The FACT (Fast Asymptotic Coherent Transmission) Model is the new Navy Interim Standard Transmission Model for Ocean environments which may be treated within the context of a single sound-speed profile and a flat bottom. It is a ray-acoustics model designed for the computation of transmission loss as a function of range and frequency at fixed depth. The classical ray treatment has been augmented with higher order asymptotic...
corrections in the vicinity of caustics, and the phased addition of selected paths experiencing significant, predictable coherence effects. The computer program is fully automated requiring only the specification of the environment and the essential parameters.

This report consists of two volumes, the first describing the physics and mathematics contained in the FACT Model as well as comparisons of FACT and normal-mode results. The second volume describing the program structure and flow with complete samples of input and output. Volume I has been distributed to a broad community of both technical and application-oriented users as a Maury Center Report. Volume II is intended primarily for programmers attempting to implement the model on their computers and is being distributed as an AESD Technical Note only to recipients of the FACT program. The complete program listing and punched-card deck will be provided by AESD to qualified users upon request.
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4. PROGRAM STRUCTURE AND FLOW

This section is divided into four subsections:

4.1 Description of inputs
4.2 Sequence of calculations
4.3 Description of outputs
4.4 Detailed flow charts and descriptions of each of the basic programs and subroutines in the FACT package.

These sections were taken largely from the Ocean Data Systems, Inc. final report on FACT model development for AESD.*

The basic flow of the FACT model, exclusive of input and output is summarized in Figure 4-1, and is considerably expanded upon in sections 4.2 and 4.3. The complete program listing and punched-card deck are available from AESD upon request.

The objective of FACT is to estimate, by using ray-tracing techniques, the acoustic transmission loss in a single-profile, flat-bottom ocean environment, as a function of range and frequency. Additionally, if requested, FACT will produce the arrival angles (at the receiver) of individual ray paths, again as a function of range. Transmission loss (dB re 1 yard) is tabulated in a single array

of dimension 250x6 at up to 250 equally spaced range points for each of one to six frequencies. Arrival information is written to an auxiliary (tape or disk) file as individual records containing fields for range, angle, and intensities at up to six frequencies.

As indicated in the documentation included as part of the FACT Handout, the primary component of the FACT Package is a single subroutine FACTTL, which may be incorporated into any of a number of complete programs requiring an estimation of transmission loss versus range and frequency. One example of a stand-alone program is included: TLOSS, a program which reads input parameters from cards, calls on FACTTL for losses, and prints and/or plots the results. This program is primarily useful to analysts requiring a small number of runs as part of a design program on a demand basis.

Two additional transmission loss models may be used to supplement FACT in those cases where a full FACT solution is liable to result in excessive running times. These models, SHALTL and HFCHTL, are designed specifically to approximate the results of a complete FACT solution in shallow-water transmission and half-channel transmission respectively. Subroutine HFCHTL is an integral component
of FACTTL in that the output of HFCHTL is supplemented by the output of FACTTL for the direct and bottom-reflected paths. On the other hand, in order to employ subroutine SHALTL a modification to TLOSS is required (e.g., replacing the call to FACTTL by a call to SHALTL). Care should be exercised in using both of these models as both serve only as quick-running alternatives to the normal FACT processing. Additionally, the HFCHTL model requires further care in use in that it is valid only for the specific frequencies and source/receiver combinations contained within the listing.

The documentation which follows is designed to supplement the user-oriented material presented in the FACT Handout. It is intended for computer programmers, and is primarily concerned with the overall structure and interrelation of the various components of the FACT Package. The organization of this material follows that of the FACT programs components is presented in Section 4.4.

The FACT model itself, written entirely in FORTRAN IV, is invoked by a single call to subroutine FACTTL. Core requirement, excluding input and output, but including all other FACT and system computational routines, is approximately 8,400 decimal (20,300 octal) cells on the CDC 6400/6600.
4.1 Inputs

The inputs to FACT are primarily geometrical and environmental in nature. They are:

- A sound velocity profile: the speed of sound is specified at each of up to 50 points from the surface to the bottom. Depth/velocity pairs are in feet and feet per second or meters and meters per second.
- Surface and bottom conditions: wave height in feet; FNWC bottom class.
- Source and receiver positions: depths in feet.
- Frequency information: frequencies in Hertz; coherency flags.
- Range information: number and spacing of range points in nautical miles.

4.2 Sequence of Calculation

In the following presentation, only the most significant steps in determining transmission loss are outlined; many computational steps, such as the calculation of constants and other factors essential to the calculation are covered in detail in the sections dealing with individual subroutines. Some liberties have been taken in describing the sequences of calculations, but it is essentially as follows:
Profile correction: The profile points are corrected to take account of spherical earth geometry. Note that depths and depth indices are often used interchangeably (as appropriate) in discussing FACT.

Axis location: The deep sound channel axis, if any, of the profile is located, and, under certain conditions the source and receiver depths are altered to allow simulation of axis-to-axis transmission.

Profile augmentation: The source and receiver depths are inserted in the profile as explicit points, altered slightly, if necessary, to avoid equal velocities at the two depths.

Source selection: For the remainder of the FACT calculations, the source and receiver depths are selected from the two depths of interest by assigning the depth with the lesser sound velocity as the source depth -- the starting point for the ray tracing process. The index of this point in the profile, \( i_1 \), is used hereafter to designate the source (or source depth); the other index, \( i_2 \), is used to designate the receiver or receiver depth. (Care is taken to distinguish the "true" source from the ray-tracing source where the distinction is important.)
Geometry factors: A number of flags are set (at various points throughout the program) to indicate various geometrical relationships between source and receiver.

Low-frequency effects: The WKB phase factors for low frequency cutoff are calculated.

Ray selection: The angles of the rays to be traced from $K_1$ to $K_2$ are selected, grouped into one or more families. The selection is based on the velocity profile, source, and receiver depths. Rays are chosen so that within each family, an analytical fit of Range versus Angle can be made, thus smoothing and retaining legitimate caustics while removing false caustics; the functional form of the fit will vary with family type. If the profile and associated source and receiver depths lead either to more than 20 families or 100 rays, processing is terminated and the transmission loss array is returned with zero values for all entries.

Ray tracing notes: Because the environment is single profile, flat bottom, any ray which is traced exhibits a periodicity over the range of interest and is actually traced for only a single such cycle.

Within a single period, each ray angle selected may represent one, two, or four paths (arrivals) from source to receiver, per period, depending upon the geometry involved: the source angle may be positive, negative, or both, and may either be reflected or refracted at the receiver, or may cross and re-cross the receiver depths. Each arrival is assigned a number, termed the arrival order, indicating the number of deep cycles which the ray has undergone; arrival order corresponds to the direct path. The ordering of arrival ranges within a single period or cycle of a ray, and the assignment of these ranges (plus multiples of the period) to individual arrival orders is determined and controlled by a number of flags and indices which are detailed elsewhere.

Path combinations: Depending upon the geometries involved, two or four paths from the source to the receiver may be combined into a single path of doubled or quadrupled intensity. This may happen for instance, if the source is so close to the surface that the downgoing ray and the surface-reflected upgoing ray are essentially parallel and arrive at the receiver at essentially identical angles. A similar geometry may apply at the receiver, or at
both the source and receiver. The processing of such combined rays is controlled by several flags indicating the simplified situation.

Family processing: Each family, in turn, is processed to determine its contributions to the total intensity arising from the source, and equivalently, overall transmission loss. At the same time, individual arrival angles and intensities are written to a separate file for later processing. This loop on families is the major processing loop in FACT. Within each family, the zero-order or direct path is processed first. This is followed by a loop in which subsequent orders 1, 2, 3, ... are processed in turn. There is no fixed limit on the number of orders which FACT may be required to process; this loop is terminated only when significant intensity no longer is being contributed by any path within the family at the ranges of interest.

Half-channel note: When a half-channel case has been flagged on input, only the direct and bottom and surface-reflected arrivals are processed as outlined above. In these cases, the non-direct path, non-bottom and surface reflected contribution to intensities are approximated and added by a separate half-channel model.
. Final processing: When all families have been processed, surface-duct contributions, if present, are added to those intensities already calculated, and then converted to transmission losses (re one yard).

Processing of an arrival order of a family of rays consists of the following steps:

. The arrival ranges for each of the (one to four) paths with this order are calculated.

. For each path, the coefficients and parameters required to express range as a function of ray angle are calculated. Any one of four possible functional forms is used according to family characteristics.

. If the range intervals for all four paths exceed the maximum range of interest, processing of arrival orders for the family is terminated.

. Subroutine INSTOR (or CUSP if applicable) is called to calculate and add the intensity arising from each (smoothed and fitted) path to the transmission loss array at each range point for each frequency.

. If the intensities from all four paths drop below a specified minimum value, processing of arrival orders for the family is terminated.

Processing of one path of an arrival order by INSTOR or CUSP consists of the following steps:
The type of fit of range versus ray angle is examined to determine whether or not a caustic exists, and to find the minimum and maximum ranges at which contributions to total intensity are made. If this range interval is beyond the range of interest, processing of the path is terminated.

At each applicable range point, the number of arrivals (rays) is calculated: zero indicates the shadow zone of a caustic, one or two indicates an illuminated region.

The intensity contribution from each ray is added to the transmission loss array for each frequency at the range being processed. The intensity is computed as an analytic function of range, frequency, and the values of ray angle and the derivations of range with ray angle at this range; the latter are obtained by examination of the range versus ray angle fit.

The calculated intensities are modified, if required by factors reflecting coherent, semi-coherent, or incoherent path addition, shadow-zone fall-off, low-frequency cutoff effects, and bottom-bounce losses as applicable.

If flagged, range, arrival angle, and intensity information is written to an external file.
When all range points have been processed, a flag is set to indicate if the minimum range of the path has exceeded the range of interest, or if the contribution to intensity has dropped below a specified minimum value.

### 4.3 Outputs

The primary output from subroutine FACTTL is an array, TL, of dimension 250x6, giving transmission loss (in dB re 1 yard) at each of the range points and frequencies specified as input parameters. If the ray selection process results either in too many rays (> 100) or too many families (> 20), a two-line message will be printed indicating this condition, and the TL array will contain zeros at the specified ranges and frequencies.

If, in addition, arrival information is desired, the parameter IAR should be set indicating the FORTRAN unit to which arrival records should be written. The format of these records is detailed in the description of subroutine INSTOR.

The output file is never positioned nor are any file marks written; these functions are delegated to the calling program.

Optional debugging output is also available via an input parameter; care should be taken in setting this flag, as the potential exists for many hundreds of pages of output from a single run.
4.4 Components of the FACT Package

This section consists of a description of each of the components of the FACT Package -- the driver programs, the main computational routine, and auxiliary subroutines and functions. For each of these, the following material is included:

- A brief description of the function of the component in the Model.
- Equations used by the component when these are not immediately evident from the function of the component and/or the program listing.
- Parametric and common input and output variables.
- Flow charts, expressed in physical terms to the greatest extent possible, for the major programs and routines of the Model.
- Additional material, as applicable, to present the details of the program logic not included in the flow charts for the routine.
INSERT SOURCE AND RECEIVER IN PROFILE

DETERMINE RAYS TO BE TRACED

LOOP ON RAY FAMILY

TRACE RAYS FOR FIRST CYCLE

PROCESS DIRECT PATHS - COMPUTE NPATHS

LOOP ON NPATHS

FIT R(θ)

PROCESS TL(R) IN INSTOR

END LOOP ON NPATHS & PROCESSING OF DIRECT PATHS

PROCESS ALL SUBSEQUENT ARRIVAL ORDERS - RECOMPUTE NPATHS

INCREMENT ALL ARRIVALS BY ONE PERIOD

LOOP ON NPATHS

DOES FAMILY CONTAIN ACUSPED CAUSTIC?

NO

FIT R(θ)

PROCESS TL(R) IN INSTOR

END LOOP ON NPATHS

YES

FIT R(θ) & PROCESS TL(R) IN CUSP

END LOOP ON ARRIVAL ORDERS

END LOOP ON RAY FAMILIES

RETURN

Figure 4-1. OVERVIEW OF PROGRAM FLOW IN PACTEL
**PROGRAM TLOSS**

TLOSS is the driver which reads card inputs, invokes FACTL to compute transmission loss (and arrival structure) versus range and frequency, and prints and/or plots the results.

**CARD INPUTS**

The card input formats and sequence are detailed in the FACT Handout, pages 5-9 through 12. See also subroutine RDPROF, page 4-17.

**PRINTED OUTPUTS**

The formats for tabulated and plotted printer outputs are detailed in the FACT Handout, pages 5-14 through 33. See also subroutine TLHEAD, and PLOTTL, pages 4-19 and 20. TLOSS also prints the data on the input cards as they are read.

**COMMON USAGE**

None

**NOTE**

A complete FORTRAN listing of TLOSS is included in the portion of the FACT Handout included in this report, pages 5-43 through 47.
Begin TLOSS

Read and print first card
80 columns of title information

End of File?
No → E.O.F. → End TLOSS

Read and print second card
Profile header, etc.

Call RDPROF to read,
convert, and print profile cards

Read and print range card

Read and print frequency
card

Read source & receiver
card

End of File?
No → E.O.F. → End TLOSS

Yes → Source depth $\geq 10^6$?
No →

If source and/or receiver
depths negative, put at bottom

Convert coherency flags
to internal values

Call TLHEAD to print head-
ing if tabulated listing
has been requested

A

B

TLOSS 1
Continue TLOSS

Start

Call FACTTL to calculate transmission loss, and (if requested) arrival structure

Yes

Was case aborted by FACTL?

No

Print losses vs. range if tabulated listing has been requested

Call TLHEAD and PLOTTL if line-printer plots of losses vs. frequency have been requested

No

Was arrival structure calculated?

Yes

Read arrival structure file, store in transmission loss array as integer angle less than 25° vs. range

No

Call TLHEAD and PLOTTL to plot arrival angles vs. range on line printer

End

4-16 TLOSS 2
SUBROUTINE RDPROF

RDPROF is called from TLOSS to read profile data from cards, and convert, if necessary, to FACT units. Card formats are detailed in the FACT Handout. Input data is printed as it is read; see pages 5-14, 5-23 and 24, and 5-33.

PARAMETER INPUT

N   t No. of Profile Points

CARD INPUTS

A) N Positive:
   Z   Profile Depths (4/Card), meters or feet
   C   Profile Velocities (4/Card), mtrs/sec or ft/sec

B) N Negative:
   D   Profile Depths, meters
   T   Profile Temperatures, degrees Centigrade
   S   Profile Salinities, parts/thousand

PRINTED OUTPUTS

The data read from cards is printed along with the results of any conversions performed. One of three applicable formats is used:

1) Depths in feet and velocities in feet per second.
2) Depths in meters and velocities in meters per second, plus depths in feet and velocities in feet per second.
3) Depths in meters, temperatures in degrees Centigrade,
RDPROF (Cont'd)

salinities in parts per thousand, plus depths and velocities as in 2).

PARAMETER OUTPUTS

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<thead>
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<tr>
<td>Z</td>
<td>Array (50) of Profile Depths, feet</td>
</tr>
<tr>
<td>C</td>
<td>Array (50) of Profile Velocities, ft/sec</td>
</tr>
</tbody>
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COMMON STORAGE

None
SUBROUTINE TLHEAD

TLHEAD is called from TLOSS for the purpose of printing any of three different heading formats; these are detailed in the FACT Handout.

PARAMETER INPUTS

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<tr>
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</tr>
<tr>
<td>S</td>
<td>Source Depth, feet</td>
</tr>
<tr>
<td>R</td>
<td>Receiver Depth, feet</td>
</tr>
<tr>
<td>IF</td>
<td>Array (6) of Frequencies, Hz</td>
</tr>
<tr>
<td>JC</td>
<td>Array (6) of Coherency Flags, (0, 1 or 2)</td>
</tr>
<tr>
<td>IX</td>
<td>Array (6) of Characters to be Used for Plotting</td>
</tr>
<tr>
<td>NF</td>
<td>No. of Frequencies</td>
</tr>
<tr>
<td>ITYP</td>
<td>Heading Type, 0, 1, 2</td>
</tr>
</tbody>
</table>

PRINTED OUTPUTS

A) ITYP = 0:
Page Heading for Tabular Transmission Loss vs. Range

B) ITYP = 1:
Page Heading for Plot of Transmission Loss vs. Range

C) ITYP = 2:
Page Heading for Plot of Arrival Angle vs. Range

COMMON STORAGE

None
SUBROUTINE PLOTTL

PLOTTL is called by FACTTL for the purpose of plotting, using the line printer, either transmission loss versus range or arrival angle versus range. The plot format, examples of which appear in the FACT Handout, consists of an array of printer positions 121 columns wide and 51 columns high, augmented by horizontal and vertical scale information. Input is taken from an array, TL, of dimension 250 (range points) by 6 (frequencies or angles). Up to 250 range points and up to 6 frequencies or angles may be plotted. Either a separate (input) or a single (default) plotting character may be used for each frequency or angle; this is controlled by flag IX. Alternate range points only are plotted when the number of range points exceeds 120. MNDB is the minimum value of the plot: If greater than zero, the abscissa values increase downward from MNDB to MNDB + 50; if less than zero, the abscissa values decrease downward from ABS(MNDB) to ABS(MNDB) - 50. The units of the incremental range, DR, are arbitrary, but such that the maximum range is 9999.9 (nm) or less.

PARAMETER INPUTS

NR Number of range points, ≤ 250
DR Incremental range, nautical miles
NF Number of frequencies, ≤ 6
IX Array (6) of plotting characters; or zero
MNDB Minimum value of output plot, dB or degrees
TL Array (250,6) of values to be plotted, dB or degrees

4-20
PRINTED OUTPUT

Line printer plot of the values in TL as a function of range, with up to six plotted values at each of up to 120 range points.

COMMON STORAGE

None
SUBROUTINE FACTTL

FACTTL is the subroutine which is to be invoked in order to calculate transmission loss (and arrival angle) vs. range. All input and output is directed by the values of the parameters of the call to FACTTL; the common storage of FACT and its subroutines must be kept separate from that of any calling routine. A condensed description of the major processing done by FACTTL is found on pages 5-5 through 7.

PARAMETER INPUTS

YS  Source depth, feet
YR  Receiver depth, feet
FREQB  Array (6) of frequencies, Hz
IC  Array (6) of coherency flags; 0, 1 or 2
WHF  Wave height, feet
IB  FNWC bottom type, 1-9
NPTSPP  No. of points in sound velocity profile, ≤ 50
IL  Index of surface layer in profile, ≤ 50
YPP  Array (50) of profile depths, feet
CPP  Array (50) of profile velocities, feet per second
NR  No. of range points, ≤ 250
DR  Incremental range, feet
IARVTP  File unit for arrival output if ≠ 0
IP  Debugging print flag, 0 or 1
FACTTL (Cont'd)

PARAMETER OUTPUTS

TL Array (250,6) of transmission loss vs. range and frequency, dB

FILE OUTPUT

Unit IARVTP One record for each arrival angle at each range point, including path loss vs. frequency. (See INSTOR for format, page 4-79)

COMMON VALUES CALCULATED

/RANGE/ NRANGE No. of range points (≤ 250)
NFREQ No. of frequencies (≤ 6)
IFQMIN Index of lowest frequency ≤ 6
FREQ Array (6) of (radian frequencies)**-1/3
FREQX Array (6) of frequencies in KHz
RANGE Array (6) of range values, feet

/FLAGS/ IGTYP Type of family being processed 1-4
THMIN Angle giving minimum range in fit, Rad
THMAX Angle giving maximum range in fit, Rad
CONST Const*(Receiver Velocity)**1/3
CLC2 Ratio of source depth velocity/receiver depth velocity
CBC2 Ratio of bottom velocity/receiver depth velocity
ICOH Flag to indicate combination of arrivals, 0-3
IRSR Flag to indicate surface reflection
NBOT No. of bottom reflections
<table>
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<th>Description</th>
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<td>IBTYP</td>
<td>FNWC bottom type</td>
</tr>
<tr>
<td>IFLAG</td>
<td>Array (6) of coherency flags</td>
</tr>
<tr>
<td>DK</td>
<td>Array (2,6) of semi-coherent phase factors</td>
</tr>
<tr>
<td>/RAYZER/</td>
<td>IREFRZ Flag indicating grazing family</td>
</tr>
<tr>
<td></td>
<td>THETMB Critical angle for bottom type, radians</td>
</tr>
<tr>
<td></td>
<td>THBINC Incremental angle for bottom rays, radians</td>
</tr>
<tr>
<td>/INIT/</td>
<td>AK Vertex velocity of ray to be traced</td>
</tr>
<tr>
<td></td>
<td>SINTHO Sine of initial angle of ray to be traced</td>
</tr>
<tr>
<td></td>
<td>IML Index of mixing layer in input profile</td>
</tr>
<tr>
<td>/INPUTS/</td>
<td>IRAY Number of rays (in TH) in family being processed (≤ 100)</td>
</tr>
<tr>
<td></td>
<td>KP Index (in N) of arrival being processed (1-4)</td>
</tr>
<tr>
<td></td>
<td>NP Index of path being processed (1-4)</td>
</tr>
<tr>
<td></td>
<td>NORDER Arrival order being processed</td>
</tr>
<tr>
<td></td>
<td>NG Index of group (family) being processed (≤ 20)</td>
</tr>
<tr>
<td></td>
<td>IPAR Flag for type of family being processed (1 or 2)</td>
</tr>
<tr>
<td></td>
<td>R Array (100,4) of arrival ranges vs. angle and arrival, ft</td>
</tr>
<tr>
<td></td>
<td>TH Array (100) of ray angles in family being processed, rad</td>
</tr>
<tr>
<td>/FITS/</td>
<td>THF Array (3) of angles of fit of R vs. 0</td>
</tr>
<tr>
<td></td>
<td>A Array (5) of coefficients of fit</td>
</tr>
</tbody>
</table>
FACTTL (Cont'd)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XMIN</td>
<td>Ordinate value for min value of fit</td>
</tr>
<tr>
<td>XMAX</td>
<td>Ordinate value for max value of fit</td>
</tr>
<tr>
<td>RMIN</td>
<td>Minimum value of range in fit</td>
</tr>
<tr>
<td>RMAX</td>
<td>Maximum value of range in fit</td>
</tr>
<tr>
<td>RANMIN</td>
<td>Minimum range value to be fit</td>
</tr>
<tr>
<td>/CUSPCM/</td>
<td>CCUSP</td>
</tr>
<tr>
<td>/AUTCOH/</td>
<td>FNMIN</td>
</tr>
<tr>
<td>FNMAX</td>
<td>Max no. of range pts/surf image cycle = 6</td>
</tr>
<tr>
<td>FNXI</td>
<td>Reciprocal of FNMAX-FNMIN</td>
</tr>
<tr>
<td>FNCYC</td>
<td>Array (2,6) of cycles of phase difference</td>
</tr>
</tbody>
</table>

**NOTE**

Following the flow charts for FACTTL, additional pages are presented which elaborate on the geometry of the ray paths which are used in the FACT trans calculation, and the values of flags and indices required to sequence the corresponding path ranges as a function of family, arrival order and path index.
Begin FACTTL

Calculate run constants and parameters; set table of range values

Call INSERT to correct profile, insert source and receiver points (moved, if required, to simulate axis-to-axis transmission)

Set frequency-dependent parameters, depth and phase constants, velocity factors, etc.

Call TABTH2 to tabulate bottom angle as a function of receiver ray angle

Determine relative geometry of source and receiver

Call CRITA to determine factors for low-frequency cut-off effects

Call ANGSCH to determine number of families to trace (NCRPS), and the angles and number of rays in each family

Zero out transmission loss array TL

More than 20 families or 100 rays?

Yes → Exit FACTTL
Continue FACTTL

Loop over all families
NG = 1, NGRPS

Determine contribution of family to intensities and arrival angles (See FACTTL 3 for flow)

Call HFCHTL for other than direct and bottom bounce paths of half-channel cases

Determine surface duct parameters

Loop over all range points

Loop over all frequencies

Add in surface duct contributions if present. Add in volume absorption. Convert intensities to dB re 1 yd.

Write out duct contribution to arrivals

Exit FACTTL
FACTTL - Loop on Families

- Initialize family parameters

- Loop over all rays in family IR = NR1, NR2

- Call RANGER to calculate ray period and source-receiver ranges of first two arrivals of ray

- Calculate source-receiver ranges of third and fourth arrivals of ray

- Calculate minimum and maximum ray angles for family; calculate surface reflection parameters

- For surface-reflected family, compute phase relationships of up- and down-going rays

- Determine geometry for pairing of arrivals and set ICONH flag
Continue FACTTL - Loop on Families

- Determine parameters for direct path (NORDER = 0) arrivals; Determine no. of paths NPATHS

Loop over direct path arrivals
NP = 1, NPATHS

- Determine direct path contribution to intensities and arrival angles (See FACTTL5 for flow)

- Is this other than last family of a half-channel case? Yes/No

Yes

- Determine parameters for non-direct paths (NORDER≠) arrivals; Determine no. of paths NPATHS

Loop over higher arrival orders:
NORDER = 1, 2, 3, ...

- Determine higher order contributions to intensities and arrival angles (See FACTTL 6 for flow)
FACTTL - Loop on direct path arrivals

Set index for path arrival ranges

Is this the third or fourth arrival of a grazing ray, or the second arrival of a cusp with source shallower than receiver?

Yes

Call SETSNR to determine arrival angle signs

No

Call FINDFT to determine coeffs. of fit types 1 or 2 & assoc. params.

Processing last family?

Yes

Call FITBOT to determine coeffs. of fit type 4 and assoc. params.

No

Turn off cusp flag for direct path

Call INSTOR to determine direct path contribution to intensities and arrival angles

Restore cusp flag, reset end flag
FACTTL - Loop on higher arrival orders

1. Increment arrival order, compute no. of bottom bounces
2. Is this last family and number of bottom-bounces > 4?
   - Yes
   - No
     - Set flag to limit bottom rays; compute phase relationships of up and down going rays
     - Determine ranges of all paths of all rays of family at this arrival order
     - Does family contain cusped caustic?
       - No
       - Yes
         - Call CUSP to determine contribution of this arrival order to intensities and arrival angles
         - Loop over each path of this arrival order NP=1,NPATHS
           - Determine contribution of path to intensities and arrival angles (See FACTTL flow)
           - Has intensity contribution of this family ceased to be significant?
             - Yes
             - No
FACTTL - Loop on paths of higher arrival orders

1. Set index for path arrival ranges
2. Call SETSNR to determine arrival angle signs
3. Processing last Family?
   - Yes: Call FITBOT to determine coefficients of fit type 4 & assoc. params.
   - No: Third or fourth arrival of grazing ray?
     - Yes: Call FINDFT to limit to coefficients of fit type 1 or 2 & assoc. params.
     - No: Limiting bottom rays?
       - Yes: Range of path beyond max. range of interest?
         - No: Call INSTOR to determine path contribution to intensities and arrival angles
         - Yes: Path intensities above minimum?
           - Yes: Indicate path did not contribute
           - No: Path intensities above minimum?
             - Yes: Indicate path did not contribute
             - No: Path intensities above minimum?
<table>
<thead>
<tr>
<th>RECEIVER DEPTH - K2</th>
<th>AT SURFACE</th>
<th>IN BETWEEN</th>
<th>ON BOTTOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT SURFACE</td>
<td>--</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>IN BETWEEN</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>ON BOTTOM</td>
<td>6</td>
<td>5</td>
<td>--</td>
</tr>
</tbody>
</table>

FACTTL - Setting Of Geometry Indicator KFLAG
<table>
<thead>
<tr>
<th>NORDER = 0</th>
<th>NORDER = 1, 2, 3...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PATH GEOMETRY</strong></td>
<td><strong>IPF (NP)</strong></td>
</tr>
<tr>
<td><strong>KFLAG</strong></td>
<td><strong>ICON</strong></td>
</tr>
<tr>
<td>K1</td>
<td>0</td>
</tr>
<tr>
<td>1: DEEPER THAN K2</td>
<td>2</td>
</tr>
<tr>
<td>THAN PL</td>
<td>3</td>
</tr>
<tr>
<td>K2</td>
<td>0</td>
</tr>
<tr>
<td>1: DEEPER THAN PL</td>
<td>1</td>
</tr>
<tr>
<td>THAN PL</td>
<td>3</td>
</tr>
<tr>
<td>K1 SURFACE</td>
<td>0</td>
</tr>
<tr>
<td>K2 BELOW</td>
<td>2</td>
</tr>
<tr>
<td>K1 BOTTOM</td>
<td>0</td>
</tr>
<tr>
<td>K2 ABOVE</td>
<td>2</td>
</tr>
<tr>
<td>K2 SURFACE</td>
<td>0</td>
</tr>
<tr>
<td>K1 BELOW</td>
<td>1</td>
</tr>
<tr>
<td>K2 BOTTOM</td>
<td>0</td>
</tr>
<tr>
<td>K1 ABOVE</td>
<td>1</td>
</tr>
<tr>
<td>K1 SURFACE</td>
<td>0</td>
</tr>
<tr>
<td>K2 BOTTOM</td>
<td>1</td>
</tr>
<tr>
<td>K1 BOTTOM</td>
<td>0</td>
</tr>
</tbody>
</table>

**FACTL - INDICES FOR DETERMINATION OF ARRIVAL TIMES IN R (ANGLE-PATH ARRAY)**
KFLAG = 1
(K1 deeper than K2)

ICOH = 0

(ICOH = 1 NOT POSSIBLE)

ICOH = 2

ICOH = 3

FACTTL - Coherence Geometry for Combining Ray Paths
1 of 8

4-35
KFLAG = 1
(K2 deeper than K1)

ICOH = 0

ICOH = 1

(ICOH = 2 NOT POSSIBLE)

ICOH = 3

FACTTL - Coherence Geometry for Combining Ray Paths
2 of 8
4-36
KFLAG = 2

ICOH = 0

\[ R_X = \rho - (\Theta - \Theta) \]

ICOH = 2

FACTTL - Coherence Geometry for Combining Ray Paths
3 of 8
FACTTL - Coherence Geometry for Combining Ray Paths
4 of 8
FACTTL - Coherence Geometry for Combining Ray Paths
5 of 8

4-39
KF
LAC
-5
ICOII

KFLAG = 5

ICOH = 0

ICOH = 1

FACTTL - Coherence Geometry for Combining Ray Paths
6 of 8
4-40
KFLAG = 6

ICOH = 0

FACTTL - Coherence Geometry for Combining Ray Paths
7 of 8

4-41
FACTTL - Coherence Geometry for Combining Ray Paths
8 of 8
KFLAG = 1
(K1 deeper than K2)

![Diagram showing ray paths]

<table>
<thead>
<tr>
<th>ORDER</th>
<th>N_P</th>
<th>0</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
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<tr>
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<td>①</td>
<td>①</td>
<td>①</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>①</td>
<td>①</td>
<td>①</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>①</td>
<td>①+P</td>
<td>①</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>①+P</td>
<td>①+P</td>
<td>①+P</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>①+2P</td>
<td>①+2P</td>
<td>①+2P</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>①+3P</td>
<td>①+3P</td>
<td>①+3P</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>①+P</td>
<td>①+P</td>
<td>①+P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>①+P</td>
<td>①+1P</td>
<td>①+P</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>①+2P</td>
<td>①+2P</td>
<td>①+2P</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>①+3P</td>
<td>①+3P</td>
<td>①+3P</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>①+2P</td>
<td>①+2P</td>
<td>①+2P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>①+2P</td>
<td>①+3P</td>
<td>①+2P</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>①+3P</td>
<td>①+3P</td>
<td>①+3P</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>①+3P</td>
<td>①+3P</td>
<td>①+3P</td>
</tr>
</tbody>
</table>

FACTTL - Ray Path Range Selection
1 of 8

4-43
KFLAG = 1
(K2 deeper than K1)

<table>
<thead>
<tr>
<th>ORDER</th>
<th>LP</th>
<th>0</th>
<th>1</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0+P</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0+P</td>
<td></td>
<td>0+P</td>
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<tr>
<td></td>
<td>3</td>
<td>0+P</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0+P</td>
<td>0+P</td>
<td>0+P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0+P</td>
<td>0+P</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0+2P</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0+2P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0+2P</td>
<td>0+3P</td>
<td>0+2P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0+2P</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0+3P</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0+3P</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

etc.  etc.
<table>
<thead>
<tr>
<th>ORDER</th>
<th>N.P</th>
<th>FOR ICH VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0 + ρ</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>θ + 2 ρ</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>θ + 2 ρ</td>
</tr>
</tbody>
</table>

etc. |

etc.

PACTTL - Ray Path Range Selection
3 of 8

4-48
**KFLAG = 3**

<table>
<thead>
<tr>
<th>KZ1</th>
<th>KZ2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>

**Table: Crossing of Channels**

<table>
<thead>
<tr>
<th>Number</th>
<th>Up</th>
<th>Icon Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0 + P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0 + 2P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0 + 2P</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0 + 3P</td>
</tr>
</tbody>
</table>

**FACTTL - Ray Path Range Selection**

4 of 8
KFLAG = 4

<table>
<thead>
<tr>
<th>ORDER</th>
<th>N.R</th>
<th>ORDER</th>
<th>N.R</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

ORDER or RADIUS FOR ICH0 VALUES

FACTTL - Ray Path Range Selection
5 of 8
4-47
KFLAG = 5

<table>
<thead>
<tr>
<th>UPT</th>
<th>ORDERING OF RANGES FOR SLOW VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>( \theta + \phi )</td>
</tr>
<tr>
<td>2</td>
<td>( \phi + \theta )</td>
</tr>
<tr>
<td>2</td>
<td>( \theta + \phi )</td>
</tr>
<tr>
<td>2</td>
<td>( \phi + \theta )</td>
</tr>
<tr>
<td>1</td>
<td>( \theta + \phi )</td>
</tr>
<tr>
<td>2</td>
<td>( \phi + \theta )</td>
</tr>
</tbody>
</table>

FACTIL - Ray Path Range Selection
6 of 8

4-49
KFLAG = 6

![Diagram](image)

ICOH = 0

<table>
<thead>
<tr>
<th>ORDER</th>
<th>NP</th>
<th>Observed or Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

etc

FACTIL: Ray Path Range Selection
7 of 8
4-49
KFLAG = 7

ICOH = 0

<table>
<thead>
<tr>
<th>ORDER</th>
<th>NP</th>
<th>Observation of Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0 + P</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0 + 2P</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0 + 3P</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0 + 4P</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0 + 5P</td>
</tr>
<tr>
<td>etc</td>
<td></td>
<td>etc</td>
</tr>
</tbody>
</table>

FACTTL - Ray Path Range Selection
8 of 8

4-50
SUBROUTINE SHALTL

SHALTL is a self-contained model for estimating shallow-water (less than 1000 feet) transmission loss for bottom-class/frequency combinations permitting perfect reflection of rays at grazing angles on the bottom less than some critical angles. A trivial modification to TLOSS will cause SHALTL to be called in place of FACTTL for these combinations which may be followed for a call to FACTTL for the remaining cases. Note that a single frequency is processed by each call to SHALTL.

SHALTL assumes a homogeneous (uniform sound velocity) medium and includes an average surface image interference effect. A simplified bottom-loss approximation assumes a bottom which is perfectly reflecting to a critical angle THCDG. Above this angle, the bottom has a constant loss FL90 for the first order path and is perfectly absorbing for higher order paths. The constants THCDG and FL90 are chosen from 3x3 arrays as a function of bottom type (1-3) and frequency band (0-150 Hz, 151-699 Hz, and 700-1000 Hz).

PARAMETER INPUTS

<table>
<thead>
<tr>
<th>YS</th>
<th>Source depth, feet</th>
<th>D</th>
<th>Bottom depth, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>YR</td>
<td>Receiver depth, feet</td>
<td>NR</td>
<td>No. of range points, ≤250</td>
</tr>
<tr>
<td>F</td>
<td>Frequency, Hz</td>
<td>DR</td>
<td>Incremental range, feet</td>
</tr>
<tr>
<td>IB</td>
<td>Bottom type, 1-3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PARAMETER OUTPUT

TL Array (25) of transmission loss versus range,
dB re 1 yard
SUBROUTINE INSERT

INSERT is called by FACTTL at the beginning of each case to process the input sound velocity profile. INSERT corrects all depths and velocities to account for spherical-earth effects, and ensures that explicit points for source and receiver depths are inserted in the profile and that they are at points of unequal sound velocity. Prior to inserting these source and receiver depths in the profile, INSERT calls AXIS to account for axis-to-axis transmission; this call may result in the source and receiver depths being changed. For ray-tracing purposes, INSERT chooses, from these two depths, the point with the lesser sound speed as the source for ray-tracing purposes: throughout the remainder of the FACT program, the term source refers to this point. Three indices are set by INSERT as the result of this processing: K1, the index of the ray-tracing source; K2, the index of the ray-tracing receiver; and KRC (=1 or 2) indicating which of these is the depth at which arrival angles are to be calculated.

INSERT constructs the final sound velocity profile in common area /VELOC/ and the gradients of this profile in common area /GRADS/.

PARAMETER INPUTS

Y1  Source depth, feet
Y2  Receiver depth, feet
NPTS  No. of points in sound velocity profile ≤ 50
INSERT (Cont'd)

**COMMON INPUTS**

/INIT/

IML Index of mixing layer in profile YX,CX

**PARAMETER OUTPUTS**

Y1 Corrected source depth, feet
Y2 Corrected receiver depth, feet
KRC Flag indicating arrival angle depth

**COMMON OUTPUTS**

/VELOC/

NPTSP No. of points in temporary
YPP Array (60) of corrected profile depths, feet
CPP Array (60) of corrected profile velocities, feet per second

/GRADS/

G Array (60) of profile gradients, (sec^-1)

/INIT/

K1 Index of ray tracing source in corrected profile
K2 Index of ray tracing receiver in corrected profile
YML Mixing layer depth in corrected profile
IMLP Index of mixing layer in corrected profile
G1 Gradient above mixing layer in corrected profile
G2 Gradient below mixing layer in corrected profile

4-54
INSERT (Cont'd)

/CUSPM/  ICUSP  Cusped caustic flag
/PERIOD/  PERO  Period of zero degree traced from K1
IAXFG    Flag indicating source-receiver-axis geometry
COSA    Limiting ray angle (at axis) for analytic
ANGP    low frequency cutoff, and its cosine
Apply spherical earth correction to source and receiver depths, and to input profile depths and velocities

Determine mixing layer characteristics

Call AXIS to locate axis index, move source and receiver if required, and calculate angle of ray at axis grazing next layer

Source and receiver depths within 10 feet of each other

Set flag ICUSP=1 if source/rcvr not at surface or bottom; otherwise ICUSP=0

Move source depth slightly, avoiding equal velocities (See INSERT 3 for flow)

Insert source and receiver depths in profile, storing profile in /VELOC/, gradients in /GRADS/; determine source and receiver indices K1, K2, and KRC

Set flag ICUSP=0

Source and receiver velocities equal?

No

Modify profile to avoid equal velocities

Yes

Set flag ICUSP=0

Source and receiver velocities equal?

No

Modify profile to avoid equal velocities

Yes

Set flag ICUSP=0

Source and receiver velocities equal?

No

Modify profile to avoid equal velocities

Yes
A

Is source depth at profile axis?

No

Are source and receiver on same side of profile axis?

Yes

Set IAXFG=1

Call RANGER to compute period of zero degree ray from source

No

Set IAXFG=2

Set IAXFG=1

If mixing layer exists, determine its index in corrected profile

Yes

End INSERT
INSERT - Move Source Depth Slightly

Is source depth on profile?
  Yes
  No
  Where is source?
    In
    Between
    At
    Surface
    On
    Bottom
  No
  Is gradient below = 0?
    Yes
    Increase velocity at profile point by 2 feet/second
    No
  Is gradient below = 0?
    Yes
    Increase source depth by min. of:
      a) 1/2 layer thickness
      b) Distance to get 2 ft/sec. velocity
      c) 10 feet
    No
    Decrease source depth by min. of:
      a) 1/2 layer thickness
      b) Distance to get 2 ft/sec. velocity
      c) 10 feet

4-58
SUBROUTINE AXIS

AXIS is called from INSERT to determine the parameters required to handle axis-to-axis transmission. Initially, the deep sound channel axis is located (if present) and the smaller of the two velocities immediately to either side of the axis is obtained. This information is used to fit a smooth (quadratic) function to the velocity profile which is continuous in velocity and gradient at the axis. The period of the zero-degree ray at the axis is then determined as an analytic function of the smoothed-profile coefficients. Subsequently, the angle of the ray which has the same period in the linearly-segmented profile is determined by means of a simple closed-form expression. If the two turning-point (vertex) depths of this ray about the axis bound both the source and receiver depths, then the source and receiver depths are required to take on the depth value of one of the turning points.

When no axis exists, the "axis" depth index is set either to the surface or to the bottom, and the period of the zero degree ray (PERO) is set to 0.

Following the above calculations, AXIS determines the limit angle for analytical low-frequency cut-off effects. This angle is the angle of the ray at the axis which just grazes the next layer in the velocity profile.

4-59
PARAMETER INPUTS

YS  Source depth, feet
YR  Receiver depth, feet
IPR  Debugging print flag

COMMON INPUTS

/VELOCX/  NPTS  No. of points in sound velocity profile
          Y  Array (60) of profile depths, feet
          C  Array (60) of profile velocities, ft/sec

PARAMETER OUTPUTS

YS  Adjusted source depth, feet
YR  Adjusted receiver depth, feet

COMMON OUTPUTS

/PERIOD/  YUP*  Minimum depth of axis ray, feet
          YDN*  Maximum depth of axis ray, feet
          PER0  Period of axis ray, feet
          COSA  Limit angle at axis for analytical
                 ANGP  low-frequency cutoff, radians, and its cosine
          LX  Index of axis in profile

*LX ≠ 0 or NPTS only
SUBROUTINE TABTH2

TABTH2 is called by FACTTL to tabulate the ray angle at the bottom, $\theta_B$, as a function of the ray angle at the receiver depth, $\theta_{K2}$. Twenty-one equally-spaced values of $\theta_{K2}$ are tabulated, from $\theta_{\text{Min}}$ to $\pi/2$, along with the corresponding (unequally-spaced) values of $\theta_B$. The value of $\theta_{\text{Min}}$ is that of the first ray which touches the bottom. For ease in interpolation (by function THBOT), the ratios of the corresponding increments in the two tables are also tabulated.

PARAMETER INPUT

CBC2  Ratio of bottom velocity to receiver depth
velocity

COMMON OUTPUTS

/TH2TAB/

TH2MIN  Minimum ray angle at receiver depth
FACTOR  Reciprocal of increment in $\theta_{K2}$
TH2T   Array of 21 values of $\theta_{K2}$
THDT   Array of 21 values of $\theta_B$
RATIO  Array of 20 ratios of $\Delta \theta_B/\Delta \theta_{K2}$
SUBROUTINE CRITA

CRITA is called by FACTTL to compute the WKB phase factors for low-frequency cutoff effects. The deep-sound channel is first located (as in subroutine AXIS), and subroutine RAYT is called to compute the relative phase of the ray along the axis with initial angle such that the next layer in the profile is just grazed (this is the limit angle for analytical cut-off effects which was calculated by AXIS). CRITA then determines the relative phases for each frequency being processed, using analytical expressions for rays at less than the limiting angle, and by iteration (using RAYT) for rays crossing more than one layer in the profile. For each frequency attenuation factors are calculated in the form of beam patterns (amplitude vs. angle); these are analytic for rays below the limit angle and tabulated for rays above the limit angle. An array of flags is also produced for rapid determination (in INSTOR and CUSP) of which beam pattern type applies at each frequency.

PARAMETER INPUT

IPR Debugging print flag

COMMON INPUTS

/VELOC/ LMAX No. of points in profile
Z Array (60) of profile depths, feet
V Array (60) of profile velocities, ft/sec
CRITA (Cont'd)

/INIT/ L Index of source depth in profile
/RANGEL/ NFREQ No. of frequencies
IFQMIN Index of lowest frequency
FQ Array (6) of frequencies, Hz
/PERIOD/ COSA Limit angle for analytical beam patterns, radians, and its cosine
ANGP

COMMON OUTPUTS
/CRIT/ BEE2 Coefficient of analytic low-frequency cut-off amplitudes
Cl Velocity at source (K1), ft/sec
CX Velocity at profile axis, ft/sec
JALF All frequencies - analytical flag
JAIF Array (6) of individual analytical frequency flags
CRITANX Array (6) of critical angles vs. frequency
CAX Array (6,4) of beam pattern angles vs. frequency
SS Array (6,4) of beam pattern amplitudes vs. frequency

4-63
SUBROUTINE RAYT

RAYT is called from CRITA to determine the relative phase (in terms of travel time) along a ray traced over one cycle, adjusted, if required, to account for surface and/or bottom reflections.

PARAMETER INPUTS

LA     Index of source in velocity profile
COSTHO Cosine of initial ray angle

COMMON INPUTS

/VELOC/ LMAX  No. of points in velocity profile
         Z      Array (60) of profile depths, feet
         C      Array (60) of profile velocities, ft/sec
/GRADS/ G     Array (60) of profile gradients, (sec⁻¹)

PARAMETER OUTPUT

CUTOFF Relative phase of ray, seconds
SUBROUTINE ANGSCH

ANGSCH is called from FACTTL to determine the families of rays to be processed, as a function of the sound velocity profile, and the source and receiver depths. Each family is chosen so that a smooth fit of ray range vs. ray angle can be made. Up to 100 rays in up to 20 families are allowed; if profile and source/receiver data cause these maxima to be exceeded, a diagnostic message is printed (on FORTRAN unit 6) and a flag is set to indicate this condition. The ray angles, in radians, are stored in a single array, THETA. The array IGRP is used to designate the index of the first ray in each family, and a second array, IGRAZE, indicates that the first ray in family just grazes a specified profile point.

The rays in each group are constrained to be at least three in number, with a maximum spacing of .5 degrees. A new family begins when a relative maximum in the profile is encountered, when either the surface or bottom is encountered, and when the profile gradient decreases by more than a specified increment.

COMMON INPUTS

/VELOC/ NPTS No. of points in sound velocity profile
Y Array (60) of profile depths, feet
C Array (60) of profile velocities, ft/sec
ANGSCH (Cont'd)

/GRADS/  G  Array (60) of profile gradients, (sec\(^{-1}\))

/INIT/  K1  Index of source depth in profile
        K2  Index of receiver depth in profile
        YML Mixing layer depth, feet
        IMLP Index of mixing layer depth in profile
        IML  Index of mixing layer (as input)

/RAYZER/  THBINC Bottom angle increment (\(\approx 5^\circ\)), radians
         THETMB Critical angle for FNWC bottom type, radians

COMMON OUTPUTS

/RAYZER/  IRFFRZ Flag indicating grazing ray at K2
/CUSPCM/  ICUSP Flag indicating cusped caustic (turned off
         if source and receiver within mixed layer)

/ANGLES/  NRRAYS Number of rays in all families \(\leq 100\) or 999
         NGRPS Number of families of rays \(\leq 20\)
         ISURF Index of first ray of hit surface
         IBOT Index of first ray to hit bottom
         IGRP Array (20) of indices of first ray in each family
         IGRAZE Array (20) of grazing flags
         THETA Array (100) of initial ray angles, radians
SUBROUTINE RANGER

RANGER is called from FACTTL, INSERT, and AXIS to compute the ranges associated with one up- and down-going cycle of a ray traced from the source depth (K1). The initial ray angle is positive if possible (source not at the surface) and is traced for a quarter-cycle, or until the ray hits the surface; the process is then repeated for a ray with negative angle if possible (source not at the bottom). As these rays are traced, RANGER calculates depth versus range; the crossings, if any, of the receiver depth (K2) are noted, and the corresponding ranges are saved.

The outputs from RANGER are the period of the ray, the maximum and minimum depths attained by the ray, and the distances to the first and second crossings of the receiver depth. If the receiver depth is not reached, these are instead the ranges to the first and second crossings of the source level, i.e., the half- and full-period ranges.

COMMON INPUTS

/VELOC/ NPTS No. of points in sound velocity profile
        Y Array (60) of profile depths, feet
        C Array (60) of profile velocities, ft/sec
/GRADS/  G Array (60) of profile gradients, (sec⁻¹)
/INIT/   K1 Index of source depth
RANGER (Cont'd)

/INIT/

K2 Index of receiver depth
AK Vertex velocity of ray being traced, ft/sec
SINTHO Sine of initial ray angle at K1

PARAMETER OUTPUTS

R1 Range of first crossing of receiver depth, feet
R2 Range of second crossing of receiver depth, feet
P Full-cycle period of ray, feet

COMMON OUTPUTS

/PERIOD/

YUP Minimum depth attained by ray, feet
YDN Maximum depth attained by ray, feet
RANGER - Geometry for Ray Tracing
SUBROUTINE FITBOT

FITBOT is called by FACTTL to determine the coefficients of the fit of range vs. ray angle at the receiver ($\theta_{K2}$) for the last (bottom- and surface-reflecting) family. For rays with bottom angles less than $30^\circ$, the form of the fit is:

$$R = A(1) + A(2) \times (\theta_{K2} - \theta_{Min})^3 + A(3) \times (\theta_{K2} - \theta_{Min})$$

For bottom angles greater than $30^\circ$, the form of the fit is:

$$R = \frac{1}{A(4) \times \tan(\theta_{K2}) + A(5)}$$

All coefficients are calculated by FITBOT with the exception of $A(4)$ which is calculated in FACTTL to give the correct limiting range for the (implicit) $90^\circ$ ray. The derivatives of $R$ vs. $\theta_{K2}$ are continuous at the value of $\theta_{K2}$ corresponding to the $30^\circ$ bottom ray.

PARAMETER INPUTS

R     Array (2) of ranges to be fit, feet
TH    Array (2) of angles (at $K2$) to be fit, radians
A     Array value [A(4)] of coefficient determined in FACTTL

PARAMETER OUTPUTS

A     Array values [A(1), A(2), A(3), A(5)] of coefficients of fit of range vs. ray angle

4-70
SUBROUTINE FINDFT

FINDFT is called by FACTTL to determine the coefficients of the fit of ray range vs. ray angle at the receiver for all families except the last (bottom- and surface-reflected) family. The form of the fit is:

\[ R = A(1) + A(2) \cdot X(\theta_{K2}) + A(3) \cdot [X(\theta_{K2})]^2 \]

The form of the function \( X(\theta_{K2}) \) depends upon the value of IPAR:

- IPAR = 1: \( X(\theta_{K2}) = \tan(\theta_{K2}) \)
- IPAR = 2: \( X(\theta_{K2}) = (\theta_{K2} - \theta_{\text{Min}})^3 \)

Three points are used in the fit: The minimum and maximum values of \( \theta_{K2} \), plus a third point which is the value of \( \theta_{K2} \) which gives a minimum or maximum value of range within the region of interest, or, if no minimum or maximum exists, the value of \( \theta_{K2} \) corresponding to the second ray in the family. For families with grazing rays at the receiver (Flag IREFRZ = 1), the three values of \( \theta_{K2} \) are 0, and the values \( \theta_{K2} \) corresponding to the last ray in the family.

FINDFT also sets various parameters giving ranges in range, angle, and \( X \), over which the fit of range vs. angle is valid. See the documentation of INSTOR for a diagram showing the notation employed (page 4-83).
### FINDFT (Cont'd)

#### PARAMETER INPUT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPRNT</td>
<td>Debugging print flag</td>
</tr>
</tbody>
</table>

#### COMMON INPUTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/FLAGS/</td>
<td>CLC2</td>
<td>Ratio of source depth velocity to receiver depth velocity</td>
</tr>
<tr>
<td>/INPUTS/</td>
<td>KRAY</td>
<td>No. of rays in family being fit, ( \leq 100 )</td>
</tr>
<tr>
<td></td>
<td>KP</td>
<td>Index of ray paths in array R, 1-4</td>
</tr>
<tr>
<td></td>
<td>NORDER</td>
<td>Arrival order being processed</td>
</tr>
<tr>
<td></td>
<td>NG</td>
<td>Index of family being fit, ( \leq 20 )</td>
</tr>
<tr>
<td></td>
<td>IPAR</td>
<td>Flag indicating functional form of fit</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>Array ((100,4)) of ray ranges vs. source angle and path index, feet</td>
</tr>
<tr>
<td></td>
<td>TH</td>
<td>Array ((100)) of ray source angles, radians</td>
</tr>
<tr>
<td>/INIT/</td>
<td>K1</td>
<td>Index of source depth</td>
</tr>
<tr>
<td></td>
<td>K2</td>
<td>Index of receiver depth</td>
</tr>
<tr>
<td>/RAYZER/</td>
<td>IREFRZ</td>
<td>Flag indicating first ray grazes receiver depth</td>
</tr>
<tr>
<td>/CUSPCM/</td>
<td>ICUSP</td>
<td>Flag indicating cusped caustic</td>
</tr>
</tbody>
</table>

#### COMMON OUTPUTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/FLAGS/</td>
<td>THMIN</td>
<td>Angle at receiver of shallowest (at source) ray, radians</td>
</tr>
<tr>
<td></td>
<td>THMAX</td>
<td>Angle at receiver of steepest (at source) ray, radians</td>
</tr>
<tr>
<td>/FITS/</td>
<td>THF</td>
<td>Array ((3)) of receiver ray angles, radians</td>
</tr>
</tbody>
</table>
FINDFT (Cont'd)

/FITS/

RF  Array (3) of ranges of fit, feet
A   Array (3) of coefficients of fit
XMIN Value of X(THMIN)
XMAX Value of X(THMAX)
RMIN Range corresponding to THMIN
RMAX Range corresponding to THMAX
RANMIN Minimum range spanned by fit, feet
SUBROUTINE FITQ

FITQ is called by FINDPT and CUSP to determine the coefficients of the quadratic function

\[ Y = A(1) + A(2) \cdot X + A(3) \cdot X^2 \]

which passes through the three points \( X(1), Y(1); X(2), Y(2); \) and \( X(3), Y(3), \) where \( X(1) \neq X(2) \neq X(3) \neq X(1). \)

PARAMETER INPUTS

\[
\begin{align*}
X & \quad \text{Array (3) of ordinate values} \\
Y & \quad \text{Array (3) of abscissa values}
\end{align*}
\]

PARAMETER OUTPUTS

\[
\begin{align*}
A & \quad \text{Array (3) of coefficients of fit}
\end{align*}
\]
SUBROUTINE INSTOR

INSTOR is called by FACTTL to add the intensity contributions arising from one arrival of one order of one family of rays to each applicable point in array TL over the range of interest. INSTOR is also called by CUSP to process any smooth caustic which may be associated with a cusped caustic.

The range interval is determined by the coefficients and parameters of the fit of range vs. (receiver) ray angle, calculated by FACTTL or CUSP and passed through common areas /FITS/ and /FLAGS/. The contribution of each arrival (which may actually represent several arrivals) at a given range point within this interval is subsequently added to the array TL by:

\[
TL(Range, Freq) = TL(Range, Freq) + \frac{FACT}{XL(Freq)}
\]

\(XL\) is the reciprocal ray intensity and is determined from one of four arrival geometries; FACT is a modifying factor (in the range 0-4) which accounts for the effects of in-, semi-, or fully-coherent combination of multiply-combined arrivals under the ICOH and IFLAG options. \(XL\) may also be modified to account for bottom-bounce losses and low-frequency cut-off effects.

The four arrival geometries and the corresponding reciprocal intensity factors are as follows. See relevant geometry diagrams on pages 4-83, 96 and 97.
1) Single-ray (no caustic) arrival:

\[ \Xi(f) = \Xi_1 = \text{RANGE}(K) \cdot \sin(l) \cdot \text{RP} / \cos^2 \theta \]

where:

\[ \text{RANGE}(K) = \text{Range in feet, } R \]
\[ \sin(l) = \sin(\theta_1) \quad (\theta_1 = \text{ray angle at source}) \]
\[ \cos^2 \theta = \cos(\theta_2) \quad (\theta_2 = \text{ray angle at receiver}) \]
\[ \text{RP} = \left| \frac{dR}{d\theta} \right| \text{ at range } R \]

2) Shadow zone of a smooth caustic:

\[ \Xi(f) = \Xi_1(f) \cdot \text{FAIRY}(XAIR) \cdot \text{RANGE}(K) / \text{RC} \]

Using:

\[ \Xi_1(f) = \Xi_1(f) \cdot f \]
\[ \Xi_1 = \text{CONST} \cdot \text{SINC} \cdot \text{RC} \cdot \text{ABS} \left( \frac{\text{RP} \cdot 2 / \text{SINC}}{1.3} \right) \]
\[ \text{FACTOR} = \frac{1}{(\cos(1.57079 \cdot \text{ABS} \text{DRAIR} / (\text{RCUT-RC})))}, \text{IRFG=1} \]
\[ \text{FACTOR} = 1, \text{IRFG=0} \]
\[ \text{BETA1} = (2 \cdot (\text{SINC} / 5000.) \cdot 2 / \text{ABS} \text{RP}) \cdot (1.3) \]

where:

\[ \text{RANGE}(K) = \text{Range in feet, } R \]
\[ \text{RC} = \text{Range of caustic, feet} \]
\[ f = (\text{Radian frequency})^{-1/3} \]
INSTOR (Cont'd)

\[
\text{CONST} = C_{K2}^{1/3}/2^{5/3} \cdot \eta \cdot \text{Ai}^2(0)
\]

\[
\text{SINC1} = \sin \theta_{K1} \quad (\theta_{K1} \text{ is source angle corresponding to } \theta_C = \theta_{K2} \text{ at caustic})
\]

\[
\text{RPP} = d^2R/d\theta^K_2 \text{ evaluated at range } RC
\]

\[
\text{SINC} = \sin \theta_C
\]

\[
\text{COSC} = \cos \theta_C
\]

\[
\text{RCUT} = \text{Range at which shadow zone is tapered off}
\]

\[
\text{IRFG} = \text{Flag indicated shadow zone tapered off at RCUT}
\]

\[
\text{FAIRY}(X) = \text{Modified Airy function } = [\text{Ai}(0)/\text{Ai}(-X)]^2
\]

3) Illuminated region of a smooth caustic (no cusped caustic):

\[
X_1(f \text{req}) = X_{IC}(f \text{req}) \cdot \text{FAIRY}(X_{AIR}) \cdot 2 \cdot \text{RANGE}(K)/RC, \; X_{AIR} < 1.77
\]

Using:

\[
X_{AIR} = BETA(f \text{req}) \cdot DRAIR
\]

\[
X_{IC}(f \text{req}) \text{ is calculated as in 2) above}
\]

\[
X_{IT1} \text{ is calculated as in 2) above}
\]

4) Illuminated region of a smooth caustic associated with a cusp:

a) Steep Branch (\( |\theta_{K2}| > |\theta_C| \)):

\[
X_1(f \text{req}) \text{ is calculated as in 3) above}
\]

b) Shallow Branch (\( |\theta_{K2}| < |\theta_C| \)):

\[
X_1(f \text{req}) = \text{AMIN1}(X_1(f \text{req}), \; X_{ICP})
\]

4-77
Using:

\[ \xi(f) = \xi(f) \cdot \text{FAIRY}(\text{XAIR}) \cdot 2 \cdot \text{RANGE}(K) / RC \]
\[ \xi_{\text{CP}} = \xi_{\text{CUSP}}(\text{RANGE}(K), 1000 \cdot \text{FREQ}(f) \cdot \text{RANGE}(K) / \cos^2) \]

\( \xi(f) \) is calculated as in 3) above

Where:

\[ \text{FREQ}(f) = \text{Frequency in Hz} \]
\[ \xi_{\text{CUSP}}(X) = \text{Intensity Function - see CUSP, page 4-93} \]

In addition to calculating the intensity contributions as outlined above, INSTOR determines when these are no longer significant, thus signaling the end of the loop on NORDER in FACTTL. This condition arises when the intensities fall below a minimum value, or when the range of an order is greater than the maximum range of interest. Flag IGTYP in common area /FLAGS/ is set negative to indicate that this has occurred.

Arrival information (range, ray angle, and ray intensities at each frequency) is calculated and written on file IARVTP if this flag is not zero.

**PARAMETER INPUTS**

- **KRC**: Flag indicating arrival angle depth
- **SNTHR**: Sign of ray angle at depth flagged by KRC
- **IP**: Debugging print flag
- **IARVTP**: Flag indicating file for arrival information output
PARAMETER OUTPUTS

TL Array (250,6) of intensities vs. range and frequency

FILE OUTPUT

Unit IARVTPI One record for each arrival angle at each
range point. The format of each BCD record
is as follows:

<table>
<thead>
<tr>
<th>Position</th>
<th>Format</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1H</td>
<td>Blank</td>
</tr>
<tr>
<td>2-7</td>
<td>F6.1</td>
<td>Range, Nautical Miles</td>
</tr>
<tr>
<td>8-9</td>
<td>2X</td>
<td>Blank</td>
</tr>
<tr>
<td>10-16</td>
<td>F7.3</td>
<td>Arrival Angle, Degrees</td>
</tr>
<tr>
<td>17-18</td>
<td>2X</td>
<td>Blank</td>
</tr>
<tr>
<td>19-23</td>
<td>F5.1</td>
<td>Loss at 1st Frequency, dB</td>
</tr>
<tr>
<td>24-25</td>
<td>2X</td>
<td>Blank</td>
</tr>
<tr>
<td>26-30</td>
<td>F5.1</td>
<td>Loss at 2nd Frequency, dB</td>
</tr>
<tr>
<td>etc</td>
<td>etc</td>
<td>etc</td>
</tr>
<tr>
<td>52-58</td>
<td>F5.1</td>
<td>Loss at 6th Frequency, dB</td>
</tr>
</tbody>
</table>

COMMON INPUTS

/FLAGS/

IGTYPPI Type of family (fit) being processed
THMIN  Shallowest ray angle in family being processed
THMAX  Steepest ray angle in family being processed
CONST  Coefficient for caustic intensities
INSTOR (Cont'd)

C1C2  Ratio of source velocity/receiver velocity
C2C2  Ratio of bottom velocity/receiver velocity
ICOH  Flag indicating combination of arrivals
IRSR  Flag indicating surface-reflected rays
NBOT  No. of bottom bounces of family
IBTYP  FNWC bottom type
IFLAG  Array (6) of coherency flags vs. frequency
F     Array (2,6) of semi-coherent phase factors vs. frequency

.FITS/ A Array (5) of coefficients of fit of R vs. θ
XMIN  Minimum value of argument of fit
XMAX  Maximum value of argument of fit
EMIN  Range of minimum-angle ray in family
EMAX  Range of maximum-angle ray in family
RANMIN  Minimum range at which intensities result

.INFO. B KP Index of range of path being processed
NORDER  Order of arrival of path being processed

/RANGE/ NRANGE  No. of range points
NFREQ  No. of frequencies
IFQMIN  Index of minimum frequency
FREQ  Array (6) of (radian frequencies) •••(-1/3)
FREQK  Array (6) of frequencies, KHz
RANGE  Array (250) of range points, feet

/PAYZER/ IRFFRZ  Flag indicating grazing arrival at receiver
INSTOR (Cont'd)

/AUTCOH/

FNMIN  Min. no. of range points per surface-image cycle
FNMAX  Max. no. of range points per surface-image cycle
FNXI    Reciprocal of FNMAX-FNMIN
FNCYC   Array (2,6) of cycles of phase difference of up- and down-going rays at K1 and K2 vs. freq.

/CUSPCM/

ICUSP   Flag = 1 if processing smooth caustic associated with a cusp

/CRIT/

BEE2    Coefficient of analytic low-frequency cut-off amplitudes
C1      Velocity at source (K1), ft/sec
CX      Velocity at profile axis, ft/sec
JALF    All-frequencies-analytical flag
JAIF    Array (6) of individual analytical frequency flags
CRITANX Array (6) of critical angles vs. frequency
CAX     Array (6,4) of beam pattern angles vs. frequency
SS      Array (6,4) of beam pattern amplitudes vs. frequency

/PERIOD/

PERO    Period of zero-degree ray at source, feet
ANGP    Limit angle for analytical beam patterns
IAXFG   Flag indicating source-receiver-axis geometry

4-81
COMMON OUTPUTS

/FITS/ RANMIN Minimum range at which fit is applicable

/FLAGS/ IGTYPE Set negative to indicate no contribution to intensity
R is quadratic in $X_1(\theta)$ or $X_2(\theta)$

i.e., $R = A(1) + A(2) \cdot X(\theta) + A(3) \cdot [X(\theta)]^2$

$X_1(\theta) = \tan(\theta) \quad \text{IPAR} = 1$

$X_2(\theta) = \theta - \theta_{\text{min}} \quad \text{IPAR} = 2$

NOTE: Throughout this figure $\theta = \theta_{K2} = \text{Ray angle at receiver (K2)}$
<table>
<thead>
<tr>
<th>ICOH</th>
<th>SNTHR</th>
<th>NANG</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(≠0)</td>
<td>4</td>
<td>SNTHR</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>+1.</td>
<td>-1.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>SNTHR</td>
<td>SNTHR</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>.</td>
<td>(≠0)</td>
<td>4</td>
<td>-1.</td>
<td>-1.</td>
<td>+1.</td>
<td>-1.</td>
</tr>
</tbody>
</table>

INSTCR - Determination of No. of Arrival Angles and Their Signs
$\text{RCUT} = \left[ \text{FACTOR IN TABLE (N=NOTORDER)} \right] \times \text{PERO}$

$IREFZ = 1 \text{ so } KP \neq 3, 4$

**ICAUST**

<table>
<thead>
<tr>
<th>ICUSP = 0:</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAXFG = 1:</td>
<td>NONE</td>
<td>MIN RANGE</td>
<td>MAX RANGE</td>
</tr>
<tr>
<td>KP =</td>
<td>1</td>
<td>0</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
<td>$N - \frac{1}{2}$</td>
</tr>
</tbody>
</table>

**ICAUST**

<table>
<thead>
<tr>
<th>ICUSP = 1:</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAXFG = 2:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KP =</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**ICAUST**

<table>
<thead>
<tr>
<th>ICUSP = 1:</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRSR =</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**NOTE:** RCUT = 0 if IREFZ = 0

**INSTOR - Determination of RCUT**

4-85
Begin INSTOR

Determine number of ray paths that have been combined under the ICOH option, and the corresponding arrival angle signs.

Initialize default values for caustic ranges and flags.

Test family type:

1 2 3 or 4

Compute \( \theta \) caustic from parameters of type 1 fit.

\( \theta \) caustic included in family?

Test family type:

1 2

Compute angles and ranges associated with type 1 caustic.

Caustic range \( \leq 0 \)?

Compute \( \delta^2 R / \delta \theta^2 \) at range of type 1 caustic.

Yes

\( \delta^2 R / \delta \theta^2 \) at range of type 2 caustic

No

B

A

INSTOR 1
Determine frequency-and-range-independent portions of caustic intensity expressions

Determine maximum and minimum ranges over which fit of range vs. $\theta$ is applicable

Set flag to indicate max. or min. range caustic

Determine range of cusp from which caustic originated

Determine frequency-dependent, range-independent portions of caustic intensity expressions

Determine no. of range points per cycle of surface-image interference pattern (combined path, surf-reflection, and coherency flags $\neq 0$)

Determine indices $K_{MIN}$ and $K_{MAX}$ of range points spanned by this path of this order of this family

Any points spanned?

Yes

No
Continue INSTOR

Loop over range points: \( K = K_{\text{MIN}}, K_{\text{MAX}} \)

Determine No. of rays through range point = JFLAG: = 0? Yes

No

Loop over rays through range point: \( J = 1, \text{IFLAG} \)

Determine \( \partial R/\partial \theta \) in illuminated region according to type of fit; determine illuminated region frequency-independent intensity factor

Loop over frequency: \( NF=1, \text{NFREQ} \)

Determine frequency-dependent contribution to intensity (See INSTOR 5 for flow)

Output arrival angle information if flagged

D
Yes
Did intensity fall below minimum value of interest?

No
Exit INSTOR

Yes
Is the minimum range of this path for this order greater than the maximum range of interest?

No
Exit INSTOR

Set flag to indicate no intensity contribution made by this path

Exit INSTOR

Continue INSTOR

D

E

Exit INSTOR
INSTOR - Loop On Frequency

1. In shadow zone of caustic?
   - Yes
   - No
2. In illuminated region of caustic?
   - Yes
   - No
3. Beyond maximum range of expression of caustic intensity?
   - Yes
   - No
4. Processing shallow branch from cusp?
   - Yes
   - No
5. Calculate intensity from one-ray expression
6. Calculate intensity from maximum of Illum. zone and cusp intensity
7. Calculate intensity from illuminated caustic expression
8. Calculate intensity from shadow zone caustic expression
9. Attenuate intensity if ray has undergone bottom bounces

F

INSTOR 5
Continue INSTOR - Loop on frequency

Determine factor for modifying intensity to account for coherency geometry and for coherency addition type

Modify intensity by coherency and low-frequency cutoff factors

Add intensity to TL array as a function of range and frequency
SUBROUTINE CUSP

CUSP is called by FACTTL to add the intensity contributions arising from each order (other than direct) of a family containing a cusped caustic, to each applicable point in the array TL over the range of interest. CUSP also calls INSTOR to process any smooth caustic which may be associated with a cusped caustic.

The range interval is determined directly from ray path distances for the cusp itself; CUSP also calculates the coefficients and parameters of the fit of range vs. (receiver) ray angle for the smooth caustic (if any) which are passed through common area /FITS/ to INSTOR. For each range point in the interval covered, the intensity contribution to each frequency arising from one arrival order is added to the array TL by:

\[
\text{TL(Range, Freq)} = \text{TL(Range, Freq)} + \frac{1}{XIP(Freq)}
\]

XIP is the reciprocal ray intensity and may be modified to account for bottom-bounce losses and low-frequency cutoff effects. It is computed from:

\[
XIP(Freq) = XI(Freq) \times \frac{\text{RAN/CST}}{}
\]

Using:

\[
XI(Freq) = \text{XCUSP(IR, RAN, 1000. \times \text{FREQ}(Freq))}
\]

\[
\text{CST} = \cos(\theta)
\]

Where:

\[
\text{RAN} = \text{Range in feet, R}
\]

4-92
CUSP (Cont'd)

THETA = Angle of ray at range R, estimated from linear or quadratic fit depending upon ray being processed.

XICUSP = Function computing vertical spreading for a ray near the cusp as a function of region (one or three ray), range, and frequency.

IR = 1 in one-ray region, 2 in three-ray region of cusp.

In addition to calculating cusp intensity contributions as outlined above, CUSP determines when these are no longer significant, thus signaling the end of the loop on NORDER in FACTTL. This condition arises when the intensities from the smooth caustics calculated by INSTOR fall below a minimum value, or when the range of an order is greater than the maximum range of interest. Flag IDONE is set to indicate this condition.

Arrival information (range, ray angle, and ray intensities at each frequency) is calculated and written on file IARVTP if this flag is not zero.

PARAMETER INPUTS

K1 Index of source depth
X2 Index of receiver depth
KRC Flag indicating arrival angle depth
CUSP (Cont'd)

IPRNT  Debugging print flag
IARVTP  Flag indicating file for arrival information output

PARAMETER OUTPUTS

IDONE  Flag indicating end of contribution to intensities
IL  Array (250,6) of intensities vs. range and frequency

FILE OUTPUT

Unit IARVTP One record for each arrival angle at each range point. See INSTOR for format specifications.

COMMON INPUTS

/INPUTS/  N*  Number of rays in family
R  Array (100,4) of ranges vs. ray angle and arrival, feet
TH  Array (100) of ray angles of family, radians

/RANGE/  NRANGE  No. of range points
NFREQ  No. of frequencies
FREQK  Array (6) of frequencies, KHz
RANGE  Array (250) of ranges, feet

/FLAGS/  IGTYP  Type of family being processed
NBOT  No. of bottom bounces at this order
IBTYP  FNWC bottom type

/CUSPCH/  CCUSP  Velocity at cusp, ft/sec

/GRADS/  G  Array (60) of profile gradients, (sec⁻¹)

*NRAYS elsewhere

4-94
CUSP (Cont'd)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANGP</td>
<td>Limit angle for low-frequency cutoff</td>
</tr>
<tr>
<td>BEE2</td>
<td>Coefficient of low-frequency cut-off amplitudes</td>
</tr>
<tr>
<td>C1</td>
<td>Velocity at source (K1), ft/sec</td>
</tr>
<tr>
<td>CX</td>
<td>Velocity at profile axis, ft/sec</td>
</tr>
<tr>
<td>JALF</td>
<td>All-frequencies-analytical flag</td>
</tr>
<tr>
<td>JAIF</td>
<td>Array (6) of individual analytical frequency flags</td>
</tr>
<tr>
<td>CRITANX</td>
<td>Array (6) of critical angles vs. frequency</td>
</tr>
<tr>
<td>CAX</td>
<td>Array (6,4) of beam pattern angles vs. frequency</td>
</tr>
<tr>
<td>SS</td>
<td>Array (6,4) of beam pattern amplitudes vs. frequency</td>
</tr>
</tbody>
</table>

COMMON OUTPUTS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>THF</td>
<td>Array (3) of angles of fit of R vs. θ for smooth caustic, radians</td>
</tr>
<tr>
<td>RF</td>
<td>Array (3) of ranges of fit, feet</td>
</tr>
<tr>
<td>A</td>
<td>Array (3) of coefficients of fit</td>
</tr>
<tr>
<td>XMIN</td>
<td>Minimum value of argument of fit</td>
</tr>
<tr>
<td>XMAX</td>
<td>Maximum value of argument of fit</td>
</tr>
<tr>
<td>RMIN</td>
<td>Range of minimum-angle ray in family</td>
</tr>
<tr>
<td>RMAX</td>
<td>Range of maximum-angle ray in family</td>
</tr>
<tr>
<td>RANMIN</td>
<td>Minimum range at which intensities result</td>
</tr>
<tr>
<td>RCUSP</td>
<td>Range of cusp, feet</td>
</tr>
<tr>
<td>BCUSP</td>
<td>Cusp parameter beta</td>
</tr>
</tbody>
</table>

4-95
CUSP - Parameters Of Fit Of Smooth Caustic
CUSP - Selection of Intensities in Region of CUSP with A Smooth Caustic
Begin CUSP

Determine ranges associated with cusp

Determine type of cusp

<table>
<thead>
<tr>
<th>Minimum Range</th>
<th>Maximum Range</th>
<th>Out of Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A

Search for minimum range smooth caustic
- Found
- Not Found

Caustic type = 1

Search for maximum range smooth caustic
- Not Found
- Found

Caustic type = 2

Determine indices KMIN and KMAX of range points spanned by this order

All Ranges beyond maximum range of interest?
Yes
No

Determine cusp parameters and path indices

Determine signs of arrival angles

Cusp ranges alone beyond max range of interest?
Yes
No

A

B

CUSP 1
Continue CUSP

Loop over range points: \( K = \text{KMIN}, \text{KMAX} \)

Determine no. of rays at range point = NRAYS

Compute intensity factor for each frequency

Loop over number of rays: \( I = 1, \text{NRAYS} \)

Determine angle of ray being processed and corresponding cut-off angle

Loop over frequency: \( NF = 1, \text{NFREQ} \)

Compute intensity contribution of ray, attenuate if ray has undergone bottom bounces, modify by low-freq. cutoff factor

Add intensity to TL array as a function of range and frequency

Output arrival angle information if flagged

CUSP 2
Smooth caustic also present? 

Yes

No

Exit CUSP

Determine coeffis. of fit type 1 and associated parameters

Call SETSNR to determine arrival angle signs

Call INSTOR to process smooth caustic

Did intensity of min-range smooth caustic fail to contribute significantly 

Yes

Set flag to indicate intensity contribution made

Exit CUSP 

Set flag to indicate no intensity contribution

Exit CUSP
SUBROUTINE HFCHTL

HFCHTL is called by FACTTL to calculate the intensities for other than direct and bottom-surface-reflected paths when the half-channel indicator has been set on input (index of mixing layer at bottom depth: IML = NPTS). The routine is strictly applicable only for three source/receiver depth combinations (60/60 feet, 200/300 feet, 200/60 feet) and frequencies (50, 300, 850, 1700 Hz). The computed intensities are proportional to 1/Range; the constant of proportionality is initially expressed as a transmission loss (dB re 1 foot) in the form:

\[ TL = A - B \cdot \log \left( \frac{D}{1000} \right) \]

where D is the half-channel depth in feet.

The coefficients A and B are each chosen from a separate 3x4 array as a function of source/receiver depth combination and of frequency. The coefficients in these arrays were themselves computed by FACT, using a temporary correction set to bypass the contributions to transmission loss arising from the direct and bottom-surface-reflecting paths. These FACT runs were made using a simple pressure-gradient profile (\( \frac{\Delta \text{velocity}}{\Delta \text{depth}} = 0.018 \text{ sec}^{-1} \)) to half-channel depths of 1000 and 18,000 feet.

PARAMETER INPUTS

NR No. of range points, \( \leq 250 \)
HFCHTL (Cont'd)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPREQ</td>
<td>No. of frequencies, ≤ 6</td>
</tr>
<tr>
<td>YS</td>
<td>Source depth, feet</td>
</tr>
<tr>
<td>YR</td>
<td>Receiver depth, feet</td>
</tr>
<tr>
<td>D</td>
<td>Depth of half-channel, feet</td>
</tr>
<tr>
<td>FREQB</td>
<td>Array (6) of frequencies, Hz</td>
</tr>
<tr>
<td>RANGE</td>
<td>Array (250) of range points, feet</td>
</tr>
</tbody>
</table>

PARAMETER OUTPUTS

TL Array (250, 6) to which intensities are added

as a function of range and frequency.
SUBROUTINE QUAD

QUAD is called from INSTOR to solve the quadratic equation expressing \( R \) as a function of \( X(\theta) \), in order to find the value(s) of \( X(\theta) \) (and thus the value(s) of \( \theta \)), if any, at the range point being processed in INSTOR. The roots are constrained to lie between \( X_{\text{MIN}} = X(\theta_{\text{Min}}) \) and \( X_{\text{MAX}} = X(\theta_{\text{Max}}) \). QUAD returns the number of roots = 0, 1 or 2, and the corresponding (ordered) values of \( X(\theta) \). See diagram page 4-83.

The notation in QUAD

\[
Y = A(1) + A(2)X + A(3)X^2
\]

corresponds to

\[
R = A(1) + A(2)X(\theta) + A(3)X(\theta)^2
\]

in INSTOR.

PARAMETER INPUTS

- \( A \): Array (3) of coefficients of fit
- \( X_{\text{MIN}} \): Minimum value allowable for \( X \)
- \( X_{\text{MAX}} \): Maximum value allowable for \( X \)
- \( Y \): The range for which \( X \) values are desired

PARAMETER OUTPUTS

- \( X \): Array (2) of solutions of equation
- \( IFLAG \): No. of \( X \) values returned (0, 1 or 2)
FUNCTION SPEED

SPEED is called from INSERT to linearly interpolate in the sound velocity profile to determine the velocity corresponding to a source or receiver depth which has not been explicitly included as a point on the input profile. The results are unpredictable if this depth is less than the minimum profile depth; the last segment of the profile is linearly extrapolated for a depth greater than the maximum profile depth.

PARAMETER INPUT

YP       Depth at which velocity is to be determined, feet

COMMON INPUT

/VELOCX/ NPTS   No. of points on profile
          Y   Array (60) of profile depths, feet
          C   Array (60) of profile velocities, ft/sec

FUNCTION OUTPUT

SPEED   Interpolated value of velocity at depth YP, ft/sec
FUNCTION SETSNR

SETSNR is called from FACTTL and CUSP to determine the sign(s) of the arrival angle(s) at the depth at which arrival information is being determined. It returns the sign(s) of the angle of the ray(s) corresponding to the path of interest, which may be multiple, according to the coherency option in effect. If $KRC = 1$, the sign of the angle(s) at depth $K1$ is returned; if $KRC = 2$, the sign of the angle(s) at depth $K2$ is returned. A value of 0. is returned to indicate that both up- and down-going rays (signs = +1. and -1.) are present.

PARAMETER INPUTS

<table>
<thead>
<tr>
<th>ICOH</th>
<th>Coherency option in effect - 0, 1, 2 or 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRC</td>
<td>Flag indicating arrival depth</td>
</tr>
<tr>
<td>$K1$</td>
<td>Index of source depth</td>
</tr>
<tr>
<td>$K2$</td>
<td>Index of receiver depth</td>
</tr>
<tr>
<td>$KP$</td>
<td>Index of path being processed</td>
</tr>
</tbody>
</table>

FUNCTION OUTPUT

| SETSNR | Sign(s) of arrival angles: +1., -1., 0. |

See below for values returned as a function of input parameters.
<table>
<thead>
<tr>
<th>KRC = 0:</th>
<th>0.</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRC = 1:</td>
<td></td>
</tr>
<tr>
<td>ICOH</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1.</td>
</tr>
<tr>
<td>1</td>
<td>0.</td>
</tr>
<tr>
<td>2</td>
<td>1.</td>
</tr>
<tr>
<td>3</td>
<td>0.</td>
</tr>
</tbody>
</table>

| KRC = 2: |
| (K1 Deeper Than K2) |
| ICOH | 1 | 2 | 3 | 4 |
| 0  | -1. | -1. | +1. | +1. |
| 1  | -1. | -1. | +1. | +1. |
| 2  | 0. | 0. | 0. | 0. |
| 3  | 0. | 0. | 0. | 0. |

| KRC = 2: |
| (K2 Deeper Than K1) |
| ICOH | 1 | 2 | 3 | 4 |
| 0  | +1. | +1. | -1. | -1. |
| 1  | +1. | +1. | -1. | -1. |
| 2  | 0. | 0. | 0. | 0. |
| 3  | 0. | 0. | 0. | 0. |

SETSNR - Function Value Returned

4-107
FUNCTION FAIRY

FAIRY is called by INSTOR as a step in calculating the intensities which exist in the neighborhood of a smooth caustic. The function is related to the Airy function (for real arguments) as follows:

\[
FAIRY(X) = \begin{cases} 
\frac{Ai(0)}{Ai(-X)}^2 & -1.77 \leq -X \leq 4.0 \\
\frac{Ai(0)}{Ai(-1)} & X < -4.0 \\
0.752 \cdot (X)^{1/2} & X > 1.77
\end{cases}
\]

The function is approximated over the primary range of interest by 10.**CX, where CX is interpolated from tabulated values of C(I) vs. I; these values are:

\[
C(I) = 2 \log_{10} \left[ \frac{Ai(0)}{Ai(I-11)} \right] \quad I = 1(1)31
\]

This range of I corresponds to -X ranging from -2. to +4. at intervals of 0.2.

PARAMETER INPUT

X  Argument of function

FUNCTION OUTPUT

FAIRY  Functional value corresponding to X
FUNCTION XICUSP

XICUSP is called by Cusp and INSTOR as a step in calculating the intensities which exist in the neighborhood of a cusped caustic. The function computes the vertical spreading near the cusp, returning the single-path value assuming three equal-amplitude paths in the interference (three-ray) region and one path in the one-ray region.

The calculation is three-step:

1) \[ X = \left( \frac{\alpha' \cdot W}{C} \right)^{1/2} \]
   where:
   \( \alpha' \) = Cusp parameter
   \( W \) = Radian frequency
   \( C \) = Cusp sound velocity

2) \[ Y = f[(R-R_C) \cdot X] \]
   where:
   \( R \) = Range of interest, feet
   \( R_C \) = Range of cusp, feet
   \( f \) is calculated by call to function FE2B. The sign of the argument is positive in the one-ray region, negative in the three-ray region.

3) \[ XICUSP = \frac{\pi}{X \cdot Y} \]

PARAMETER INPUTS

IR Flag indicating one- or three-ray region
RAN Range of interest, feet
FREQ Frequency, Hz
XICUSP (Cont'd)

FUNCTION OUTPUT

XICUSP  Functional value of spreading

4-110
FUNCTION PE2B

PE2B is called from XICUSP to calculate the Pearcey-function component of the expression for vertical spreading in the vicinity of a cusp. The function is related to the Pearcey function as follows:

\[
PE2B(y) = \begin{cases} 
\frac{\pi}{y} & y \leq -3.5 \\
\frac{\text{Pe}(y)}{\sqrt[3]{\pi}} & -3.5 < y \leq 0 \\
\frac{\text{Pe}(y)}{\pi} & 0 < y < 2 \\
\frac{\pi}{y} & y \geq 2.0 
\end{cases}
\]

The function \(\text{Pe}(y)\) is approximated over the primary range of interest by \(\text{Pe}^2\), where \(P\) is interpolated from tabulated values of \(PT(I)\) vs. \(I; I = 1(1)23\). This range of \(I\) corresponds to \(y\) ranging from \(-3.5\) to \(2.0\) at intervals of \(0.25\).

PARAMETER INPUT

\(Y\) Argument of function

FUNCTION OUTPUT

\(PE2B\) Functional value corresponding to \(y\)
FUNCTION THBOT

THBOT is called by INSTOR and CUSP to determine the ray angle at the bottom as a function of the ray angle at the receiver depth. This angle is determined from linear interpolation in the values of bottom angle vs. receiver ray angle as previously tabulated by routine TABTHZ.

PARAMETER INPUTS

TH2 Ray angle at receiver depth (K2)

COMMON INPUTS

/TH2TAB/

TH2MIN Minimum ray angle at receiver depth
FACTOR Reciprocal of increment of TH2T values
TH2T Array (21) of ray angles at receiver depth
THBT Array (21) of ray angles at the bottom
RATIO Array (20) of ratio of increments of TH2T to increment of THBT

FUNCTION OUTPUT

THBOT Interpolated value of bottom angle
FUNCTION BOTTOM

BOTTOM is called from INSTOR and CUSP to calculate the intensity attenuation occurring along bottom-bounce ray paths. The attenuation is returned as a value between 0 and 1. Currently, BOTTOM returns a 1 (no attenuation) if the input bottom type is 0, and calls upon FNWC routine BTMLOS for bottom types 1-9. This routine may be replaced or restructured according to the desires of the FACT user.

PARAMETER INPUTS

<table>
<thead>
<tr>
<th>NBOT</th>
<th>No. of bottom bounces</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBTYP</td>
<td>Bottom type, 0-9</td>
</tr>
<tr>
<td>THB</td>
<td>Ray angle at bottom, radians</td>
</tr>
<tr>
<td>FREQ</td>
<td>Frequency, Hz</td>
</tr>
</tbody>
</table>

FUNCTION OUTPUTS

| BOTTOM | Bottom attenuation |
5. THE FACT HANDOUT

The following pages contain a reproduction of the AESD FACT Handout, a computer-maintained document which is an integral part of the FACT Package. The various sections are as follows:

- A description of the physical basis of the FACT Model;
- A description of the computer program flow;
- A description of the FACT Package Program Library;
- A description of the input card formats accepted by the TLOSS program;
- A description of the input deck structure;
- A listing of a sample set of input data cards;
- The outputs resulting from this input deck;
- The listing produced by a CDC 6600 FORTRAN compilation of FACT.

Of the last section, only the listing of the program TLOSS is included in this report.
FAST ASYMPTOTIC COHERENT TRANSMISSION (FACT) MODEL
DEVELOPED BY
ACOUSTIC ENVIRONMENTAL SUPPORT DETACHMENT
OFFICE OF NAVAL RESEARCH
1 APRIL 1973

THE FACT MODEL IS A RAY ACOUSTIC MODEL WHICH UTILIZES
HIGHER ORDER THEORY FOR THE SOLUTION IN THOSE AREAS IN WHICH
THE ASSUMPTIONS OF RAY ACOUSTICS ARE LIMITING. THE PRINCIPAL
IMPROVEMENTS OF THE FACT PROGRAM ARE AS FOLLOWS--

THE GEOMETRIC INTENSITIES COMPUTED BY THE CLASSICAL
EXPRESSIONS OF RAY ACOUSTICS ARE DISCARDED AT CAUSTICS WHERE
THEY PREDICT INFINITE INTENSITY. RATHER, THE FIELD NEAR THE
CAUSTIC IS EVALUATED USING THE APPROPRIATE ASYMPTOTIC EXPRESSIONS
FOR THE PARTICULAR TYPE OF CAUSTIC--

1. SMOOTH CAUSTICS (2-RAY SYSTEMS) - BREKHOFSKICH'S EXPRESSIONS.
2. CUSED CAUSTICS (2-RAY SYSTEMS) FOR SOURCE AND RECEIVER
AT THE SAME DEPTH - LUONG'S EXPRESSIONS.
3. COMBINED SMOOTH AND CUSED CAUSTICS (4-RAY SYSTEMS). THE
RMS SUM OF THE SMOOTH AND CUSED-CAUSTIC FIELDS.

CAUSTIC FIELDS ARE EXTENDED INTO THE SHADOW ZONE TO THE RANGE
OF THE CUSP WHERE THE SMOOTH CAUSTIC ORIGINATED.

THE TOTAL INTENSITY AT ANY ONE RANGE POINT IS COMPUTED
BY A "SEMI-COHERENT" ADDITION OF ARRIVALS. FOR SHALLOW SOURCES
AND/OR RECEIVERS THE PATHS WITHIN AN ARRIVAL ORDER WHICH DIFFER
ONLY BY A SURFACE REFLECTION AT THE SOURCE (AND RECEIVER) HAVE
PREDICTABLE PHASES RELATIVE TO ONE ANOTHER. PHASE DIFFERENCES
BETWEEN DIFFERENT FAMILIES OF ARRIVAL ORDERS ARE LESS PRE-
DICTABLE. THE "SEMI-COHERENT" SUMMATION REFERS TO THE COHERENT
OR PHASED SUMMATION OF THE FIRST SET OF PATHS FOLLOWED BY THE
INCOHERENT OR POWER SUMMATION OF THE RESULTING SETS. AS THE
RATE IN THE OSCILLATIONS OF A PARTICULAR COHERENT SUMMATION
INCREASES THE RANGE GRID MAY BECOME TOO COARSE TO ADEQUATELY
SAMPLE THE OSCILLATIONS. WHEN THIS OCCURS THE SUMMATION IS
PERFORMED WITH AN EFFECTIVELY REDUCED COHERENCE UNTIL FOR VERY
COARSE GRIDS ALL PATHS ARE SUMMED INCOHERENTLY.

AXIS-TO-AXIS TRANSMISSION IS TREATED IN THE FOLLOWING WAY.
THE PERIOD OF THE AXIS RAY IS COMPUTED FOR THE SMOOTH PROFILE
CORRESPONDING TO THE LINEARLY SEGMENTED PROFILE. THE RAY WITH
THE SAME PERIOD WHEN TRACED IN THE LINEARLY SEGMENTED PROFILE
IS FOUND AND THE DEPTHS OF ITS HORIZONTAL TURNING POINTS ARE
DETERMINED. IF THE SOURCE AND RECEIVER ARE BETWEEN THESE DEPTHS,
THEY ARE BOTH MOVED TO THE NEAREST DEPTHS. THE NET EFFECT OF THIS
MOVE IS TO PRODUCE A CUSED CAUSTIC AT THE RANGE OF THE CUSP
WHICH WOULD OCCUR FOR THE AXIAL-RAY FAMILY IN THE EQUIVALENT
SMOOTH PROFILE.
A WKB PHASE-INTEGRAL TECHNIQUE IS USED TO REDUCE THE INTENSITY (ON A FREQUENCY DEPENDENT BASIS) OF THE RAYS shallower than the ray-equivalent of the first normal mode. This simulates low-frequency cut-off effects on rays which cycle with vertical amplitudes which are small in terms of wavelengths.

A SHALLOW WATER MODEL IS INCLUDED WHICH MAY BE EXERCISED FOR WATER DEPTHS OF LESS THAN 1000 FEET, AND FREQUENCY/BOTTOM COMBINATIONS WHERE RAYS STRIKING THE BOTTOM AT LESS THAN CRITICAL SUFFER NO REFLECTION LOSS. THE RESULTING TRANSMISSION LOSS CURVE IS A SMOOTHED APPROXIMATION TO THE CURVE GENERATED IN THE ACTUAL MODEL AND REQUIRES CONSIDERABLY LESS COMPUTATION TIME. FOR ASRAP PURPOSES THE SHALLOW WATER MODEL IS ALWAYS USED WHERE APPROPRIATE. FOR THE GENERAL USER IT IS OPTIONAL.

A HALF CHANNEL MODEL HAS ALSO BEEN INCLUDED SPECIFICALLY FOR ASRAP PURPOSES. FOR THE PARTICULAR SOURCE DEPTHS AND FREQUENCIES USED IN ASRAP HALF-CHANNEL CASES THE INTENSITY DUE TO NRH PATHS IS APPROXIMATED BY A CURVE OF THE FORM OF

\[ TL = A * 10^* \log (R) \]

WHERE A IS A FUNCTION OF THE SOURCE AND RECEIVER DEPTHS, THE FREQUENCY, AND THE BOTTOM DEPTH. AGAIN THIS CURVE APPROXIMATES THE NORMAL FACT RESULT, HOWEVER, TAKES CONSIDERABLY LESS COMPUTER TIME. FOR ASRAP THIS IS ALWAYS USED WHERE APPROPRIATE. FOR GENERAL USERS IT WILL BE INVOKED WHEN THE MIXED LAYER DEPTH IS SET TO THE BOTTOM, HOWEVER UNLESS THE SOURCE AND RECEIVER DEPTHS AND FREQUENCIES CORRESPOND TO ASRAP CASES IT SHOULD BE AVOIDED. FINALLY, THE BASIC TRANSMISSION LOSS PROGRAM (EXCLUDING THE SHALLOW-WATER AND HALF CHANNEL APPROXIMATIONS) MAY BE USED TO OBTAIN ARRIVAL STRUCTURE AS FOLLOWS. FOR EACH RAY THROUGH EACH RANGE POINT A RECORD IS WRITTEN ON DISC (OR TAPE) CONTAINING

\[ RANGE, ANGLE, TL(I), I=1, NFREQ \] (FORMAT OF 10.3)

WHICH MAY BE USED FOR LATER COMPUTATIONS. THE ANGLE (RANGE) CURVE IS ALSO PLOTTED (ON THE LINE PRINTER).
FACT Model Program Flow

This section describes the program flow in the transmission loss module (subroutine FACTIL). The other decks, FLOSS, etc., are merely driven programs to call FACTIL.

FACTIL -
- Initialization of Variables and Arrays
- CALL INSERT
  - Makes spherical earth corrections on profile and source and receiver
  - Computes mixed layer and thermocline gradients for surface duct calculation (if applicable)
- CALL AXIS
  - Computes period of zero-degree ray along axis of smoothed equivalent profile and source and receiver (if necessary) to simulate axis-to-axis transmission.
  - Computes limiting angle for subsequent phase integral calculations.
  - Inserts source and receiver into profile moving them slightly or changing sound speeds slightly to prevent them from having the same sound speed.
  - Computes information needed for subsequent location of the cusps from which smooth caustics in the first family of rays originate.
  - Computation of frequency-dependent factor for coherence, absorption, and surface ducts.
- CALL TAB1
  - Tabulates the ray angle at the bottom in terms of the angle at either the source or receiver depth (whichever has a higher sound speed).
- CALL CRITA
  - Computes the phase factors for low-frequency cut-off effects.
- CALL ANSCH
  - Determines rays to be traced and defines ray families within which interpolations are valid in a smoothed angle versus range curve.
- LOOP ON EACH FAMILY
  - CALL RANGE FOR EACH RAY IN FAMILY
    - COMPUTES PHASE AN DIFFERENCES OF FIRST AND SECOND
      ARRIVALS OF UPGOING RAY.
    - COMPUTE SENSIBLE PHASE FACTORS FOR THIS FAMILY.
    - GROUP ARRIVALS FOR COHESIVE CORRELATION OR IF CLOSE
      ENOUGH IN RANGE TO BE CONSIDERED IDENTICAL. THE
      NUMBER OF ARRIVALS IN A SINGLE ORDER MAY THEN BE
      REDUCED FROM THE USUAL FOUR TO TWO OR ONE WITH
      CORRESPONDING CHANGES IN AMPLITUDE.
    - PROCESS EACH REMAINING ARRIVAL IN SUCCESSIVE ARRIVAL
      ORDERS UNTIL THE FAMILY (AND ITS CAUSTIC SHADOW ZONE
      FIELDS) HAS EXCEEDED THE MAXIMUM RANGE OF INTEREST.
  - FOR STEEPEST RAY FAMILY (BOTTOM-REFLECTED
    SURFACE-REFLECTED) CALL FIRMRT
    - COMPUTES PARAMETERS OF FIVE COEFFICIENT FIT
      TO RITHEMAI USING MINIMUM RAY. PAW AT CRITICAL
      ANGLE OF LOW FREQUENCY REFLECTION COEFFICIENT,
      AND IMPLICITLY 90-DEGREE RAY.
  - FOR DEEPER FAMILIES CALL FIRMRT
    - FITS A QUADRATIC IN EITHER TAN(RITHEMAI) OR Q(THETA-NTHETAI)
      TO RITHEMAI THROUGH BOUNDING
      ANGLES OF FAMILY AND MIN (OR MAX) RANGE POINT
      IN FAMILY.
  - CALL INSTOR IF FAMILY DOES NOT CONTAIN CUSPED CAUSTICS
    - COMPUTES THE INTENSITY CONTRIBUTION FROM THE
      FAMILY AT EACH RANGE POINT.
    - CAUSTIC PARAMETERS AND FIELDS ARE COMPUTED AS
      WELL AS ALL SENSIBLE PHASE FACTORS AND BOTTOM-
      REFLECTION LOSSES.
  - CALL CUSP FOR FAMILIES WITH CUSPED CAUSTICS
    - COMPUTES FAMILY PARAMETERS AND CUSPED CAUSTIC
      CORRECTIONS.
    - CALLS XICUSP TO COMPUTE CUSPED CAUSTIC FIELDS.
    - ADDS IN BOTTOM REFLECTION LOSS IF ANY.
    - FOR FOUR RAY SYSTEMS CALLS INSTOR TO COMPUTE
      SMOOTH CAUSTIC CONTRIBUTION.
  - END PROCESSING OF A FAMILY, GO TO NEXT FAMILY
THE FACT PACKAGE PROGRAM LIBRARY CONTAINS ALL FORTRAN ROUTINES REQUIRED TO IMPLEMENT THE FACT ACOUSTIC MODEL. THE PROGRAM LIBRARY COMPONENTS ARE AS FOLLOWS....

MAIN PROGRAM TLOSS -- READS CARD INPUT, COMPUTES LOSSES THRU SUBROUTINE CALLS, AND PRINTS AND/OR PLOTS ON THE LINE PRINTER THE RESULTS.

SUBROUTINE FACTIL -- THE FACT WAY TRACING MODEL
SUBROUTINE SHALIL -- A SIMPLIFIED MODEL FOR SHALLOW WATER, CALLED INSTEAD OF FACTIL BY AUTOIL UNDER CERTAIN CONDITIONS.
SUBROUTINE WFCNL -- A SIMPLIFIED HALF-CHANNEL MODEL, USED BY FACTIL FOR ASREAP CASES.

THE FACT MODEL SUBROUTINE FACTIL REQUIRES THE FOLLOWING ADDITIONAL ROUTINES....
11 COMPUTATIONAL SUBROUTINES...
INSERT, AXIS, TABTH, TARTHE
CRITA, RAYT, ANESCH
RANGER, FITBOT, FINTOFT
FITQ, INSTOR, CISP
QUAD
6 FUNCTIONAL SUBROUTINES....
SPEED, SELSWM, FAIRY
XICUSP, PEZB, THBOT
BOTTOM, BTHLOS
FOR INPUT AND OUTPUT PROGRAM TLOSS REQUIRES....
3 INPUT-OUTPUT SUBROUTINES....
ROPRF, TiHEAD, PLOTTL

TO MAKE AN OBJECT PROGRAM FOR THE CARD INPUT PROGRAM TLOSS, ALL COMPONENTS WITH THE EXCEPTION OF AUTOIL AND SHALIL SHOULD BE COMPILED. THE RESULTING PROGRAM OCCUPIES APPROXIMATELY 46880 (OCTAL) WORDS ON THE CDC 6600.

IN THE CDC 6600 FACT PACKAGE PROGRAM LIBRARY, THE FOLLOWING CONVENTIONS HAVE BEEN FOLLOWED....

EACH CPC IS A SINGLE PROGRAM, ROUTINE, OR FUNCTION.
THE CPC NAME IS IDENTICAL TO THE ROUTINE NAME.
ALL DECKS ARE SEQUENCED WITHOUT CORRECTIONS.
THE CARD INPUTS TO THIS ARE DETAILED IN THE COMMENTS WITHIN
THAT PROGRAM, AND REPEATED HERE FOR REFERENCE PURPOSES.

<table>
<thead>
<tr>
<th>CARD</th>
<th>34.4</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
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<td>4A10</td>
</tr>
<tr>
<td>2</td>
<td>(EOF END RUN)</td>
<td></td>
</tr>
<tr>
<td>34.B</td>
<td>43.IL,IP,IN,IP,IAO</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>(I;1),(I;1),(I;1)</td>
<td>6F10.2</td>
</tr>
<tr>
<td>5</td>
<td>(I;1)</td>
<td>15.5,F10.2</td>
</tr>
<tr>
<td>6</td>
<td>55.0,JC11 (I;1,A)</td>
<td>6F18.2</td>
</tr>
</tbody>
</table>

(EOF ENDS RUN)

15.GG. 1064 GOES BACK TO READ CARD 1)

FACTORS CALLED TO COMPUTE LOSSES
LOST PRINTED AND/OR PLotted

(GOES TO READ CARD 6)

# IS NO. OF PROFILE POINTS 2.LE.(ARSIN)-.LE. 50

*FOR A POSITIVE, PROFILE IS INPUT DIRECTLY IN DEPTH.
VELOCITY PAIRS, W/CARD. A VELOCITY .LT. 1000 IS USED AS AN
INDICATION OF METRIC INPUT (MM PER SEC) BOTH DEPTHS + VELOCITIES
ARE CONVERTED TO ENGLISH UNITS (FT,FT PER SEC).

*FOR A NEGATIVE, PROFILE IS INPUT AS DEPTH, TEMP.,
SALINITY TRIPLET, SIGNUM. METRIC UNITS ARE ASSUMED TO BE CENTS,FT.
WILSON'S FORMULA IS USED TO COMPUTE VELOCITIES. DEPTHS +
VELOCITIES ARE THEN CONVERTED TO ENGLISH UNITS.

*THE INPUT PROFILE IS ALWAYS PRINTED, IF CALCULATIONS +
CONVERSIONS ARE REQUIRED, THE RESULTING VALUES ARE ALSO PRINTED.

*THE BOTTOM DEPTH IS ALWAYS 771.

IL IS THE INDEX OF THE HIGHEST LAYER DEPTH IN THE INPUT PROFILE (SEPAREAT
COMPUTATIONS ARE THEN PERFORMED FOR A SURFACE DUCT OF THIS
DIMENSION AND NO DUCT ARE TRACED IN THE DUCT). EITHER I
OR G CAN BE USED TO INDICATE THAT NO LAYER IS PRESENT.
I.E., IL = both (ARSIN), iL = (ARSIN) INDICATES THAT A
WAVE-CHANNEL CONDITION IS PRESENT AND THAT THE ROUTINE
WORKED (NORMALLY USED ONLY FOR ARSAP) SHOULD BE USED.

JB IS THE BOTTOM TYPE
A NEGATIVE VALUE INDICATES THAT THE USER WILL SUPPLY A BOTTOM LOS
FUNCTION, AND MODIFY FUNCTION BOTTOM TO CALL THE REPLACEMENT FOR
THE DEFAULT FUNCTION ATLOS.
1-9 INDICATES FUNC BOTTOM LOSS FUNCTIONS
IN IS THE WAVE HEIGHT IN FEET

IPL IS THE PRINT/PLOT INDICATOR
  0. PRINT ONLY (DB, LOSS VS. RANGE)
  1. PLOT ONLY (DB, LOSS VS. RANGE, 1 PAGE/FREQUENCY)
  2. PRINT AND PLOT (#9 PLUS 1)
  3. PLOT FLOT ONLY (DB, LOSS VS. RANGE, ALL FREQUENCIES ON SAME PLOT)
  4. PRINT AND PLOT (#9 PLUS -1)

IAF IS THE ARRIVAL CALCULATION INDICATOR
  0. N ARRIVALS
  1. ARRIVAL ANGLES VS. RANGE CALCULATED AND PLOTTED

NR IS THE NUMBER OF RANGE POINTS 1 ,LE 250

OR IS THE INCREMENTAL (AND FIRST) RANGE IN N MI.

FII) ARE THE FREQUENCIES - UP TO SIX - IN HERTZ.

S IS THE SOURCE DEPTH IN FEET.

A IS THE RECEIVER DEPTH IN FEET.

*IF EITHER SOURCE OR RECEIVER DEPTH IS OUTSIDE THE PROFILE LIMITS (LESS THAN ZERO OR GREATER THAN 2(NII)) THE SOURCE OR RECEIVER IS BOTTOMED.

JCII ARE THE COHERENCY INDICATORS, AND CORRESPOND TO THE FIELDS 1-TO-1
B = SEMI-COHERENCE
1 = INCOHERENCE
2 = FULL COHORENCE

*THE VALUES OF JCII ARE NORMALLY LEFT BLANK TO INDICATE THAT SEMI-COHERENCE IS TO BE USED FOR ALL FREQUENCIES.
OUTPUT DATA

THE RESULTS ARE PRESENTED IN ANY ONE OF FIVE OUTPUT FORMATS, DEPENDING ON THE PRINTOUT PARAMETER AS SPECIFIED ON THE TYPE 2 DATA CARD (INTEGER VARIABLE IPL).

THE FIRST DATA PRINTED IS THE TITLE CARD.

THE SECOND DATA PRINTED VERIFIES THE INPUT PARAMETERS AS FOLLOWS--

FIRST, M, IL, IN, AND IM ARE PRINTED.
SECOND, ALL THE INPUT VALUES OF DEPTH AND VELOCITY OR TEMP.-SALINITY ARE PRINTED, PLUS ANY CONVERSIONS MADE.

THIRD, THE RANGE AND INCREMENT PARAMETERS BEING USED ARE PRINTED.

FOURTH, FACT PRINTS ALL FREQUENCIES BEING CONSIDERED AND THE COHERENCE OPTION--

0 = SCOH
1 = ICH
2 = FCM

UP TO THIS POINT, FACT HAS PRINTED ONLY DATA VALUES, TO ALLOW FOR VERIFICATION AND REFERENCE USE.

FACT WILL NOW PRINT COMPUTED RESULTS. THERE ARE TWO RESULT LISTINGS AVAILABLE--(1) A TABLE OF TRANSMISSION LOSSES, AND (2) A GRAPH OF TRANSMISSION LOSSES (AND ARRIVAL STRUCTURE WHEN APPROPRIATE). WHETHER FACT WILL PRINT ONLY THE FIRST, ONLY THE SECOND, OR BOTH DEPENDS ON WHAT IPL PARAMETER WAS SPECIFIED ON THE TYPE 2 DATA CARD. THREE SAMPLE CASES ARE GIVEN BELOW TO ILLUSTRATE THE TYPES OF OUTPUT AND FOR REFERENCE PURPOSES IN CONVERTING FACT DECKS TO OTHER SYSTEMS/COMPUTERS.
DATA INPUT CARDS FOR SAMPLE FACT RUNS

<table>
<thead>
<tr>
<th>COL.</th>
<th>1</th>
<th>11</th>
<th>21</th>
<th>31</th>
<th>41</th>
<th>51</th>
<th>61</th>
<th>71</th>
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<td></td>
</tr>
</tbody>
</table>

FACT SAMPLE RUN NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.

\[
\begin{array}{cccccccc}
0.0 & 0.0 & 0.0 & 67.25 & 153.24 & 76.20 & 1579.7 & 88.39 & 1525.8 \\
0.01 & 0.01 & 0.01 & 154.47 & 1514.2 & 1516.8 & 237.73 & 1509.9 \\
0.02 & 0.02 & 0.02 & 1509.5 & 1449.7 & 390.12 & 1496.6 & 408.41 & 1490.0 \\
0.03 & 0.03 & 0.03 & 1491.1 & 1488.7 & 342.92 & 1486.7 & 612.62 & 1483.5 \\
0.04 & 0.04 & 0.04 & 1482.5 & 1481.2 & 483.40 & 1481.2 & 899.17 & 1481.5 \\
0.05 & 0.05 & 0.05 & 1412.1 & 1408.0 & 1480.96 & 1480.9 & 1600.12 & 1480.7 \\
0.06 & 0.06 & 0.06 & 1349.7 & 1404.39 & 1491.1 & 2499.26 & 1498.1 & 2999.09 & 1505.9 \\
0.07 & 0.07 & 0.07 & 1235.57 & 1525.47 & 1547.8 &  &  &  & \\
0.08 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.09 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.10 & 100.0 & 100.0 &  &  &  &  &  &  &
\end{array}
\]

FACT SAMPLE RUN NO. 2 -- PROFILE IN MINS AND MINS/SEC WITH TWO POINT LAYER.

\[
\begin{array}{cccccccc}
0.0 & 0.0 & 0.0 & 67.25 & 153.24 & 76.20 & 1579.7 & 88.39 & 1525.8 \\
0.01 & 0.01 & 0.01 & 154.47 & 1514.2 & 1516.8 & 237.73 & 1509.9 \\
0.02 & 0.02 & 0.02 & 1509.5 & 1449.7 & 390.12 & 1496.6 & 408.41 & 1490.0 \\
0.03 & 0.03 & 0.03 & 1491.1 & 1488.7 & 342.92 & 1486.7 & 612.62 & 1483.5 \\
0.04 & 0.04 & 0.04 & 1482.5 & 1481.2 & 483.40 & 1481.2 & 899.17 & 1481.5 \\
0.05 & 0.05 & 0.05 & 1412.1 & 1408.0 & 1480.96 & 1480.9 & 1600.12 & 1480.7 \\
0.06 & 0.06 & 0.06 & 1349.7 & 1404.39 & 1491.1 & 2499.26 & 1498.1 & 2999.09 & 1505.9 \\
0.07 & 0.07 & 0.07 & 1235.57 & 1525.47 & 1547.8 &  &  &  & \\
0.08 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.09 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.10 & 100.0 & 100.0 &  &  &  &  &  &  &
\end{array}
\]

FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.

\[
\begin{array}{cccccccc}
0.0 & 0.0 & 0.0 & 67.25 & 153.24 & 76.20 & 1579.7 & 88.39 & 1525.8 \\
0.01 & 0.01 & 0.01 & 154.47 & 1514.2 & 1516.8 & 237.73 & 1509.9 \\
0.02 & 0.02 & 0.02 & 1509.5 & 1449.7 & 390.12 & 1496.6 & 408.41 & 1490.0 \\
0.03 & 0.03 & 0.03 & 1491.1 & 1488.7 & 342.92 & 1486.7 & 612.62 & 1483.5 \\
0.04 & 0.04 & 0.04 & 1482.5 & 1481.2 & 483.40 & 1481.2 & 899.17 & 1481.5 \\
0.05 & 0.05 & 0.05 & 1412.1 & 1408.0 & 1480.96 & 1480.9 & 1600.12 & 1480.7 \\
0.06 & 0.06 & 0.06 & 1349.7 & 1404.39 & 1491.1 & 2499.26 & 1498.1 & 2999.09 & 1505.9 \\
0.07 & 0.07 & 0.07 & 1235.57 & 1525.47 & 1547.8 &  &  &  & \\
0.08 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.09 & 100.0 & 100.0 &  &  &  &  &  &  & \\
0.10 & 100.0 & 100.0 &  &  &  &  &  &  &
\end{array}
\]

THE RESULTING FACT OUTPUT APPEARS ON THE FOLLOWING PAGES
**PLOT SAMPLE RUN NO. 2 -- PROFILE IN MTS AND MTS/SEC WITH TWO POINT LAYER.**

**SOURCE DEPTH = 455.0 FT. RECEIVED DEPTH = 18643.7 FT.**

**ARRIVAL STRUCTURE -- ANGLE VS. RANGE**

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<tr>
<th></th>
<th>0.0</th>
<th>12.0</th>
<th>24.0</th>
<th>36.0</th>
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<th>72.0</th>
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</tbody>
</table>

[Diagram of data points and graph]
PACT SAMPLE RUN NO. 2 -- PROFILE IN GTS AND NYST/SC WITH TWO POINT LAYER.

**SOURCE DEPTH = 995.0 FT, RECEIVED DEPTH = 124.5 FT**

**GEOLOGICAL STRUCTURE -- ANGLE VS. RANGE**

<table>
<thead>
<tr>
<th>0.0</th>
<th>10.0</th>
<th>20.0</th>
<th>30.0</th>
<th>40.0</th>
<th>50.0</th>
<th>60.0</th>
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<th>80.0</th>
<th>90.0</th>
<th>100.0</th>
<th>110.0</th>
<th>120.0</th>
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<td></td>
</tr>
</tbody>
</table>

**AEROD**

**GEO**

**HIS**

**FAC**

**FAC**

**FAC**
| Depth (ft) | T (°C) | S (psu) | C (g/l)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>0.0000</td>
<td>0.6000</td>
<td>14.9861</td>
<td>49.7483</td>
</tr>
<tr>
<td>12.0000</td>
<td>0.6000</td>
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<td>49.7483</td>
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F-OT SAMPLE RUN NO. 5 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.
FACT SAMPLE ORG. No. 3 - PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLETS.

SOURCE DEPTH = 46.4 FT. RECEPTIVE DEPTH = 621.3 FT

LEGEND: 17 ft. = T.

0.0 12.0 24.0 36.0 48.0 60.0 72.0 84.0 96.0 108.0 120.0 132.0 144.0 156.0 168.0 180.0 192.0 204.0 216.0

AESD
FACT SAMPLE RUN NO. 3 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLET.

SOURCE DEPTH = 213.0 FT, RECEIVED DEPTH = 665.0 FT

LEGEND:
- 153 Hz. SEC = °
- 158 Hz. SEC = °
- 163 Hz. SEC = °
- 168 Hz. SEC = °
- 173 Hz. SEC = °
- 178 Hz. SEC = °
- 183 Hz. SEC = °

AESO

5-37
THE FOLLOWING PAGES CONTAIN A COMPLETE FORTRAN COMPILATION
ON THE CDC 6600 OF ALL ROUTINES WHICH COMPOSE THE AERO FACT
PACKAGE.

THE AERO DESIGNATION FOR THIS PARTICULAR VERSION IS--

FACTA00PL9C

ALL INQUIRIES REGARDING THE CODE SHOULD REFER TO THIS DESIGNATION,
AND, IF APPLICABLE, THE INDIVIDUAL CARD IDENTIFIERS WHICH APPEAR
AT THE RIGHT OF EACH LINE OF CODE.

MACHINE-READABLE SOURCE CODE, EITHER ON CARDS, OR IN SEVEN- OR
NINE-TRACK MAGNETIC TAPE FORMAT, IS AVAILABLE UPON WRITTEN
REQUEST TO AERO.

IT IS EXPECTED THAT UPDATED VERSIONS OF FACT WILL CONTINUE TO BE
DEVELOPED BY AERO. ORGANIZATIONS WHICH HAVE RECEIVED MACHINE-
READABLE DISTRIBUTIONS WILL AUTOMATICALLY BE NOTIFIED AS TO THE
AVAILABILITY OF THESE UPDATED VERSIONS AS THEY APPEAR.
PROGRAM TLOSS

DIMENSION TITLE(4), EIF(1), EIF(2), EIF(3), EIF(4), EIF(5),
      EIF(6), EIF(7), EIF(8), EIF(9), EIF(10)

DATA (RINT, INT, INT, INT, INT, INT)

PROGRAM TLOSS IS THE INPUT/OUTPUT DRIVER FOR THE FACTYL
      TRANSMISSION LOSS SUMMATION.
      TLOSS READS INPUT DATA, CALLS FACTYL, AND PRINTS, OR PLOTS,
      ON BOTH PRINTS AND PLOTS THE RESULTS.
      CYCLES ON SOURCE/RECEIVER DEPTH COMBINATIONS
      AND ON COMBINED INPUT NOISES.
      PRINTS THE SYMBOLS FOR PLOTTING.

READ AND PRINT FIRST CARD -- 40 -- 88 COLUMNS OF TITLE INFORMATION

$ READ (1,160) TITLE(I), I = 1,60
$ FORMAT (160)

IF (IFIRST.GE.1) GOTO 150
WRITE (1,160) TITLE(I), I = 1,60
$ FORMAT (160)

READ AND PRINT SECOND CARD

C = NO. OF POINTS IN PROFILE
C = FOR VELOCITY VERSUS DEPTH
C = FOR TEMP. AND SALINITY VERSUS DEPTH
C = INDEX OF LAYER DEPTH IN PROFILE
C = ALL FOR NO LAYER PRESENT
C = N FOR HALF CHANNEL MODEL
C = BOTTOM LOSS INDEX (F-5)
C = WAVE HEIGHT IN FEET
C = PLOT/PRINT FLAG
C = PRINT ONLY
C = PLOT ONLY
C = PRINT AND PLOT
C = SEPARATE PLOTS FOR EACH FREQUENCY
C = ONE PLOT FOR ALL FREQUENCIES
C = DO NOT COMPUTE ARRIVAL STRUCTURE
C = COMPUTE AND PLOT ARRIVAL STRUCTURE

END
PROGRAM FLOSS

READ 16,20(1) 16, 18, IN, PLC, YCR
20 FORMAT (16I9)
C
WRITE 16,20(1) 16, 18, IN
90 FORMAT (16.6, 41.6, 1)
C
IF (166.21) ICR = 0
IF (166.21) ICR = 0
C
CALL READ PROFILE CARDS, CONVERT TO
ENGLISH UNITS IF REQUIRED, AND PRINT OUT RESULTS.
C
CALL READ IN. 4, C
C
READ AND PRINT RANGE CARD
C
NAME = NO. OF RANGE POINTS (E.G. 2981)
3440 = INCREMENTAL RANGE IN M.M.
C
READ 16,444(1), DRMM
444 FORMAT (13.9, 43.2)
C
WRITE 16,444(1), DRMM
45 FORMAT (13.9, 43.2, 7)
C
NAME = DRMM = 678, 1
C
READ FREQUENCY CARD, COUNT FREQUENCIES,
AND PRINT FREQUENCIES IN HERTZ.
C
READ 16,464(1) (F11, 1 = 1.6)
464 FORMAT (16F6.2)
C
IF (116.81) ICR = 11.6
IF (116.81) ICR = 11.6
C
IF ICR = 11.6
C
100 CONTINUE
C
WRITE 16,499(1) (F11, 1 = 1.6)
499 FORMAT (11, 49.2, 7)
C
100 CONTINUE
C
READ DEPTHS AND COMPLEMENT VALUES
C
S = SOURCE DEPTH IN FEET (FOR END OF S-A CARDS FLAG)
R = RECEIVER DEPTH IN FEET
110
program 9T55

C IF interpolation IVF.B) GO TO 359
C
C COMPUTE RANGE INDEX FOR THIS RANGE
C
C 0 = RND0000 = 4999
C
C ROUND ANGLE TO NEAREST INTEGER (DISREGARD IF .GT. 36 DEGREES)
C
C
210 IF IF.I.GT.36 GO TO 223
  THETA + 5HTHETA + (36/THETA)
C
C PUT ANGLE IN TL OF INDEX ; IF NOT ALREADY THERE
C
C
215 GO TO tl - 1,6
  IF TRIG.I.EQ.ZERO) GO TO 329
  IF TRIG.I.EQ.ONE) GO TO 320
  TRIG.I = TRIG.I
C
220 GO TO 379
B39 CONTINUE

C GO TO 329
C
C
C 399 CONTINUE
C
C CALL THREAD AND PLOTLL TO PLOT ARRIVAL STRUCTURE
C
C
250 IF IF.I.EQ.ZERO) GO TO 49
  CALL THREAD(L,5,H,2,49)
  CALL PLOTLL(L,H,W,2,49

259 GO TO 63

C
F49
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Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

   Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

   DISTRIBUTION STATEMENT A: Approved for Public Release; Distribution is unlimited.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

   BRIAN LINK
   By direction
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