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THE FACT MODEL VOLUME II

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OCEAN DATA SYSTEMS, INC.

and

C. W. STOFFORD

NAVY ENVIRONMENTAL SUPPORT DETACHMENT

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NUMERICAL MODELING OF TIDE
NEAR OCEAN SURFACE
AND ENVIRONMENTAL EFFECTS
ON STATIONARY OBJECTS

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

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y 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 describes 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

*C. L. Baker, FACT Transmission Loss Model Development for Acoustic Environmental Support Detachment - Final Report, Ocean Data Systems, Inc., June 30, 1973 on Contract N00014-73-C-0131.

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 HFCCTL, are designed specifically to approximate the results of a complete FACT solution in shallow-water transmission and half-channel transmission respectively. Subroutine HFCCTL 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, K1, is used hereafter to designate the source (or source depth); the other index, K2, 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 K1 to K2 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.

^{*} Wentzel-Kramers-Brillouin approximation - see L. M. Brekhovskikh, Waves in Layered Media, Academic Press, New York, 1960b, pp 452-3.

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 values at the specified ranges and frequencies.

If, in addition, arrival information is desired, the input 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.

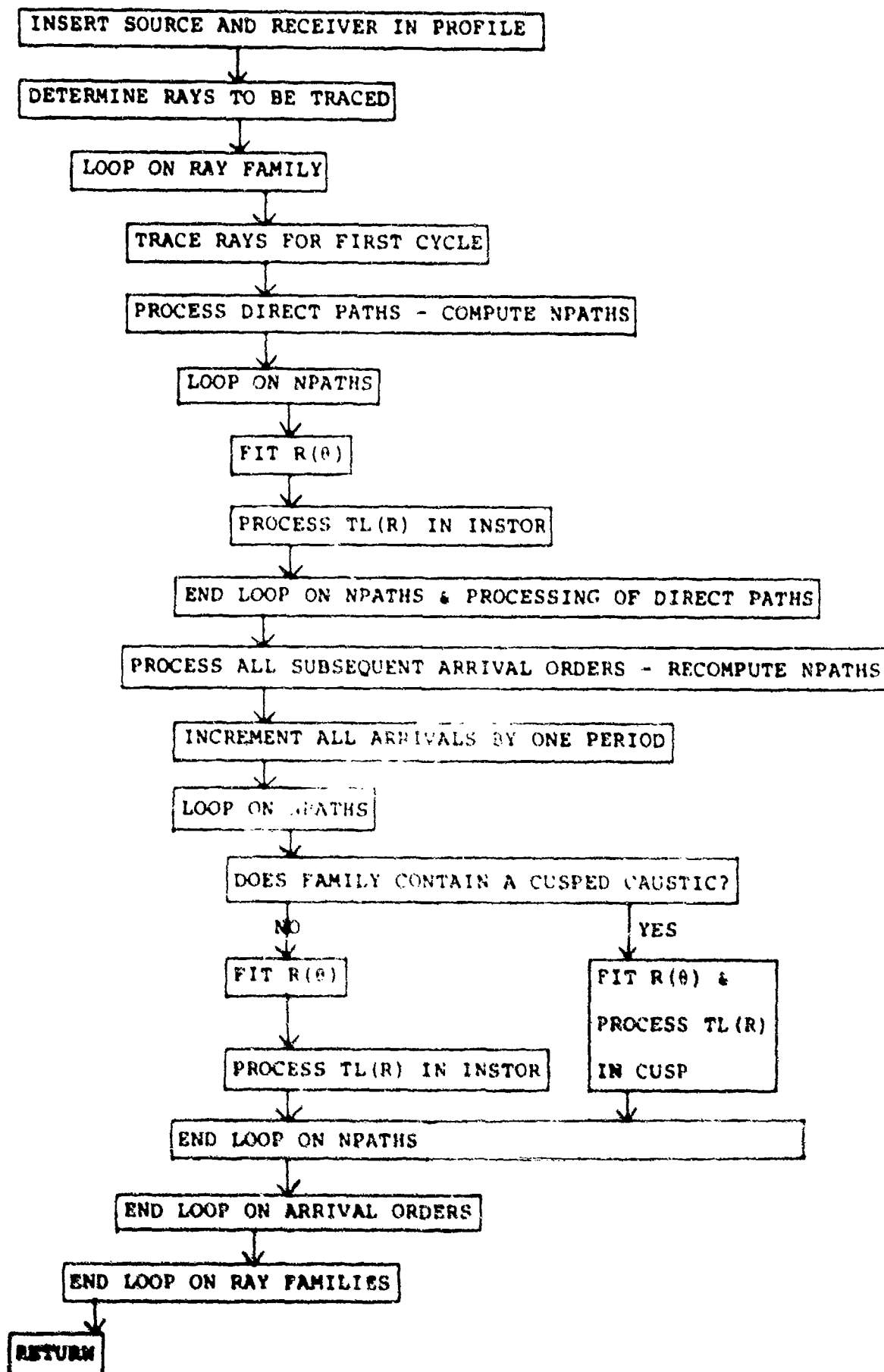


Figure 4-1. OVERVIEW OF PROGRAM FLOW IN FACETL

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

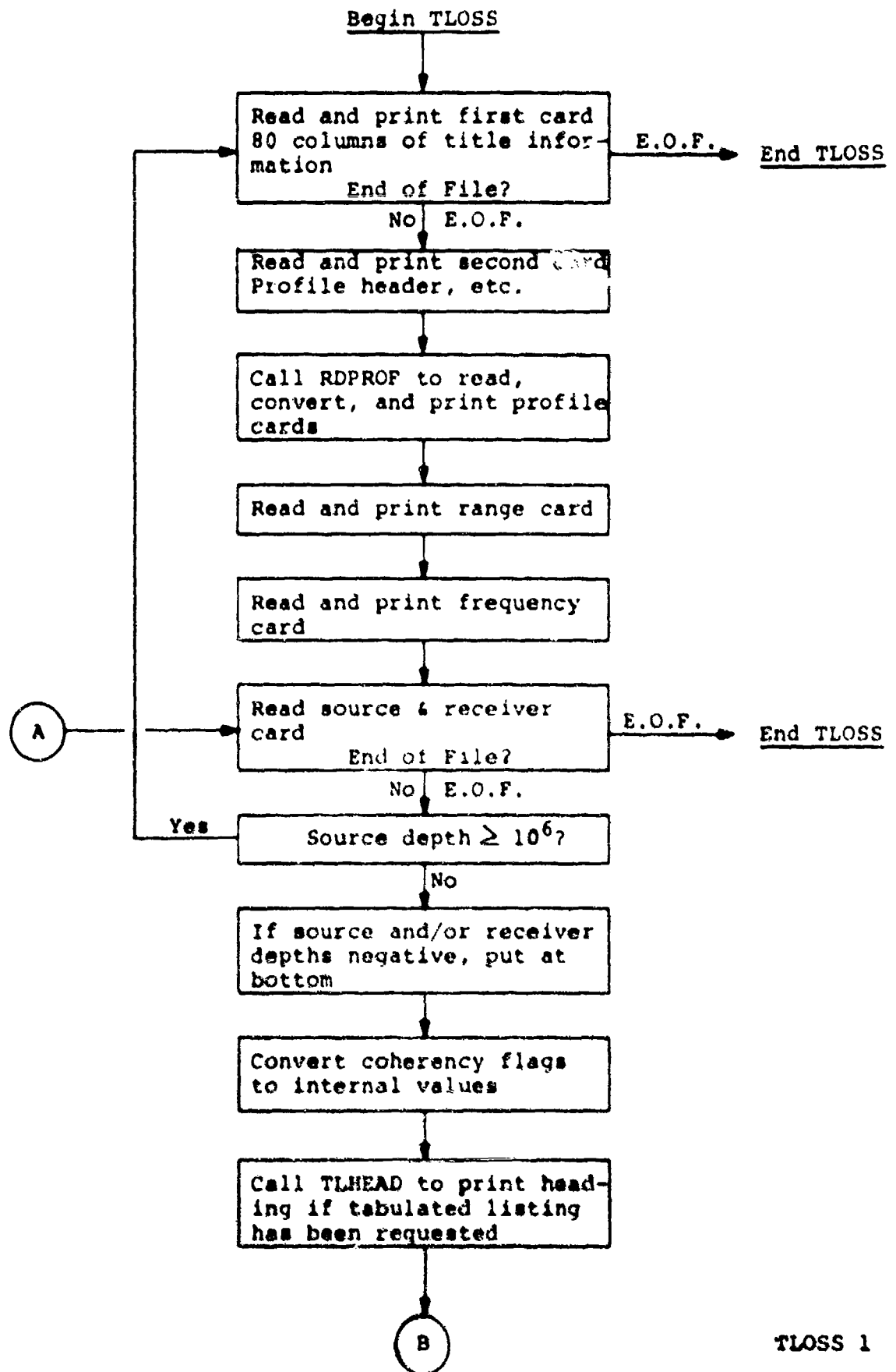
The formats for tabulated and plotted printer outputs are detailed in the FACT Handout, pages 5-14 through 33. See also subroutine TLHEAD, and PLOTTL, pages 4-19 and 20. TLOSS also prints the data on the input cards as they are read.

COMMON USAGE

None

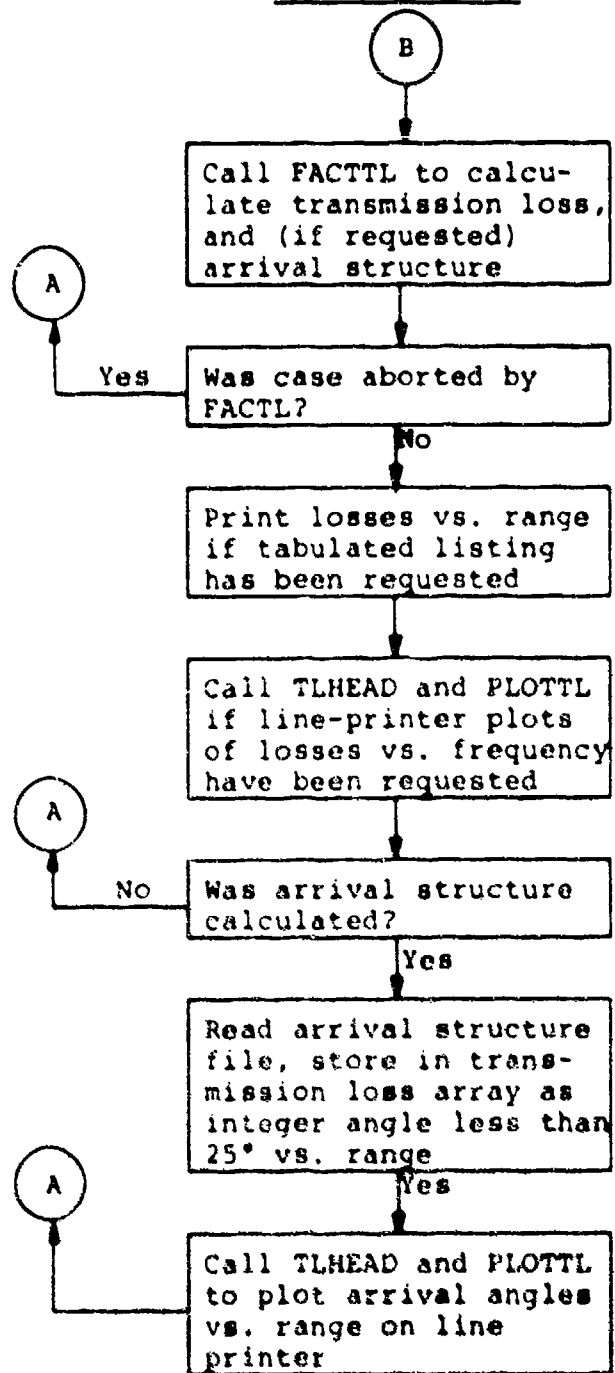
NOTE

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



TLOSS 1

Continue TLOSS



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 ± 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
and velocities as in 2).

PARAMETER OUTPUTS

Z Array (50) of Profile Depths, feet
C Array (50) of Profile Velocities, ft/sec

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

TITLE	80 Character Title (8 words, 10 char/word)
S	Source Depth, feet
R	Receiver Depth, feet
IF	Array (6) of Frequencies, Hz
JC	Array (6) of Coherency Flags, (0,1 or 2)
IX	Array (6) of Characters to be Used for Plotting
NF	No. of Frequencies
ITYP	Heading Type, 0,1,2

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

PLOTTL (Cont'd)

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 $\neq 0$
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
	FREQK	Array (6) of frequencies in KHz
	RANGE	Array (250) 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

FACTTL (Cont'd)

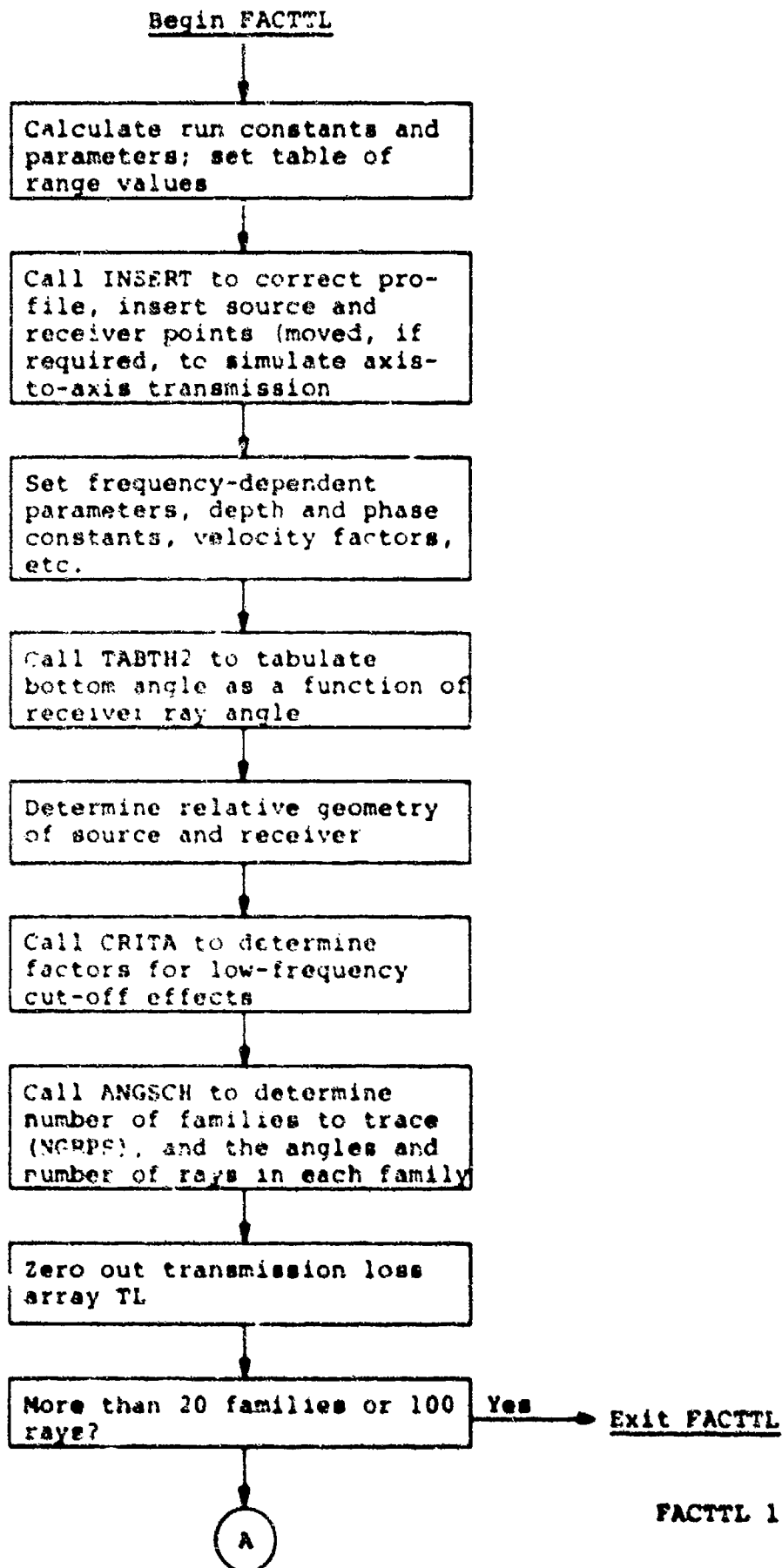
	IBTYP	FNWC bottom type
	IFLAG	Array (6) of coherency flags
	DK	Array (2,6) of semi-coherent phase factors
/RAYZER/	IREFRZ	Flag indicating grazing family
	THETMB	Critical angle for bottom type, radians
	THBINC	Incremental angle for bottom rays, radians
/INIT/	AK	Vertex velocity of ray to be traced
	SINTHO	Sine of initial angle of ray to be traced
	IML	Index of mixing layer in input profile
/INPUTS/	IRAY	Number of rays (in TH) in family being processed (≤ 100)
	KP	Index (in R) of arrival being processed (1-4)
	NP	Index of path being processed (1-4)
	NORDER	Arrival order being processed
	NG	Index of group (family) being processed (≤ 20)
	IPAR	Flag for type of family being processed (1 or 2)
	R	Array (100,4) of arrival ranges vs. angle and arrival, ft
	TH	Array (100) of ray angles in family being processed, rad
/FITS/	THF	Array (3) of angles of fit of R vs. θ
	A	Array (5) of coefficients of fit

FACTTL (Cont'd)

	XMIN	Ordinate value for min value of fit
	XMAX	Ordinate value for max value of fit
	RMIN	Minimum value of range in fit
	RMAX	Maximum value of range in fit
	RANMIN	Minimum range value to be fit
/CUSPCM/	CCUSP	Velocity at cusp depth, ft/sec
/AUTCOH/	FNMIN	Min no. of range pts/surf image cycle = 8/3
	FNMAX	Max no. of range pts/surf image cycle = 6
	FNXI	Reciprocal of FNMAX-FNMIN
	FNCYC	Array (2,6) of cycles of phase difference

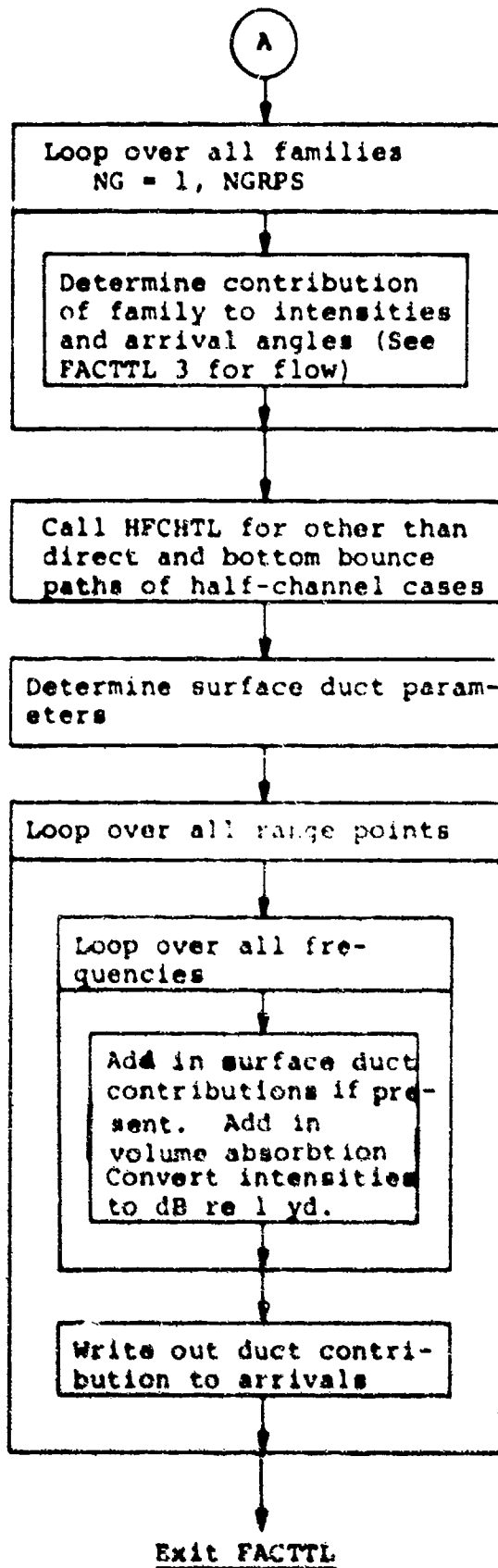
NOTE

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 transmittance 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.

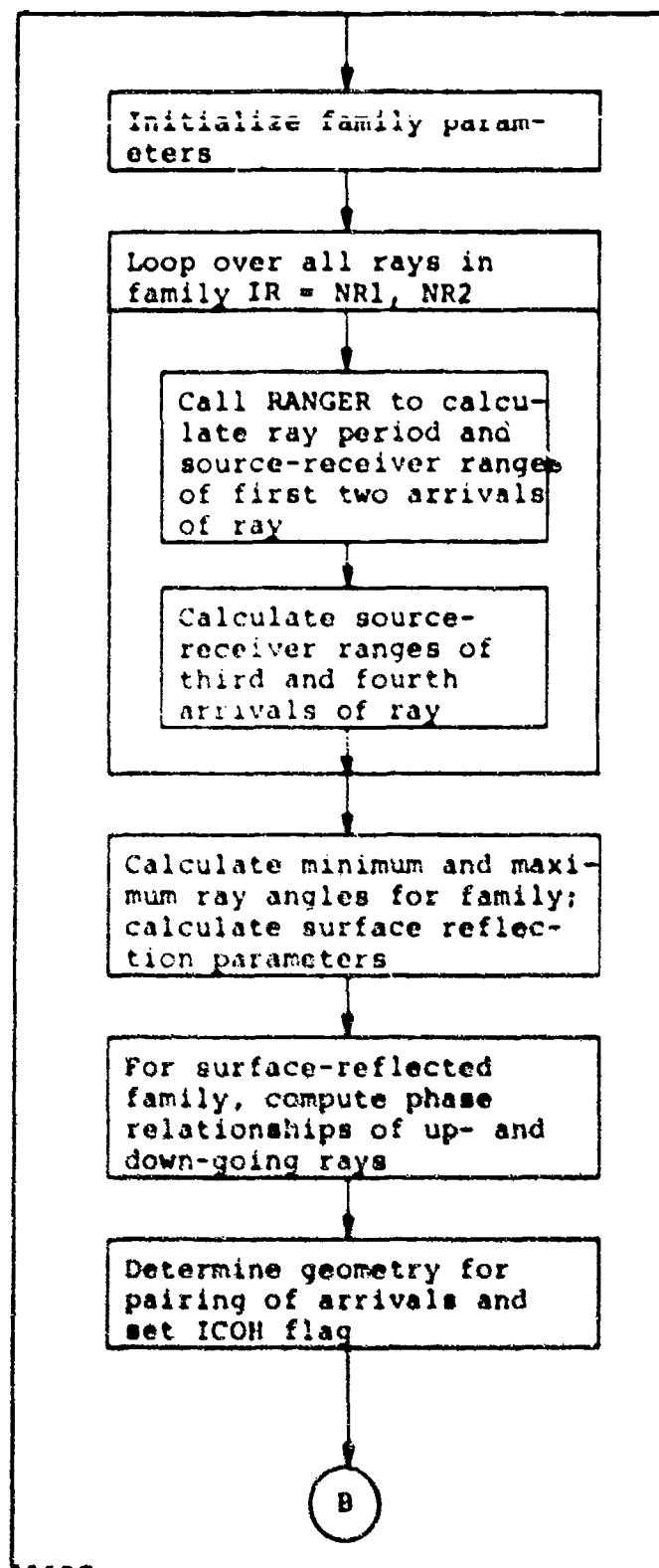


FACTTL 1

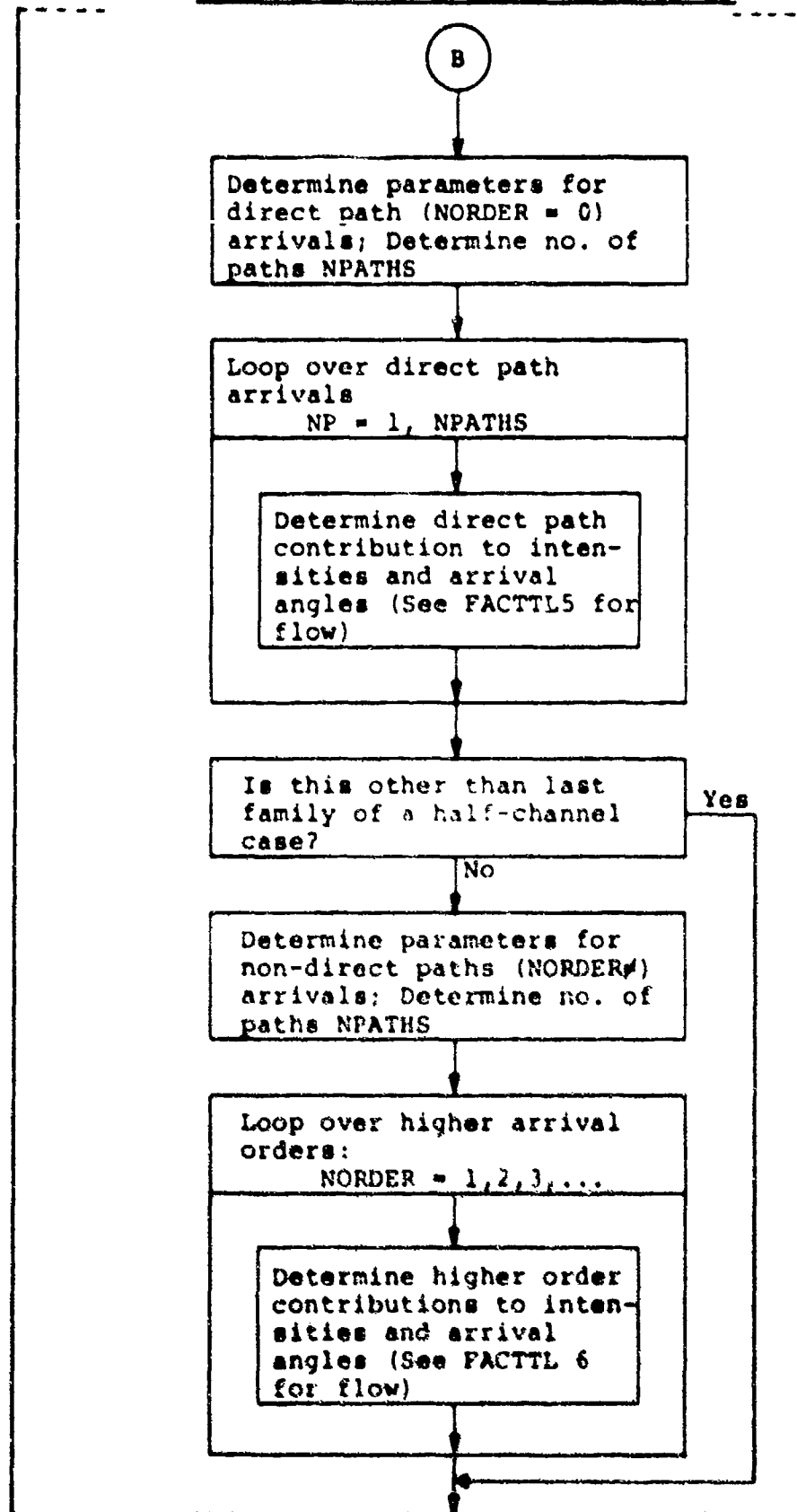
Continue FACTTL



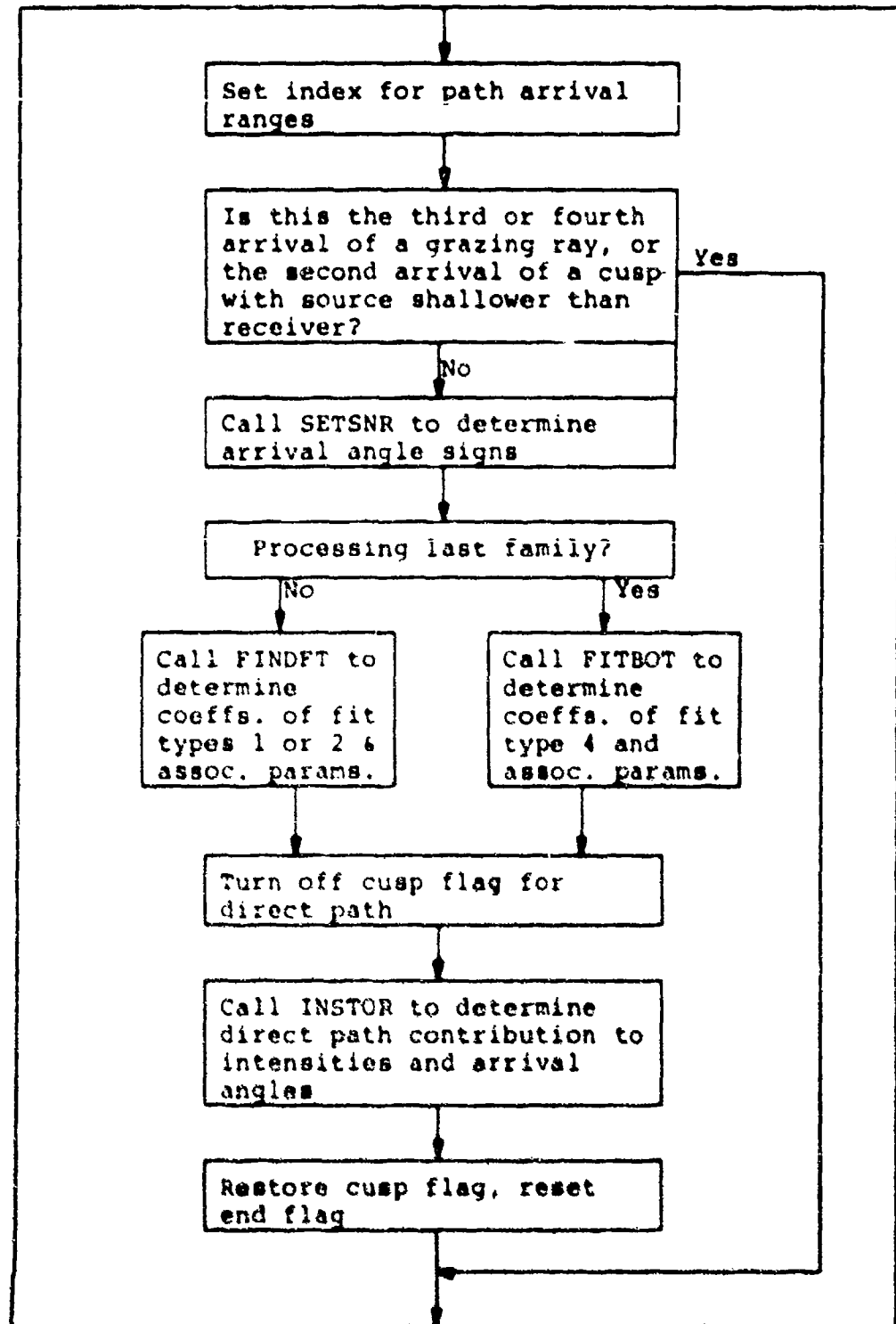
FACTTL - Loop on Families



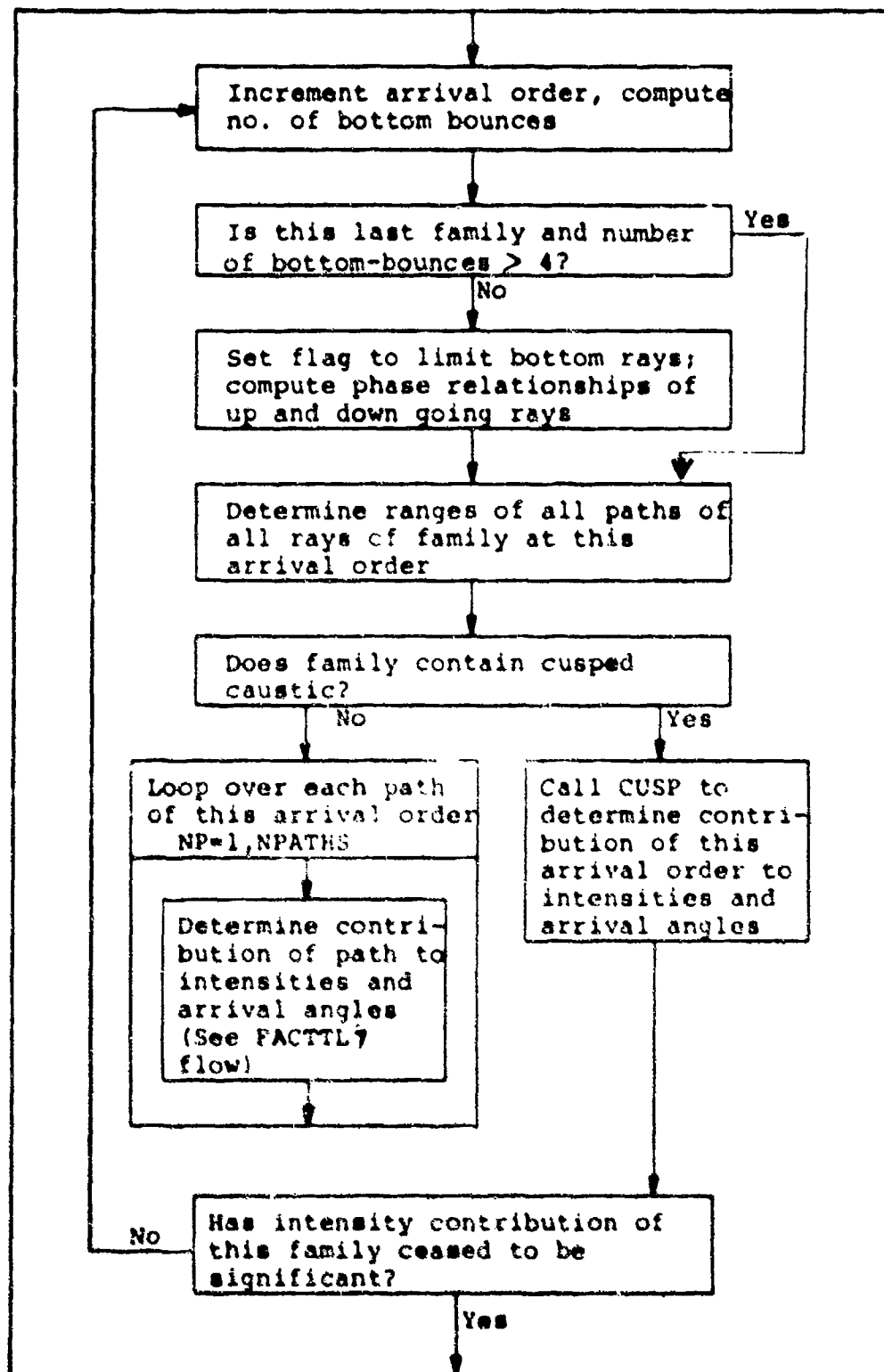
Continue FACTTL - Loop on Families



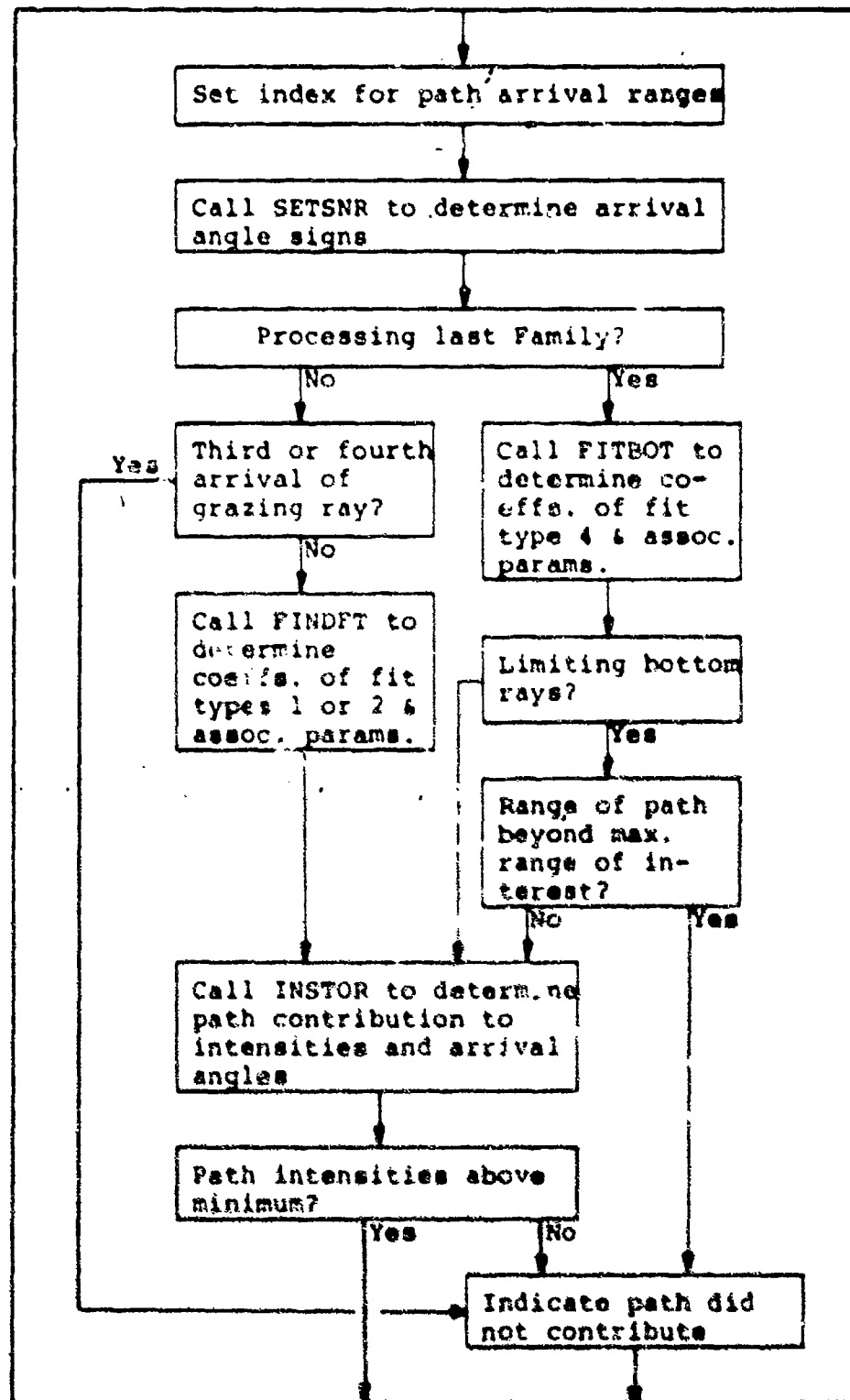
FACTTL - Loop on direct path arrivals



FACTTL - Loop on higher arrival orders



FACTTL - Loop on paths of higher arrival orders



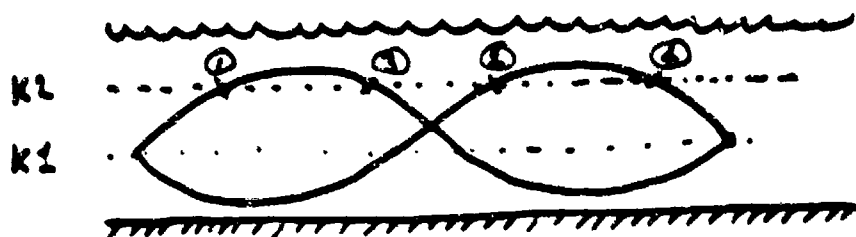
RECEIVER DEPTH-K2	SOURCE DEPTH - K1		
	AT SURFACE	IN BETWEEN	ON BOTTOM
AT SURFACE	--	4	7
IN BETWEEN	2	1	3
ON BOTTOM	6	5	--

FACTTL - Setting Of Geometry Indicator KFLAG

PATH GEOMETRY				NORDER = 0				NORDER = 1, 2, 3...							
FLAG	ICON	NPATHS	IPF (NP)		TEMP	NPATHS	IPF (NP)				IONE (NP)				
			1	2			1	2	3	4		1	2	3	4
K:	0	2	①	③	0	4	②	④	①	③	1	1	0	0	
1: DEEPER	2	1	①	-	2	2	②	①	-	-	1	0	-	-	
THAN K2	3	1	①	-	2	1	②	-	-	-	1	-	-	-	
K2	0	2	②	②	0	4	④	③	②	①	1	1	0	0	
1: DEEPER	1	1	②	-	1	2	④	②	-	-	1	0	-	-	
THAN K1	3	1	②	-	1	1	④	-	-	-	1	-	-	-	
K1 SURFACE	0	1	①	-	0	2	③	①	-	-	1	0	-	-	
2: K2 BELOW	2	1	①	-	0	1	③	-	-	-	1	-	-	-	
K1 BOTTOM	0	2	①	③	0	2	①	③	-	-	0	0	-	-	
3: K2 ABOVE	2	1	①	-	2	1	①	-	-	-	0	-	-	-	
K2 SURFACE	0	1	①	-	0	2	②	①	-	-	1	0	-	-	
4: K1 BELOW	1	1	①	-	0	1	②	-	-	-	1	-	-	-	
K2 BOTTOM	0	2	②	①	0	2	②	①	-	-	0	0	-	-	
5: K1 ABOVE	1	1	②	-	1	1	②	-	-	-	0	-	-	-	
K1 SURFACE	0	1	①	-	0	1	①	-	-	-	0	-	-	-	
6: K2 BOTTOM	0	1	①	-	0	1	①	-	-	-	0	-	-	-	
K1 SURFACE	0	1	①	-	0	1	①	-	-	-	0	-	-	-	
7: K1 BOTTOM	0	1	①	-	0	1	①	-	-	-	0	-	-	-	
K2 SURFACE	0	1	①	-	0	1	①	-	-	-	0	-	-	-	

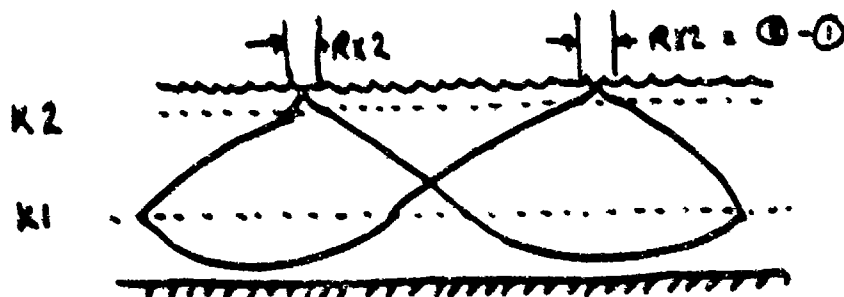
FACITL - Indices for Determination of Arrival Ranges
 ①, ② etc. refer to path subscript values in R (angle,path) array

KFLAG = 1
(K1 deeper than K2)

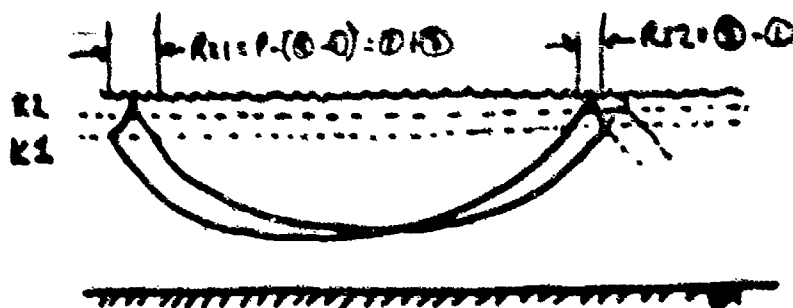


ICOH = 0

(ICOH = 1 NOT POSSIBLE)



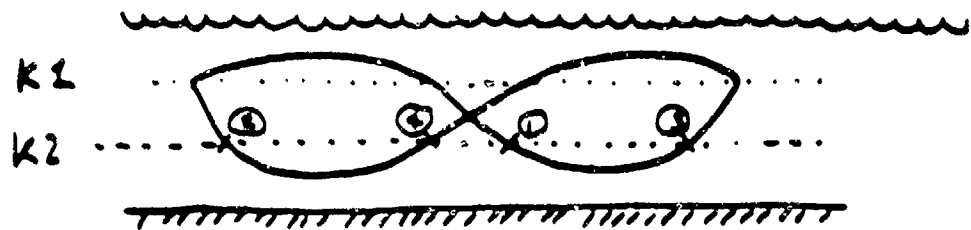
ICOH = 2



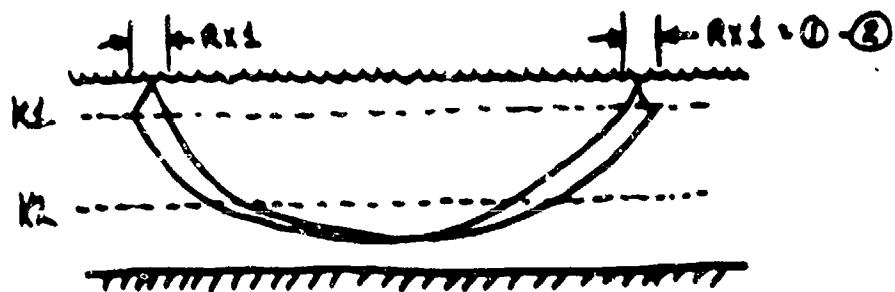
ICOH = 3

FACTTL - Coherence Geometry for Combining Ray Paths
1 of 8

$KFLAG = 1$
 (K2 deeper than K1)

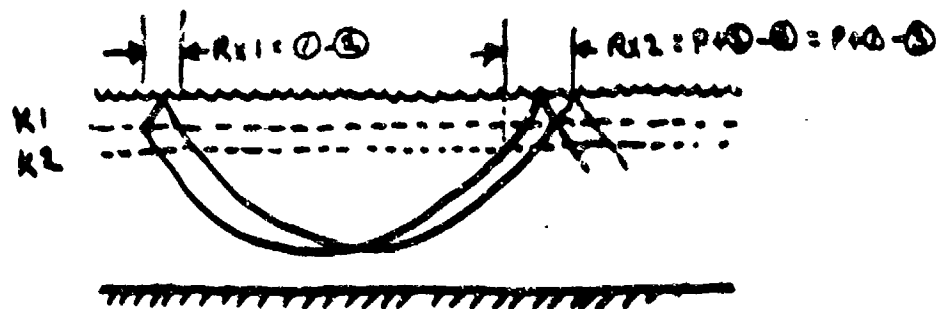


ICOH = 0



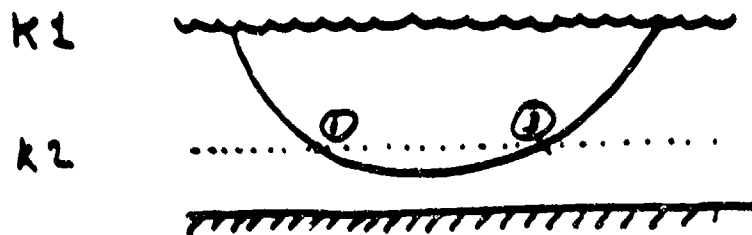
ICOH = 1

(ICOH = 2 NOT POSSIBLE)

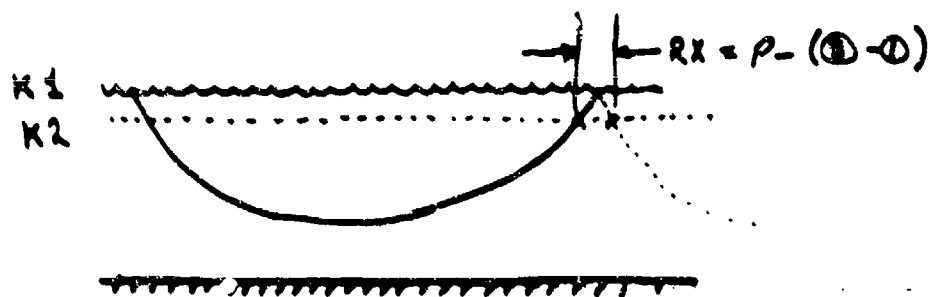


ICOH = 3

KFLAG = 2



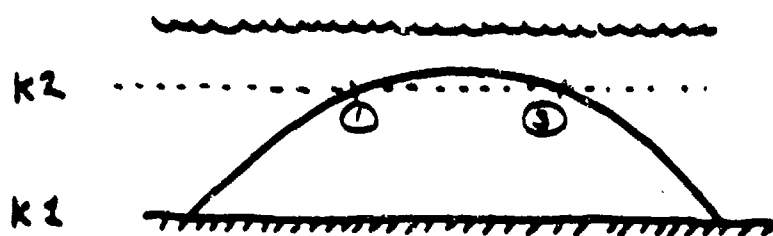
ICOH = 0



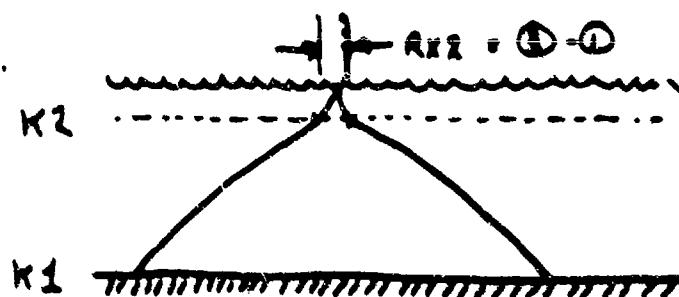
ICOH = 2

FACTTL - Coherence Geometry for Combining Ray Paths
3 of 8

KFLAG = 3



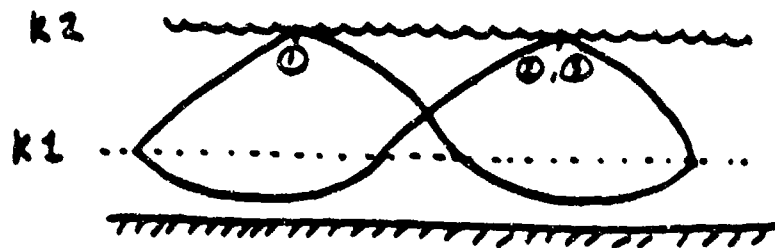
ICOH = 0



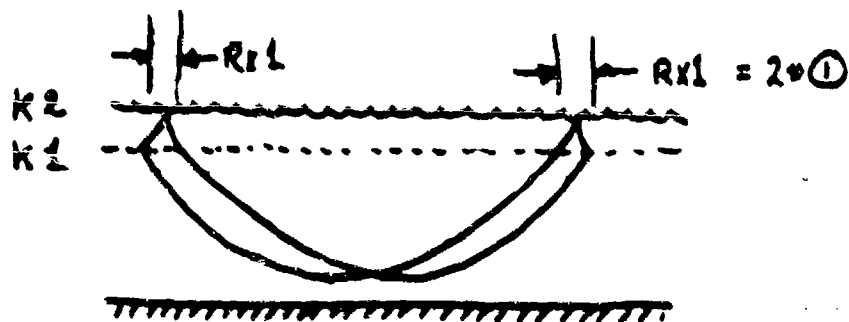
ICOH = 2

FACTTL - Coherence Geometry for Combining Ray Paths
4 of 8

KFLAG = 4



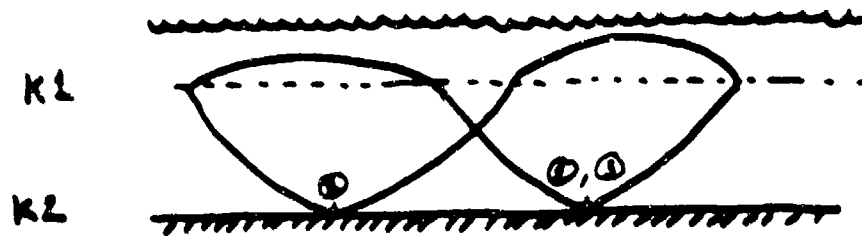
ICOH = 0



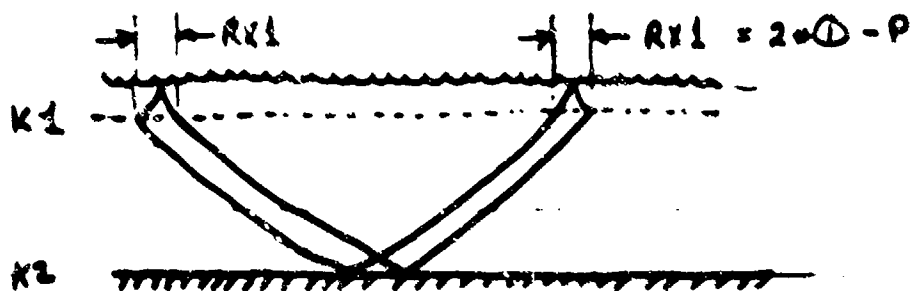
ICOH = 1

FACTTL - Coherence Geometry for Combining Ray Paths
5 of 8

$$\underline{KFLAG = 5}$$



$$ICOH = 0$$

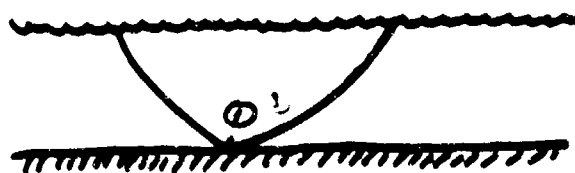


$$ICOH = 1$$

KFLAG = 6

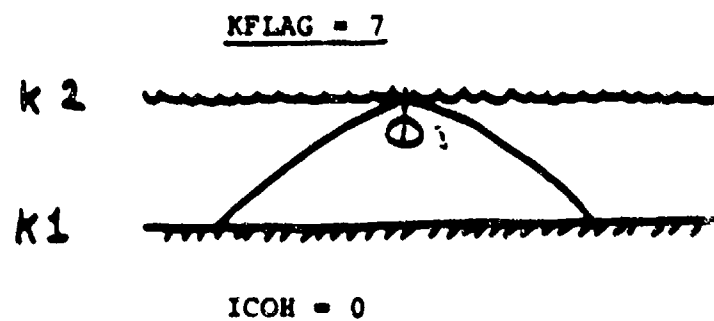
k1

k2



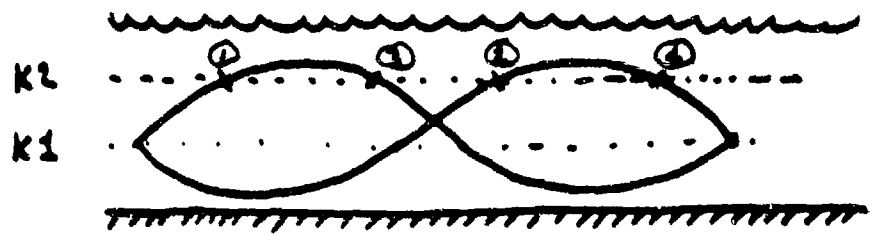
ICOH = 0

FACTTL - Coherence Geometry for Combining Ray Paths
7 of 8



FACTTL - Coherence Geometry for Combining Ray Paths
8 of 8

KFLAG = 1
(K1 deeper than K2)



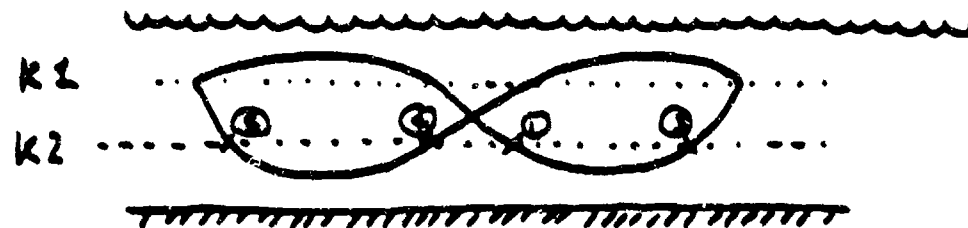
ORDERING OF RANGES FOR ICOM VALUES				
WORDER	NP	1	2	3
0	1	①	①	①
	2	②	-	-
1	1	②	②	②
	2	③	① + P	-
	3	① + P	-	-
	4	③ + P	-	-
2	1	③ + P	② + P	② + P
	2	④ + P	① + 1.P	-
	3	① + 2.P	-	-
	4	③ + 2.P	-	-
3	1	④ + 2.P	① + 2.P	② + 2.P
	2	① + 2.P	① + 3.P	-
	3	① + 3.P	-	-
	4	④ + 3.P	-	-

etc.

e + e.

FACTTL - Ray Path Range Selection
1 of 8

KFLAG = 1
(K2 deeper than K1)



		ORDERING OF RANGES FOR ILON VALUES		
NUMBER	NP	0	1	3
0	1	①	②	③
	2	①	-	-
1	1	④	④	④
	2	②	② + P	-
	3	② + P	-	-
	4	① + P	-	-
2	1	④ + P	④ + P	④ + P
	2	④ + P	④ + 2·P	-
	3	④ + 2·P	-	-
	4	① + 2·P	-	-
3	1	④ + 2·P	④ + 2·P	④ + 2·P
	2	④ + 2·P	④ + 3·P	-
	3	④ + 3·P	-	-
	4	① + 3·P	-	-

etc

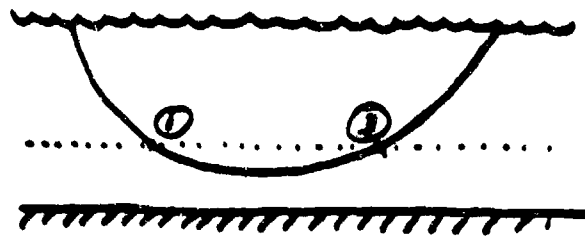
etc.

FACTTL - Ray Path Range Selection
2 of 8

KFLAG = 2

K1

K2



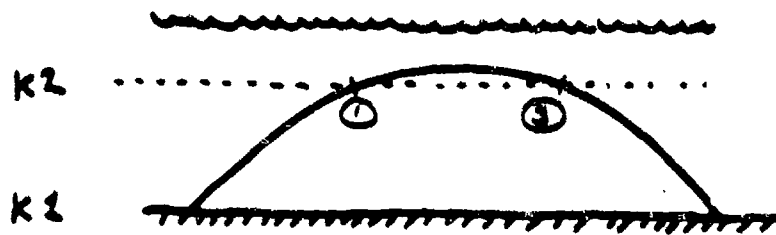
		ORDERING OF RANGES FOR ILOH VALUES	
ORDER	N P	0	2
0	1	①	①
1	1	②	②
	2	① + P	-
2	1	③ + P	③ + P
	2	① + 2 P	-
3	1	④ + 2 P	④ + 2 P
	2	① + 3 P	-

etc.

etc

FACTTL - Ray Path Range Selection
3 of 8

KFLAG = 3



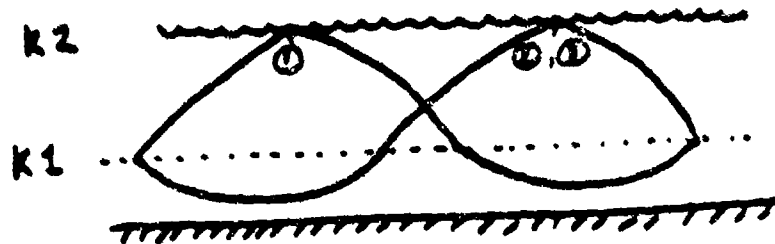
		SEQUENCE OF RANGES FOR ICON VALUES	
NUMBER	NP	0	1
0	1	①	①
	2	②	-
1	1	① + P	① + P
	2	② + P	-
2	1	① + 2·P	① + 2·P
	2	② + 2·P	-
3	1	① + 3·P	① + 3·P
	2	② + 3·P	-

etc

etc

FACTTL - Ray Path Range Selection
4 of 8

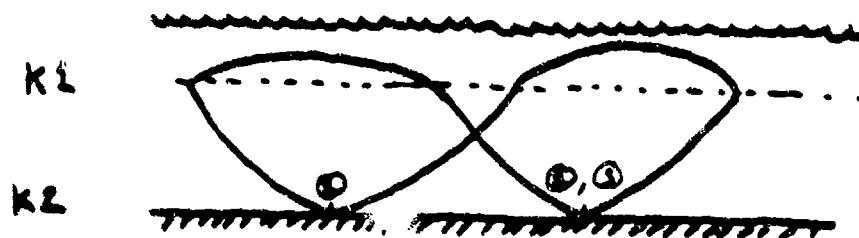
KFLAG = 4



		ORDERING OF RANGES FOR ICON VALUES	
NOORDER	NP	0	1
0	1	①	①
1	1	②	③
	2	① + P	—
2	1	② + P	③ + P
	2	① + 2 P	—
3	1	③ + 2 P	④ + 2 P
	2	① + 3 P	—

FACTTL - Ray Path Range Selection
5 of 6

KFLAG = 5

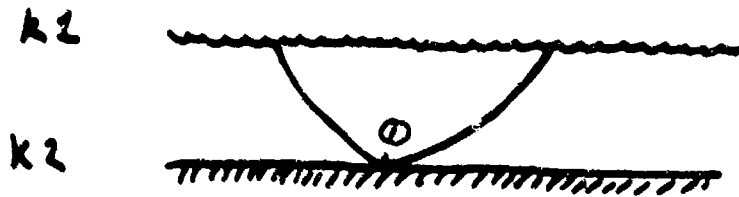


		ORDERING OF RANGES FOR ICON VALUES	
ORDER	UP	0	1
0	1	①	②
	2	①	-
1	1	② + p	③ + p
	2	① + p	-
2	1	③ + 2p	② + 2p
	2	① + 2p	-
3	1	② + 3p	③ + 3p
	2	① + 3p	-

etc.

etc.

KFLAG = 6



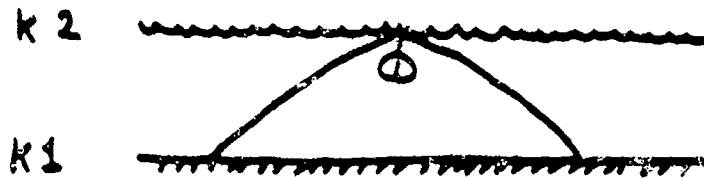
ICOH = 0

NORDER	NP	ORDERING OF RANGES
0	1	①
1	1	① + P
2	1	① + 2 · P
3	1	① + 3 · P
4	1	① + 4 · P
5	1	① + 5 · P

etc

FACTTL - Ray Path Range Selection
7 of 8

KFLAG = 7



ICOH = 0

ORDER	NP	ORDER OF RANGES
0	1	①
1	1	① + P
2	1	① + 2·P
3	1	① + 3·P
4	1	① + 4·P
5	1	① + 5·P
etc		etc

FACTTL - Ray Path Range Selection
8 of 8

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

YS	Source depth, feet	D	Bottom depth, feet
YR	Receiver depth, feet	NR	No. of range points, ≤ 250
F	Frequency, Hz	DR	Incremental range, feet
IB	Bottom type, 1-3		

SHALTL (Cont'd)

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)

YX Array (50) of profile depths, feet
CX Array (50) of profile velocities, feet per second
IPRNT Debugging print flag

COMMON INPUTS

/INIT/ IML Index of mixing layer in profile YX,CX

PARAMETER OUTPUTS

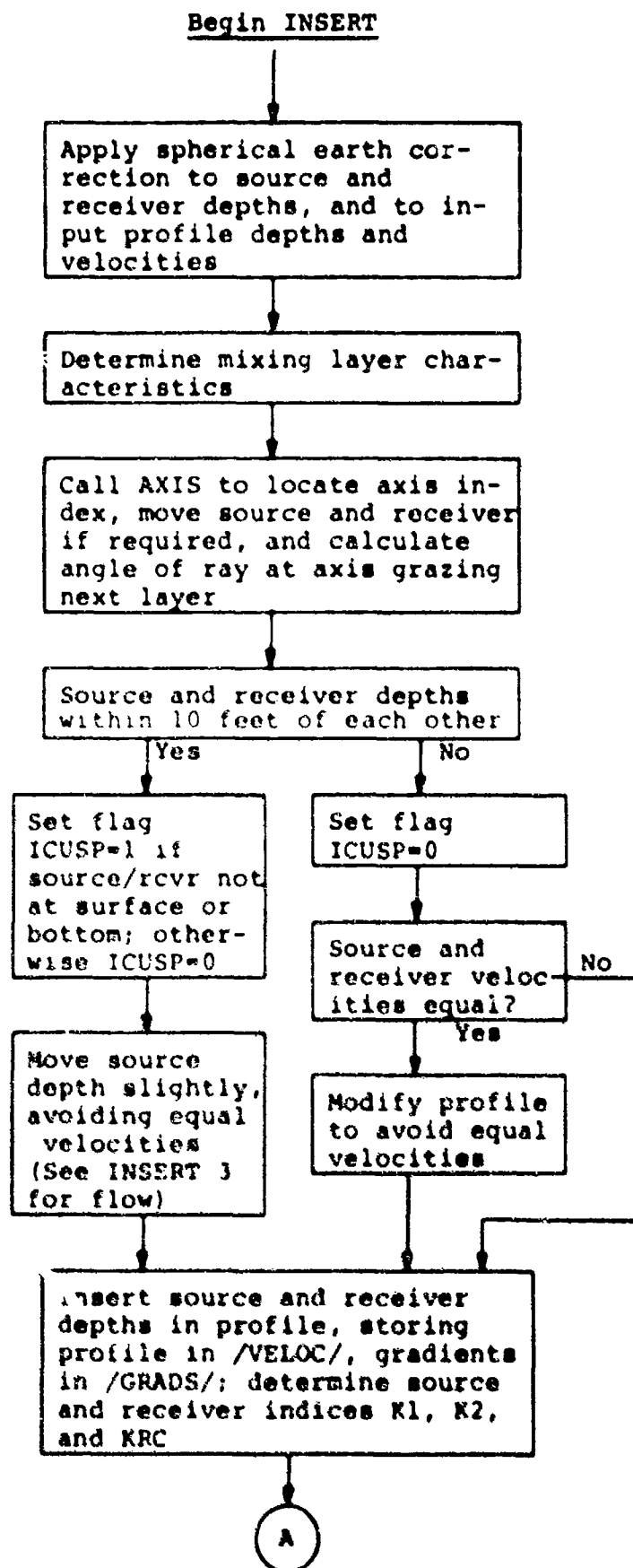
Y1 Corrected source depth, feet
Y2 Corrected receiver depth, feet
KRC Flag indicating arrival angle depth

COMMON OUTPUTS

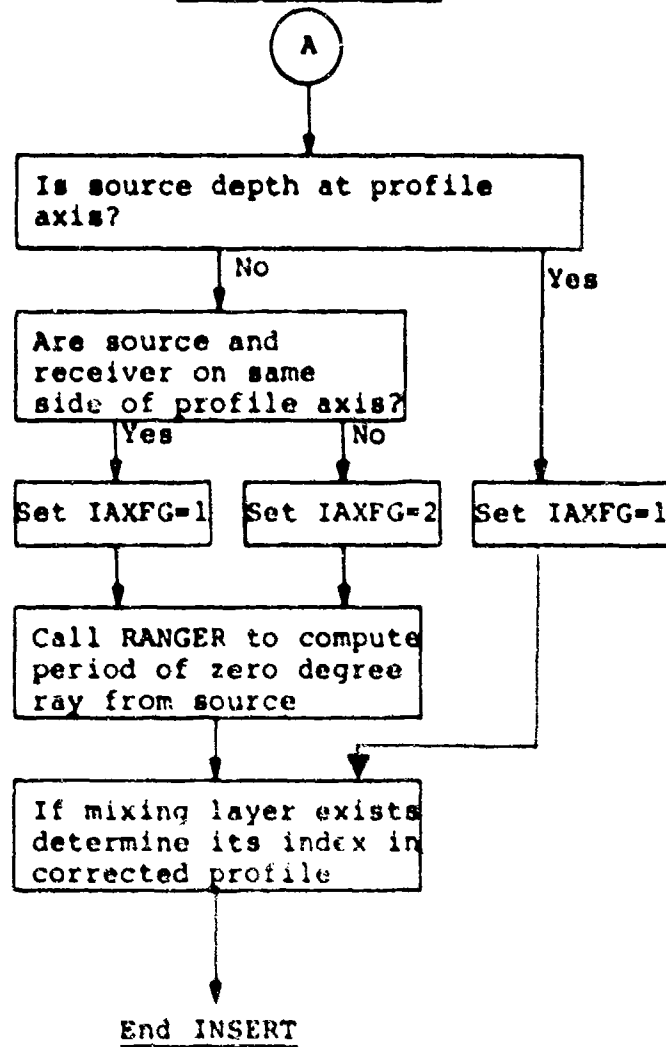
/VELOC/ NPTSP No. of points in temporary
 YPP Array (60) of corrected profile depths, feet
 CPP Array (60) of corrected profile velocities,
 feet per second
/GRADS/ G Array (60) of profile gradients, (sec^{-1})
/INIT/ K1 Index of ray tracing source in corrected
 profile
 K2 Index of ray tracing receiver 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

INSERT (Cont'd)

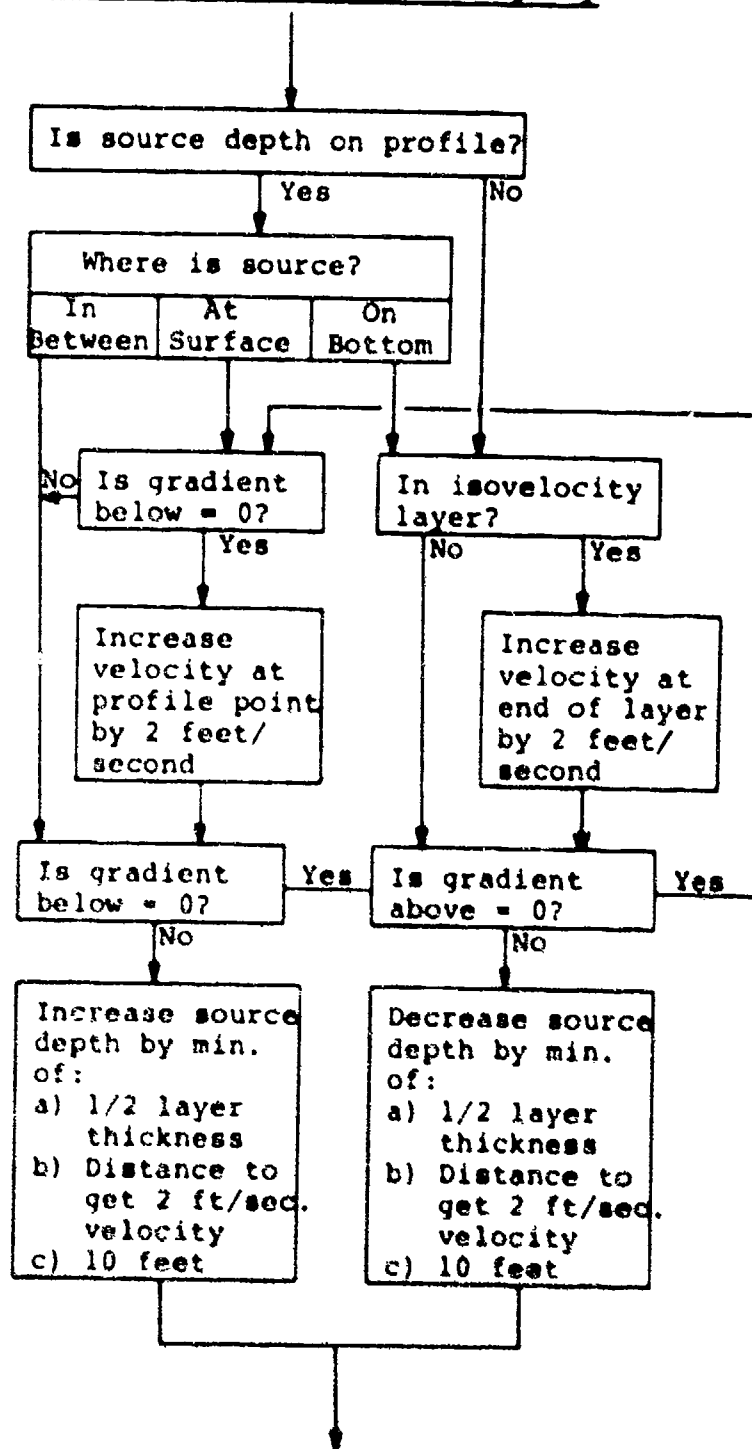
/CUSPCM/	ICUSP	Cusped caustic flag
/PERIOD/	PERO	Period of zero degree traced from K1
	IAXFG	Flag indicating source-receiver-axis geometry
	COSA	Limiting ray angle (at axis) for analytic low frequency cutoff, and its cosine
	ANGP	



Continue INSERT



INSERT - Move Source Depth Slightly



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.

AXIS (Cont'd)

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
	PERO	Period of axis ray, feet
	COSA	Limit angle at axis for analytical low-frequency cutoff, radians, and its cosine
	ANGP	
	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, θ_B , as a function of the ray angle at the receiver depth, θ_{K2} . Twenty-one equally-spaced values of θ_{K2} are tabulated, from θ_{Min} to $\pi/2$, along with the corresponding (unequally-spaced) values of θ_B . The value of θ_{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 θ_{K2}
	TH2T	Array of 21 values of θ_{K2}
	THBT	Array of 21 values of θ_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
	PQ	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
	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

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 ($=5^\circ$), 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/	NRAYS	Number of rays in all families ≤ 100 or 999
	NGRPS	Number of families of rays ≤ 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)

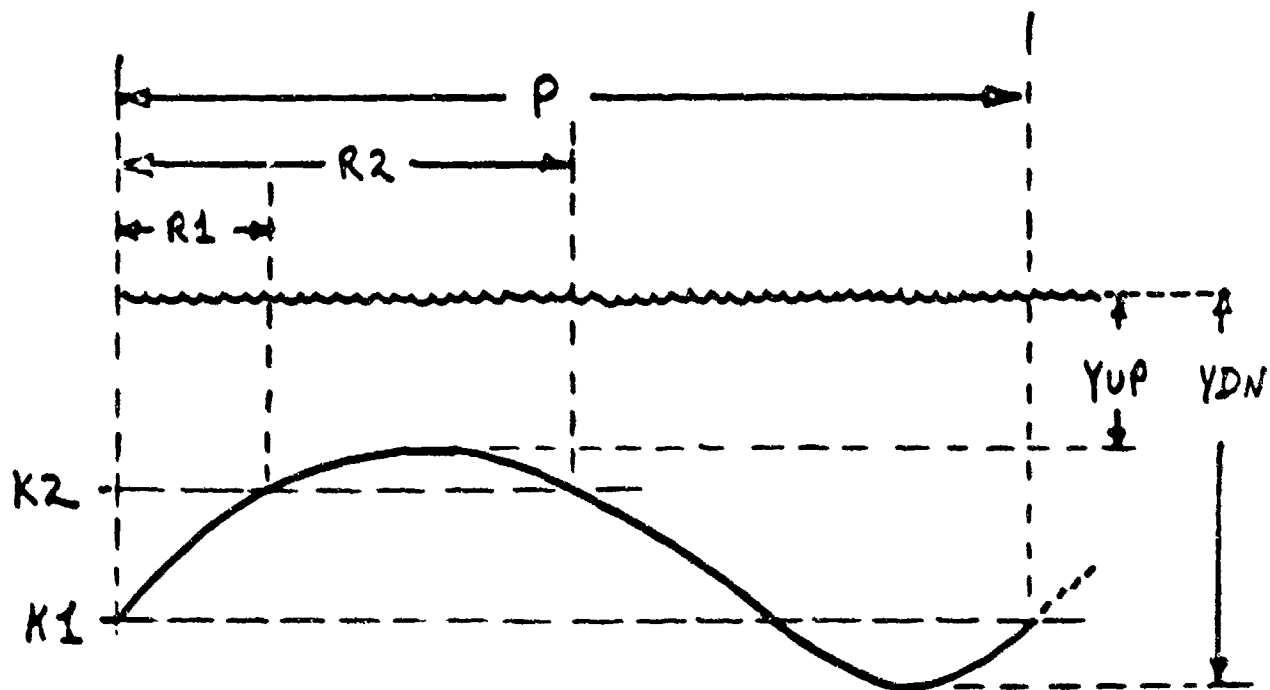
/INIT/	K2	Index of receiver depth
	AK	Vertex velocity of ray being traced, ft/sec
	SINTHO	Sine of initial ray angle at K1

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 (θ_{K2}) for the last (bottom- and surface-reflecting) family. For rays with bottom angles less than 30° , the form of the fit is:

$$R = A(1) + A(2) \cdot (\theta_{K2} - \theta_{Min})^4 + A(3) \cdot (\theta_{K2} - \theta_{Min})$$

For bottom angles greater than 30° , the form of the fit is:

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

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° ray. The derivatives of R vs. θ_{K2} are continuous at the value of θ_{K2} corresponding to the 30° 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

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:

$$\text{IPAR} = 1: \quad X(\theta_{K2}) = \text{TAN}(\theta_{K2})$$

$$\text{IPAR} = 2: \quad X(\theta_{K2}) = (\theta_{K2} - \theta_{\text{Min}})^4$$

Three points are used in the fit: The minimum and maximum values of θ_{K2} , plus a third point which is the value of θ_{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 θ_{K2} corresponding to the second ray in the family. For families with grazing rays at the receiver (Flag IREFRZ = 1), the three values of θ_{K2} are 0, and the values $\pm\theta_{K2}$ 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

```
IPRNT      Debugging print flag
```

COMMON INPUTS

```

/FLAGS/      ClC2      Ratio of source depth velocity to receiver
                    depth velocity

```

/INPUTS/	KRAY	No. of rays in family being fit, ≤ 100
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26
27	27	27
28	28	28
29	29	29
30	30	30
31	31	31
32	32	32
33	33	33
34	34	34
35	35	35
36	36	36
37	37	37
38	38	38
39	39	39
40	40	40
41	41	41
42	42	42
43	43	43
44	44	44
45	45	45
46	46	46
47	47	47
48	48	48
49	49	49
50	50	50
51	51	51
52	52	52
53	53	53
54	54	54
55	55	55
56	56	56
57	57	57
58	58	58
59	59	59
60	60	60
61	61	61
62	62	62
63	63	63
64	64	64
65	65	65
66	66	66
67	67	67
68	68	68
69	69	69
70	70	70
71	71	71
72	72	72
73	73	73
74	74	74
75	75	75
76	76	76
77	77	77
78	78	78
79	79	79
80	80	80
81	81	81
82	82	82
83	83	83
84	84	84
85	85	85
86	86	86
87	87	87
88	88	88
89	89	89
90	90	90
91	91	91
92	92	92
93	93	93
94	94	94
95	95	95
96	96	96
97	97	97
98	98	98
99	99	99
100	100	100

KP Index of ray paths in array R, 1-4

NORDER Arrival order being processed

NG Index of family being fit, ≤ 20

IPAR Flag indicating functional form of fit

R Array '100,4) of ray ranges vs. source
 angle and path index, feet

TH Array (100) of ray source angles, radians

/INIT/	K1	Index of source depth
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26
27	27	27
28	28	28
29	29	29
30	30	30
31	31	31
32	32	32
33	33	33
34	34	34
35	35	35
36	36	36
37	37	37
38	38	38
39	39	39
40	40	40
41	41	41
42	42	42
43	43	43
44	44	44
45	45	45
46	46	46
47	47	47
48	48	48
49	49	49
50	50	50
51	51	51
52	52	52
53	53	53
54	54	54
55	55	55
56	56	56
57	57	57
58	58	58
59	59	59
60	60	60
61	61	61
62	62	62
63	63	63
64	64	64
65	65	65
66	66	66
67	67	67
68	68	68
69	69	69
70	70	70
71	71	71
72	72	72
73	73	73
74	74	74
75	75	75
76	76	76
77	77	77
78	78	78
79	79	79
80	80	80
81	81	81
82	82	82
83	83	83
84	84	84
85	85	85
86	86	86
87	87	87
88	88	88
89	89	89
90	90	90
91	91	91
92	92	92
93	93	93
94	94	94
95	95	95
96	96	96
97	97	97
98	98	98
99	99	99

K2 Index of receiver depth

```

/RAZER/      IREFR2      Flag indicating first ray grazes receiver
                        depth

```

/CUSPCM/	ICUSP	Flag indicating cusped caustic
----------	-------	--------------------------------

COMMON OUTPUTS

/FLAGS/	THMIN	Angle at receiver of shallowest (at source)
		ray, radians

THMAX Angle at receiver of steepest (at source)
ray, radians

/FITS/ THF Array (3) of receiver ray angles, radians

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 FINDFT 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

X Array (3) of ordinate values

Y Array (3) of abscissa values

PARAMETER OUTPUTS

A Array (3) of coefficients of fit

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:

$$TL(Range, Freq) = TL(Range, Freq) + FACT/XL(Freq)$$

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 ICON 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.

INSTOR (Cont'd)

- 1) Single-ray (no caustic) arrival:

$$XI(freq) = XIT1 = RANGE(K) \cdot SIN1(1) \cdot RP / COS2$$

where:

RANGE(K) = Range in feet, R

SIN1(1) = $|\sin \theta_{K1}|$ (θ_{K1} = ray angle at source)

COS2 = $|\cos \theta_{K2}|$ (θ_{K2} = ray angle at receiver)

RP = $|dR/d\theta_{K2}|$ at range R

- 2) Shadow zone of a smooth caustic:

$$XI(freq) = XIC(freq) \cdot FAIRY(XAIR) \cdot RANGE(K) / RC$$

Using:

$$XIC(freq) = XIC1 \cdot FREQ(freq)$$

$$XIC1 = CONST \cdot SIN1 \cdot RC \cdot (ABS(RPP) \cdot 2 / SINC) \cdot (1./3.) / COSC$$

$$XAIR = -BETA(freq) \cdot DRAIR \cdot FACTOR$$

$$BETA(freq) = BETA1 / FREQ(freq) \cdot 2$$

$$DRAIR = ABS(RC - RANGE(K))$$

$$FACTOR = 1. / (\cos(1.57079 \cdot ABS(DRAIR / (RCUT - RC)))) \cdot IRFG = 1$$
$$= 1. \quad , \quad IRFG = 0$$

$$BETA1 = (2. \cdot (SINC / 5000.) \cdot 2 / ABS(RPP)) \cdot (1./3.)$$

where:

RANGE(K) = Range in feet, R

RC = Range of caustic, feet

FREQ = (Radian frequency)^{-1/3}

INSTOR (Cont'd)

CONST = $C_{K2}^{1/3} / 2^{5/3} \cdot \pi \cdot Ai^2(0)$
SINC1 = $\sin \theta_{K1}$ (θ_{K1} is source angle corresponding
to $\theta_C = \theta_{K2}$ at caustic)
RPP = $d^2 R / d\theta_{K2}^2$ evaluated at range RC
SINC = $\sin \theta_C$
COSC = $\cos \theta_C$
RCUT = Range at which shadow zone is tapered off
IRFG = Flag indicated shadow zone tapered off
at RCUT
FAIRY(X) = Modified Airy function $\approx [Ai(0)/Ai(-X)]^2$

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

XI(freq) = XIC(freq) * FAIRY(XAIR) * 2 * RANGE(K) / RC, XAIR < 1.77
= XIT1, XAIR > 1.77

Using:

XAIR = BETA(freq) * DRAIR
XIC(freq) is calculated as in 2) above
XIT1 is calculated as in 2) above

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

a) Steep Branch ($|\theta_{K2}| \geq |\theta_C|$):
XI(freq) is calculated as in 3) above
b) Shallow Branch ($|\theta_{K2}| < |\theta_C|$):
XI(freq) = AMIN1(XI(freq), XICP)

INSTOR (Cont'd)

Using:

$$XI(freq) = XIC(freq) \cdot FAIRY(XAIR) \cdot 2 \cdot RANGE(K) / RC$$

$$XICP = XICUSP(RANGE(K), 1000 \cdot FREQK(freq)) \cdot RANGE(K) / COS2$$

XIC(freq) is calculated as in 3) above

Where:

FREQK(freq) = Frequency in Hz

XICUSP(X) = 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

INSTOR (Cont'd)

PARAMETER OUTPUTS

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

FILE OUTPUT

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

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

COMMON INPUTS

/FLAGS/	IGTYP	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
	CBC2	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
	PF	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
	PMIN	Range of minimum-angle ray in family
	RMAX	Range of maximum-angle ray in family
	RANMIN	Minimum range at which intensities result
/INPCL	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
/RAYZER/	IRFRZ	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

INSTOR (Cont'd)

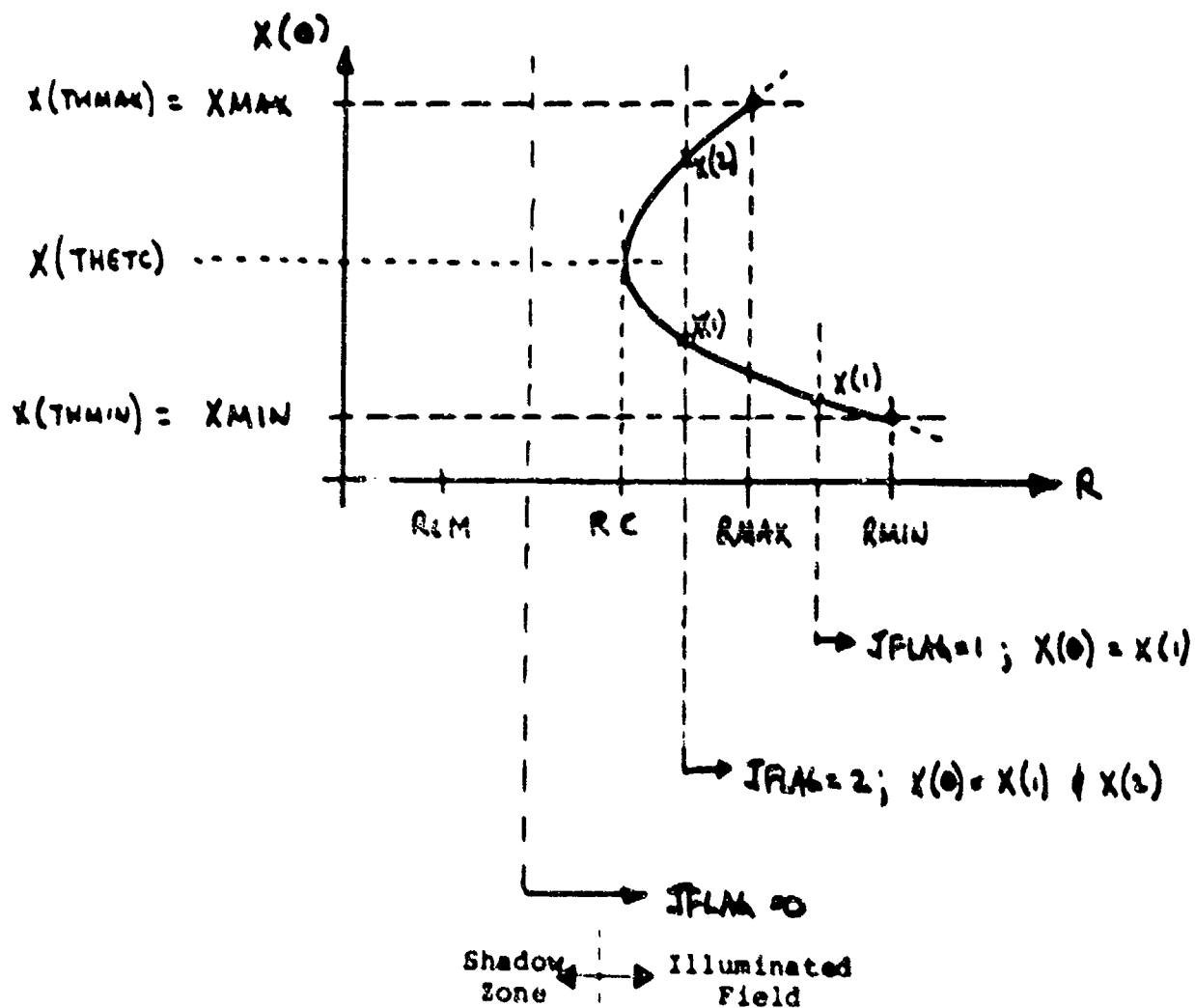
COMMON OUTPUTS

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

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

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



INSTOR - Fit of R vs. θ

NOTE: Throughout this figure $\theta = \theta_{K2}$ = Ray angle at receiver (K2)

ICOH	SNTHR	NANG	SGN(I)			
			1	2	3	4
0	($\neq 0$)	4	SNTHR	-	-	-
1 or 2	=0	2	+1.	-1.	-	-
	$\neq 0$	2	SNTHR	SNTHR	-	-
3	(=0)	4	-1.	-1.	+1.	-1.

INSTCP - Determination of No. of
Arrival Angles and Their Signs

$$RCUT = \left[\text{FACTOR IN TABLE (N=NORDER)} \right] \cdot PERO$$

IREFRZ = 1 so KP $\neq$ 3,4

ICAUST

ICUSP = 0:

IAXFG = 1:

KP =

	1	2	3
	(NONE)	(MIN RANGE)	(MAX RANGE)
1	0	N	N+ $\frac{1}{2}$
2	0	N- $\frac{1}{2}$	N

IAXFG = 2:

KP =

1	0	N	N+1
2	0	N	N+1

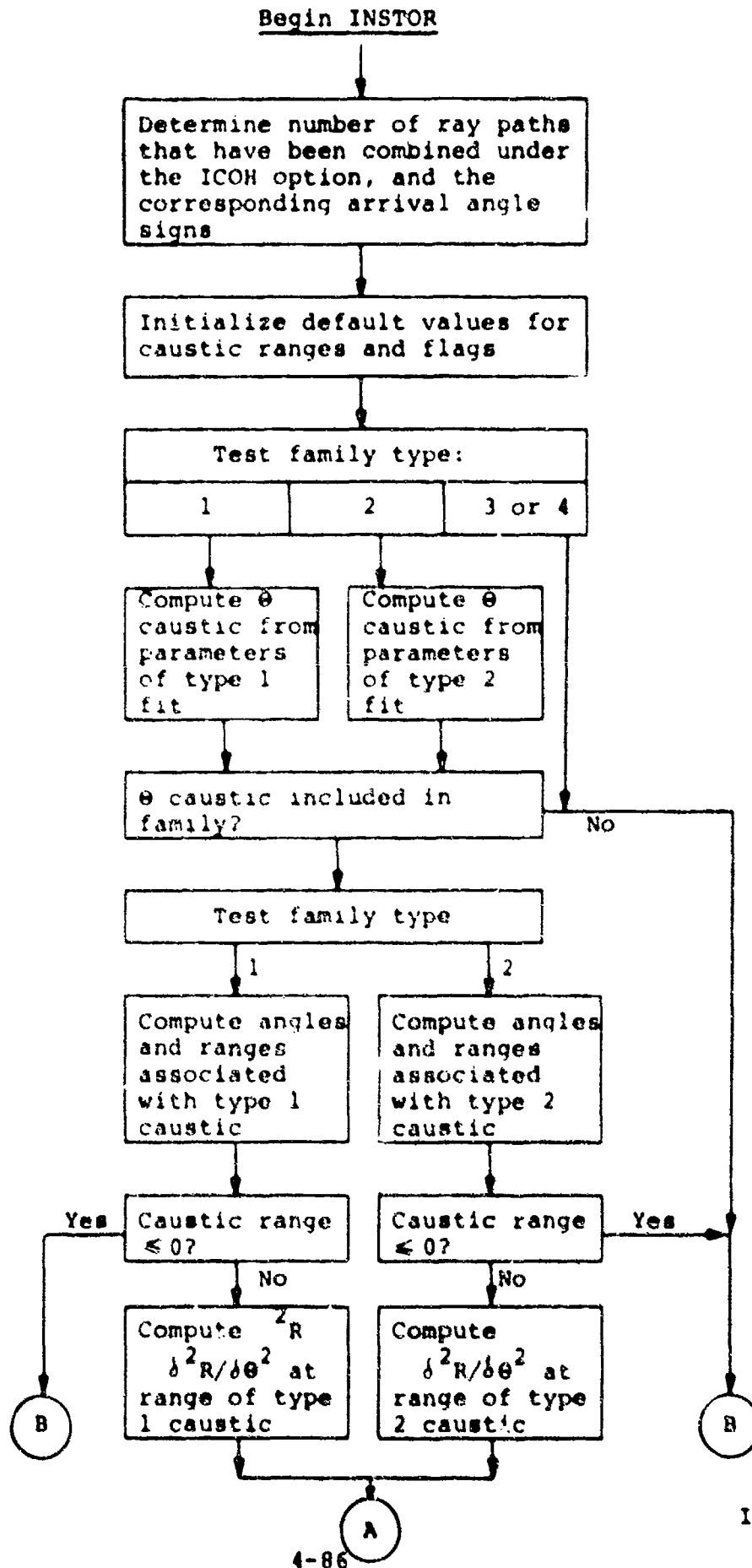
ICUSP = 1:

IRSR =

0	0	N- $\frac{1}{2}$	N+ $\frac{1}{2}$
1	0	N-1	N+1

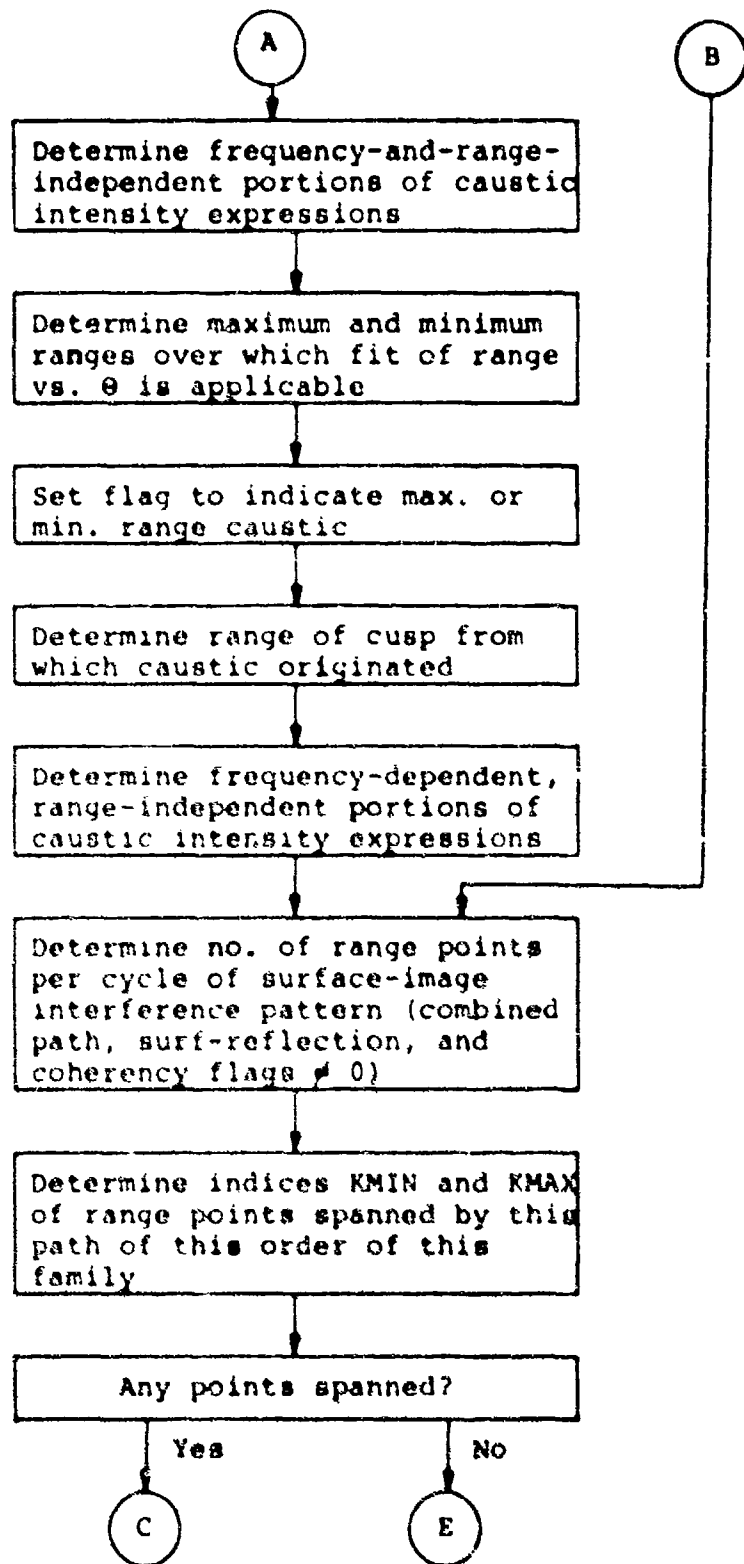
NOTE: RCUT = 0 if IREFRZ = 0

INSTOR - Determination of RCUT

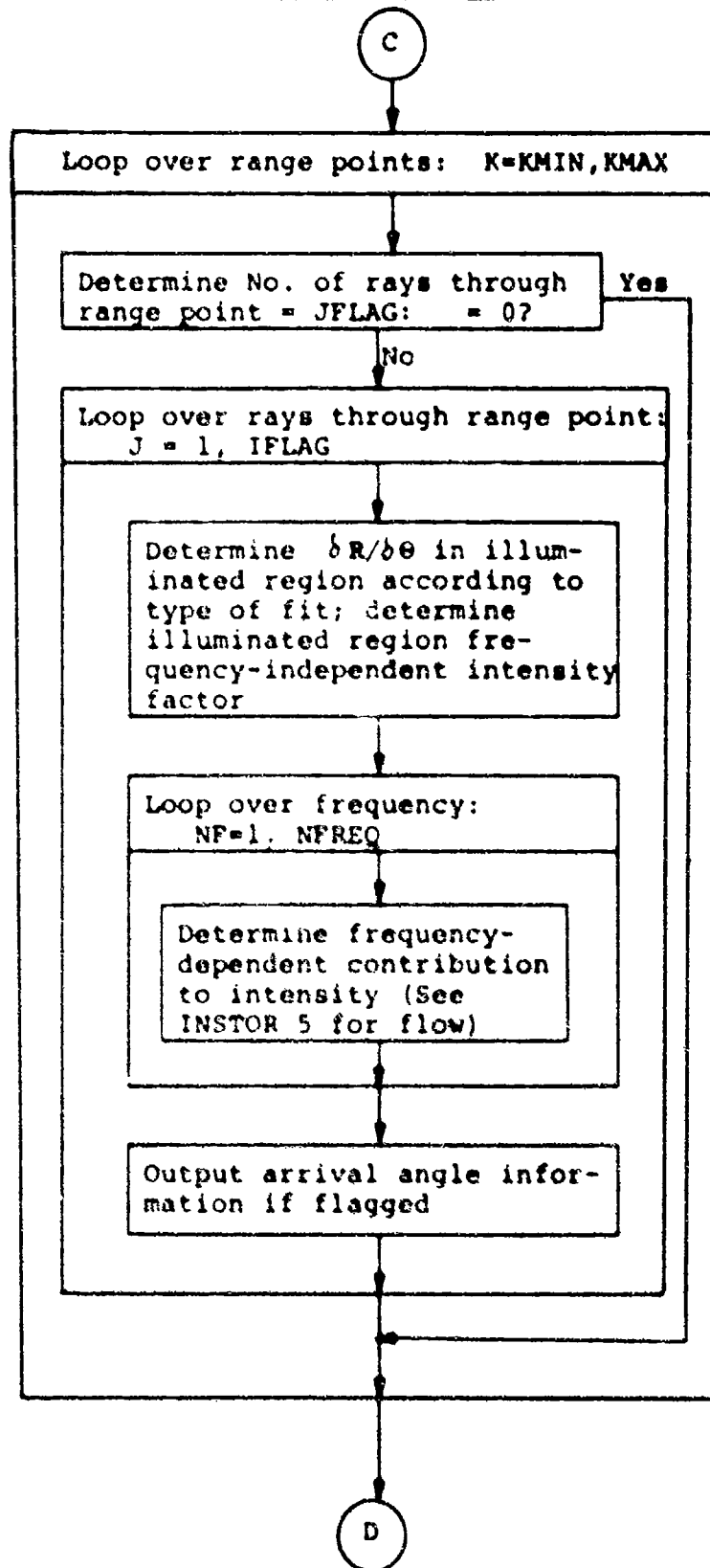


INSTOR 1

Continue INSTOR

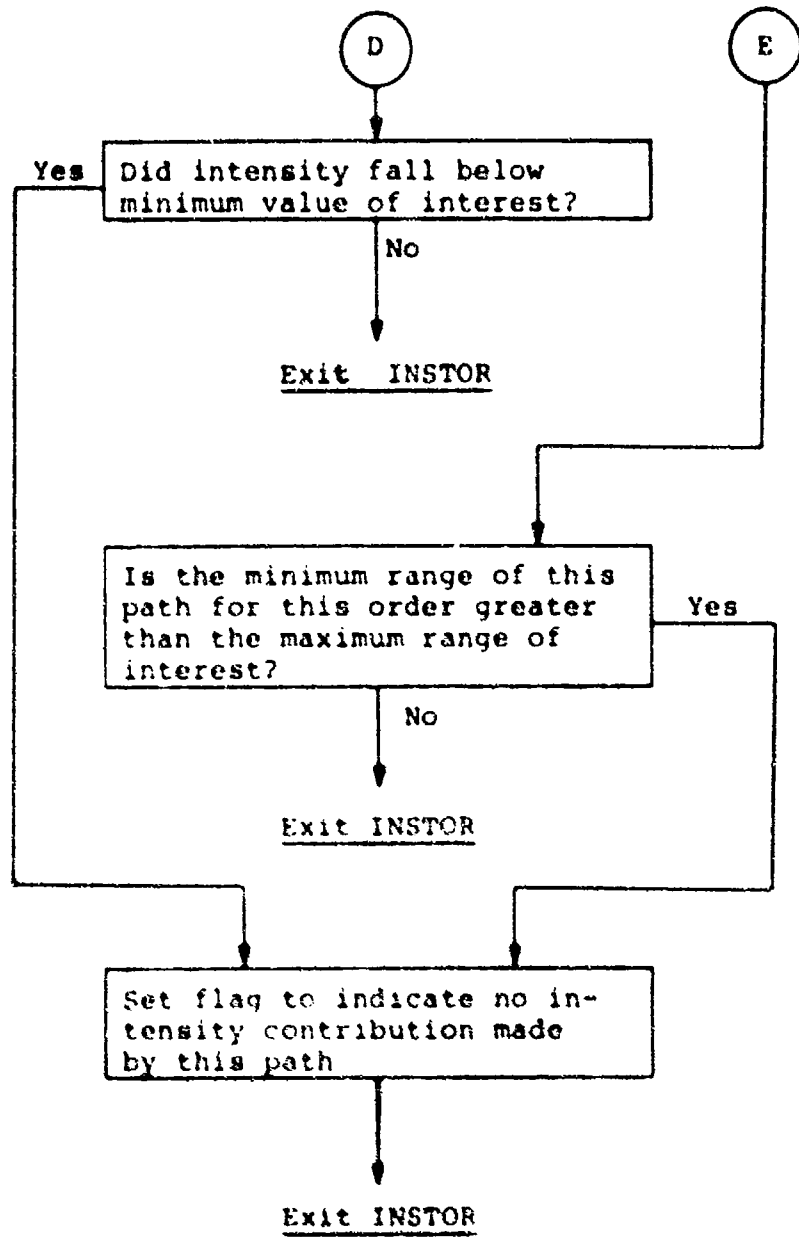


Continue INSTOR

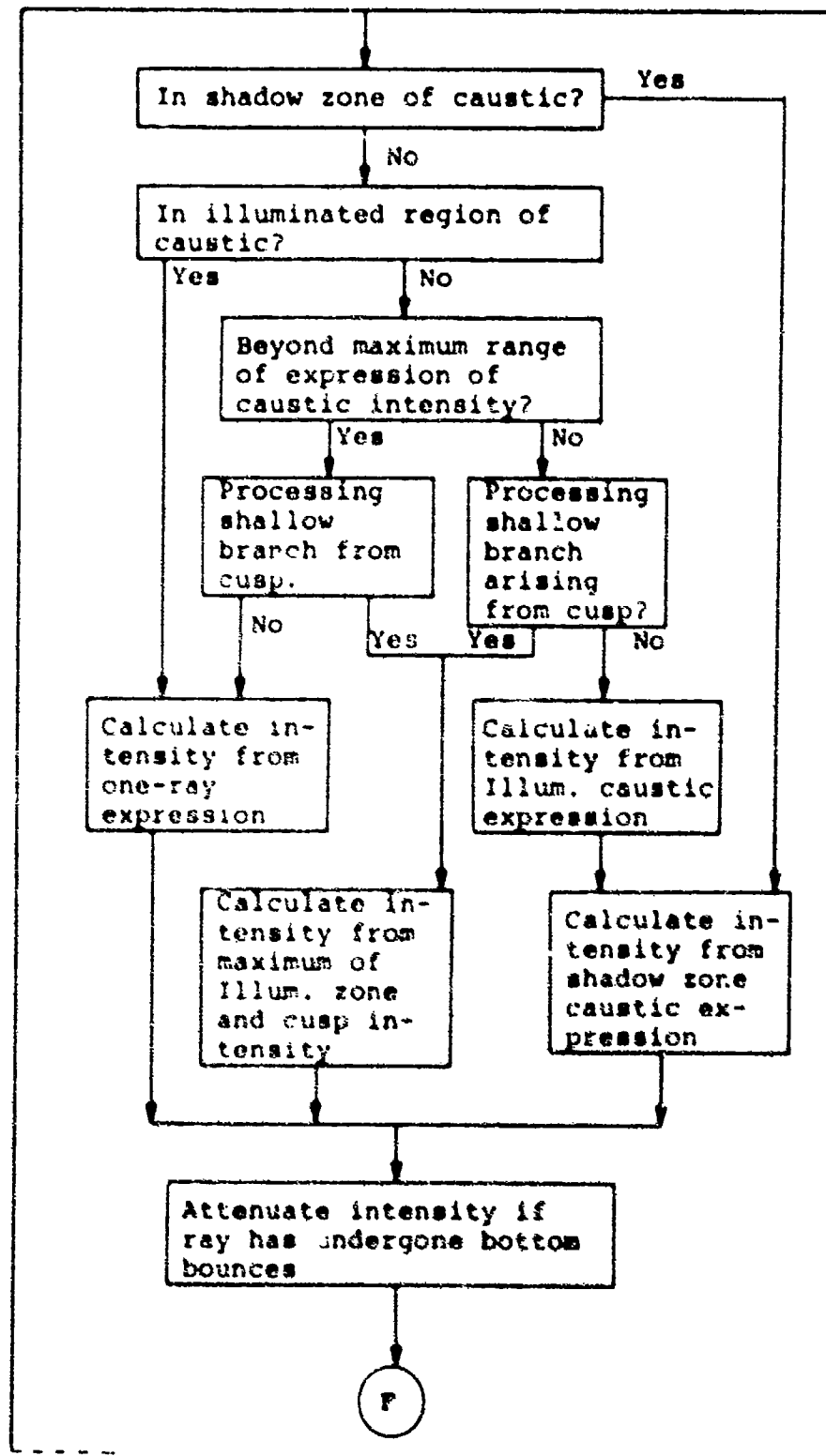


INSTOR 3

Continue INSTOR

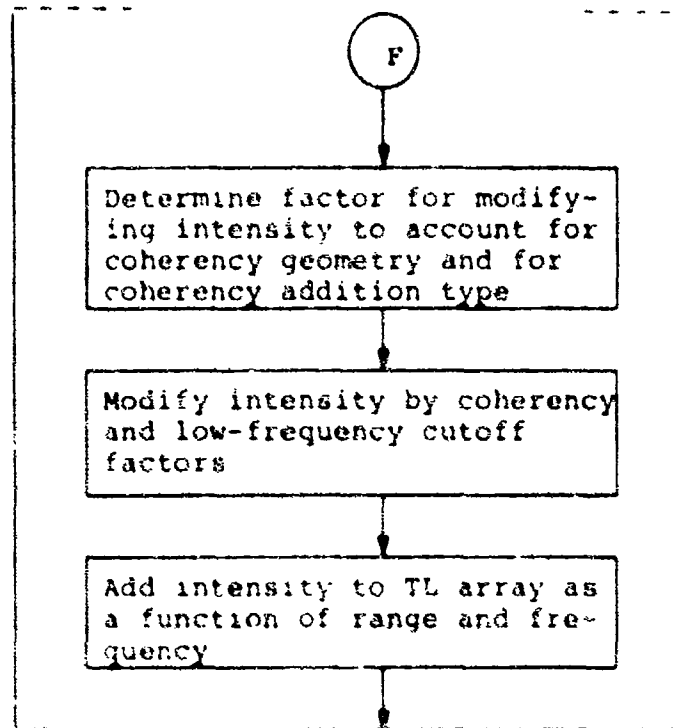


INSTOR - Loop On Frequency



INSTOR 5

Continue INSTOR - Loop on frequency



INSTOR 6

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:

$$TL(\text{Range}, \text{Freq}) = TL(\text{Range}, \text{Freq}) + 1./XIP(\text{Freq})$$

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:

$$XIP(\text{Freq}) = XI(\text{Freq}) \cdot RAN / CST$$

Using:

$$XI(\text{Freq}) = XICUSP(IR, RAN, 1000. \cdot \text{FREQ}(\text{Freq}))$$

$$CST = \cos(\text{THETA})$$

Where:

$$RAN = \text{Range in feet, } R$$

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
- K2 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
/RANGEL/ 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
/CUSPCM/ CCUSP Velocity at cusp, ft/sec
/GRADS/ G Array (60) of profile gradients, sec^{-1}

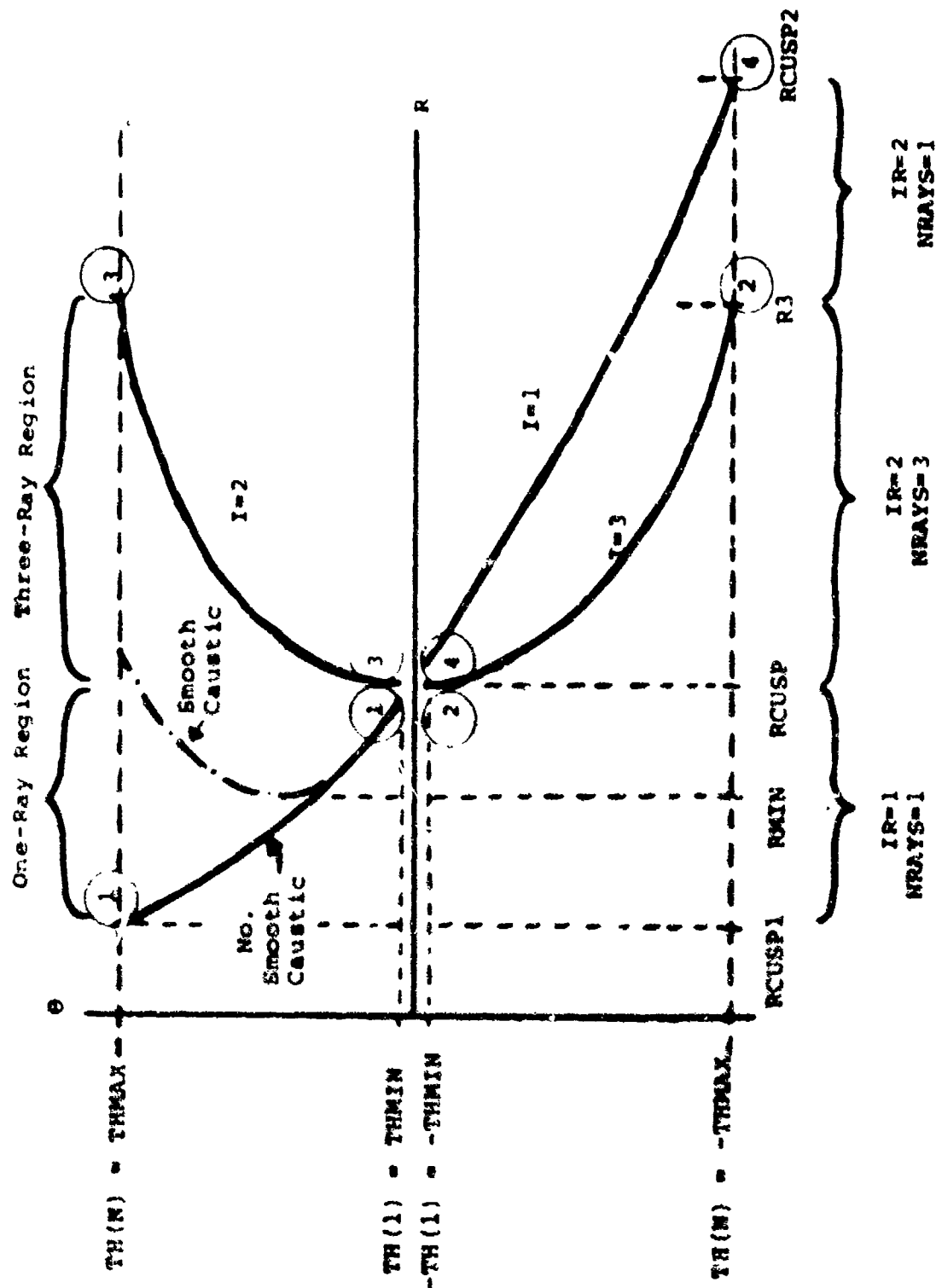
*NRAYS elsewhere

CUSP (Cont'd)

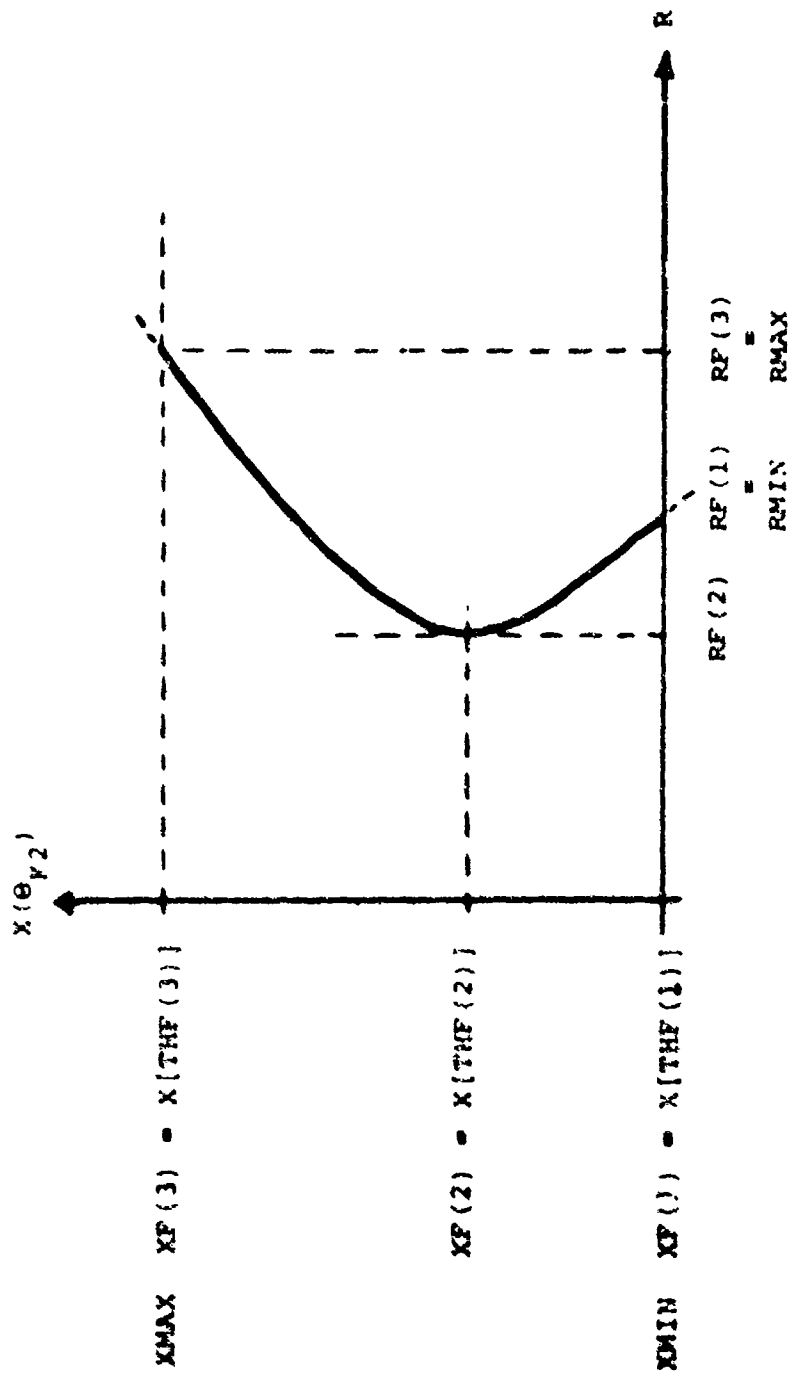
/PERIOD/	ANGP	Limit angle for low-frequency cutoff
/CRIT/	BEE2	Coefficient of low-frequency cut-off amplitudes
	C1	Velocity at source (K1), ft/sec
	CX	Velocity at profile axis, ft/sec
	JALF	All-frequencies-analytical flag
	JAIF	Array (6) of individual analytical frequency flags
	CRITANX	Array (6) of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

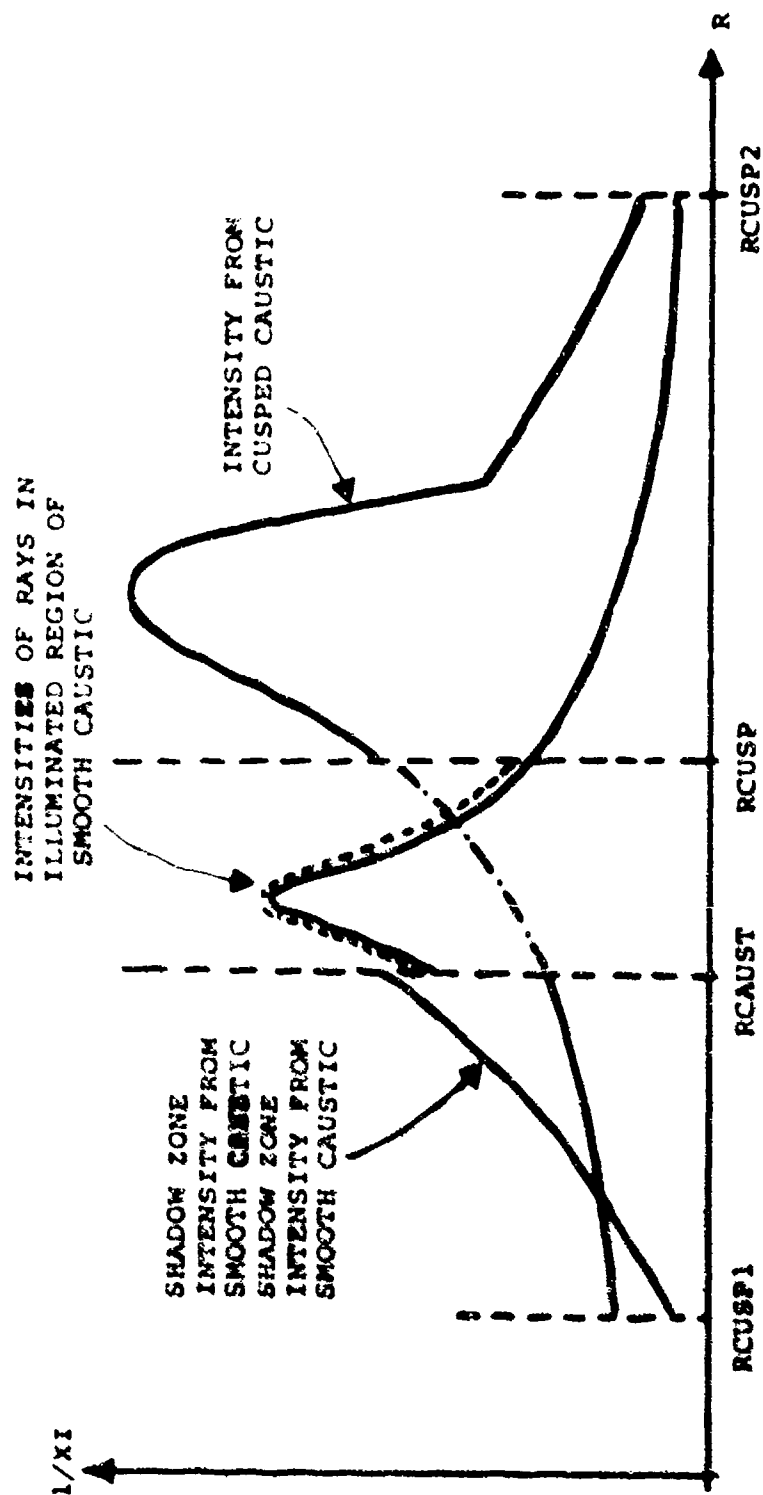
COMMON OUTPUTS

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

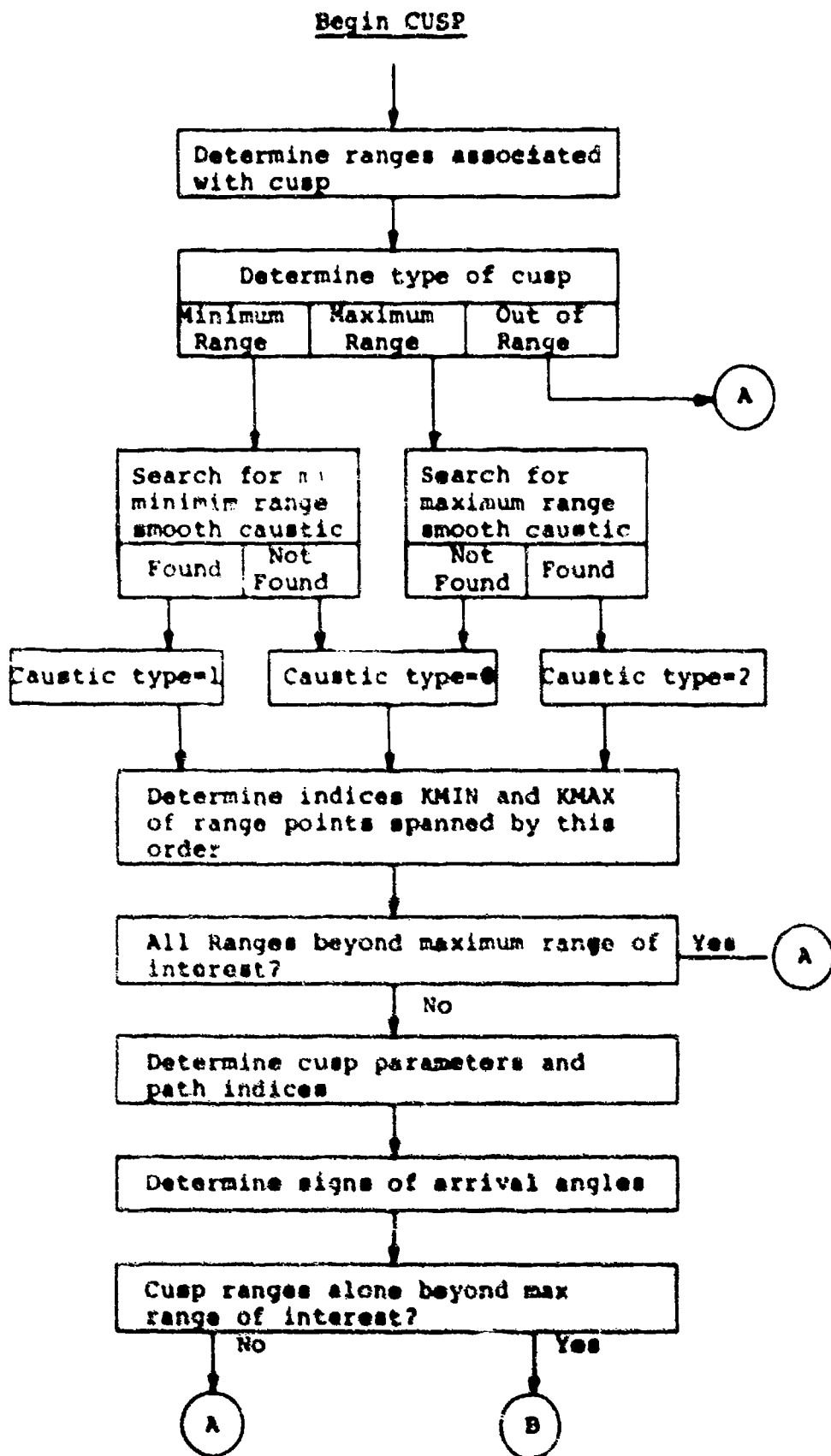


(1, 2) etc. refer to path subscript values in R (angle, path) array



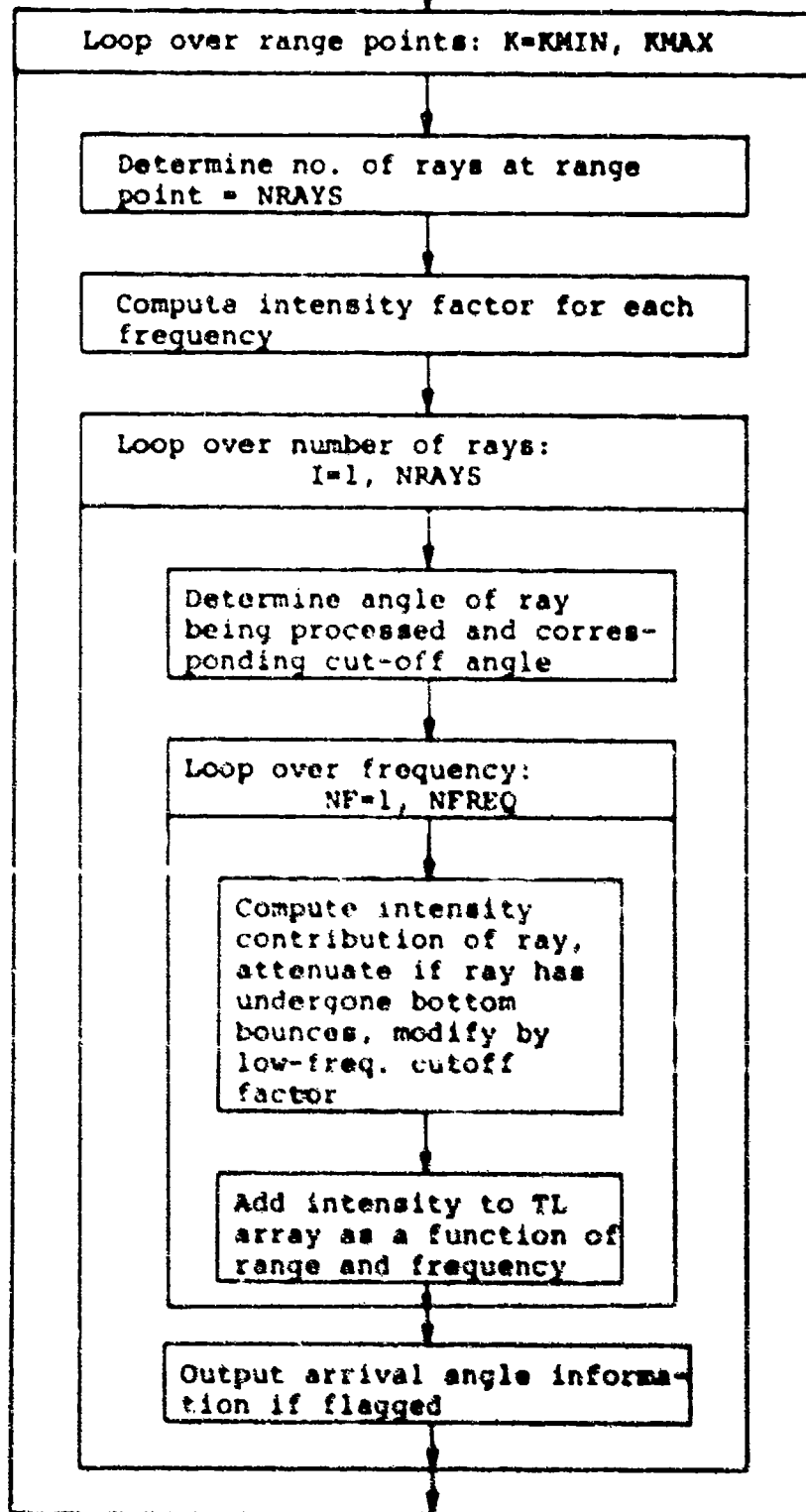


CUSP - Selection of Intensities in Region of Cusp with a Smooth Caustic



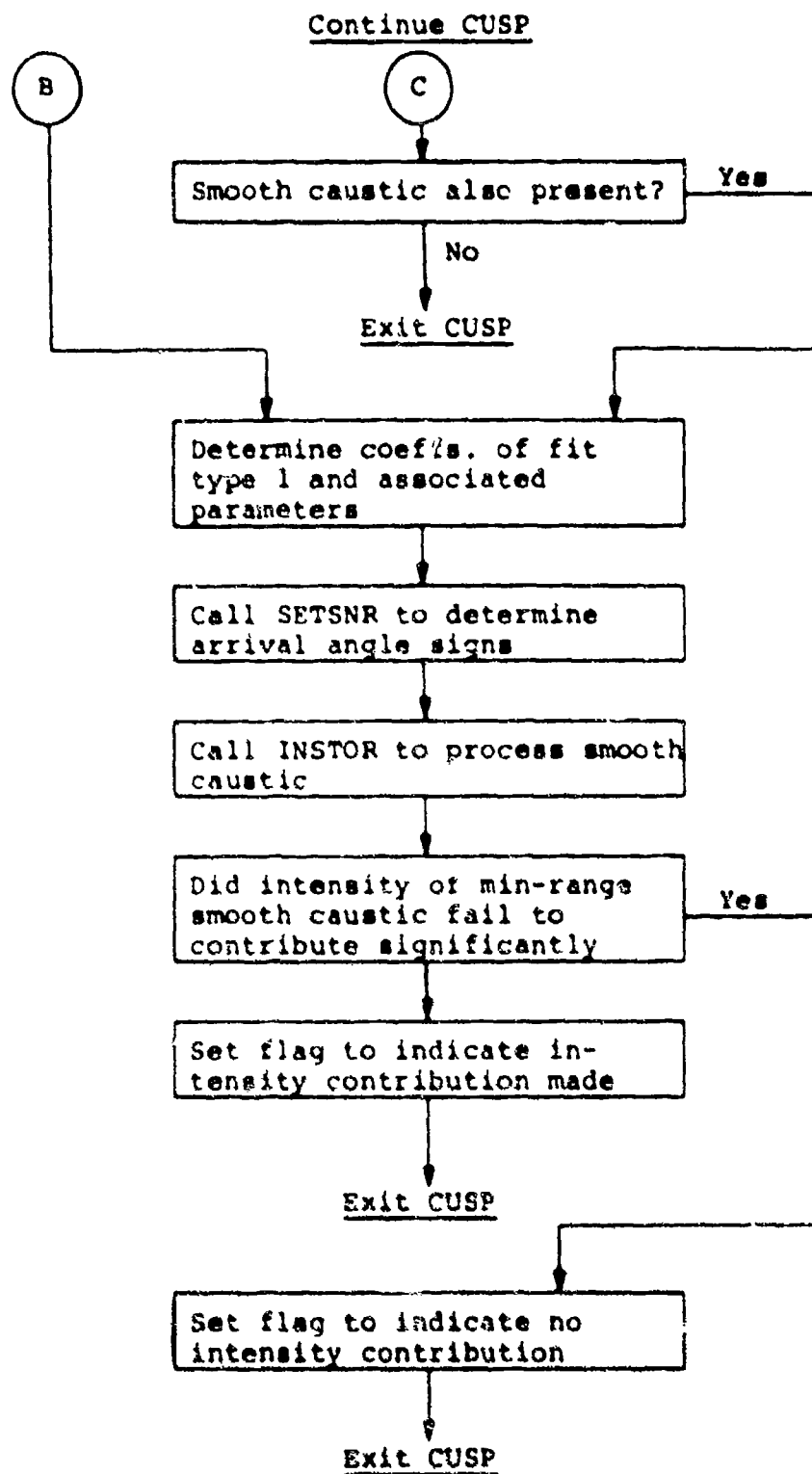
Continue CUSP

B



C

CUSP 2



SUBROUTINE HFCCTL

HFCCTL 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 i/Range ; the constant of proportionality is initially expressed as a transmission loss (dB re 1 foot) in the form:

$$TL = A - B \cdot \log (D/1000)$$

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 ($\Delta \text{velocity}/\Delta \text{depth} = .018 \text{ sec}^{-1}$) to half-channel depths of 1000 and 18,000 feet.

PARAMETER INPUTS

NR No. of range points, ≤ 250

HFCHTL (Cont'd)

NPREQ	No. of frequencies, ≤ 6
YS	Source depth, feet
YR	Receiver depth, feet
D	Depth of half-channel, feet
FREQB	Array (6) of frequencies, Hz
RANGE	Array (250) of range points, feet

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 θ), if any, at the range point being processed in INSTOR. The roots are constrained to lie between $XMIN = X(\theta_{Min})$ and $XMAX = X(\theta_{Max})$. 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

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

corresponds to

$$R = A(1) + A(2) \cdot X(\theta) + A(3) \cdot X(\theta)^2$$

in INSTOR.

PARAMETER INPUTS

A Array (3) of coefficients of fit
XMIN Minimum value allowable for X
XMAX 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

ICOH	Coherency option in effect - 0,1,2 or 3
KRC	Flag indicating arrival depth
K1	Index of source depth
K2	Index of receiver depth
KP	Index of path being processed

FUNCTION OUTPUT

SETSNR Sign(s) of arrival angles: +1., -1., 0.
See below for values returned as a function of
input parameters.

KRC = 0: 0.

KRC = 1:

ICOH	KP			
	1	2	3	4
0	1.	-1.	1.	-1.
1	0.	0.	0.	0.
2	1.	-1.	1.	-1.
3	0.	0.	0.	0.

KRC = 2:

(K1 Deeper
Than K2)

ICOH	KP			
	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	KP			
	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

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:

$$\begin{aligned}\text{FAIRY}(X) &= \left[\frac{\text{Ai}(0)}{\text{Ai}(-X)} \right]^2 & -1.77 \leq -X \leq 4.0 \\ &= \left[\frac{\text{Ai}(0)}{\text{Ai}(-4)} \right] & X < -4.0 \\ &= .792 \cdot (X)^{2/2} & X > 1.77\end{aligned}$$

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:

$$C(I) = 2 \log_{10} \left[\frac{\text{Ai}(0)}{\text{Ai}(\frac{I-11}{5})} \right] \quad I = 1(1)31$$

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:

$$1) \quad X = \left[\frac{\mathcal{A} \cdot W}{C} \right]^{1/2}$$

where:

$\mathcal{A}$ = Cusp parameter

W = Radian frequency

C = Cusp sound velocity

$$2) \quad Y = f[\pm(R - R_C) \cdot X]$$

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.

$$3) \quad XICUSP = \pi / (X \cdot Y)$$

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
--------	-------------------------------

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:

$$\begin{aligned} \text{PE2B}(y) &= \pi / -y & y \leq -3.5 \\ &= \frac{\text{Pe}(y)}{y} & -3.5 < y \leq 0 \\ &= \text{Pe}(y) & 0 < y < 2. \\ &= \pi / y & y \geq 2.0 \end{aligned}$$

The function $\text{Pe}(y)$ is approximated over the primary range of interest by $\text{Pe} \approx 2$, where P is interpolated from tabulated values of $\text{PT}(I)$ 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

NBOT	No. of bottom bounces
IBTYP	Bottom type, 0-9
THB	Ray angle at bottom, radians
FREQ	Frequency, Hz

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) - BREKHOVSKIKH'S EXPRESSIONS.
2. CUSPED CAUSTICS (3-RAY SYSTEMS) FOR SOURCE AND RECEIVER AT THE SAME DEPTH - LUDWIG'S EXPRESSIONS.
3. COMBINED SMOOTH AND CUSPED CAUSTICS (4-RAY SYSTEMS). THE RMS SUM OF THE SMOOTH AND CUSPED-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-SCRIPTABLE. 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 AXIAL 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 NEARER DEPTH. THE NET EFFECT OF THIS MOVE IS TO PRODUCE A CUSPED CAUSTIC AT THE RANGE OF THE CUSP WHICH WOULD OCCUR FOR THE AXIAL-RAY FAMILY IN THE EQUIVALENT SMOOTH PROFILE.

A WEG 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 CLASS 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 FACT 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 WAS ALSO BEEN INCLUDED SPECIFICALLY FOR ASRAP PURPOSES. FOR THE PARTICULAR SOURCE DEPTHS AND FREQUENCIES USED IN ASRAP HALF-CHANNEL CASES THE INTENSITY DUE TO RSR PATHS IS APPROXIMATED BY A CURVE OF THE FORM OF

$$TL = A + 10 \cdot LOG (R)$$

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 8F10.3)

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

FACT MODAL PROGRAM FLOW

THIS SECTION DESCRIBES THE PROGRAM FLOW IN THE TRANSMISSION LOSS MODULE (SUBROUTINE FACTIL). THE OTHER DECKS, LOSS, ETC. ARE RECALLY DRIVEN PROGRAMS TO CALL FACTIL.

FACTIL -

- INITIALIZATION OF VARIABLES AND ARRAYS
- CALL INSEPT
- MAKES SPHERICAL EARTH CORRECTIONS ON PROFILE AND SOURCE AND RECEIVER
- COMPUTES WIND 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 MOVES 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 CONVERGENCE, ABSORPTION, AND SURFACE DUCTS.
- CALL TABTM2
- 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 WKB PHASE FACTORS FOR LOW-FREQUENCY CUT-OFF EFFECTS.
- CALL ANGSCM
- 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 PROLOG AND RANGE OF FIRST AND SECOND REFLECTIONS
- COMPUTE SEMI-COHERENT PHASE FACTORS FOR THIS FAMILY.
- GROUP ARRIVALS FOR COHERENT COMBINATION 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 FIELD) HAS EXCEEDED THE MAXIMUM RANGE OF INTEREST.
- FOR STEEPEST RAY FAMILY (BOTTOM-REFLECTED SURFACE-REFLECTED) CALL FIT90T
- COMPUTES PARAMETERS OF FIVE COEFFICIENT FIT TO R(THETA) USING MINIMUM RAY, RAY AT CRITICAL ANGLE OF LOW FREQUENCY BOTTOM-REFLECTION COEFFICIENT, AND IMPLICITLY 90-DEGREE RAY.
- FOR SHALLOWER FAMILIES CALL FIT90T
- FITS A QUADRATIC IN EITHER TAN(THETA) OF SORT (THETA-TAN(THETA)) FOR R(THETA) 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 SEMI-COHERENT FACTORS AND BOTTOM-REFLECTION LOSSES.
- CALL CUSP FOR FAMILIES WITH CUSPED CAUSTICS
- COMPUTES FAMILY PARAMETERS AND CUSPED CAUSTIC CORRECTIONS.
- CALLS FITCUSP 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

- ADD IN HALF-CHANNEL WGM BOTTOM-REFLECTED CONTRIBUTION
 (FOR ASSESS IT: HALF CHANNEL CASES ONLY)
- ADD IN OUC'ED CONTRIBUTION
- CONVERT TO LOSS(R,F) (INCLUDING VOLUME ABSORPTION)
RETURN

THE FACT PACKAGE PROGRAM LIBRARY CONTAINS ALL FORTRAN ROUTINES REQUIRED TO IMPLEMENT THE FACT ACOUSTIC MODEL. THE PROGRAM LIBRARY COMPONENTS ARE AS FOLLOWS....

MAINPROGRAM TLOSS-- READS CARD INPUTS, COMPUTES LOSSES THRU SUBROUTINE CALLS, AND PRINTS AND/OR PLOTS (ON THE LINE PRINTED) THE RESULTS.

SUBROUTINE FACITL--THE FACT WAY TRACING MODEL
SUBROUTINE SHALTL--A SIMPLIFIED MODEL FOR SHALLOW WATER,
CALLED INSTEAD OF FACITL BY AUTOTL
UNDER CERTAIN CONDITIONS.
SUBROUTINE MFCWTL--A SIMPLIFIED HALF-CHANNEL MODEL, USED BY FACITL FOR ASRAP CASES.

THE FACT MODEL SUBROUTINE FACITL REQUIRES THE FOLLOWING ADDITIONAL ROUTINES....
13 COMPUTATIONAL SUBROUTINES...

INSERT	AXIS	TABTHZ
CRITA	RAYT	ANGSCH
RANGER	FITOT	FINDFT
FITG	INSTOR	CUSP
QUAD		

SPEED	SETSR	FAIRY
XICUSP	PEZB	TMBOT
BOTOM	BTNLOS	

FOR INPUT AND OUTPUT PROGRAM TLOSS REQUIRES....		
3 INPUT-OUTPUT SUBROUTINES....	ROPROP	TLHEAD
		PLOTTL

TO MAKE AN OBJECT PROGRAM FOR THE CARD INPUT PROGRAM TLOSS, ALL COMPONENTS WITH THE EXCEPTION OF AUTOTL AND SHALTL SHOULD BE COMPILED. THE RESULTING PROGRAM OCCUPIES APPROXIMATELY 44693 1024-BIT WORDS ON THE CDC 6600.

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

EACH OFCK IS A SINGLE PROGRAM, ROUTINE, OR FUNCTION. THE OFCK NAME IS IDENTICAL TO THE ROUTINE NAME. ALL DECKS ARE SEQUENCED WITHOUT CORRECTIONS.

THE CARD INPUTS TO ILOS ARE DETAILED IN THE COMMENTS WITHIN
THIS PROGRAM, AND REPEATED HERE FOR REFERENCE PURPOSES.

CARD	DATA	FORMAT
1	TITLE	4A10
2	(EOP EMOI EUNI)	615
3A,B,....	N,IL,IP,IM,IP,IP,IP P(1),C(1), (1=1,M) OR D(1),T(1),C(1) N,DEMT P(1), (1=1,M) S,JC(1), (1=1,M)	8F10.2 1F8.2,F6.2,F6.2 15.5X,F18.2 8F10.2 2F10.2,615
4	(EOP EMOI EUNI)	615
5	15.0E. 10E6 GRES BACK TO READ CARD 1)	

FACTIL CALLED TO COMPUTE LOSSES
LOSSES PRINTED AND/OR PLOTTED

(GOES TO READ CARD 6)

4 IS NO. OF PROFILE POINTS 2,LE,(495MIN),LE. 50

*FOR A POSITIVE, PROFILE IS INPUT DIRECTLY IN DEPTH,
VELOCITY PAIRS. 3/CARD. A VELOCITY -LT. 1000 IS USED AS AN
INDICATOR OF METRIC INPUT (M PER S) BOTH DEPTHS & VELOCITIES
ARE CONVERTED TO ENGLISH UNITS (FT.FT PER SEC).

*FOR A NEGATIVE, PROFILE IS INPUT AS DEPTH. TEMP..
CALCULATED. 3/CARD. METRIC UNITS ARE ASSUMED (M,CENT,PPH).
WILSONS 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 7(M)

11 IS THE INPUT OF THE MIXED LAYER DEPTH IN THE INPUT PROFILE (SEPARATE
COMPUTATIONS ARE THEN PERFORMED FOR A SURFACE DUCT OF THIS
DIMENSION AND NO DUCTS ARE TRACKED IN THE DUCT). EITHER 1
OR 2 CAN BE USED TO INDICATE THAT NO LAYER IS PRESENT.
0 -LE. IL -LE. (ARSIM). IL - (ARSIM) INDICATES THAT A
HALF-CHANNEL CONDITION IS PRESENT AND THAT THE ROUTINE
MFCMIL (NORMALLY USED ONLY FOR ASRAM) SHOULD BE USED.

12 IS THE BOTTOM TYPE
A NEGATIVE VALUE INDICATES THAT THE USER WILL SUPPLY A BOTTOM LOSS
FUNCTION, AND MODIFY FUNCTION BOTTOM TO CALL THE REPLACEMENT FOR
THE DEFAULT FUNCTION MFCMIL.
1-9 INDICATES FIVE BOTTOM LOSS FUNCTIONS

5-10

```

-----
LISTED 7-0-0 (END OF RECORD) ON VS .GE. 1066 (NEW RUN)
      LAST CARD OF SOURCE--RECEIVER OFFSET
-----
SOURCE AND RECEIVER DATA
-----
TYPE 6 CAPD--SOURCE AND RECEIVER DATA
-----
          F1      F2      F3      F4      F5      F6      XXXXXXXXXXXXXXXX
          TYPE 5 CAPD--FREQUENCY INFORMATION
-----
          000001  XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
              TYPE 4 CAPD--RANGE INFORMATION
-----
          NO
          TYPE 3 CAPD--
          OPTM, VELOCITY
          NO
          OPTM, TEMPERATURE, SALINITY
-----
          TYPE 2 CAPD--DATA SET
          TYPE 3 CAPD--DATA SET
-----
          IL  IN  IM  IOL  IOP  IOW  IXX  IYY  IZZ  T(1)  T(2)  T(3)  T(4)  T(5)  T(6)  T(7)  T(8)  T(9)  C(1)  C(2)  C(3)  C(4)  C(5)  C(6)  C(7)  C(8)  C(9)  C(10)  C(11)  C(12)  C(13)  C(14)  C(15)  C(16)  C(17)  C(18)  C(19)  C(20)  C(21)  C(22)  C(23)  C(24)  C(25)  C(26)  C(27)  C(28)  C(29)  C(30)  C(31)  C(32)  C(33)  C(34)  C(35)  C(36)  C(37)  C(38)  C(39)  C(40)  C(41)  C(42)  C(43)  C(44)  C(45)  C(46)  C(47)  C(48)  C(49)  C(50)  C(51)  C(52)  C(53)  C(54)  C(55)  C(56)  C(57)  C(58)  C(59)  C(60)  C(61)  C(62)  C(63)  C(64)  C(65)  C(66)  C(67)  C(68)  C(69)  C(70)  C(71)  C(72)  C(73)  C(74)  C(75)  C(76)  C(77)  C(78)  C(79)  C(80)  C(81)  C(82)  C(83)  C(84)  C(85)  C(86)  C(87)  C(88)  C(89)  C(90)  C(91)  C(92)  C(93)  C(94)  C(95)  C(96)  C(97)  C(98)  C(99)  C(100)  C(101)  C(102)  C(103)  C(104)  C(105)  C(106)  C(107)  C(108)  C(109)  C(110)  C(111)  C(112)  C(113)  C(114)  C(115)  C(116)  C(117)  C(118)  C(119)  C(120)  C(121)  C(122)  C(123)  C(124)  C(125)  C(126)  C(127)  C(128)  C(129)  C(130)  C(131)  C(132)  C(133)  C(134)  C(135)  C(136)  C(137)  C(138)  C(139)  C(140)  C(141)  C(142)  C(143)  C(144)  C(145)  C(146)  C(147)  C(148)  C(149)  C(150)  C(151)  C(152)  C(153)  C(154)  C(155)  C(156)  C(157)  C(158)  C(159)  C(160)  C(161)  C(162)  C(163)  C(164)  C(165)  C(166)  C(167)  C(168)  C(169)  C(170)  C(171)  C(172)  C(173)  C(174)  C(175)  C(176)  C(177)  C(178)  C(179)  C(180)  C(181)  C(182)  C(183)  C(184)  C(185)  C(186)  C(187)  C(188)  C(189)  C(190)  C(191)  C(192)  C(193)  C(194)  C(195)  C(196)  C(197)  C(198)  C(199)  C(200)  C(201)  C(202)  C(203)  C(204)  C(205)  C(206)  C(207)  C(208)  C(209)  C(210)  C(211)  C(212)  C(213)  C(214)  C(215)  C(216)  C(217)  C(218)  C(219)  C(220)  C(221)  C(222)  C(223)  C(224)  C(225)  C(226)  C(227)  C(228)  C(229)  C(230)  C(231)  C(232)  C(233)  C(234)  C(235)  C(236)  C(237)  C(238)  C(239)  C(240)  C(241)  C(242)  C(243)  C(244)  C(245)  C(246)  C(247)  C(248)  C(249)  C(250)  C(251)  C(252)  C(253)  C(254)  C(255)  C(256)  C(257)  C(258)  C(259)  C(260)  C(261)  C(262)  C(263)  C(264)  C(265)  C(266)  C(267)  C(268)  C(269)  C(270)  C(271)  C(272)  C(273)  C(274)  C(275)  C(276)  C(277)  C(278)  C(279)  C(280)  C(281)  C(282)  C(283)  C(284)  C(285)  C(286)  C(287)  C(288)  C(289)  C(290)  C(291)  C(292)  C(293)  C(294)  C(295)  C(296)  C(297)  C(298)  C(299)  C(300)  C(301)  C(302)  C(303)  C(304)  C(305)  C(306)  C(307)  C(308)  C(309)  C(310)  C(311)  C(312)  C(313)  C(314)  C(315)  C(316)  C(317)  C(318)  C(319)  C(320)  C(321)  C(322)  C(323)  C(324)  C(325)  C(326)  C(327)  C(328)  C(329)  C(330)  C(331)  C(332)  C(333)  C(334)  C(335)  C(336)  C(337)  C(338)  C(339)  C(340)  C(341)  C(342)  C(343)  C(344)  C(345)  C(346)  C(347)  C(348)  C(349)  C(350)  C(351)  C(352)  C(353)  C(354)  C(355)  C(356)  C(357)  C(358)  C(359)  C(360)  C(361)  C(362)  C(363)  C(364)  C(365)  C(366)  C(367)  C(368)  C(369)  C(370)  C(371)  C(372)  C(373)  C(374)  C(375)  C(376)  C(377)  C(378)  C(379)  C(380)  C(381)  C(382)  C(383)  C(384)  C(385)  C(386)  C(387)  C(388)  C(389)  C(390)  C(391)  C(392)  C(393)  C(394)  C(395)  C(396)  C(397)  C(398)  C(399)  C(400)  C(401)  C(402)  C(403)  C(404)  C(405)  C(406)  C(407)  C(408)  C(409)  C(410)  C(411)  C(412)  C(413)  C(414)  C(415)  C(416)  C(417)  C(418)  C(419)  C(420)  C(421)  C(422)  C(423)  C(424)  C(425)  C(426)  C(427)  C(428)  C(429)  C(430)  C(431)  C(432)  C(433)  C(434)  C(435)  C(436)  C(437)  C(438)  C(439)  C(440)  C(441)  C(442)  C(443)  C(444)  C(445)  C(446)  C(447)  C(448)  C(449)  C(450)  C(451)  C(452)  C(453)  C(454)  C(455)  C(456)  C(457)  C(458)  C(459)  C(460)  C(461)  C(462)  C(463)  C(464)  C(465)  C(466)  C(467)  C(468)  C(469)  C(470)  C(471)  C(472)  C(473)  C(474)  C(475)  C(476)  C(477)  C(478)  C(479)  C(480)  C(481)  C(482)  C(483)  C(484)  C(485)  C(486)  C(487)  C(488)  C(489)  C(490)  C(491)  C(492)  C(493)  C(494)  C(495)  C(496)  C(497)  C(498)  C(499)  C(500)  C(501)  C(502)  C(503)  C(504)  C(505)  C(506)  C(507)  C(508)  C(509)  C(510)  C(511)  C(512)  C(513)  C(514)  C(515)  C(516)  C(517)  C(518)  C(519)  C(520)  C(521)  C(522)  C(523)  C(524)  C(525)  C(526)  C(527)  C(528)  C(529)  C(530)  C(531)  C(532)  C(533)  C(534)  C(535)  C(536)  C(537)  C(538)  C(539)  C(540)  C(541)  C(542)  C(543)  C(544)  C(545)  C(546)  C(547)  C(548)  C(549)  C(550)  C(551)  C(552)  C(553)  C(554)  C(555)  C(556)  C(557)  C(558)  C(559)  C(560)  C(561)  C(562)  C(563)  C(5
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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, MP, 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 CONVERGENCE OPTION--

0 = SCOM
1 = ICOM
2 = PCOM

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

COL.	1	2	3	4	5	6	7	8
1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1

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

0000.00 4776.00 12000.00 4992.00

120 100.0 1.00

00.00 1200.00

1200.00 1200.00

0000000000

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

1	2	3	4	5	6	7	8	9
10	1512.1	47.05	1512.8	76.20	1579.7	88.34	1525.8	
11	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
12	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
13	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
14	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
15	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
16	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
17	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
18	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
19	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
20	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
21	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
22	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
23	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
24	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
25	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
26	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
27	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
28	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
29	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
30	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
31	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
32	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
33	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
34	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
35	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
36	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
37	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
38	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
39	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
40	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
41	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
42	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
43	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
44	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
45	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
46	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
47	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
48	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
49	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	
50	1512.1	1512.8	1512.8	1512.8	1512.8	1512.8	1512.8	

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

1	2	3	4	5	6	7	8	9
0000.00	12.76	35.11	0010.00	12.08	35.12	0020.00	11.74	35.13
0010.00	11.11	35.15	0077.00	09.56	35.31	0125.00	09.98	35.27
0110.00	08.71	35.25	0229.00	08.20	35.21	0379.00	07.89	35.15
0210.00	07.42	35.14	0614.00	07.12	35.11	0814.00	05.82	35.04
0310.00	06.55	34.48	1203.00	04.28	34.92	1600.00	03.99	34.89
0410.00	03.76	34.89						
0510.00	150.0	2.00						
0610.00	600.00							
0710.00	3000.00							

THE RESULTING FACT OUTPUT APPEARS ON THE FOLLOWING PAGES

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

2	2	6	6
3.00000	6776.71000		
12000.00000	4992.30000		

120	1.00
25.00	100.00

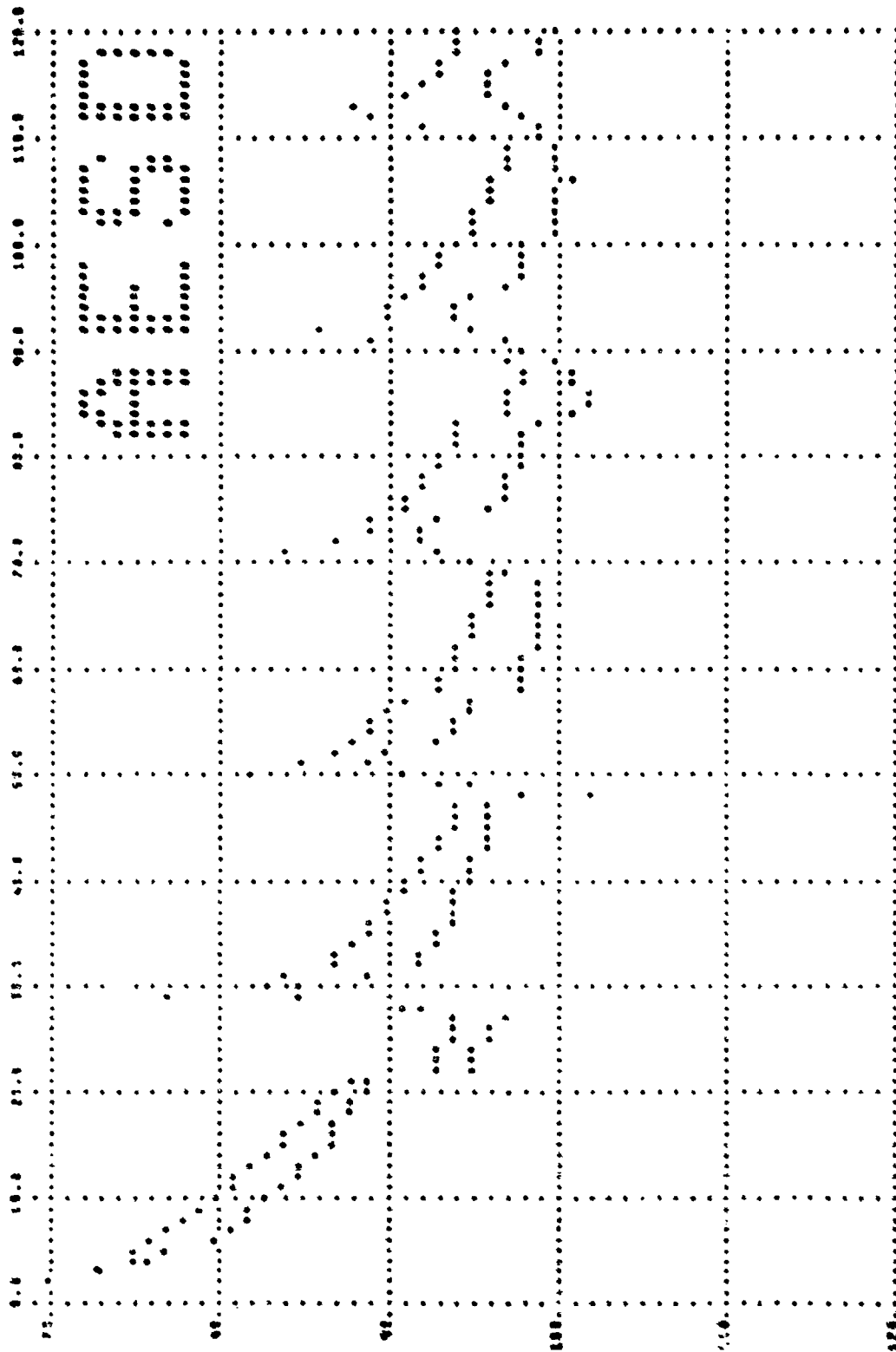
5-15

10.50.22 09/27/76

PACT SAMPLE RUN NO. 1 -- ASSUME GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.

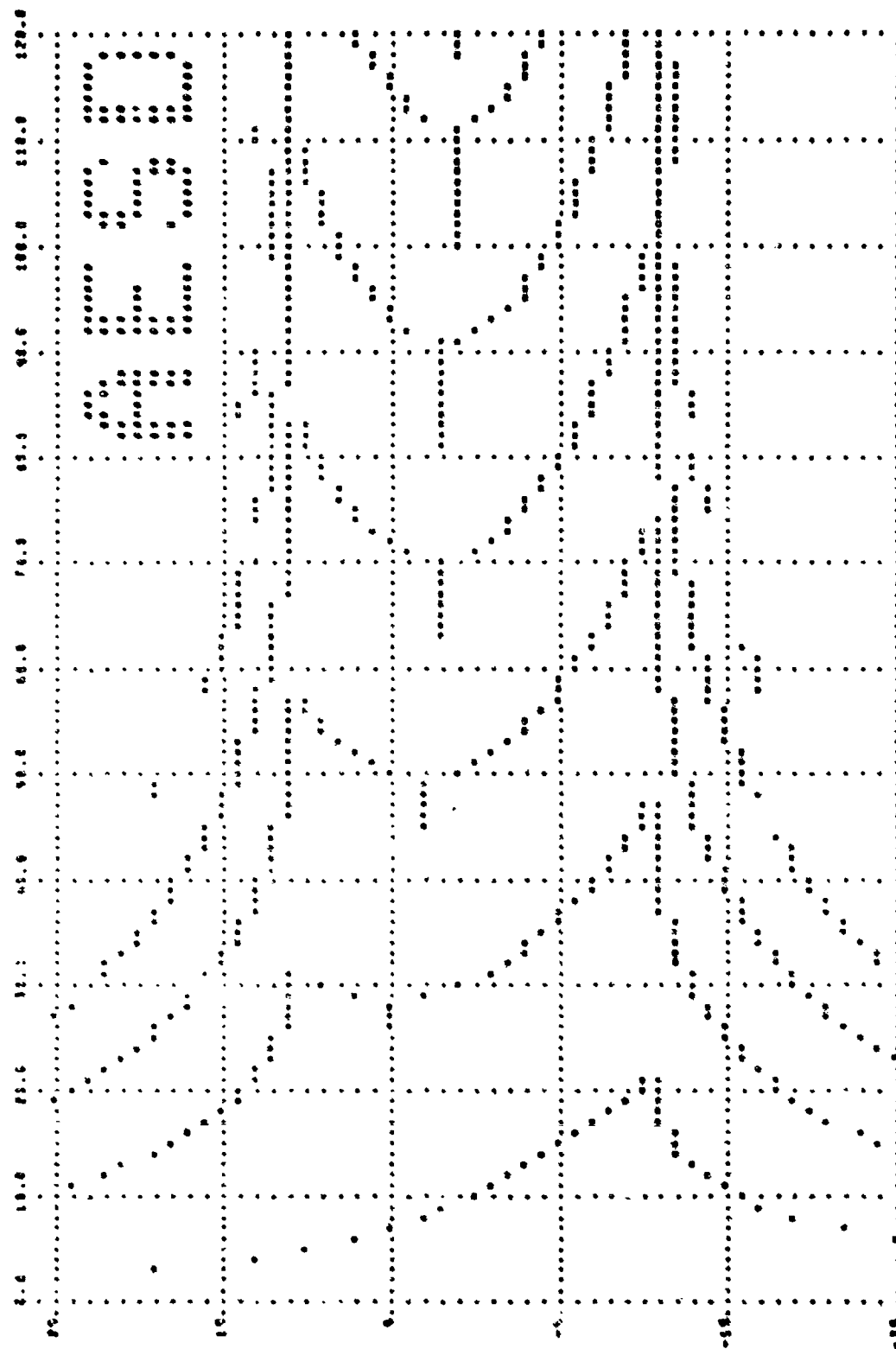
SOURCE 1000000 65.0 FT. RECEIVER 0000000 7200.0 FT

LEGEND-- T1 = T2, SCOM = 0 100 = T2, SCOM = 0



Source: *See* 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 1910, 1911, 1912, 1913, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922, 1923, 1924, 1925, 1926, 1927, 1928, 1929, 1930, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1939, 1940, 1941, 1942, 1943, 1944, 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582

由是可見，*《論衡》* 之「命」，即「命定」之義，即「命定論」之義。



25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200

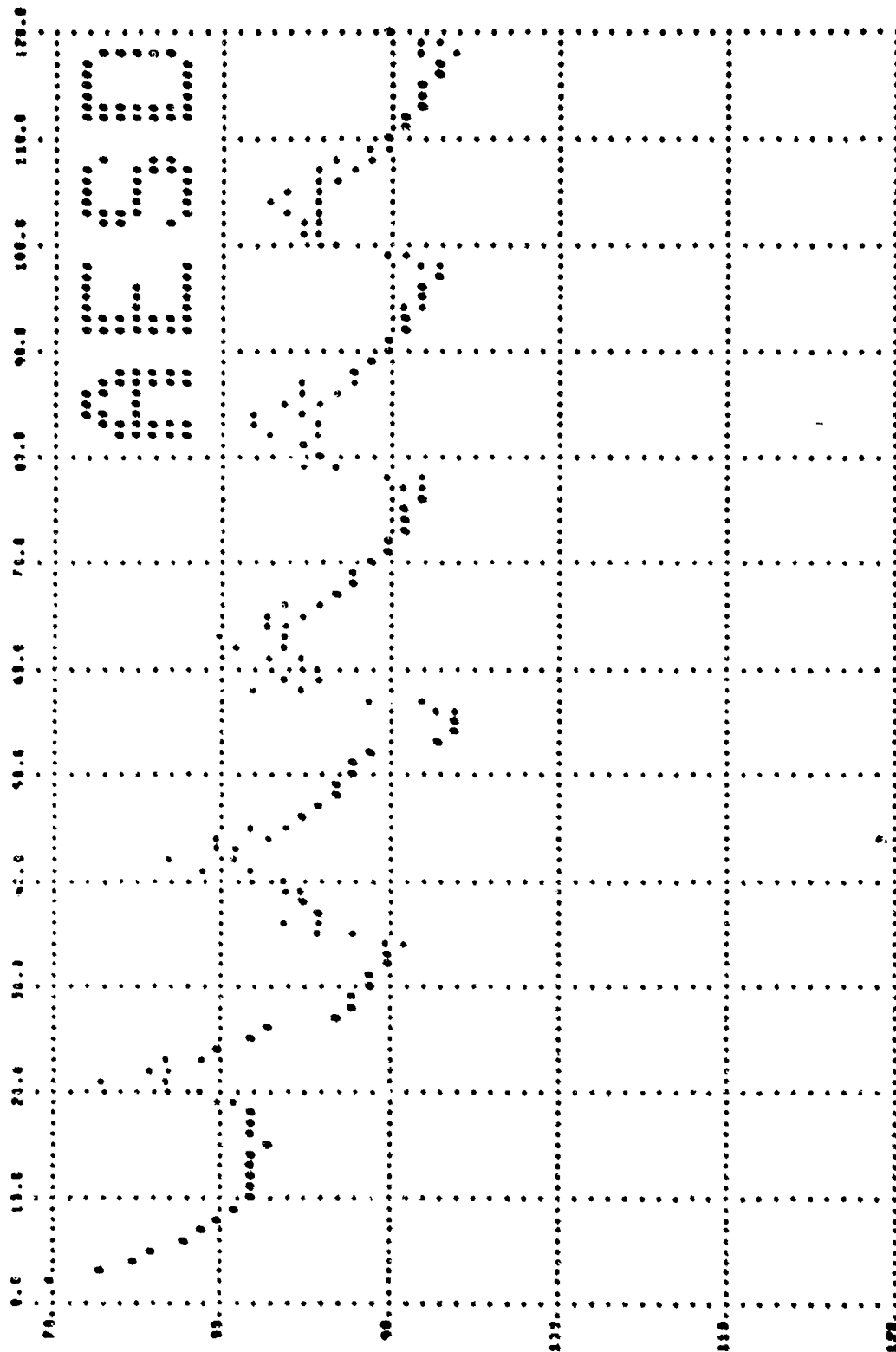
201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300

10.50.60 09/27/74

PAGE 3 SAMPLE FROM NO. 1 -- PRESSURE GRADIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.

SOURCE DATA = 7200.0 FT. REFERENCE DEPTH = 7233.0 FT

LEAD 40-- 24 MZ. SCAL = 0 133 MZ. SCAL = 0

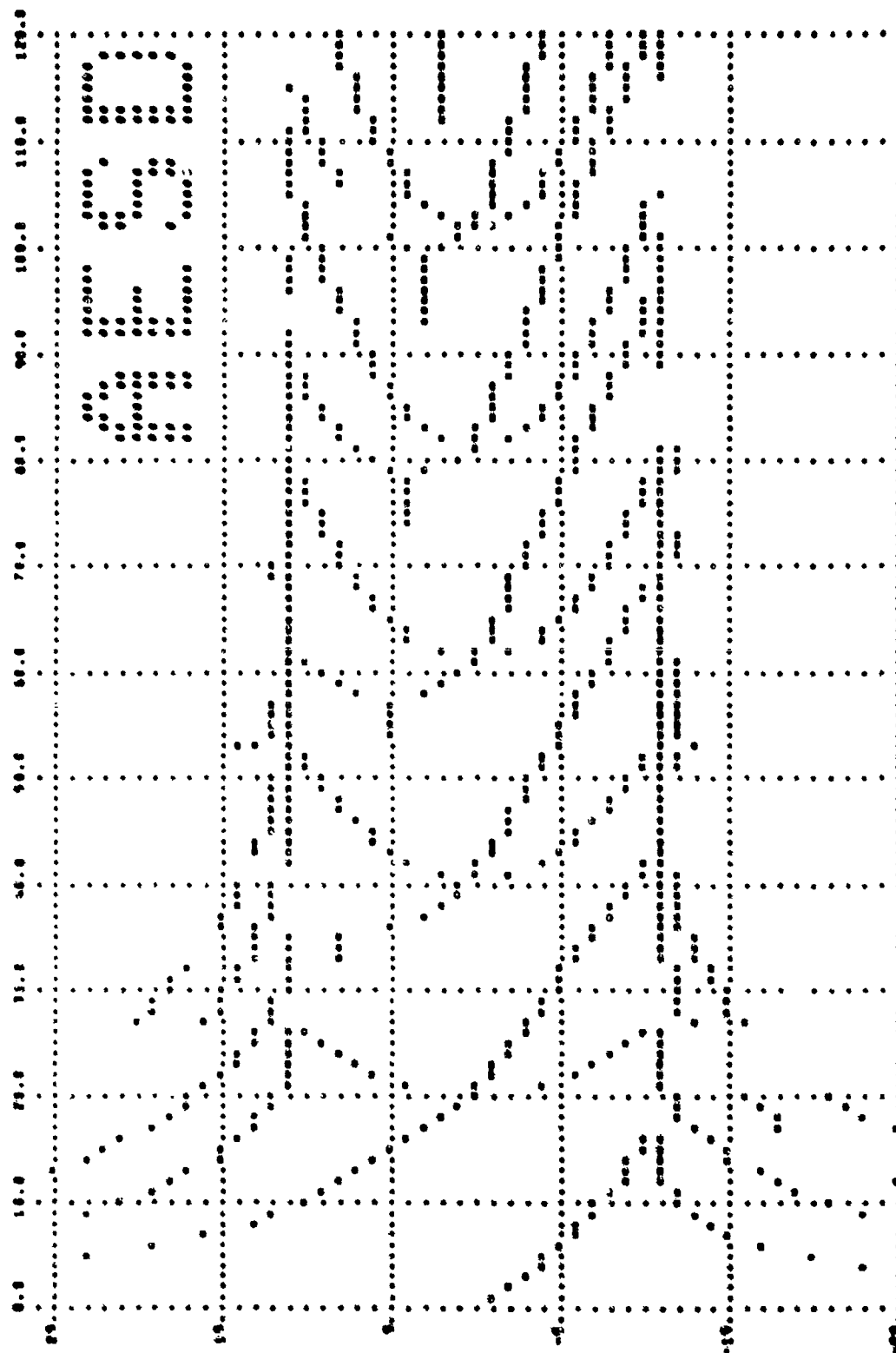


10.90.90 0927776

PAGE 1 SAMPLE RUN NO. 1 -- PRESSURE COEFFICIENT PROFILE, ARRIVAL STRUCTURE COMPUTED.

SOURCE DEPTH = 2200.0 FT, RECEIVED DEPTH = 2200.0 FT

ARRIVAL STRUCTURE -- ANGLE VS. RANGE



10.1	15.9	10.1	15.9
11.1	16.9	11.1	16.9
12.1	17.9	12.1	17.9
13.1	18.9	13.1	18.9
14.1	19.9	14.1	19.9
15.1	20.9	15.1	20.9
16.1	21.9	16.1	21.9
17.1	22.9	17.1	22.9
18.1	23.9	18.1	23.9
19.1	24.9	19.1	24.9
20.1	25.9	20.1	25.9
21.1	26.9	21.1	26.9
22.1	27.9	22.1	27.9
23.1	28.9	23.1	28.9
24.1	29.9	24.1	29.9
25.1	30.9	25.1	30.9
26.1	31.9	26.1	31.9
27.1	32.9	27.1	32.9
28.1	33.9	28.1	33.9
29.1	34.9	29.1	34.9
30.1	35.9	30.1	35.9
31.1	36.9	31.1	36.9
32.1	37.9	32.1	37.9
33.1	38.9	33.1	38.9
34.1	39.9	34.1	39.9
35.1	40.9	35.1	40.9
36.1	41.9	36.1	41.9
37.1	42.9	37.1	42.9
38.1	43.9	38.1	43.9
39.1	44.9	39.1	44.9
40.1	45.9	40.1	45.9
41.1	46.9	41.1	46.9
42.1	47.9	42.1	47.9
43.1	48.9	43.1	48.9
44.1	49.9	44.1	49.9
45.1	50.9	45.1	50.9
46.1	51.9	46.1	51.9
47.1	52.9	47.1	52.9
48.1	53.9	48.1	53.9
49.1	54.9	49.1	54.9
50.1	55.9	50.1	55.9
51.1	56.9	51.1	56.9
52.1	57.9	52.1	57.9
53.1	58.9	53.1	58.9
54.1	59.9	54.1	59.9
55.1	60.9	55.1	60.9
56.1	61.9	56.1	61.9
57.1	62.9	57.1	62.9
58.1	63.9	58.1	63.9
59.1	64.9	59.1	64.9
60.1	65.9	60.1	65.9
61.1	66.9	61.1	66.9
62.1	67.9	62.1	67.9
63.1	68.9	63.1	68.9
64.1	69.9	64.1	69.9
65.1	70.9	65.1	70.9
66.1	71.9	66.1	71.9
67.1	72.9	67.1	72.9
68.1	73.9	68.1	73.9
69.1	74.9	69.1	74.9
70.1	75.9	70.1	75.9
71.1	76.9	71.1	76.9
72.1	77.9	72.1	77.9
73.1	78.9	73.1	78.9
74.1	79.9	74.1	79.9
75.1	80.9	75.1	80.9
76.1	81.9	76.1	81.9
77.1	82.9	77.1	82.9
78.1	83.9	78.1	83.9
79.1	84.9	79.1	84.9
80.1	85.9	80.1	85.9
81.1	86.9	81.1	86.9
82.1	87.9	82.1	87.9
83.1	88.9	83.1	88.9
84.1	89.9	84.1	89.9
85.1	90.9	85.1	90.9
86.1	91.9	86.1	91.9
87.1	92.9	87.1	92.9
88.1	93.9	88.1	93.9
89.1	94.9	89.1	94.9
90.1	95.9	90.1	95.9
91.1	96.9	91.1	96.9
92.1	97.9	92.1	97.9
93.1	98.9	93.1	98.9
94.1	99.9	94.1	99.9
95.1	100.9	95.1	100.9
96.1	101.9	96.1	101.9
97.1	102.9	97.1	102.9
98.1	103.9	98.1	103.9
99.1	104.9	99.1	104.9
100.1	105.9	100.1	105.9

10-34-50 09/27/70

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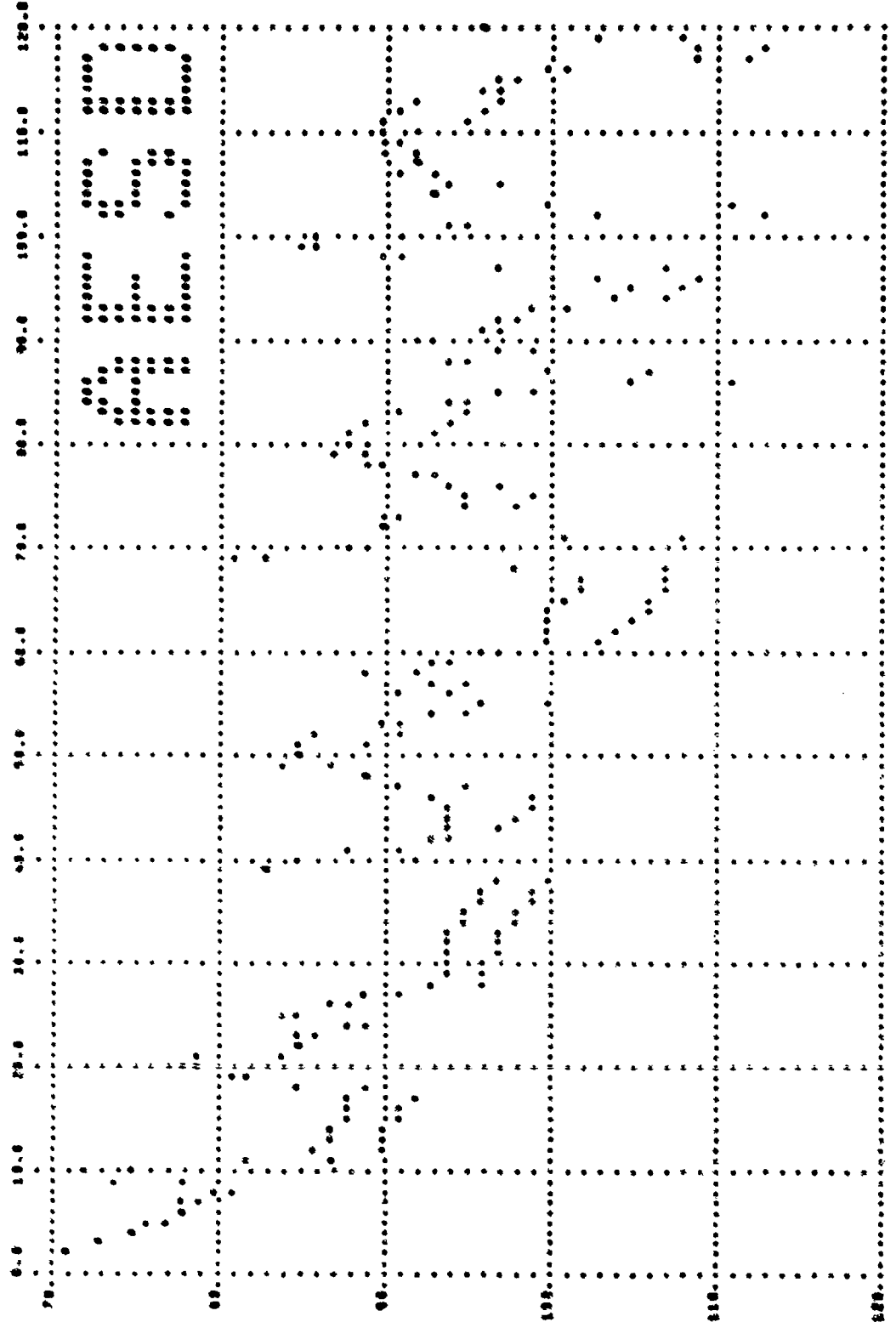
10-34-50 09/27/70

10-55-66 09/27/76

PAGE 1 SAMPLE RUN NO. 2 -- PROFILE IN WINDS AND WINDS/KIC WITH TWO POINT LAYERS.

STATION NAME = 931.1 ST. QUANTIZE TIME = 1000.0 ST

LEADER-- 111 WZ, SCOM = 0 110 WZ, SCOM = 0

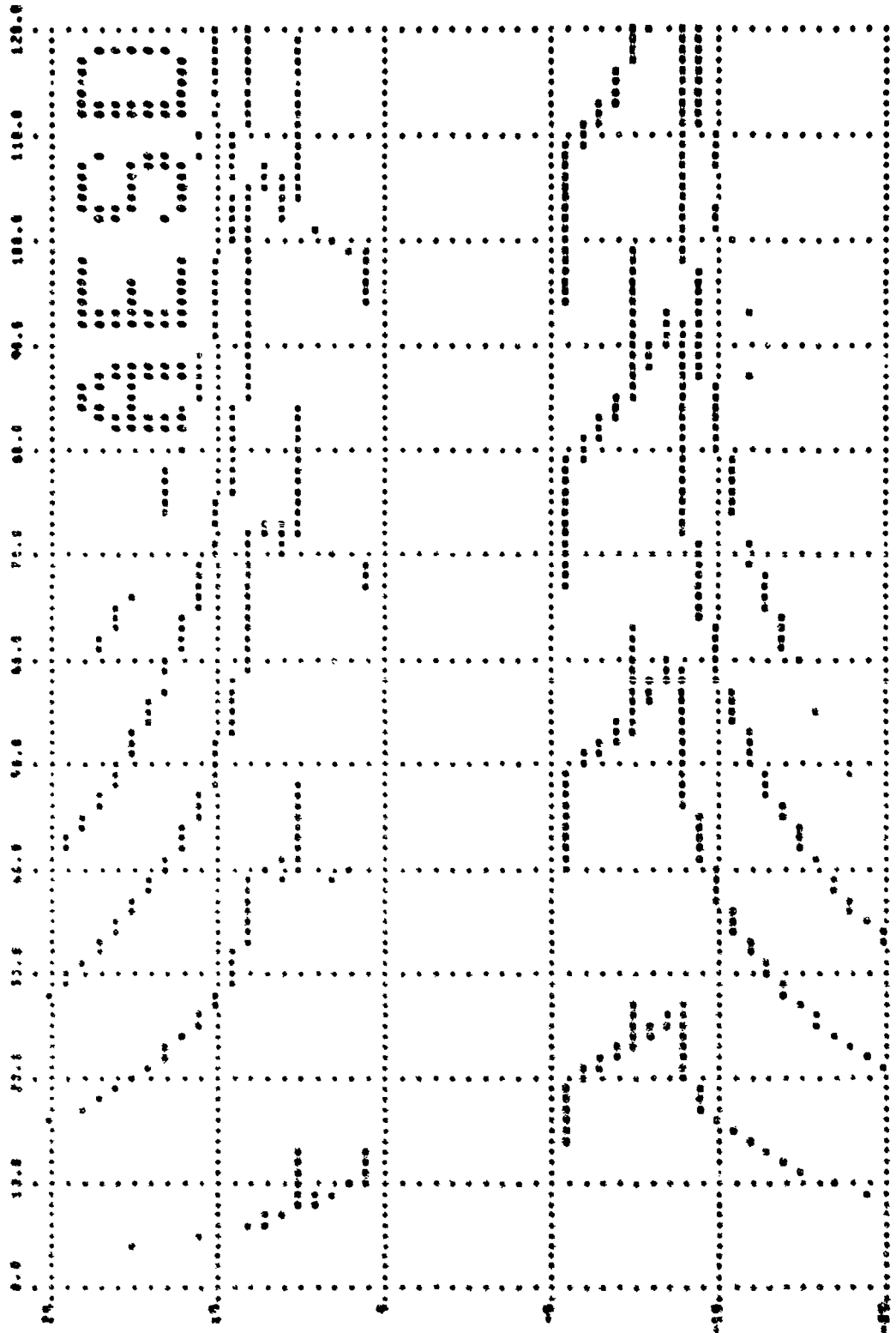


10-51-09 09/27/76

FACT SAMPLE RUN NO. 2 -- PROFILE IN MTS AND MTS/SEC WITH TWO DINTY LAYEN.

BOUNDARY DATA = 525.0 FT. ORIGIN OF MOUNTAIN = 10000.0 FT

ANOMALY STRUCTURE -- ANOMALY OF. 00000



10.01.00 00/27/70

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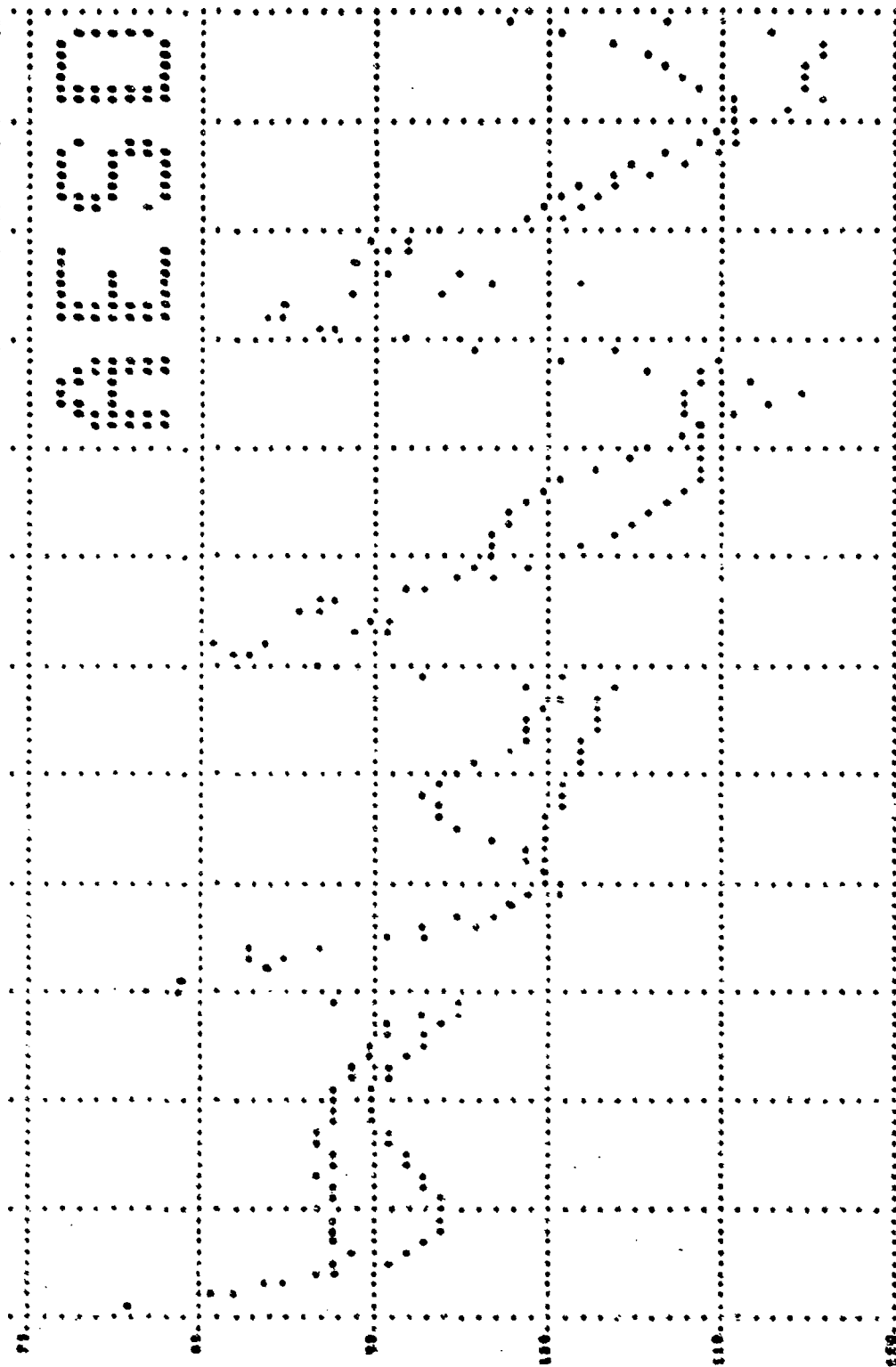
10.31.14 09/27/76

PACT SAMPLE RUN NO. 2 -- PROFILE IN WT% AND WT%/SEC WITH TWO POINT LAYERS.

SOURCE DATA - 001.0 WT. EXCLUSIVE ORIGIN - 100.0 WT

LEADERS-- 120 WT. SEC - 0 101 WT. SEC - 0

1.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0 110.0 120.0

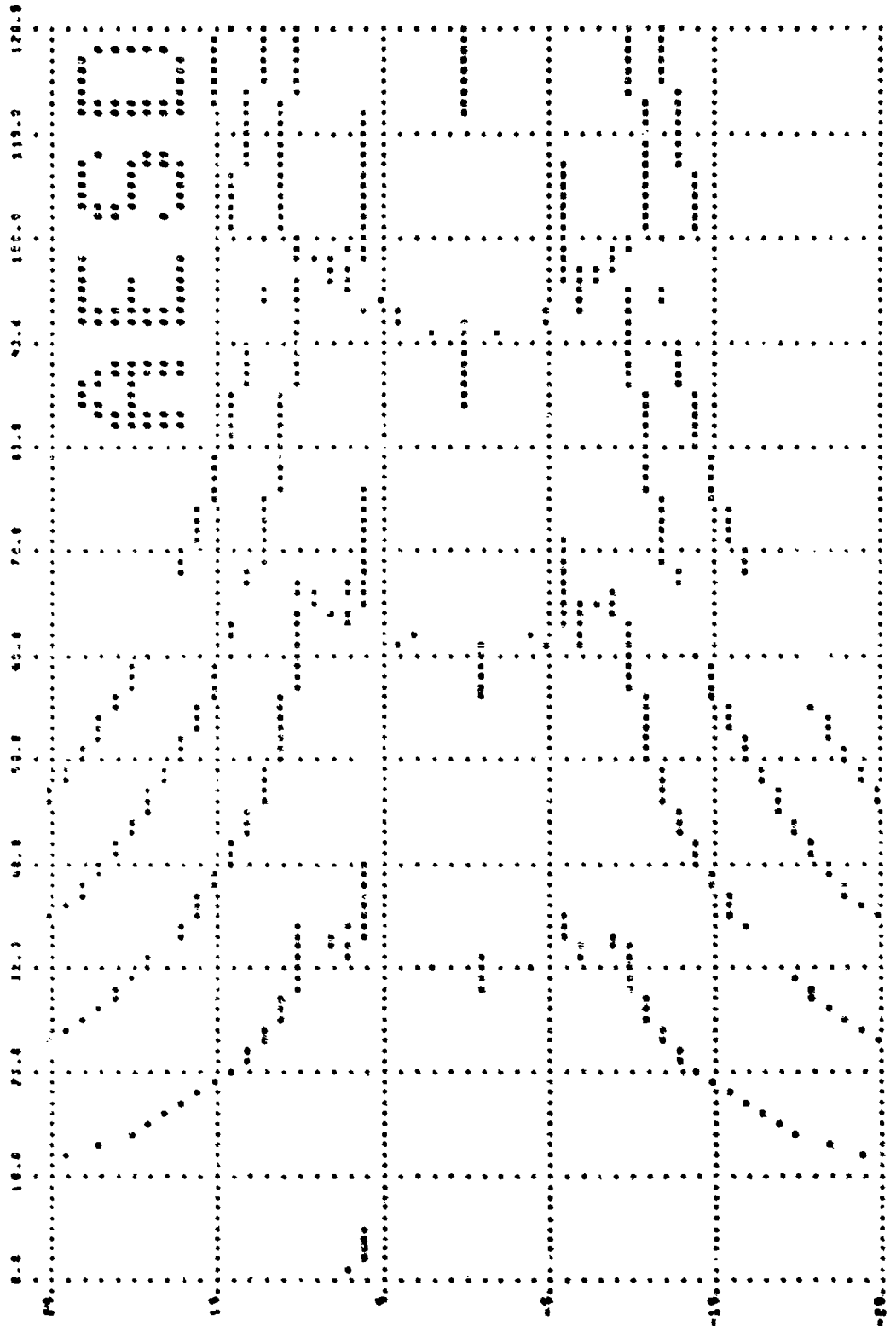


PAGE SAMPLE RUN NO. 2 -- SAMPLES IN STES AND MILES/SEC WITH TWO POINT LARS.

10.5.10 09/27/74

SOURCE DATA = 000.0 ST, 000.0000000000 000.0 ST

000.0000000000 -- 000.0 ST, 000.0000000000



P-C7 SAMPLE QJM NO. 1 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY TRIPLES.

-10	P	T				
3.00000	12.26000	35.11300	0.00000	1490.64511	6917.47003	
13.00330	12.60000	35.12000	32.00000	1490.66219	6916.98221	
23.00330	11.76000	35.13000	65.01400	1497.06002	6911.62737	
30.00300	11.11000	35.15300	126.67102	1495.17917	6905.46349	
37.00300	9.56000	35.17000	252.62467	1490.44001	6899.09635	
125.00300	0.98000	35.27000	610.10499	1489.02675	6885.25036	
153.00300	0.71000	35.25000	501.96850	1489.44006	6883.16154	
229.00600	0.26000	34.21000	751.11234	1487.71300	6880.95079	
379.00600	7.00000	25.15000	1263.43032	1480.91201	6884.75497	
520.00300	7.62000	25.14000	1732.28346	1489.53955	6886.16276	
610.00000	7.12000	25.11000	2014.41570	1499.75304	6887.63390	
810.00300	9.07000	25.04000	2678.60367	1497.91176	6881.27217	
1221.00000	4.95300	24.96000	3349.73793	1485.95022	6875.19102	
1263.00300	4.20300	24.92000	3937.00707	1487.76417	6881.12917	
1608.00000	3.09000	24.89000	4593.17505	1489.86432	6888.00631	
1951.00300	3.76000	24.89000	5000.54260	1491.43559	6893.16130	

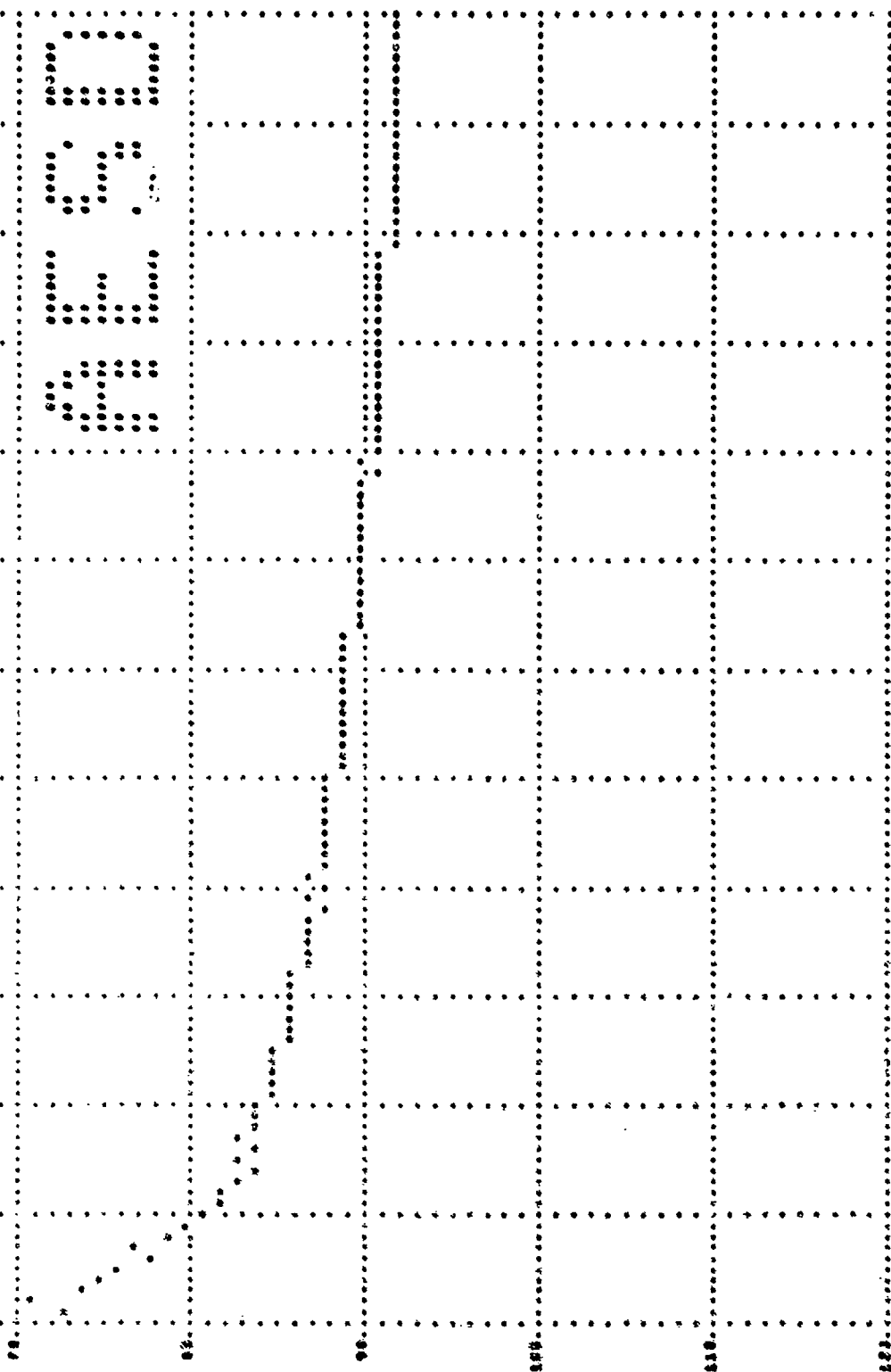
120 2.00
90.00 196.00

[illegible]

[illegible]

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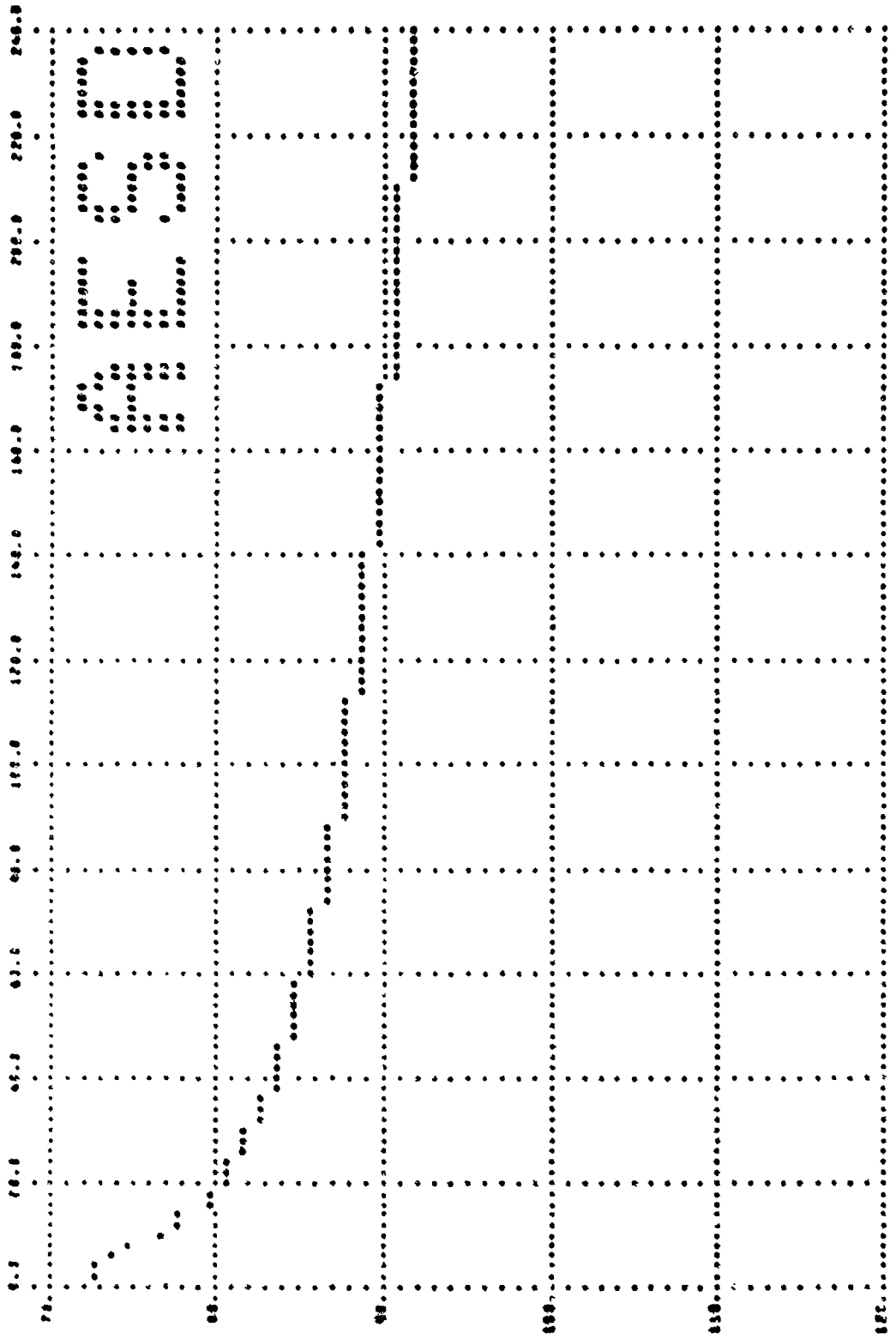


10.91.31 09/27/74

FACT SAMPLE NO. 3 -- MOBILE IN TEMPERATURE/SALINITY TOWERS.

WATER TEMPERATURE 0 01.0 FT. SURFACE DEPTH 000.0 FT

LEGEND-- 15) M2, SCOM +



10-52-52 09/27/72

1947-1948

10 7' 00 89 0 01 64 01 02 57 20 ' 00 2'. 11 0 01 09 01 00 00

100-438,481-155 1300 155

[illegible]

Figure 1

25

Figure 6

(a) $\frac{d\sigma}{d\Omega}$ vs θ at $E = 0.078 \text{ MeV}$

(b) $\frac{d\sigma}{d\Omega}$ vs θ at $E = 0.090 \text{ MeV}$

(c) $\frac{d\sigma}{d\Omega}$ vs θ at $E = 0.100 \text{ MeV}$

Figure 1

333

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Figure 1

Figure 1

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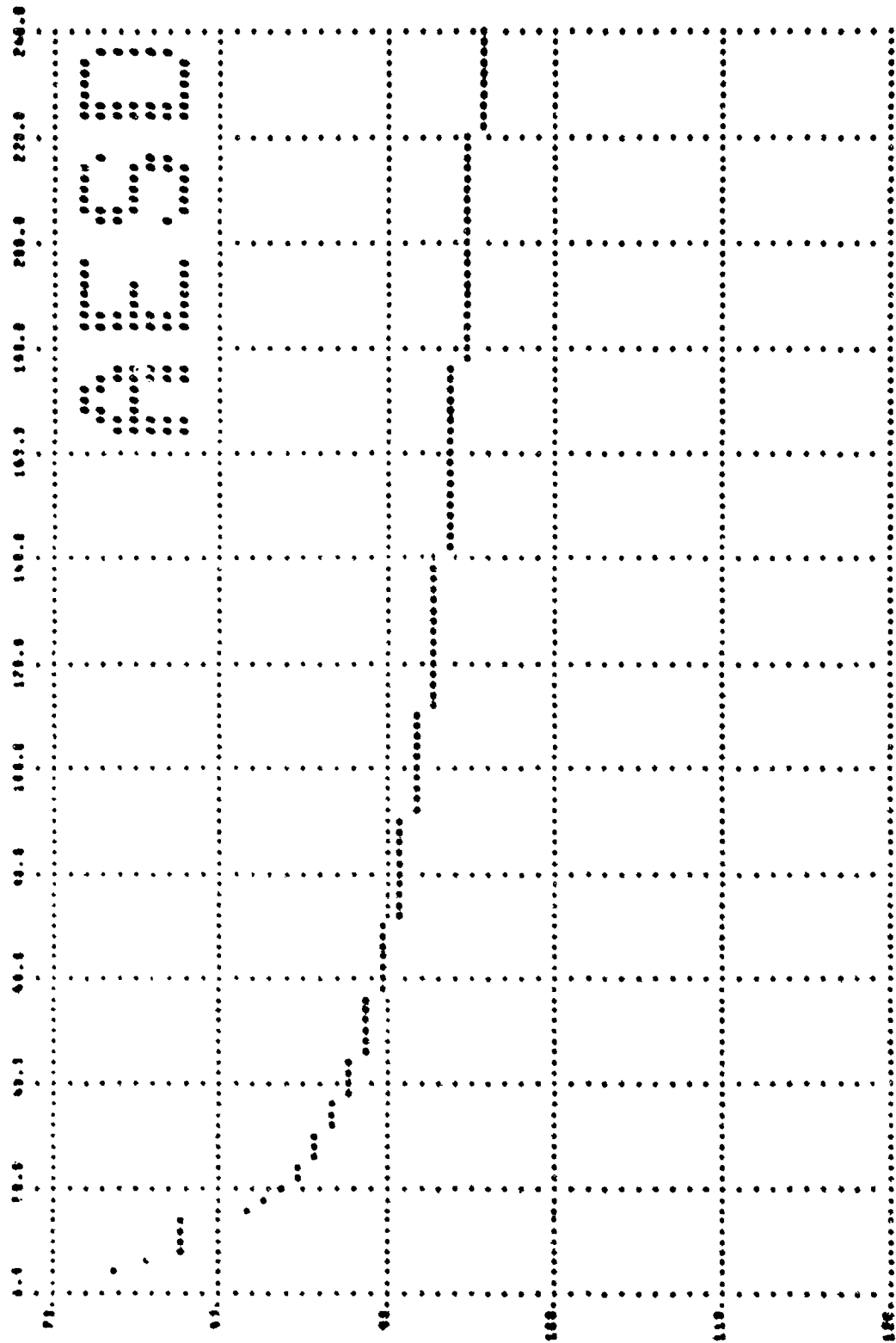
.....

10-91-20 00/27/76

FACT SAMPLE RUN NO. 3 -- PROFILE IN DENSITY/TEMPERATURE/SALINITY VALUES.

NOISE LEVEL = 100.0 FT. MICROSECONDS = 0.000.0 FT

LEAD WT. = 33 WT. 100M = 0



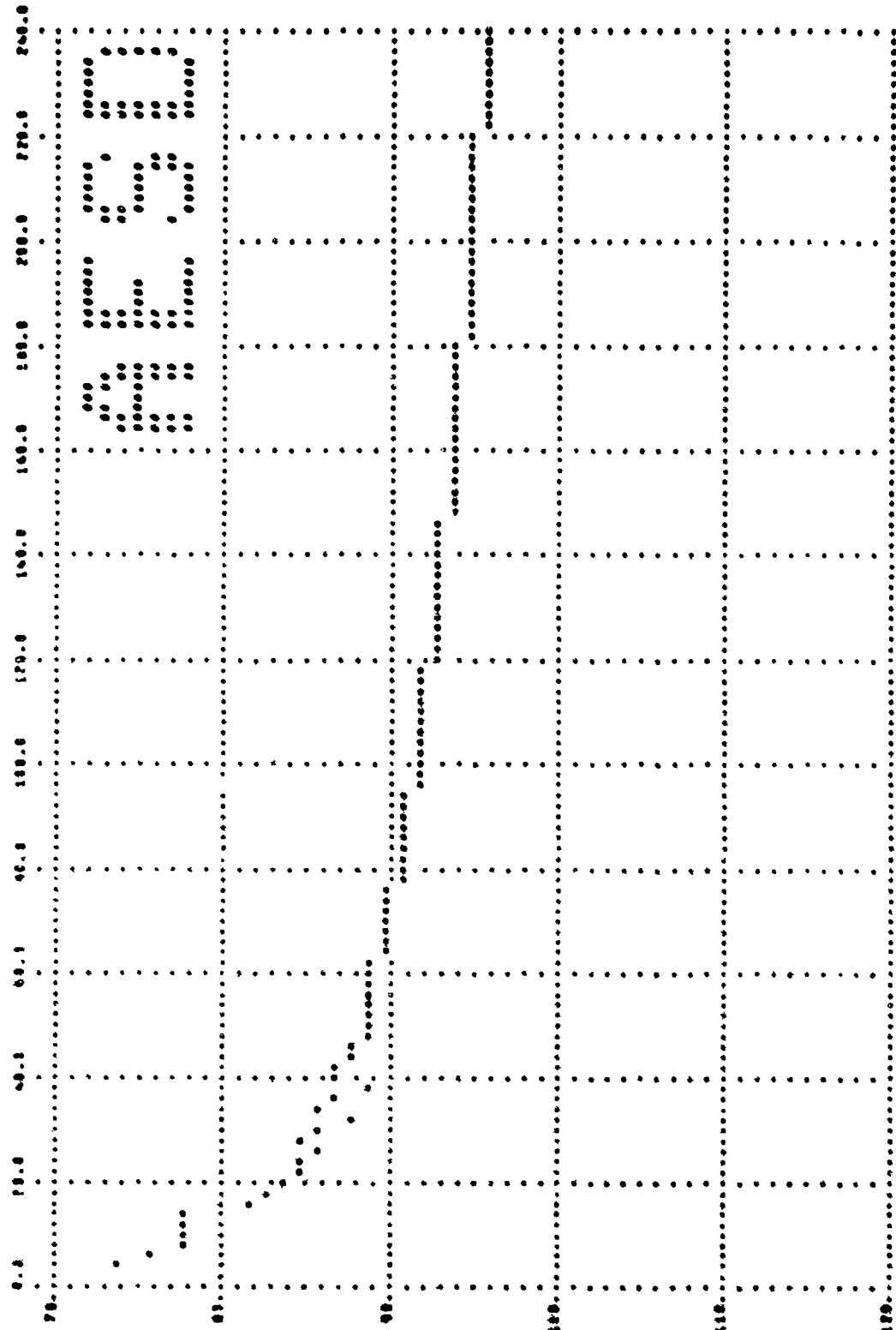
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PLAT SAMPLE RUN NO. 1 -- PROFILE IN DEPTH/TEMPERATURE/SALINITY (TEMPERATURE)

10.51.30 00/27/70

STATION NAME: 300.0 FT. DEPTH/TEMPERATURE/SALINITY (TEMPERATURE)

LEGEND: 100 mT. 100m



THE FOLLOWING PAGES CONTAIN A COMPLETE FORTRAN COMPILATION
ON THE CDC 6700 OF ALL ROUTINES WHICH COMPOSE THE AESD FACT
PACKAGE.

THE AESD DESIGNATION FOR THIS PARTICULAR VERSION IS--

FACIMCPL9C

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

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

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

1971 SCOV 8-8 60 OF 3-8 CARS FLAC

PROGRAM	LOSS	CDC LOSS FROM 03.0-0340 OPT-08	79/2776	13-16-70.	PAGE
115	C	JC(1) = COMPLEMENT FOR I-TM FREQUENCY = 1 FOR SEMI-CONDUCTOR = 1 FOR INDUCTOR = 2 FOR FULLY CONDUCTOR	LOSS	112	
	C		LOSS	113	
	C		LOSS	114	
	C		LOSS	115	
	C		LOSS	116	
	C		LOSS	117	
	C		LOSS	118	
	C		LOSS	119	
	C		LOSS	120	
	C		LOSS	121	
	C		LOSS	122	
	C		LOSS	123	
	C		LOSS	124	
	C		LOSS	125	
	C		LOSS	126	
	C		LOSS	127	
	C		LOSS	128	
	C		LOSS	129	
	C		LOSS	130	
	C		LOSS	131	
	C		LOSS	132	
	C		LOSS	133	
	C		LOSS	134	
	C		LOSS	135	
	C		LOSS	136	
	C		LOSS	137	
	C		LOSS	138	
	C		LOSS	139	
	C		LOSS	140	
	C		LOSS	141	
	C		LOSS	142	
	C		LOSS	143	
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1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.
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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
Unavailable	Beam, J. P., et al.	LONG-RANGE ACOUSTIC PROPAGATION LOSS MEASUREMENTS OF PROJECT TRANSLANT I IN THE ATLANTIC OCEAN EAST OF BERMUDA	Naval Underwater Systems Center	740612	ADC001521	U
Unavailable	Cornyn, J. J., et al.	AMBIENT-NOISE PREDICTION. VOLUME 2. MODEL EVALUATION WITH IOMEDEX DATA	Naval Research Laboratory	740701	AD0530983	U
Unavailable	Unavailable	COHERENCE OF HARMONICALLY RELATED CW SIGNALS	Naval Underwater Systems Center	740722	ADB181912	U
Unavailable	Banchero, L. A., et al.	IOMEDEX SOUND VELOCITY ANALYSIS AND ENVIRONMENTAL DATA SUMMARY	Naval Oceanographic Office	740801	ADC000419	U
3810	Unavailable	CONSTRUCTION AND CALIBRATION OF USRD TYPE F58 VIBROSEIS MONITORING HYDROPHONES SERIALS 1 THROUGH 7	Naval Research Laboratory	741002	ND	U
ARL-TM-73-11; ARL-TM-73-12	Ellis, G. E., et al.	ARL PRELIMINARY DATA ANALYSIS FROM ACODAC SYSTEM; ANALYSIS OF THE BLAKE TEST ACODAC DATA	University of Texas, Applied Research Laboratories	741015	ADA001738; ND	U
Unavailable	Mitchell, S. K., et al.	QUALITY CONTROL ANALYSIS OF SUS PROCESSING FROM ACODAC DATA	University of Texas, Applied Research Laboratories	741015	ADB000283	U
Unavailable	Unavailable	MEDEX PROCESSING SYSTEM. VOLUME II. SOFTWARE	Bunker-Ramo Corp. Electronic Systems Division	741021	ADB000363	U
Unavailable	Spofford, C. W.	FACT MODEL. VOLUME I	Maury Center for Ocean Science	741101	ADA078581	U
Unavailable	Bucca, P. J., et al.	SOUND VELOCITY STRUCTURE OF THE LABRADOR SEA, IRMINGER SEA, AND BAFFIN BAY DURING THE NORLANT-72 EXERCISE	Naval Oceanographic Office	741101	ADC000461	U
Unavailable	Anderson, V. C.	VERTICAL DIRECTIONALITY OF NOISE AND SIGNAL TRANSMISSIONS DURING OPERATION CHURCH ANCHOR	Scripps Institution of Oceanography Marine Physical Laboratory	741115	ADA011110	U
Unavailable	Baker, C. L., et al.	FACT MODEL. VOLUME II	Office of Naval Research	741201	ADA078539	U
ARL-TR-74-53	Anderson, A. L.	CHURCH ANCHOR EXPLOSIVE SOURCE (SUS) PROPAGATION MEASUREMENTS (U)	University of Texas, Applied Research Laboratories	741201	ADC002497; ND	U
MCR106	Cherkis, N. Z., et al.	THE NEAT 2 EXPERIMENT VOL 1 (U)	Maury Center for Ocean Science	741201	NS; ND	U
MCR107	Cherkis, N. Z., et al.	THE NEAT 2 EXPERIMENT VOL 2 - APPENDICES (U)	Maury Center for Ocean Science	741201	NS; ND	U
Unavailable	Mahler, J., et al.	INTERIM SHIPPING DISTRIBUTION	Tetra, Tech, BB&N, & PSI	741217	ND	U
75-9M7-VERAY-R1	Jones, C. H.	LRAPP VERTICAL ARRAY - PHASE IV	Westinghouse Electric Corp.	750113	ADA008427; ND	U
AESD-TN-75-01	Spofford, C. W.	ACOUSTIC AREA ASSESSMENT	Office of Naval Research	750201	ADA090109; ND	U