | | |
| R$1DSQ | | SBR | | | | | | | | | | | | |
| R$1EXP | | SBR | | | | | | | | | | | | |
| RAN | R*4 | ARR | 10 | 51 | 143 | 143 | 146 | 146 | 189 | 220 | 220 | 238 | 255 | 256 |
| | | | 259 | 260 | 283 | 291 | | | | | | | | |
| RANGE1 | R*4 | VAR | 68 | 69 | 70 | 145 | 147 | 189 | 189 | 193 | 204 | | | |
| RANGE2 | R*4 | VAR | 70 | 145 | 146 | 147 | 166 | 168 | 189 | 193 | 204 | | | |
| RA1 | R*4 | ARR | 10 | 96 | 138 | 161 | 211 | 211 | | | | | | |
| RA2 | R*4 | ARR | 10 | 97 | 161 | 184 | 211 | | | | | | | |
| RB1 | R*4 | ARR | 10 | 100 | 140 | 163 | 213 | 213 | | | | | | |
| RB2 | R*4 | ARR | 10 | 101 | 163 | 186 | 213 | | | | | | | |
| RE | R*4 | ARR | 10 | 118 | 238 | | | | | | | | | |
| REC | I*4 | PAR | 8 | 10 | 10 | 10 | 10 | | | | | | | |
| REC5 | I*4 | PAR | 8 | 10 | 10 | 10 | | | | | | | | |
| RERHO1 | R*4 | VAR | 73 | 253 | 253 | 255 | 255 | 257 | 257 | 259 | 259 | | | |
| RERHO2 | R*4 | VAR | 74 | 254 | 254 | 256 | 256 | 258 | 258 | 260 | 260 | | | |
| RHO1 | R*4 | VAR | 5 | 67 | 69 | 73 | 165 | 168 | | | | | | |
| RHO2 | R*4 | VAR | 5 | 67 | 69 | 74 | 165 | 168 | | | | | | |
| RHO3 | R*4 | VAR | 5 | 67 | 69 | 165 | 168 | | | | | | | |
| RMAX | R*4 | VAR | 38 | 42 | 43 | 50 | 53 | 146 | | | | | | |
| RMXKM | R*4 | VAR | 53 | 54 | 274 | 278 | | | | | | | | |
| RNG | I*4 | PAR | 8 | 10 | 10 | 10 | | | | | | | | |
| RT1 | R*4 | ARR | 10 | 98 | 139 | 162 | 212 | 212 | | | | | | |
| RT2 | R*4 | ARR | 10 | 99 | 162 | 185 | 212 | | | | | | | |
| R11 | R*4 | ARR | 10 | 90 | 135 | 158 | 208 | 208 | | | | | | |
| R12 | R*4 | ARR | 10 | 91 | 158 | 181 | 208 | | | | | | | |
| R21 | R*4 | ARR | 10 | 92 | 136 | 159 | 209 | 209 | | | | | | |
| R22 | R*4 | ARR | 10 | 93 | 159 | 182 | 209 | | | | | | | |
| R31 | R*4 | ARR | 10 | 94 | 137 | 160 | 210 | 210 | | | | | | |
| R32 | R*4 | ARR | 10 | 95 | 160 | 183 | 210 | | | | | | | |
| SA | R*4 | ARR | 10 | 106 | 226 | 226 | 229 | | | | | | | |
| SB | R*4 | ARR | 10 | 108 | 228 | 228 | 231 | | | | | | | |
| SCALF | R*4 | VAR | 189 | 190 | 191 | 192 | 193 | 193 | 204 | 207 | 208 | 209 | 210 | 211 |
| | | | 212 | 213 | | | | | | | | | | |
| SE | R*8 | ARR | 2 | 10 | 102 | 222 | 222 | 238 | 243 | 244 | | | | |
| SHEAR | R*4 | VAR | 3 | 68 | 166 | | | | | | | | | |
| SIGO | R*4 | VAR | 38 | 42 | 43 | 230 | 230 | | | | | | | |
| SIG1 | R*4 | VAR | 38 | 42 | 43 | 231 | 231 | | | | | | | |
| SM | R*4 | ARR | 10 | 131 | 204 | 238 | | | | | | | | |

MOATL CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOC | I*4 | PAR | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | | | |
| SOLID | | SBR | 84 | 175 | | | | | | | | | | |
| ST | R*4 | ARR | 10 | 107 | 227 | 227 | 230 | | | | | | | |
| SYMBOL | | SBR | 295 | | | | | | | | | | | |
| S1 | R*4 | ARR | 10 | 103 | 223 | 223 | 229 | | | | | | | |
| S2 | R*4 | ARR | 10 | 104 | 224 | 224 | 229 | | | | | | | |
| S3 | R*4 | ARR | 10 | 105 | 225 | 225 | 229 | | | | | | | |
| TH | | COM | 4 | | | | | | | | | | | |
| TITLE | R*4 | ARR | 10 | 37 | 42 | 43 | 60 | 63 | | | | | | |
| TN | | COM | 3 | | | | | | | | | | | |
| TNH | | COM | 6 | | | | | | | | | | | |
| TNI | | COM | 5 | | | | | | | | | | | |
| TNIH | | COM | 7 | | | | | | | | | | | |
| UNRM1 | R*4 | ARR | 3 | 118 | 118 | 118 | 131 | 131 | 131 | 155 | 202 | 202 | 202 | |
| UNRM2 | R*4 | ARR | 3 | 155 | 203 | 203 | 203 | | | | | | | |
| WN | R*8 | ARR | 2 | 10 | 134 | 207 | 222 | 230 | 230 | 231 | 231 | | | |
| X | R*4 | VAR | 283 | 288 | 289 | 291 | 295 | | | | | | | |
| XLENG | R*4 | VAR | 54 | 55 | 274 | 275 | 278 | 296 | | | | | | |
| XXR1 | R*4 | VAR | 202 | 204 | 204 | | | | | | | | | |
| XXR2 | R*4 | VAR | 203 | 204 | | | | | | | | | | |
| X2 | R*4 | VAR | 55 | 281 | | | | | | | | | | |
| Y | R*4 | VAR | 284 | 285 | 285 | 286 | 286 | 288 | 289 | 292 | 293 | 293 | 294 | 294 |
| | | | 295 | | | | | | | | | | | |
| YLENG | R*4 | VAR | 56 | 57 | 275 | 277 | 278 | 284 | 284 | 285 | 285 | 292 | 292 | 293 |
| | | | 293 | | | | | | | | | | | |
| Y2 | R*4 | VAR | 57 | 279 | 280 | | | | | | | | | |
| Z1 | R*4 | ARR | 3 | 75 | 169 | | | | | | | | | |
| Z2 | R*4 | ARR | 3 | 76 | 170 | | | | | | | | | |

SOURCE LISTING

```
CSN          STATEMENT

                SUBROUTINE FLUID
             DOUBLE PRECISION TWOPI,DL1,HH1,DL2,HH2,SPEED,DEPTH,AK1,AK2,AK3,
            >AKN,YOU,A,PV,SOUND
             COMMON/TN/Z1(150),C1(150),Z2(150),C2(150),ABSOR(150),ATTEN2(150),
            >ATTENC(150),ATTENS(150),AIRH2O(150),H2O2ND(150),UNRM1(150,1202),
            >UNRM2(150,1202),MDPRNT,INC1,INC2,H2,LI1,LI2,SHEAR,NMODE,KA,ND1,
            >ND2,N2
             COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
             COMMON/TNH/AKN(150)
             COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
            >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
             COMMON/NIFLU/A
             COMMON/NH/AK1,AK2,LOOP
             COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
             COMMON/TNIH/PPRCN,PMGTD
             DIMENSION LAMP(3),DEPTH(1202),X(650),Y(650),MDNUM(12),LDEPTH(2)
             DATA LDEPTH/' DEP','TH  '/
             DATA LAMP/'AMPL','ITUD','E'/
       8001 FORMAT (//,55X,'COMPRESSIONAL VELOCITY',/,60X,F10.3)
       9001 FORMAT (////,55X,'SOUND SPEED PROFILE',//,49X,'  DEPTH     DEPTH
            >  VELOCITY',//)
      10001 FORMAT (45X,3F11.3)
      11001 FORMAT (/)
      12001 FORMAT (1H1,/,35X,'MAXIMUM NUMBER OF MODES =',I3,10X,'NUMBER OF MO
            >DES CALCULATED =',I3,//)
      13001 FORMAT (1H1)
      14001 FORMAT (' MODE NO. =',I3,5X,'PHASE VELOCITY =',D20.12)
      15001 FORMAT (' UPPER AMPLITUDES MATCHED FOR THIS MODE STARTING AT NORMA
            >LIZED DEPTH =',F7.4)
      16001 FORMAT (' NUMBER OF ITERATE SOLUTIONS =',I3,5X,'THE EIGENFUNCTION
            >WAS SCALED DOWN',I3,' TIME(S)')
      17001 FORMAT (' LAYER 2 ATTEN RATIO = DEFAULT ZERO')
      18001 FORMAT (' LAYER 3 ATTEN RATIO = DEFAULT ZERO')
      19001 FORMAT ('    WAVE NUMBER        WATER ABSORPTION      LAYER 2 ATTEN
            > RATIO     LAYER 3 ATTEN RATIO     AIR/H2O SCATTER     H2O/2ND SCA
            >TTER')
      20001 FORMAT (D20.12,4X,2(E11.4,13X),E11.4,11X,E11.4,9X,E11.4,//)
      21001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
            >Z.',//,' FIRST LAYER',///)
      22001 FORMAT (10X,12(3X,I3,'MODE'),/)
      23001 FORMAT (4X,2A4,12(1X,2A4,A1))
      24001 FORMAT (13F10.4)
      25001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
            >Z.',//,' SECOND LAYER',///)
             TWOPI=6.2831853071795800
             F2=(F/1000.)*(F/1000.)
             EPW=.1*F2/(1.+F2)+40.*F2/(4100.+F2)+2.75E-4*F2
             EPW=EPW*.1151292546*1.093613298E-3
             X(1)=Z1(1)
             CMIN1=C1(1)
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FLUID SOURCE LISTING

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CSN        STATEMENT

           CMAX1=C1(1)
              DO 20 J=2,ND1
           IF (C1(J).LT.CMIN1) CMIN1=C1(J)
           IF (C1(J).GT.CMAX1) CMAX1=C1(J)
           X(J)=Z1(J)
        20 Z1(J)=Z1(J)/H12
           Y(1)=Z2(1)
           Z2(1)=Z1(ND1)
           CMIN2=C2(1)
           CMAX2=C2(1)
              DO 30 J=2,ND2
           IF (C2(J).LT.CMIN2) CMIN2=C2(J)
           IF (C2(J).GT.CMAX2) CMAX2=C2(J)
           Y(J)=Z2(J)
        30 Z2(J)=Z2(J)/H12
           CMIN=AMIN1(CMIN1,CMIN2)
           WRITE(6,8001) COMP
           WRITE(6,9001)
           WRITE(6,10001) (Z1(I),X(I),C1(I),I=1,ND1)
           WRITE(6,11001)
           WRITE(6,10001) (Z2(I),Y(I),C2(I),I=1,ND2)
           DL1=DBLE(1.0)/LI1
           HH1=DL1*DL1*H12*H12
           DL2=DBLE(H2)/H12/LI2
           HH2=DL2*DL2*H12*H12
           N1=LI1+1
           N1PLS1=N1+1
           N1PLS2=N1+2
           N1PLS3=N1+3
           N1MNS1=N1-1
           N1MNS2=N1-2
           N2=LI2+1
           N2MNS1=N2-1
           NT=N1+N2
           NTMNS1=NT-1
           NTMNS2=NT-2
           DEPTH(1)=0.0
           DEPTH(N1)=1.0
           DEPTH(N1PLS1)=1.0
           DEPTH(NT)=DBLE(H2)/H12+1.0
           SPEED(1)=HH1/C1(1)/C1(1)
           SPEED(N1)=HH1/C1(ND1)/C1(ND1)
           SPEED(N1PLS1)=HH2/C2(1)/C2(1)
           SPEED(NT)=HH2/C2(ND2)/C2(ND2)
           K=2
              DO 50 INTERP=2,N1MNS1
           DEPTH(INTERP)=(INTERP-1.0)*DL1
           KK=K
              DO 40 J=KK,ND1
              IF (DEPTH(INTERP).GT.Z1(J)) GO TO 40
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FLUID SOURCE LISTING

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           STATEMENT

           SPEED(INTERP)=((C1(J)-C1(J-1))*(DEPTH(INTERP)-Z1(J-1))/
          >(DBLE(Z1(J))-Z1(J-1)))+C1(J-1)
           SOUND(INTERP)=SPEED(INTERP)
           SPEED(INTERP)=HH1/(SPEED(INTERP)*SPEED(INTERP))
              GO TO 50
        40 K=K+1
        50 CONTINUE
           K=2
              DO 70 INTERP=N1PLS2,NTMNS1
           DEPTH(INTERP)=(INTERP-1-N1)*DL2+1.0
           KK=K
              DO 60 J=KK,ND2
              IF (DEPTH(INTERP).GT.Z2(J)) GO TO 60
           SPEED(INTERP)=((C2(J)-C2(J-1))*(DEPTH(INTERP)-Z2(J-1))/
          >(DBLE(Z2(J))-Z2(J-1)))+C2(J-1)
           SOUND(INTERP)=SPEED(INTERP)
           SPEED(INTERP)=HH2/(SPEED(INTERP)*SPEED(INTERP))
              GO TO 70
        60 K=K+1
        70 CONTINUE
           IZERO=0
           AK1=TWOPI*F/COMP
           AK3=AK1
           AK2=TWOPI*F/CMIN
           SREC=39.4784176*F*F/(C1(1)*C1(1))
           BOTTOM=39.4784176*F*F/(C1(ND1)*C1(ND1))
              CALL ITRTF (AK1)
           MAXMD=NCR
           NMODE=MINO(NMODE,MAXMD)
           MGROPS=INT(NMODE/12.0+0.02)+1
              DO 350 M=1,MGROPS
           IBASE=(M-1)*12
           IF (M.LT.MGROPS) NIC=12
           IF (M.EQ.MGROPS) NIC=MOD(NMODE,12)
              IF (NIC.EQ.0) GO TO 350
              DO 340 IC=1,NIC
           I=IBASE+IC
           MDNUM(IC)=I
              CALL HALFF
           AK1=AK3
           AK2=AKN(I)
           ODD=0.0
           ODD1=0.0
           ODD2=0.0
           ODD3=0.0
           EVEN=0.0
           EVEN1=0.0
           EVEN2=0.0
           EVEN3=0.0
              DO 200 J=2,N1MNS1,2
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 CSN          STATEMENT

0136     200 EVEN1=EVEN1+YØU(J)*YØU(J)
0137            DØ 210 J=3,N1MNS2,2
0138     210 ØDD1=ØDD1+YØU(J)*YØU(J)
0139            DØ 220 J=N1PLS2,NTMNS1,2
0140     220 EVEN2=EVEN2+YØU(J)*YØU(J)
0141            DØ 230 J=N1PLS3,NTMNS2,2
0142     230 ØDD2=ØDD2+YØU(J)*YØU(J)
0143            DØ 234 J=2,N1MNS1,2
0144     234 EVEN3=EVEN3+YØU(J)*YØU(J)/SØUND(J)
0145            DØ 236 J=3,N1MNS2,2
0146     236 ØDD3=ØDD3+YØU(J)*YØU(J)/SØUND(J)
0147            DØ 240 J=N1PLS2,NTMNS1,2
0148     240 EVEN=EVEN+YØU(J)*YØU(J)/SØUND(J)
0149            DØ 250 J=N1PLS3,NTMNS2,2
0150     250 ØDD=ØDD+YØU(J)*YØU(J)/SØUND(J)
0151         AI1=RHØ1*(DL1/3.0)*(YØU(1)*YØU(1)+4.0*EVEN1+2.0*ØDD1+YØU(N1)*
            >YØU(N1))
0152         AI2=RHØ2*(DL2/3.0)*(YØU(N1+1)*YØU(N1+1)+4.0*EVEN2+2.0*ØDD2+
            >YØU(NT)*YØU(NT))
0153         AI3=RHØ2*RHØ2*YØU(NT)*YØU(NT)/RHØ3/2.0/DSQRT(A)
0154         AI4=RHØ2*(DL2/3.0)*(YØU(N1+1)*YØU(N1+1)/C2(1)+4.0*EVEN+2.0*ØDD+
            >YØU(NT)*YØU(NT)/C2(ND2))
0155         AI5=RHØ1*(DL1/3.0)*(YØU(1)*YØU(1)/C1(1)+4.0*EVEN3+2.0*ØDD3+
            >YØU(N1)*YØU(N1)/C1(ND1))
0156         AI=AI1+AI2+AI3
0157         ANØRM=SQRT(1.0/AI)
0158            DØ 260 J=1,NT
0159         IF (KA.EQ.0) UNRM1(I,J)=YØU(J)*ANØRM
0160         IF (KA.EQ.1) UNRM2(I,J)=YØU(J)*ANØRM
0161     260 CØNTINUE
0162            IF (KA.EQ.1) GØ TØ 270
0163         YNM1=UNRM1(I,1)
0164         YNM2=UNRM1(I,2)
0165         YNM3=UNRM1(I,3)
0166         YNM4=UNRM1(I,N1)
0167         YNM5=UNRM1(I,N1PLS1)
0168         YNM6=UNRM1(I,N1PLS2)
0169         YNM7=UNRM1(I,N1PLS3)
0170            GØ TØ 275
0171     270 YNM1=UNRM2(I,1)
0172         YNM2=UNRM2(I,2)
0173         YNM3=UNRM2(I,3)
0174         YNM4=UNRM2(I,N1)
0175         YNM5=UNRM2(I,N1PLS1)
0176         YNM6=UNRM2(I,N1PLS2)
0177         YNM7=UNRM2(I,N1PLS3)
0178     275 DYØUA=(-3.*YNM1+4.*YNM2-YNM3)/(2.*DL1)
0179         DYØUB=(-3.*YNM5+4.*YNM6-YNM7)/(2.*DL2)
0180         AKN2=AKN(I)*AKN(I)
0181            IF (SRFC-AKN2.GT.PPRCN) GØ TØ 280
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FLUID            SOURCE LISTING

    CSN              STATEMENT

    0182              AIRH2O(I)=0.0
    0183                 GO TO 290
    0184          280 AIRH2O(I)=RHO1*DYOUA*DYOUA/(4.*AKN(I)*H12**3*SQRT(SRFC-AKN2))
    0185          290    IF (BOTTOM-AKN2.GT.PPRCN) GO TO 300
    0186              H2O2ND(I)=0.0
    0187                 GO TO 310
    0188          300 H2O2ND(I)=RHO1*SQRT(BOTTOM-AKN2)*(YNM4*YNM4+DYOUB*
                     >DYOUB/(H12*H12*(BOTTOM-AKN2)))/(4.0*AKN(I)*H12)
    0189          310 PV=TWOPI*F/AKN(I)
    0190                 IF (AI4.GT.AI/PMGTD) GO TO 313
    0191              AI4=0.
    0192          313 ATTEN2(I)=6.2831853*F*AI4/(AKN(I)*AI)
    0193                 IF (AI3.GT.AI/PMGTD) GO TO 315
    0194              AI3=0.
    0195          315 ATTENC(I)=6.2831853*F*AI3/(COMP*AKN(I)*AI)
    0196              ATTENS(I)=0.0
    0197              ABSOR(I)=6.2831853*F*AI5*EPW/(AKN(I)*AI)
    0198                 IF (IC.GT.1) GO TO 330
    0199              WRITE(6,12001) MAXMD,NMODE
    0200          330 IF (MOD(IC,7).EQ.0) WRITE(6,13001)
    0201              WRITE(6,14001) I,PV
    0202              IF (IZERO.EQ.2) WRITE(6,15001) DEPTH(MATCH)
    0203              WRITE(6,16001) LOOP,IFG
    0204              IF (AI4.LE.AI/PMGTD) WRITE(6,17001)
    0205              IF (AI3.LE.AI/PMGTD) WRITE(6,18001)
    0206              WRITE(6,19001)
    0207              WRITE(6,20001) AKN(I),ABSOR(I),ATTEN2(I),ATTENC(I),AIRH2O(I),
                     >H2O2ND(I)
    0208          340 CONTINUE
    0209                 IF (MOPRNT.EQ.0) GO TO 350
    0210              WRITE(6,21001) F
    0211              WRITE(6,22001) (MDNUM(K),K=1,NIC)
    0212              WRITE(6,23001) LDEPTH,(LAMP(1),LAMP(2),LAMP(3),K=1,NIC)
    0213              I1=IBASE+1
    0214              INIC=IBASE+NIC
    0215                 DO 345 J=1,N1,INC1
    0216              IF (KA.EQ.0) WRITE(6,24001) DEPTH(J),(UNRM1(K,J),K=I1,INIC)
    0217              IF (KA.EQ.1) WRITE(6,24001) DEPTH(J),(UNRM2(K,J),K=I1,INIC)
    0218          345 CONTINUE
    0219              WRITE(6,25001) F
    0220              WRITE(6,22001) (MDNUM(K),K=1,NIC)
    0221              WRITE(6,23001) LDEPTH,(LAMP(1),LAMP(2),LAMP(3),K=1,NIC)
    0222                 DO 349 J=N1PLS1,NT,INC2
    0223              IF (KA.EQ.0) WRITE(6,24001) DEPTH(J),(UNRM1(K,J),K=I1,INIC)
    0224              IF (KA.EQ.1) WRITE(6,24001) DEPTH(J),(UNRM2(K,J),K=I1,INIC)
    0225          349 CONTINUE
    0226          350 CONTINUE
    0227              RETURN
    0228              END
```

FLUID CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | | |
|---|---|---|---|---|---|---|
| 20 | | 43 | 39 | | | |
| 30 | | 52 | 48 | | | |
| 40 | | 92 | 86 | 87 | | |
| 50 | | 93 | 83 | 91 | | |
| 60 | | 104 | 98 | 99 | | |
| 70 | | 105 | 95 | 103 | | |
| 200 | | 136 | 135 | | | |
| 210 | | 138 | 137 | | | |
| 220 | | 140 | 139 | | | |
| 230 | | 142 | 141 | | | |
| 234 | | 144 | 143 | | | |
| 236 | | 146 | 145 | | | |
| 240 | | 148 | 147 | | | |
| 250 | | 150 | 149 | | | |
| 260 | | 161 | 158 | | | |
| 270 | | 171 | 162 | | | |
| 275 | | 178 | 170 | | | |
| 280 | | 184 | 181 | | | |
| 290 | | 185 | 183 | | | |
| 300 | | 188 | 185 | | | |
| 310 | | 189 | 187 | | | |
| 313 | | 192 | 190 | | | |
| 315 | | 195 | 193 | | | |
| 330 | | 200 | 198 | | | |
| 340 | | 208 | 121 | | | |
| 345 | | 218 | 215 | | | |
| 349 | | 225 | 222 | | | |
| 350 | | 226 | 116 | 120 | 209 | |
| 8001 | | 14 | 54 | | | |
| 9001 | | 15 | 55 | | | |
| 10001 | | 16 | 56 | 58 | | |
| 11001 | | 17 | 57 | | | |
| 12001 | | 18 | 199 | | | |
| 13001 | | 19 | 200 | | | |
| 14001 | | 20 | 201 | | | |
| 15001 | | 21 | 202 | | | |
| 16001 | | 22 | 203 | | | |
| 17001 | | 23 | 204 | | | |
| 18001 | | 24 | 205 | | | |
| 19001 | | 25 | 206 | | | |
| 20001 | | 26 | 207 | | | |
| 21001 | | 27 | 210 | | | |
| 22001 | | 28 | 211 | 220 | | |
| 23001 | | 29 | 212 | 221 | | |
| 24001 | | 30 | 216 | 217 | 223 | 224 |
| 25001 | | 31 | 219 | | | |

FLUID CROSS REFERENCE LISTING

| SYMBOL | TYPE | USAGE | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | R*8 | VAR | 2 | 7 | 153 | | | | | | | | | |
| ABSCR | R*4 | ARR | 3 | 197 | 207 | | | | | | | | | |
| AI | R*4 | VAR | 156 | 157 | 190 | 192 | 193 | 195 | 197 | 204 | 205 | | | |
| AIRH2O | R*4 | ARR | 3 | 182 | 184 | 207 | | | | | | | | |
| AI1 | R*4 | VAR | 151 | 156 | | | | | | | | | | |
| AI2 | R*4 | VAR | 152 | 156 | | | | | | | | | | |
| AI3 | R*4 | VAR | 153 | 156 | 193 | 194 | 195 | 205 | | | | | | |
| AI4 | R*4 | VAR | 154 | 190 | 191 | 192 | 204 | | | | | | | |
| AI5 | R*4 | VAR | 155 | 197 | | | | | | | | | | |
| AKN | R*8 | ARR | 2 | 5 | 126 | 180 | 180 | 184 | 188 | 189 | 192 | 195 | 197 | 207 |
| AKN2 | R*4 | VAR | 180 | 181 | 184 | 185 | 188 | 188 | | | | | | |
| AK1 | R*8 | VAR | 2 | 8 | 107 | 108 | 112 | 125 | | | | | | |
| AK2 | R*8 | VAR | 2 | 8 | 109 | 126 | | | | | | | | |
| AK3 | R*8 | VAR | 2 | 108 | 125 | | | | | | | | | |
| AMIN1 | R*4 | IFN | 53 | | | | | | | | | | | |
| ANORM | R*4 | VAR | 157 | 159 | 160 | | | | | | | | | |
| ATTENC | R*4 | ARR | 3 | 195 | 207 | | | | | | | | | |
| ATTENS | R*4 | ARR | 3 | 196 | | | | | | | | | | |
| ATTEN2 | R*4 | ARR | 3 | 192 | 207 | | | | | | | | | |
| BOTTOM | R*4 | VAR | 111 | 185 | 188 | 188 | | | | | | | | |
| CMAX1 | R*4 | VAR | 38 | 41 | 41 | | | | | | | | | |
| CMAX2 | R*4 | VAR | 47 | 50 | 50 | | | | | | | | | |
| CMIN | R*4 | VAR | 53 | 109 | | | | | | | | | | |
| CMIN1 | R*4 | VAR | 37 | 40 | 40 | 53 | | | | | | | | |
| CMIN2 | R*4 | VAR | 46 | 49 | 49 | 53 | | | | | | | | |
| COMP | R*4 | VAR | 4 | 54 | 107 | 195 | | | | | | | | |
| C1 | R*4 | ARR | 3 | 37 | 38 | 40 | 40 | 41 | 41 | 56 | 78 | 78 | 79 | 79 |
| | | | 88 | 88 | 88 | 110 | 110 | 111 | 111 | 155 | 155 | | | |
| C2 | R*4 | ARR | 3 | 46 | 47 | 49 | 49 | 50 | 50 | 58 | 80 | 80 | 81 | 81 |
| | | | 100 | 100 | 100 | 154 | 154 | | | | | | | |
| DBLE | R*4 | IFN | 59 | 61 | 77 | 88 | 100 | | | | | | | |
| DEPTH | R*8 | ARR | 2 | 11 | 74 | 75 | 76 | 77 | 84 | 87 | 88 | 96 | 99 | 100 |
| | | | 202 | 216 | 217 | 223 | 224 | | | | | | | |
| DL1 | R*8 | VAR | 2 | 6 | 59 | 60 | 60 | 84 | 151 | 155 | 178 | | | |
| DL2 | R*8 | VAR | 2 | 6 | 61 | 62 | 62 | 96 | 152 | 154 | 179 | | | |
| DSQRT | R*4 | IFN | 153 | | | | | | | | | | | |
| DYOUA | R*4 | VAR | 178 | 184 | 184 | | | | | | | | | |
| DYCLB | R*4 | VAR | 179 | 188 | 188 | | | | | | | | | |
| EPW | R*4 | VAR | 34 | 35 | 35 | 197 | | | | | | | | |
| EVEN | R*4 | VAR | 131 | 148 | 148 | 154 | | | | | | | | |
| EVEN1 | R*4 | VAR | 132 | 136 | 136 | 151 | | | | | | | | |
| EVEN2 | R*4 | VAR | 133 | 140 | 140 | 152 | | | | | | | | |
| EVEN3 | R*4 | VAR | 134 | 144 | 144 | 155 | | | | | | | | |
| F | R*4 | VAR | 4 | 33 | 33 | 107 | 109 | 110 | 110 | 111 | 111 | 189 | 192 | 195 |
| | | | 197 | 210 | 219 | | | | | | | | | |
| FLUID | R*4 | ENT | 1 | | | | | | | | | | | |
| F2 | R*4 | VAR | 33 | 34 | 34 | 34 | 34 | 34 | | | | | | |
| HALFE | | SBR | 124 | | | | | | | | | | | |
| HH1 | R*8 | VAR | 2 | 6 | 60 | 78 | 79 | 90 | | | | | | |
| HH2 | R*8 | VAR | 2 | 6 | 62 | 80 | 81 | 102 | | | | | | |

FLUID CROSS REFERENCE LISTING

| SYMBOL | TYPE | USAGE | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H12 | R*4 | VAR | 4 | 43 | 52 | 60 | 60 | 61 | 62 | 62 | 77 | 184 | 188 | 188 |
| | | | 188 | | | | | | | | | | | |
| H2 | R*4 | VAR | 3 | 61 | 77 | | | | | | | | | |
| H2T2ND | R*4 | ARR | 3 | 186 | 188 | 207 | | | | | | | | |
| I | I*4 | VAR | 9 | 56 | 56 | 56 | 56 | 58 | 58 | 58 | 58 | 122 | 123 | 126 |
| | | | 159 | 160 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 171 | 172 | 173 |
| | | | 174 | 175 | 176 | 177 | 180 | 180 | 182 | 184 | 184 | 186 | 188 | 188 |
| | | | 189 | 192 | 192 | 195 | 195 | 196 | 197 | 197 | 201 | 207 | 207 | 207 |
| | | | 207 | 207 | 207 | | | | | | | | | |
| IBASE | I*4 | VAR | 117 | 122 | 213 | 214 | | | | | | | | |
| IC | I*4 | VAR | 121 | 122 | 123 | 198 | 200 | | | | | | | |
| IFG | I*4 | VAR | 9 | 203 | | | | | | | | | | |
| INC1 | I*4 | VAR | 3 | 215 | | | | | | | | | | |
| INC2 | I*4 | VAR | 3 | 222 | | | | | | | | | | |
| INIC | I*4 | VAR | 214 | 216 | 217 | 223 | 224 | | | | | | | |
| INT | I*4 | IFN | 115 | | | | | | | | | | | |
| INTERP | I*4 | VAR | 83 | 84 | 84 | 87 | 88 | 88 | 89 | 89 | 90 | 90 | 90 | 95 |
| | | | 96 | 96 | 99 | 100 | 100 | 101 | 101 | 102 | 102 | 102 | | |
| ITRIF | | SBR | 112 | | | | | | | | | | | |
| IZERO | I*4 | VAR | 9 | 106 | 202 | | | | | | | | | |
| I1 | I*4 | VAR | 213 | 216 | 217 | 223 | 224 | | | | | | | |
| J | I*4 | VAR | 39 | 40 | 40 | 41 | 41 | 42 | 42 | 43 | 43 | 48 | 49 | 49 |
| | | | 50 | 50 | 51 | 51 | 52 | 52 | 86 | 87 | 88 | 88 | 88 | 88 |
| | | | 88 | 88 | 98 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 135 | 136 |
| | | | 136 | 137 | 138 | 138 | 139 | 140 | 140 | 141 | 142 | 142 | 143 | 144 |
| | | | 144 | 144 | 145 | 146 | 146 | 146 | 147 | 148 | 148 | 148 | 149 | 150 |
| | | | 150 | 150 | 158 | 159 | 159 | 160 | 160 | 215 | 216 | 216 | 217 | 217 |
| | | | 222 | 223 | 223 | 224 | 224 | | | | | | | |
| K | I*4 | VAR | 82 | 85 | 92 | 92 | 94 | 97 | 104 | 104 | 211 | 211 | 212 | 216 |
| | | | 216 | 217 | 217 | 220 | 220 | 221 | 223 | 223 | 224 | 224 | | |
| KA | I*4 | VAR | 3 | 159 | 160 | 162 | 216 | 217 | 223 | 224 | | | | |
| KK | I*4 | VAR | 85 | 86 | 97 | 98 | | | | | | | | |
| LAMP | I*4 | ARR | 11 | 13 | 212 | 212 | 212 | 221 | 221 | 221 | | | | |
| LDEPTH | I*4 | ARR | 11 | 12 | 212 | 221 | | | | | | | | |
| LI1 | I*4 | VAR | 3 | 59 | 63 | | | | | | | | | |
| LI2 | I*4 | VAR | 3 | 61 | 69 | | | | | | | | | |
| LOOP | I*4 | VAR | 8 | 203 | | | | | | | | | | |
| M | I*4 | VAR | 116 | 117 | 118 | 119 | | | | | | | | |
| MATCH | I*4 | VAR | 6 | 202 | | | | | | | | | | |
| MAXND | I*4 | VAR | 113 | 114 | 199 | | | | | | | | | |
| MDNUM | I*4 | ARR | 11 | 123 | 211 | 220 | | | | | | | | |
| MDPRNT | I*4 | VAR | 3 | 209 | | | | | | | | | | |
| MGROPS | I*4 | VAR | 115 | 116 | 118 | 119 | | | | | | | | |
| MINO | I*4 | IFN | 114 | | | | | | | | | | | |
| MOD | I*4 | IFN | 119 | 200 | | | | | | | | | | |
| NCR | I*4 | VAR | 9 | 113 | | | | | | | | | | |
| ND1 | I*4 | VAR | 3 | 39 | 45 | 56 | 79 | 79 | 86 | 111 | 111 | 155 | | |
| ND2 | I*4 | VAR | 3 | 48 | 58 | 81 | 81 | 98 | 154 | | | | | |
| NH | | COM | 8 | | | | | | | | | | | |
| NI | | COM | 6 | | | | | | | | | | | |

FLUID CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIC | I*4 | VAR | 118 | 119 | 120 | 121 | 211 | 212 | 214 | 220 | 221 | | | |
| NIFLU | | COM | 7 | | | | | | | | | | | |
| NIH | | COM | 9 | | | | | | | | | | | |
| NMODE | I*4 | VAR | 3 | 114 | 114 | 115 | 119 | 199 | | | | | | |
| NT | I*4 | VAR | 6 | 71 | 72 | 73 | 77 | 81 | 152 | 152 | 153 | 153 | 154 | 154 |
| | | | 158 | 222 | | | | | | | | | | |
| NTMNS1 | I*4 | VAR | 72 | 95 | 139 | 147 | | | | | | | | |
| NTMNS2 | I*4 | VAR | 6 | 73 | 141 | 149 | | | | | | | | |
| N1 | I*4 | VAR | 4 | 63 | 64 | 65 | 66 | 67 | 68 | 71 | 75 | 79 | 96 | 151 |
| | | | 151 | 152 | 152 | 154 | 154 | 155 | 155 | 166 | 174 | 215 | | |
| N1MNS1 | I*4 | VAR | 6 | 67 | 83 | 135 | 143 | | | | | | | |
| N1MNS2 | I*4 | VAR | 6 | 68 | 137 | 145 | | | | | | | | |
| N1PLS1 | I*4 | VAR | 6 | 64 | 76 | 80 | 167 | 175 | 222 | | | | | |
| N1PLS2 | I*4 | VAR | 6 | 65 | 95 | 139 | 147 | 168 | 176 | | | | | |
| N1PLS3 | I*4 | VAR | 6 | 66 | 141 | 149 | 169 | 177 | | | | | | |
| N2 | I*4 | VAR | 3 | 69 | 70 | 71 | | | | | | | | |
| N2MNS1 | I*4 | VAR | 6 | 70 | | | | | | | | | | |
| PDD | R*4 | VAR | 127 | 150 | 150 | 154 | | | | | | | | |
| PDD1 | R*4 | VAR | 128 | 138 | 138 | 151 | | | | | | | | |
| PDD2 | R*4 | VAR | 129 | 142 | 142 | 152 | | | | | | | | |
| PDD3 | R*4 | VAR | 130 | 146 | 146 | 155 | | | | | | | | |
| PMGTD | R*4 | VAR | 10 | 190 | 193 | 204 | 205 | | | | | | | |
| PPRCN | R*4 | VAR | 10 | 181 | 185 | | | | | | | | | |
| PV | R*8 | VAR | 2 | 199 | 201 | | | | | | | | | |
| R$1DSQ | | SBR | | | | | | | | | | | | |
| R$1SQR | | SBR | | | | | | | | | | | | |
| RHO1 | R*4 | VAR | 4 | 151 | 155 | 184 | 188 | | | | | | | |
| RHO2 | R*4 | VAR | 4 | 152 | 153 | 153 | 154 | | | | | | | |
| RHO3 | R*4 | VAR | 4 | 153 | | | | | | | | | | |
| SHEAR | R*4 | VAR | 3 | | | | | | | | | | | |
| SOUND | R*8 | ARR | 2 | 6 | 89 | 101 | 144 | 146 | 148 | 150 | | | | |
| SPEED | R*8 | ARR | 2 | 6 | 78 | 79 | 80 | 81 | 88 | 89 | 90 | 90 | 90 | 100 |
| | | | 101 | 102 | 102 | 102 | | | | | | | | |
| SQRT | R*4 | IFN | 157 | 184 | 188 | | | | | | | | | |
| SRFC | R*4 | VAR | 110 | 181 | 184 | | | | | | | | | |
| TN | | COM | 3 | | | | | | | | | | | |
| TNH | | COM | 5 | | | | | | | | | | | |
| TNI | | COM | 4 | | | | | | | | | | | |
| TNIH | | COM | 10 | | | | | | | | | | | |
| TWOPT | R*8 | VAR | 2 | 6 | 32 | 107 | 109 | 189 | | | | | | |
| UNRM1 | R*4 | ARR | 3 | 159 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 216 | 223 | |
| UNRM2 | R*4 | ARR | 3 | 160 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 217 | 224 | |
| X | R*4 | ARR | 11 | 36 | 42 | 56 | | | | | | | | |
| Y | R*4 | ARR | 11 | 44 | 51 | 58 | | | | | | | | |
| YNM1 | R*4 | VAR | 163 | 171 | 178 | | | | | | | | | |
| YNM2 | R*4 | VAR | 164 | 172 | 178 | | | | | | | | | |
| YNM3 | R*4 | VAR | 165 | 173 | 178 | | | | | | | | | |
| YNM4 | R*4 | VAR | 166 | 174 | 188 | 188 | | | | | | | | |
| YNM5 | R*4 | VAR | 167 | 175 | 179 | | | | | | | | | |
| YNM6 | R*4 | VAR | 168 | 176 | 179 | | | | | | | | | |

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FLUID       CROSS REFERENCE LISTING

   SYMBOL    TYPE/USAGE       REFERENCES

   YNM7      R*4   VAR     169    177    179
   YOU       R*8   ARR       2      9    136    136    138    138    140    140    142    142    144    144
                           146    146    148    148    150    150    151    151    151    151    152    152
                           152    152    153    153    154    154    154    154    155    155    155    155
                           159    160
   Z1        R*4   ARR       3     36     42     43     43     45     56     87     88     88     88
   Z2        R*4   ARR       3     44     45     51     52     52     58     99    100    100    100
```

SOURCE LISTING

CSN STATEMENT

```
      SUBROUTINE ITRTF (AKN)
      DOUBLE PRECISION OMEGA2,TWOPI,A,HH2,AKN,YOU,SPEED,DL2,PPLUS1,[illegible],
     >PMNS1,B,DL1,HH1,UMAX,UABVL,SOUND
      COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
      COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
     >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
      COMMON/NIFLU/A
      COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
      COMMON/TNIH/PPRCN,PMGTD
      COMMON/IH/UMAX
      MATCH=0
         IF (IZERO.NE.1) GO TO 10
         DO 6 J=3,N1MNS2
         IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 6
      MATCH=J
         GO TO 10
    6 CONTINUE
         DO 8 J=N1PLS3,NTMNS2
         IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 8
      MATCH=J
         GO TO 10
    8 CONTINUE
      MATCH=NTMNS2
   10 NCR=0
      IFG=0
      OMEGA2=TWOPI*TWOPI*F*F
      A=DABS(HH2*(AKN*AKN-OMEGA2/(DBLE(COMP)*COMP)))
      YOU(NT)=DBLE(RHO3)/RHO2
      YOU(NT-1)=YOU(NT)+DSQRT(A)-YOU(NT)*(OMEGA2*SPEED(NT)-HH2*AKN*AKN)/
     >2.0
      UMAX=DMAX1(DABS(YOU(NT)),DABS(YOU(NT-1)))
      A=A/(DL2*DL2)
         DO 31 J=2,N2MNS1
      NTMJ=NT-J
      PPLUS1=12.0+OMEGA2*SPEED(NTMJ)-HH2*AKN*AKN
      P=24.0-10.0*(OMEGA2*SPEED(NTMJ+1)-HH2*AKN*AKN)
      PMNS1=12.0+OMEGA2*SPEED(NTMJ+2)-HH2*AKN*AKN
      YOU(NTMJ)=(P/PPLUS1)*YOU(NTMJ+1)-(PMNS1/PPLUS1)*YOU(NTMJ+2)
      UABVL=DABS(YOU(NTMJ))
      IF (UABVL.GT.UMAX) UMAX=UABVL
      IF (DSIGN(1.D0,YOU(NTMJ))*YOU(NTMJ+1).LE.0.) NCR=NCR+1
         IF (UABVL.LT.PMGTD) GO TO 22
         DO 21 JD=NTMJ,NT
      IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.
   21 YOU(JD)=YOU(JD)/PMGTD
      UMAX=UMAX/PMGTD
      IFG=IFG+1
   22    IF (NTMJ.EQ.MATCH) GO TO 131
   31 CONTINUE
      B=(3.0*YOU(N1PLS1)-4.0*YOU(N1PLS1+1)+YOU(N1PLS1+2))/(2.0*DL2)
```

```
CSN        STATEMENT

           YØU(N1)=RHØ2*YØU(N1PLS1)/RHØ1
           YØU(N1-1)=YØU(N1)+DL1*B-YØU(N1)*(ØMEGA2*SPEED(N1)-HH1*AKN*AKN)/2.0
           IF (DABS(YØU(N1)).GT.UMAX) UMAX=DABS(YØU(N1))
           IF (DABS(YØU(N1-1)).GT.UMAX) UMAX=DABS(YØU(N1-1))
           IF (DSIGN(1.D0,YØU(N1))*YØU(N1-1).LE.0.) NCR=NCR+1
              DØ 121 J=2,N1MNS1
           N1MJ=N1-J
           PPLUS1=12.0+ØMEGA2*SPEED(N1MJ)-HH1*AKN*AKN
           P=24.0-10.0*(ØMEGA2*SPEED(N1MJ+1)-HH1*AKN*AKN)
           PMNS1=12.0+ØMEGA2*SPEED(N1MJ+2)-HH1*AKN*AKN
           YØU(N1MJ)=(P/PPLUS1)*YØU(N1MJ+1)-(PMNS1/PPLUS1)*YØU(N1MJ+2)
           UABVL=DABS(YØU(N1MJ))
           IF (UABVL.GT.UMAX) UMAX=UABVL
           IF (DSIGN(1.D0,YØU(N1MJ))*YØU(N1MJ+1).LE.0.) NCR=NCR+1
              IF (UABVL.LT.PMGTD) GØ TØ 51
              DØ 41 JD=N1MJ,NT
           IF (DABS(YØU(JD)).LT.1.D0) YØU(JD)=0.
        41 YØU(JD)=YØU(JD)/PMGTD
           UMAX=UMAX/PMGTD
           IFG=IFG+1
        51    IF (N1MJ.EQ.MATCH) GØ TØ 131
       121 CØNTINUE
              GØ TØ 151
       131 IZERØ=2
           YØU(1)=0.0
           YØU(2)=DSQRT(HH1)*1.D-10
              DØ 135 J=3,N1
           PPLUS1=12.0+ØMEGA2*SPEED(J)-HH1*AKN*AKN
           P=24.0-10.0*(ØMEGA2*SPEED(J-1)-HH1*AKN*AKN)
           PMNS1=12.0+ØMEGA2*SPEED(J-2)-HH1*AKN*AKN
           PPLUS1=(P/PPLUS1)*YØU(J-1)-(PMNS1/PPLUS1)*YØU(J-2)
              IF (J.EQ.MATCH) GØ TØ 148
           YØU(J)=PPLUS1
              IF (DABS(YØU(J)).LT.PMGTD) GØ TØ 135
              DØ 133 JD=2,J
           IF (DABS(YØU(JD)).LT.1.D0) YØU(JD)=0.0
       133 YØU(JD)=YØU(JD)/PMGTD
       135 CØNTINUE
           B=(-3.0*YØU(N1MNS2)+4.0*YØU(N1MNS1)-YØU(N1))/(2.0*DL1)
           YØU(N1PLS1)=RHØ1*YØU(N1)/RHØ2
           YØU(N1PLS2)=YØU(N1PLS1)+DL2*B-YØU(N1PLS1)*
          >(ØMEGA2*SPEED(N1PLS1)-HH2*AKN*AKN)/2.0
              DØ 145 J=N1PLS3,NTMNS2
           PPLUS1=12.0+ØMEGA2*SPEED(J)-HH2*AKN*AKN
           P=24.0-10.0*(ØMEGA2*SPEED(J-1)-HH2*AKN*AKN)
           PMNS1=12.0+ØMEGA2*SPEED(J-2)-HH2*AKN*AKN
           PPLUS1=(P/PPLUS1)*YØU(J-1)-(PMNS1/PPLUS1)*YØU(J-2)
              IF (J.EQ.MATCH) GØ TØ 148
           YØU(J)=PPLUS1
              IF (DABS(YØU(J)).LT.PMGTD) GØ TØ 145
```

ITRTF SOURCE LISTING

```
CSN     STATEMENT

           DO 143 JD=2,J
        IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.0
    143 YOU(JD)=YOU(JD)/PNGTD
    145 CONTINUE
           GO TO 151
    148 JMNS1=J-1
           DO 149 JD=2,JMNS1
        YOU(JD)=(YOU(JD)/PPLUS1)*YOU(MATCH)
        IF (DABS(YOU(JD)).LT.1./PNGTD) YOU(JD)=0.0
    149 CONTINUE
    151 CONTINUE
        RETURN
        END
```

ITRTF CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | |
|---|---|---|---|---|---|
| 6 | | 15 | 11 | 12 | |
| 8 | | 20 | 16 | 17 | |
| 10 | | 22 | 10 | 14 | 19 |
| 21 | | 42 | 40 | | |
| 22 | | 45 | 39 | | |
| 31 | | 46 | 30 | | |
| 41 | | 65 | 63 | | |
| 51 | | 68 | 62 | | |
| 121 | | 69 | 53 | | |
| 131 | | 71 | 45 | 68 | |
| 133 | | 84 | 82 | | |
| 135 | | 85 | 74 | 81 | |
| 143 | | 99 | 97 | | |
| 145 | | 100 | 89 | 96 | |
| 148 | | 102 | 79 | 94 | |
| 149 | | 106 | 103 | | |
| 151 | | 107 | 70 | 101 | |

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | R*8 | VAR | 2 | 5 | 25 | 27 | 29 | 29 | | | | | | |
| AKN | R*8 | DAR | 1 | 2 | 12 | 17 | 25 | 25 | 27 | 27 | 32 | 32 | 33 | 33 |
| | | | 34 | 34 | 49 | 49 | 55 | 55 | 56 | 56 | 57 | 57 | 75 | 75 |
| | | | 76 | 76 | 77 | 77 | 88 | 88 | 90 | 90 | 91 | 91 | 92 | 92 |
| B | R*8 | VAR | 2 | 47 | 49 | 86 | 88 | | | | | | | |
| COMP | R*4 | VAR | 3 | 25 | 25 | | | | | | | | | |
| DABS | R*4 | IFN | 25 | 28 | 28 | 36 | 41 | 50 | 50 | 51 | 51 | 59 | 64 | 81 |
| | | | 83 | 96 | 98 | 105 | | | | | | | | |
| DBLE | R*4 | IFN | 25 | 26 | | | | | | | | | | |
| DL1 | R*8 | VAR | 2 | 4 | 49 | 86 | | | | | | | | |
| DL2 | R*8 | VAR | 2 | 4 | 29 | 29 | 47 | 88 | | | | | | |
| DMAX1 | R*4 | IFN | 28 | | | | | | | | | | | |
| DSIGN | R*4 | IFN | 38 | 52 | 61 | | | | | | | | | |
| DSQRT | R*4 | IFN | 27 | 73 | | | | | | | | | | |
| F | R*4 | VAR | 3 | 12 | 17 | 24 | 24 | | | | | | | |
| HH1 | R*8 | VAR | 2 | 4 | 49 | 55 | 56 | 57 | 73 | 75 | 76 | 77 | | |
| HH2 | R*8 | VAR | 2 | 4 | 25 | 27 | 32 | 33 | 34 | 88 | 90 | 91 | 92 | |
| H12 | R*4 | VAR | 3 | | | | | | | | | | | |
| I | I*4 | VAR | 6 | | | | | | | | | | | |
| IFG | I*4 | VAR | 6 | 23 | 44 | 44 | 67 | 67 | | | | | | |
| IH | | COM | 8 | | | | | | | | | | | |
| ITRTF | I*4 | ENT | 1 | | | | | | | | | | | |
| IZERO | I*4 | VAR | 6 | 10 | 71 | | | | | | | | | |
| J | I*4 | VAR | 11 | 12 | 13 | 16 | 17 | 18 | 30 | 31 | 53 | 54 | 74 | 75 |
| | | | 76 | 77 | 78 | 78 | 79 | 80 | 81 | 82 | 89 | 90 | 91 | 92 |
| | | | 93 | 93 | 94 | 95 | 96 | 97 | 102 | | | | | |
| JD | I*4 | VAR | 40 | 41 | 41 | 42 | 42 | 63 | 64 | 64 | 65 | 65 | 82 | 83 |

ITRTF CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 83 | 84 | 84 | 97 | 98 | 98 | 99 | 99 | 103 | 104 | 104 | 105 |
| | | | 105 | | | | | | | | | | | |
| JMNS1 | I*4 | VAR | 102 | 103 | | | | | | | | | | |
| MATCH | I*4 | VAR | 4 | 9 | 13 | 18 | 21 | 45 | 68 | 79 | 94 | 104 | | |
| NCR | I*4 | VAR | 6 | 22 | 38 | 38 | 52 | 52 | 61 | 61 | | | | |
| NI | | COM | 4 | | | | | | | | | | | |
| NIFLU | | COM | 5 | | | | | | | | | | | |
| NIH | | COM | 6 | | | | | | | | | | | |
| NT | I*4 | VAR | 4 | 26 | 27 | 27 | 27 | 27 | 28 | 28 | 31 | 40 | 63 | |
| NTMJ | I*4 | VAR | 31 | 32 | 33 | 34 | 35 | 35 | 35 | 36 | 38 | 38 | 40 | 45 |
| NTMNS2 | I*4 | VAR | 4 | 16 | 21 | 89 | | | | | | | | |
| N1 | I*4 | VAR | 3 | 48 | 49 | 49 | 49 | 49 | 50 | 50 | 51 | 51 | 52 | 52 |
| | | | 54 | 74 | 86 | 87 | | | | | | | | |
| N1MJ | I*4 | VAR | 54 | 55 | 56 | 57 | 58 | 58 | 58 | 59 | 61 | 61 | 63 | 68 |
| N1MNS1 | I*4 | VAR | 4 | 53 | 86 | | | | | | | | | |
| N1MNS2 | I*4 | VAR | 4 | 11 | 86 | | | | | | | | | |
| N1PLS1 | I*4 | VAR | 4 | 47 | 47 | 47 | 48 | 87 | 88 | 88 | 88 | | | |
| N1PLS2 | I*4 | VAR | 4 | 88 | | | | | | | | | | |
| N1PLS3 | I*4 | VAR | 4 | 16 | 89 | | | | | | | | | |
| N2MNS1 | I*4 | VAR | 4 | 30 | | | | | | | | | | |
| OMEGA2 | R*8 | VAR | 2 | 24 | 25 | 27 | 32 | 33 | 34 | 49 | 55 | 56 | 57 | 75 |
| | | | 76 | 77 | 88 | 90 | 91 | 92 | | | | | | |
| P | R*8 | VAR | 2 | 33 | 35 | 56 | 58 | 76 | 78 | 91 | 93 | | | |
| PMGTD | R*4 | VAR | 7 | 39 | 42 | 43 | 62 | 65 | 66 | 81 | 84 | 96 | 99 | 105 |
| PMNS1 | R*8 | VAR | 2 | 34 | 35 | 57 | 58 | 77 | 78 | 92 | 93 | | | |
| PPLUS1 | R*8 | VAR | 2 | 32 | 35 | 35 | 55 | 58 | 58 | 75 | 78 | 78 | 78 | 80 |
| | | | 90 | 93 | 93 | 93 | 95 | 104 | | | | | | |
| PPRCN | R*4 | VAR | 7 | | | | | | | | | | | |
| R$1DSQ | | SBR | | | | | | | | | | | | |
| RHO1 | R*4 | VAR | 3 | 48 | 87 | | | | | | | | | |
| RHO2 | R*4 | VAR | 3 | 26 | 48 | 87 | | | | | | | | |
| RHO3 | R*4 | VAR | 3 | 26 | | | | | | | | | | |
| SOUND | R*8 | ARR | 2 | 4 | 12 | 17 | | | | | | | | |
| SPEED | R*8 | ARR | 2 | 4 | 27 | 32 | 33 | 34 | 49 | 55 | 56 | 57 | 75 | 76 |
| | | | 77 | 88 | 90 | 91 | 92 | | | | | | | |
| TNI | | COM | 3 | | | | | | | | | | | |
| TNIH | | COM | 7 | | | | | | | | | | | |
| TWOPI | R*8 | VAR | 2 | 4 | 12 | 17 | 24 | 24 | | | | | | |
| UABVL | R*8 | VAR | 2 | 36 | 37 | 37 | 39 | 59 | 60 | 60 | 62 | | | |
| UMAX | R*8 | VAR | 2 | 8 | 28 | 37 | 37 | 43 | 43 | 50 | 50 | 51 | 51 | 60 |
| | | | 60 | 66 | 66 | | | | | | | | | |
| YOU | R*8 | ARR | 2 | 6 | 26 | 27 | 27 | 27 | 28 | 28 | 35 | 35 | 35 | 36 |
| | | | 38 | 38 | 41 | 41 | 42 | 42 | 47 | 47 | 47 | 48 | 48 | 49 |
| | | | 49 | 49 | 50 | 50 | 51 | 51 | 52 | 52 | 58 | 58 | 58 | 59 |
| | | | 61 | 61 | 64 | 64 | 65 | 65 | 72 | 73 | 78 | 78 | 80 | 81 |
| | | | 83 | 83 | 84 | 84 | 86 | 86 | 86 | 87 | 87 | 88 | 88 | 88 |
| | | | 93 | 93 | 95 | 96 | 98 | 98 | 99 | 99 | 104 | 104 | 104 | 105 |
| | | | 105 | | | | | | | | | | | |

SOURCE LISTING

CSN STATEMENT

```
      SUBROUTINE HALFF
      DOUBLE PRECISION AK1,AK2,ANEW,AK,ZK,YOU,AKNL,AKNR,ZL,ZR,AR1,AL1,
     >ZR1,ZL1,ZNEW,AKA,AKN,UMAX
      COMMON/TNH/AKN(150)
      COMMON/TH/EPSLN
      COMMON/NH/AK1,AK2,LOOP
      COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
      COMMON/TNIH/PPRCN,PMGTD
      COMMON/IH/UMAX
      DIMENSION AK(2),ZK(2)
C
C     ********** PART 1 **********
C
      IZERO=0
      LOOP=0
         DO 52 K=1,2
      J=I+1-K
         IF (K.EQ.2) GO TO 12
         CALL ITRTF (AK1)
      LOOP=LOOP+1
      NA1=NCR
         CALL ITRTF (AK2)
      LOOP=LOOP+1
      NA2=NCR
   12 ANEW=((AK2-AK1)*(J-NA1)/(NA2-NA1))+AK1
         CALL ITRTF (ANEW)
      LOOP=LOOP+1
         IF (NCR.EQ.J) GO TO 42
         IF (NCR.GT.J) GO TO 32
      AK2=ANEW
      NA2=NCR
         GO TO 12
   32 AK1=ANEW
      NA1=NCR
         GO TO 12
   42 AK(K)=ANEW
      IF (K.EQ.1) IP1=IFG
      IF (K.EQ.2) IP2=IFG
   52 ZK(K)=YOU(1)
      AKNL=AK(1)
      AKNR=AK(2)
      ZL=ZK(1)
      ZR=ZK(2)
C
C     ********** PART 2 **********
C
      ICLSIN=0
   62 ICLSIN=ICLSIN+1
         IF (ICLSIN.EQ.20) GO TO 112
      AR1=AKNR-(1.E-12)
```

```
HALFF          SOURCE LISTING

               STATEMENT

              AL1=AKNL+(1.E-12)
                 CALL ITRTF (AR1)
              IP4=IFG
              ZR1=YOU(1)
                 CALL ITRTF (AL1)
              IP3=IFG
          64     IF (IP1-IP3) 66,70,68
          66  IF (DABS(ZL).LE.1.D0) ZL=0.
              ZL=ZL/PMGTD
              IP1=IP1+1
                 GO TO 64
          68  IF (DABS(ZL1).LE.1.D0) ZL1=0.
              ZL1=ZL1/PMGTD
              IP3=IP3+1
                 GO TO 64
          70  CONTINUE
          72     IF (IP2-IP4) 74,78,76
          74  IF (DABS(ZR).LE.1.D0) ZR=0.
              ZR=ZR/PMGTD
              IP2=IP2+1
                 GO TO 72
          76  IF (DABS(ZR1).LE.1.D0) ZR1=0.
              ZR1=ZR1/PMGTD
              IP4=IP4+1
                 GO TO 72
          78  ZL1=YOU(1)
                 IF (DABS(ZR1).GT.DABS(ZR)) GO TO 82
                 IF (DABS(ZL1).LE.DABS(ZL)) GO TO 122
          82  ANEW=(AKNR+AKNL)/2.0
                 CALL ITRTF (ANEW)
              ZNEW=YOU(1)
                 IF (NCR.NE.I) GO TO 102
              AKNL=ANEW
              IP1=IFG
              ZL=ZNEW
                 GO TO 62
         102  AKNR=ANEW
              IP2=IFG
              ZR=ZNEW
                 GO TO 62
      C
      C  ********** PART 3 **********
      C
         112     IF (IP1-IP2) 117,119,118
         117  IF (DABS(ZL).LE.1.D0) ZL=0.
              ZL=ZL/PMGTD
              IP1=IP1+1
                 GO TO 112
         118  IF (DABS(ZR).LE.1.D0) ZR=0.
              ZR=ZR/PMGTD
```

HALFF SØURCE LISTING

```
CSN        STATEMENT

           IP2=IP2+1
              GØ TØ 112
       119 AKA=AKNL+(ZL*(AKNR-AKNL))/(ZL-ZR)
           FLØG=1.0
              GØ TØ 132
       122 AKA=(AKNL+AKNR)/2.0
           FLØG=2.0
       132    CALL ITRTF (AKA)
           LØØP=LØØP+1
           EPLØN=EPSLN*UMAX
              IF (DABS(YØU(1)).GT.EPLØN) GØ TØ 162
              IF (DABS(AKNL-AKA).LE.1.E-12)  GØ TØ 222
              IF (DABS(AKNR-AKA).LE.1.E-12) GØ TØ 222
       162    IF (NCR.NE.I) GØ TØ 192
              IF (DABS(AKNL-AKA).LE.PPRCN) GØ TØ 212
           IP1=IFG
           ZL=YØU(1)
           AKNL=AKA
              IF (FLØG.GT.1.5) GØ TØ 112
              GØ TØ 122
       192    IF (DABS(AKNR-AKA).LE.PPRCN) GØ TØ 212
           IP2=IFG
           ZR=YØU(1)
           AKNR=AKA
              IF (FLØG.GT.1.5) GØ TØ 112
              GØ TØ 122
       212 IZERØ=1
              CALL ITRTF (AKA)
       222 AKN(I)=AKA
           RETURN
           END
```

HALFF CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | | | |
|---|---|---|---|---|---|---|---|
| 12 | | 21 | 14 | 28 | 31 | | |
| 32 | | 29 | 25 | | | | |
| 42 | | 32 | 24 | | | | |
| 52 | | 35 | 12 | | | | |
| 62 | | 41 | 79 | 83 | | | |
| 64 | | 50 | 54 | 58 | | | |
| 66 | | 51 | 50 | | | | |
| 68 | | 55 | 50 | | | | |
| 70 | | 59 | 50 | | | | |
| 72 | | 60 | 64 | 68 | | | |
| 74 | | 61 | 60 | | | | |
| 76 | | 65 | 60 | | | | |
| 78 | | 69 | 60 | | | | |
| 82 | | 72 | 70 | | | | |
| 102 | | 80 | 75 | | | | |
| 112 | | 84 | 42 | 88 | 92 | 109 | 115 |
| 117 | | 85 | 84 | | | | |
| 118 | | 89 | 84 | | | | |
| 119 | | 93 | 84 | | | | |
| 122 | | 96 | 71 | 110 | 116 | | |
| 132 | | 98 | 95 | | | | |
| 162 | | 104 | 101 | | | | |
| 192 | | 111 | 104 | | | | |
| 212 | | 117 | 105 | 111 | | | |
| 222 | | 119 | 102 | 103 | | | |

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AK | R*8 | ARR | 2 | 9 | 32 | 36 | 37 | | | | | | | |
| AKA | R*8 | VAR | 2 | 93 | 96 | 98 | 102 | 103 | 105 | 108 | 111 | 114 | 118 | 119 |
| AKN | R*8 | ARR | 2 | 3 | 119 | | | | | | | | | |
| AKNL | R*8 | VAR | 2 | 36 | 44 | 72 | 76 | 93 | 93 | 96 | 102 | 105 | 108 | |
| AKNR | R*8 | VAR | 2 | 37 | 43 | 72 | 80 | 93 | 96 | 103 | 111 | 114 | | |
| AK1 | R*8 | VAR | 2 | 5 | 15 | 21 | 21 | 29 | | | | | | |
| AK2 | R*8 | VAR | 2 | 5 | 18 | 21 | 26 | | | | | | | |
| AL1 | R*8 | VAR | 2 | 44 | 48 | | | | | | | | | |
| ANEW | R*8 | VAR | 2 | 21 | 22 | 26 | 29 | 32 | 72 | 73 | 76 | 80 | | |
| AR1 | R*8 | VAR | 2 | 43 | 45 | | | | | | | | | |
| DABS | R*4 | IFN | 51 | 55 | 61 | 65 | 70 | 70 | 71 | 71 | 85 | 89 | 101 | 102 |
| | | | 103 | 105 | 111 | | | | | | | | | |
| EPLON | R*4 | VAR | 100 | 101 | | | | | | | | | | |
| EPSLN | R*4 | VAR | 4 | 100 | | | | | | | | | | |
| FLOG | R*4 | VAR | 94 | 97 | 109 | 115 | | | | | | | | |
| HALFF | R*4 | ENT | 1 | | | | | | | | | | | |
| I | I*4 | VAR | 6 | 13 | 75 | 104 | 119 | | | | | | | |
| ICLSIN | I*4 | VAR | 40 | 41 | 41 | 42 | | | | | | | | |
| IFG | I*4 | VAR | 6 | 33 | 34 | 46 | 49 | 77 | 81 | 106 | 112 | | | |

HALFF CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IH | | COM | 8 | | | | | | | | | | | |
| IP1 | I*4 | VAR | 33 | 50 | 53 | 53 | 77 | 84 | 87 | 87 | 106 | | | |
| IP2 | I*4 | VAR | 34 | 60 | 63 | 63 | 81 | 84 | 91 | 91 | 112 | | | |
| IP3 | I*4 | VAR | 49 | 50 | 57 | 57 | | | | | | | | |
| IP4 | I*4 | VAR | 46 | 60 | 67 | 67 | | | | | | | | |
| ITRTF | | SBR | 15 | 18 | 22 | 45 | 48 | 73 | 98 | 118 | | | | |
| IZERO | I*4 | VAR | 6 | 10 | 117 | | | | | | | | | |
| J | I*4 | VAR | 13 | 21 | 24 | 25 | | | | | | | | |
| K | I*4 | VAR | 12 | 13 | 14 | 32 | 33 | 34 | 35 | | | | | |
| LOOP | I*4 | VAR | 5 | 11 | 16 | 16 | 19 | 19 | 23 | 23 | 99 | 99 | | |
| NA1 | I*4 | VAR | 17 | 21 | 21 | 30 | | | | | | | | |
| NA2 | I*4 | VAR | 20 | 21 | 27 | | | | | | | | | |
| NCR | I*4 | VAR | 6 | 17 | 20 | 24 | 25 | 27 | 30 | 75 | 104 | | | |
| NH | | COM | 5 | | | | | | | | | | | |
| NIH | | COM | 6 | | | | | | | | | | | |
| PMGTD | R*4 | VAR | 7 | 52 | 56 | 62 | 66 | 86 | 90 | | | | | |
| PPRCN | R*4 | VAR | 7 | 105 | 111 | | | | | | | | | |
| TH | | COM | 4 | | | | | | | | | | | |
| TNH | | COM | 3 | | | | | | | | | | | |
| TNIH | | COM | 7 | | | | | | | | | | | |
| UMAX | R*8 | VAR | 2 | 8 | 100 | | | | | | | | | |
| YOU | R*8 | ARR | 2 | 6 | 35 | 47 | 69 | 74 | 101 | 107 | 113 | | | |
| ZK | R*8 | ARR | 2 | 9 | 35 | 38 | 39 | | | | | | | |
| ZL | R*8 | VAR | 2 | 38 | 51 | 51 | 52 | 52 | 71 | 78 | 85 | 85 | 86 | 86 |
| | | | 93 | 93 | 107 | | | | | | | | | |
| ZL1 | R*8 | VAR | 2 | 55 | 55 | 56 | 56 | 69 | 71 | | | | | |
| ZNEW | R*8 | VAR | 2 | 74 | 78 | 82 | | | | | | | | |
| ZR | R*8 | VAR | 2 | 39 | 61 | 61 | 62 | 62 | 70 | 82 | 89 | 89 | 90 | 90 |
| | | | 93 | 113 | | | | | | | | | | |
| ZR1 | R*8 | VAR | 2 | 47 | 65 | 65 | 66 | 66 | 70 | | | | | |

SOURCE LISTING

```
CSN          STATEMENT

0001               SUBROUTINE SOLID
0002          DOUBLE PRECISION TWOPI,A,DCOMP,B,DSHEAR,URA,RAYL,XRA,RA1,RA2,
             >FRA,DRA,DL1,HH1,DL2,HH2,SPEED,DEPTH,KRAY,KMAX,KSHEAR,AK1,AK2,YOU,
             >AKN,PV,SOUND
0003          INTEGER ADCRS,RAYCRS
0004          REAL KCOMP,KCOMP2,KSHR2
0005          COMMON/TN/Z1(150),C1(150),Z2(150),C2(150),ABSOR(150),ATTEN2(150),
             >ATTENC(150),ATTENS(150),AIRH20(150),H202ND(150),UNRM1(150,1202),
             >UNRM2(150,1202),MDPRNT,INC1,INC2,H2,LI1,LI2,SHEAR,NMODE,KA,ND1,
             >ND2,N2
0006          COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
0007          COMMON/TNH/AKN(150)
0008          COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
             >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
0009          COMMON/NISOL/DCOMP,DSHEAR,KRAY,ADCRS
0010          COMMON/NH/AK1,AK2,LOOP
0011          COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0012          COMMON/TNIH/PPRCN,PMGTD
0013          DIMENSION LAMP(3),DEPTH(1202),X(650),Y(650),MDNUM(12),LDEPTH(2)
0014          DATA LDEPTH/' DEP','TH  '/
0015          DATA LAMP/'AMPL','ITUD','E'/
0016     8001 FORMAT (//,35X,'COMPRESSIONAL VELOCITY    SHEAR VELOCITY    RAYLEI
             >GH VELOCITY',/,40X,F10.3,3X,2(9X,F10.3))
0017     9001 FORMAT (////,55X,'SOUND SPEED PROFILE',//,49X,'  DEPTH     DEPTH
             >  VELOCITY',//)
0018    10001 FORMAT (45X,3F11.3)
0019    11001 FORMAT (/)
0020    12001 FORMAT (1H1,/,35X,'MAXIMUM NUMBER OF MODES =',I3,10X,'NUMBER OF MO
             >DES CALCULATED =',I3,//)
0021    13001 FORMAT (1H1)
0022    14001 FORMAT (' MODE NO. =',I3,5X,'PHASE VELOCITY =',D20.12)
0023    15001 FORMAT (' UPPER AMPLITUDES MATCHED FOR THIS MODE STARTING AT NORMA
             >LIZED DEPTH =',F7.4)
0024    16001 FORMAT (' NUMBER OF ITERATE SOLUTIONS =',I3,5X,'THE EIGENFUNCTION
             >WAS SCALED DOWN',I3,' TIME(S)')
0025    17001 FORMAT (' LAYER 2 ATTEN RATIO = DEFAULT ZERO')
0026    18001 FORMAT (' COMP ATTEN RATIO = DEFAULT ZERO')
0027    18002 FORMAT (' SHEAR ATTEN RATIO = DEFAULT ZERO')
0028    19001 FORMAT ('   WAVE NUMBER        WATER ABSORPTION  LAYER 2 ATTEN RATI
             >O   COMP ATTEN RATIO   SHEAR ATTEN RATIO   AIR/H2O SCATTER   H2O/2
             >ND SCATTER')
0029    20001 FORMAT (D19.12,4X,E11.4,9X,2(E11.4,10X),E11.4,2(8X,E10.4),//)
0030    21001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
             >Z.',//,' FIRST LAYER',///)
0031    22001 FORMAT (10X,12(3X,I3,'MODE'),/)
0032    23001 FORMAT (4X,2A4,12(1X,2A4,A1))
0033    24001 FORMAT (13F10.4)
0034    25001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
             >Z.',//,' SECOND LAYER',///)
0035          TWOPI=6.2831853071795800
```

SOLID SOURCE LISTING

CSN STATEMENT

```
      F2=(F/1000.)*(F/1000.)
      EPW=.1*F2/(1.+F2)+40.*F2/(4100.+F2)+2.75E-4*F2
      EPW=EPW*.115129254 6*1.093613298E-3
      DCOMP=DBLE(COMP)
      DSHEAR=DBLE(SHEAR)
      A=1.0/(DCOMP*DCOMP)
      B=1.0/(DSHEAR*DSHEAR)
      URA=(DCOMP*DCOMP-2.0*DSHEAR*DSHEAR)/(2.0*(DCOMP*DCOMP-
     >DSHEAR*DSHEAR))
      RAYL=((0.87+1.12*URA)/(1.0+URA))*DSHEAR
      XRA=1.0/(RAYL*RAYL)
         DO 10 J=1,5
      RA1=DSQRT(XRA-A)*DSQRT(XRA-B)
      RA2=(DSQRT(XRA-A)/DSQRT(XRA-B))+(DSQRT(XRA-B)/DSQRT(XRA-A))
      FRA=RA1-(XRA-(B/2.0))*(XRA-(B/2.0))/XRA
      DRA=0.5*RA2-(1.0-((B*B)/(4.0*XRA*XRA)))
   10 XRA=XRA-(FRA/DRA)
      RAYL=DSQRT(1.0/XRA)
      X(1)=Z1(1)
      CMIN1=C1(1)
      CMAX1=C1(1)
         DO 20 J=2,ND1
      IF (C1(J).LT.CMIN1) CMIN1=C1(J)
      IF (C1(J).GT.CMAX1) CMAX1=C1(J)
      X(J)=Z1(J)
   20 Z1(J)=Z1(J)/H12
      Y(1)=Z2(1)
      Z2(1)=Z1(ND1)
      CMIN2=C2(1)
      CMAX2=C2(1)
         DO 30 J=2,ND2
      IF (C2(J).LT.CMIN2) CMIN2=C2(J)
      IF (C2(J).GT.CMAX2) CMAX2=C2(J)
      Y(J)=Z2(J)
   30 Z2(J)=Z2(J)/H12
      CMIN=AMIN1(CMIN1,CMIN2)
      WRITE(6,8001) COMP,SHEAR,RAYL
      WRITE(6,9001)
      WRITE(6,10001) (Z1(I),X(I),C1(I),I=1,ND1)
      WRITE(6,11001)
      WRITE(6,10001) (Z2(I),Y(I),C2(I),I=1,ND2)
      DL1=DBLE(1.0)/LI1
      HH1=DL1*DL1*H12*H12
      DL2=DBLE(H2)/H12/LI2
      HH2=DL2*DL2*H12*H12
      N1=LI1+1
      N1PLS1=N1+1
      N1PLS2=N1+2
      N1PLS3=N1+3
      N1MNS1=N1-1
```

SOLID SOURCE LISTING

CSN STATEMENT

```
      N1MNS2=N1-2
      N2=LI2+1
      N2MNS1=N2-1
      NT=N1+N2
      NTMNS1=NT-1
      NTMNS2=NT-2
      DEPTH(1)=0.0
      DEPTH(N1)=1.0
      DEPTH(N1PLS1)=1.0
      DEPTH(NT)=DBLE(H2)/H12+1.0
      SPEED(1)=HH1/C1(1)/C1(1)
      SPEED(N1)=HH1/C1(ND1)/C1(ND1)
      SPEED(N1PLS1)=HH2/C2(1)/C2(1)
      SPEED(NT)=HH2/C2(ND2)/C2(ND2)
      K=2
         DO 50 INTERP=2,N1MNS1
      DEPTH(INTERP)=(INTERP-1.0)*DL1
      KK=K
         DO 40 J=KK,ND1
         IF (DEPTH(INTERP).GT.Z1(J)) GO TO 40
      SPEED(INTERP)=((C1(J)-C1(J-1))*(DEPTH(INTERP)-Z1(J-1))/
     >(DBLE(Z1(J))-Z1(J-1)))+C1(J-1)
      SOUND(INTERP)=SPEED(INTERP)
      SPEED(INTERP)=HH1/(SPEED(INTERP)*SPEED(INTERP))
         GO TO 50
   40 K=K+1
   50 CONTINUE
      K=2
         DO 70 INTERP=N1PLS2,NTMNS1
      DEPTH(INTERP)=(INTERP-1-N1)*DL2+1.0
      KK=K
         DO 60 J=KK,ND2
         IF (DEPTH(INTERP).GT.Z2(J)) GO TO 60
      SPEED(INTERP)=((C2(J)-C2(J-1))*(DEPTH(INTERP)-Z2(J-1))/
     >(DBLE(Z2(J))-Z2(J-1)))+C2(J-1)
      SOUND(INTERP)=SPEED(INTERP)
      SPEED(INTERP)=HH2/(SPEED(INTERP)*SPEED(INTERP))
         GO TO 70
   60 K=K+1
   70 CONTINUE
      IZERO=0
      ADCRS=1
      KRAY=TWOPI*F/RAYL
      KMAX=TWOPI*F/CMIN
      KCOMP=6.2831853*F/COMP
      KCOMP2=KCOMP*KCOMP
      KSHEAR=TWOPI*F/DSHEAR
      KSHR2=KSHEAR*KSHEAR
      SRFC=39.4784176*F*F/(C1(1)*C1(1))
      BOTTOM=39.4784176*F*F/(C1(ND1)*C1(ND1))
```

SOLID SOURCE LISTING

CSN STATEMENT

```
         CALL ITRTS (KRAY,I)
      RAYCRS=NCR
         CALL ITRTS (KSHEAR,I)
      MAXMD=NCR+1
      NMODE=MINO(NMODE,MAXMD)
      MGROPS=INT(NMODE/12.0+0.02)+1
         DO 350 M=1,MGROPS
      IBASE=(M-1)*12
      IF (M.LT.MGROPS) NIC=12
      IF (M.EQ.MGROPS) NIC=MOD(NMODE,12)
         IF (NIC.EQ.0) GO TO 350
         DO 340 IC=1,NIC
      I=IBASE+IC
      MDNUM(IC)=I
         IF (I.LE.RAYCRS) GO TO 180
      AK1=KSHEAR
      AK2=KRAY
      ADCRS=0
      IM=I-1
         GO TO 190
  180 AK1=KRAY
      AK2=KMAX
      ADCRS=1
      IM=I
         IF (AK1.LT.AK2) GO TO 190
      AK1=KSHEAR
      AK2=KRAY
  190    CALL HALFS (IM)
      ODD=0.0
      ODD1=0.0
      ODD2=0.0
      ODD3=0.0
      EVEN=0.0
      EVEN1=0.0
      EVEN2=0.0
      EVEN3=0.0
         DO 200 J=2,N1MNS1,2
  200 EVEN1=EVEN1+YOU(J)*YOU(J)
         DO 210 J=3,N1MNS2,2
  210 ODD1=ODD1+YOU(J)*YOU(J)
         DO 220 J=N1PLS2,NTMNS1,2
  220 EVEN2=EVEN2+YOU(J)*YOU(J)
         DO 230 J=N1PLS3,NTMNS2,2
  230 ODD2=ODD2+YOU(J)*YOU(J)
         DO 234 J=2,N1MNS1,2
  234 EVEN3=EVEN3+YOU(J)*YOU(J)/SOUND(J)
         DO 236 J=3,N1MNS2,2
  236 ODD3=ODD3+YOU(J)*YOU(J)/SOUND(J)
         DO 240 J=N1PLS2,NTMNS1,2
  240 EVEN=EVEN+YOU(J)*YOU(J)/SOUND(J)
```

SOLID SOURCE LISTING

```
CSN        STATEMENT

              DO 250 J=N1PLS3,NTMNS2,2
       250 ODD=ODD+YOU(J)*YOU(J)/SOUND(J)
           AI1=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)+4.0*EVEN1+2.0*ODD1+YOU(N1)*
          >YOU(N1))
           AI2=RHO2*(DL2/3.0)*(YOU(N1+1)*YOU(N1+1)+4.0*EVEN2+2.0*ODD2+
          >YOU(NT)*YOU(NT))
           AKN2=AKN(I)*AKN(I)
           QCOMP=AKN2-KCOMP2
           CMPRT=SQRT(QCOMP)
           QSHEAR=2.0*AKN2-KSHR2
           SHEART=SQRT(AKN2-KSHR2)
           QSHR2=QSHEAR*QSHEAR
           Q=RHO3*QSHR2/(H12*QCOMP*KSHR2*KSHR2)
           AI3=Q*(0.5/CMPRT+2.0*QCOMP*KSHR2/(SHEART*QSHR2)+
          >6.0*SHEART*QCOMP/QSHR2-4.0*CMPRT/QSHEAR)
              IF (IFG.LE.0) GO TO 255
           AI3=AI3/PMGTD/PMGTD
           IF (IFG.GT.1) AI3=0.
       255 AI4=RHO2*(DL2/3.0)*(YOU(N1+1)*YOU(N1+1)/C2(1)+4.0*EVEN+2.0*ODD+
          >YOU(NT)*YOU(NT)/C2(ND2))
           AI5=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)/C1(1)+4.0*EVEN3+2.0*ODD3+
          >YOU(N1)*YOU(N1)/C1(ND1))
           AI=AI1+AI2+AI3
           ANORM=SQRT(1.0/AI)
              DO 260 J=1,NT
           IF (KA.EQ.0) UNRM1(I,J)=YOU(J)*ANORM
           IF (KA.EQ.1) UNRM2(I,J)=YOU(J)*ANORM
       260 CONTINUE
              IF (KA.EQ.1) GO TO 270
           YNM1=UNRM1(I,1)
           YNM2=UNRM1(I,2)
           YNM3=UNRM1(I,3)
           YNM4=UNRM1(I,N1)
           YNM5=UNRM1(I,N1PLS1)
           YNM6=UNRM1(I,N1PLS2)
           YNM7=UNRM1(I,N1PLS3)
           YNM8=UNRM1(I,NTMNS2)
           YNM9=UNRM1(I,NTMNS1)
           YNM10=UNRM1(I,NT)
              GO TO 275
       270 YNM1=UNRM2(I,1)
           YNM2=UNRM2(I,2)
           YNM3=UNRM2(I,3)
           YNM4=UNRM2(I,N1)
           YNM5=UNRM2(I,N1PLS1)
           YNM6=UNRM2(I,N1PLS2)
           YNM7=UNRM2(I,N1PLS3)
           YNM8=UNRM2(I,NTMNS2)
           YNM9=UNRM2(I,NTMNS1)
           YNM10=UNRM2(I,NT)
```

SOLID SOURCE LISTING

```
CSN          STATEMENT

0228      275 DYOUA=(-3.*YNM1+4.*YNM2-YNM3)/(2.*DL1)
0229          DYOUB=(-3.*YNM5+4.*YNM6-YNM7)/(2.*DL2)
0230          DYOUC=(YNM8-4.*YNM9+3.*YNM10)/(2.*DL2)
0231          DYOUC=DYOUC*DYOUC
0232             IF (SRFC-AKN2.GT.PPRCN) GO TO 280
0233          AIRH2O(I)=0.0
0234             GO TO 290
0235      280 AIRH2O(I)=RHO1*DYOUA*DYOUA/(4.*AKN(I)*H12**3*SQRT(SRFC-AKN2))
0236      290    IF (BOTTOM-AKN2.GT.PPRCN) GO TO 300
0237          H2O2ND(I)=0.0
0238             GO TO 310
0239      300 H2O2ND(I)=RHO1*SQRT(BOTTOM-AKN2)*(YNM4*YNM4+DYOUB*
         >DYOUB/(H12*H12*(BOTTOM-AKN2)))/(4.0*AKN(I)*H12)
0240      310 PV=TWOPI*F/AKN(I)
0241             IF (AI4.GT.AI/PMGTD) GO TO 313
0242          AI4=0.
0243      313 ATTEN2(I)=6.2831853*F*AI4/(AKN(I)*AI)
0244          ATTENC(I)=KCOMP*Q*.5/(CMPRT*H12*H12*AKN(I))
0245          DYOU=DYOUC
0246          DUTSC=1./PMGTD/ATTENC(I)
0247             IF (DYOU.GT.DUTSC) GO TO 315
0248          DYOU=0.
0249      315 ATTENC(I)=ATTENC(I)*DYOU
0250          ATTENS(I)=AKN(I)*Q/(H12*H12*KSHEAR)*(2.*KSHR2*QCOMP/(SHEART*QSHR2)
         >+8.*SHEART*QCOMP/QSHR2-4.*CMPRT/QSHEAR)
0251          DUTSS=1./PMGTD/ATTENS(I)
0252             IF (DYOUC.GT.DUTSS) GO TO 317
0253          DYOUC=0.
0254      317 ATTENS(I)=ATTENS(I)*DYOUC
0255          ABSOR(I)=6.2831853*F*AI5*EPW/(AKN(I)*AI)
0256             IF (IC.GT.1) GO TO 330
0257          WRITE(6,12001) MAXMD,NMODE
0258      330 IF (MOD(IC,7).EQ.0) WRITE(6,13001)
0259          WRITE(6,14001) I,PV
0260          IF (IZERO.EQ.2) WRITE(6,15001) DEPTH(MATCH)
0261          WRITE(6,16001) LOOP,IFG
0262          IF (AI4.LE.AI/PMGTD) WRITE(6,17001)
0263          IF (DYOU.LE.DUTSC) WRITE(6,18001)
0264          IF (DYOUC.LE.DUTSS) WRITE(6,18002)
0265          WRITE(6,19001)
0266          WRITE(6,20001) AKN(I),ABSOR(I),ATTEN2(I),ATTENC(I),ATTENS(I),
         >AIRH2O(I),H2O2ND(I)
0267      340 CONTINUE
0268             IF (MDPRNT.EQ.0) GO TO 350
0269          WRITE(6,21001) F
0270          WRITE(6,22001) (MDNUM(K),K=1,NIC)
0271          WRITE(6,23001) LDEPTH,(LAMP(1),LAMP(2),LAMP(3),K=1,NIC)
0272          I1=IBASE+1
0273          INIC=IBASE+NIC
0274             DO 345 J=1,N1,INC1
```

```
SOL ID            SOURCE LISTING

    CSN              STATEMENT

                 IF (KA.EQ.0) WRITE(6,24001) DEPTH(J),(UNRM1(K,J),K=I1,INIC)
                 IF (KA.EQ.1) WRITE(6,24001) DEPTH(J),(UNRM2(K,J),K=I1,INIC)
             345 CONTINUE
                 WRITE(6,25001) F
                 WRITE(6,22001) (MDNUM(K),K=1,NIC)
                 WRITE(6,23001) LDEPTH,(LAMP(1),LAMP(2),LAMP(3),K=1,NIC)
                    DO 349 J=N1PLS1,NT,INC2
                 IF (KA.EQ.0) WRITE(6,24001) DEPTH(J),(UNRM1(K,J),K=I1,INIC)
                 IF (KA.EQ.1) WRITE(6,24001) DEPTH(J),(UNRM2(K,J),K=I1,INIC)
             349 CONTINUE
             350 CONTINUE
                 RETURN
                 END
```

SOLID CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | |
|---|---|---|---|---|---|
| 10 | | 51 | 46 | | |
| 20 | | 60 | 56 | | |
| 30 | | 69 | 65 | | |
| 40 | | 109 | 103 | 104 | |
| 50 | | 110 | 100 | 108 | |
| 60 | | 121 | 115 | 116 | |
| 70 | | 122 | 112 | 120 | |
| 180 | | 153 | 147 | | |
| 190 | | 160 | 152 | 157 | |
| 200 | | 170 | 169 | | |
| 210 | | 172 | 171 | | |
| 220 | | 174 | 173 | | |
| 230 | | 176 | 175 | | |
| 234 | | 178 | 177 | | |
| 236 | | 180 | 179 | | |
| 240 | | 182 | 181 | | |
| 250 | | 184 | 183 | | |
| 255 | | 198 | 195 | | |
| 260 | | 205 | 202 | | |
| 270 | | 218 | 206 | | |
| 275 | | 228 | 217 | | |
| 280 | | 235 | 232 | | |
| 290 | | 236 | 234 | | |
| 300 | | 239 | 236 | | |
| 310 | | 240 | 238 | | |
| 313 | | 243 | 241 | | |
| 315 | | 249 | 247 | | |
| 317 | | 254 | 252 | | |
| 330 | | 258 | 256 | | |
| 340 | | 267 | 144 | | |
| 345 | | 277 | 274 | | |
| 349 | | 284 | 281 | | |
| 350 | | 285 | 139 | 143 | 268 |
| 8001 | | 16 | 71 | | |
| 9001 | | 17 | 72 | | |
| 10001 | | 18 | 73 | 75 | |
| 11001 | | 19 | 74 | | |
| 12001 | | 20 | 257 | | |
| 13001 | | 21 | 258 | | |
| 14001 | | 22 | 259 | | |
| 15001 | | 23 | 260 | | |
| 16001 | | 24 | 261 | | |
| 17001 | | 25 | 262 | | |
| 18001 | | 26 | 263 | | |
| 18002 | | 27 | 264 | | |
| 19001 | | 28 | 265 | | |
| 20001 | | 29 | 266 | | |
| 21001 | | 30 | 269 | | |
| 22001 | | 31 | 270 | 279 | |
| 23001 | | 32 | 271 | 280 | |

SOLID CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | | |
|---|---|---|---|---|---|---|
| 24001 | | 33 | 275 | 276 | 282 | 283 |
| 25001 | | 34 | 278 | | | |

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | R*8 | VAR | 2 | 41 | 47 | 48 | 48 | | | | | | | |
| ABSOR | R*4 | ARR | 5 | 255 | 266 | | | | | | | | | |
| ADCRS | I*4 | VAR | 3 | 9 | 124 | 150 | 155 | | | | | | | |
| AI | R*4 | VAR | 200 | 201 | 241 | 243 | 255 | 262 | | | | | | |
| AIRH2O | R*4 | ARR | 5 | 233 | 235 | 266 | | | | | | | | |
| AI1 | R*4 | VAR | 185 | 200 | | | | | | | | | | |
| AI2 | R*4 | VAR | 186 | 200 | | | | | | | | | | |
| AI3 | R*4 | VAR | 194 | 196 | 196 | 197 | 200 | | | | | | | |
| AI4 | R*4 | VAR | 198 | 241 | 242 | 243 | 262 | | | | | | | |
| AI5 | R*4 | VAR | 199 | 255 | | | | | | | | | | |
| AKN | R*8 | ARR | 2 | 7 | 187 | 187 | 235 | 239 | 240 | 243 | 244 | 250 | 255 | 266 |
| AKN2 | R*4 | VAR | 187 | 188 | 190 | 191 | 232 | 235 | 236 | 239 | 239 | | | |
| AK1 | R*8 | VAR | 2 | 10 | 148 | 153 | 157 | 158 | | | | | | |
| AK2 | R*8 | VAR | 2 | 10 | 149 | 154 | 157 | 159 | | | | | | |
| AMIN1 | R*4 | IFN | 70 | | | | | | | | | | | |
| ANORM | R*4 | VAR | 201 | 203 | 204 | | | | | | | | | |
| ATTENC | R*4 | ARR | 5 | 244 | 246 | 249 | 249 | 266 | | | | | | |
| ATTENS | R*4 | ARR | 5 | 250 | 251 | 254 | 254 | 266 | | | | | | |
| ATTEN2 | R*4 | ARR | 5 | 243 | 266 | | | | | | | | | |
| B | R*8 | VAR | 2 | 42 | 47 | 48 | 48 | 49 | 49 | 50 | 50 | | | |
| BOTTOM | R*4 | VAR | 132 | 236 | 239 | 239 | | | | | | | | |
| CMAX1 | R*4 | VAR | 55 | 58 | 58 | | | | | | | | | |
| CMAX2 | R*4 | VAR | 64 | 67 | 67 | | | | | | | | | |
| CMIN | R*4 | VAR | 70 | 126 | | | | | | | | | | |
| CMIN1 | R*4 | VAR | 54 | 57 | 57 | 70 | | | | | | | | |
| CMIN2 | R*4 | VAR | 63 | 66 | 66 | 70 | | | | | | | | |
| CMPRT | R*4 | VAR | 189 | 194 | 194 | 244 | 250 | | | | | | | |
| COMP | R*4 | VAR | 6 | 39 | 71 | 127 | | | | | | | | |
| C1 | R*4 | ARR | 5 | 54 | 55 | 57 | 57 | 58 | 58 | 73 | 95 | 95 | 96 | 96 |
| | | | 105 | 105 | 105 | 131 | 131 | 132 | 132 | 199 | 199 | | | |
| C2 | R*4 | ARR | 5 | 63 | 64 | 66 | 66 | 67 | 67 | 75 | 97 | 97 | 98 | 98 |
| | | | 117 | 117 | 117 | 198 | 198 | | | | | | | |
| DBLE | R*4 | IFN | 39 | 40 | 76 | 78 | 94 | 105 | 117 | | | | | |
| DCOMP | R*8 | VAR | 2 | 9 | 39 | 41 | 41 | 43 | 43 | 43 | 43 | | | |
| DEPTH | R*8 | ARR | 2 | 13 | 91 | 92 | 93 | 94 | 101 | 104 | 105 | 113 | 116 | 117 |
| | | | 260 | 275 | 276 | 282 | 283 | | | | | | | |
| DL1 | R*8 | VAR | 2 | 8 | 76 | 77 | 77 | 101 | 185 | 199 | 228 | | | |
| DL2 | R*8 | VAR | 2 | 8 | 78 | 79 | 79 | 113 | 186 | 198 | 229 | 230 | | |
| DRA | R*8 | VAR | 2 | 50 | 51 | | | | | | | | | |
| DSHEAR | R*8 | VAR | 2 | 9 | 40 | 42 | 42 | 43 | 43 | 43 | 43 | 44 | 129 | |
| DSQRT | R*4 | IFN | 47 | 47 | 48 | 48 | 48 | 48 | 52 | | | | | |
| DUTSC | R*4 | VAR | 246 | 247 | 263 | | | | | | | | | |

SØLID CRØSS REFERENCE LISTING

| SYMBØL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DUTSS | R*4 | VAR | 251 | 252 | 264 | | | | | | | | | |
| DYØU | R*4 | VAR | 245 | 247 | 248 | 249 | 263 | | | | | | | |
| DYØUA | R*4 | VAR | 228 | 235 | 235 | | | | | | | | | |
| DYØUB | R*4 | VAR | 229 | 239 | 239 | | | | | | | | | |
| DYØUC | R*4 | VAR | 230 | 231 | 231 | 231 | 245 | 252 | 253 | 254 | 264 | | | |
| EPW | R*4 | VAR | 37 | 38 | 38 | 255 | | | | | | | | |
| EVEN | R*4 | VAR | 165 | 182 | 182 | 198 | | | | | | | | |
| EVEN1 | R*4 | VAR | 166 | 170 | 170 | 185 | | | | | | | | |
| EVEN2 | R*4 | VAR | 167 | 174 | 174 | 186 | | | | | | | | |
| EVEN3 | R*4 | VAR | 168 | 178 | 178 | 199 | | | | | | | | |
| F | R*4 | VAR | 6 | 36 | 36 | 125 | 126 | 127 | 129 | 131 | 131 | 132 | 132 | 240 |
| | | | 243 | 255 | 269 | 278 | | | | | | | | |
| FRA | R*8 | VAR | 2 | 49 | 51 | | | | | | | | | |
| F2 | R*4 | VAR | 36 | 37 | 37 | 37 | 37 | 37 | | | | | | |
| HALFS | | SBR | 160 | | | | | | | | | | | |
| HH1 | R*8 | VAR | 2 | 8 | 77 | 95 | 96 | 107 | | | | | | |
| HH2 | R*8 | VAR | 2 | 8 | 79 | 97 | 98 | 119 | | | | | | |
| H12 | R*4 | VAR | 6 | 60 | 69 | 77 | 77 | 78 | 79 | 79 | 94 | 193 | 235 | 239 |
| | | | 239 | 239 | 244 | 244 | 250 | 250 | | | | | | |
| H2 | R*4 | VAR | 5 | 78 | 94 | | | | | | | | | |
| H2Ø2ND | R*4 | ARR | 5 | 237 | 239 | 266 | | | | | | | | |
| I | I*4 | VAR | 11 | 73 | 73 | 73 | 73 | 75 | 75 | 75 | 75 | 133 | 135 | 145 |
| | | | 146 | 147 | 151 | 156 | 187 | 187 | 203 | 204 | 207 | 208 | 209 | 210 |
| | | | 211 | 212 | 213 | 214 | 215 | 216 | 218 | 219 | 220 | 221 | 222 | 223 |
| | | | 224 | 225 | 226 | 227 | 233 | 235 | 235 | 237 | 239 | 239 | 240 | 243 |
| | | | 243 | 244 | 244 | 246 | 249 | 249 | 250 | 250 | 251 | 254 | 254 | 255 |
| | | | 255 | 259 | 266 | 266 | 266 | 266 | 266 | 266 | 266 | | | |
| IBASE | I*4 | VAR | 140 | 145 | 272 | 273 | | | | | | | | |
| IC | I*4 | VAR | 144 | 145 | 146 | 256 | 258 | | | | | | | |
| IFG | I*4 | VAR | 11 | 195 | 197 | 261 | | | | | | | | |
| IM | I*4 | VAR | 151 | 156 | 160 | | | | | | | | | |
| INC1 | I*4 | VAR | 5 | 274 | | | | | | | | | | |
| INC2 | I*4 | VAR | 5 | 281 | | | | | | | | | | |
| INIC | I*4 | VAR | 273 | 275 | 276 | 282 | 283 | | | | | | | |
| INT | I*4 | IFN | 138 | | | | | | | | | | | |
| INTERP | I*4 | VAR | 100 | 101 | 101 | 104 | 105 | 105 | 106 | 106 | 107 | 107 | 107 | 112 |
| | | | 113 | 113 | 116 | 117 | 117 | 118 | 118 | 119 | 119 | 119 | | |
| ITRTS | | SBR | 133 | 135 | | | | | | | | | | |
| IZERØ | I*4 | VAR | 11 | 123 | 260 | | | | | | | | | |
| I1 | I*4 | VAR | 272 | 275 | 276 | 282 | 283 | | | | | | | |
| J | I*4 | VAR | 46 | 56 | 57 | 57 | 58 | 58 | 59 | 59 | 60 | 60 | 65 | 66 |
| | | | 66 | 67 | 67 | 68 | 68 | 69 | 69 | 103 | 104 | 105 | 105 | 105 |
| | | | 105 | 105 | 105 | 115 | 116 | 117 | 117 | 117 | 117 | 117 | 117 | 169 |
| | | | 170 | 170 | 171 | 172 | 172 | 173 | 174 | 174 | 175 | 176 | 176 | 177 |
| | | | 178 | 178 | 178 | 179 | 180 | 180 | 180 | 181 | 182 | 182 | 182 | 183 |
| | | | 184 | 184 | 184 | 202 | 203 | 203 | 204 | 204 | 274 | 275 | 275 | 276 |
| | | | 276 | 281 | 282 | 282 | 283 | 283 | | | | | | |
| K | I*4 | VAR | 99 | 102 | 109 | 109 | 111 | 114 | 121 | 121 | 270 | 270 | 271 | 275 |
| | | | 275 | 276 | 276 | 279 | 279 | 280 | 282 | 282 | 283 | 283 | | |
| KA | I*4 | VAR | 5 | 203 | 204 | 206 | 275 | 276 | 282 | 283 | | | | |

```
SOLID        CROSS REFERENCE LISTING

  SYMBOL    TYPE/USAGE      REFERENCES

   KCOMP    R*4   VAR      4     127     128     128     244
   KCOMP2   R*4   VAR      4     128     188
   KK       I*4   VAR    102     103     114     115
   KMAX     R*8   VAR      2     126     154
   KRAY     R*8   VAR      2       9     125     133     149     153     159
   KSHEAR   R*8   VAR      2     129     130     130     135     148     158     250
   KSHR2    R*4   VAR      4     130     190     191     193     193     194     250
   LAMP     I*4   ARR     13      15     271     271     271     280     280     280
   LDEPTH   I*4   ARR     13      14     271     280
   LI1      I*4   VAR      5      76      80
   LI2      I*4   VAR      5      78      86
   LOOP     I*4   VAR     10     261
   M        I*4   VAR    139     140     141     142
   MATCH    I*4   VAR      8     260
   MAXMD    I*4   VAR    136     137     257
   MDNUM    I*4   ARR     13     146     270     279
   MDPRNT   I*4   VAR      5     268
   MGRCPS   I*4   VAR    138     139     141     142
   MINO     I*4   IFN    137
   MOD      I*4   IFN    142     258
   NCR      I*4   VAR     11     134     136
   ND1      I*4   VAR      5      56      62      73      96      96     103     132     132     199
   ND2      I*4   VAR      5      65      75      98      98     115     198
   NH             COM     10
   NI             COM      8
   NIC      I*4   VAR    141     142     143     144     270     271     273     279     280
   NIH            COM     11
   NISCL          COM      9
   NMODE    I*4   VAR      5     137     137     138     142     257
   NT       I*4   VAR      8      88      89      90      94      98     186     186     198     198     202     216
                         227     281
   NTMNS1   I*4   VAR     89     112     173     181     215     226
   NTMNS2   I*4   VAR      8      90     175     183     214     225
   N1       I*4   VAR      6      80      81      82      83      84      85      88      92      96     113     185
                         185     186     186     198     198     199     199     210     221     274
   N1MNS1   I*4   VAR      8      84     100     169     177
   N1MNS2   I*4   VAR      8      85     171     179
   N1PLS1   I*4   VAR      8      81      93      97     211     222     281
   N1PLS2   I*4   VAR      8      82     112     173     181     212     223
   N1PLS3   I*4   VAR      8      83     175     183     213     224
   N2       I*4   VAR      5      86      87      88
   N2MNS1   I*4   VAR      8      87
   ODD      R*4   VAR    161     184     184     198
   ODD1     R*4   VAR    162     172     172     185
   ODD2     R*4   VAR    163     176     176     186
   ODD3     R*4   VAR    164     180     180     199
   PMGTD    R*4   VAR     12     196     196     241     246     251     262
   PPRCN    R*4   VAR     12     232     236
   PV       R*8   VAR      2     240     259
   Q        R*4   VAR    193     194     244     250
```

SOLID CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QCOMP | R*4 | VAR | 188 | 189 | 193 | 194 | 194 | 250 | 250 | | | | | |
| QSHEAR | R*4 | VAR | 190 | 192 | 192 | 194 | 250 | | | | | | | |
| QSHR2 | R*4 | VAR | 192 | 193 | 194 | 194 | 250 | 250 | | | | | | |
| R$1DSQ | | SBR | | | | | | | | | | | | |
| R$1SQR | | SBR | | | | | | | | | | | | |
| RAYCRS | I*4 | VAR | 3 | 134 | 147 | | | | | | | | | |
| RAYL | R*8 | VAR | 2 | 44 | 45 | 45 | 52 | 71 | 125 | | | | | |
| RA1 | R*8 | VAR | 2 | 47 | 49 | | | | | | | | | |
| RA2 | R*8 | VAR | 2 | 48 | 50 | | | | | | | | | |
| RHO1 | R*4 | VAR | 6 | 185 | 199 | 235 | 239 | | | | | | | |
| RHO2 | R*4 | VAR | 6 | 186 | 198 | | | | | | | | | |
| RHO3 | R*4 | VAR | 6 | 193 | | | | | | | | | | |
| SHEAR | R*4 | VAR | 5 | 40 | 71 | | | | | | | | | |
| SHEART | R*4 | VAR | 191 | 194 | 194 | 250 | 250 | | | | | | | |
| SOLID | R*4 | ENT | 1 | | | | | | | | | | | |
| SOUND | R*8 | ARR | 2 | 8 | 106 | 118 | 178 | 180 | 182 | 184 | | | | |
| SPEED | R*8 | ARR | 2 | 8 | 95 | 96 | 97 | 98 | 105 | 106 | 107 | 107 | 107 | 117 |
| | | | 118 | 119 | 119 | 119 | | | | | | | | |
| SQRT | R*4 | IFN | 189 | 191 | 201 | 235 | 239 | | | | | | | |
| SRFC | R*4 | VAR | 131 | 232 | 235 | | | | | | | | | |
| TN | | COM | 5 | | | | | | | | | | | |
| TNH | | COM | 7 | | | | | | | | | | | |
| TNI | | COM | 6 | | | | | | | | | | | |
| TNIH | | COM | 12 | | | | | | | | | | | |
| TWOPI | R*8 | VAR | 2 | 8 | 35 | 125 | 126 | 129 | 240 | | | | | |
| UNRM1 | R*4 | ARR | 5 | 203 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 |
| | | | 275 | 282 | | | | | | | | | | |
| UNRM2 | R*4 | ARR | 5 | 204 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 |
| | | | 276 | 283 | | | | | | | | | | |
| URA | R*8 | VAR | 2 | 43 | 44 | 44 | | | | | | | | |
| X | R*4 | ARR | 13 | 53 | 59 | 73 | | | | | | | | |
| XRA | R*8 | VAR | 2 | 45 | 47 | 47 | 48 | 48 | 48 | 48 | 49 | 49 | 49 | 50 |
| | | | 50 | 51 | 51 | 52 | | | | | | | | |
| Y | R*4 | ARR | 13 | 61 | 68 | 75 | | | | | | | | |
| YNM1 | R*4 | VAR | 207 | 218 | 228 | | | | | | | | | |
| YNM10 | R*4 | VAR | 216 | 227 | 230 | | | | | | | | | |
| YNM2 | R*4 | VAR | 208 | 219 | 228 | | | | | | | | | |
| YNM3 | R*4 | VAR | 209 | 220 | 228 | | | | | | | | | |
| YNM4 | R*4 | VAR | 210 | 221 | 239 | 239 | | | | | | | | |
| YNM5 | R*4 | VAR | 211 | 222 | 229 | | | | | | | | | |
| YNM6 | R*4 | VAR | 212 | 223 | 229 | | | | | | | | | |
| YNM7 | R*4 | VAR | 213 | 224 | 229 | | | | | | | | | |
| YNM8 | R*4 | VAR | 214 | 225 | 230 | | | | | | | | | |
| YNM9 | R*4 | VAR | 215 | 226 | 230 | | | | | | | | | |
| YOU | R*8 | ARR | 2 | 11 | 170 | 170 | 172 | 172 | 174 | 174 | 176 | 176 | 178 | 178 |
| | | | 180 | 180 | 182 | 182 | 184 | 184 | 185 | 185 | 185 | 185 | 186 | 186 |
| | | | 186 | 186 | 198 | 198 | 198 | 198 | 199 | 199 | 199 | 199 | 203 | 204 |
| Z1 | R*4 | ARR | 5 | 53 | 59 | 60 | 60 | 62 | 73 | 104 | 105 | 105 | 105 | |
| Z2 | R*4 | ARR | 5 | 61 | 62 | 68 | 69 | 69 | 75 | 116 | 117 | 117 | 117 | |

SOURCE LISTING

STATEMENT

```
      SUBROUTINE ITRTS (AKN,L)
      DOUBLE PRECISION OMEGA2,TWOPI,CKN,YOU,DSHEAR,DCOMP,AKN,KRAY,DL2,
     >HH2,SPEED,PPLUS1,P,PMNS1,B,DL1,HH1,UMAX,UABVL,SOUND
      COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
      COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
     >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
      COMMON/NISOL/DCOMP,DSHEAR,KRAY,ADCRS
      COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
      COMMON/TNIH/PPRCN,PMGTD
      COMMON/IH/UMAX
      INTEGER ADCRS
      MATCH=0
         IF (IZERO.NE.1) GO TO 10
         DO 6 J=3,N1MNS2
         IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 6
      MATCH=J
         GO TO 10
    6 CONTINUE
         DO 8 J=N1PLS3,NTMNS2
         IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 8
      MATCH=J
         GO TO 10
    8 CONTINUE
      MATCH=NTMNS2
   10 NCR=0
      IFG=0
      OMEGA2=TWOPI*TWOPI*F*F
      CKN=TWOPI*F/AKN
      YOU(NT)=RHO3*DSHEAR**4/RHO2/(DSQRT(OMEGA2)*CKN**3)
      YOU(NT)=YOU(NT)*(4.0*DSQRT(1.0-CKN*CKN/(DCOMP*DCOMP))*
     >DSQRT(DABS(1.0-CKN*CKN/(DSHEAR*DSHEAR)))-(2.0-CKN*CKN/
     >(DSHEAR*DSHEAR))**2)/DSQRT(1.0-CKN*CKN/(DCOMP*DCOMP))
      IF (DABS(AKN-KRAY).LT.PPRCN) YOU(NT)=0.
      YOU(NT-1)=YOU(NT)-DL2*H12-YOU(NT)*
     >(OMEGA2*SPEED(NT)-HH2*AKN*AKN)/2.0
      UMAX=DMAX1(DABS(YOU(NT)),DABS(YOU(NT-1)))
         IF (DABS(AKN-KRAY).GE.PPRCN) GO TO 11
      IF (ADCRS.EQ.1) NCR=NCR+1
         GO TO 15
   11 IF (DSIGN(1.D0,YOU(NT))*YOU(NT-1).LT.0.) NCR=NCR+1
   15    DO 31 J=2,N2MNS1
      NTMJ=NT-J
      PPLUS1=12.0+OMEGA2*SPEED(NTMJ)-HH2*AKN*AKN
      P=24.0-10.0*(OMEGA2*SPEED(NTMJ+1)-HH2*AKN*AKN)
      PMNS1=12.0+OMEGA2*SPEED(NTMJ+2)-HH2*AKN*AKN
      YOU(NTMJ)=(P/PPLUS1)*YOU(NTMJ+1)-(PMNS1/PPLUS1)*YOU(NTMJ+2)
      UABVL=DABS(YOU(NTMJ))
      IF (UABVL.GT.UMAX) UMAX=UABVL
      IF (DSIGN(1.D0,YOU(NTMJ))*YOU(NTMJ+1).LE.0.) NCR=NCR+1
         IF (UABVL.LT.PMGTD) GO TO 22
```

CSN STATEMENT

```
      DO 21 JD=NTMJ,NT
      IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.
   21 YOU(JD)=YOU(JD)/PMGTD
      UMAX=UMAX/PMGTD
      IFG=IFG+1
   22    IF (NTMJ.EQ.MATCH) GO TO 131
   31 CONTINUE
      B=(3.0*YOU(N1PLS1)-4.0*YOU(N1PLS1+1)+YOU(N1PLS1+2))/(2.0*DL2)
      YOU(N1)=RHO2*YOU(N1PLS1)/RHO1
      YOU(N1-1)=YOU(N1)+DL1*B-YOU(N1)*(OMEGA2*SPEED(N1)-HH1*AKN*AKN)/2.0
      IF (DABS(YOU(N1)).GT.UMAX) UMAX=DABS(YOU(N1))
      IF (DABS(YOU(N1-1)).GT.UMAX) UMAX=DABS(YOU(N1-1))
      IF (DSIGN(1.D0,YOU(N1))*YOU(N1-1).LE.0.) NCR=NCR+1
         DO 121 J=2,N1MNS1
      N1MJ=N1-J
      PPLUS1=12.0+OMEGA2*SPEED(N1MJ)-HH1*AKN*AKN
      P=24.0-10.0*(OMEGA2*SPEED(N1MJ+1)-HH1*AKN*AKN)
      PMNS1=12.0+OMEGA2*SPEED(N1MJ+2)-HH1*AKN*AKN
      YOU(N1MJ)=(P/PPLUS1)*YOU(N1MJ+1)-(PMNS1/PPLUS1)*YOU(N1MJ+2)
      UABVL=DABS(YOU(N1MJ))
      IF (UABVL.GT.UMAX) UMAX=UABVL
      IF (DSIGN(1.D0,YOU(N1MJ))*YOU(N1MJ+1).LE.0.) NCR=NCR+1
         IF (UABVL.LT.PMGTD) GO TO 51
         DO 41 JD=N1MJ,NT
      IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.
   41 YOU(JD)=YOU(JD)/PMGTD
      UMAX=UMAX/PMGTD
      IFG=IFG+1
   51    IF (N1MJ.EQ.MATCH) GO TO 131
  121 CONTINUE
         GO TO 151
  131 IZERO=2
      YOU(1)=0.0
      YOU(2)=DSQRT(HH1)*1.D-10
         DO 135 J=3,N1
      PPLUS1=12.0+OMEGA2*SPEED(J)-HH1*AKN*AKN
      P=24.0-10.0*(OMEGA2*SPEED(J-1)-HH1*AKN*AKN)
      PMNS1=12.0+OMEGA2*SPEED(J-2)-HH1*AKN*AKN
      PPLUS1=(P/PPLUS1)*YOU(J-1)-(PMNS1/PPLUS1)*YOU(J-2)
         IF (J.EQ.MATCH) GO TO 148
      YOU(J)=PPLUS1
         IF (DABS(YOU(J)).LT.PMGTD) GO TO 135
         DO 133 JD=2,J
      IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.0
  133 YOU(JD)=YOU(JD)/PMGTD
  135 CONTINUE
      B=(-3.0*YOU(N1MNS2)+4.0*YOU(N1MNS1)-YOU(N1))/(2.0*DL1)
      YOU(N1PLS1)=RHO1*YOU(N1)/RHO2
      YOU(N1PLS2)=YOU(N1PLS1)+DL2*B-YOU(N1PLS1)*
     >(OMEGA2*SPEED(N1PLS1)-HH2*AKN*AKN)/2.0
```

ITRTS SØURCE LISTING

```
      STATEMENT

         DØ 145 J=N1PLS3,NTMNS2
      PPLUS1=12.0+ØMEGA2*SPEED(J)-HH2*AKN*AKN
      P=24.0-10.0*(ØMEGA2*SPEED(J-1)-HH2*AKN*AKN)
      PMNS1=12.0+ØMEGA2*SPEED(J-2)-HH2*AKN*AKN
      PPLUS1=(P/PPLUS1)*YØU(J-1)-(PMNS1/PPLUS1)*YØU(J-2)
         IF (J.EQ.MATCH) GØ TØ 148
      YØU(J)=PPLUS1
         IF (DABS(YØU(J)).LT.PMGTD) GØ TØ 145
         DØ 143 JD=2,J
      IF (DABS(YØU(JD)).LT.1.D0) YØU(JD)=0.0
  143 YØU(JD)=YØU(JD)/PMGTD
  145 CØNTINUE
         GØ TØ 151
  148 JMNS1=J-1
         DØ 149 JD=2,JMNS1
      YØU(JD)=(YØU(JD)/PPLUS1)*YØU(MATCH)
      IF (DABS(YØU(JD)).LT.1./PMGTD) YØU(JD)=0.0
  149 CØNTINUE
  151 CØNTINUE
      RETURN
      END
```

ITRTS CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | |
|---|---|---|---|---|---|
| 6 | | 16 | 12 | 13 | |
| 8 | | 21 | 17 | 18 | |
| 10 | | 23 | 11 | 15 | 20 |
| 11 | | 35 | 32 | | |
| 15 | | 36 | 34 | | |
| 21 | | 48 | 46 | | |
| 22 | | 51 | 45 | | |
| 31 | | 52 | 36 | | |
| 41 | | 71 | 69 | | |
| 51 | | 74 | 68 | | |
| 121 | | 75 | 59 | | |
| 131 | | 77 | 51 | 74 | |
| 133 | | 90 | 88 | | |
| 135 | | 91 | 80 | 87 | |
| 143 | | 105 | 103 | | |
| 145 | | 106 | 95 | 102 | |
| 148 | | 108 | 85 | 100 | |
| 149 | | 112 | 109 | | |
| 151 | | 113 | 76 | 107 | |

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADCRS | I*4 | VAR | 5 | 9 | 33 | | | | | | | | | |
| AKN | R*8 | DAR | 1 | 2 | 13 | 18 | 26 | 29 | 30 | 30 | 32 | 38 | 38 | 39 |
| | | | 39 | 40 | 40 | 55 | 55 | 61 | 61 | 62 | 62 | 63 | 63 | 81 |
| | | | 81 | 82 | 82 | 83 | 83 | 94 | 94 | 96 | 96 | 97 | 97 | 98 |
| | | | 98 | | | | | | | | | | | |
| B | R*8 | VAR | 2 | 53 | 55 | 92 | 94 | | | | | | | |
| CKN | R*8 | VAR | 2 | 26 | 27 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | |
| COMP | R*4 | VAR | 3 | | | | | | | | | | | |
| DABS | R*4 | IFN | 28 | 29 | 31 | 31 | 32 | 42 | 47 | 56 | 56 | 57 | 57 | 65 |
| | | | 70 | 87 | 89 | 102 | 104 | 111 | | | | | | |
| DCOMP | R*8 | VAR | 2 | 5 | 28 | 28 | 28 | 28 | | | | | | |
| DL1 | R*8 | VAR | 2 | 4 | 55 | 92 | | | | | | | | |
| DL2 | R*8 | VAR | 2 | 4 | 30 | 53 | 94 | | | | | | | |
| DMAX1 | R*4 | IFN | 31 | | | | | | | | | | | |
| DSHEAR | R*8 | VAR | 2 | 5 | 27 | 28 | 28 | 28 | 28 | | | | | |
| DSIGN | R*4 | IFN | 35 | 44 | 58 | 67 | | | | | | | | |
| DSQRT | R*4 | IFN | 27 | 28 | 28 | 28 | 79 | | | | | | | |
| F | R*4 | VAR | 3 | 13 | 18 | 25 | 25 | 26 | | | | | | |
| HH1 | R*8 | VAR | 2 | 4 | 55 | 61 | 62 | 63 | 79 | 81 | 82 | 83 | | |
| HH2 | R*8 | VAR | 2 | 4 | 30 | 38 | 39 | 40 | 94 | 96 | 97 | 98 | | |
| H12 | R*4 | VAR | 3 | 30 | | | | | | | | | | |
| I | I*4 | VAR | 6 | | | | | | | | | | | |
| IFG | I*4 | VAR | 6 | 24 | 50 | 50 | 73 | 73 | | | | | | |
| IH | | COM | 8 | | | | | | | | | | | |
| ITRTS | I*4 | ENT | 1 | | | | | | | | | | | |

| SYMBØL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IZERØ | I*4 | VAR | 6 | 11 | 77 | | | | | | | | | |
| J | I*4 | VAR | 12 | 13 | 14 | 17 | 18 | 19 | 36 | 37 | 59 | 60 | 80 | 81 |
| | | | 82 | 83 | 84 | 84 | 85 | 86 | 87 | 88 | 95 | 96 | 97 | 98 |
| | | | 99 | 99 | 100 | 101 | 102 | 103 | 108 | | | | | |
| JD | I*4 | VAR | 46 | 47 | 47 | 48 | 48 | 69 | 70 | 70 | 71 | 71 | 88 | 89 |
| | | | 89 | 90 | 90 | 103 | 104 | 104 | 105 | 105 | 109 | 110 | 110 | 111 |
| | | | 111 | | | | | | | | | | | |
| JMNS1 | I*4 | VAR | 108 | 109 | | | | | | | | | | |
| KRAY | R*8 | VAR | 2 | 5 | 29 | 32 | | | | | | | | |
| L | I*4 | DAR | 1 | | | | | | | | | | | |
| MATCH | I*4 | VAR | 4 | 10 | 14 | 19 | 22 | 51 | 74 | 85 | 100 | 110 | | |
| NCR | I*4 | VAR | 6 | 23 | 33 | 33 | 35 | 35 | 44 | 44 | 58 | 58 | 67 | 67 |
| NI | | CØM | 4 | | | | | | | | | | | |
| NIH | | CØM | 6 | | | | | | | | | | | |
| NISØL | | CØM | 5 | | | | | | | | | | | |
| NT | I*4 | VAR | 4 | 27 | 28 | 28 | 29 | 30 | 30 | 30 | 30 | 31 | 31 | 35 |
| | | | 35 | 37 | 46 | 69 | | | | | | | | |
| NTMJ | I*4 | VAR | 37 | 38 | 39 | 40 | 41 | 41 | 41 | 42 | 44 | 44 | 46 | 51 |
| NTMNS2 | I*4 | VAR | 4 | 17 | 22 | 95 | | | | | | | | |
| N1 | I*4 | VAR | 3 | 54 | 55 | 55 | 55 | 55 | 56 | 56 | 57 | 57 | 58 | 58 |
| | | | 60 | 80 | 92 | 93 | | | | | | | | |
| N1MJ | I*4 | VAR | 60 | 61 | 62 | 63 | 64 | 64 | 64 | 65 | 67 | 67 | 69 | 74 |
| N1MNS1 | I*4 | VAR | 4 | 59 | 92 | | | | | | | | | |
| N1MNS2 | I*4 | VAR | 4 | 12 | 92 | | | | | | | | | |
| N1PLS1 | I*4 | VAR | 4 | 53 | 53 | 53 | 54 | 93 | 94 | 94 | 94 | | | |
| N1PLS2 | I*4 | VAR | 4 | 94 | | | | | | | | | | |
| N1PLS3 | I*4 | VAR | 4 | 17 | 95 | | | | | | | | | |
| N2MNS1 | I*4 | VAR | 4 | 36 | | | | | | | | | | |
| ØMEGA2 | R*8 | VAR | 2 | 25 | 27 | 30 | 38 | 39 | 40 | 55 | 61 | 62 | 63 | 81 |
| | | | 82 | 83 | 94 | 96 | 97 | 98 | | | | | | |
| P | R*8 | VAR | 2 | 39 | 41 | 62 | 64 | 82 | 84 | 97 | 99 | | | |
| PMGTD | R*4 | VAR | 7 | 45 | 48 | 49 | 68 | 71 | 72 | 87 | 90 | 102 | 105 | 111 |
| PMNS1 | R*8 | VAR | 2 | 40 | 41 | 63 | 64 | 83 | 84 | 98 | 99 | | | |
| PPLUS1 | R*8 | VAR | 2 | 38 | 41 | 41 | 61 | 64 | 64 | 81 | 84 | 84 | 84 | 86 |
| | | | 96 | 99 | 99 | 99 | 101 | 110 | | | | | | |
| PPRCN | R*4 | VAR | 7 | 29 | 32 | | | | | | | | | |
| R$1DSQ | | SBR | | | | | | | | | | | | |
| RHØ1 | R*4 | VAR | 3 | 54 | 93 | | | | | | | | | |
| RHØ2 | R*4 | VAR | 3 | 27 | 54 | 93 | | | | | | | | |
| RHØ3 | R*4 | VAR | 3 | 27 | | | | | | | | | | |
| SØUND | R*8 | ARR | 2 | 4 | 13 | 18 | | | | | | | | |
| SPEED | R*8 | ARR | 2 | 4 | 30 | 38 | 39 | 40 | 55 | 61 | 62 | 63 | 81 | 82 |
| | | | 83 | 94 | 96 | 97 | 98 | | | | | | | |
| TNI | | CØM | 3 | | | | | | | | | | | |
| TNIH | | CØM | 7 | | | | | | | | | | | |
| TWØPI | R*8 | VAR | 2 | 4 | 13 | 18 | 25 | 25 | 26 | | | | | |
| UABVL | R*8 | VAR | 2 | 42 | 43 | 43 | 45 | 65 | 66 | 66 | 68 | | | |
| UMAX | R*8 | VAR | 2 | 8 | 31 | 43 | 43 | 49 | 49 | 56 | 56 | 57 | 57 | 66 |
| | | | 66 | 72 | 72 | | | | | | | | | |
| YØU | R*8 | ARR | 2 | 6 | 27 | 28 | 28 | 29 | 30 | 30 | 30 | 31 | 31 | 35 |

ITRTS CROSS REFERENCE LISTING

SYMBOL TYPE/USAGE REFERENCES

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 41 | 41 | 41 | 42 | 44 | 44 | 47 | 47 | 48 | 48 | 53 |
| 53 | 53 | 54 | 54 | 55 | 55 | 55 | 56 | 56 | 57 | 57 | 58 |
| 58 | 64 | 64 | 64 | 65 | 67 | 67 | 70 | 70 | 71 | 71 | 78 |
| 79 | 84 | 84 | 86 | 87 | 89 | 89 | 90 | 90 | 92 | 92 | 92 |
| 93 | 93 | 94 | 94 | 94 | 99 | 99 | 101 | 102 | 104 | 104 | 105 |
| 105 | 110 | 110 | 110 | 111 | 111 | | | | | | |

SOURCE LISTING

CSN STATEMENT

```
          SUBROUTINE HALFS (L)
      DOUBLE PRECISION AK1,AK2,ANEW,AK,ZK,YOU,AKNL,AKNR,ZL,ZR,AR1,AL1,
     >ZR1,ZL1,ZNEW,AKA,AKN,UMAX
      COMMON/TNH/AKN(150)
      COMMON/TH/EPSLN
      COMMON/NH/AK1,AK2,LOOP
      COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
      COMMON/TNIH/PPRCN,PMGTD
      COMMON/IH/UMAX
      DIMENSION AK(2),ZK(2)
C
C  ********** PART 1 **********
C
      IZERO=0
      LOOP=0
         DO 52 K=1,2
      J=L+1-K
         IF (K.EQ.2) GO TO 12
         CALL ITRTS (AK1,L)
      LOOP=LOOP+1
      NA1=NCR
         CALL ITRTS (AK2,L)
      LOOP=LOOP+1
      NA2=NCR
      IF (NA1.EQ.1.AND.NA2.EQ.1) NA1=2
   12 ANEW=((AK2-AK1)*(J-NA1)/(NA2-NA1))+AK1
         CALL ITRTS (ANEW,L)
      LOOP=LOOP+1
         IF (NCR.EQ.J) GO TO 42
         IF (NCR.GT.J.AND.NCR.NE.NA2) GO TO 32
      AK2=ANEW
      NA2=NCR
         GO TO 12
   32 AK1=ANEW
      NA1=NCR
         GO TO 12
   42 AK(K)=ANEW
      IF (K.EQ.1) IP1=IFG
      IF (K.EQ.2) IP2=IFG
   52 ZK(K)=YOU(1)
      AKNL=AK(1)
      AKNR=AK(2)
      ZL=ZK(1)
      ZR=ZK(2)
C
C  ********** PART 2 **********
C
      ICLSIN=0
   62 ICLSIN=ICLSIN+1
         IF (ICLSIN.EQ.20) GO TO 112
```

HALFS SOURCE LISTING

STATEMENT

```
          AR1=AKNR-(1.E-12)
          AL1=AKNL+(1.E-12)
             CALL ITRTS (AR1,L)
          IP4=IFG
          ZR1=YOU(1)
             CALL ITRTS (AL1,L)
          IP3=IFG
       64    IF (IP1-IP3) 66,70,68
       66 IF (DABS(ZL).LE.1.D0) ZL=0.
          ZL=ZL/PMGTD
          IP1=IP1+1
             GO TO 64
       68 IF (DABS(ZL1).LE.1.D0) ZL1=0.
          ZL1=ZL1/PMGTD
          IP3=IP3+1
             GO TO 64
       70 CONTINUE
       72    IF (IP2-IP4) 74,78,76
       74 IF (DABS(ZR).LE.1.D0) ZR=0.
          ZR=ZR/PMGTD
          IP2=IP2+1
             GO TO 72
       76 IF (DABS(ZR1).LE.1.D0) ZR1=0.
          ZR1=ZR1/PMGTD
          IP4=IP4+1
             GO TO 72
       78 ZL1=YOU(1)
             IF (DABS(ZR1).GT.DABS(ZR)) GO TO 82
             IF (DABS(ZL1).LE.DABS(ZL)) GO TO 122
       82 ANEW=(AKNR+AKNL)/2.0
             CALL ITRTS (ANEW,L)
          ZNEW=YOU(1)
             IF (NCR.NE.L) GO TO 102
          AKNL=ANEW
          IP1=IFG
          ZL=ZNEW
             GO TO 62
      102 AKNR=ANEW
          IP2=IFG
          ZR=ZNEW
             GO TO 62
C
C  ********** PART 3 **********
C
      112    IF (IP1-IP2) 117,119,118
      117 IF (DABS(ZL).LE.1.D0) ZL=0.
          ZL=ZL/PMGTD
          IP1=IP1+1
             GO TO 112
      118 IF (DABS(ZR).LE.1.D0) ZR=0.
```

```
HALFS          SOURCE LISTING

    CSN          STATEMENT

             ZR=ZR/PMGTD
             IP2=IP2+1
                GO TO 112
         119 AKA=AKNL+(ZL*(AKNR-AKNL))/(ZL-ZR)
             FLOG=1.0
                GO TO 132
         122 AKA=(AKNL+AKNR)/2.0
             FLOG=2.0
         132    CALL ITRTS (AKA,L)
             LOOP=LOOP+1
             EPLON=EPSLN*UMAX
                IF (DABS(YOU(1)).GT.EPLON) GO TO 162
                IF (DABS(AKNL-AKA).LE.1.E-12) GO TO 222
                IF (DABS(AKNR-AKA).LE.1.E-12)  GO TO 222
         162    IF (NCR.NE.L) GO TO 192
                IF (DABS(AKNL-AKA).LE.PPRCN) GO TO 212
             IP1=IFG
             ZL=YOU(1)
             AKNL=AKA
                IF (FLOG.GT.1.5) GO TO 112
                GO TO 122
         192    IF (DABS(AKNR-AKA).LE.PPRCN) GO TO 212
             IP2=IFG
             ZR=YOU(1)
             AKNR=AKA
                IF (FLOG.GT.1.5) GO TO 112
                GO TO 122
         212 IZERO=1
                CALL ITRTS (AKA,L)
         222 AKN(I)=AKA
             RETURN
             END
```

HALFS CROSS REFERENCE LISTING

| LABEL | TYPE | DEFN | REFERENCES | | | | |
|---|---|---|---|---|---|---|---|
| 12 | | 22 | 14 | 29 | 32 | | |
| 32 | | 30 | 26 | | | | |
| 42 | | 33 | 25 | | | | |
| 52 | | 36 | 12 | | | | |
| 62 | | 42 | 80 | 84 | | | |
| 64 | | 51 | 55 | 59 | | | |
| 66 | | 52 | 51 | | | | |
| 68 | | 56 | 51 | | | | |
| 70 | | 60 | 51 | | | | |
| 72 | | 61 | 65 | 69 | | | |
| 74 | | 62 | 61 | | | | |
| 76 | | 66 | 61 | | | | |
| 78 | | 70 | 61 | | | | |
| 82 | | 73 | 71 | | | | |
| 102 | | 81 | 76 | | | | |
| 112 | | 85 | 43 | 89 | 93 | 110 | 116 |
| 117 | | 86 | 85 | | | | |
| 118 | | 90 | 85 | | | | |
| 119 | | 94 | 85 | | | | |
| 122 | | 97 | 72 | 111 | 117 | | |
| 132 | | 99 | 96 | | | | |
| 162 | | 105 | 102 | | | | |
| 192 | | 112 | 105 | | | | |
| 212 | | 118 | 106 | 112 | | | |
| 222 | | 120 | 103 | 104 | | | |

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AK | R*8 | ARR | 2 | 9 | 33 | 37 | 38 | | | | | | | |
| AKA | R*8 | VAR | 2 | 94 | 97 | 99 | 103 | 104 | 106 | 109 | 112 | 115 | 119 | 120 |
| AKN | R*8 | ARR | 2 | 3 | 120 | | | | | | | | | |
| AKNL | R*8 | VAR | 2 | 37 | 45 | 73 | 77 | 94 | 94 | 97 | 103 | 106 | 109 | |
| AKNR | R*8 | VAR | 2 | 38 | 44 | 73 | 81 | 94 | 97 | 104 | 112 | 115 | | |
| AK1 | R*8 | VAR | 2 | 5 | 15 | 22 | 22 | 30 | | | | | | |
| AK2 | R*8 | VAR | 2 | 5 | 18 | 22 | 27 | | | | | | | |
| AL1 | R*8 | VAR | 2 | 45 | 49 | | | | | | | | | |
| ANEW | R*8 | VAR | 2 | 22 | 23 | 27 | 30 | 33 | 73 | 74 | 77 | 81 | | |
| AR1 | R*8 | VAR | 2 | 44 | 46 | | | | | | | | | |
| DABS | R*4 | IFN | 52 | 56 | 62 | 66 | 71 | 71 | 72 | 72 | 86 | 90 | 102 | 103 |
| | | | 104 | 106 | 112 | | | | | | | | | |
| EPLON | R*4 | VAR | 101 | 102 | | | | | | | | | | |
| EPSLN | R*4 | VAR | 4 | 101 | | | | | | | | | | |
| FLOG | R*4 | VAR | 95 | 98 | 110 | 116 | | | | | | | | |
| HALFS | R*4 | ENT | 1 | | | | | | | | | | | |
| I | I*4 | VAR | 6 | 120 | | | | | | | | | | |
| ICLSIN | I*4 | VAR | 41 | 42 | 42 | 43 | | | | | | | | |
| IFG | I*4 | VAR | 6 | 34 | 35 | 47 | 50 | 78 | 82 | 107 | 113 | | | |

HALFS CROSS REFERENCE LISTING

| SYMBOL | TYPE/USAGE | | REFERENCES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IH | | COM | 8 | | | | | | | | | | | |
| IP1 | I*4 | VAR | 34 | 51 | 54 | 54 | 78 | 85 | 88 | 88 | 107 | | | |
| IP2 | I*4 | VAR | 35 | 61 | 64 | 64 | 82 | 85 | 92 | 92 | 113 | | | |
| IP3 | I*4 | VAR | 50 | 51 | 58 | 58 | | | | | | | | |
| IP4 | I*4 | VAR | 47 | 61 | 68 | 68 | | | | | | | | |
| ITRTS | | SBR | 15 | 18 | 23 | 46 | 49 | 74 | 99 | 119 | | | | |
| IZERO | I*4 | VAR | 6 | 10 | 118 | | | | | | | | | |
| J | I*4 | VAR | 13 | 22 | 25 | 26 | | | | | | | | |
| K | I*4 | VAR | 12 | 13 | 14 | 33 | 34 | 35 | 36 | | | | | |
| L | I*4 | DAR | 1 | 13 | 15 | 18 | 23 | 46 | 49 | 74 | 76 | 99 | 105 | 119 |
| LOOP | I*4 | VAR | 5 | 11 | 16 | 16 | 19 | 19 | 24 | 24 | 100 | 100 | | |
| NA1 | I*4 | VAR | 17 | 21 | 21 | 22 | 22 | 31 | | | | | | |
| NA2 | I*4 | VAR | 20 | 21 | 22 | 26 | 28 | | | | | | | |
| NCR | I*4 | VAR | 6 | 17 | 20 | 25 | 26 | 26 | 28 | 31 | 76 | 105 | | |
| NH | | COM | 5 | | | | | | | | | | | |
| NIH | | COM | 6 | | | | | | | | | | | |
| PMGTD | R*4 | VAR | 7 | 53 | 57 | 63 | 67 | 87 | 91 | | | | | |
| PPRCN | R*4 | VAR | 7 | 106 | 112 | | | | | | | | | |
| TH | | COM | 4 | | | | | | | | | | | |
| TNH | | COM | 3 | | | | | | | | | | | |
| TNIH | | COM | 7 | | | | | | | | | | | |
| UMAX | R*8 | VAR | 2 | 8 | 101 | | | | | | | | | |
| YOU | R*8 | ARR | 2 | 6 | 36 | 48 | 70 | 75 | 102 | 108 | 114 | | | |
| ZK | R*8 | ARR | 2 | 9 | 36 | 39 | 40 | | | | | | | |
| ZL | R*8 | VAR | 2 | 39 | 52 | 52 | 53 | 53 | 72 | 79 | 86 | 86 | 87 | 87 |
| | | | 94 | 94 | 108 | | | | | | | | | |
| ZL1 | R*8 | VAR | 2 | 56 | 56 | 57 | 57 | 70 | 72 | | | | | |
| ZNEW | R*8 | VAR | 2 | 75 | 79 | 83 | | | | | | | | |
| ZR | R*8 | VAR | 2 | 40 | 62 | 62 | 63 | 63 | 71 | 83 | 90 | 90 | 91 | 91 |
| | | | 94 | 114 | | | | | | | | | | |
| ZR1 | R*8 | VAR | 2 | 48 | 66 | 66 | 67 | 67 | 71 | | | | | |