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MODAL ACOUSTIC TRANSMISSION LOSS (MOATL): A TRANSMISSION-LOSS C--ETC(U)

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NRL ~~Report~~ 8429

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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August ~~26,~~ 1980

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Coherent loss	Shallow-water acoustics	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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 ρ_1 is bounded above by a pressure-release surface and below by a second fluid layer, which has thickness H_2 and uniform density ρ_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 ρ_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}.

Manuscript submitted May 6, 1980.

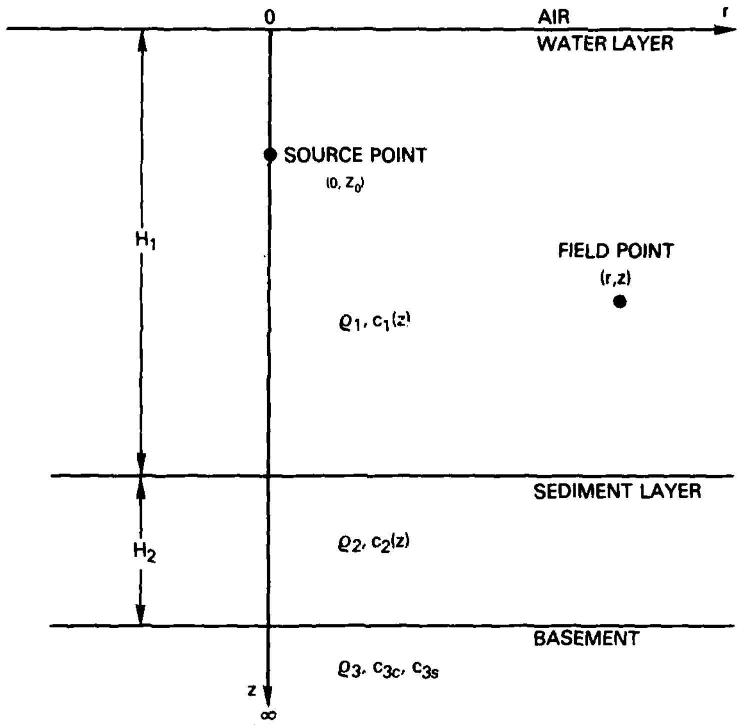


Fig. 1 — Physical model. An infinite half-space consisting of two fluid layers bounded above by air and having respective depths H_1 and H_2, densities ρ_1 and ρ_2, and a third, semi-infinite layer of density ρ_3, compressional velocity c_{3c}, and shear velocity c_{3s} (if it is a solid). At the source 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, θ) plane, and the z-axis is perpendicular to the surface with z increasing downward. A harmonic point source of unit strength and angular frequency ω lies on the z-axis at depth z_0. The velocity potential Φ at any field point (r, θ, z) satisfies the wave equation:

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

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 $u_n(\zeta)$ satisfy the eigenvalue equation:

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

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 ζ, $\rho = \rho_1$, ρ_2, or ρ_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, δ_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 ϵ_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 ϵ_{3c} and ϵ_{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 nth 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 α_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 δ_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.

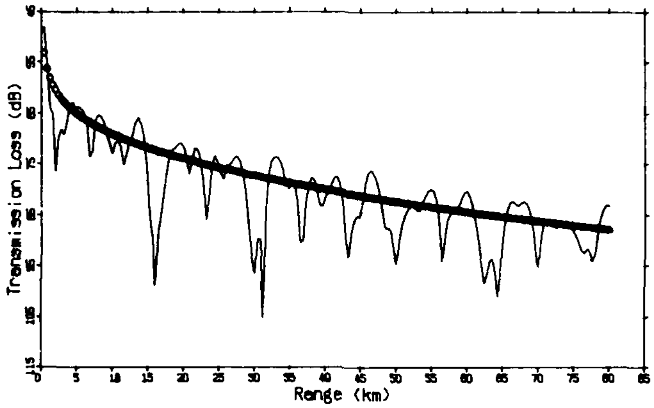
An additional approximation, that the range-dependent environment does not transfer energy from one mode to another, is made. In this approximation [5,6], called the adiabatic approximation or the conservation of mode index, energy originally propagated in a particular normal mode remains in that mode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

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

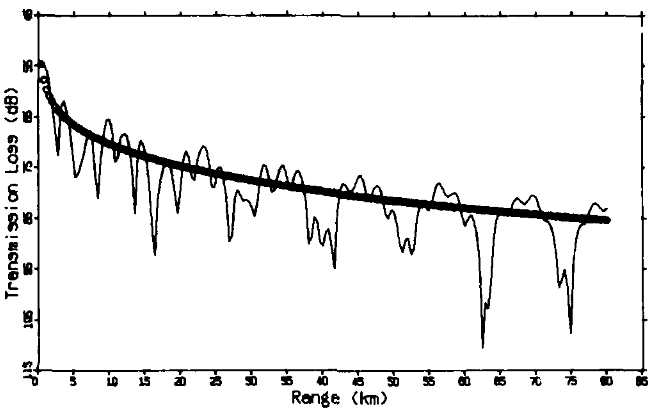
$$u_n(\zeta_0)\, u_n(\zeta) \rightarrow u_n(\zeta_0)\, u_n'(\zeta)$$

and

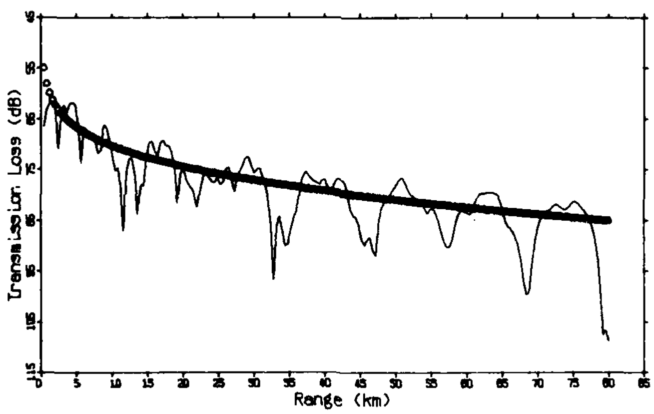
$$H_1 \rightarrow \sqrt{H_1 H_1'},$$



(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.

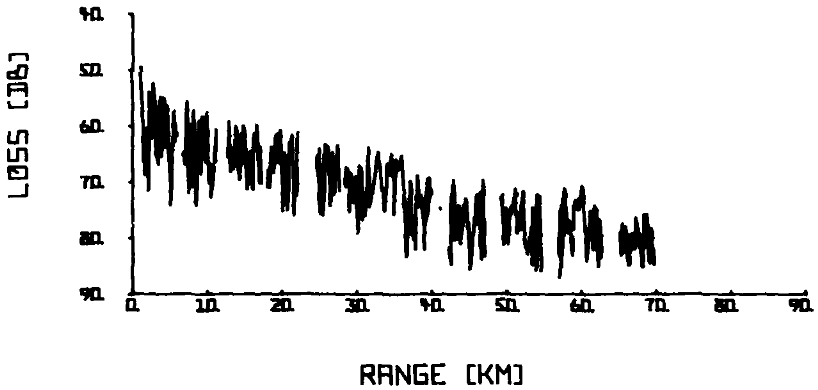


Fig. 3 — Measured CW transmission loss. Oscillations in the transmission loss are shown here for some typical measurements employing a towed CW source. The places where data are missing correspond to intervals during which the source was turned off.

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:

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

and

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

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 ϕ_n and Δ_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 nth modal eigenfunction calculated by using the environment found at the origin and evaluated at the (normalized) depth ζ_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 ζ. 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_{3_c} (FLUID case) or c_{3_s} (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
Common Blocks	
TNIH	2
TNH	12C
TNI	7
TH	1
TN	58680
NIH	968
NH	5
NIFLU	2
NI	12DB
IH	2
NISOL	7

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

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, ϵ_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, ϵ_{3_c} (EP2 in the FORTRAN), and the basement shear plane-wave absorption coefficient, ϵ_{3_s} (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 10000. 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 α_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, $\zeta_{IA1+1} < \zeta_0 < \zeta_{IA1+2}$, where ζ_{IA1+1} is the normalized depth at the top of the (IA1+1)th incremental layer; ζ_{IA1+2} is defined similarly. Note that $\zeta_1 = 0$. In the above example, ζ_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 $u_n(\zeta_0)$:

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

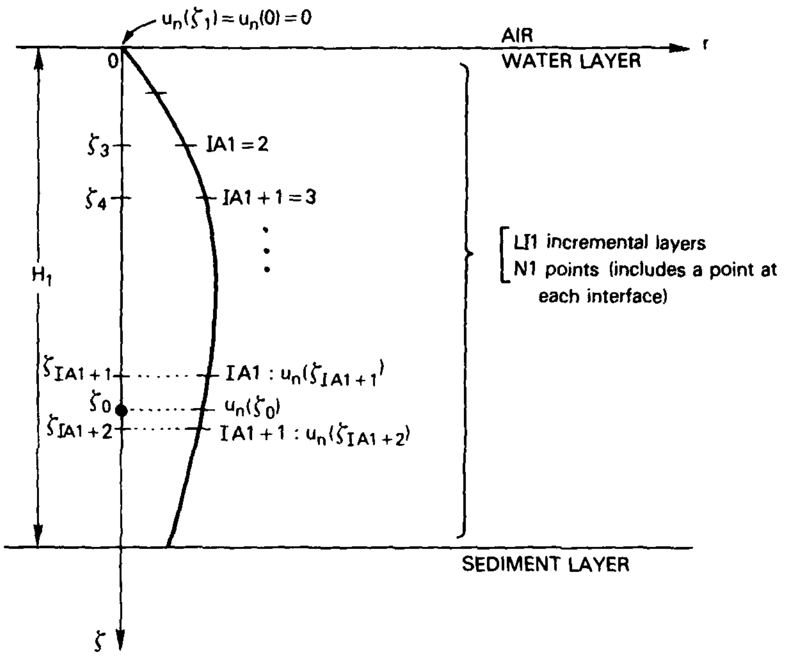


Fig. 4 — Receiver eigenfunction. The first mode (fluid-basement model) at *zero range is illustrated*, along with the values of the eigenfunction to be used in the interpolation of $u_n(\zeta_0)$.

The quantity Δ (programmed as DLTA1) is that fraction of a layer increment by which ζ_0 exceeds ζ_{IA1+1}. For a receiver in the water layer, we have:

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

For a receiver in the sediment, the calculation of Δ is performed similarly.

For a receiver depth equal to the depth of one of the incremental layer boundaries, Δ 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 ζ 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

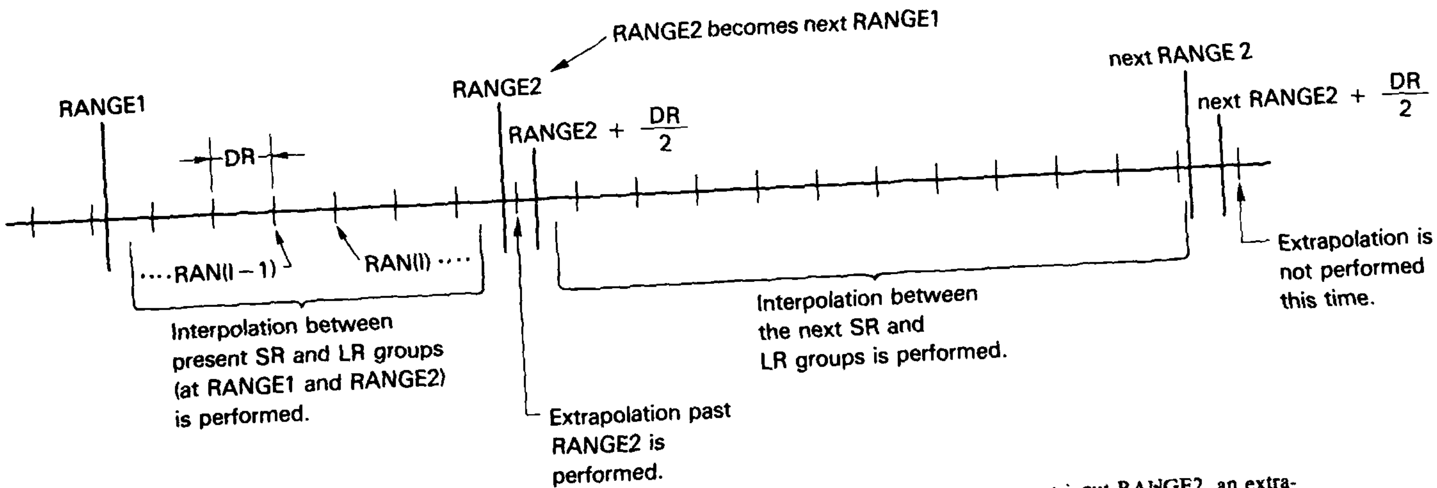


Fig. 5 — Interpolation or extrapolation at RAN(I). For the calculation range just beyond the present input RANGE2, an extrapolation is performed. If the calculation range were to lie beyond RANGE2 + (DR/2), as is the case for the next RANGE2, then RANGE2 and the present LR group would become the next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

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

where

$$\Delta = \frac{\mathrm{RAN(I) - RANGE1}}{\mathrm{RANGE2 - RANGE1}}. \tag{16}$$

The quantity Δ 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:

$$\mathrm{SCALE = SCALE - DR/(2.0*(RANGE2 - RANGE1))}. \tag{17}$$

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

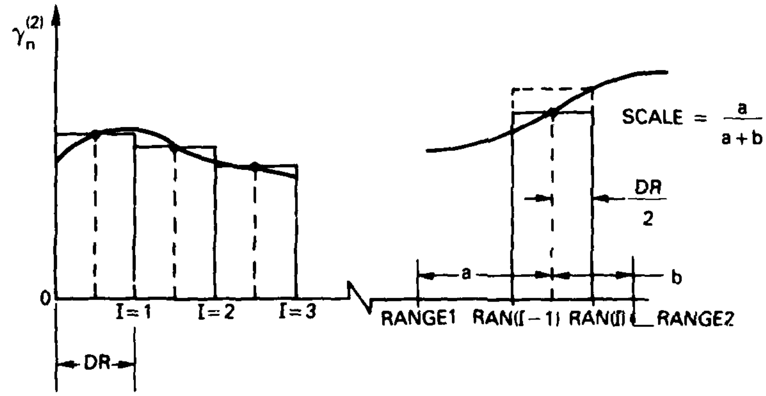


Fig. 6 — Approximation of $\int_0^r \gamma_n^{(2)}(r')dr'$. The "piece" of the integral $\int_{\mathrm{RAN(I-1)}}^{\mathrm{RAN(I)}} \gamma_n^{(2)}(r')dr'$ is approximated by DR $*$ $\gamma_n^{(2)}(r'')$, where r'' is equal to RAN(I) − (DP/2). The result is shown with solid lines, and is more accurate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

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

where we have inserted ϵ_4, ϵ_5, and ϵ_6 in place of ϵ_2, ϵ_{3c}, and ϵ_{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 σ_0 (SIG0 in the program) be the rms wave height and σ_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)*SIG0*SIG0*((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 nth 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 ζ_0 or ζ 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:

$$QS(J1,J2) = \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)\, r^{1/2}}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin \phi_n .$$

In a similar manner, we have:

$$QC\,(J1,J2) = \sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)\, r^{1/2}}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos\phi_n$$

and

$$PL\,(J1,J2,I) = \sum_{n=1}^{N} \left[\frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r}\right]^2 r. \qquad (22)$$

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):

$$COPL\,(J1,J2,I) = \left[\sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \sin\phi_n\right]^2 r + \left[\sum_{n=1}^{N} \frac{u_n(\zeta_0)\, u_n'(\zeta)}{\phi_n^{1/2}}\, e^{-\Delta_n r} \cos\phi_n\right]^2 r. \qquad (23)$$

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

PHASE (J1,J2)=ATAN2(QS (J1,J2),QC (J1,J2))*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 ρ_1 given by RERHO1. As mentioned earlier, however, the program will accommodate a receiver in the sediment. In this case, the program replaces ρ_1 by ρ_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)
          ┌──────────────────
          │                   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)
  NMFREQ  │              ND2 - Z2(I),C2(I)  (2F10.3)
          │
          │      ┌───────────────
          │      │            MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2
          │      │                 (3I5,5F10.3)
          │      │
          │      │            EPSLN,COMP,SHEAR,RANGE2,LI1,LI2,ND1,ND2
          │      │                 (F10.8,3F10.3,4I5)
          │  NRBUF-1
          │      │       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 α_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

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

                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 =  0.1503249805390 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
 0.8359469310610D-01     0.5540E-08              0.9142E-03              0.8659E-03            0.5789E-04          0.5784E-04

MODE NO. =  2      PHASE VELOCITY =  0.1513221910180 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
 0.8304380560330D-01     0.5548E-08              0.3250E-02              0.3240E-02            0.1183E-03          0.1179E-03

MODE NO. =  3      PHASE VELOCITY =  0.1530544066500 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
 0.8210394518790D-01     0.5572E-08              0.6217E-02              0.6812E-02            0.1827E-03          0.1815E-03

MODE NO. =  4      PHASE VELOCITY =  0.1556192915740 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
 0.8075072497290D-01     0.5617E-08              0.9276E-02              0.1189E-01            0.2518E-03          0.2492E-03

MODE NO. =  5      PHASE VELOCITY =  0.1591491183360 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
 0.7895972497840D-01     0.5674E-08              0.1232E-01              0.2069E-01            0.3254E-03          0.3206E-03

MODE NO. =  6      PHASE VELOCITY =  0.1637951162200 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
 0.7672005676590D-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	1.1937	-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) ( 62.99/ 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
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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
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```
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)
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```
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
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******************************** TRANSMISSION LOSS ******************************
 TEST CASE NUMBER 2


                                 NUMBER OF FREQUENCIES = 1

NO. PROFILES    NO. CALCULATION RANGES    MAXIMUM RANGE       EP1         EP2         EP3        SIG0        SIG1
      3                   10                50000.000      0.0005100   0.0000500   0.0000550   0.3000000   0.1090000

              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
0.417538013249D 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 =  0.151723428349D 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            0.9653E-02            0.2212E-07           0.2520E-07        0.7724E-03        0.7679E-03
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MODE NO. =  7      PHASE VELOCITY =  0.155338247311D 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
0.404484112314D 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
0.381456053917D 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
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                    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
0.3581592792060D 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
0.3473854009640D 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
0.3407839429360D 00      0.6121E-07          0.6530E 00             0.1613E-01          0.3233E-01          0.8780E-03          0.8616E-03

MODE NO. = 16      PHASE VELOCITY =   0.1902172689020D 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
0.3303162403050D 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
0.3171198757470D 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
0.3088260032250D 00      0.1079E-06          0.4093E 00             0.1822E-01          0.7451E-01          0.1800E-02          0.1759E-02
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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
0.2935836749570 00     0.1515E-06          0.1965E 00           0.7030E-02           0.7001E-01        0.2706E-02        0.2648E-02
```

```
NDPRNT =0        INC1 = 0        INC2 = 0         RHO1 =1.000        RHO2 =1.957        RHO3 =2.500        H1 = 190.000        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	1492.000
1.000	180.000	1700.000
1.278	230.000	1725.000

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

MODE NO. =  1     PHASE VELOCITY =  0.1485599464910 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
0.4229393894910 00    0.1373E-06          0.1150E-02          0.2411E-09          0.2593E-09          0.0000E 00        0.2534E-03

MODE NO. =  2     PHASE VELOCITY =  0.1490996078210 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
0.4214085737050 00    0.1375E-06          0.1773E-02          0.8039E-09          0.8703E-09          0.0000E 00        0.2637E-03

MODE NO. =  3     PHASE VELOCITY =  0.1497938285300 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
0.4194555522650 00    0.1378E-06          0.2888E-02          0.4629E-08          0.5053E-08          0.0000E 00        0.3475E-03

MODE NO. =  4     PHASE VELOCITY =  0.1506870633590 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
0.4169691257590 00    0.1384E-06          0.4178E-02          0.1639E-06          0.1809E-06          0.3402E-03        0.4369E-03

MODE NO. =  5     PHASE VELOCITY =  0.1509893103140 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
0.4161344464800 00    0.7623E-13          0.5286E 00          0.4576E 00          0.5068E 00          0.2202E-09        0.2648E-09

MODE NO. =  6     PHASE VELOCITY =  0.1517905273140 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
0.4139379062940 00    0.1391E-06          0.5607E-02          0.5452E-07          0.6097E-07          0.5059E-03        0.5309E-03
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MODE NO. =  7      PHASE VELOCITY =  0.1531546943800D 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
0.4107509389510D 00      0.1401E-06            0.7411E-02            0.1966E-07            0.2237E-07          0.6530E-03          0.6494E-03

MODE NO. =  8      PHASE VELOCITY =  0.1548421069700D 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
0.4057801479281D 00      0.1414E-06            0.9463E-02            0.1875E-07            0.2180E-07          0.7778E-03          0.7736E-03

MODE NO. =  9      PHASE VELOCITY =  0.1568724864180D 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
0.4005281901660D 00      0.1429E-06            0.1178E-01            0.2862E-07            0.3419E-07          0.9127E-03          0.8964E-03

MODE NO. = 10      PHASE VELOCITY =  0.1592780626740D 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
0.3944790137240D 00      0.1446E-06            0.1476E-01            0.6443E-07            0.7962E-07          0.1047E-02          0.1027E-02

MODE NO. = 11      PHASE VELOCITY =  0.1621096807440D 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
0.3875985313160 00      0.1466E-06            0.1906E-01            0.2186E-06            0.2816E-06          0.1177E-02          0.1165E-02

MODE NO. = 12      PHASE VELOCITY =  0.1654229450540D 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
0.3798255015420D 00      0.1484E-06            0.2669E-01            0.1253E-05            0.1701E-05          0.1314E-02          0.1305E-02
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                    MAXIMUM NUMBER OF MODES = 22          NUMBER OF MODES CALCULATED = 19

MODE NO. = 13      PHASE VELOCITY =   0.1692561594840 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
0.3717234359050 00       0.1494E-06          0.4923E-01            0.1716E-04           0.2486E-04          0.1444E-02         0.1427E-02

MODE NO. = 14      PHASE VELOCITY =   0.1732269706410 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
0.3627140325730 00       0.8935E-07          0.4443E 00            0.1765E-02           0.2753E-02          0.9460E-03         0.9318E-03

MODE NO. = 15      PHASE VELOCITY =   0.1746595302260 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
0.3597390476810 00       0.7508E-07          0.5384E 00            0.4315E-02           0.6924E-02          0.7982E-03         0.7854E-03

MODE NO. = 16      PHASE VELOCITY =   0.1790639338760 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
0.3508906164740 00       0.1394E-06          0.1592E 00            0.2474E-02           0.4360E-02          0.1599E-02         0.1573E-02

MODE NO. = 17      PHASE VELOCITY =   0.1829494633750 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
0.3434383021010 00       0.6070E-07          0.6546E 00            0.1492E-01           0.2885E-01          0.7316E-03         0.7115E-03

MODE NO. = 18      PHASE VELOCITY =   0.1865566415500 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
0.3367977282920 00       0.1357E-06          0.2156E 00            0.6543E-02           0.1392E-01          0.1681E-02         0.1645E-02
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MODE NO. = 19      PHASE VELOCITY =  0.193268779610D 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
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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
( 62.35/ 175.467) ( 79.42/ 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/ 277.290) ( 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
( 71.59/  94.362) ( 97.97/ 131.717) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 78.91/  60.528) ( 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
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NDPRNT =0        INC1 = 0         INC2 = 0        RHO1 =1.000       RHO2 =1.957       RHO3 =2.500       H1 = 200.000       H2 =  50.000
EPSLN =0.00010000          RANGF = 50000.000            LI1 =250      LI2 = 90      ND1 = 6      ND2 = 2

                                   COMPRESSIONAL VELOCITY     SHEAR VELOCITY     RAYLEIGH VELOCITY
                                         3800.000                2194.000            2017.159
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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

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

MODE NO. = 1       PHASE VELOCITY =  0.1488434840600D 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
0.4221337167290D 00      0.1373E-06            0.7149E-03            0.1591E-09            0.1717E-09          0.0000E 00          0.1888E-03

MODE NO. = 2       PHASE VELOCITY =  0.1492932305880D 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
0.4208620365720D 00      0.1375E-06            0.1324E-02            0.5637E-09            0.6116E-09          0.0000E 00          0.2192E-03

MODE NO. = 3       PHASE VELOCITY =  0.1498823890860D 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
0.4192077099250D 00      0.1378E-06            0.2292E-02            0.2748E-08            0.3003E-08          0.0000E 00          0.2979E-03

MODE NO. = 4       PHASE VELOCITY =  0.1506149706180D 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
0.4171697104800D 00      0.1382E-06            0.3174E-02            0.2825E-07            0.3114E-07          0.3175E-03          0.3538E-03

MODE NO. = 5       PHASE VELOCITY =  0.1511915290090D 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
0.4155778665890D 00      0.7287E-13            0.5248E 00            0.4597E 00            0.5104E 00          0.2138E-09          0.2161E-09

MODE NO. = 6       PHASE VELOCITY =  0.1514970294600D 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
0.4147398354660D 00      0.1398E-06            0.4275E-02            0.2103E-06            0.2344E-06          0.4299E-03          0.4283E-03
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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
0.411724799517D 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
0.398990650579D 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 =  0.162271197717D 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
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                    MAXIMUM NUMBER OF MODES = 24          NUMBER OF MODES CALCULATED = 19

MODE NO. = 13      PHASE VELOCITY =  0.165230421485D 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
0.390269067508D 00      0.1497E-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      0.1475E-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
0.345661636704D 00      0.1146E-06           0.3229E 00           0.6090E-02            0.1144E-01          0.1232E-02         0.1201E-02
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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
0.3404584389980 00     0.7817E-07           0.5512E 00           0.1384E-01          0.2788E-01          0.8535E-03         0.8241E-03
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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) (103.38/  23.682) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 74.35/ 273.483) ( 90.41/ 273.939) (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
( 77.99/ 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/ 299.767) (100.42/ 307.415) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 72.25/  67.076) ( 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
( 84.36/ 354.742) (100.71/ 353.959) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 82.12/ 104.993) (105.32/  74.269) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


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
( 75.46/ 316.897) ( 96.79/ 306.807) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 76.27/ 153.151) ( 99.50/ 149.173) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)


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
( 77.97/ 254.980) ( 99.44/ 265.108) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)

SOURCE DEPTH(M) = 140.000
( 80.38/ 103.657) (104.43/  85.910) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII) (IIIIII/IIIIIIII)
```

```
SOURCE DEPTH(M) =  70.000
 76.22   97.81  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 77.96  100.04  IIIIII  IIIIII  IIIIII


RANGE(M) = 45000.0

SOURCE DEPTH(M) =  70.000
 77.27   99.06  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 78.95  101.41  IIIIII  IIIIII  IIIIII


RANGE(M) = 50000.0

SOURCE DEPTH(M) =  70.000
 78.26  100.20  IIIIII  IIIIII  IIIIII

SOURCE DEPTH(M) = 140.000
 79.80  102.52  IIIIII  IIIIII  IIIIII
```

REFERENCES

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

2. W.A. Kuperman, J. Acoust. Soc. Am. **58**, 365-370 (1975).

3. W.A. Kuperman and F. Ingenito, J. Acoust. Soc. Am. **61**, 1178-1187 (1977).

4. F. Ingenito, R.H. Ferris, W.A. Kuperman, and S.N. Wolf, "Shallow Water Acoustics Summary Report (First Phase)," NRL Report 8179, March 27, 1978.

5. A.D. Pierce, J. Acoust. Soc. Am. **37**, 19-27 (1965).

6. D.M. Milder, J. Acoust. Soc. Am. **46**, 1259-1263 (1969).

7. A.O. Williams, Jr., and M.N. Lewis, Research Analysis Group (Brown University) Tech. Report 56-1, May 1956.

8. C.B. Officer, *Introduction to the Theory of Sound Transmission with Application to the Ocean* (New York: McGraw Hill, 1958), p. 120.

9. E.L. Hamilton, "Sound Velocity, Elasticity, and Related Properties of Marine Sediments, North Pacific," Naval Undersea Center Tech. Pub. NUC TP 143, October 1969.

10. E.L. Hamilton, Geophysics **37**, 620-646, 1972.

11. E.L. Hamilton, J. Geophys. Res. **75**, 4423-4446, 1970.

12. E.L. Hamilton, "Prediction of Deep-Sea Sediment Properties: State-of-the-Art," in *Deep-Sea Sediments, Physical and Mechanical Properties*, ed. by A.L. Inderbitzen (Plenum Press: New York, 1974).

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.

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

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^{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 nth 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

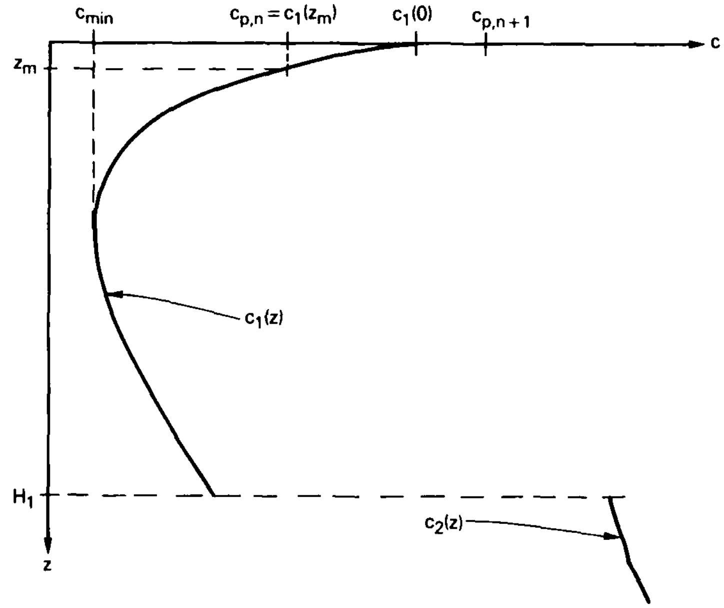

Fig. A1 — Hypothetical phase velocity configuration. For each mode order $\leqslant n$, there will be a depth z_m for which $c_1(z)$ (with $z < z_m$) will be greater than the corresponding modal phase velocity. For modes of order $> n$, $z_m = 0$.

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 ϵ_1 is the plane-wave absorption coefficient in an infinite medium of ocean water. Whereas ϵ_2, ϵ_{3c}, and ϵ_{3s} depend on the particular sediment and basement chosen (and are input variables), ϵ_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 ϵ_1 is given in dB/kyd. The coefficient ϵ_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, α_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, ϵ_2, expressed in dB/Hz-m.

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

EP3: The basement shear plane-wave absorption coefficient, ϵ_{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, α_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 the 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, Δ_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, α_n, at the SR range.

RA2(N): An array containing the water absorption, α_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 ρ_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.*, ρ_2, at the receiver range.

RHO1: The water-layer density ρ_1 at the variable range *r*.

RHO2: The ratio of the density of the sediment layer to that of water, *i.e.*, ρ_2, at the variable range *r*.

RHO3: The ratio of the density of the basement to that of water, *i.e.*, ρ_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 Δ 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 σ_0, used in calculating the term $S_{0,n}$.

SIG1: The root-mean-square excursion of the water/sediment interface σ_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),SB(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
```

```
NOATL            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)
```

```
MOATL            SOURCE LISTING

   CSN              STATEMENT

   0100               RB1(IM)=H2O2ND(IM)
   0101               RB2(IM)=H2O2ND(IM)
   0102               SE(IM)=0.0
   0103               S1(IM)=0.0
   0104               S2(IM)=0.0
   0105               S3(IM)=0.0
   0106               SA(IM)=0.0
   0107               ST(IM)=0.0
   0108               SB(IM)=0.0
   0109                  DO 100 J1=1,NDRE
   0110                  IF (DEPRE(J1).GT.H10) GO TO 95
   0111               A1=(N1-1)*DEPRE(J1)/H10
   0112               IA1=IFIX(A1)
   0113               DLTA1=A1-IA1
   0114                  GO TO 100
   0115            95 A1=(N2-1)*(DEPRE(J1)-H10)/H2+FLOAT(N1)
   0116               IA1=IFIX(A1)
   0117               DLTA1=A1-IA1
   0118           100 RE(J1,IM)=UNRM1(IM,IA1+1)+DLTA1*(UNRM1(IM,IA1+2)-UNRM1(IM,IA1+1))
   0119           110 CONTINUE
   0120                  IF (NRBUF.GT.1) GO TO 115
               C
               C  ********** PART 4 **********
               C
   0121               IF (ISPRD.EQ.0) WRITE(6,8001)
   0122               IF (ISPRD.EQ.1) WRITE(6,9001)
   0123               HS=H11
   0124               CTS=CT1
   0125               CBS=CB1
   0126                  DO 112 J2=1,NDSO
   0127               A1=(N1-1)*DEPSO(J2)/HS
   0128               IA1=IFIX(A1)
   0129               DLTA1=A1-IA1
   0130                  DO 111 IM=1,NMODE
   0131           111 SM(J2,IM)=UNRM1(IM,IA1+1)+DLTA1*(UNRM1(IM,IA1+2)-UNRM1(IM,IA1+1))
   0132           112 CONTINUE
   0133                  DO 113 IM=1,NMODE
   0134               WN(IM)=EIGVL1(IM)
   0135               G1(IM)=R11(IM)
   0136               G2(IM)=R21(IM)
   0137               G3(IM)=R31(IM)
   0138               GA(IM)=RA1(IM)
   0139               GT(IM)=RT1(IM)
   0140               GB(IM)=RB1(IM)
   0141           113 CONTINUE
               C
               C  ********** PART 5 **********
               C
   0142           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
   0143           IF (I.GT.1) RAN(I)=RAN(I-1)+DR
   0144              IF (NRBUF.EQ.1) GO TO 209
   0145              IF (RANGE2-RANGE1.LT.0.00001) GO TO 125
   0146        120   IF (RAN(I).LT.RANGE2+DR/2.0.OR.RAN(I).GE.RMAX) GO TO 160
            C
            C  ********** PART 6 **********
            C
   0147        125 RANGE1=RANGE2
   0148           H11=H12
   0149           CT1=CT2
   0150           CB1=CB2
   0151           N11=N12
   0152              DO 130 IM=1,NMODE
   0153              IF (KA.EQ.0) GO TO 129
   0154              DO 128 IA1=1,1202
   0155        128 UNRM1(IM,IA1)=UNRM2(IM,IA1)
   0156        129 CONTINUE
   0157           EIGVL1(IM)=EIGVL2(IM)
   0158           R11(IM)=R12(IM)
   0159           R21(IM)=R22(IM)
   0160           R31(IM)=R32(IM)
   0161           RA1(IM)=RA2(IM)
   0162           RT1(IM)=RT2(IM)
   0163           RB1(IM)=RB2(IM)
   0164        130 CONTINUE
   0165           READ (5,5000)MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2
   0166           READ (5,6000)EPSLN,COMP,SHEAR,RANGE2,LI1,LI2,ND1,ND2
   0167           WRITE(6,1001)
   0168           WRITE(6,7001) MDPRNT,INC1,INC2,RHO1,RHO2,RHO3,H12,H2,EPSLN,
                 >RANGE2,LI1,LI2,ND1,ND2
   0169           READ (5,7000)(Z1(J),C1(J),J=1,ND1)
   0170           READ (5,7000)(Z2(J),C2(J),J=1,ND2)
   0171           CT2=C1(1)
   0172           CB2=C1(ND1)
   0173           KA=1
   0174              IF (III.EQ.0) CALL FLUID
   0175              IF (III.EQ.1) CALL SOLID
   0176           IF (ISPRD.EQ.0) WRITE(6,8001)
   0177           IF (ISPRD.EQ.1) WRITE(6,9001)
   0178           N12=N1
   0179              DO 150 IM=1,NMODE
   0180           EIGVL2(IM)=AKN(IM)
   0181           R12(IM)=ATTEN2(IM)
   0182           R22(IM)=ATTENC(IM)
   0183           R32(IM)=ATTENS(IM)
   0184           RA2(IM)=ABSOR(IM)
```

NOATL SOURCE LISTING

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
```

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MOATL          SOURCE LISTING

   CSN            STATEMENT

   0229          QQ=EP4*S1(IM)+EP5*S2(IM)+EP6*S3(IM)+SA(IM)
   0230          QQ=QQ+2.0*ST(IM)*SIGO*SIGO*((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) GO TO 215
   0233          WRITE(6,11001) IM
   0234             GO TO 230
   0235      215 Q2=1.0/EXP(QQ)
   0236             DO 220 J2=1,NDSO
   0237             DO 220 J1=1,NDRE
   0238          Q1=RE(J1,IM)*SM(J2,IM)*DSQRT(RAN(I)/SE(IM))
   0239             IF (ABS(Q1).GE.10.**(-10)) GO TO 217
   0240          WRITE(6,12001) IM,DEPSO(J2),DEPRE(J1)
   0241             GO TO 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*DCOS(SE(IM))
   0245          PL(J1,J2,I)=PL(J1,J2,I)+Q*Q
   0246      220 CONTINUE
   0247      230 CONTINUE
           C
           C  ********** PART 9 **********
           C
   0248             DO 270 J2=1,NDSO
   0249             DO 270 J1=1,NDRE
   0250          COPL(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) COPL(J1,J2,I)=-10.0*ALOG10(
                >6.283*COPL(J1,J2,I)*RERHO1*RERHO1/(H10*HS))
   0254          IF  (ISPRD.EQ.0.AND.DEPRE(J1).GT.H10) COPL(J1,J2,I)=-10.0*ALOG10(
                >6.283*COPL(J1,J2,I)*RERHO2*RERHO2/(H10*HS))
   0255          IF  (ISPRD.EQ.1.AND.DEPRE(J1).LE.H10) COPL(J1,J2,I)=-10.0*ALOG10(
                >6.283*COPL(J1,J2,I)*RERHO1*RERHO1/(H10*HS*RAN(I)))
   0256          IF  (ISPRD.EQ.1.AND.DEPRE(J1).GT.H10) COPL(J1,J2,I)=-10.0*ALOG10(
                >6.283*COPL(J1,J2,I)*RERHO2*RERHO2/(H10*HS*RAN(I)))
   0257          IF  (ISPRD.EQ.0.AND.DEPRE(J1).LE.H10) PL(J1,J2,I)=-10.0*ALOG10(
                >6.283*PL(J1,J2,I)*RERHO1*RERHO1/(H10*HS))
   0258          IF  (ISPRD.EQ.0.AND.DEPRE(J1).GT.H10) PL(J1,J2,I)=-10.0*ALOG10(
                >6.283*PL(J1,J2,I)*RERHO2*RERHO2/(H10*HS))
   0259          IF  (ISPRD.EQ.1.AND.DEPRE(J1).LE.H10) PL(J1,J2,I)=-10.0*ALOG10(
                >6.283*PL(J1,J2,I)*RERHO1*RERHO1/(H10*HS*RAN(I)))
   0260          IF  (ISPRD.EQ.1.AND.DEPRE(J1).GT.H10) PL(J1,J2,I)=-10.0*ALOG10(
                >6.283*PL(J1,J2,I)*RERHO2*RERHO2/(H10*HS*RAN(I)))
   0261      270 CONTINUE
   0262             IF (NDRE+NDSO.EQ.2) GO TO 295
           C
           C  ********** PART 10 **********
           C
   0263             DO 290 J2=1,NDSO
   0264          WRITE(6,13001) DEPSO(J2),DEPSO(J2)
```

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MOATL           SOURCE LISTING

    CSN             STATEMENT

    0265               DO 280 J1=1,NDRE,5
    0266          280 WRITE(6,14001) COPL(J1,J2,I),PHASE(J1,J2),COPL(J1+1,J2,I),
                     >PHASE(J1+1,J2),COPL(J1+2,J2,I),PHASE(J1+2,J2),COPL(J1+3,J2,I),
                     >PHASE(J1+3,J2),COPL(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 CONTINUE
    0268               GO TO 300
    0269          295 WRITE(6,15001) COPL(1,1,I),PHASE(1,1),PL(1,1,I)
    0270          300 CONTINUE
    0271               IF (IPLOT.EQ.0) GO TO 340
            C
            C  ********** PART 11 **********
            C
    0272               DO 330 J1=1,NDRE
    0273               DO 330 J2=1,NOSO
    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,'TERANSMISSION ELEOSS EAEN
                     >OMALY E(EDEB)',90.,38)
    0280              IF (ISPRD.EQ.1) CALL CENTRE (-.3,Y2,.16,'TERANSMISSION ELEOSS E(ED
                     >EB)',90.,28)
    0281              CALL CENTRE (X2,-.46,.16,'REANGE E(EKME)',0.,14)
    0282                 DO 310 I=1,NRCALC
    0283              X=RAN(I)/(1000.*DX)
    0284              Y=YLENG-(COPL(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) GO TO 310
    0288              CALL PLOT (X, Y, 3)
    0289          310 CALL PLOT (X, Y, 2)
    0290                 DO 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 SYMBOL (X, Y, 0.08, 2, 0., 1)
    0296          330 CALL ORIGIN (XLENG+2.5,0.)
    0297          340 CONTINUE
    0298              CALL ENDPLT
    0299              END
```

NOATL 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						
H2O2NO	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

CRØSS REFERENCE LISTING

[illegible]	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							
IPLØT	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
			265	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	
NDSØ	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								
NMØDE	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	85	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										
ØRIGIN		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					
PLØT		SBR	288	289										
PLØTS		SBR	34											
PLTAR	R*4	ARR	10	34										
PMGTD	R*4	VAR	7	35										

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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$1CCS          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
   SCALE     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
   SIG0      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

0001                 SUBROUTINE FLUID
0002           DOUBLE PRECISION TWOPI,DL1,HH1,DL2,HH2,SPEED,DEPTH,AK1,AK2,AK3,
              >AKN,YOU,A,PV,SOUND
0003           COMMON/IN/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/INI/RHO1,RHO2,RHO3,H12,COMP,F,N1
0005           COMMON/INH/AKN(150)
0006           COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
              >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
0007           COMMON/NIFLU/A
0008           COMMON/NH/AK1,AK2,LOMP
0009           COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0010           COMMON/INIH/PPRCN,PMGTO
0011           DIMENSION LAMP(3),DEPTH(1202),X(650),Y(650),MDNUM(12),LDEPTH(2)
0012           DATA LDEPTH/' DEP','TH  '/
0013           DATA LAMP/'AMPL','ITUD','E'/
0014      8001 FORMAT (//,55X,'COMPRESSIONAL VELOCITY',/,60X,F10.3)
0015      9001 FORMAT (////,55X,'SOUND SPEED PROFILE',//,49X,'  DEPTH      DEPTH
              >  VELOCITY',//)
0016     10001 FORMAT (45X,3F11.3)
0017     11001 FORMAT (/)
0018     12001 FORMAT (1H1,/,35X,'MAXIMUM NUMBER OF MODES =',I3,10X,'NUMBER OF MO
              >DES CALCULATED =',I3,//)
0019     13001 FORMAT (1H1)
0020     14001 FORMAT (' MODE NO. =',I3,5X,'PHASE VELOCITY =',D20.12)
0021     15001 FORMAT (' UPPER AMPLITUDES MATCHED FOR THIS MODE STARTING AT NORMA
              >LIZED DEPTH =',F7.4)
0022     16001 FORMAT (' NUMBER OF ITERATE SOLUTIONS =',I3,5X,'THE EIGENFUNCTION
              >WAS SCALED DOWN',I3,' TIME(S)')
0023     17001 FORMAT (' LAYER 2 ATTEN RATIO = DEFAULT ZERO')
0024     18001 FORMAT (' LAYER 3 ATTEN RATIO = DEFAULT ZERO')
0025     19001 FORMAT ('     WAVE NUMBER        WATER ABSORPTION       LAYER 2 ATTEN
              > RATIO      LAYER 3 ATTEN RATIO      AIR/H2O SCATTER      H2O/2ND SCA
              >TTER')
0026     20001 FORMAT (D20.12,4X,2(F11.4,13X),E11.4,11X,E11.4,9X,F11.4,//)
0027     21001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
              >Z.',//,' FIRST LAYER',///)
0028     22001 FORMAT (10X,12(3X,I3,'MODE'),/)
0029     23001 FORMAT (4X,2A4,12(1X,2A4,A1))
0030     24001 FORMAT (13F10.4)
0031     25001 FORMAT (1H1,'MODE AMPLITUDES FOR THE SOURCE FREQUENCY OF',F9.3,' H
              >Z.',//,' SECOND LAYER',///)
0032           TWOPI=6.283185307179580
0033           F2=(F/1000.)*(F/1000.)
0034           FPW=.1*F2/(1.+F2)+40.*F2/(4100.+F2)+2.75E-4*F2
0035           FPW=FPW*.1151292546*1.093613298E-3
0036           X(1)=Z1(1)
0037           CMIN1=C1(1)
```

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FLUID          SOURCE LISTING

               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

    CSN              STATEMENT

    0088             SPEED(INTERP)=((C1(J)-C1(J-1))*(DEPTH(INTERP)-Z1(J-1))/
                    >(DBLE(Z1(J))-Z1(J-1)))+C1(J-1)
    0089             SOUND(INTERP)=SPEED(INTERP)
    0090             SPEED(INTERP)=HH1/(SPEED(INTERP)*SPEED(INTERP))
    0091                GO TO 50
    0092          40 K=K+1
    0093          50 CONTINUE
    0094             K=2
    0095                DO 70 INTERP=N1PLS2,NTMNS1
    0096             DEPTH(INTERP)=(INTERP-1-N1)*DL2+1.0
    0097             KK=K
    0098                DO 60 J=KK,ND2
    0099                IF (DEPTH(INTERP).GT.Z2(J)) GO TO 60
    0100             SPEED(INTERP)=((C2(J)-C2(J-1))*(DEPTH(INTERP)-Z2(J-1))/
                    >(DBLE(Z2(J))-Z2(J-1)))+C2(J-1)
    0101             SOUND(INTERP)=SPEED(INTERP)
    0102             SPEED(INTERP)=HH2/(SPEED(INTERP)*SPEED(INTERP))
    0103                GO TO 70
    0104          60 K=K+1
    0105          70 CONTINUE
    0106             IZERO=0
    0107             AK1=TWOPI*F/COMP
    0108             AK3=AK1
    0109             AK2=TWOPI*F/CMIN
    0110             SRFC=39.4784176*F*F/(C1(1)*C1(1))
    0111             BOTTOM=39.4784176*F*F/(C1(ND1)*C1(ND1))
    0112                CALL ITRTF (AK1)
    0113             MAXMD=NCR
    0114             NMODE=MINO(NMODE,MAXMD)
    0115             MGROPS=INT(NMODE/12.0+0.02)+1
    0116                DO 350 M=1,MGROPS
    0117             IBASE=(M-1)*12
    0118             IF (M.LT.MGROPS) NIC=12
    0119             IF (M.EQ.MGROPS) NIC=MOD(NMODE,12)
    0120                IF (NIC.EQ.0) GO TO 350
    0121                DO 340 IC=1,NIC
    0122             I=IBASE+IC
    0123             MDNUM(IC)=I
    0124                CALL HALFF
    0125             AK1=AK3
    0126             AK2=AKN(I)
    0127             ODD=0.0
    0128             ODD1=0.0
    0129             ODD2=0.0
    0130             ODD3=0.0
    0131             EVEN=0.0
    0132             EVEN1=0.0
    0133             EVEN2=0.0
    0134             EVEN3=0.0
    0135                DO 200 J=2,N1MNS1,2
```

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FLUID            SOURCE LISTING

    CSN             STATEMENT

    0136        200 EVEN1=EVEN1+YOU(J)*YOU(J)
    0137               DO 210 J=3,N1MNS2,2
    0138        210 ODD1=ODD1+YOU(J)*YOU(J)
    0139               DO 220 J=N1PLS2,NTMNS1,2
    0140        220 EVEN2=EVEN2+YOU(J)*YOU(J)
    0141               DO 230 J=N1PLS3,NTMNS2,2
    0142        230 ODD2=ODD2+YOU(J)*YOU(J)
    0143               DO 234 J=2,N1MNS1,2
    0144        234 EVEN3=EVEN3+YOU(J)*YOU(J)/SOUND(J)
    0145               DO 236 J=3,N1MNS2,2
    0146        236 ODD3=ODD3+YOU(J)*YOU(J)/SOUND(J)
    0147               DO 240 J=N1PLS2,NTMNS1,2
    0148        240 EVEN=EVEN+YOU(J)*YOU(J)/SOUND(J)
    0149               DO 250 J=N1PLS3,NTMNS2,2
    0150        250 ODD=ODD+YOU(J)*YOU(J)/SOUND(J)
    0151            AI1=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)+4.0*EVEN1+2.0*ODD1+YOU(N1)*
                  >YOU(N1))
    0152            AI2=RHO2*(DL2/3.0)*(YOU(N1+1)*YOU(N1+1)+4.0*EVEN2+2.0*ODD2+
                  >YOU(NT)*YOU(NT))
    0153            AI3=RHO2*RHC .*YOU(NT)*YOU(NT)/RHO3/2.0/DSQRT(A)
    0154            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))
    0155            AI5=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)/C1(1)+4.0*EVEN3+2.0*ODD3+
                  >YOU(N1)*YOU(N1)/C1(ND1))
    0156            AI=AI1+AI2+AI3
    0157            ANORM=SQRT(1.0/AI)
    0158               DO 260 J=1,NT
    0159            IF (KA.EQ.0) UNRM1(I,J)=YOU(J)*ANORM
    0160            IF (KA.EQ.1) UNRM2(I,J)=YOU(J)*ANORM
    0161        260 CONTINUE
    0162               IF (KA.EQ.1) GO TO 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               GO TO 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 DYDUA=(-3.*YNM1+4.*YNM2-YNM3)/(2.*DL1)
    0179            DYDUB=(-3.*YNM5+4.*YNM6-YNM7)/(2.*DL2)
    0180            AKN2=AKN(I)*AKN(I)
    0181               IF (SRFC-AKN2.GT.PPRCN) GO TO 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 (MDPRNT.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		50	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									
AESCR	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	98	100							
DEPTH	R*8	ARR	2	11	74	75	76	77	84	87	98	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											
DYQUA	R*4	VAR	178	184	184									
DYCLR	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
   H2M2ND    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      93      94     84     97     88     88     89     89     90     90     90     95
                            96      96     99    100    100    101    101    102    102    102
   ISTIF           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
                            86      89     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    215    216    217    217
                           222     223    223    224    224
   K         I*4   VAR      82      95     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
   MONUM     I*4   ARR      11     123    211    220
   MOPRNT    I*4   VAR       3     209
   MCREPS    I*4   VAR     115     116    119    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
   NF              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
			153	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										
RDD	R*4	VAR	127	150	150	154								
RDD1	R*4	VAR	128	138	138	151								
RDD2	R*4	VAR	129	142	142	152								
RDD3	R*4	VAR	130	146	146	155								
PPGTD	R*4	VAR	10	190	193	204	205							
PPRCV	R*4	VAR	10	181	185									
PV	R*8	VAR	2	199	201									
R$1DSW		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									
SREC	R*4	VAR	110	181	184									
TN		COM	3											
TNH		COM	5											
TNI		COM	4											
TNIH		COM	10											
THEFT	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

    YAMT     R*4   VAR     169     177     179
    YCU      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
```

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        SOURCE LISTING

CSN          STATEMENT

0001              SUBROUTINE ITRTF (AKN)
0002           DOUBLE PRECISION OMEGA2,TWOPI,A,HH2,AKN,YOU,SPEED,DL2,PPLUS1,
              >PMNS1,B,DL1,HH1,UMAX,UABVL,SOUND
0003           COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
0004           COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
              >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
0005           COMMON/NIFLU/A
0006           COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0007           COMMON/TNIH/PPRCN,PMGTD
0008           COMMON/IH/UMAX
0009           MATCH=0
0010              IF (IZERO.NE.1) GO TO 10
0011              DO 6 J=3,N1MNS2
0012              IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 6
0013           MATCH=J
0014              GO TO 10
0015         6 CONTINUE
0016              DO 8 J=N1PLS3,NTMNS2
0017              IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 8
0018           MATCH=J
0019              GO TO 10
0020         8 CONTINUE
0021           MATCH=NTMNS2
0022        10 NCR=0
0023           IFG=0
0024           OMEGA2=TWOPI*TWOPI*F*F
0025           A=DABS(HH2*(AKN*AKN-OMEGA2/(DBLE(COMP)*COMP)))
0026           YOU(NT)=DBLE(RHO3)/RHO2
0027           YOU(NT-1)=YOU(NT)+DSQRT(A)-YOU(NT)*(OMEGA2*SPEED(NT)-HH2*AKN*AKN)/
              >2.0
0028           UMAX=DMAX1(DABS(YOU(NT)),DABS(YOU(NT-1)))
0029           A=A/(DL2*DL2)
0030              DO 31 J=2,N2MNS1
0031           NTMJ=NT-J
0032           PPLUS1=12.0+OMEGA2*SPEED(NTMJ)-HH2*AKN*AKN
0033           P=24.0-10.0*(OMEGA2*SPEED(NTMJ+1)-HH2*AKN*AKN)
0034           PMNS1=12.0+OMEGA2*SPEED(NTMJ+2)-HH2*AKN*AKN
0035           YOU(NTMJ)=(P/PPLUS1)*YOU(NTMJ+1)-(PMNS1/PPLUS1)*YOU(NTMJ+2)
0036           UABVL=DABS(YOU(NTMJ))
0037           IF (UABVL.GT.UMAX) UMAX=UABVL
0038           IF (DSIGN(1.D0,YOU(NTMJ))*YOU(NTMJ+1).LE.0.) NCR=NCR+1
0039              IF (UABVL.LT.PMGTD) GO TO 22
0040              DO 21 JD=NTMJ,NT
0041           IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.
0042        21 YOU(JD)=YOU(JD)/PMGTD
0043           UMAX=UMAX/PMGTD
0044           IFG=IFG+1
0045        22    IF (NTMJ.EQ.MATCH) GO TO 131
0046        31 CONTINUE
0047           B=(3.0*YOU(N1PLS1)-4.0*YOU(N1PLS1+1)+YOU(N1PLS1+2))/(2.0*DL2)
```

AD-A089 367 NAVAL RESEARCH LAB WASHINGTON DC F/G 20/1
MODAL ACOUSTIC TRANSMISSION LOSS (MOATL): A TRANSMISSION-LOSS C--ETC(U)
AUG 80 J F MILLER, S N WOLF
UNCLASSIFIED NRL-8429 NL

2 OF 2
AD A089 367

END
DATE FILMED
10-80
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ITRTF               SOURCE LISTING

    CSN                STATEMENT

    0048               YOU(N1)=RHO2*YOU(N1PLS1)/RHO1
    0049               YOU(N1-1)=YOU(N1)+DL1*B-YOU(N1)*(OMEGA2*SPEED(N1)-HH1*AKN*AKN)/2.0
    0050               IF (DABS(YOU(N1)).GT.UMAX) UMAX=DABS(YOU(N1))
    0051               IF (DABS(YOU(N1-1)).GT.UMAX) UMAX=DABS(YOU(N1-1))
    0052               IF (DSIGN(1.D0,YOU(N1))*YOU(N1-1).LE.0.) NCR=NCR+1
    0053                  DO 121 J=2,N1MNS1
    0054               N1MJ=N1-J
    0055               PPLUS1=12.0+OMEGA2*SPEED(N1MJ)-HH1*AKN*AKN
    0056               P=24.0-10.0*(OMEGA2*SPEED(N1MJ+1)-HH1*AKN*AKN)
    0057               PMNS1=12.0+OMEGA2*SPEED(N1MJ+2)-HH1*AKN*AKN
    0058               YOU(N1MJ)=(P/PPLUS1)*YOU(N1MJ+1)-(PMNS1/PPLUS1)*YOU(N1MJ+2)
    0059               UABVL=DABS(YOU(N1MJ))
    0060               IF (UABVL.GT.UMAX) UMAX=UABVL
    0061               IF (DSIGN(1.D0,YOU(N1MJ))*YOU(N1MJ+1).LE.0.) NCR=NCR+1
    0062                  IF (UABVL.LT.PMGTD) GO TO 51
    0063                  DO 41 JD=N1MJ,NT
    0064               IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.
    0065            41 YOU(JD)=YOU(JD)/PMGTD
    0066               UMAX=UMAX/PMGTD
    0067               IFG=IFG+1
    0068            51    IF (N1MJ.EQ.MATCH) GO TO 131
    0069           121 CONTINUE
    0070                  GO TO 151
    0071           131 IZERO=2
    0072               YOU(1)=0.0
    0073               YOU(2)=DSQRT(HH1)*1.D-10
    0074                  DO 135 J=3,N1
    0075               PPLUS1=12.0+OMEGA2*SPEED(J)-HH1*AKN*AKN
    0076               P=24.0-10.0*(OMEGA2*SPEED(J-1)-HH1*AKN*AKN)
    0077               PMNS1=12.0+OMEGA2*SPEED(J-2)-HH1*AKN*AKN
    0078               PPLUS1=(P/PPLUS1)*YOU(J-1)-(PMNS1/PPLUS1)*YOU(J-2)
    0079                  IF (J.EQ.MATCH) GO TO 148
    0080               YOU(J)=PPLUS1
    0081                  IF (DABS(YOU(J)).LT.PMGTD) GO TO 135
    0082                  DO 133 JD=2,J
    0083               IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.0
    0084           133 YOU(JD)=YOU(JD)/PMGTD
    0085           135 CONTINUE
    0086               B=(-3.0*YOU(N1MNS2)+4.0*YOU(N1MNS1)-YOU(N1))/(2.0*DL1)
    0087               YOU(N1PLS1)=RHO1*YOU(N1)/RHO2
    0088               YOU(N1PLS2)=YOU(N1PLS1)+DL2*B-YOU(N1PLS1)*
                      >(OMEGA2*SPEED(N1PLS1)-HH2*AKN*AKN)/2.0
    0089                  DO 145 J=N1PLS3,NTMNS2
    0090               PPLUS1=12.0+OMEGA2*SPEED(J)-HH2*AKN*AKN
    0091               P=24.0-10.0*(OMEGA2*SPEED(J-1)-HH2*AKN*AKN)
    0092               PMNS1=12.0+OMEGA2*SPEED(J-2)-HH2*AKN*AKN
    0093               PPLUS1=(P/PPLUS1)*YOU(J-1)-(PMNS1/PPLUS1)*YOU(J-2)
    0094                  IF (J.EQ.MATCH) GO TO 148
    0095               YOU(J)=PPLUS1
    0096                  IF (DABS(YOU(J)).LT.PMGTD) GO TO 145
```

```
ITRTF          SOURCE LISTING

                STATEMENT

                    DO 143 JD=2,J
                IF (DABS(YOU(JD)).LT.1.DO) YOU(JD)=0.0
            143 YOU(JD)=YOU(JD)/PMGTD
            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./PMGTD) 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					
JO	I*4	VAR	40	41	41	42	42	63	64	64	65	65	82	83

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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
   NIM            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
   PMGTO    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
   RS1DSQ         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
   TNIM           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

0001                SUBROUTINE HALFF
0002            DOUBLE PRECISION AK1,AK2,ANEW,AK,ZK,YOU,AKNL,AKNR,ZL,ZR,AR1,AL1,
               >ZR1,ZL1,ZNEW,AKA,AKN,UMAX
0003            COMMON/TNH/AKN(150)
0004            COMMON/TH/EPSLN
0005            COMMON/NH/AK1,AK2,LOOP
0006            COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0007            COMMON/TNIH/PPRCN,PMGTD
0008            COMMON/IH/UMAX
0009            DIMENSION AK(2),ZK(2)
           C
           C  ********** PART 1 **********
           C
0010            IZERO=0
0011            LOOP=0
0012               DO 52 K=1,2
0013            J=I+1-K
0014               IF (K.EQ.2) GO TO 12
0015               CALL ITRTF (AK1)
0016            LOOP=LOOP+1
0017            NA1=NCR
0018               CALL ITRTF (AK2)
0019            LOOP=LOOP+1
0020            NA2=NCR
0021         12 ANEW=((AK2-AK1)*(J-NA1)/(NA2-NA1))+AK1
0022               CALL ITRTF (ANEW)
0023            LOOP=LOOP+1
0024               IF (NCR.EQ.J) GO TO 42
0025               IF (NCR.GT.J) GO TO 32
0026            AK2=ANEW
0027            NA2=NCR
0028               GO TO 12
0029         32 AK1=ANEW
0030            NA1=NCR
0031               GO TO 12
0032         42 AK(K)=ANEW
0033            IF (K.EQ.1) IP1=IFG
0034            IF (K.EQ.2) IP2=IFG
0035         52 ZK(K)=YOU(1)
0036            AKNL=AK(1)
0037            AKNR=AK(2)
0038            ZL=ZK(1)
0039            ZR=ZK(2)
           C
           C  ********** PART 2 **********
           C
0040            ICLSIN=0
0041         62 ICLSIN=ICLSIN+1
0042               IF (ICLSIN.EQ.20) GO TO 112
0043            AR1=AKNR-(1.E-12)
```

```
HALFF          SOURCE LISTING

    CSN           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              SOURCE LISTING

    CSN               STATEMENT

                  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 ITRTF (AKA)
                  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.I) 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 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      90
  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),AIRH2O(150),H2O2ND(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
```

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SOLID            SOURCE LISTING

   CSN            STATEMENT

   0036           F2=(F/1000.)*(F/1000.)
   0037           EPW=.1*F2/(1.+F2)+40.*F2/(4100.+F2)+2.75E-4*F2
   0038           EPW=EPW*.1151292546*1.093613298E-3
   0039           DCOMP=DBLE(COMP)
   0040           DSHEAR=DBLE(SHEAR)
   0041           A=1.0/(DCOMP*DCOMP)
   0042           B=1.0/(DSHEAR*DSHEAR)
   0043           URA=(DCOMP*DCOMP-2.0*DSHEAR*DSHEAR)/(2.0*(DCOMP*DCOMP-
                 >DSHEAR*DSHEAR))
   0044           RAYL=((0.87+1.12*URA)/(1.0+URA))*DSHEAR
   0045           XRA=1.0/(RAYL*RAYL)
   0046              DO 10 J=1,5
   0047           RA1=DSQRT(XRA-A)*DSQRT(XRA-B)
   0048           RA2=(DSQRT(XRA-A)/DSQRT(XRA-B))+(DSQRT(XRA-B)/DSQRT(XRA-A))
   0049           FRA=RA1-(XRA-(B/2.0))*(XRA-(B/2.0))/XRA
   0050           DRA=0.5*RA2-(1.0-((B*B)/(4.0*XRA*XRA)))
   0051        10 XRA=XRA-(FRA/DRA)
   0052           RAYL=DSQRT(1.0/XRA)
   0053           X(1)=Z1(1)
   0054           CMIN1=C1(1)
   0055           CMAX1=C1(1)
   0056              DO 20 J=2,ND1
   0057           IF (C1(J).LT.CMIN1) CMIN1=C1(J)
   0058           IF (C1(J).GT.CMAX1) CMAX1=C1(J)
   0059           X(J)=Z1(J)
   0060        20 Z1(J)=Z1(J)/H12
   0061           Y(1)=Z2(1)
   0062           Z2(1)=Z1(ND1)
   0063           CMIN2=C2(1)
   0064           CMAX2=C2(1)
   0065              DO 30 J=2,ND2
   0066           IF (C2(J).LT.CMIN2) CMIN2=C2(J)
   0067           IF (C2(J).GT.CMAX2) CMAX2=C2(J)
   0068           Y(J)=Z2(J)
   0069        30 Z2(J)=Z2(J)/H12
   0070           CMIN=AMIN1(CMIN1,CMIN2)
   0071           WRITE(6,8001) COMP,SHEAR,RAYL
   0072           WRITE(6,9001)
   0073           WRITE(6,10001) (Z1(I),X(I),C1(I),I=1,ND1)
   0074           WRITE(6,11001)
   0075           WRITE(6,10001) (Z2(I),Y(I),C2(I),I=1,ND2)
   0076           DL1=DBLE(1.0)/LI1
   0077           HH1=DL1*DL1*H12*H12
   0078           DL2=DBLE(H2)/H12/LI2
   0079           HH2=DL2*DL2*H12*H12
   0080           N1=LI1+1
   0081           N1PLS1=N1+1
   0082           N1PLS2=N1+2
   0083           N1PLS3=N1+3
   0084           N1MNS1=N1-1
```

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SCLID          SOURCE LISTING

   CSN           STATEMENT

  0085           N1MNS2=N1-2
  0086           N2=LI2+1
  0087           N2MNS1=N2-1
  0088           NT=N1+N2
  0089           NTMNS1=NT-1
  0090           NTMNS2=NT-2
  0091           DEPTH(1)=0.0
  0092           DEPTH(N1)=1.0
  0093           DEPTH(N1PLS1)=1.0
  0094           DEPTH(NT)=DBLE(H2)/H12+1.0
  0095           SPEED(1)=HH1/C1(1)/C1(1)
  0096           SPEED(N1)=HH1/C1(ND1)/C1(ND1)
  0097           SPEED(N1PLS1)=HH2/C2(1)/C2(1)
  0098           SPEED(NT)=HH2/C2(ND2)/C2(ND2)
  0099           K=2
  0100              DO 50  INTERP=2,N1MNS1
  0101           DEPTH(INTERP)=(INTERP-1.0)*DL1
  0102           KK=K
  0103              DO 40  J=KK,ND1
  0104              IF (DEPTH(INTERP).GT.Z1(J)) GO TO 40
  0105           SPEED(INTERP)=((C1(J)-C1(J-1))*(DEPTH(INTERP)-Z1(J-1))/
                >(DBLE(Z1(J))-Z1(J-1)))+C1(J-1)
  0106           SOUND(INTERP)=SPEED(INTERP)
  0107           SPEED(INTERP)=HH1/(SPEED(INTERP)*SPEED(INTERP))
  0108              GO TO 50
  0109        40 K=K+1
  0110        50 CONTINUE
  0111           K=2
  0112              DO 70  INTERP=N1PLS2,NTMNS1
  0113           DEPTH(INTERP)=(INTERP-1-N1)*DL2+1.0
  0114           KK=K
  0115              DO 60  J=KK,ND2
  0116              IF (DEPTH(INTERP).GT.Z2(J)) GO TO 60
  0117           SPEED(INTERP)=((C2(J)-C2(J-1))*(DEPTH(INTERP)-Z2(J-1))/
                >(DBLE(Z2(J))-Z2(J-1)))+C2(J-1)
  0118           SOUND(INTERP)=SPEED(INTERP)
  0119           SPEED(INTERP)=HH2/(SPEED(INTERP)*SPEED(INTERP))
  0120              GO TO 70
  0121        60 K=K+1
  0122        70 CONTINUE
  0123           IZERO=0
  0124           ADCRS=1
  0125           KRAY=TWOPI*F/RAYL
  0126           KMAX=TWOPI*F/CMIN
  0127           KCOMP=6.2831853*F/COMP
  0128           KCOMP2=KCOMP*KCOMP
  0129           KSHEAR=TWOPI*F/DSHEAR
  0130           KSHR2=KSHEAR*KSHEAR
  0131           SRFC=39.4784176*F*F/(C1(1)*C1(1))
  0132           BOTTOM=39.4784176*F*F/(C1(ND1)*C1(ND1))
```

SϽLID SOURCE LISTING

CSN STATEMENT

```
          CALL ITRTS (KRAY,I)
      RAYCRS=NCR
          CALL ITRTS (KSHEAR,I)
      MAXMD=NCR+1
      NM℈DE=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)
      ϽDD=0.0
      ODD1=0.0
      ODD2=0.0
      ϽDD3=0.0
      EVEN=0.0
      EVEN1=0.0
      EVEN2=0.0
      EVEN3=0.0
          DO 200 J=2,N1MNS1,2
  200 ΞVEN1=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 ΞVEN=EVEN+YOU(J)*YOU(J)/SOUND(J)
```

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SOL ID          SOURCE LISTING

  CSN             STATEMENT

 0183               DO 250  J=N1PLS3,NTMNS2,2
 0184          250  ODD=ODD+YOU(J)*YOU(J)/SOUND(J)
 0185               AI1=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)+4.0*EVEN1+2.0*ODD1+YOU(N1)*
                   >YOU(N1))
 0186               AI2=RHO2*(DL2/3.0)*(YOU(N1+1)*YOU(N1+1)+4.0*EVEN2+2.0*ODD2+
                   >YOU(NT)*YOU(NT))
 0187               AKN2=AKN(I)*AKN(I)
 0188               QCOMP=AKN2-KCOMP2
 0189               CMPRT=SQRT(QCOMP)
 0190               QSHEAR=2.0*AKN2-KSHR2
 0191               SHEART=SQRT(AKN2-KSHR2)
 0192               QSHR2=QSHEAR*QSHEAR
 0193               Q=RHO3*QSHR2/(H12*QCOMP*KSHR2*KSHR2)
 0194               AI3=Q*(0.5/CMPRT+2.0*QCOMP*KSHR2/(SHEART*QSHR2)+
                   >6.0*SHEART*QCOMP/QSHR2-4.0*CMPRT/QSHEAR)
 0195                 IF (IFG.LE.0) GO TO 255
 0196               AI3=AI3/PMGTD/PMGTD
 0197               IF (IFG.GT.1) AI3=0.
 0198          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))
 0199               AI5=RHO1*(DL1/3.0)*(YOU(1)*YOU(1)/C1(1)+4.0*EVEN3+2.0*ODD3+
                   >YOU(N1)*YOU(N1)/C1(ND1))
 0200               AI=AI1+AI2+AI3
 0201               ANORM=SQRT(1.0/AI)
 0202                 DO 260  J=1,NT
 0203               IF (KA.EQ.0)  UNRM1(I,J)=YOU(J)*ANORM
 0204               IF (KA.EQ.1)  UNRM2(I,J)=YOU(J)*ANORM
 0205          260  CONTINUE
 0206                 IF (KA.EQ.1)  GO TO 270
 0207               YNM1=UNRM1(I,1)
 0208               YNM2=UNRM1(I,2)
 0209               YNM3=UNRM1(I,3)
 0210               YNM4=UNRM1(I,N1)
 0211               YNM5=UNRM1(I,N1PLS1)
 0212               YNM6=UNRM1(I,N1PLS2)
 0213               YNM7=UNRM1(I,N1PLS3)
 0214               YNM8=UNRM1(I,NTMNS2)
 0215               YNM9=UNRM1(I,NTMNS1)
 0216               YNM10=UNRM1(I,NT)
 0217                 GO TO 275
 0218          270  YNM1=UNRM2(I,1)
 0219               YNM2=UNRM2(I,2)
 0220               YNM3=UNRM2(I,3)
 0221               YNM4=UNRM2(I,N1)
 0222               YNM5=UNRM2(I,N1PLS1)
 0223               YNM6=UNRM2(I,N1PLS2)
 0224               YNM7=UNRM2(I,N1PLS3)
 0225               YNM8=UNRM2(I,NTMNS2)
 0226               YNM9=UNRM2(I,NTMNS1)
 0227               YNM10=UNRM2(I,NT)
```

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SØLID            SØURCE LISTING

  CSN              STATEMENT

  0228        275 DYØUA=(-3.*YNM1+4.*YNM2-YNM3)/(2.*DL1)
  0229            DYØUB=(-3.*YNM5+4.*YNM6-YNM7)/(2.*DL2)
  0230            DYØUC=(YNM8-4.*YNM9+3.*YNM10)/(2.*DL2)
  0231            DYØUC=DYØUC*DYØUC
  0232               IF (SRFC-AKN2.GT.PPRCN) GØ TØ 280
  0233            AIRH2Ø(I)=0.0
  0234               GØ TØ 290
  0235        280 AIRH2Ø(I)=RHØ1*DYØUA*DYØUA/(4.*AKN(I)*H12**3*SQRT(SRFC-AKN2))
  0236        290    IF (BØTTØM-AKN2.GT.PPRCN) GØ TØ 300
  0237            H2Ø2ND(I)=0.0
  0238               GØ TØ 310
  0239        300 H2Ø2ND(I)=RHØ1*SQRT(BØTTØM-AKN2)*(YNM4*YNM4+DYØUB*
                 >DYØUB/(H12*H12*(BØTTØM-AKN2)))/(4.0*AKN(I)*H12)
  0240        310 PV=TWØPI*F/AKN(I)
  0241               IF (AI4.GT.AI/PMGTD) GØ TØ 313
  0242            AI4=0.
  0243        313 ATTEN2(I)=6.2831853*F*AI4/(AKN(I)*AI)
  0244            ATTENC(I)=KCØMP*Q*.5/(CMPRT*H12*H12*AKN(I))
  0245            DYØU=DYØUC
  0246            DUTSC=1./PMGTD/ATTENC(I)
  0247               IF (DYØU.GT.DUTSC) GØ TØ 315
  0248            DYØU=0.
  0249        315 ATTENC(I)=ATTENC(I)*DYØU
  0250            ATTENS(I)=AKN(I)*Q/(H12*H12*KSHEAR)*(2.*KSHR2*QCØMP/(SHEART*QSHR2)
                 >+8.*SHEART*QCØMP/QSHR2-4.*CMPRT/QSHEAR)
  0251            DUTSS=1./PMGTD/ATTENS(I)
  0252               IF (DYØUC.GT.DUTSS) GØ TØ 317
  0253            DYØUC=0.
  0254        317 ATTENS(I)=ATTENS(I)*DYØUC
  0255            ABSØR(I)=6.2831853*F*AI5*EPW/(AKN(I)*AI)
  0256               IF (IC.GT.1) GØ TØ 330
  0257            WRITE(6,12001) MAXMD,NMØDE
  0258        330 IF (MØD(IC,7).EQ.0) WRITE(6,13001)
  0259            WRITE(6,14001) I,PV
  0260            IF (IZERØ.EQ.2) WRITE(6,15001) DEPTH(MATCH)
  0261            WRITE(6,16001) LØØP,IFG
  0262            IF (AI4.LE.AI/PMGTD) WRITE(6,17001)
  0263            IF (DYØU.LE.DUTSC) WRITE(6,18001)
  0264            IF (DYØUC.LE.DUTSS) WRITE(6,18002)
  0265            WRITE(6,19001)
  0266            WRITE(6,20001) AKN(I),ABSØR(I),ATTEN2(I),ATTENC(I),ATTENS(I),
                 >AIRH2Ø(I),H2Ø2ND(I)
  0267        340 CØNTINUE
  0268               IF (MDPRNT.EQ.0) GØ TØ 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               DØ 345 J=1,N1,INC1
```

```
SOLID          SOURCE LISTING

               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) (MONUM(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	
190		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	

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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
    AIRH20   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     198     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
```

SOLID CROSS REFERENCE LISTING

SYMBOL	TYPE/USAGE		REFERENCES											
OUTSS	R*4	VAR	251	252	264									
DYOU	R*4	VAR	245	247	248	249	263							
DYOUA	R*4	VAR	228	235	235									
DYOUB	R*4	VAR	229	239	239									
DYOUC	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									
H2S2ND	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								
IN	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										
IZERO	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			
NIM		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

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CSN          STATEMENT

0001              SUBROUTINE ITRTS (AKN,L)
0002         DOUBLE PRECISION OMEGA2,TWOPI,CKN,YOU,DSHEAR,DCOMP,AKN,KRAY,DL2,
            >HH2,SPEED,PPLUS1,P,PMNS1,B,DL1,HH1,UMAX,UABVL,SOUND
0003         COMMON/TNI/RHO1,RHO2,RHO3,H12,COMP,F,N1
0004         COMMON/NI/SOUND(1202),SPEED(1202),TWOPI,DL1,HH1,DL2,HH2,MATCH,
            >N1PLS1,N1PLS2,N1PLS3,N1MNS1,N1MNS2,N2MNS1,NT,NTMNS2
0005         COMMON/NISOL/DCOMP,DSHEAR,KRAY,ADCRS
0006         COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0007         COMMON/TNIH/PPRCN,PMGTD
0008         COMMON/IH/UMAX
0009         INTEGER ADCRS
0010         MATCH=0
0011            IF (IZERO.NE.1) GO TO 10
0012            DO 6 J=3,N1MNS2
0013            IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 6
0014         MATCH=J
0015            GO TO 10
0016       6 CONTINUE
0017            DO 8 J=N1PLS3,NTMNS2
0018            IF (TWOPI*F/SOUND(J).LT.AKN) GO TO 8
0019         MATCH=J
0020            GO TO 10
0021       8 CONTINUE
0022         MATCH=NTMNS2
0023      10 NCR=0
0024         IFG=0
0025         OMEGA2=TWOPI*TWOPI*F*F
0026         CKN=TWOPI*F/AKN
0027         YOU(NT)=RHO3*DSHEAR**4/RHO2/(DSQRT(OMEGA2)*CKN**3)
0028         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))
0029         IF (DABS(AKN-KRAY).LT.PPRCN) YOU(NT)=0.
0030         YOU(NT-1)=YOU(NT)-DL2*H12-YOU(NT)*
            >(OMEGA2*SPEED(NT)-HH2*AKN*AKN)/2.0
0031         UMAX=DMAX1(DABS(YOU(NT)),DABS(YOU(NT-1)))
0032            IF (DABS(AKN-KRAY).GE.PPRCN) GO TO 11
0033         IF (ADCRS.EQ.1) NCR=NCR+1
0034            GO TO 15
0035      11 IF (DSIGN(1.D0,YOU(NT))*YOU(NT-1).LT.0.) NCR=NCR+1
0036      15    DO 31 J=2,N2MNS1
0037         NTMJ=NT-J
0038         PPLUS1=12.0+OMEGA2*SPEED(NTMJ)-HH2*AKN*AKN
0039         P=24.0-10.0*(OMEGA2*SPEED(NTMJ+1)-HH2*AKN*AKN)
0040         PMNS1=12.0+OMEGA2*SPEED(NTMJ+2)-HH2*AKN*AKN
0041         YOU(NTMJ)=(P/PPLUS1)*YOU(NTMJ+1)-(PMNS1/PPLUS1)*YOU(NTMJ+2)
0042         UABVL=DABS(YOU(NTMJ))
0043         IF (UABVL.GT.UMAX) UMAX=UABVL
0044         IF (DSIGN(1.D0,YOU(NTMJ))*YOU(NTMJ+1).LE.0.) NCR=NCR+1
0045            IF (UABVL.LT.PMGTD) GO TO 22
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ITRTS SOURCE LISTING

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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
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ITRTS          SOURCE LISTING

  CSN            STATEMENT

                    DO 145 J=N1PLS3,NTMNS2
                 PPLUS1=12.0+OMEGA2*SPEED(J)-HH2*AKN*AKN
                 P=24.0-10.0*(OMEGA2*SPEED(J-1)-HH2*AKN*AKN)
                 PMNS1=12.0+OMEGA2*SPEED(J-2)-HH2*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 145
                    DO 143 JD=2,J
                 IF (DABS(YOU(JD)).LT.1.D0) YOU(JD)=0.0
             143 YOU(JD)=YOU(JD)/PMGTD
             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./PMGTD) YOU(JD)=0.0
             149 CONTINUE
             151 CONTINUE
                 RETURN
                 END
```

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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
```

```
ITRTS        CROSS REFERENCE LISTING

  SYMBCL     TYPE/USAGE       REFERENCES

   IZERO     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              COM       4
   NIH             COM       6
   NISOL           COM       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      67      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
   OMEGA2    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
   PPRLN     R*4   VAR       7      29      32
   R$1DSQ          SAR
   RHO1      R*4   VAR       3      54      93
   RHO2      R*4   VAR       3      27      54      93
   RHO3      R*4   VAR       3      27
   SCUND     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             COM       3
   TNIH            COM       7
   TWOPI     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
   YOU       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

0001              SUBROUTINE HALFS (L)
0002           DOUBLE PRECISION AK1,AK2,ANEW,AK,ZK,YOU,AKNL,AKNR,ZL,ZR,AR1,AL1,
              >ZR1,ZL1,ZNEW,AKA,AKN,UMAX
0003           COMMON/TNH/AKN(150)
0004           COMMON/TH/EPSLN
0005           COMMON/NH/AK1,AK2,LOOP
0006           COMMON/NIH/IZERO,NCR,YOU(1202),I,IFG
0007           COMMON/TNIH/PPRCN,PMGTD
0008           COMMON/IH/UMAX
0009           DIMENSION AK(2),ZK(2)
         C
         C  ********** PART 1 **********
         C
0010           IZERO=0
0011           LOOP=0
0012              DO 52 K=1,2
0013           J=L+1-K
0014              IF (K.EQ.2) GO TO 12
0015              CALL ITRTS (AK1,L)
0016           LOOP=LOOP+1
0017           NA1=NCR
0018              CALL ITRTS (AK2,L)
0019           LOOP=LOOP+1
0020           NA2=NCR
0021           IF (NA1.EQ.1.AND.NA2.EQ.1) NA1=2
0022        12 ANEW=((AK2-AK1)*(J-NA1)/(NA2-NA1))+AK1
0023              CALL ITRTS (ANEW,L)
0024           LOOP=LOOP+1
0025              IF (NCR.EQ.J) GO TO 42
0026              IF (NCR.GT.J.AND.NCR.NE.NA2) GO TO 32
0027           AK2=ANEW
0028           NA2=NCR
0029              GO TO 12
0030        32 AK1=ANEW
0031           NA1=NCR
0032              GO TO 12
0033        42 AK(K)=ANEW
0034           IF (K.EQ.1) IP1=IFG
0035           IF (K.EQ.2) IP2=IFG
0036        52 ZK(K)=YOU(1)
0037           AKNL=AK(1)
0038           AKNR=AK(2)
0039           ZL=ZK(1)
0040           ZR=ZK(2)
         C
         C  ********** PART 2 **********
         C
0041           ICLSIN=0
0042        62 ICLSIN=ICLSIN+1
0043              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										
FPSLN	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											
IN		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											
PPGID	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					