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NAVAL UNDERWATER SYSTEMS CENTER  
NEW LONDON LABORATORY  
NEW LONDON, CONNECTICUT 06320

Technical Memorandum

A COMPARISON OF MULTIPATH ARRIVAL STRUCTURES  
OBSERVED IN THE PRESENCE OF A SURFACE DUCT  
WITH PREDICTIONS OBTAINED USING CLASSICAL RAY  
TECHNIQUES AND THE PARABOLIC EQUATION METHOD

14 February 1985

Prepared by: Herbert G. Freese  
Herbert A. Freese  
Advanced Systems Concepts  
Submarine Sonar Department

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

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ABSTRACT

Observed underwater acoustic multipath arrival structures are compared with theoretical predictions based on historic sound speed profiles for the vicinity of the Mid-Atlantic Ridge (3500 m water) and the Blake Plateau (1000 m water). Examining these comparisons for surface duct environmental conditions resulted in the conclusion that wave theory is necessary for predicting the distribution of received energy and that classical ray theory (i.e., ray propagation using the high frequency assumption without sound leakage correction) is inadequate.

ADMINISTRATIVE INFORMATION

This technical memorandum was originally prepared under Project No. A62000, 'Acoustic Communications for Submarines and Surface Vessels,' Principal Investigator, A. W. Ellinhorpe. The sponsoring activity was the Naval Sea Systems Command, NAVSEA 63DB, D. M. Early, Program Manager. The memorandum is being issued under Project No. A65000, 'Environmental Acoustic Support for Shipboard Sonar', Principal Investigator, B. F. Cole. The sponsoring activity is the Naval Sea Systems Command, NAVSEA 63R1, D. E. Porter, Program Manager.

When this memorandum was originally prepared (14 May 1981) the author was located at the New London Laboratory, Naval Underwater Systems Center, New London, Connecticut 06320. The author is presently located at Arete Associates, Arlington, Virginia 22202.

### INTRODUCTION

Observations of multipath arrival structures made at sea using short pulses have indicated that energy leaking into and out of surface ducts can play a significant role in the propagation of acoustic energy. This leakage phenomenon was first reported over twenty years ago by W. Thorpe and others with reference to leakage into and out of refracted-surface reflected (RSR) paths. Recent experience has indicated that this leakage phenomenon can also be of importance for energy propagating via bottom bounce modes.

This leakage phenomenon will be quite general, since surface ducts exist for a good portion of the year in many regions of the world's oceans. In fact, Thorpe et al., also demonstrated that the surface duct need only be present over some part of the total range in order for the leaky arrivals to exist. The particular leakage mechanism which is referred to is shown pictorially in Figure 1. Simply stated it is tunnelling through a potential barrier, an effect which diminishes with increasing frequency and with increasing distance of the source/receiver from the duct boundary. This does not imply that the effect is important only at low frequencies; first, depending on the particular source/receiver geometry and the duct shape, this effect could have an impact on current and future operational sonars, and second, scattering into and out of the duct by internal/surface wave action may enhance the effect.

This phenomenon leads to the characteristic arrival pattern shown in Figure 2. The salient aspects of this arrival structure are a set of equally spaced early arrivals followed by arrivals with rapidly decreasing increasing with range. If classical ray techniques are used in an attempt to predict the arrival structure the earlier equally spaced arrivals will be missing. On the other hand, solutions which account for the wave nature of the acoustic field will be successful.

The purpose of this memorandum is to compare observed multipath arrival structures with those predicted using ray theory (CONGRATS I) and wave theory (parabolic equation (PE)) and to indicate the superiority of the latter under the conditions stated herein.

### DISCUSSION

We wish to examine a set of multipath arrival structures obtained in the vicinity of the Mid-Atlantic Ridge (3500 m water) and the Blake Plateau (1000 m water). These data sets are of interest because it was suspected that leakage into and out of a surface duct and into bottom bounce paths played an important role in determining the arrival structure.

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Several examples which illustrate the nature of the multipath structure are shown in Figures 3 through 6. These data, which are a subset of those to be used in this memorandum, were obtained at 500 and 1600 Hz using 10 msec Gaussian pulses (Blake) and at 750 Hz using 20 msec Gaussian pulses (Mid-Atlantic Ridge). In all cases shown, the arrival structure usually represents an average of the received intensity over thousands of received pulses. Note also that the time scales on these plots is not the same for each case.

We will proceed by using historical sound velocity profiles obtained from reference (a) as inputs to a ray program (CONGRATS I) and a wave program (PE), profiles which are appropriate for the area in which the data were taken. For the PE simulation we will use the program described in reference (b) to propagate pulses whose duration is short enough to resolve the individual paths. A comparison between the two theoretical techniques (at 500 Hz) and the observations will then be made with particular attention being payed to the relative path arrival times. In each case the water depth will be chosen to match the average water depth in the experimental areas.

The first data set which we will examine are those obtained in the vicinity of the mid-Atlantic Ridge during the month of November. The results of the PE and CONGRATS runs for a water depth of 3500 meters are shown in Appendix A. The arrival time data are summarized in Figures 7 through 10 using a water depth appropriate for the experimental area. We have identified each path on these figures using the following terminology: DS indicates a surface duct path, Bn indicates a bottom bounce path interacting with the bottom n times, and a subscript '1' is attached to a path if it is generated by energy leaking through the duct. The ray theory results are always referenced to an imaginary straight line ray traveling in the duct. As can be observed from this set of data the agreement between the observed arrival times and PE technique is quite good. As expected the ray theory quite generally fails to predict the earlier, leaky arrivals.

The second data set which we wish to examine was obtained in the month of February in the vicinity of the Blake Plateau. The results of the CONGRATS I and PE run are summarized in Appendix B using a water depth of 900 meters. The arrival time data is summarized in Figure 11 using the appropriate water depth. Again, the ray theory results are referenced to an imaginary ducted ray. Note that the PE technique predicts the arrival structure quite nicely while the ray technique does not predict the earlier arrivals.

The last data set was also obtained in the vicinity of the Mid-Atlantic Ridge, but this time during the month of March. The CONGRATS I and PE runs for this time of year and area are shown in Appendix C for a water depth of 3500 meters. The arrival time data is summarized in Figures 12 and 13 using the appropriate water depth. The agreement between the PE technique and the observations on the first data set are good out to about 37.5 nautical miles but then the agreement is no longer good, perhaps because of scattering in the surface duct and/or a change in the sound speed profile in the vicinity of the duct. The results for the second data set show a good agreement between the PE method out to 117 nautical miles but the ray technique again fails once the leaky modes can be excited.

### CONCLUSIONS

Being able to understand this leakage phenomenon and to calculate its effect on the received signal energy is important for a number of reasons. First the existence of energy which can leak into and out of a surface duct (or any duct for that matter) is certainly important for establishing a physical understanding of the propagation physics. The matter of proper path identification falls into this category. This is true regardless of whether the energy leaks into bottom bounce modes or RSR modes. A second, an even more important reason for accounting for this phenomenon carefully is its possible impact on operational systems and algorithms. For example, the effect of this mechanism on sonar systems and system design could be significant. This is particularly true if one considers that under certain circumstances, these leaky paths contain a significant portion of the received energy.

Another conclusion which one can draw from these comparisons is that one is well advised to avoid standard ray techniques such as CONGRATS and FACT for example, when it is suspected that leakage may be important. Techniques such as RAYMODE should also be avoided in these instances because, although RAYMODE accounts for leakage out of the duct it does not allow for leakage back into the duct. This is true even though the technique on which it is based (multipath expansion) is quite general and includes wave effects. In this regard, H. Weinberg has implemented a program based on the multipath expansion technique which offers the promise of a proper accounting of all the propagating energy. A comparison of multipath arrival patterns computed using Weinberg's technique, will be made with our observations in a subsequent memorandum.

Finally, full wave techniques such as PE, FFP, and normal modes, account properly for the received energy. They however generally suffer from a burden of requiring excessive computer time in order to make the necessary computations.

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REFERENCES

- (a) E. Podezwa, "Sound Speed Profiles for the North Atlantic Ocean", NUSC Technical Document 5447
- (b) H. Freese and P. Maciejewski, "Solution of the Parabolic Wave Equation Implemented on a Floating Point Systems Array Processor", NUSC Technical Memorandum No. 811062

LEAKAGE MECHANISM

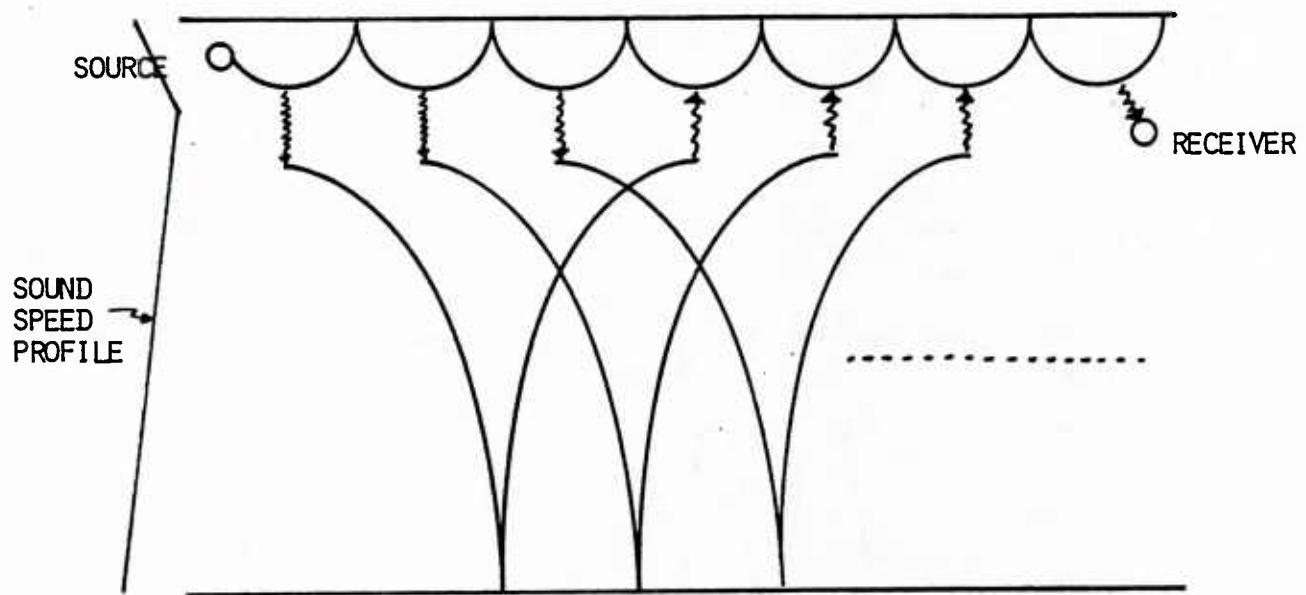


FIGURE 1. ILLUSTRATION OF LEAKAGE PHENOMENON

TYPICAL ARRIVAL STRUCTURE

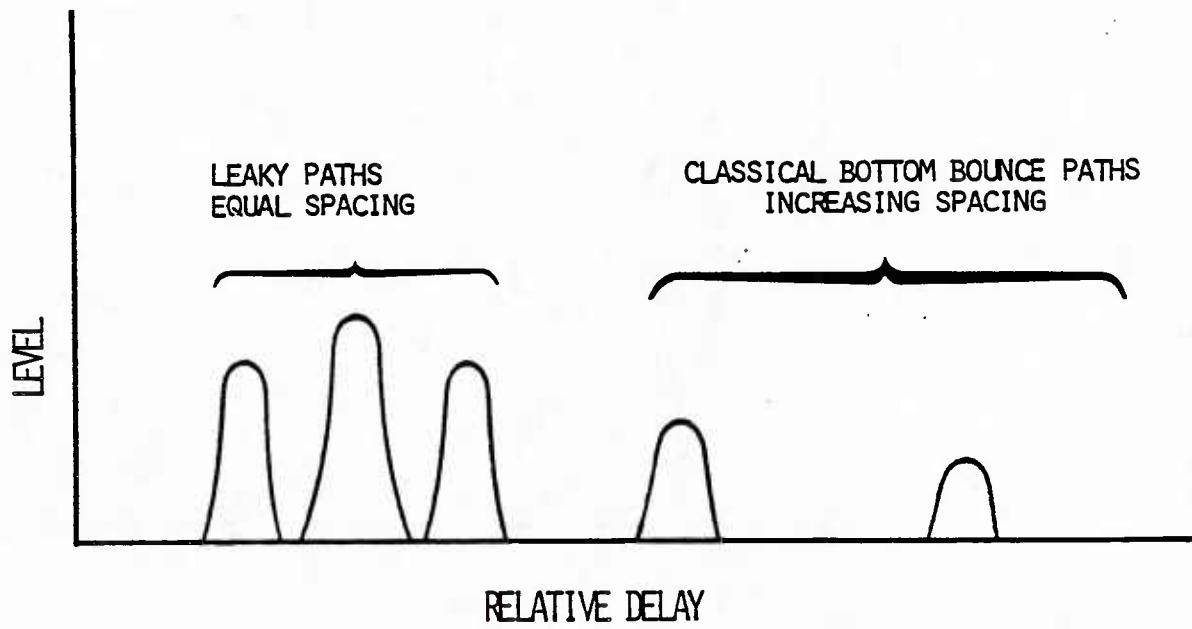


FIGURE 2. TYPICAL ARRIVAL STRUCTURE

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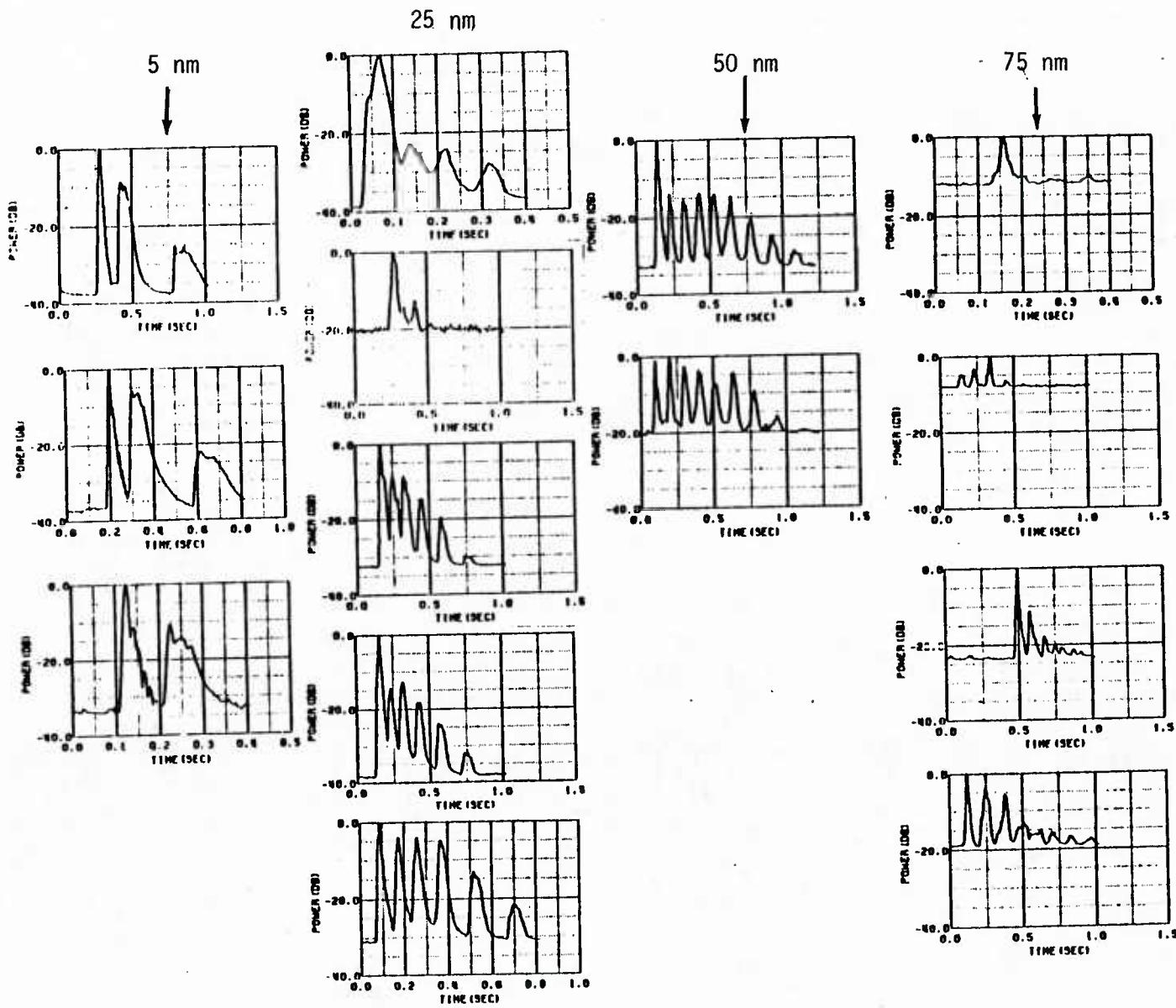


FIGURE 3. BLAKE DATA, 500 Hz, JANUARY

12

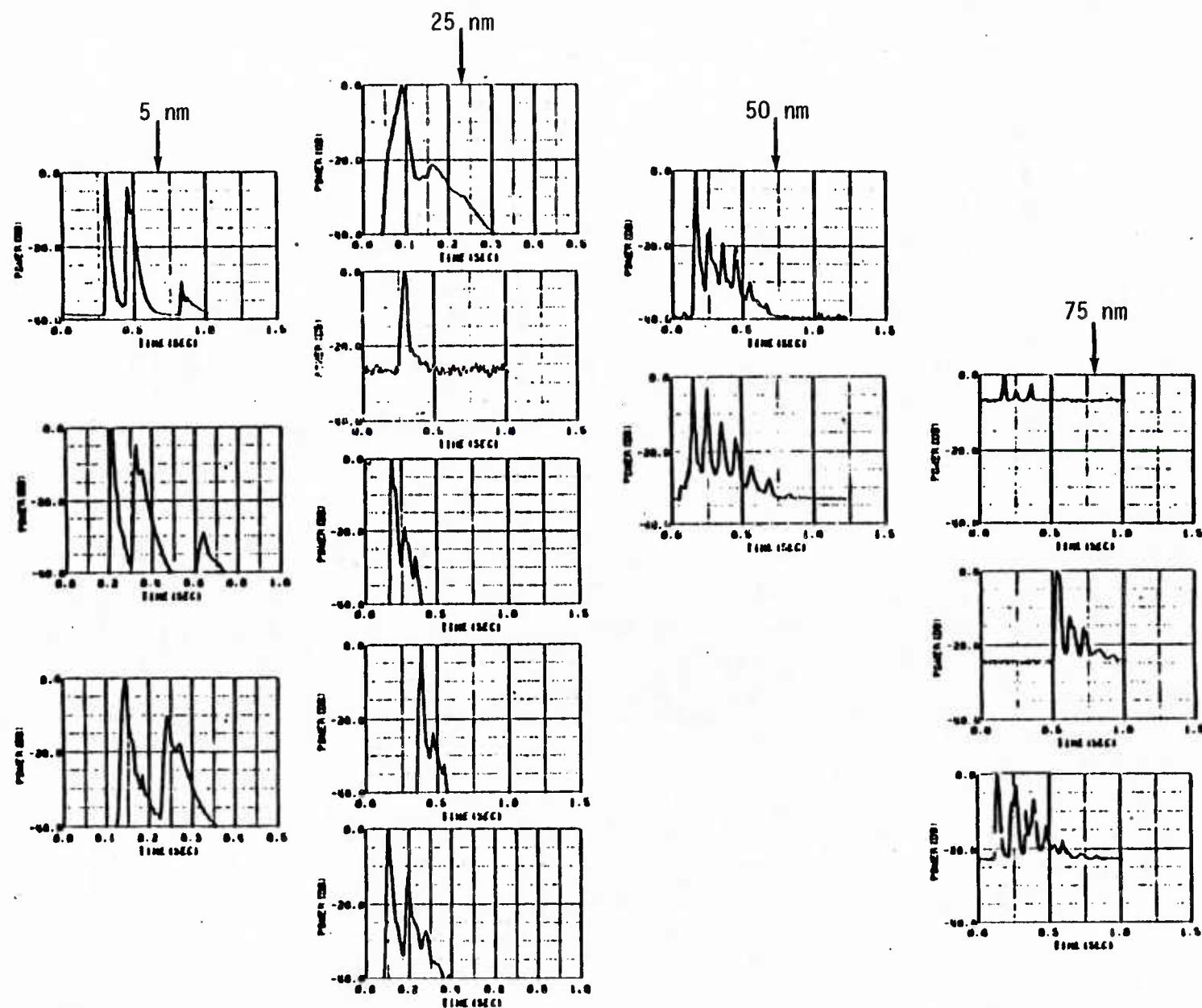


FIGURE 4 BLAKE DATA, 1600 HZ, JANUARY

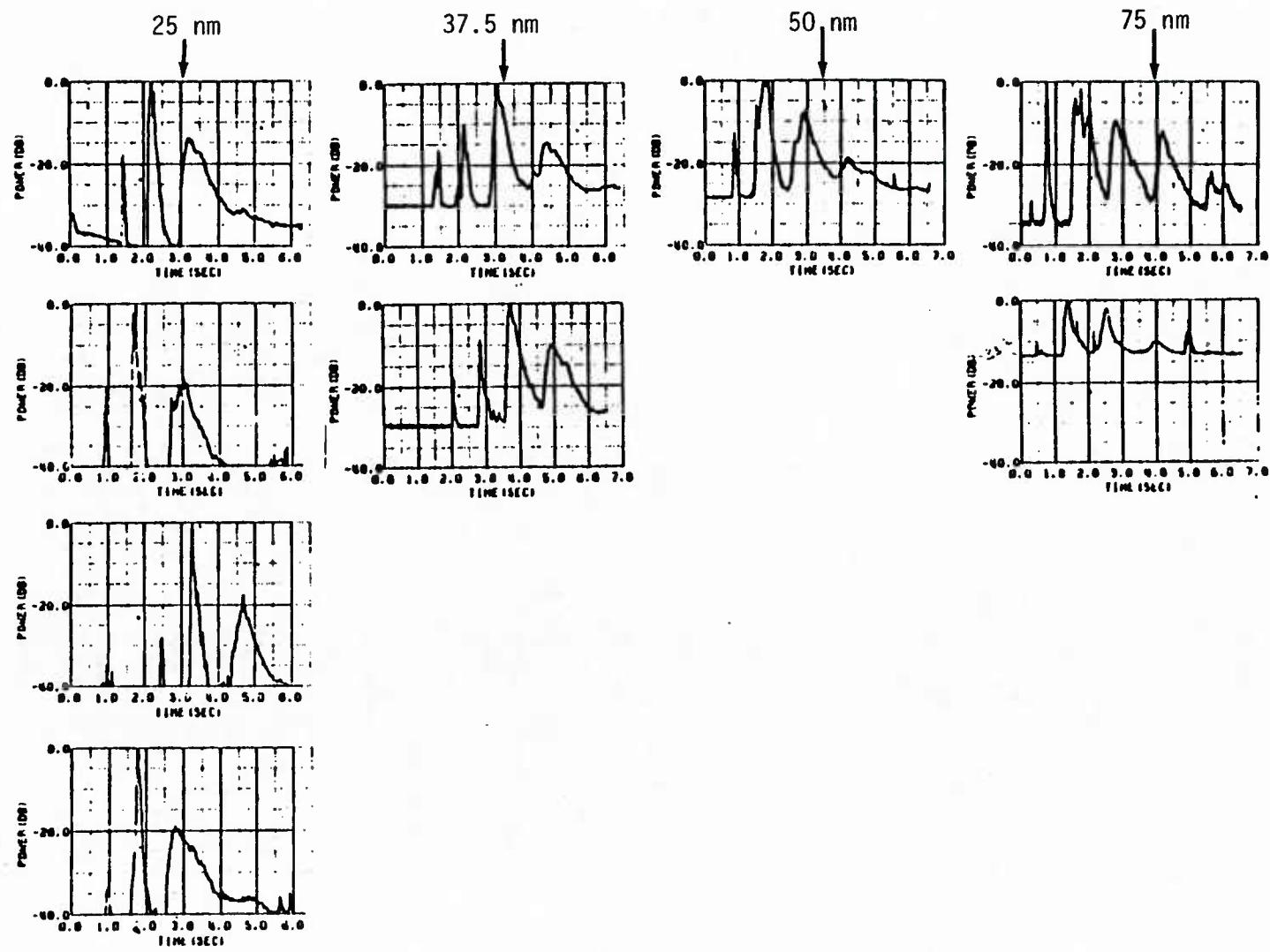


FIGURE 5 RIDGE DATA # 1, 750 HZ, MARCH

14

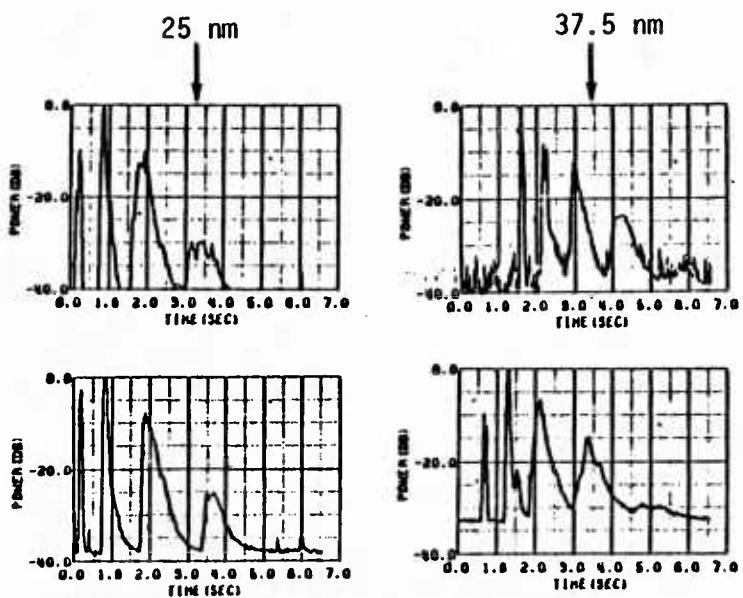


FIGURE 6 RIDGE DATA # 2, 750 HZ, MARCH

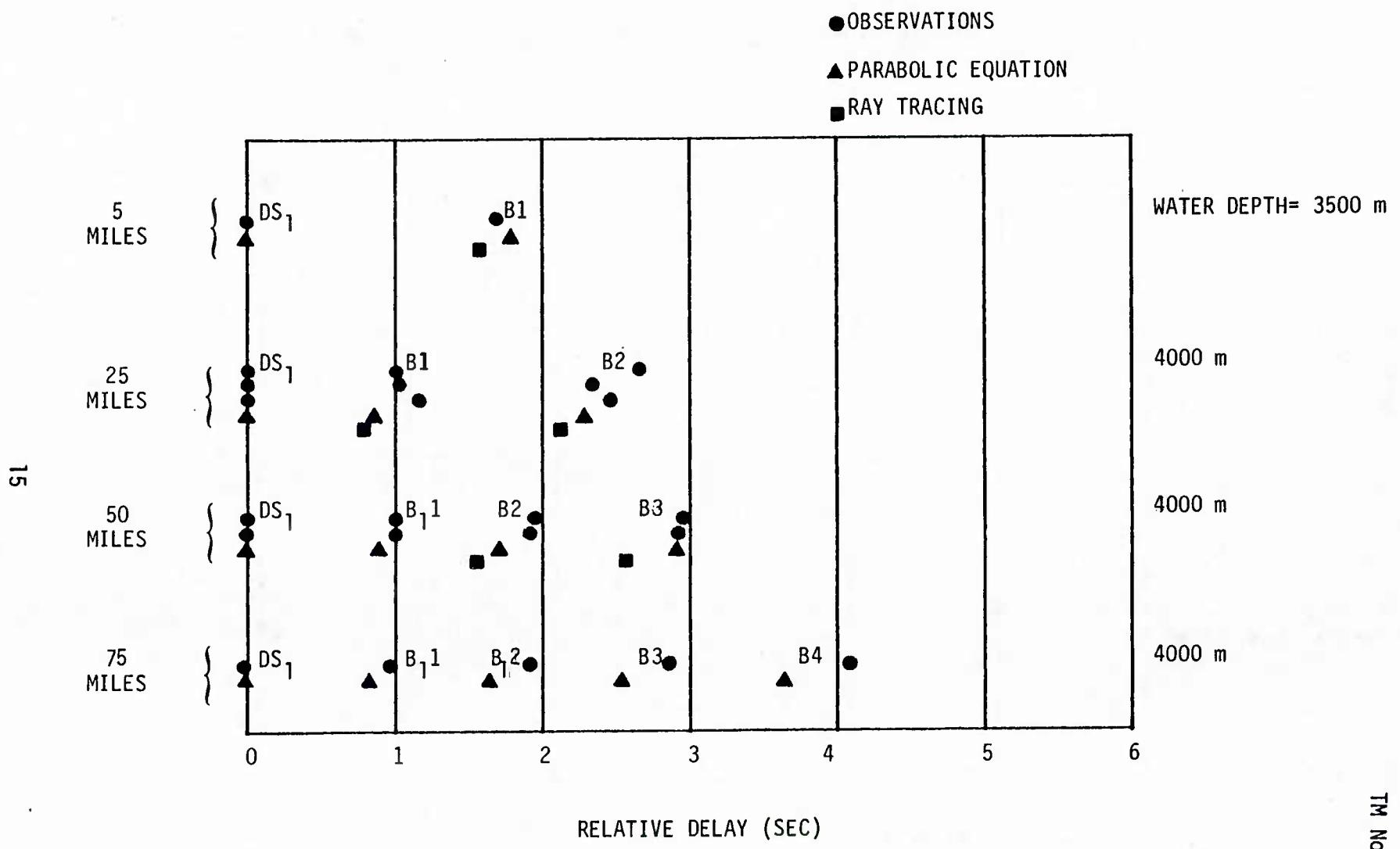


FIGURE 7 RELATIVE ARRIVAL TIME, MID-ATLANTIC RIDGE # 1 NOVEMBER

TM No. 811061

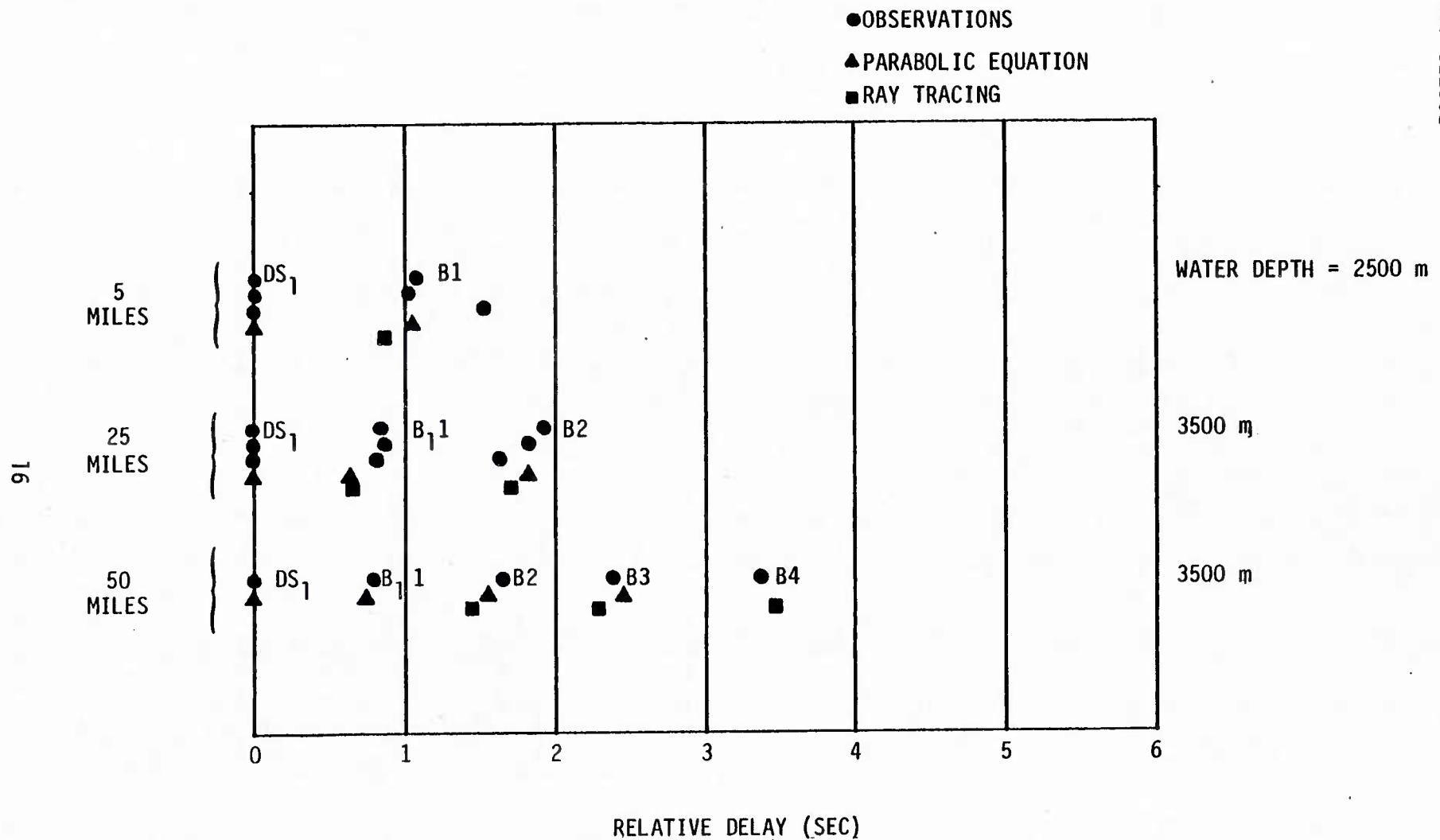


FIGURE 8 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 2 NOVEMBER

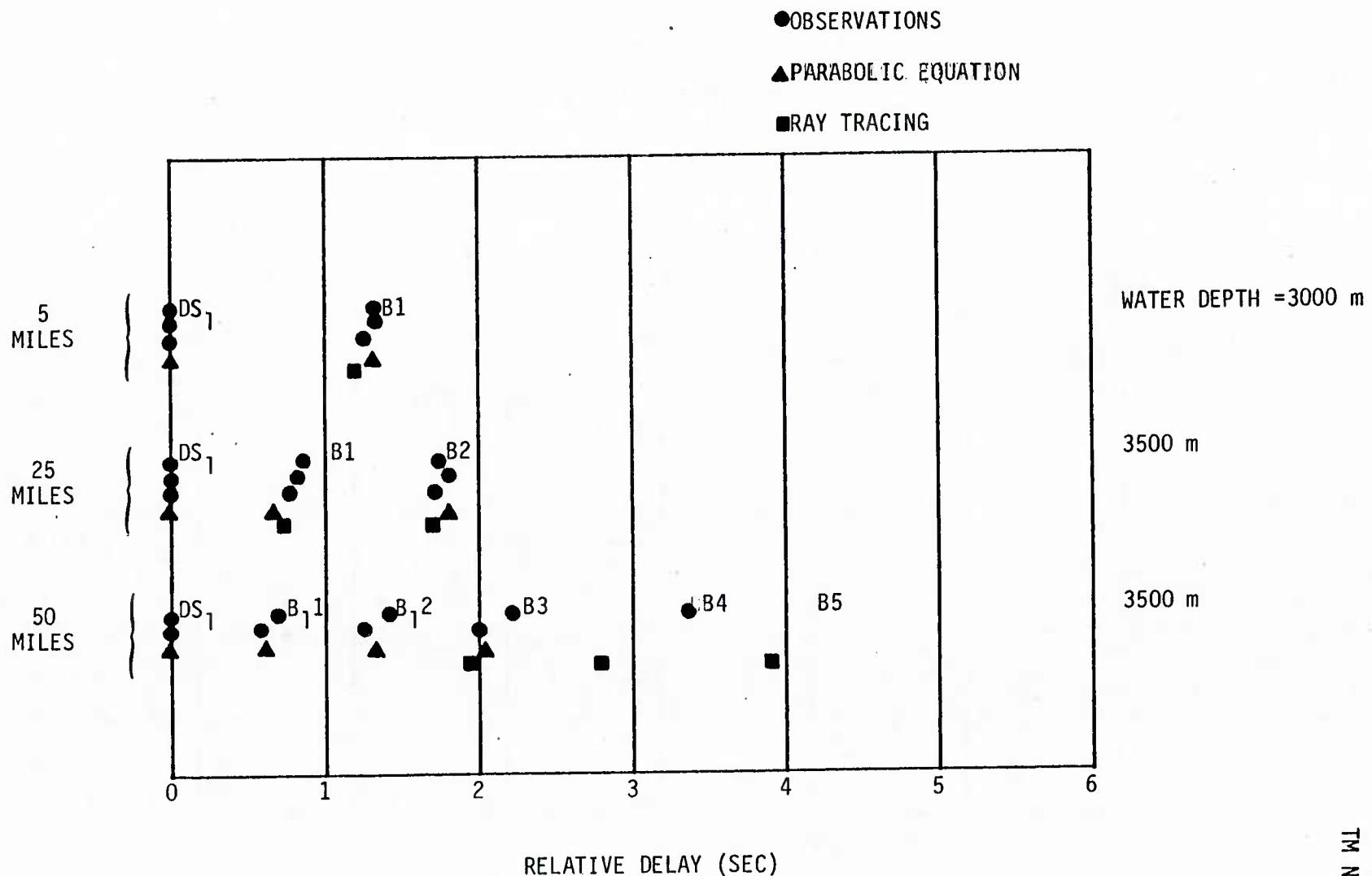


FIGURE 9 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 3 NOVEMBER

TM No. 811061

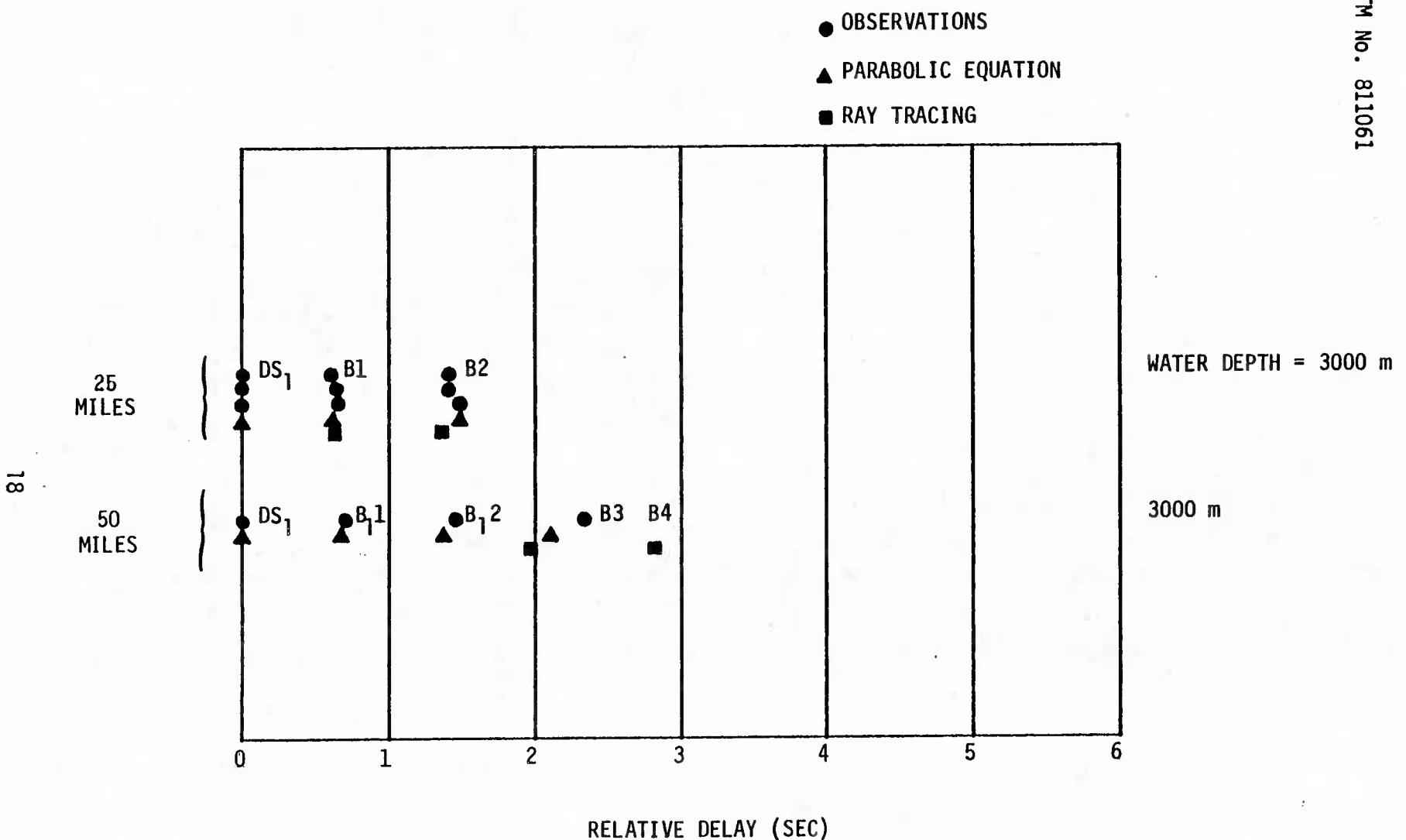


FIGURE 10 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 4 NOVEMBER

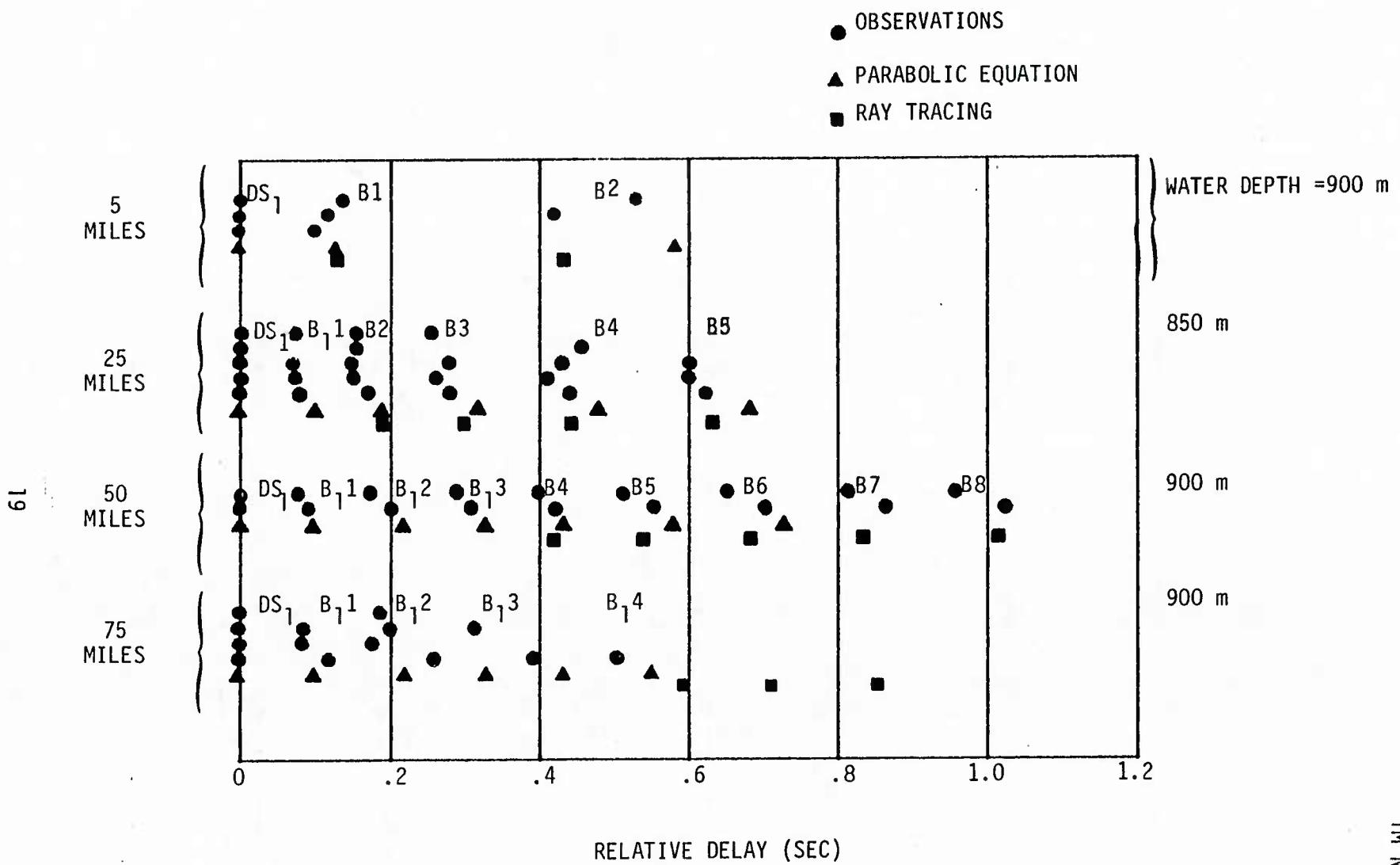


FIGURE 11. RELATIVE ARRIVAL TIMES, BLAKE PLATEAU JANUARY

TM NO. 811061

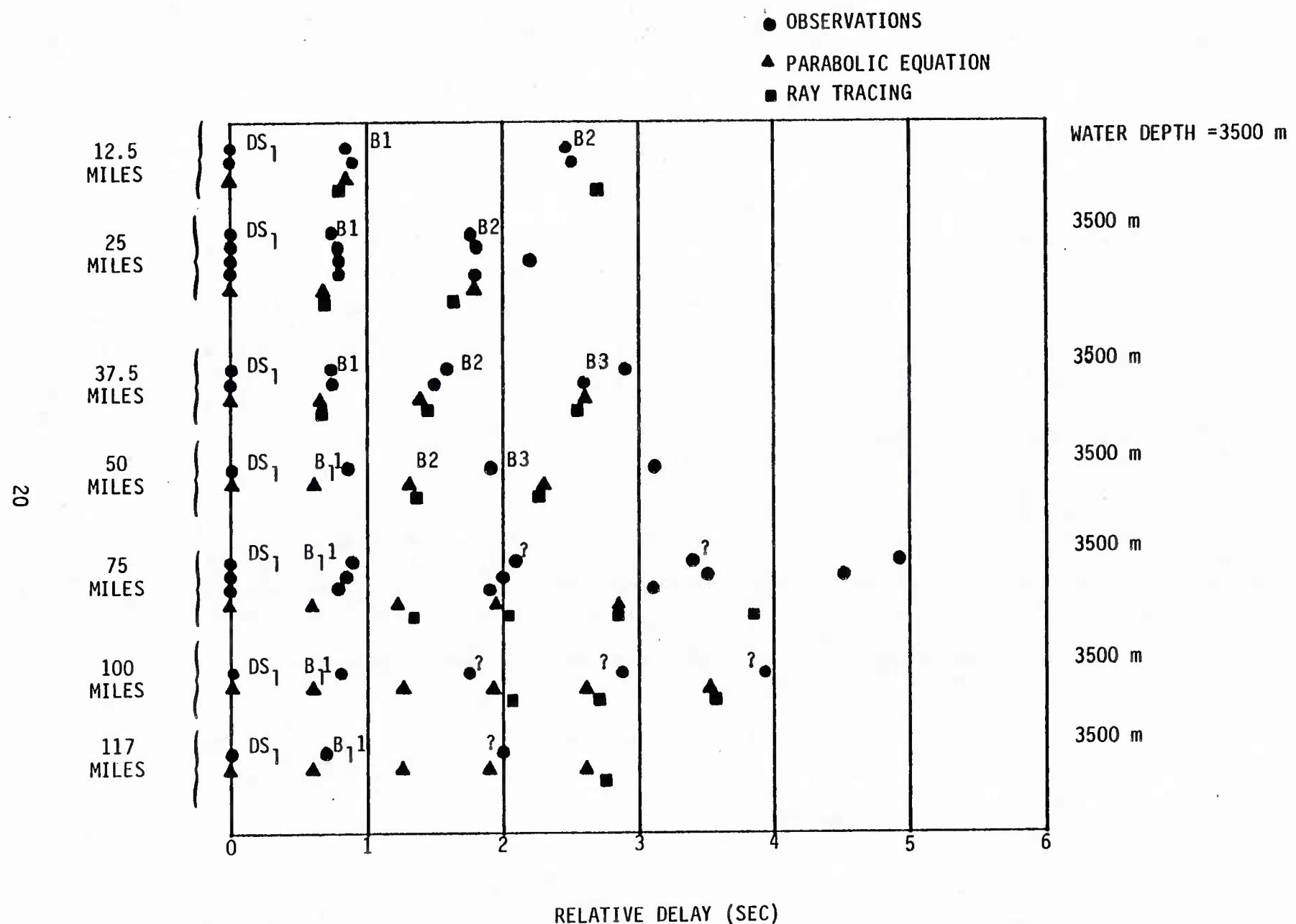


FIGURE 12 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 1 MARCH

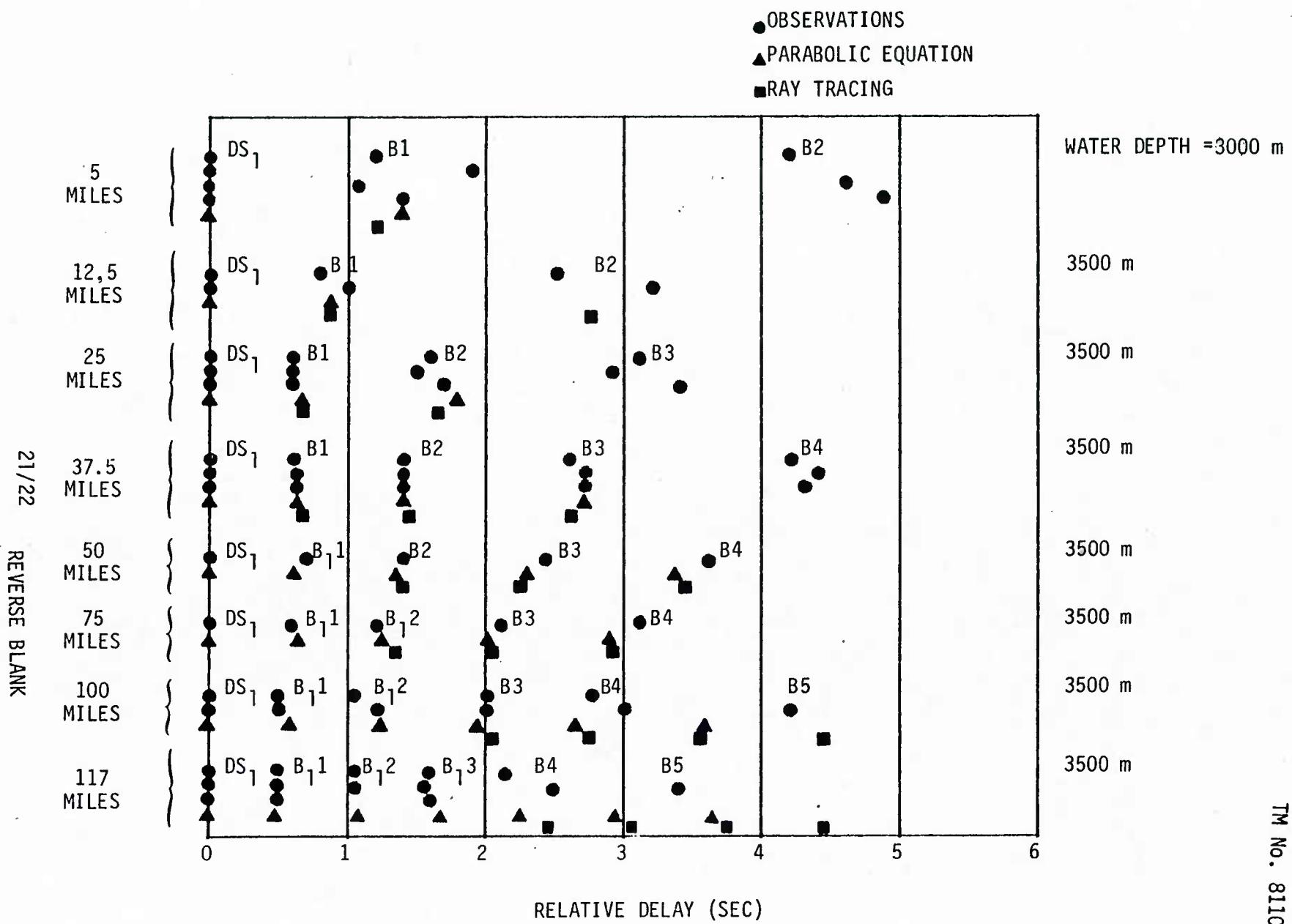


FIGURE 13 RELATIVE ARRIVAL TIMES, MID-ATLANTIC RIDGE # 2 MARCH

TM No. 811061

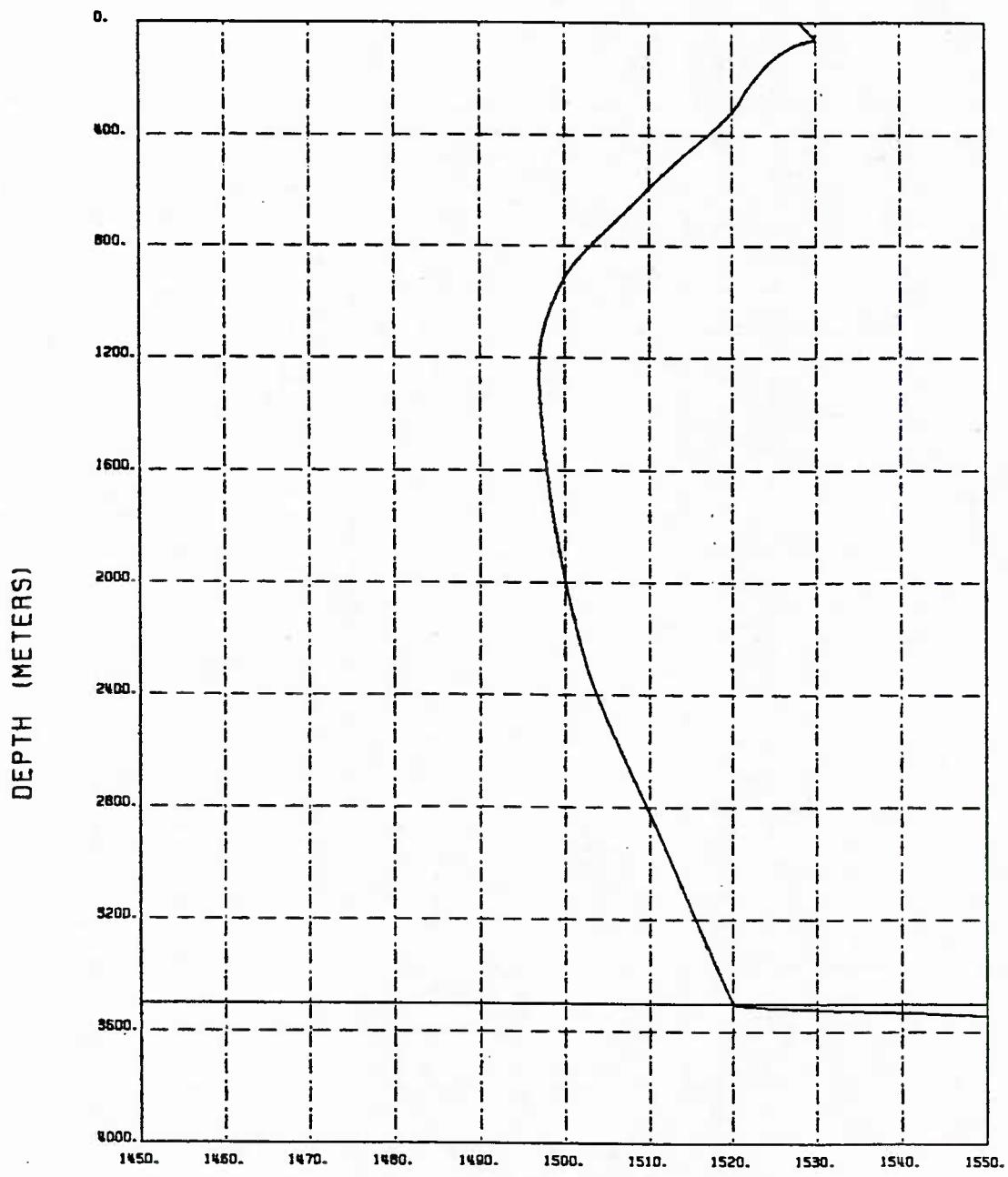
APPENDIX A

MID-ATLANTIC RIDGE PE  
& RAY TRACING RESULTS  
(NOVEMBER PROFILE)

A1/A2

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TM No. 811061



## SOUND SPEED (METERS/SEC)

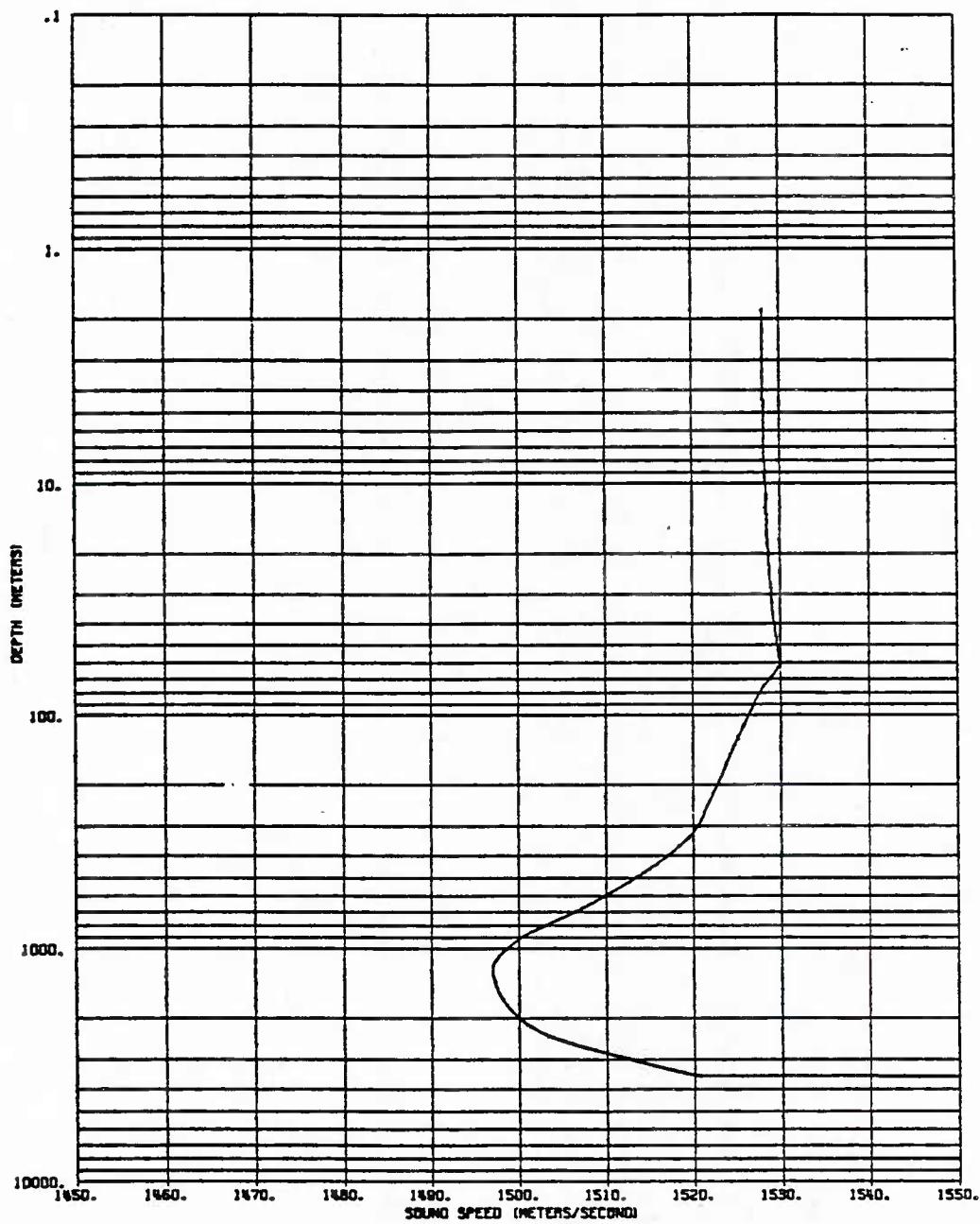
FREQUENCY = 495.0 HZ

SOURCE DEPTH = 78.0 METERS  
 SOURCE RIM = 11.0 DEGREES  
 SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS  
 BOTTOM DEPTH = 3501.3 METERS  
 VERTICAL MESH SPACING = 1.81 METERS  
 BOTTOM ATTENUATION CONSTANT = 0.001000  
 ATTENUATION SCALE LENGTH = 500.0  
 SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS  
 RANGE MESH SPACING = 62.50 METERS

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**E11DEC35 RIDGE**

FREQUENCY = 495.0 HZ

SOURCE DEPTH = 78.0 METERS  
 SOURCE AIM = 11.0 DEGREES  
 SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS  
 BOTTOM DEPTH = 3501.3 METERS  
 VERTICAL MESH SPACING = 1.81 METERS  
 BOTTOM ATTENUATION CONSTANT = 0.001000  
 ATTENUATION SCALE LENGTH = 500.0  
 SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS  
 RANGE MESH SPACING = 62.50 METERS

TM No. 811061

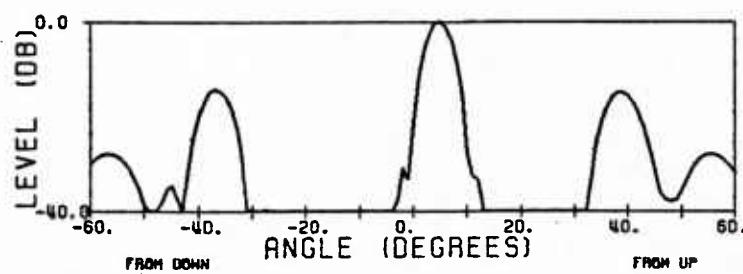
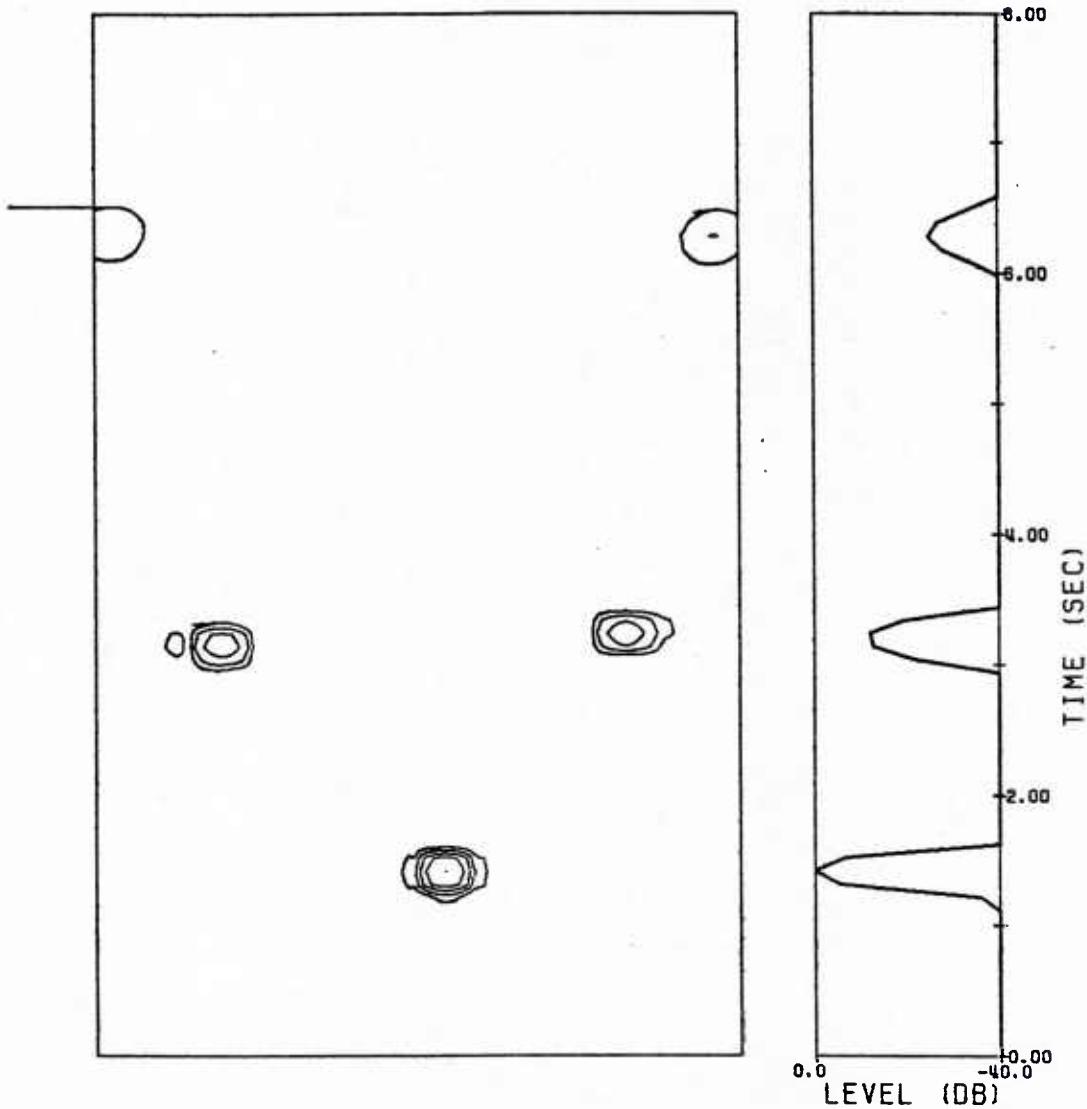
RANGE = 5 MILES

A5/A6

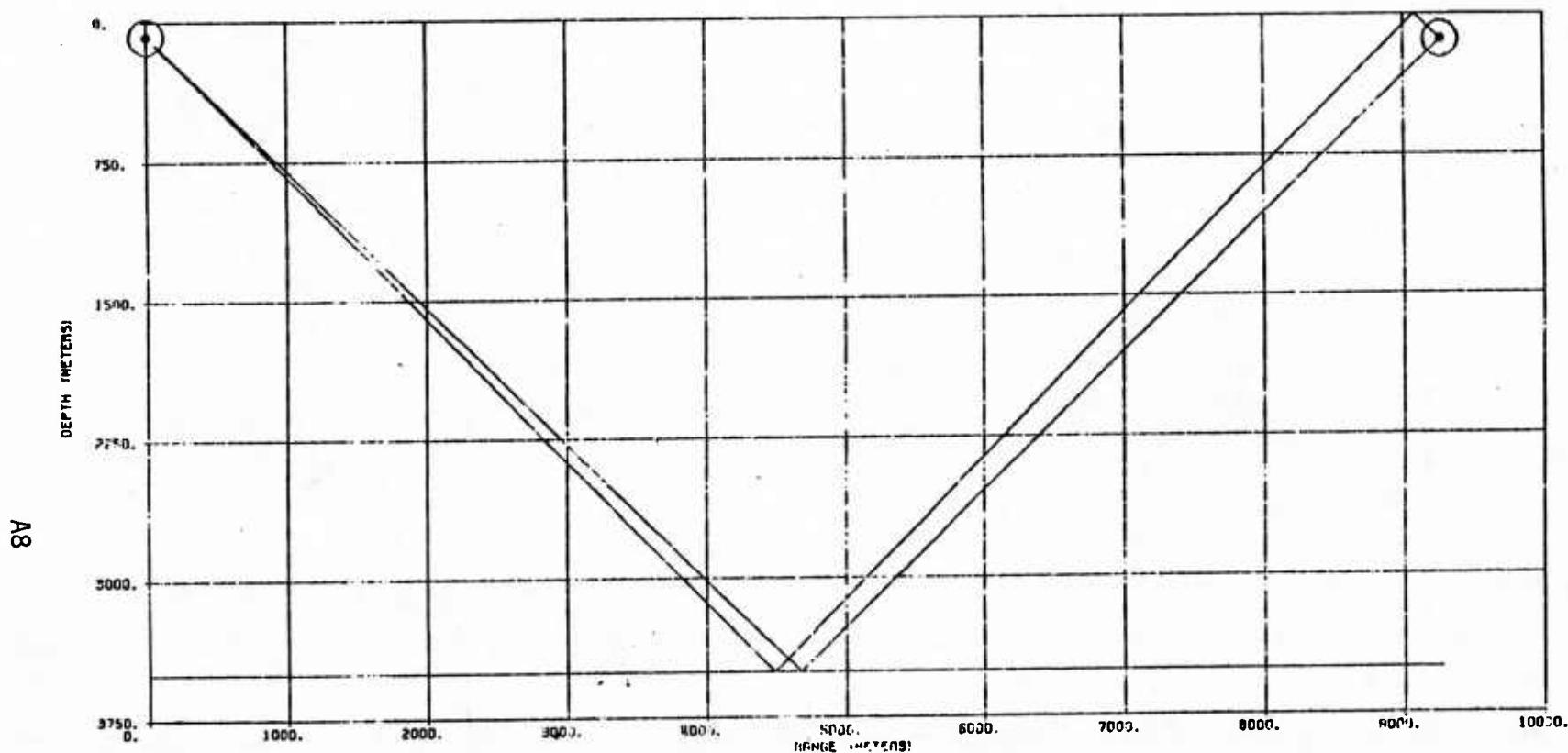
REVERSE BLANK

TM No. 811061

## E11DEC35 RIDGE



ANGLE, DELAY MAX=-92.04 DB  
 ANGLE MAX=-90.20 DB  
 DELAY MAX=-85.72 DB  
 DESIRED RANGE= 5.0 NAUTICAL MILES  
 STARTING FREQUENCY= 495. HZ.  
 STOPPING FREQUENCY= 505. HZ.  
 STARTING DEPTH= 102.98 METERS  
 STOPPING DEPTH= 162.60 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 10.0 METERS  
 SOURCE AIM= 11.0 DEGREES



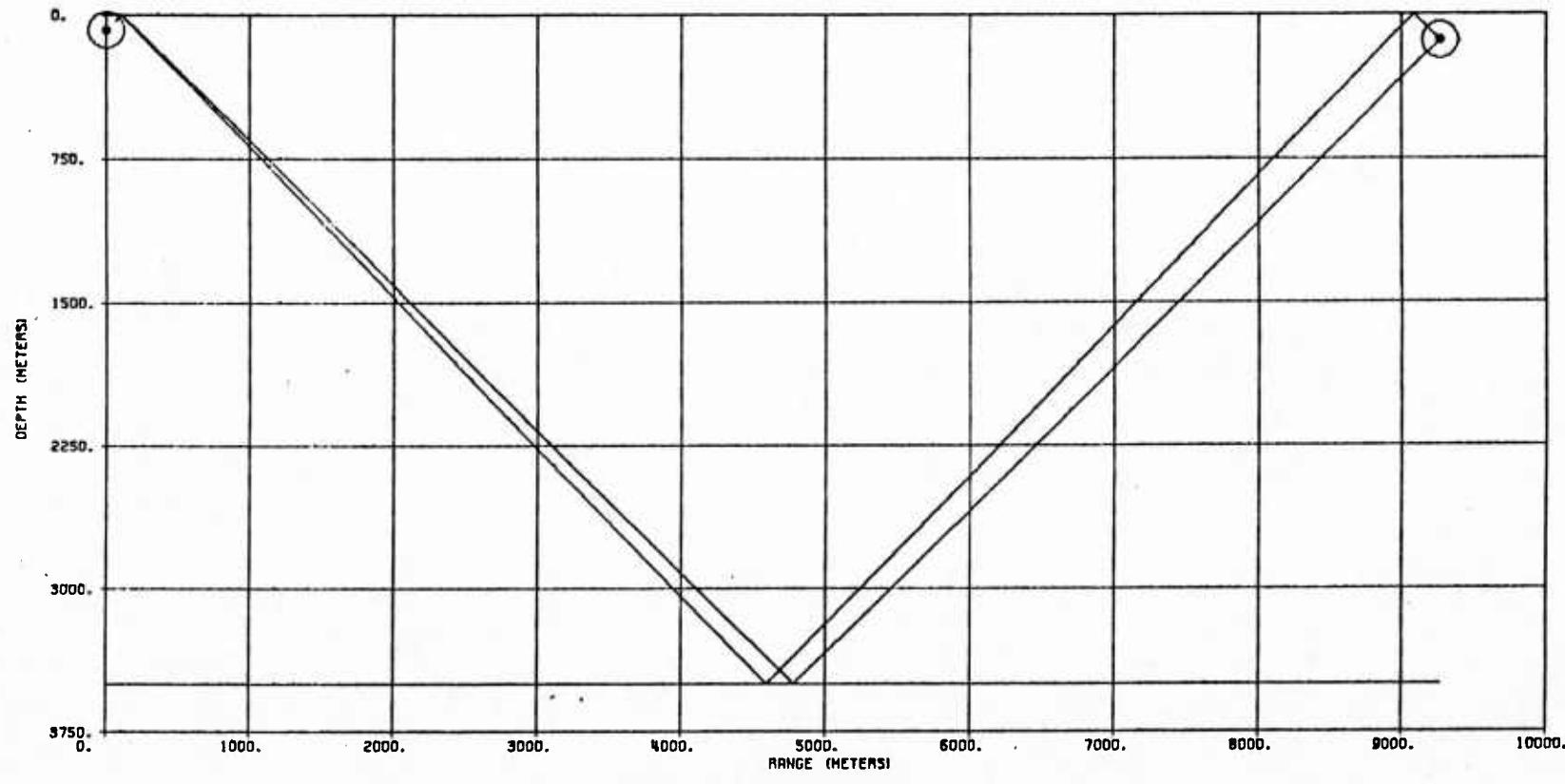
## RUN FOR 6T20C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERBALS
-5.1 36.3	-35.9 36.4	7.62" 7.720	0.0 -36.3	35.5 36.7	80.86 81.02	1 2

A9/A10  
REVERSE BLANK



RUN FOR BT20C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-35.8	-35.8	7.683	-35.8	36.2	80.95	2
-96.9	37.1	7.789	-36.9	37.3	81.10	3

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RANGE = 25 MILES

A11/A12

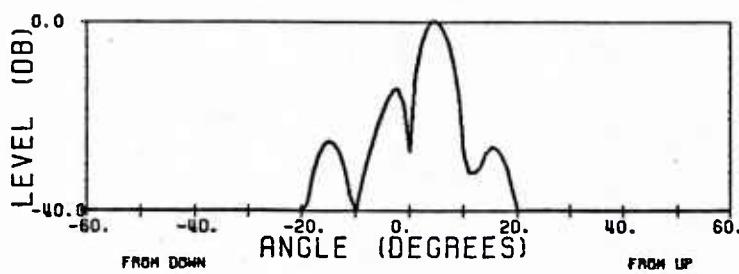
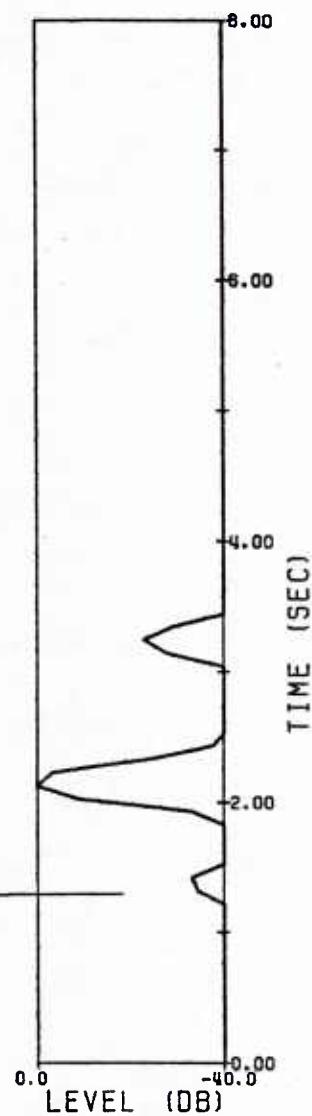
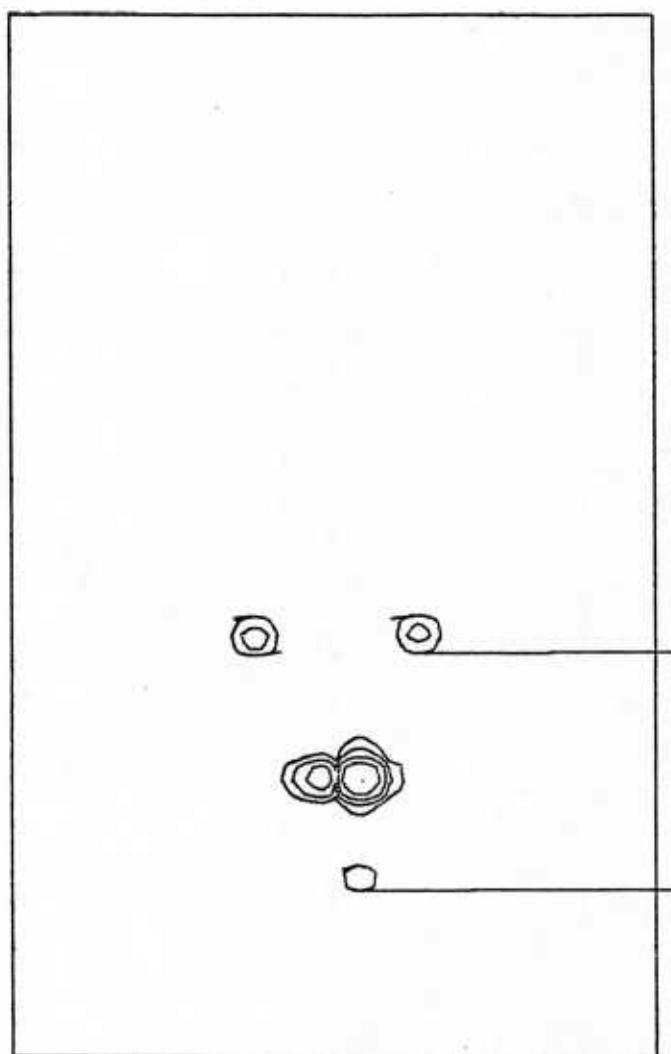
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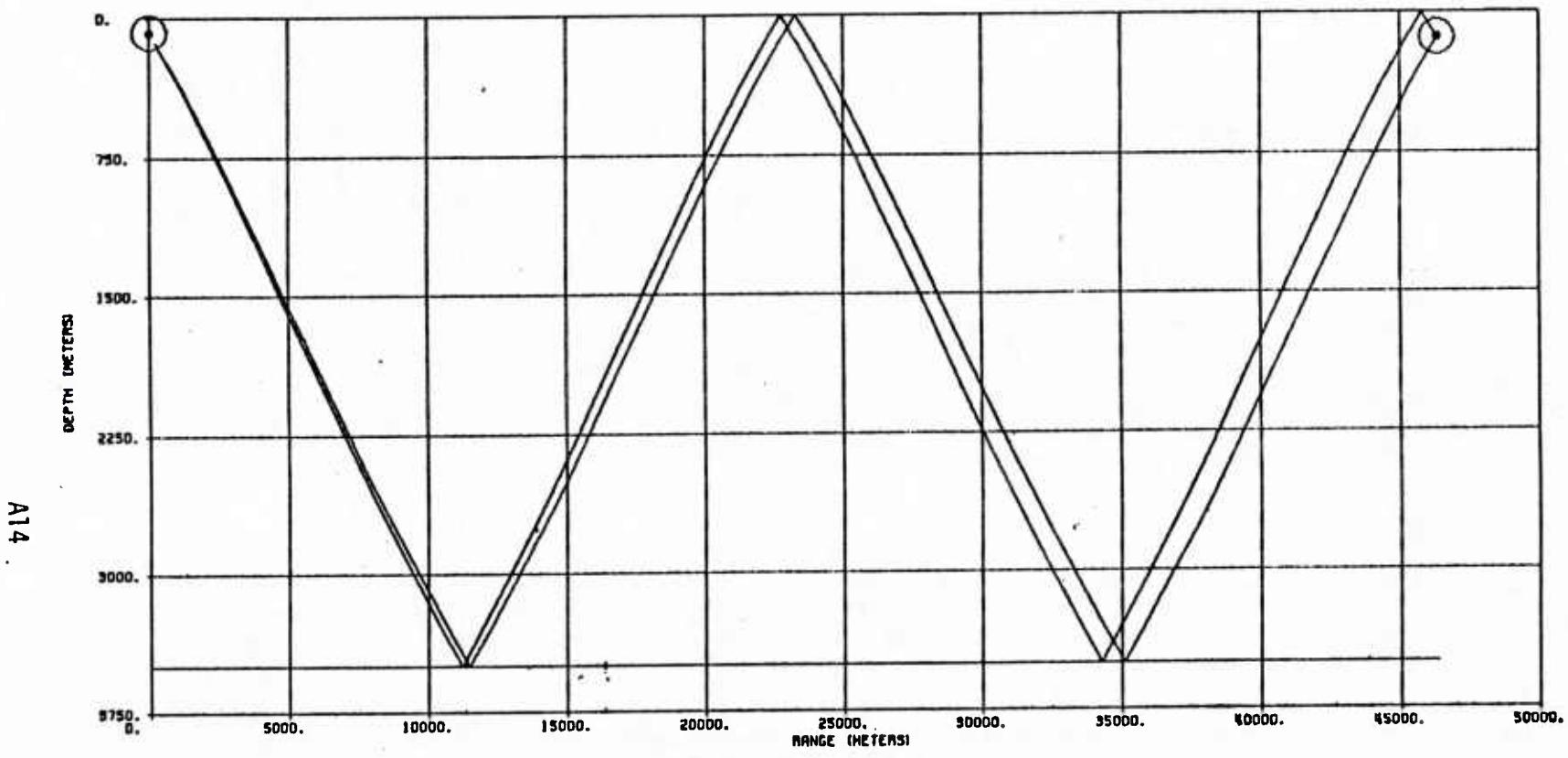
5-SEP-80 14:05:41

TM No. 811061

E11DEC35 RIDGE



ANGLE, DELAY MAX=-80.19 DB  
ANGLE MAX=-78.11 DB  
DELAY MAX=-79.67 DB  
DESIRED RANGE= 25.0 NAUTICAL MILES  
STARTING FREQUENCY= 495. HZ.  
STOPPING FREQUENCY= 505. HZ.  
STARTING DEPTH= 102.98 METERS  
STOPPING DEPTH= 162.60 METERS  
SOURCE DEPTH=78.0 METERS  
SOURCE WIDTH=10.0 METERS  
SOURCE AIM=11.0 DEGREES

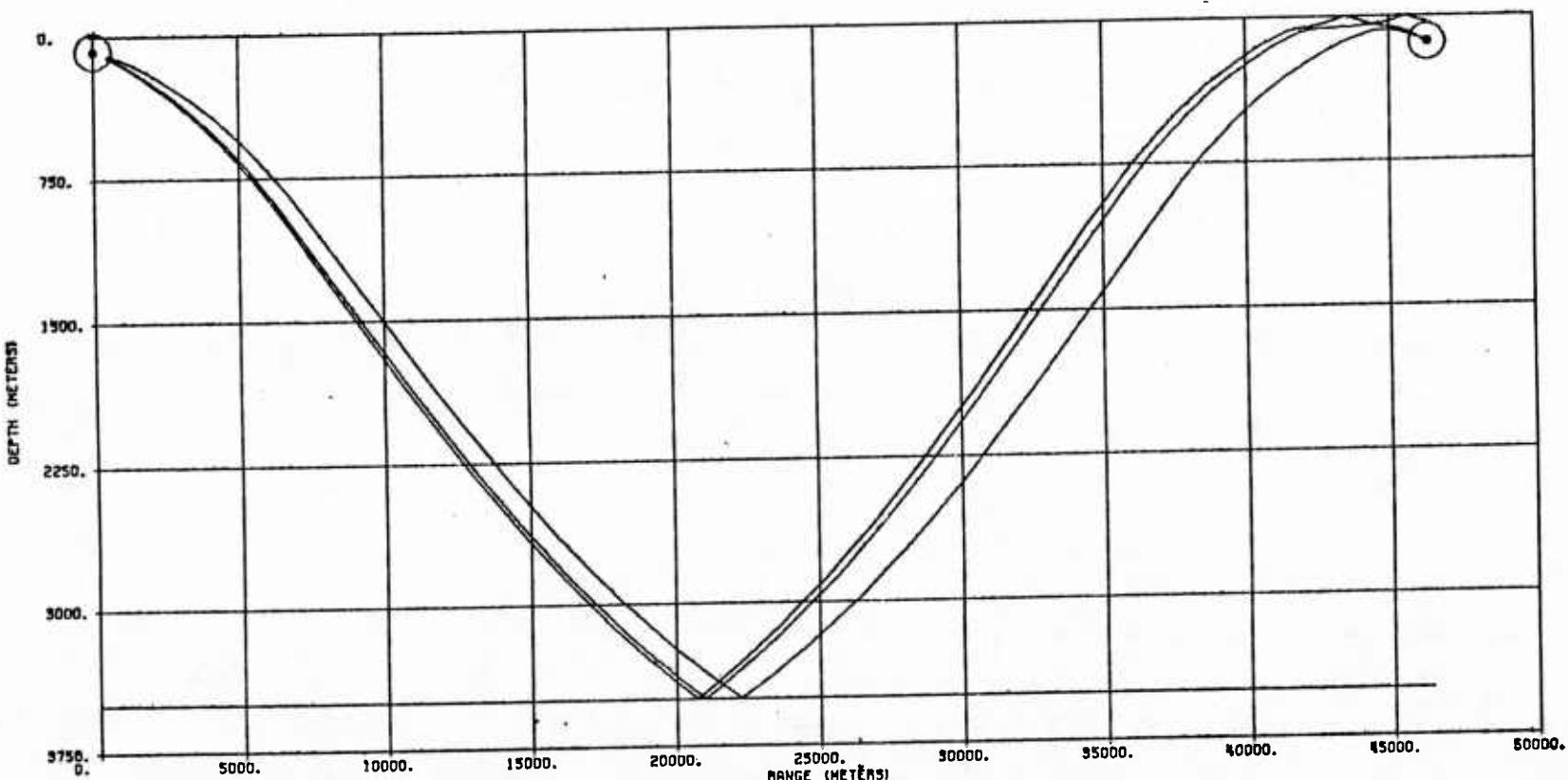


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
19.8 14.2	-14.2 14.7	92.075 92.118	-13.7 -14.2	14.8 15.3	92.21 92.33	3 4

A15

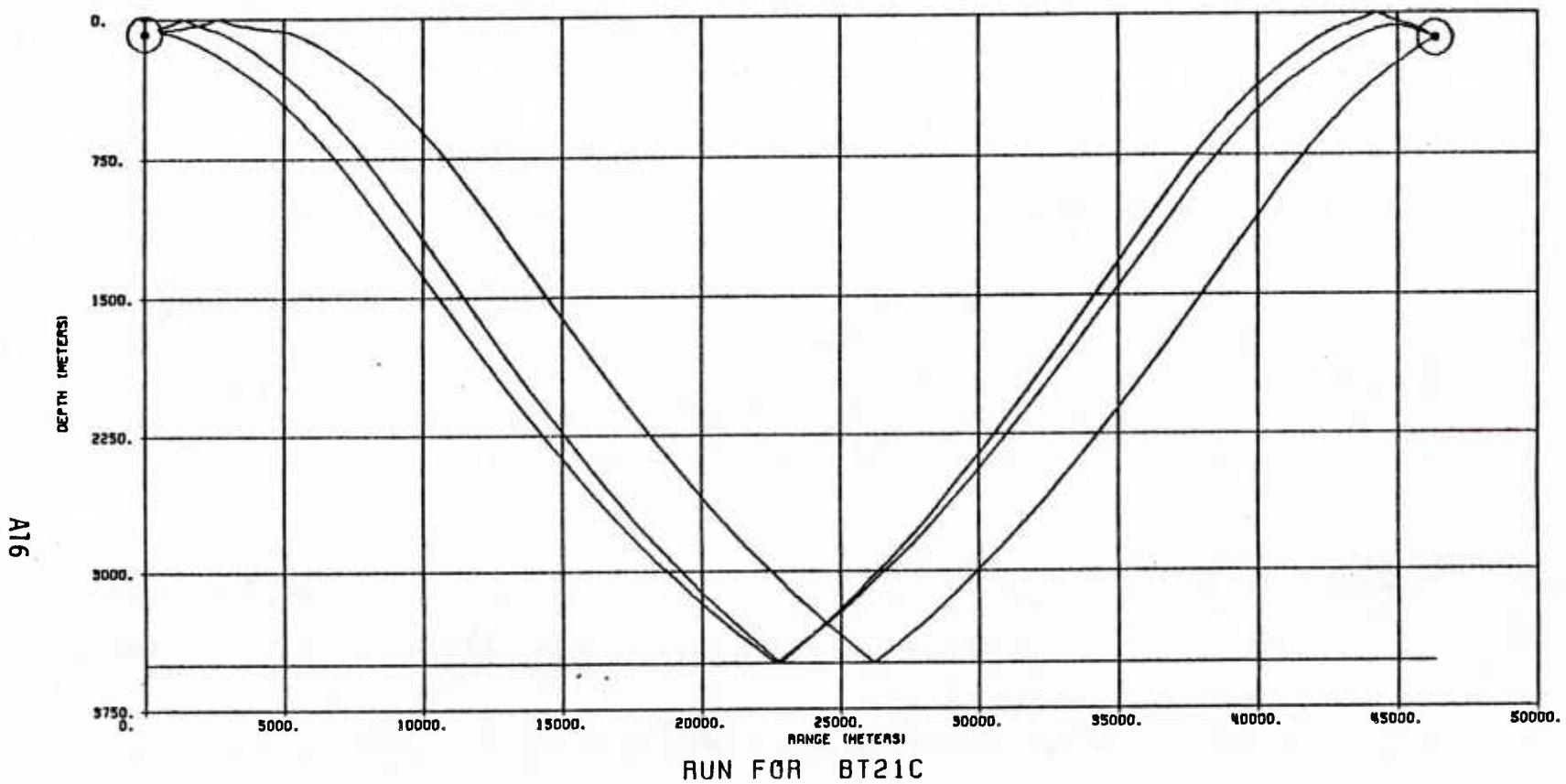


RUN FOR BT21C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
1.6	4.0	31.062	0.0	6.0	84.20	2
3.3	4.9	31.064	-3.2	6.7	91.12	2
3.0	4.7	31.065	-2.9	6.5	108.46	2

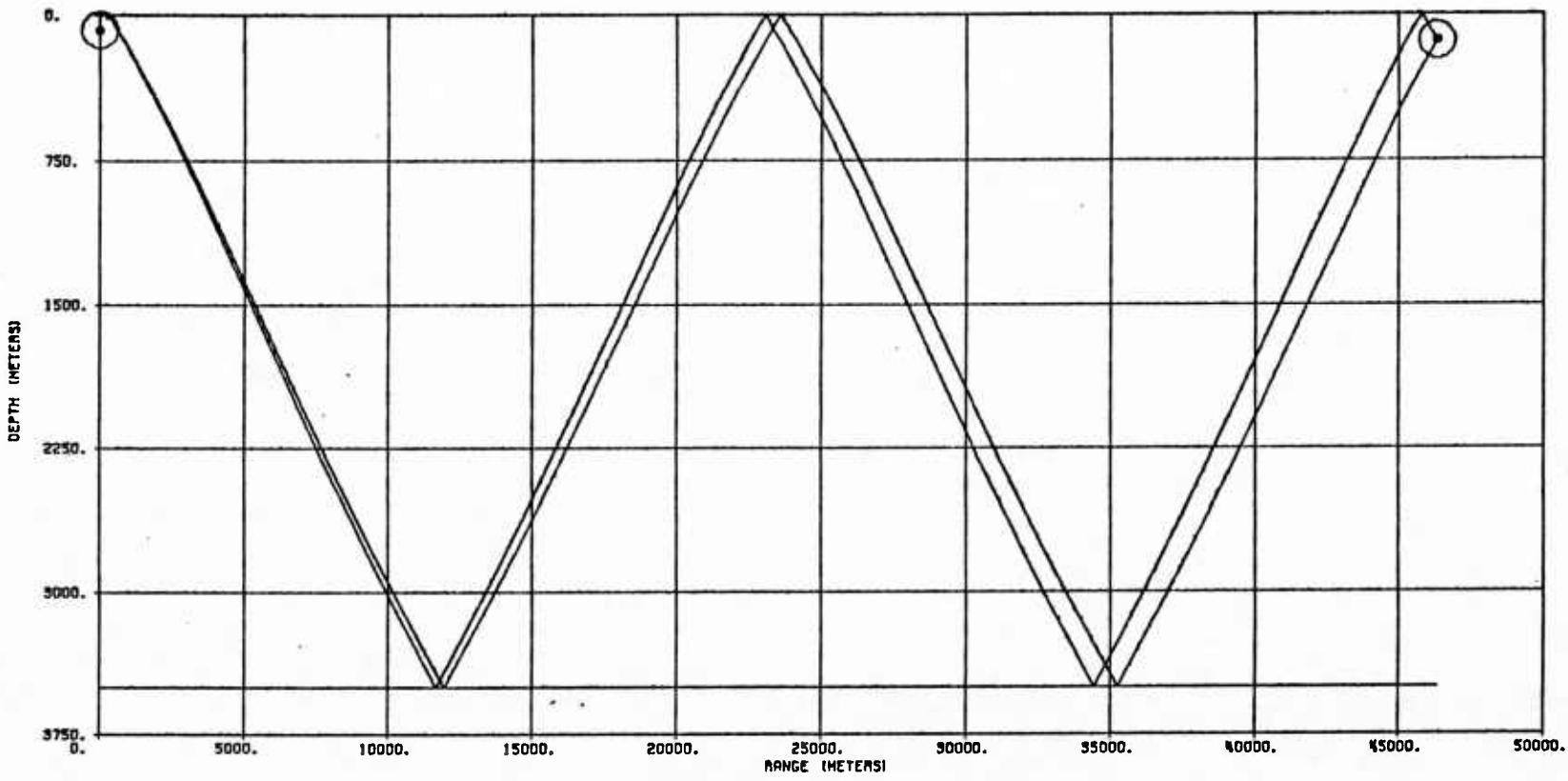


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-3.1	-4.8	31.059	-2.9	6.6	94.40	2
-2.1	4.3	31.062	0.0	6.2	94.47	3
-4.0	5.4	31.069	-3.9	7.0	90.48	3

A17/A18      REVERSE BLANK



RUN FOR BT21C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-14.0	-14.5	32.100	-14.0	15.2	92.28	4
-14.5	14.9	32.143	-14.4	15.6	92.40	5

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RANGE = 50 MILES

A19/A20

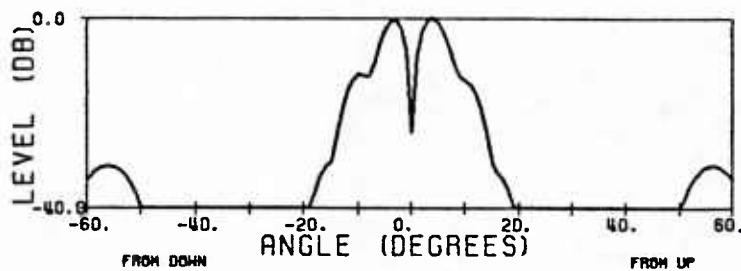
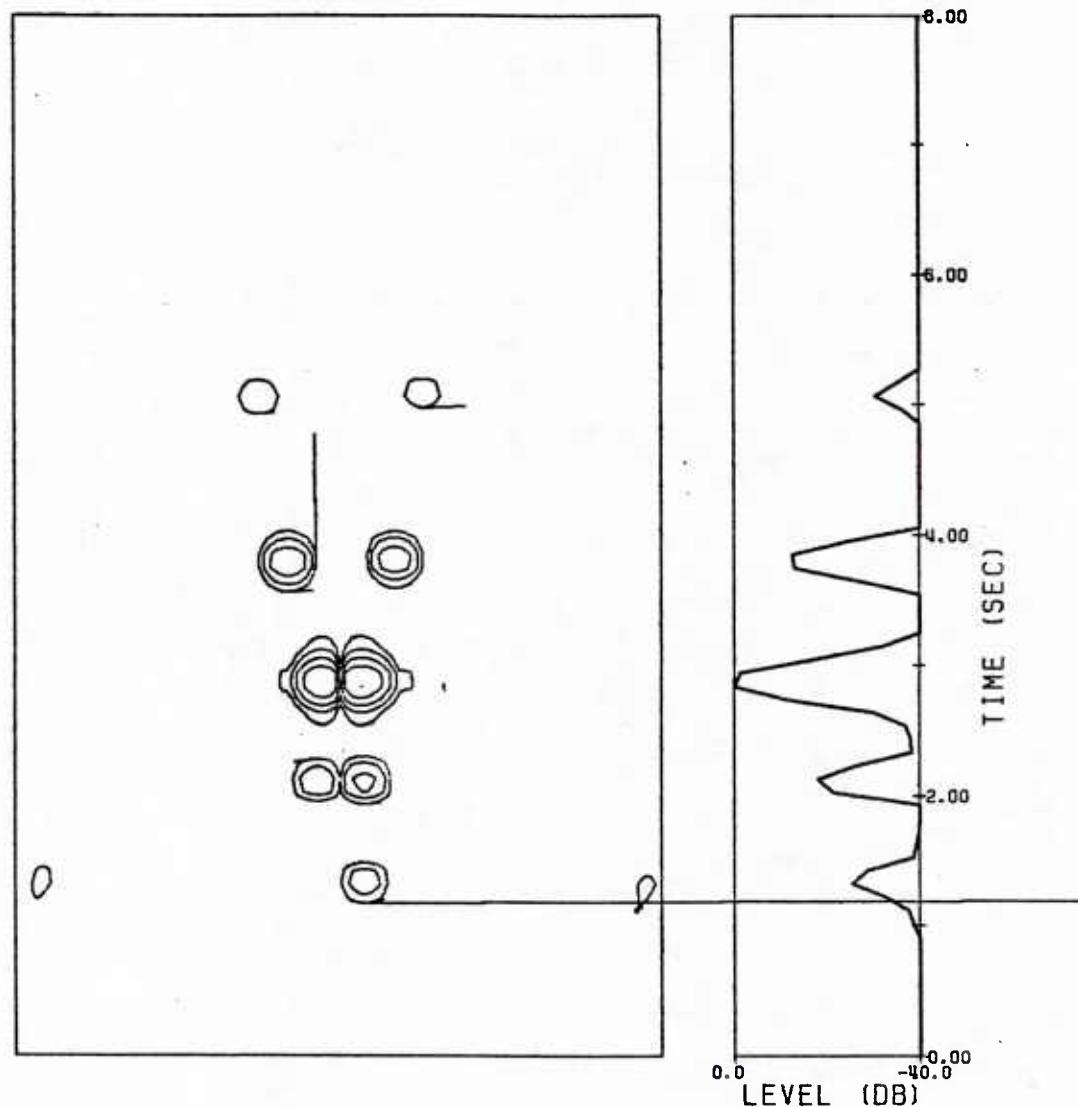
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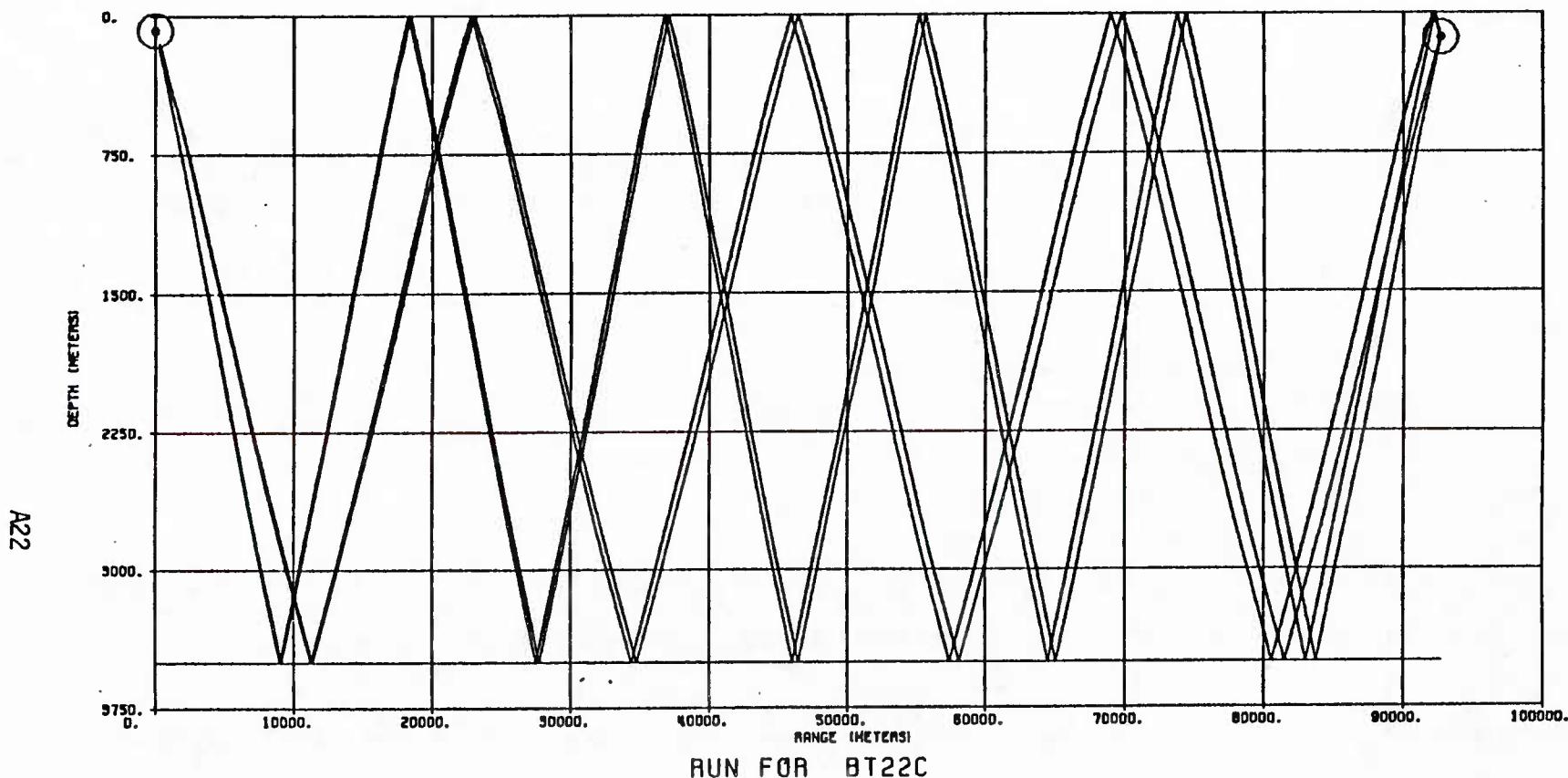
5-SEP-80 14:09:00

TM No. 811061

# E11DEC35 RIDGE



ANGLE,DELAY MAX=-102.52 DB  
ANGLE MAX=-99.78 DB  
DELAY MAX=-93.55 DB  
DESIRED RANGE= 49.9 NAUTICAL MILES  
STARTING FREQUENCY= 495. HZ.  
STOPPING FREQUENCY= 505. HZ.  
STARTING DEPTH= 102.98 METERS  
STOPPING DEPTH= 162.60 METERS  
SOURCE DEPTH= 78.0 METERS  
SOURCE WIDTH= 10.0 METERS  
SOURCE AIM= 11.0 DEGREES

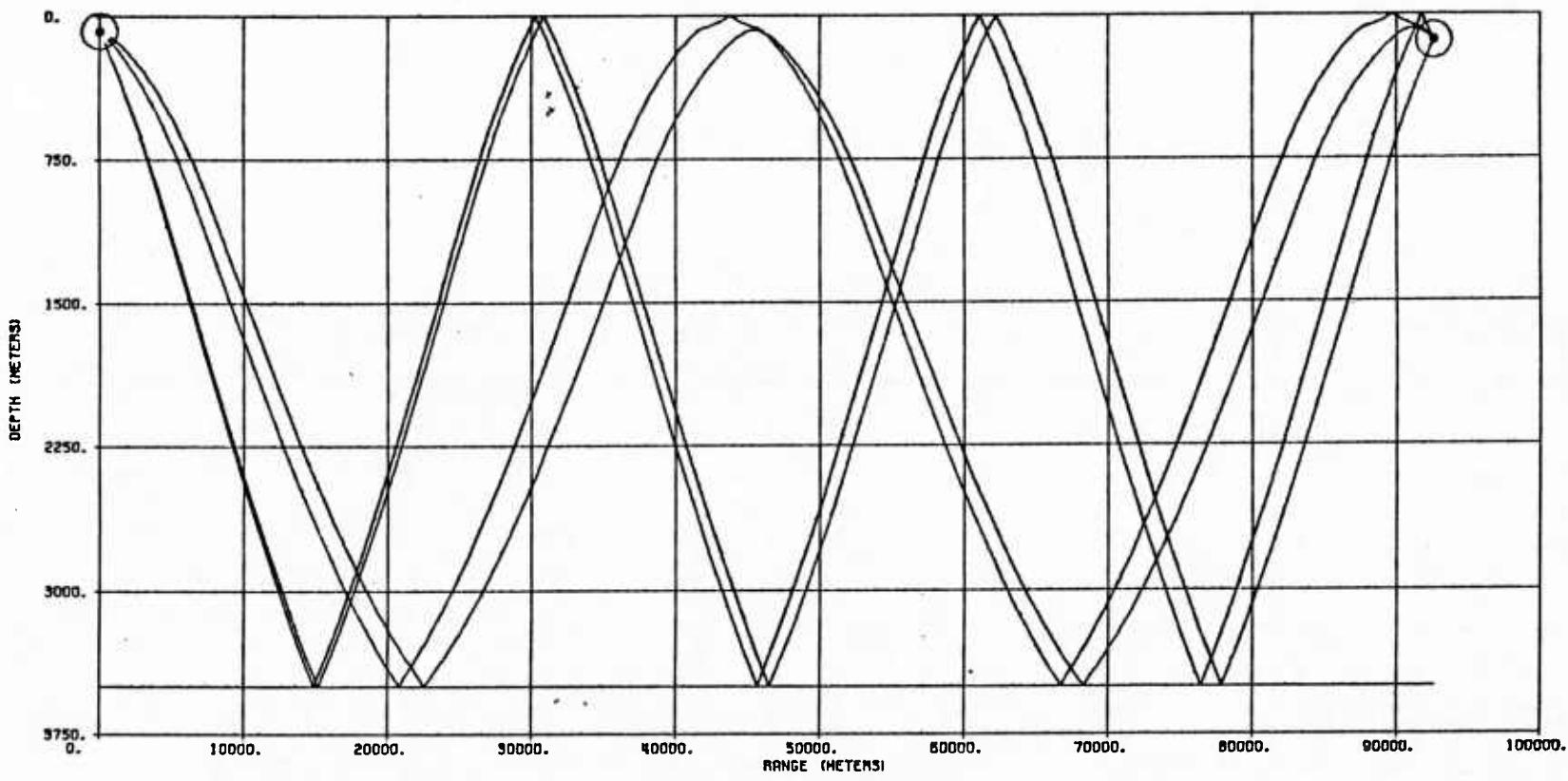


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
13.9	-14.4	64.184	-13.9	15.1	98.28	7
14.2	14.6	64.227	-14.1	15.3	98.35	8
18.4	-18.8	65.672	-18.4	19.3	98.98	9
18.6	19.0	65.720	-18.6	19.5	99.02	10

A23

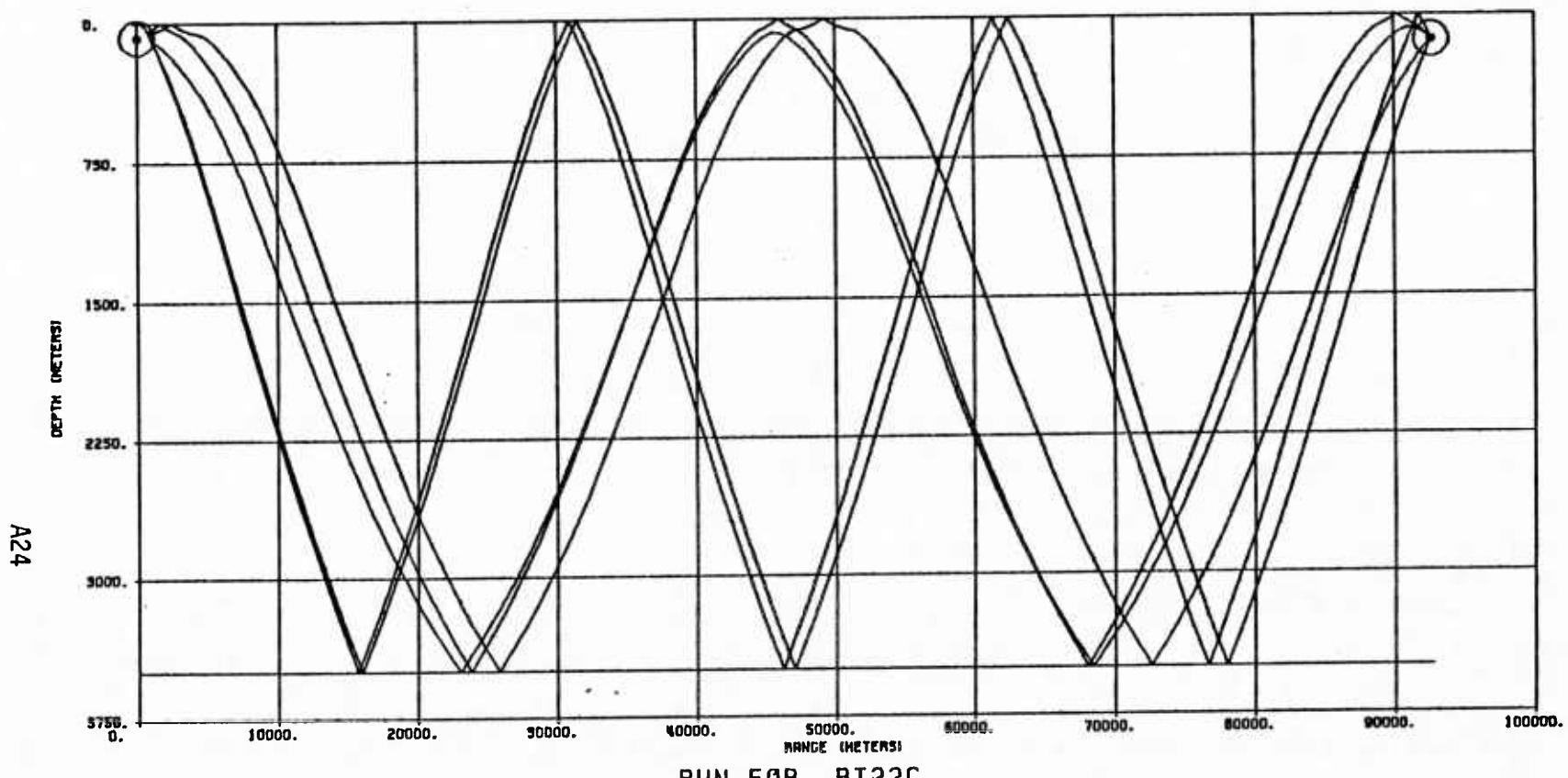


## RUN FOR BT22C

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
1.1	3.8	62.123	0.0	5.9	88.48	4
3.2	4.9	62.126	-3.1	6.6	97.65	4
8.8	-8.6	63.000	-8.8	10.6	96.93	5
9.1	9.8	63.027	-9.1	10.8	97.10	6

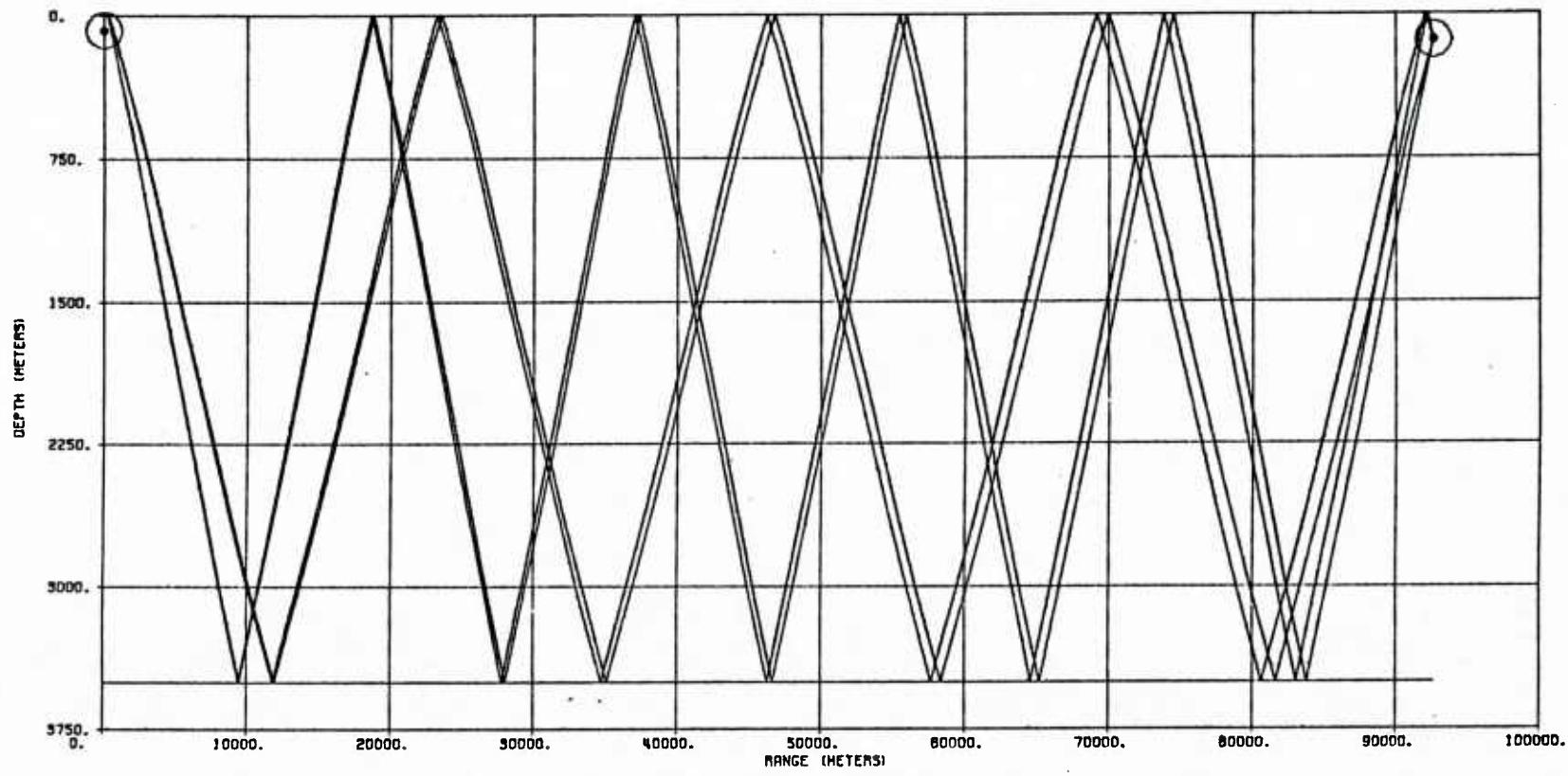


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (dB)	NUMBER OF REVERSALS
-3.1	-4.8	62.120	-3.0	6.6	99.12	4
-1.4	3.9	62.123	0.0	6.0	88.70	5
-9.6	5.1	62.130	-3.4	6.8	96.77	5
-8.0	-9.7	63.015	-9.0	10.7	97.05	6
-6.3	10.0	63.049	-9.3	11.0	97.23	7

A25/A26  
REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.1	-14.5	64.209	-14.1	15.2	98.32	8
-14.3	14.8	64.252	-14.3	15.4	98.38	9
-18.5	-18.9	65.704	-18.5	19.4	99.09	10
-18.7	19.1	65.761	-18.7	19.6	99.03	11

TM No. 811061

TM No. 811061

RANGE = 75 MILES

A27/A28

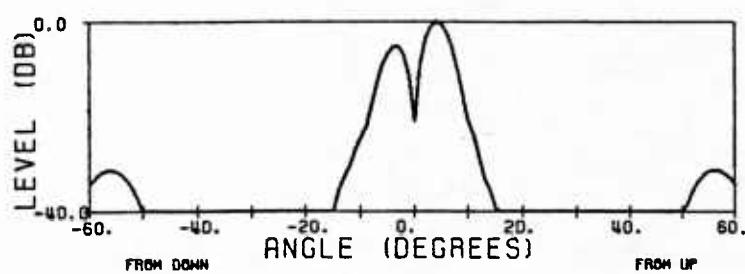
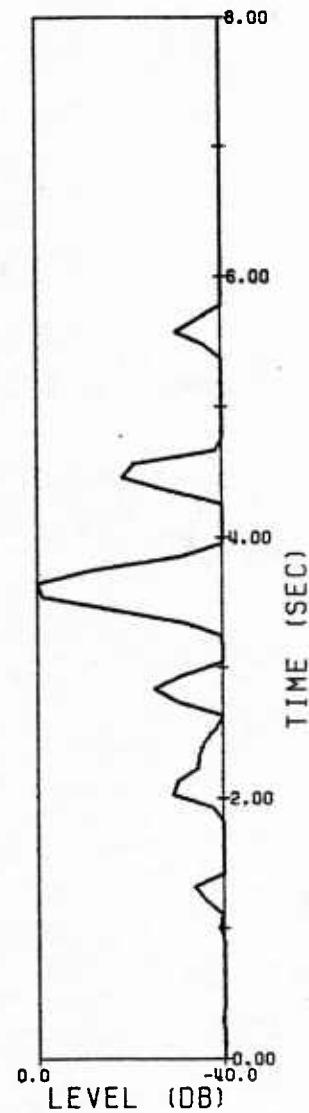
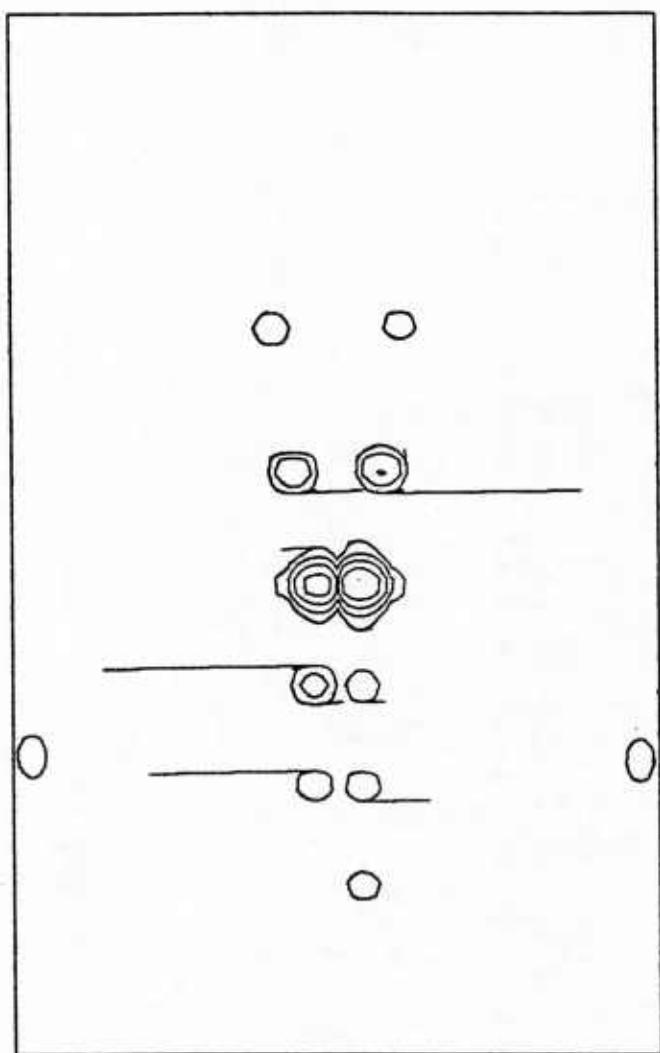
REVERSE BLANK

PERF: 30-AUG-80 19:12:06

5-SEP-80 14:15:51

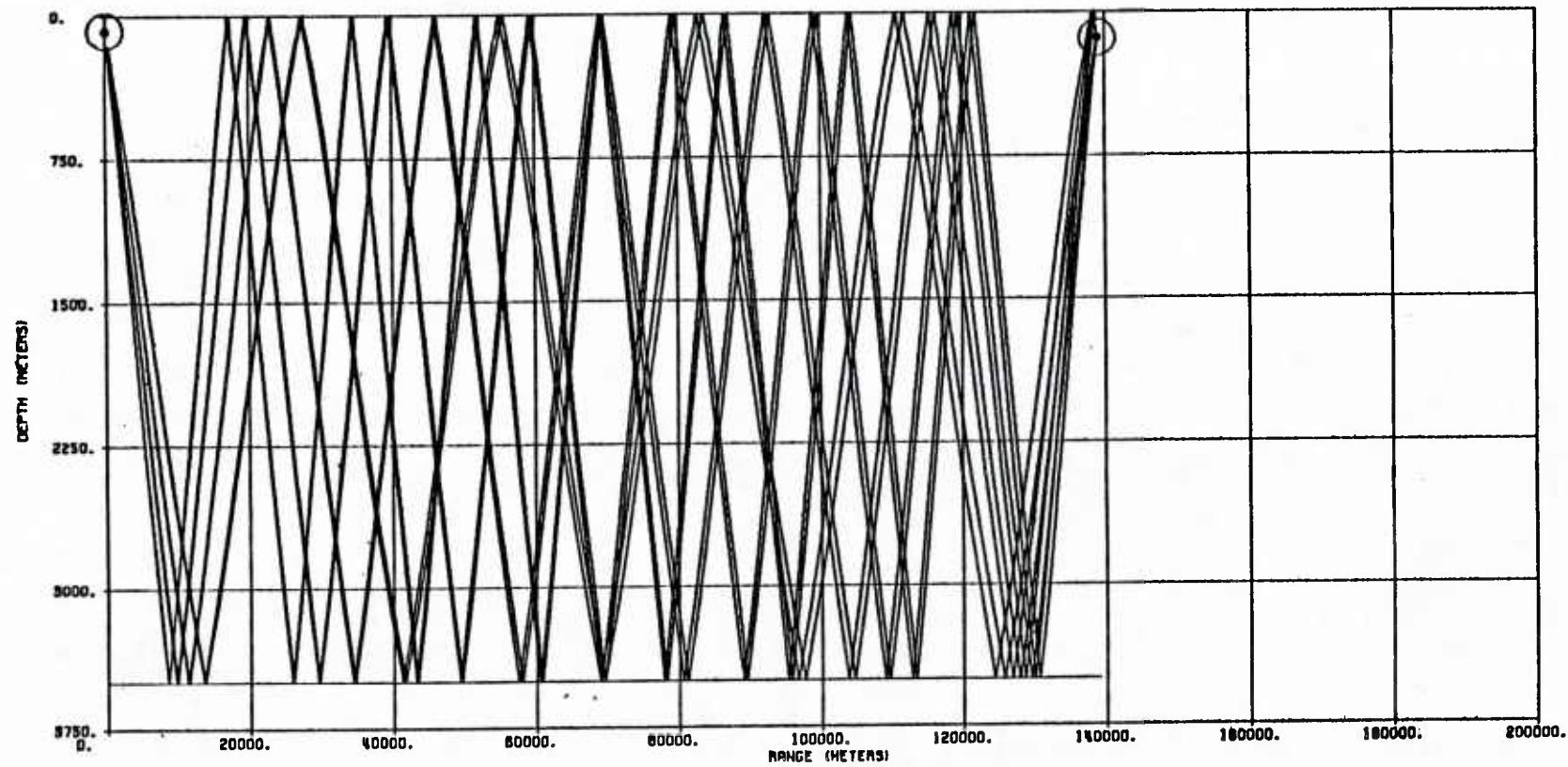
TM No. 811061

# E11DEC35 RIDGE



ANGLE,DELAY MAX=-105.09 DB  
ANGLE MAX=-102.36 DB  
DELAY MAX=-97.73 DB  
DESIRED RANGE= 74.9 Nautical Miles  
STARTING FREQUENCY= 495. Hz.  
STOPPING FREQUENCY= 505. Hz.  
STARTING DEPTH= 102.98 METERS  
STOPPING DEPTH= 162.60 METERS  
SOURCE DEPTH= 78.0 METERS  
SOURCE WIDTH=10.0 METERS  
SOURCE AIM=11.0 DEGREES

A30



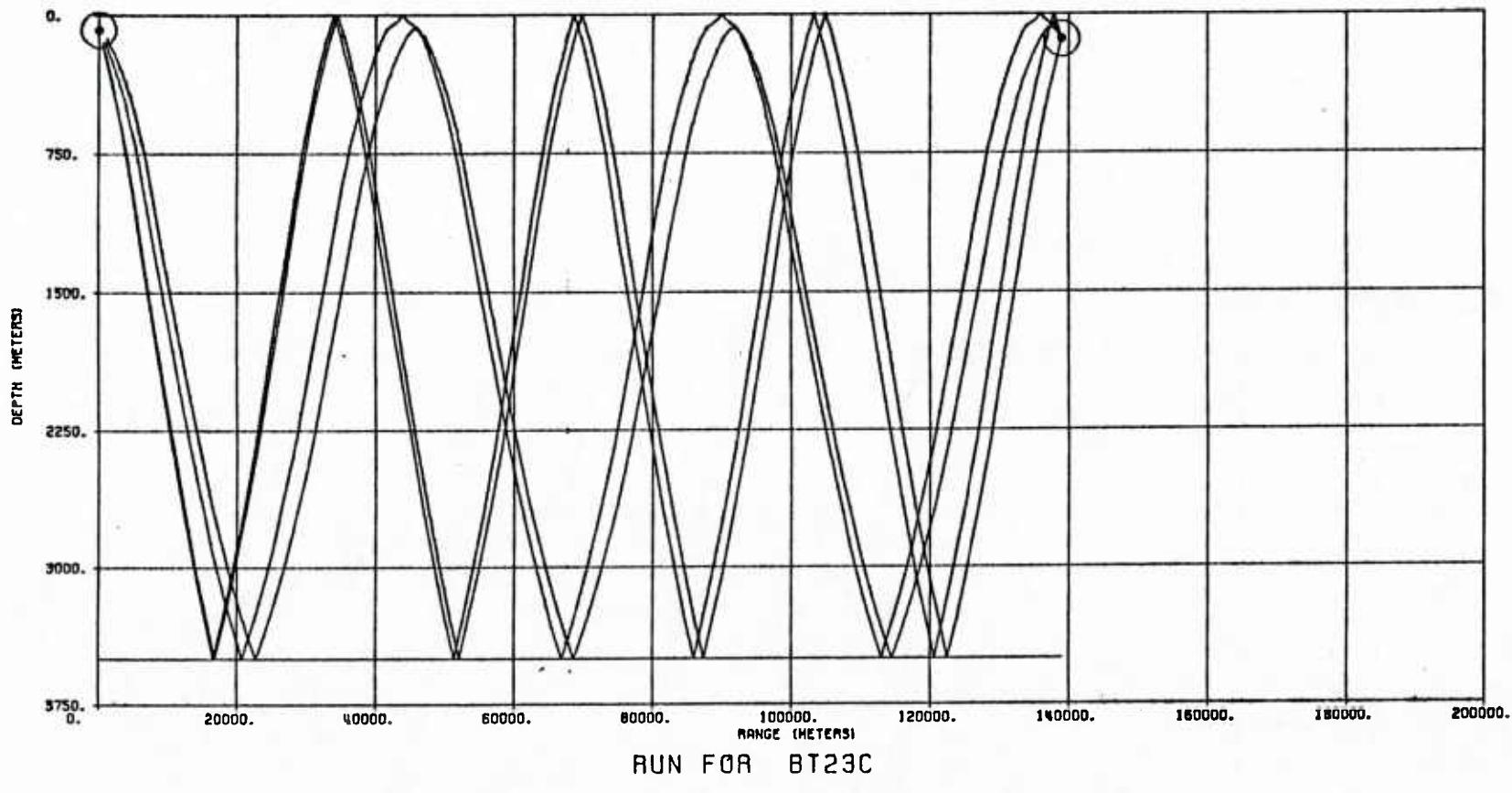
## RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
10.7	-11.9	95.053	-10.7	12.2	101.07	9
10.9	11.5	95.086	-10.9	12.9	101.17	10
14.0	-14.5	96.293	-14.0	15.1	101.81	11
14.2	14.6	96.336	-14.1	15.3	101.85	12
17.0	-17.4	97.735	-17.0	18.0	102.31	13
17.2	17.5	97.788	-17.1	18.1	102.33	14
19.9	-20.2	99.373	-19.8	20.7	102.69	15
20.0	20.9	99.433	-20.0	20.8	102.70	16

A31



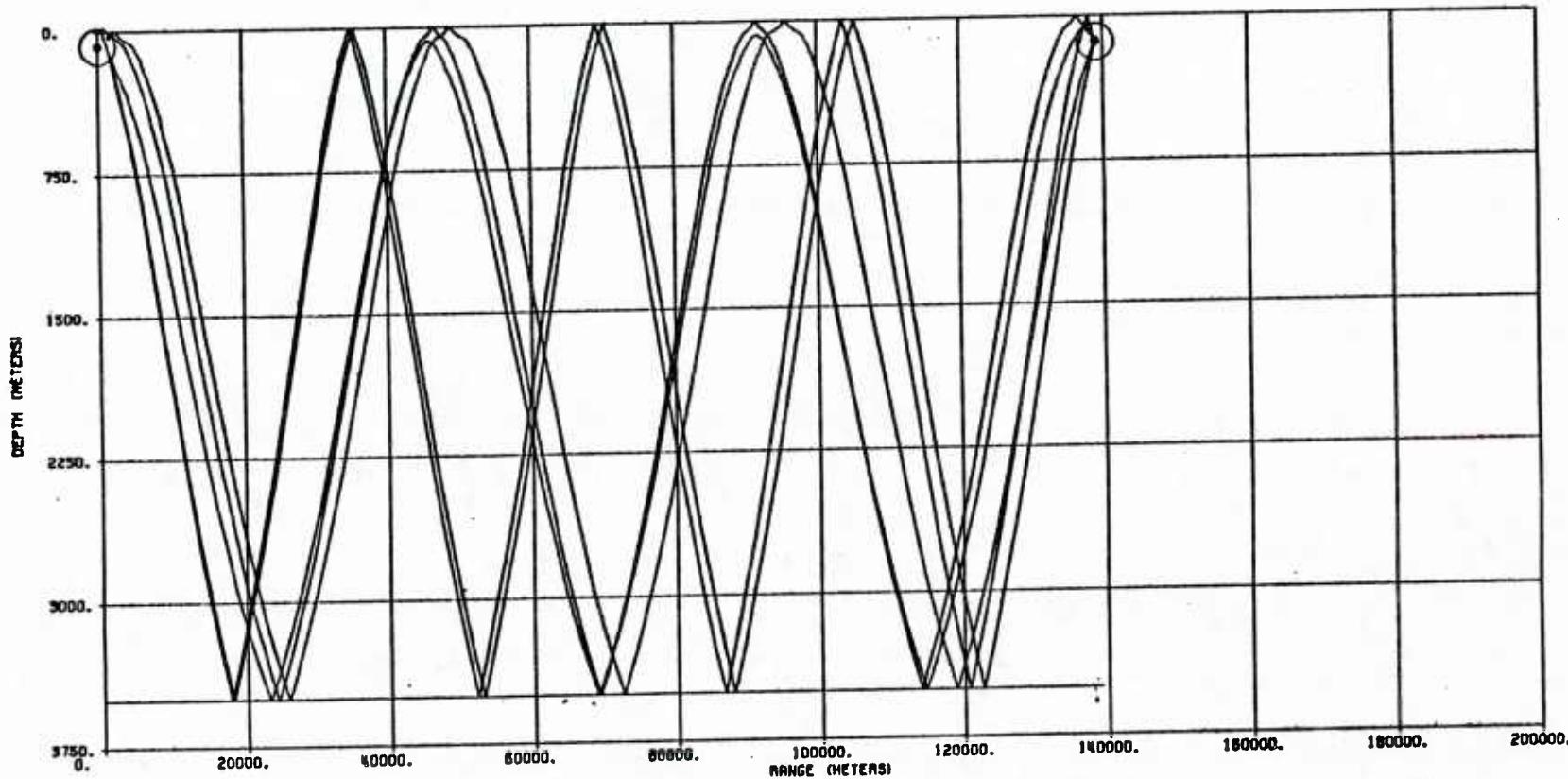
SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
0.9	3.8	93.183	0.0	5.9	90.85	6
3.2	4.9	93.187	-3.1	6.6	101.34	6
7.0	-7.9	94.019	-6.9	9.0	99.73	7
7.2	8.1	94.041	-7.2	9.2	99.94	8

TM NO. 811061

A32



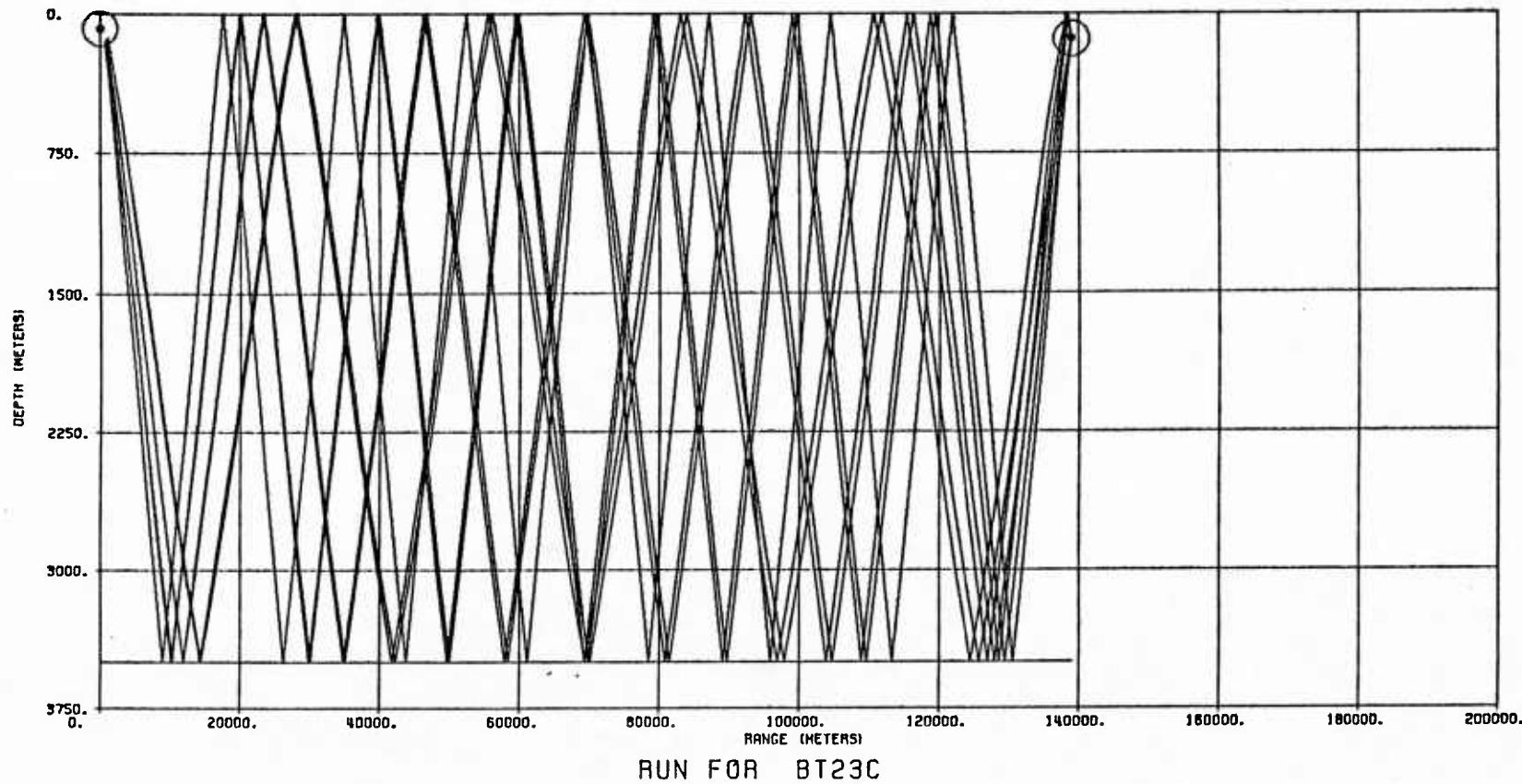
## RUN FOR BT23C

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 198998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-3.1	-4.8	93.181	-3.0	6.6	102.54	6
-1.1	3.8	93.183	0.0	5.9	90.95	7
-3.4	5.0	93.181	-3.3	6.7	100.54	7
-7.1	-8.0	94.031	-7.1	9.2	99.87	8
-7.4	8.2	94.053	-7.3	9.8	100.04	9

A33/A34  
REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 138998.21 METERS

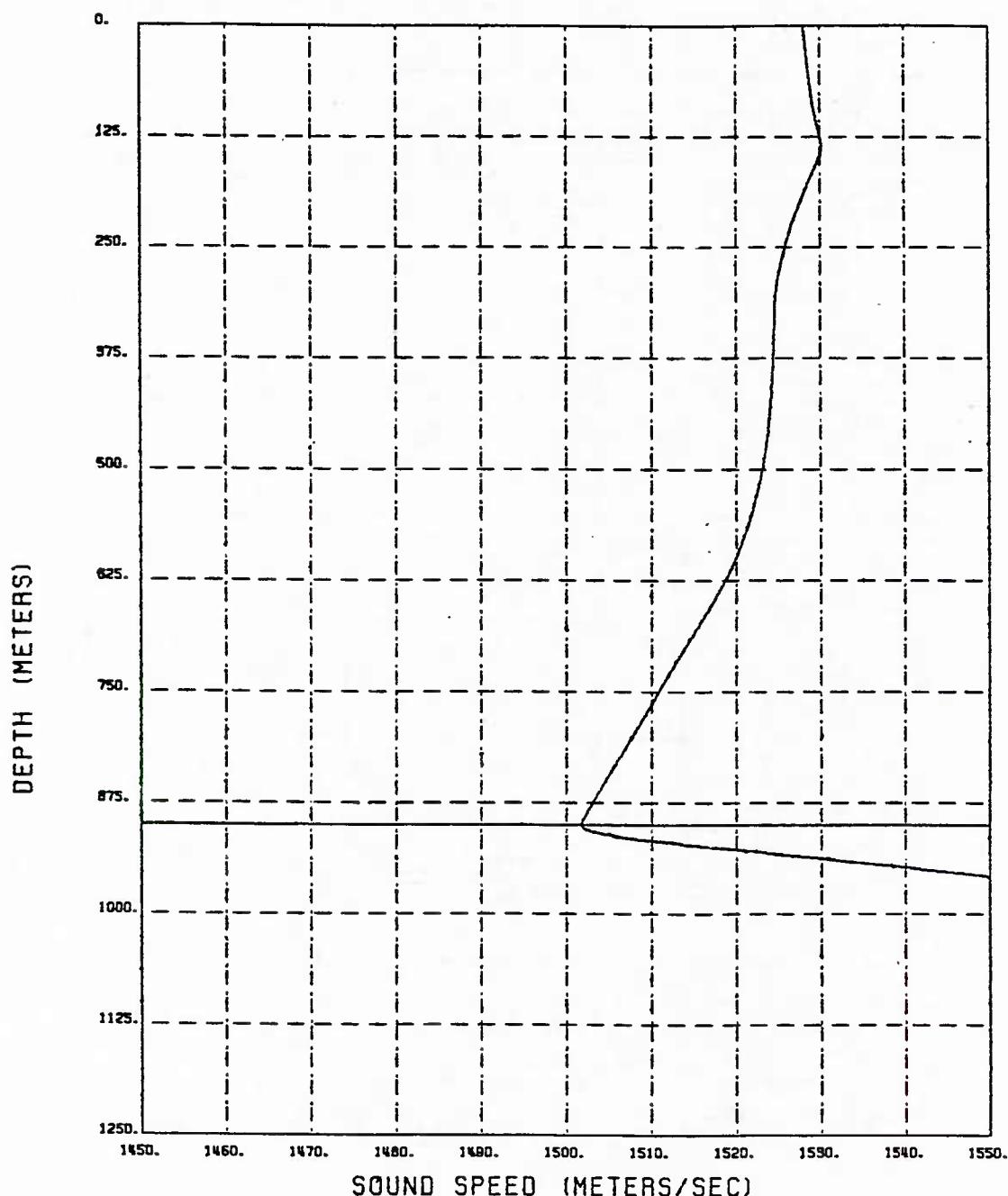
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-10.8	-11.4	95.072	-10.8	12.3	101.12	10
-11.0	11.6	95.105	-11.0	12.4	101.18	11
-14.1	-14.6	96.317	-14.1	15.2	101.83	12
-14.2	14.7	96.361	-14.2	15.4	101.88	13
-17.1	-17.5	97.765	-17.1	18.0	102.33	14
-17.2	17.6	97.818	-17.2	18.2	102.35	15
-19.9	-20.3	99.407	-19.9	20.7	102.69	16

APPENDIX B

BLAKE PLATEAU PE  
& RAY TRACING RESULTS  
(FEBRUARY PROFILE)

B1/B2

REVERSE BLANK

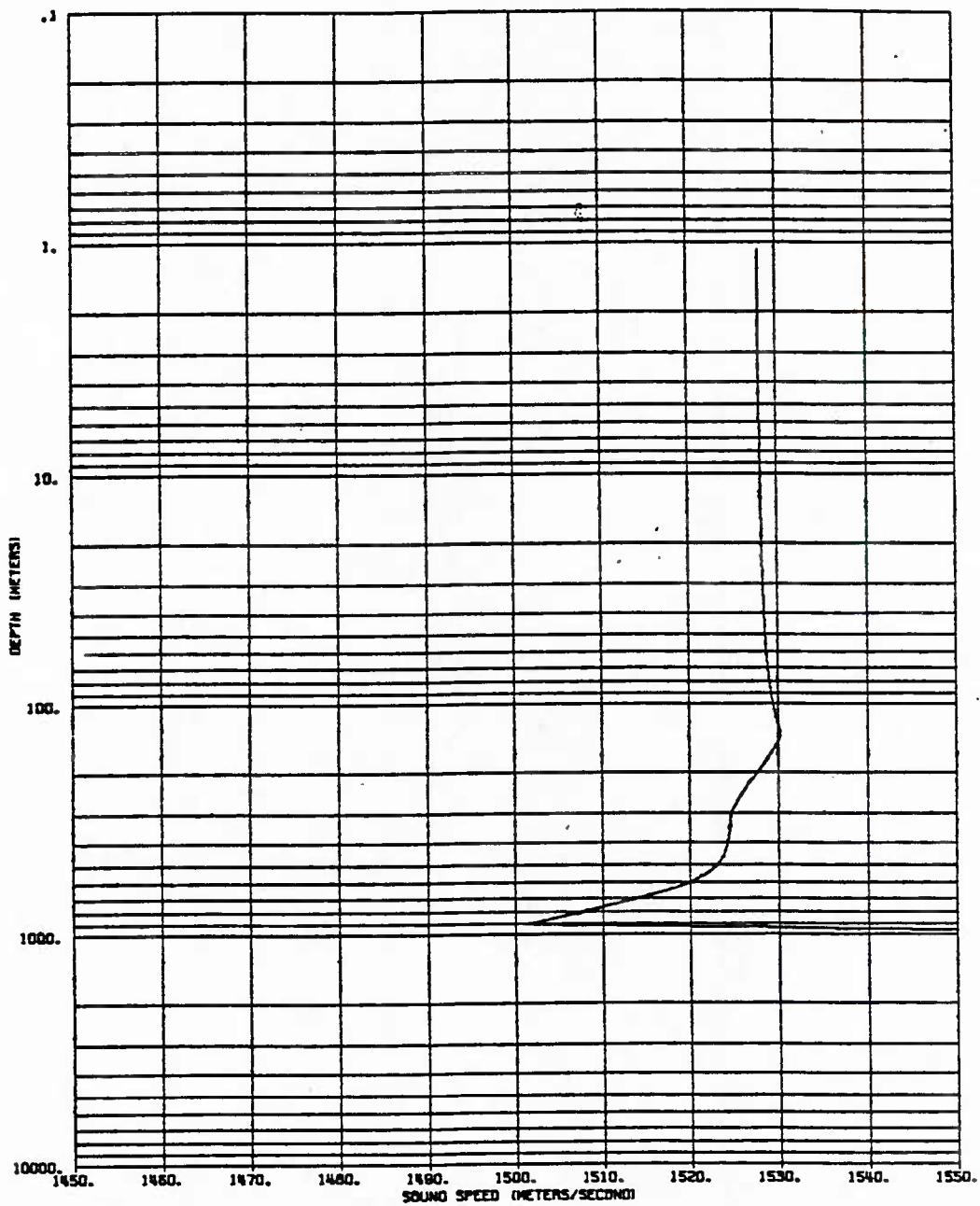


FREQUENCY = 460.0 HZ

SOURCE DEPTH = 78.0 METERS  
 SOURCE AIM = 4.0 DEGREES  
 SOURCE WIDTH = 6.1 METERS

PROBLEM DEPTH = 1100.0 METERS  
 BOTTOM DEPTH = 900.2 METERS  
 VERTICAL MESH SPACING = 1.07 METERS  
 BOTTOM ATTENUATION CONSTANT = 0.001000  
 ATTENUATION SCALE LENGTH = 500.0  
 SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS  
 RANGE MESH SPACING = 62.50 METERS



A17CFEB90 BLAKE  
FREQUENCY = 460.0 Hz

SOURCE DEPTH = 78.0 METERS  
SOURCE AIM = 4.0 DEGREES  
SOURCE WIDTH = 6.1 METERS

PROBLEM DEPTH = 1100.0 METERS  
BOTTOM DEPTH = 900.2 METERS  
VERTICAL MESH SPACING = 1.07 METERS  
BOTTOM ATTENUATION CONSTANT = 0.001000  
ATTENUATION SCALE LENGTH = 500.0  
SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 138750. METERS  
RANGE MESH SPACING = 62.50 METERS

TM No. 811061

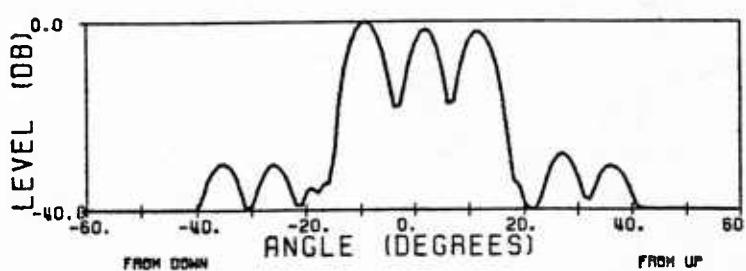
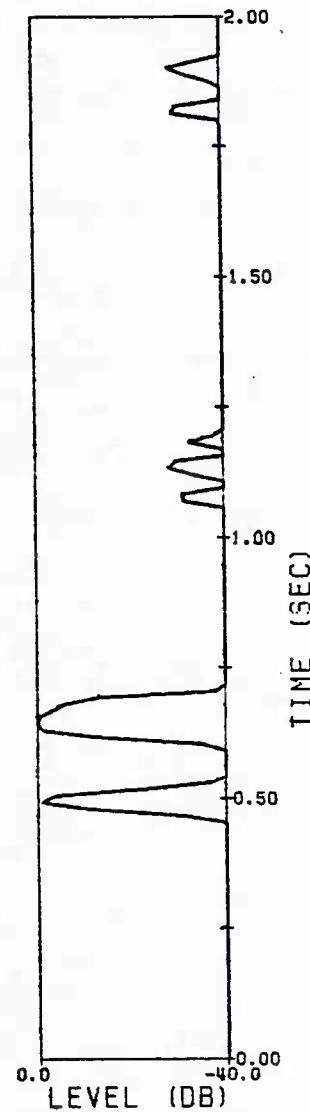
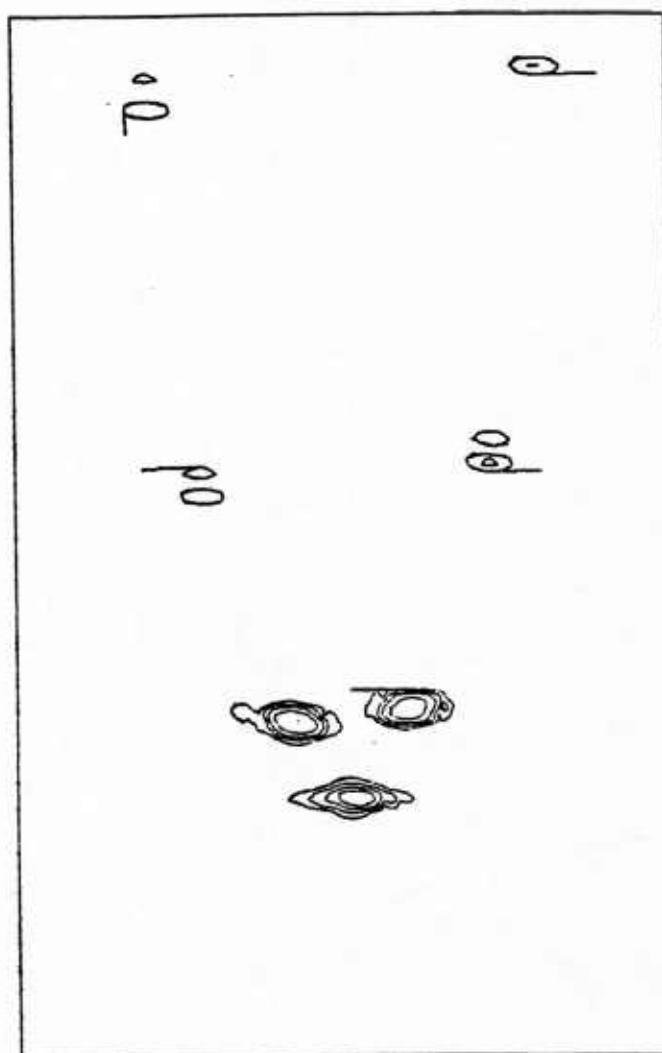
RANGE = 5 MILES

B5/B6

REVERSE BLANK

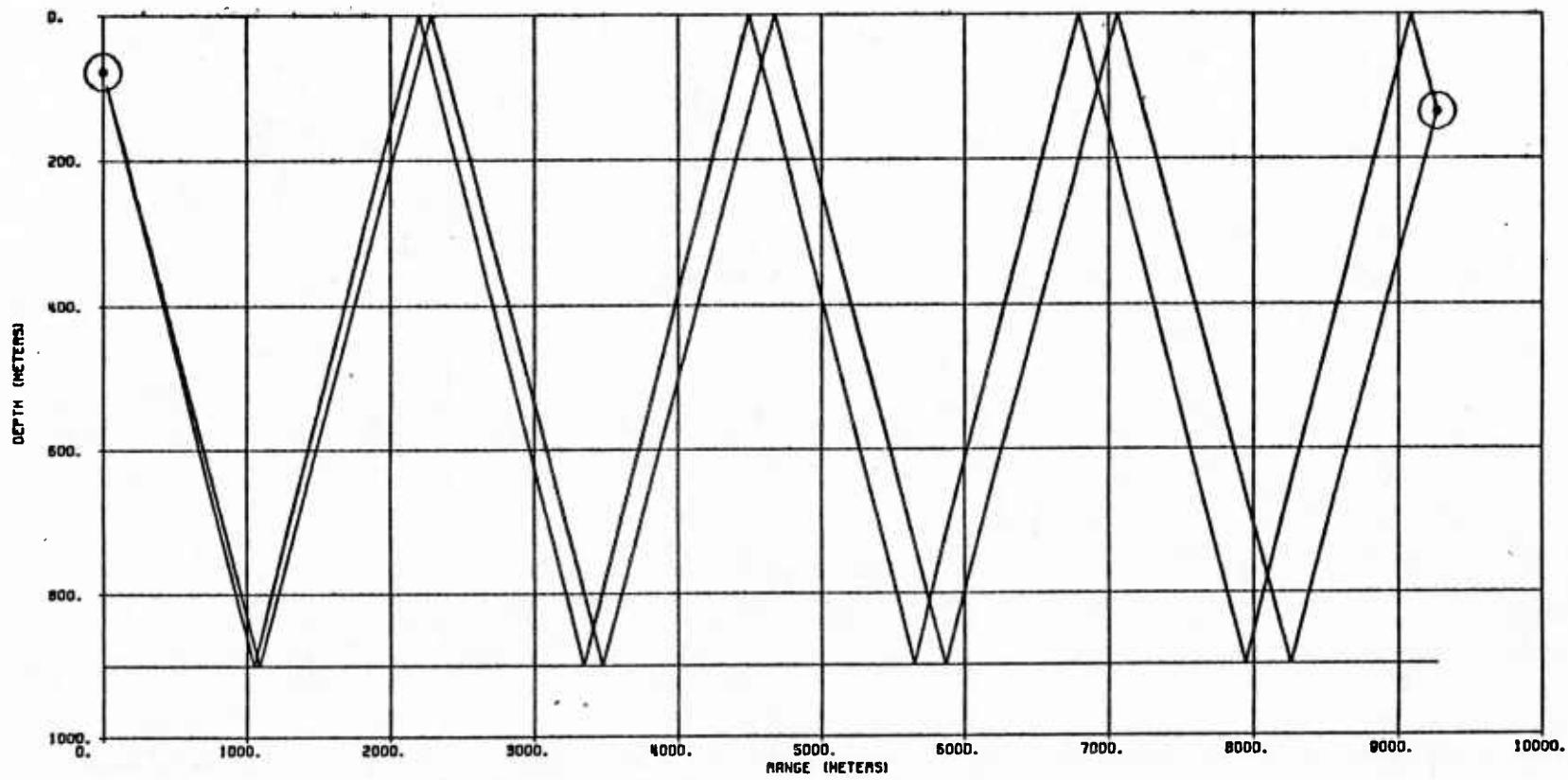
TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-81.72 DB  
 ANGLE MAX=-78.16 DB  
 DELAY MAX=-75.02 DB  
 DESIRED RANGE= 5.0 NAUTICAL MILES  
 STARTING FREQUENCY= 460. HZ.  
 STOPPING FREQUENCY= 540. HZ.  
 STARTING DEPTH= 104.20 METERS  
 STOPPING DEPTH= 164.36 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 6.1 METERS  
 SOURCE AIM= 4.0 DEGREES

B8

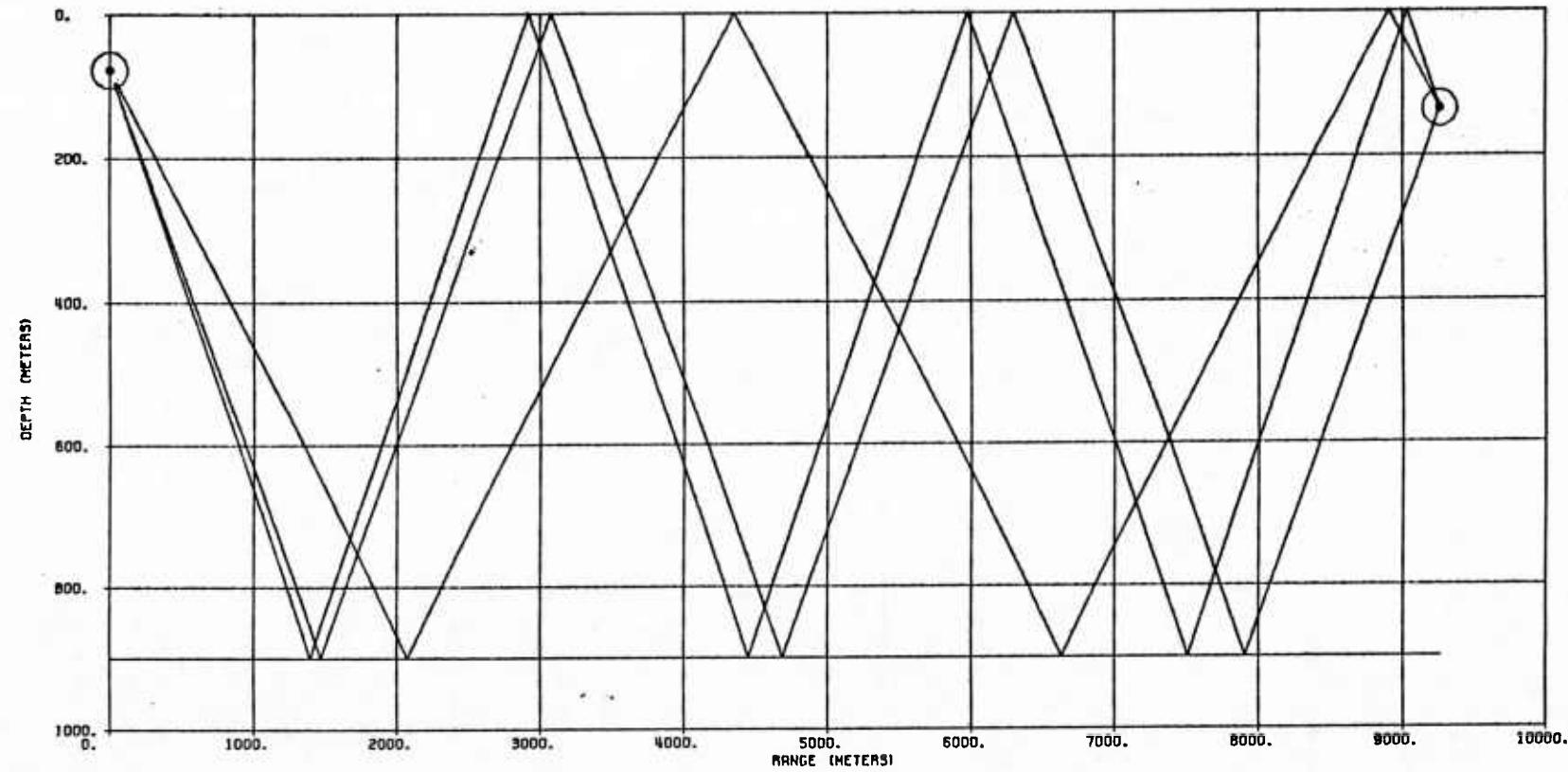


## RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

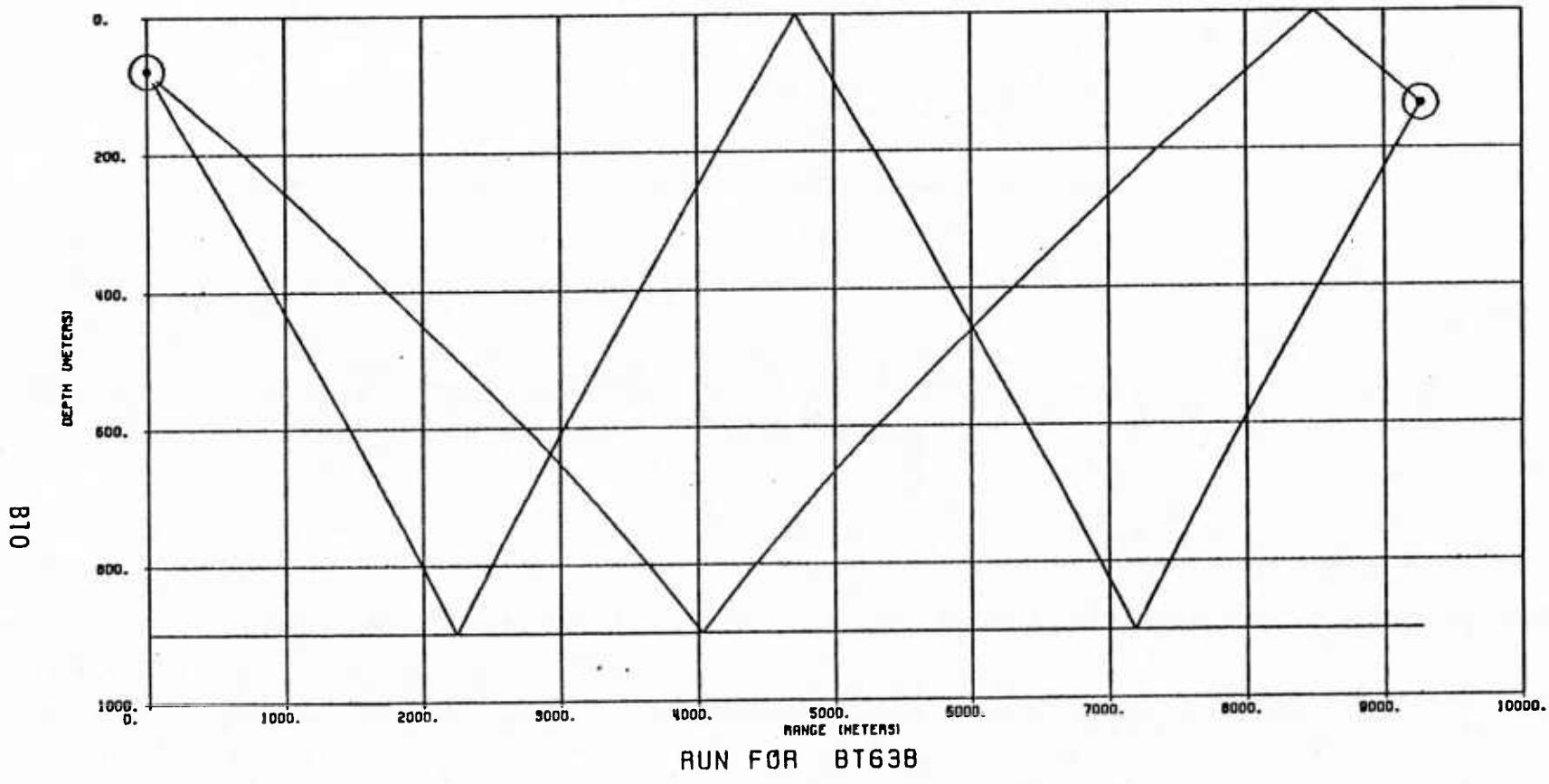
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
36.6 37.7	-36.5 37.6	7.632 7.740	-36.6 -37.7	37.9 39.0	81.15 81.29	7 8



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

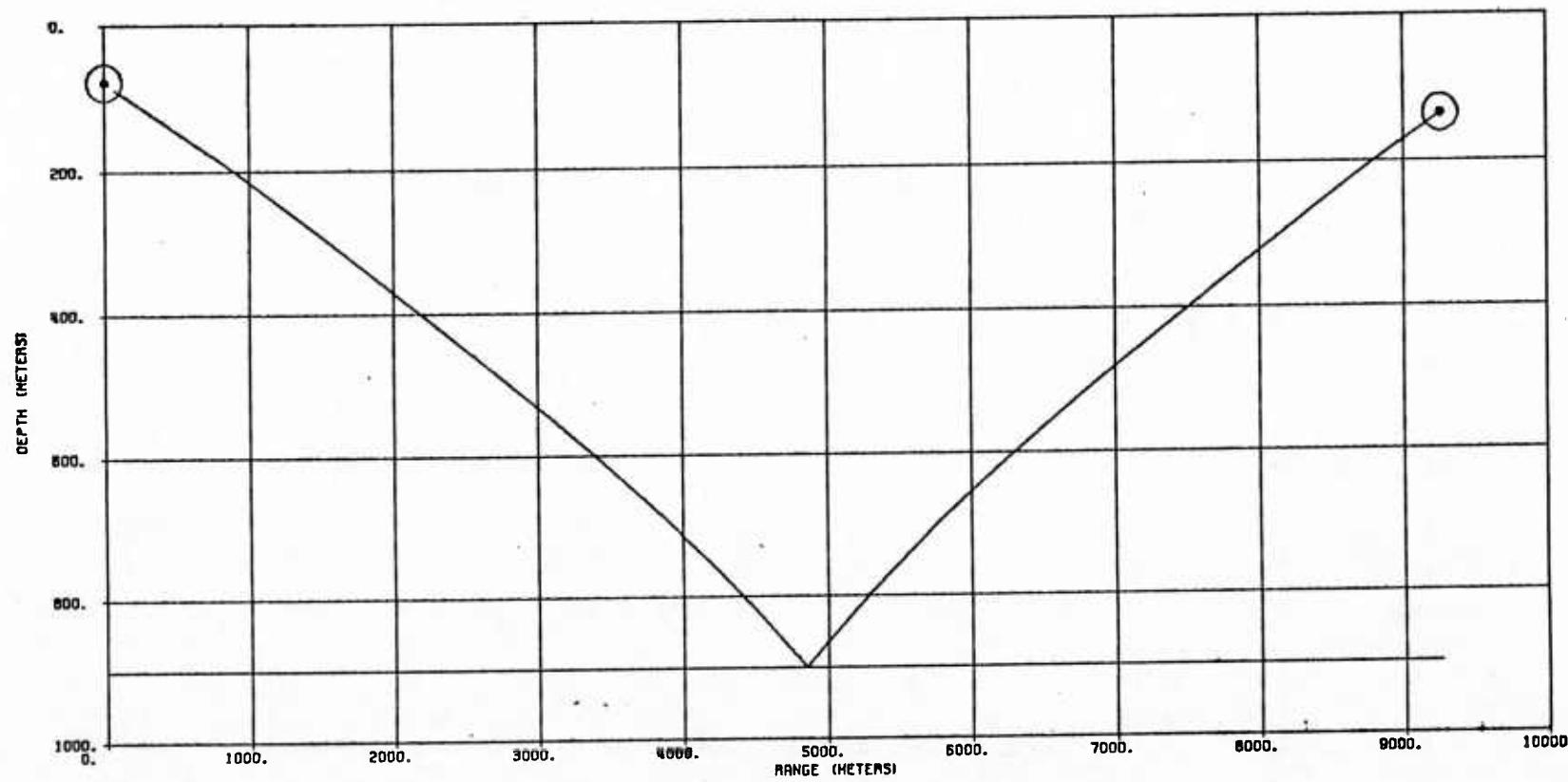
TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
20.8	20.7	6.550	-20.8	23.3	79.62	4
28.7	-28.6	6.984	-28.7	30.5	80.31	5
30.0	29.9	7.071	-30.0	31.7	60.44	6



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
10.0 19.2	9.8 -19.1	6.212 6.489	-10.2 -19.3	14.7 21.9	78.45 79.45	2 3

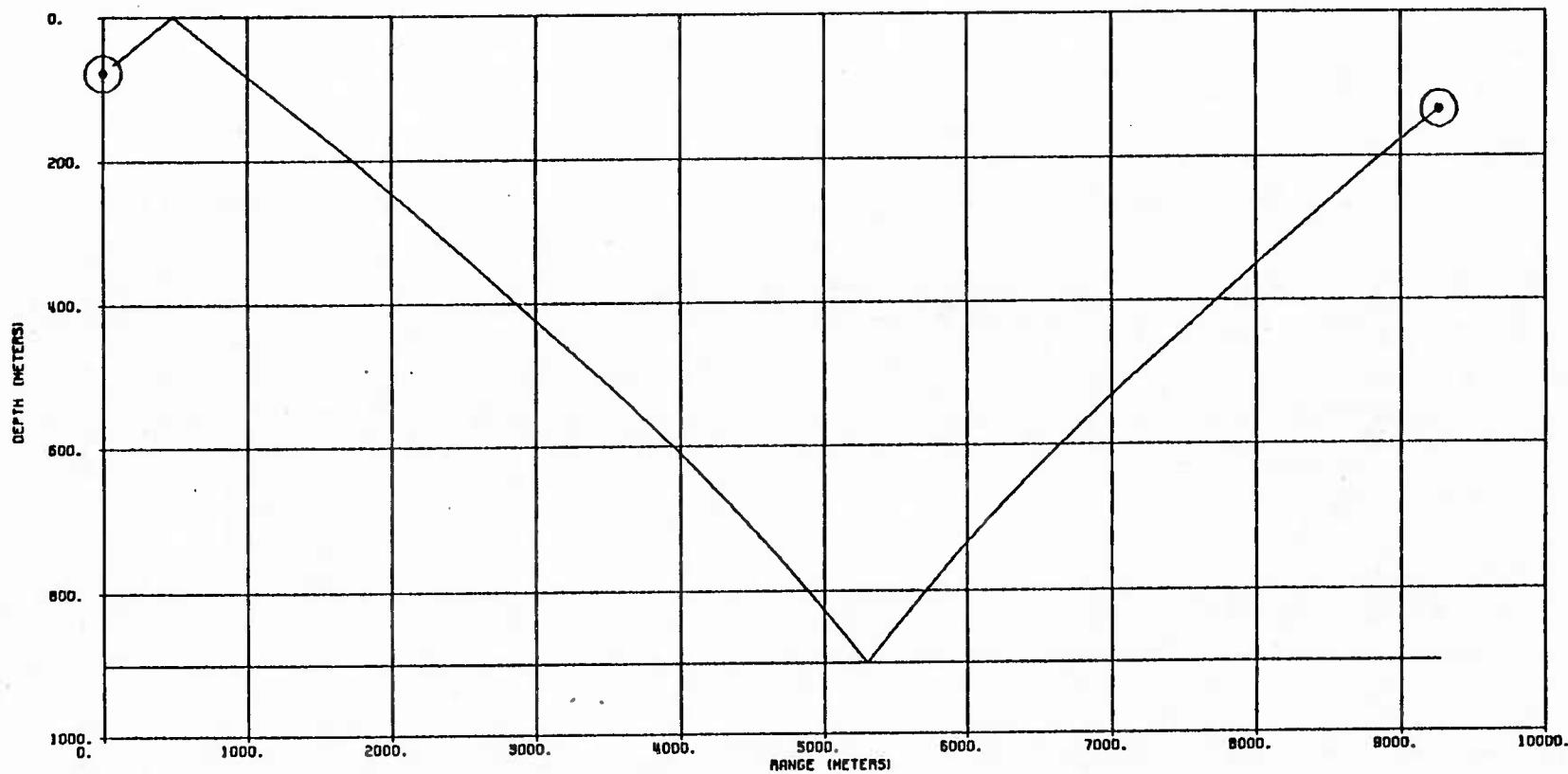


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
7.8	-7.5	6.184	0.0	13.4	77.69	1

B12



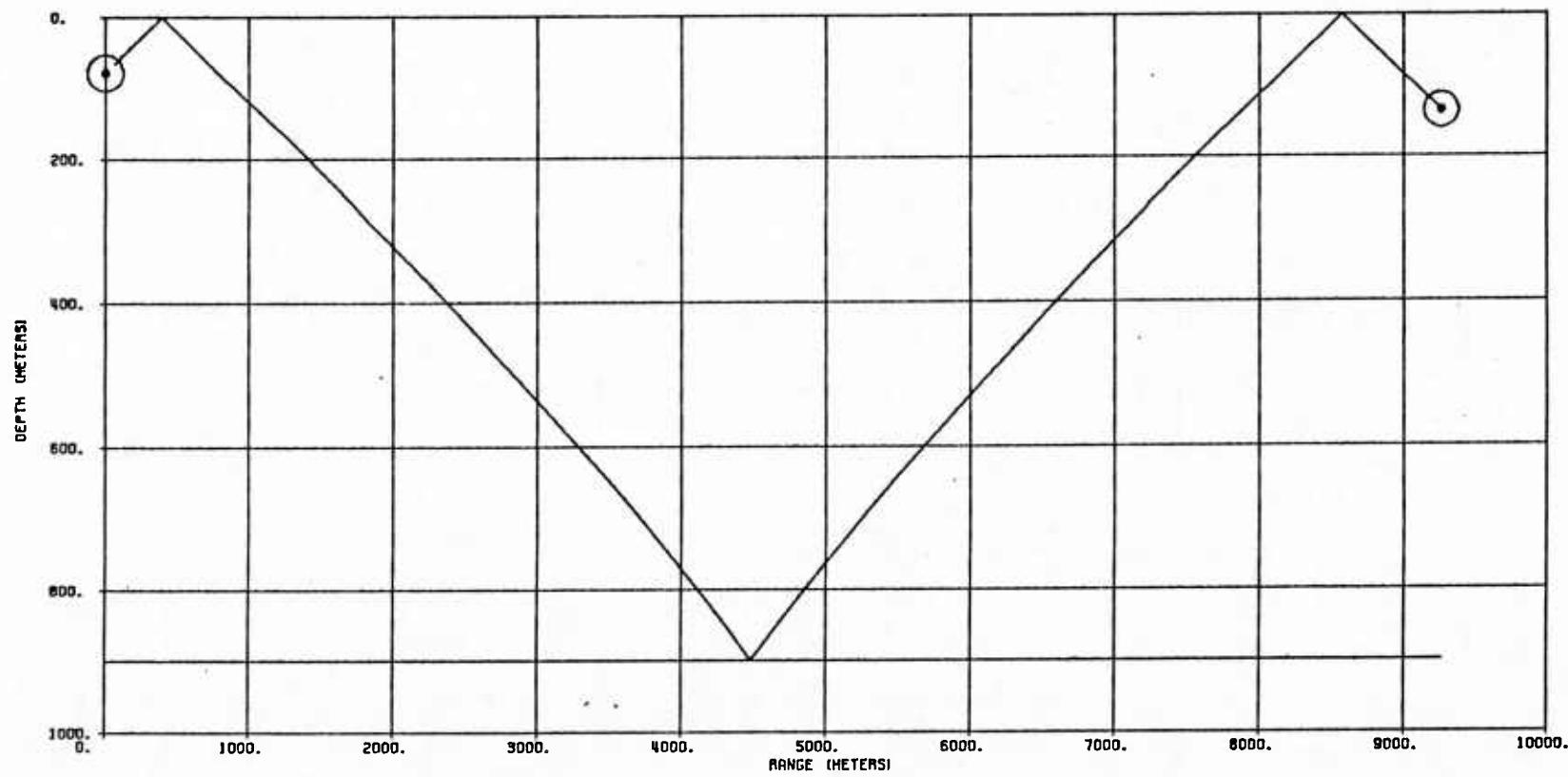
## RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-9.1	-8.8	6.199	-9.3	14.1	78.18	2

B13



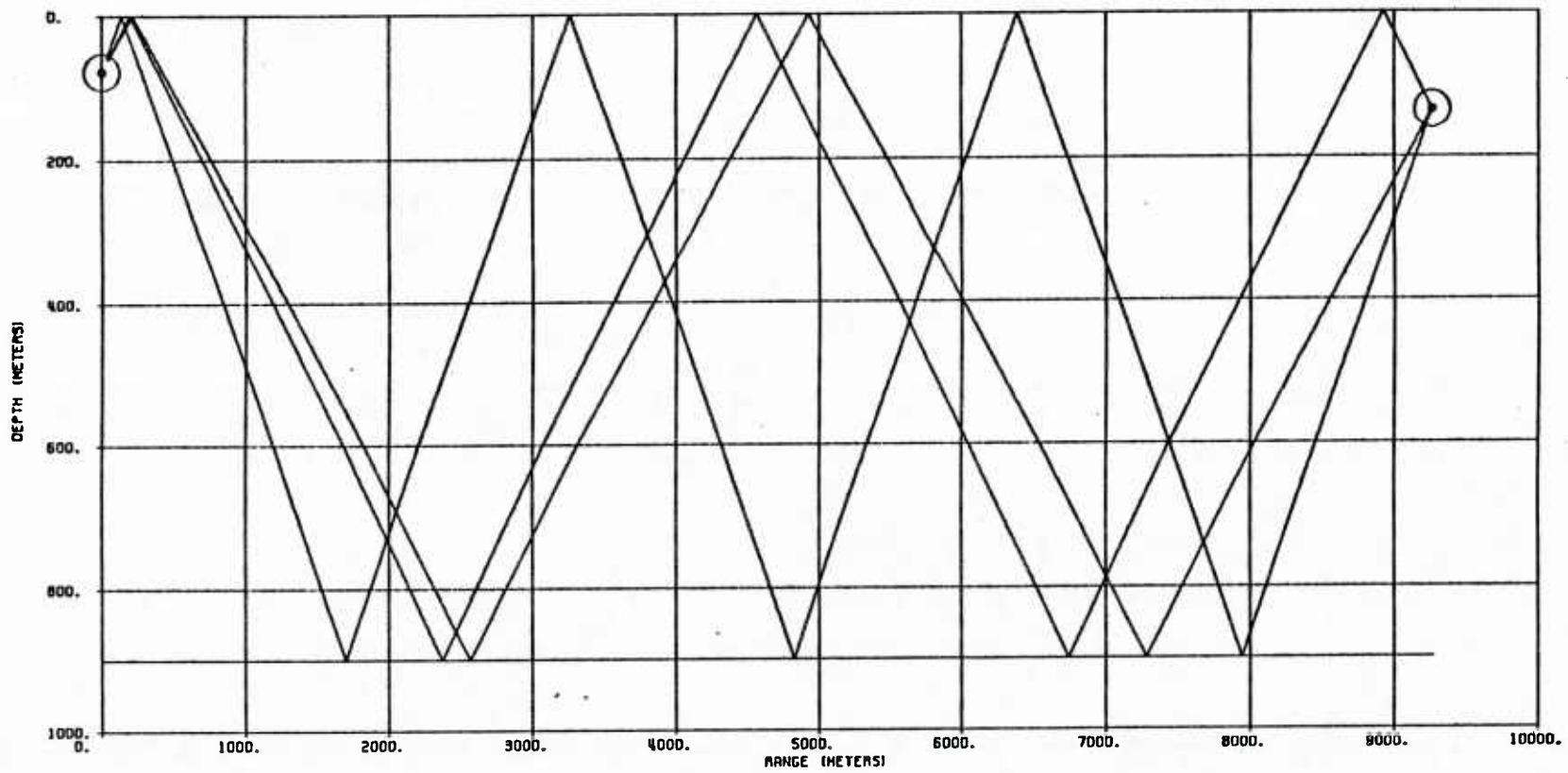
RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-11.1	10.9	6.291	-11.3	15.5	78.69	3

814



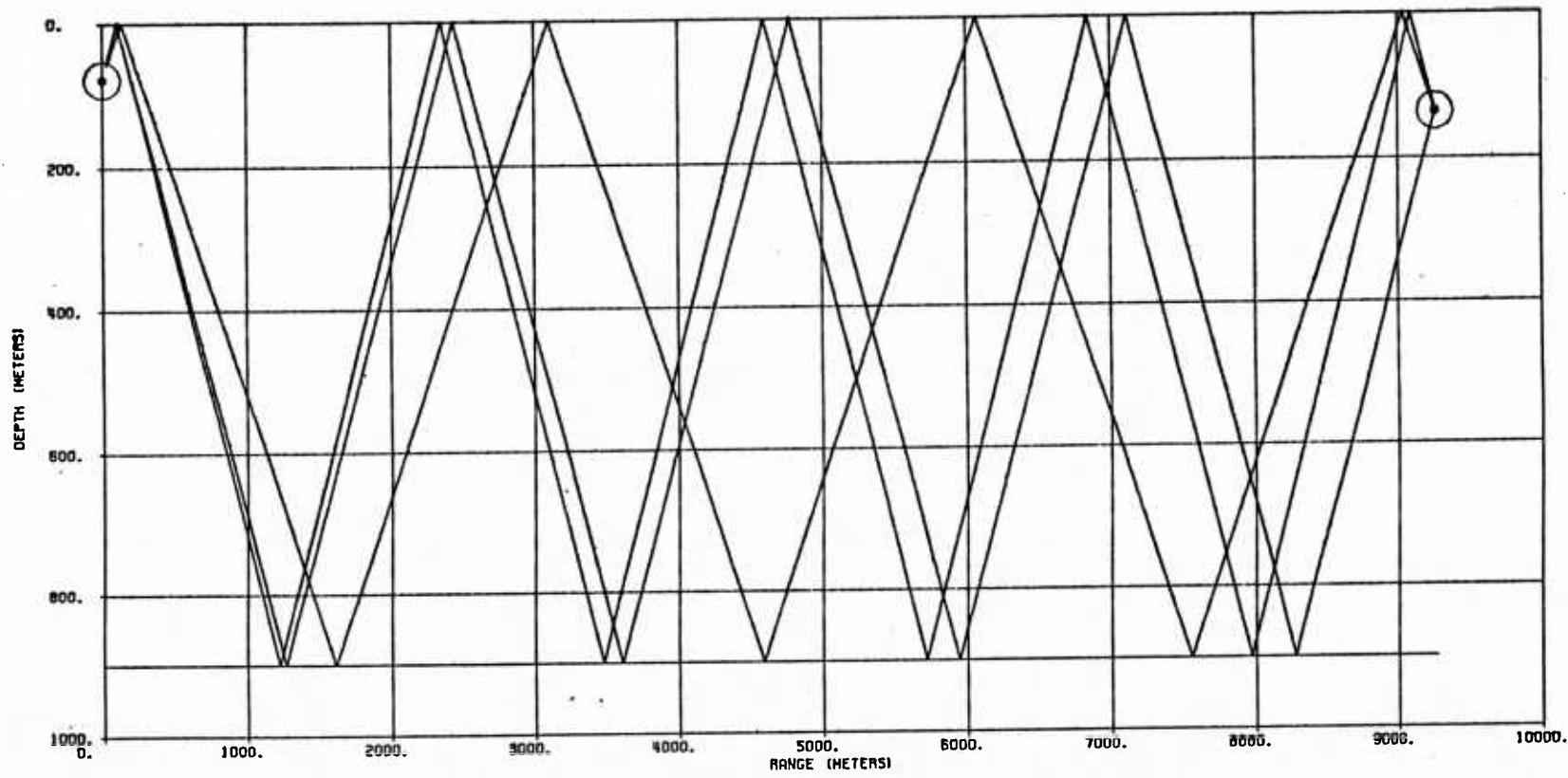
## RUN FOR BT63B

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-20.1	-20.0	6.524	-20.2	22.7	79.55	4
-21.7	21.6	6.587	-21.8	24.1	79.70	5
-29.4	-29.3	7.034	-29.5	31.2	80.39	6

B15/B16 REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-30.7	30.6	7.123	-30.8	32.4	80.52	7
-37.2	-37.2	7.694	-37.3	36.5	81.23	8
-38.3	38.2	7.803	-38.3	39.6	81.36	9

TM No. 811061

TM No. 811061

RANGE = 25 MILES

B17/B18

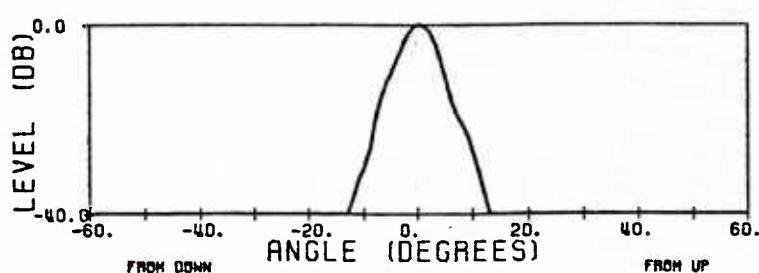
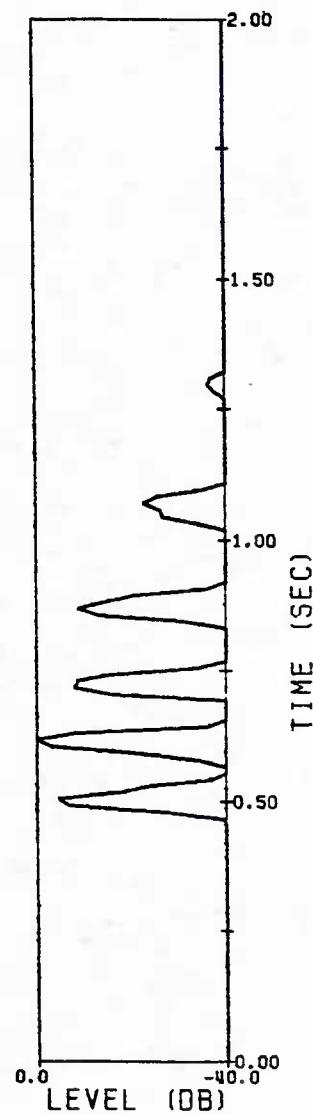
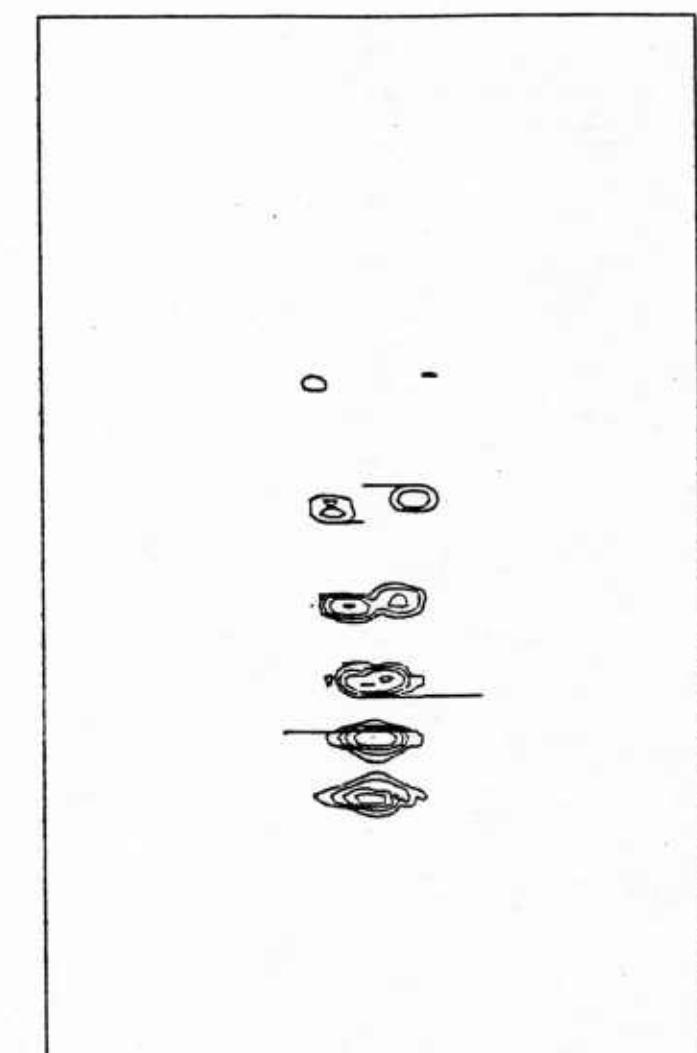
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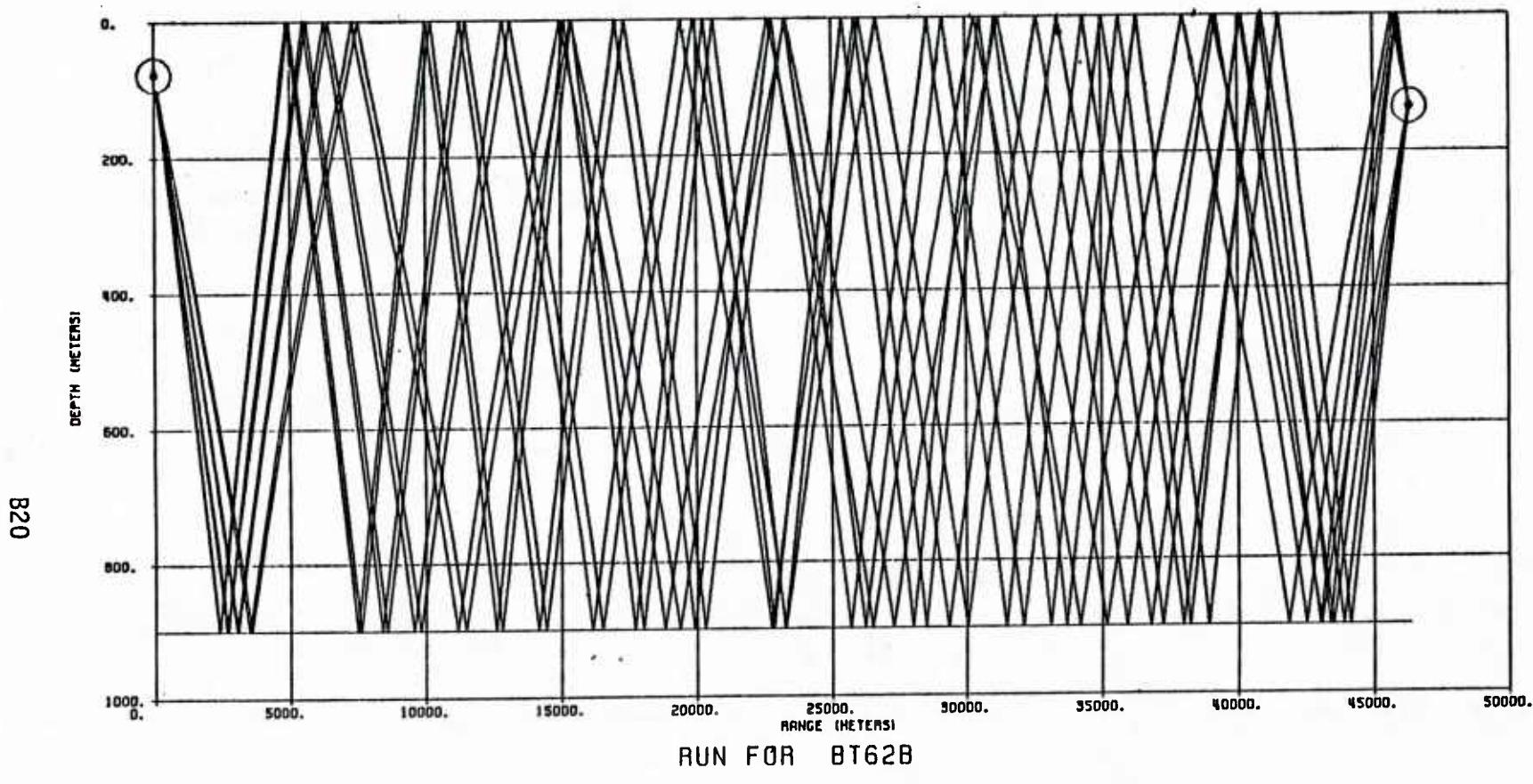
8-SEP-80 14:49:26

TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-96.15 DB  
ANGLE MAX=-92.25 DB  
DELAY MAX=-89.28 DB  
DESIRED RANGE= 25.0 NAUTICAL MILES  
STARTING FREQUENCY= 460. HZ.  
STOPPING FREQUENCY= 540. HZ.  
STARTING DEPTH= 104.20 METERS  
STOPPING DEPTH= 164.36 METERS  
SOURCE DEPTH=78.0 METERS  
SOURCE WIDTH=6.1 METERS  
SOURCE AIM=4.0 DEGREES

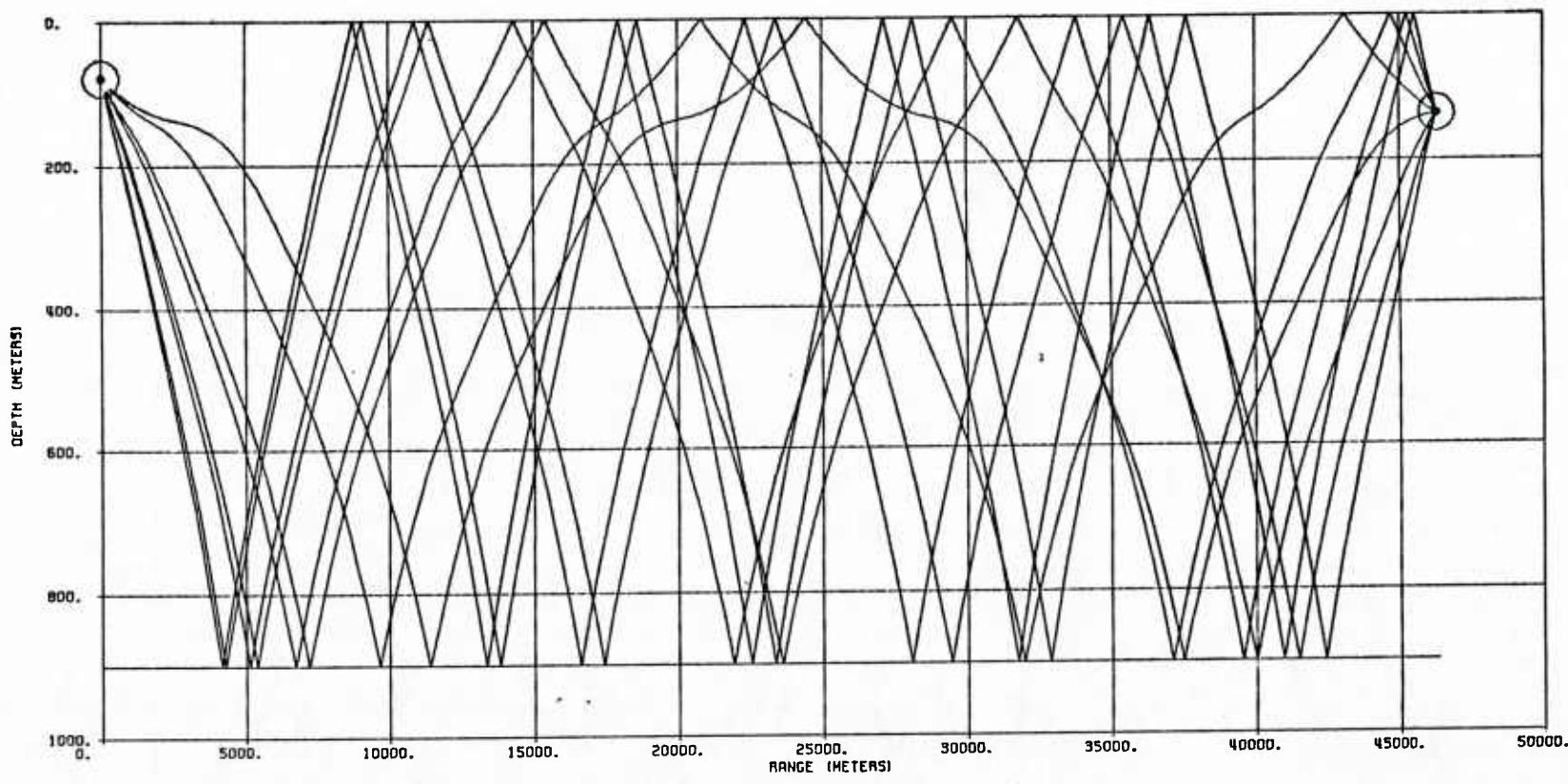


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
11.6	-11.4	31.249	-11.0	15.0	92.62	11
12.0	11.8	31.285	-12.1	16.1	92.70	12
13.9	-13.7	31.535	-14.0	17.5	92.92	13
14.2	14.0	31.578	-14.3	17.8	92.97	14
16.0	-15.9	31.862	-16.2	19.3	93.16	15
16.4	16.2	31.912	-16.5	19.6	93.20	16
16.2	-16.0	32.229	-18.3	21.1	93.35	17
16.5	16.4	32.285	-18.6	21.3	93.39	18

B21



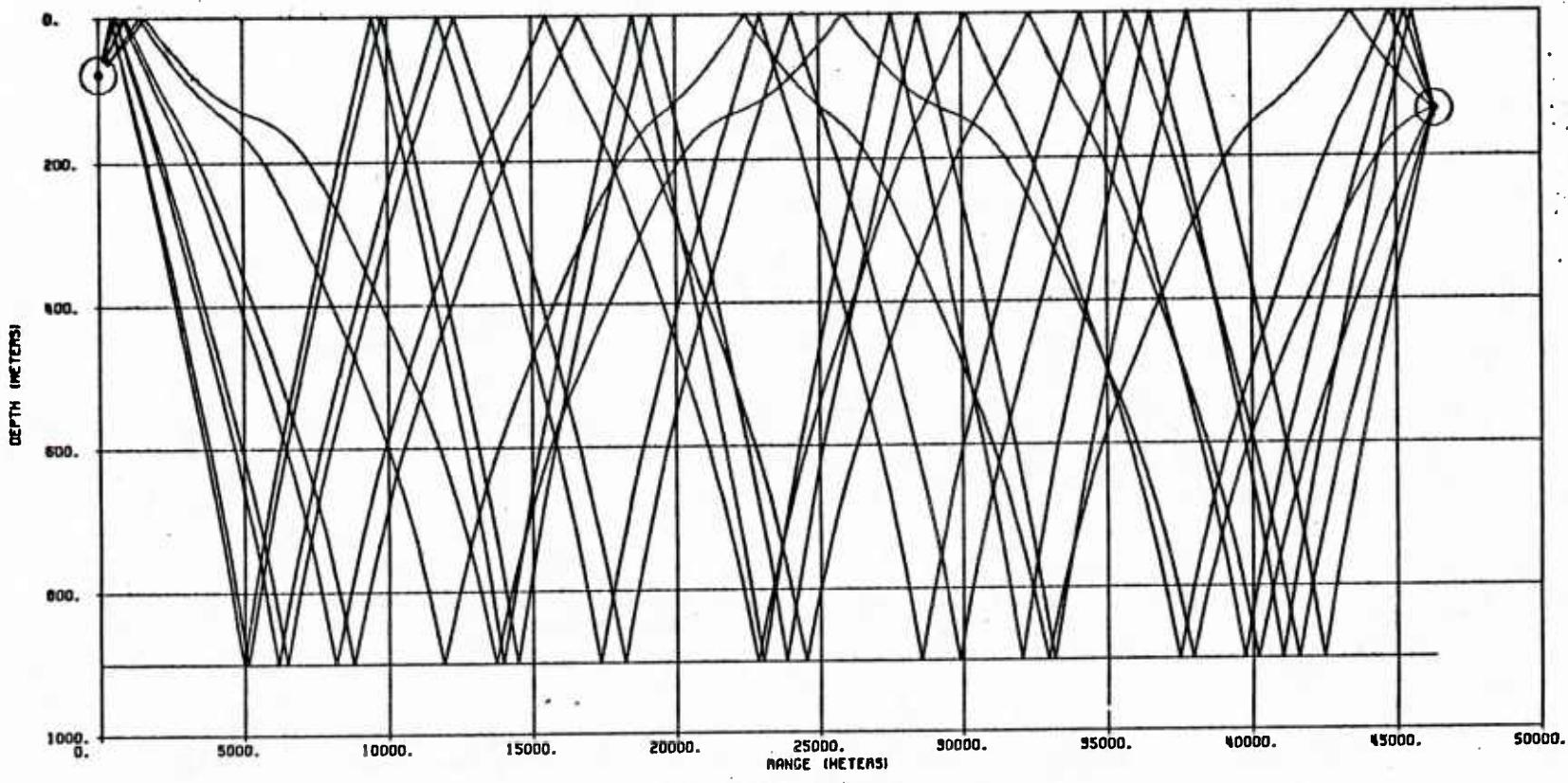
SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
2.3	-0.5	30.511	-3.0	11.1	90.87	3
2.6	1.3	30.518	-3.3	11.2	89.65	4
4.2	-3.6	30.639	-4.7	11.6	90.29	5
4.8	4.2	30.653	-5.2	11.8	90.82	6
6.0	-6.4	30.802	-7.1	12.8	91.54	7
7.2	6.9	30.823	-7.5	13.0	91.77	8
9.2	-9.0	31.004	-9.4	14.2	92.21	9
9.7	9.4	31.034	-9.9	14.5	92.33	10

TM No. 811061

B22



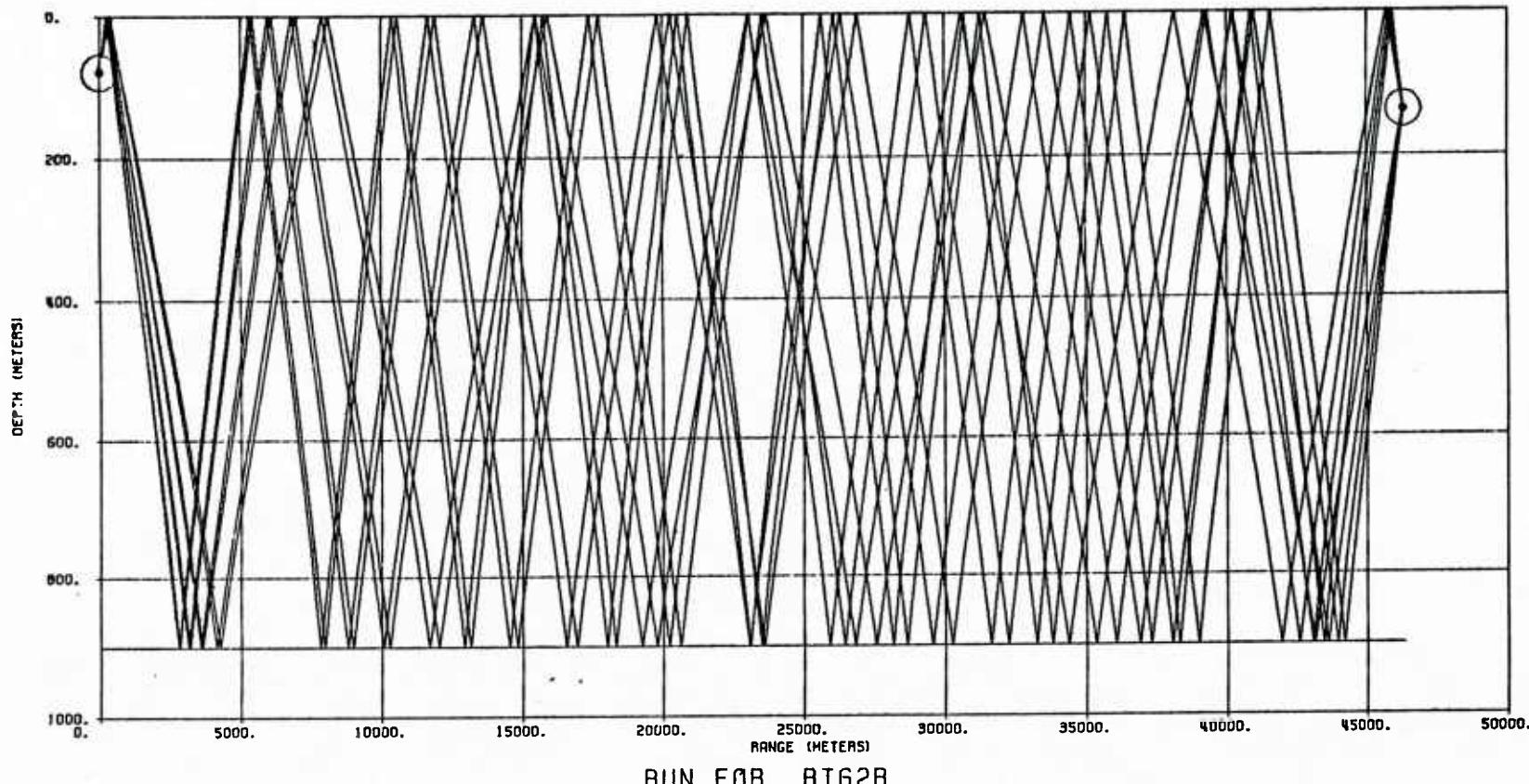
## RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-2.8	-0.8	30.516	-3.1	11.1	89.57	4
-2.8	1.7	30.523	-3.5	11.2	89.72	5
-4.5	-3.8	30.648	-4.8	11.8	90.56	6
-5.1	4.5	30.663	-5.4	12.0	91.03	7
-7.0	-6.7	30.814	-7.3	12.9	91.67	8
-7.5	7.2	30.837	-7.8	13.2	91.88	9
-9.5	-9.2	31.021	-9.7	14.4	92.28	10
-9.8	8.6	31.051	-10.1	14.6	92.39	11

B23/B24  
REVERSE BLANK



RUN FOR BT62B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-11.8	-11.6	31.270	-12.0	16.0	92.67	12
-12.2	12.0	31.307	-12.3	16.3	92.74	13
-14.1	-13.9	31.560	-14.2	17.7	92.95	14
-14.4	14.2	31.604	-14.6	18.0	93.00	15
-16.2	-16.1	31.891	-16.4	19.4	93.18	16
-16.6	16.4	31.941	-16.7	19.7	93.22	17
-18.3	-18.2	32.261	-18.4	21.2	93.38	18
-18.7	18.5	32.318	-18.8	21.5	93.41	19

TM No. 811061

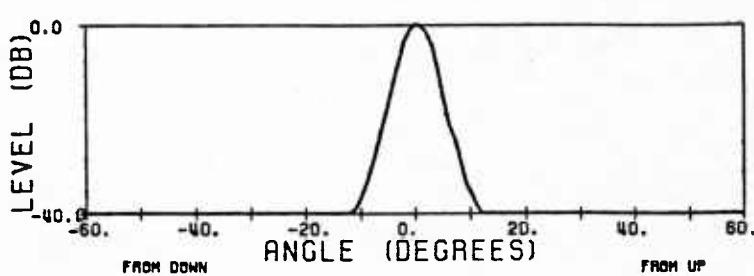
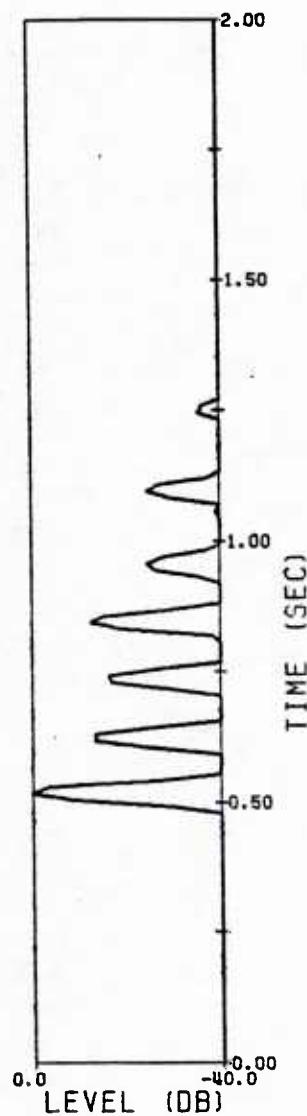
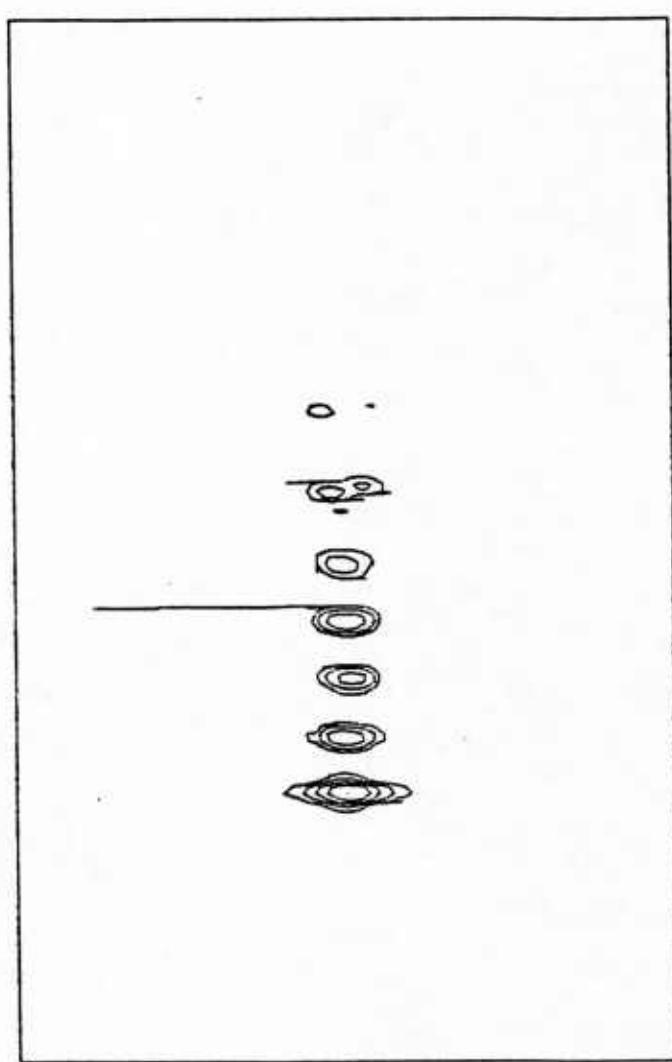
RANGE = 50 MILES

B25/B26

REVERSE BLANK

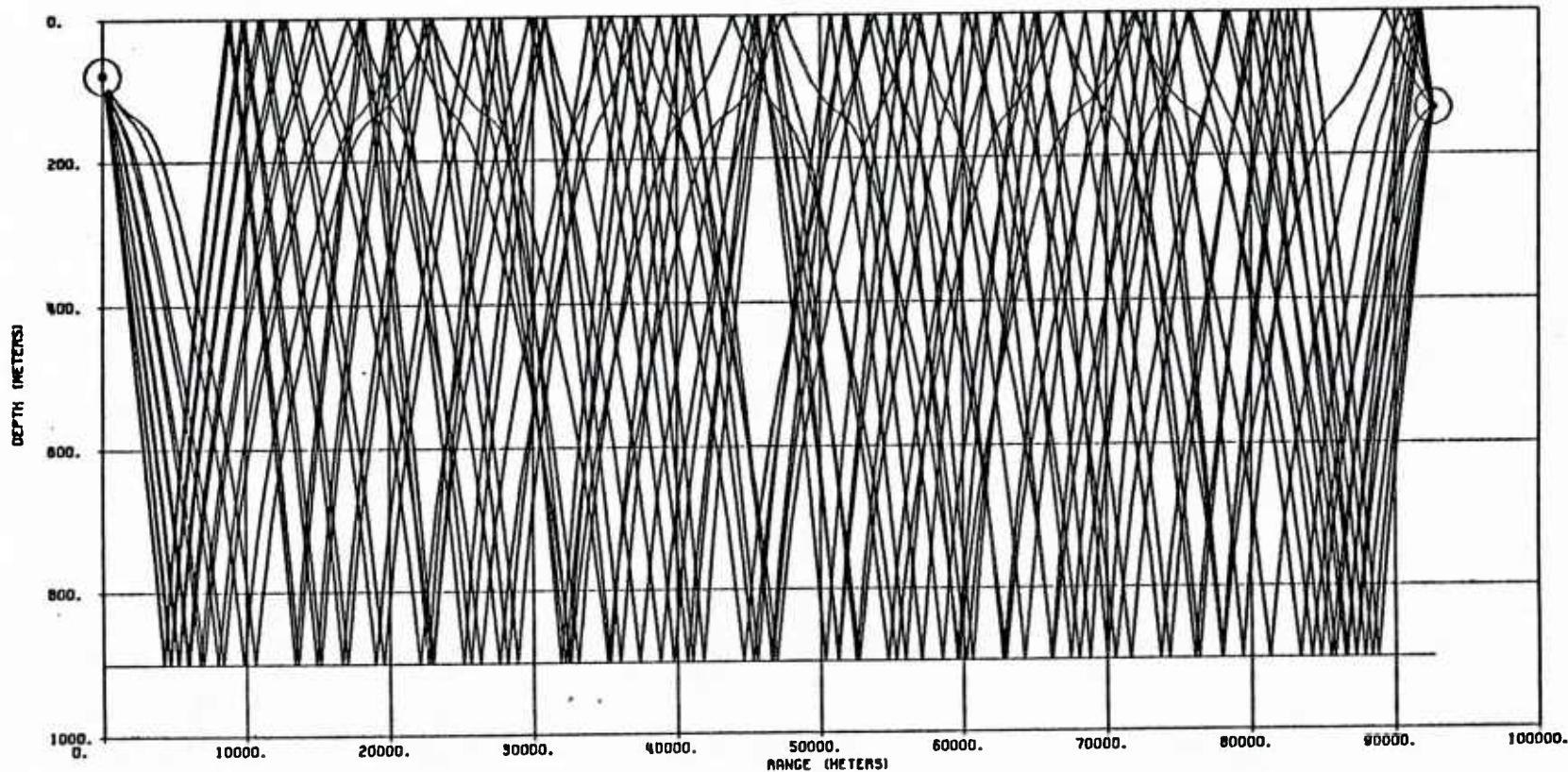
TM No. 811061

A17CFEB90 BLAKE



ANGLE,DELAY MAX=-98.50 DB  
 ANGLE MAX=-95.86 DB  
 DELAY MAX=-91.84 DB  
 DESIRED RANGE= 49.9 NAUTICAL MILES  
 STARTING FREQUENCY= 460. HZ.  
 STOPPING FREQUENCY= 540. HZ.  
 STARTING DEPTH= 104.20 METERS  
 STOPPING DEPTH= 164.36 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 6.1 METERS  
 SOURCE AIM= 4.0 DEGREES

B28



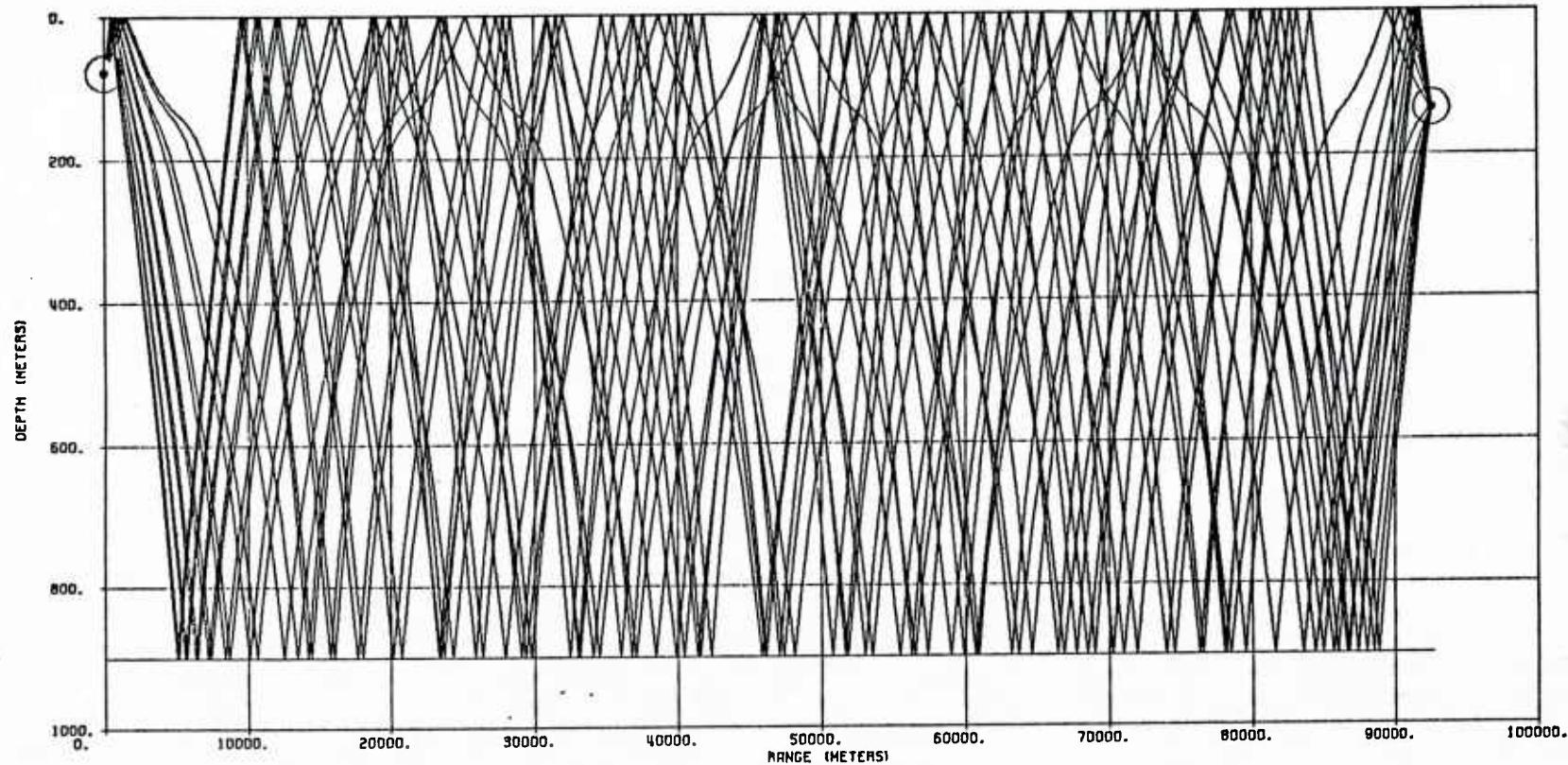
## RUN FOR BT61B

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.4	-0.8	61.027	-3.1	11.1	95.98	7	6.0	5.5	61.163	-5.3	12.4	97.36	14
2.5	1.2	61.035	-3.2	11.1	95.76	6	7.0	-6.6	61.620	-7.2	12.8	97.66	15
3.2	-2.3	61.152	-3.8	11.3	95.67	9	7.2	6.8	61.542	-7.5	13.0	97.77	16
3.5	2.7	61.162	-4.0	11.4	96.07	10	8.2	-7.9	61.816	-8.4	13.6	98.01	17
4.4	-3.8	61.290	-4.9	11.7	96.55	11	8.4	8.1	61.841	-8.6	13.7	98.09	18
4.7	4.1	61.304	-5.1	11.8	96.79	12	9.4	-9.1	62.032	-9.6	14.3	98.29	19
5.7	-5.3	61.445	-6.0	12.3	97.18	13	9.6	9.3	62.061	-9.8	14.5	98.34	20

B29/B30  
REVERSE BLANK



RUN FOR BT61B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-2.4	-1.0	61.032	-3.1	11.1	85.55	8	-6.1	5.7	61.475	-6.4	12.4	87.44	15
-2.6	1.4	61.040	-3.3	11.2	85.59	9	-7.1	-6.7	61.633	-7.4	12.9	87.73	16
-3.4	-2.5	61.158	-3.9	11.4	85.83	10	-7.3	7.0	61.655	-7.6	13.1	87.84	17
-3.7	2.9	61.169	-4.2	11.4	86.22	11	-8.9	-8.0	61.831	-8.6	13.6	88.05	18
-4.6	-4.0	61.298	-5.0	11.8	86.65	12	-8.5	8.2	61.857	-8.8	13.8	88.14	19
-4.9	4.3	61.313	-5.3	11.9	86.90	13	-9.5	-9.3	62.049	-9.7	14.4	88.31	20
-5.8	-5.4	61.456	-6.2	12.3	97.27	14	-9.7	9.5	62.078	-9.9	14.5	98.38	21

TM No. 811061

TM No. 811061

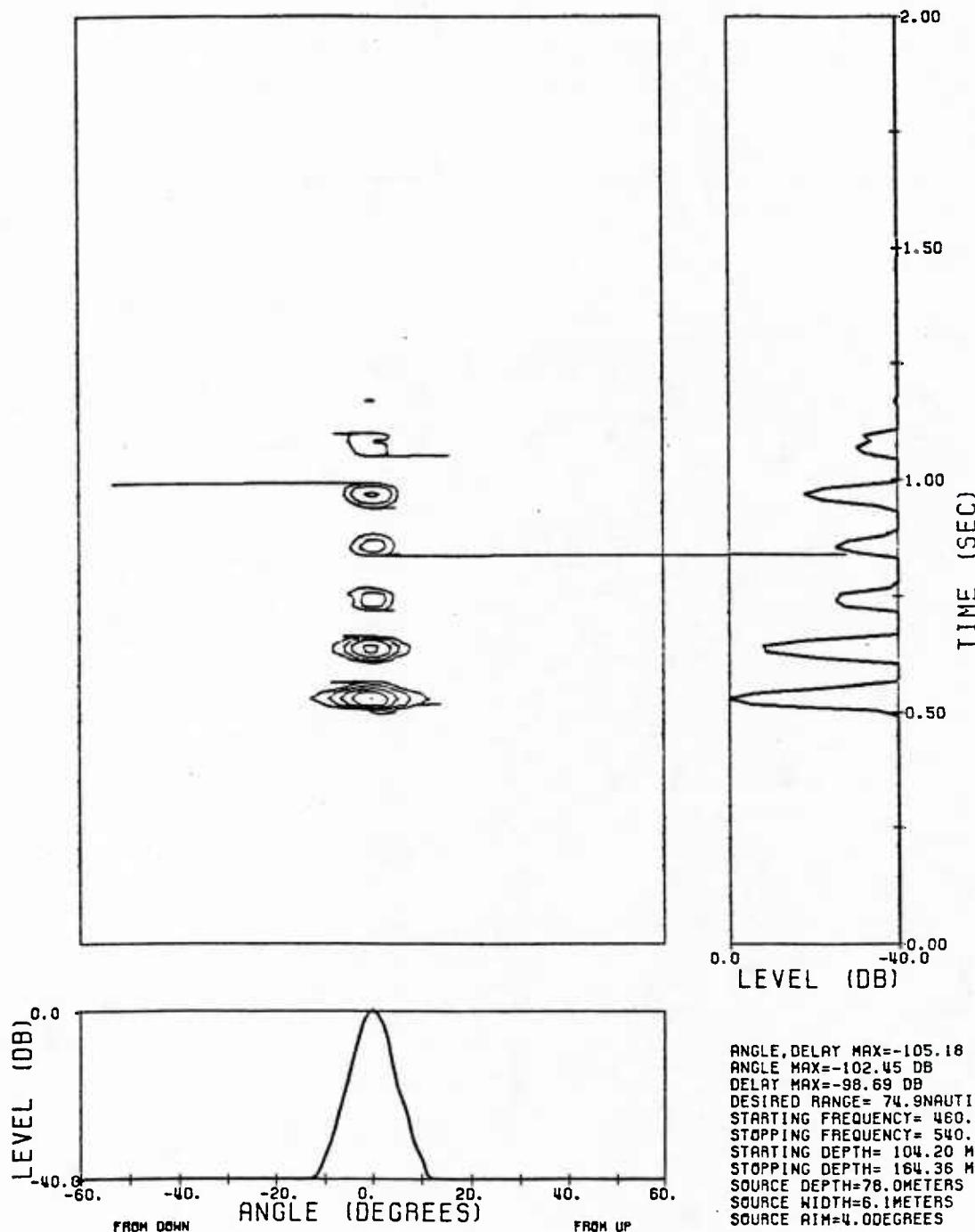
RANGE = 75 MILES

B31/B32

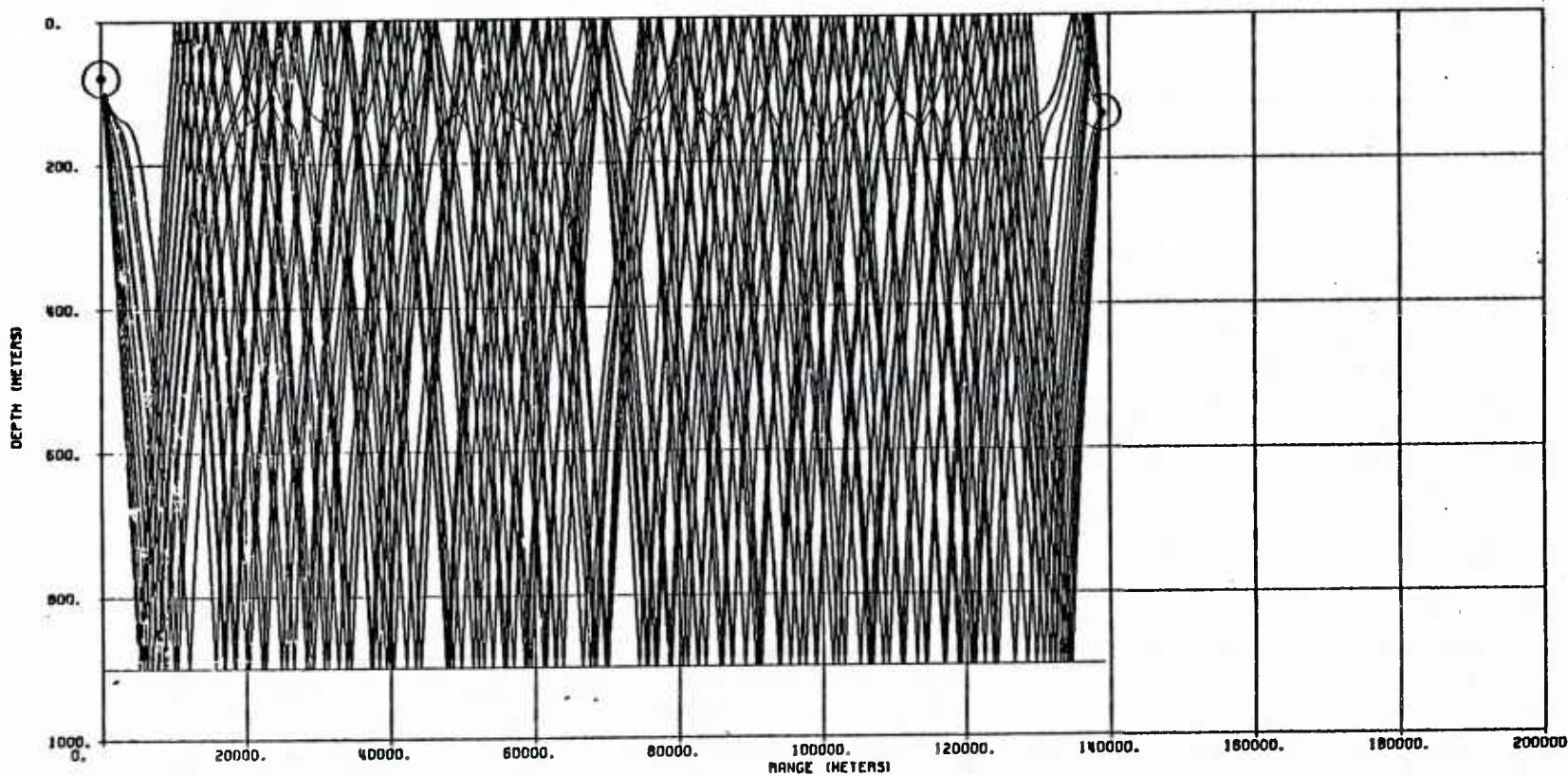
REVERSE BLANK

TM No. 811061

A17CFEB90 BLAKE



B33.



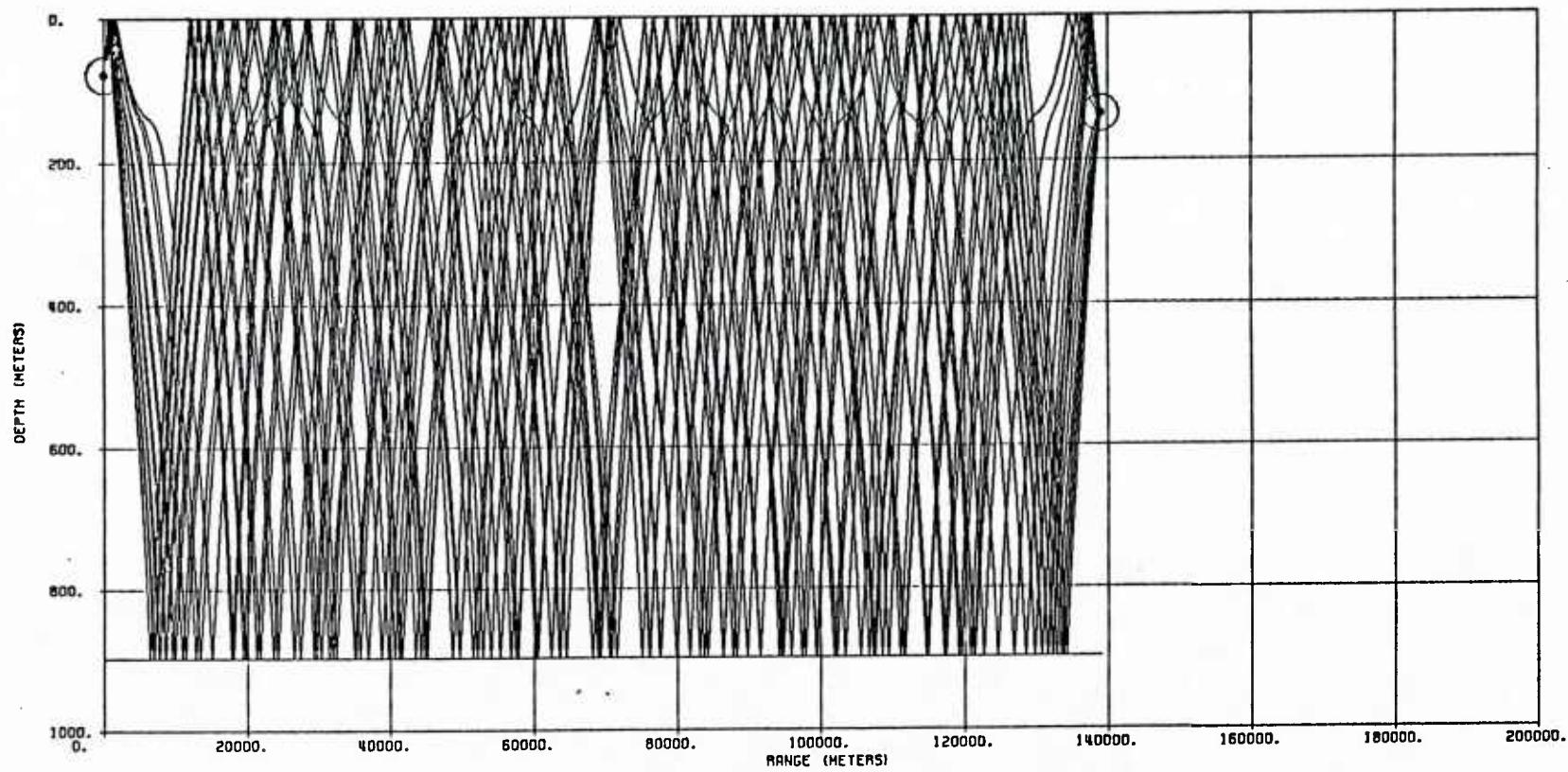
## RUN FOR BT60B

SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
2.3	0.3	91.431	-3.0	11.1	106.59	10	4.7	4.1	91.955	-5.1	11.8	100.30	18
2.4	-0.9	91.594	-3.1	11.1	99.74	11	5.4	-4.8	92.094	-5.7	12.1	100.57	19
2.5	1.2	91.551	-3.2	11.1	99.32	12	5.5	5.1	92.111	-5.9	12.2	100.69	20
2.9	-1.9	91.667	-3.5	11.2	99.04	13	6.2	-5.8	92.260	-6.5	12.5	100.93	21
3.1	2.2	91.677	-3.7	11.3	99.96	14	6.4	5.9	92.279	-6.7	12.6	101.02	22
3.7	-2.9	91.799	-4.2	11.5	99.60	15	7.0	-6.7	92.439	-7.3	12.9	101.21	23
3.9	3.2	91.810	-4.4	11.5	99.82	16	7.2	6.8	92.461	-7.4	13.0	101.30	24
4.5	-3.3	91.940	-4.9	11.7	100.15	17	7.8	-7.5	92.632	-8.1	13.4	101.45	25

B35/B36 REVERSE BLANK



RUN FOR BT60B

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS	TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-2.3	0.4	91.436	-3.0	11.1	106.45	11	-4.6	-4.0	91.949	-5.0	11.8	100.21	18
-2.5	-1.0	91.549	-3.2	11.1	99.10	12	-4.8	4.2	91.963	-5.2	11.9	100.37	19
-2.6	1.3	91.557	-3.3	11.2	99.19	13	-5.4	-5.0	92.104	-5.8	12.1	100.69	20
-3.0	-2.0	91.673	-3.6	11.3	99.14	14	-5.6	5.2	92.121	-6.0	12.2	100.76	21
-3.2	2.3	91.683	-3.8	11.3	99.43	15	-6.3	-5.9	92.271	-6.6	12.5	101.00	22
-3.8	-3.1	91.806	-4.3	11.5	99.69	16	-6.4	6.0	92.291	-6.7	12.6	101.09	23
-4.0	3.3	91.818	-4.4	11.6	99.93	17	-7.1	-6.8	92.452	-7.4	13.0	101.26	24
							-7.3	6.9	92.474	-7.5	13.0	101.34	25

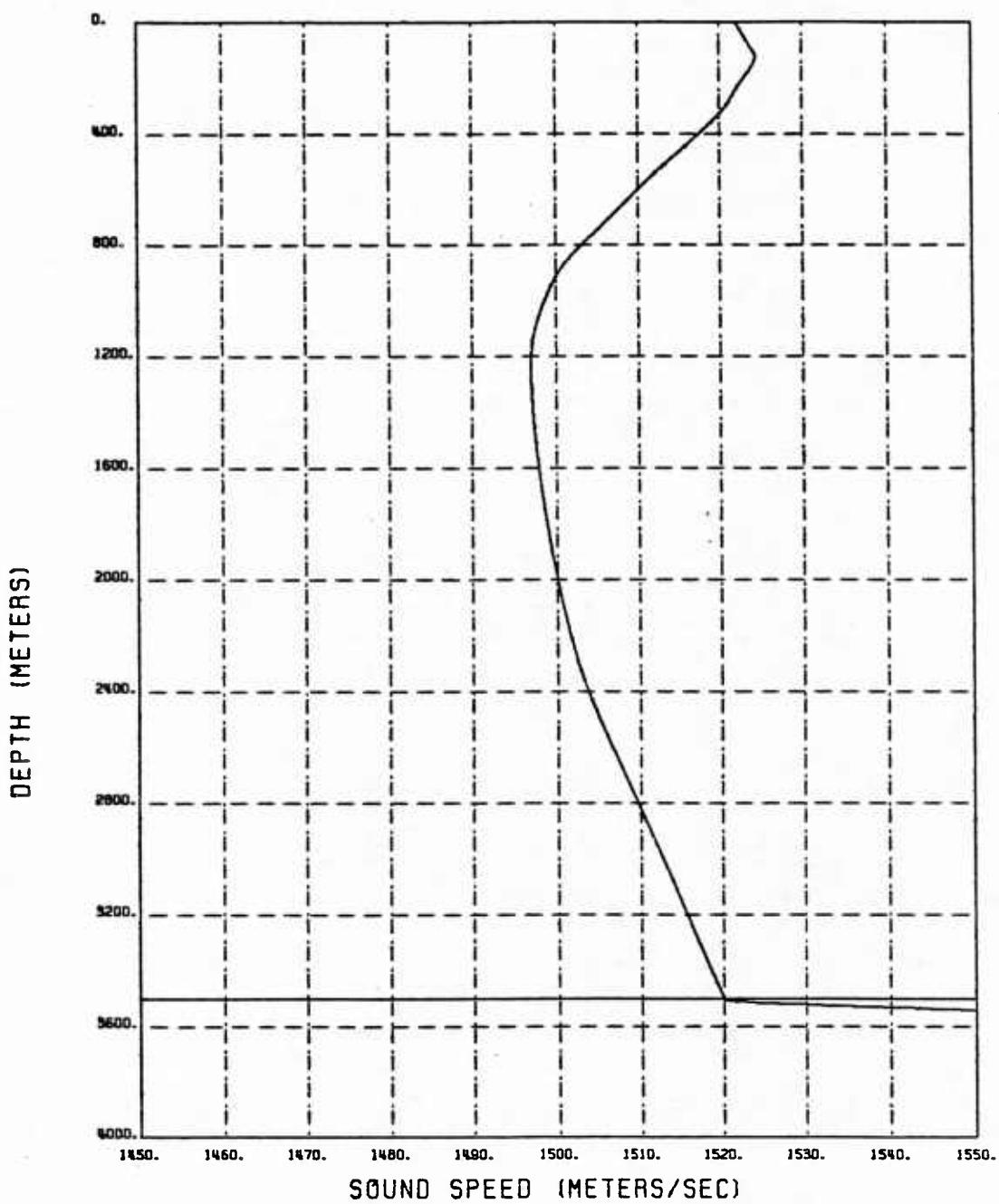
TM No. 811061

APPENDIX C

MID-ATLANTIC RIDGE PE  
& RAY TRACING RESULTS  
(MARCH PROFILE)

C1/C2

REVERSE BLANK



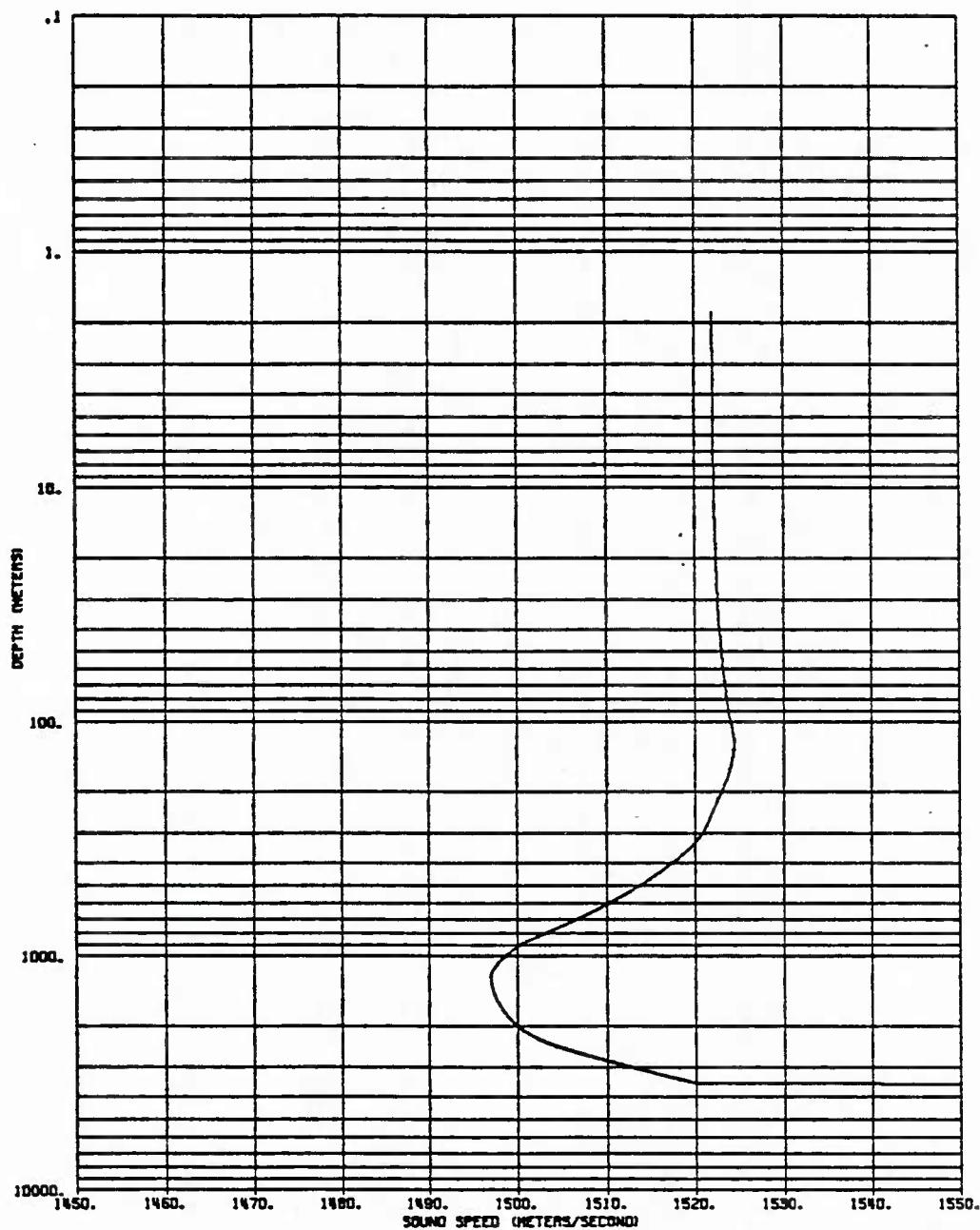
FREQUENCY = 495.0 Hz

SOURCE DEPTH = 78.0 METERS  
SOURCE AIM = 15.0 DEGREES  
SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS  
BOTTOM DEPTH = 3501.3 METERS  
VERTICAL MESH SPACING = 1.81 METERS  
BOTTOM ATTENUATION CONSTANT = 0.001000  
ATTENUATION SCALE LENGTH = 500.0  
SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 216875. METERS  
RANGE MESH SPACING = 62.50 METERS

TM No. 811061



## E11MAR35 RIDGE

FREQUENCY = 495.0 Hz

SOURCE DEPTH = 78.0 METERS  
 SOURCE AIM = 15.0 DEGREES  
 SOURCE WIDTH = 10.0 METERS

PROBLEM DEPTH = 3700.0 METERS  
 BOTTOM DEPTH = 3501.3 METERS  
 VERTICAL MESH SPACING = 1.81 METERS  
 BOTTOM ATTENUATION CONSTANT = 0.001000  
 ATTENUATION SCALE LENGTH = 500.0  
 SVP TRANSITION REGION=500.0 METERS

PROBLEM RANGE = 216875. METERS  
 RANGE MESH SPACING = 62.50 METERS

TM No. 811061

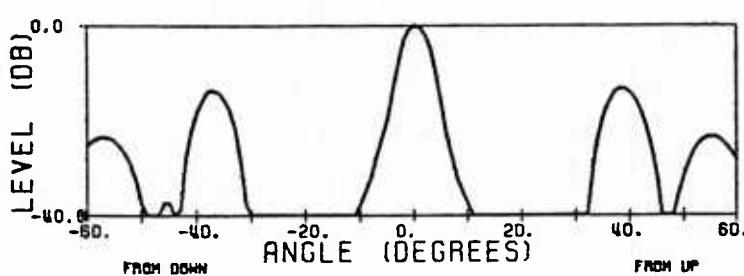
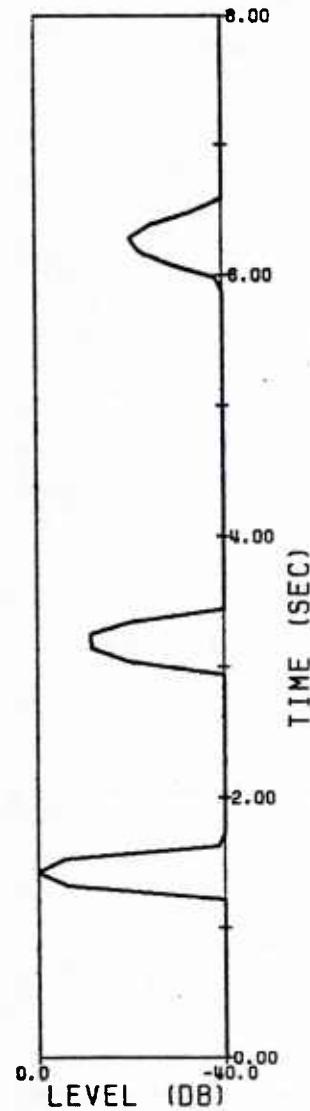
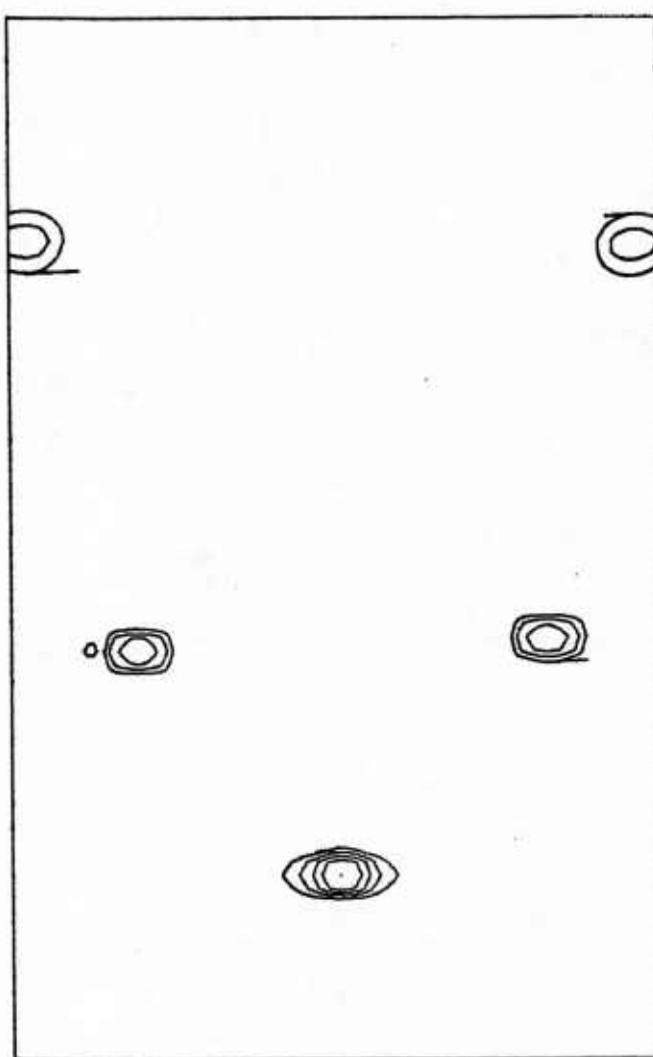
RANGE = 5 MILES

C5/C6

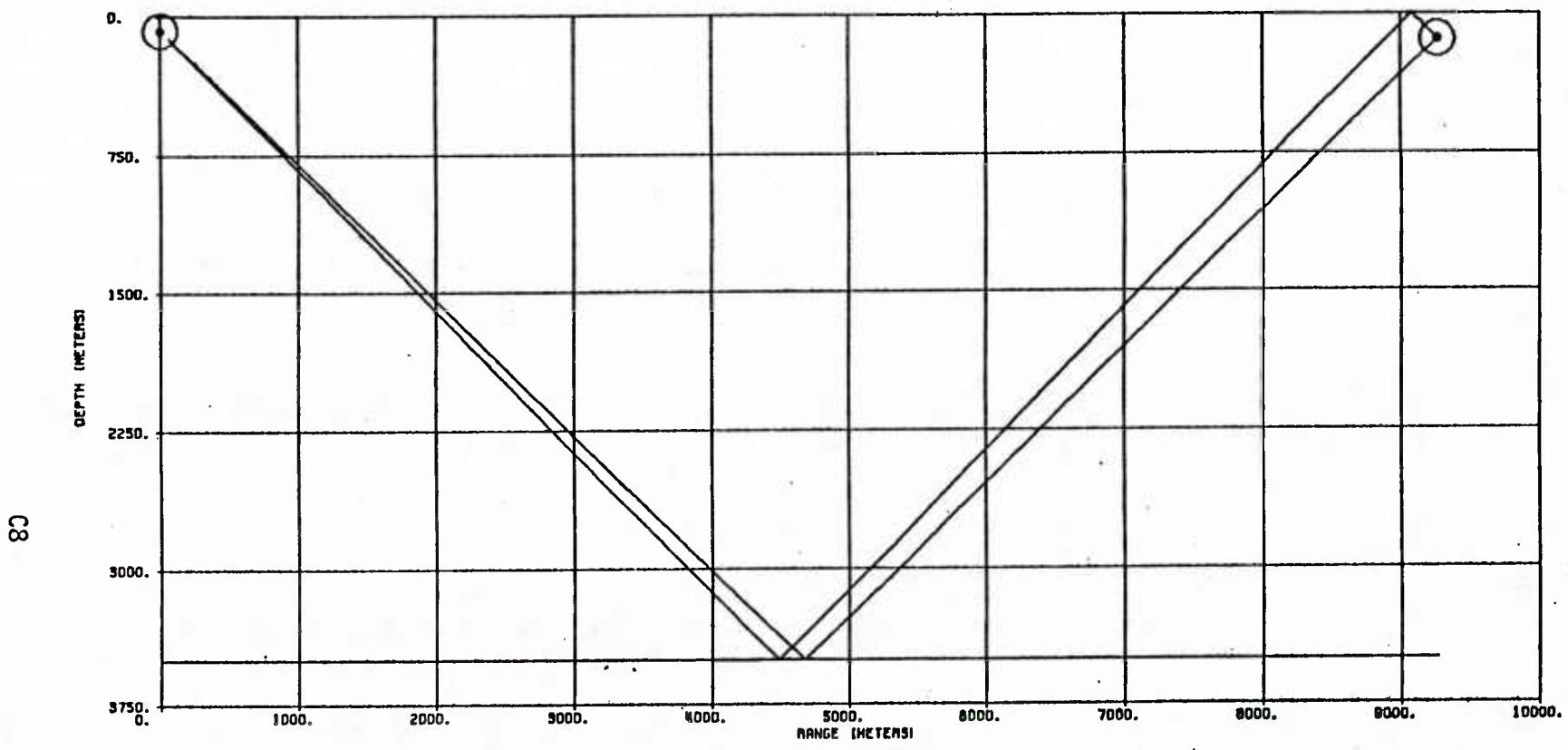
REVERSE BLANK

TM No. 811061

## E11MAR35 RIDGE



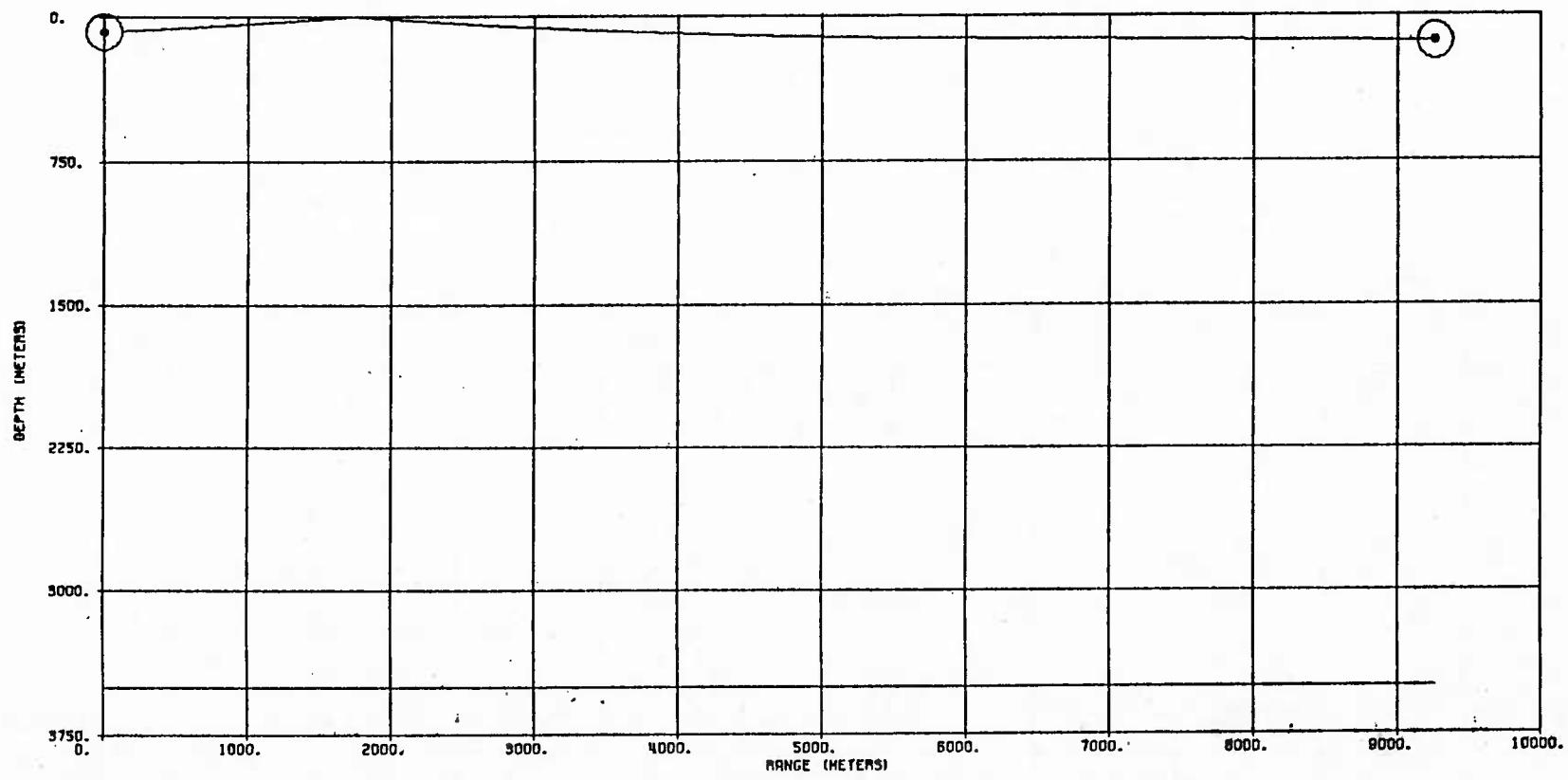
ANGLE,DELAY MAX=-82.95 DB  
 ANGLE MAX=-81.13 DB  
 DELAY MAX=-76.44 DB  
 DESIRED RANGE= 5.0 NAUTICAL MILES  
 STARTING FREQUENCY= 495. HZ.  
 STOPPING FREQUENCY= 505. HZ.  
 STARTING DEPTH= 102.98 METERS  
 STOPPING DEPTH= 162.60 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 10.0 METERS  
 SOURCE AIM= 15.0 DEGREES



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERALS
35.3 96.5	-35.3 36.4	7.624 7.728	0.0 -36.6	35.5 36.7	80.91 81.06	1 2



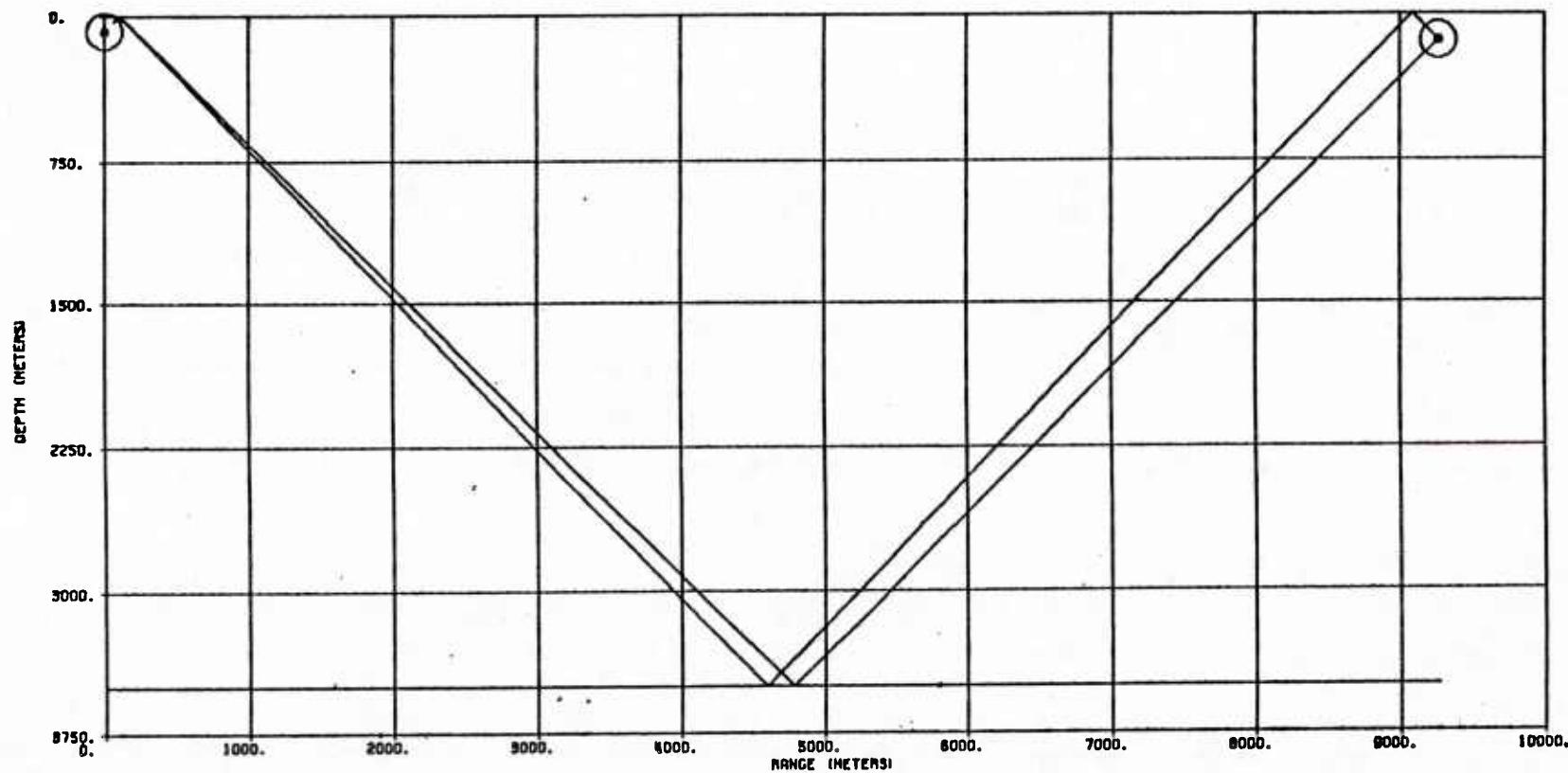
RUN FOR BT57C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-1.9	0.6	6.084	-3.2	0.0	88.84	1

C10



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 9266.55 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-36.0 -37.1	-36.0 37.1	7.684 7.790	-36.1 -37.2	36.2 37.3	81.00 81.15	2 3

TM No. 811061

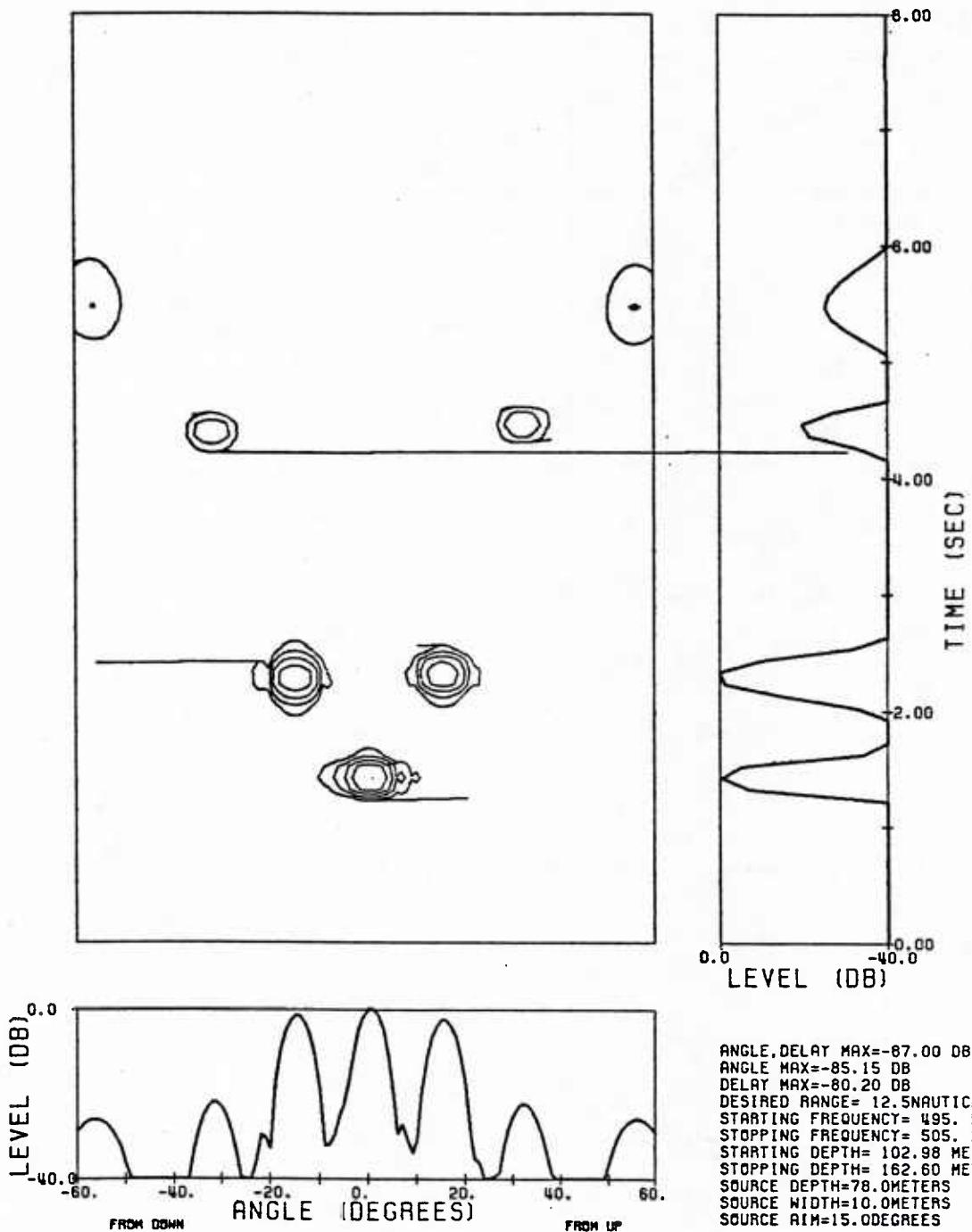
RANGE = 12.5 MILES

C11/C12

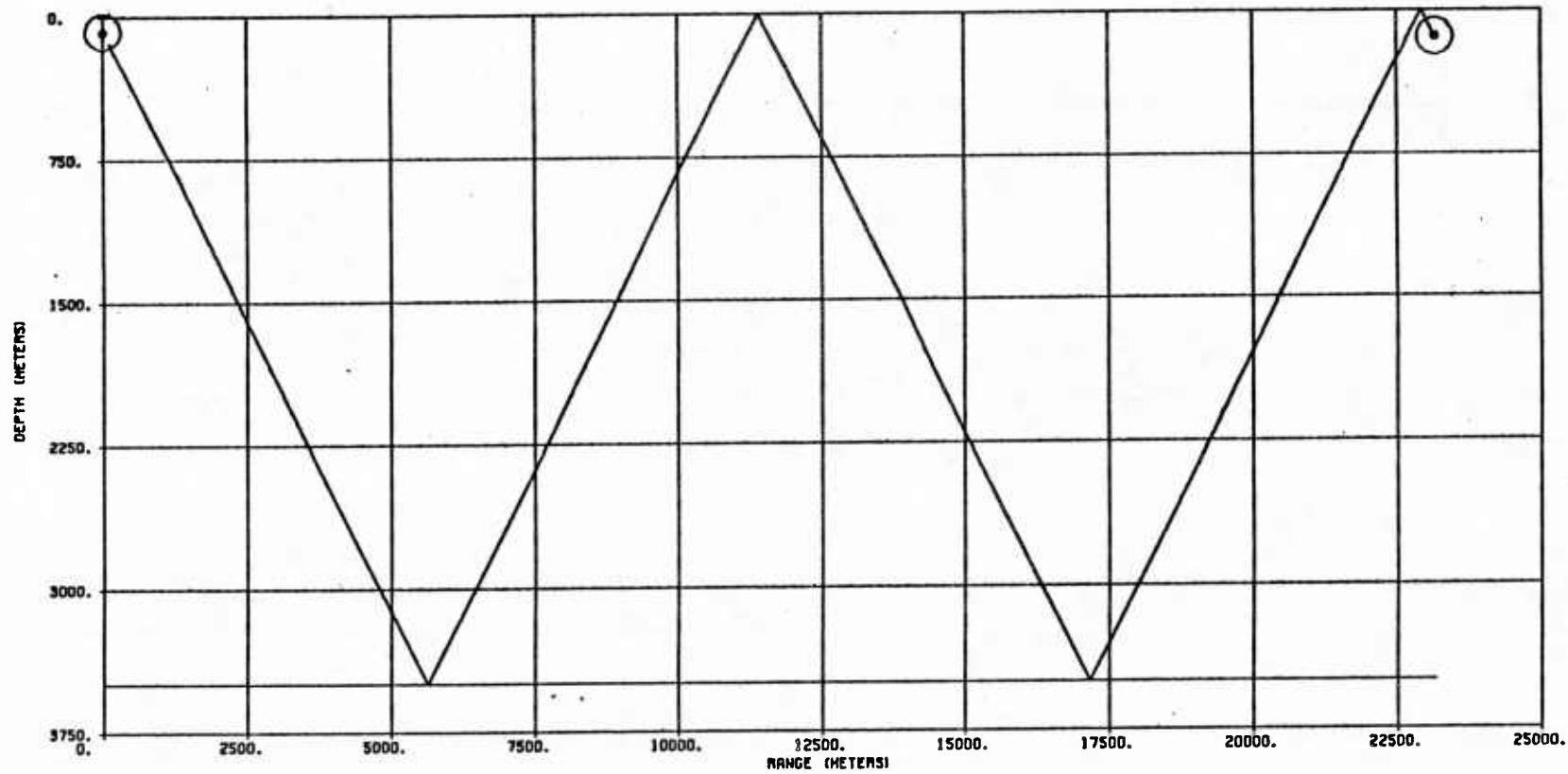
REVERSE BLANK

TM No. 811061

## E11MAR35 RIDGE



C14



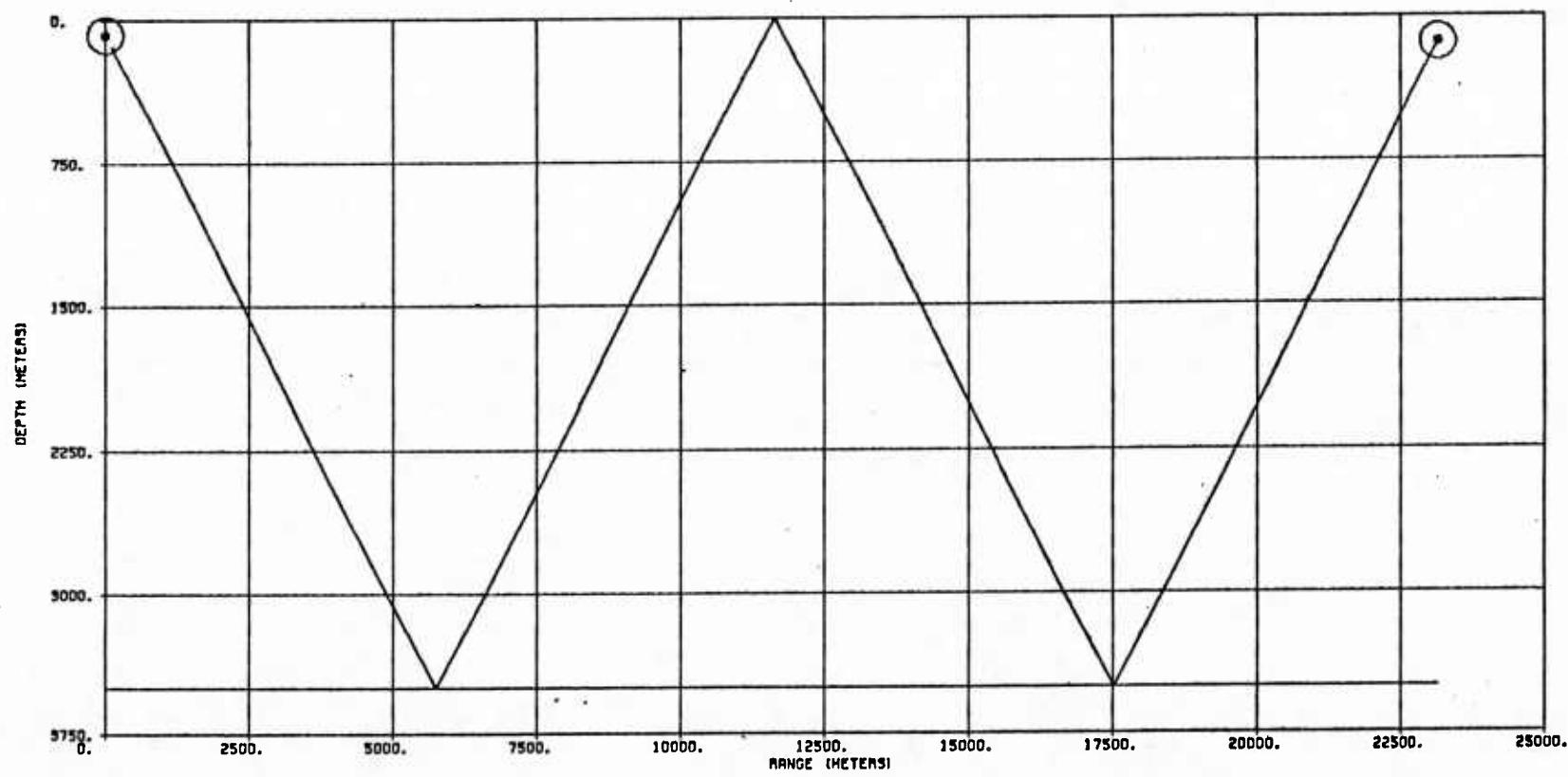
## RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
30.2	30.2	17.980	-30.3	30.4	88.30	4

C15



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

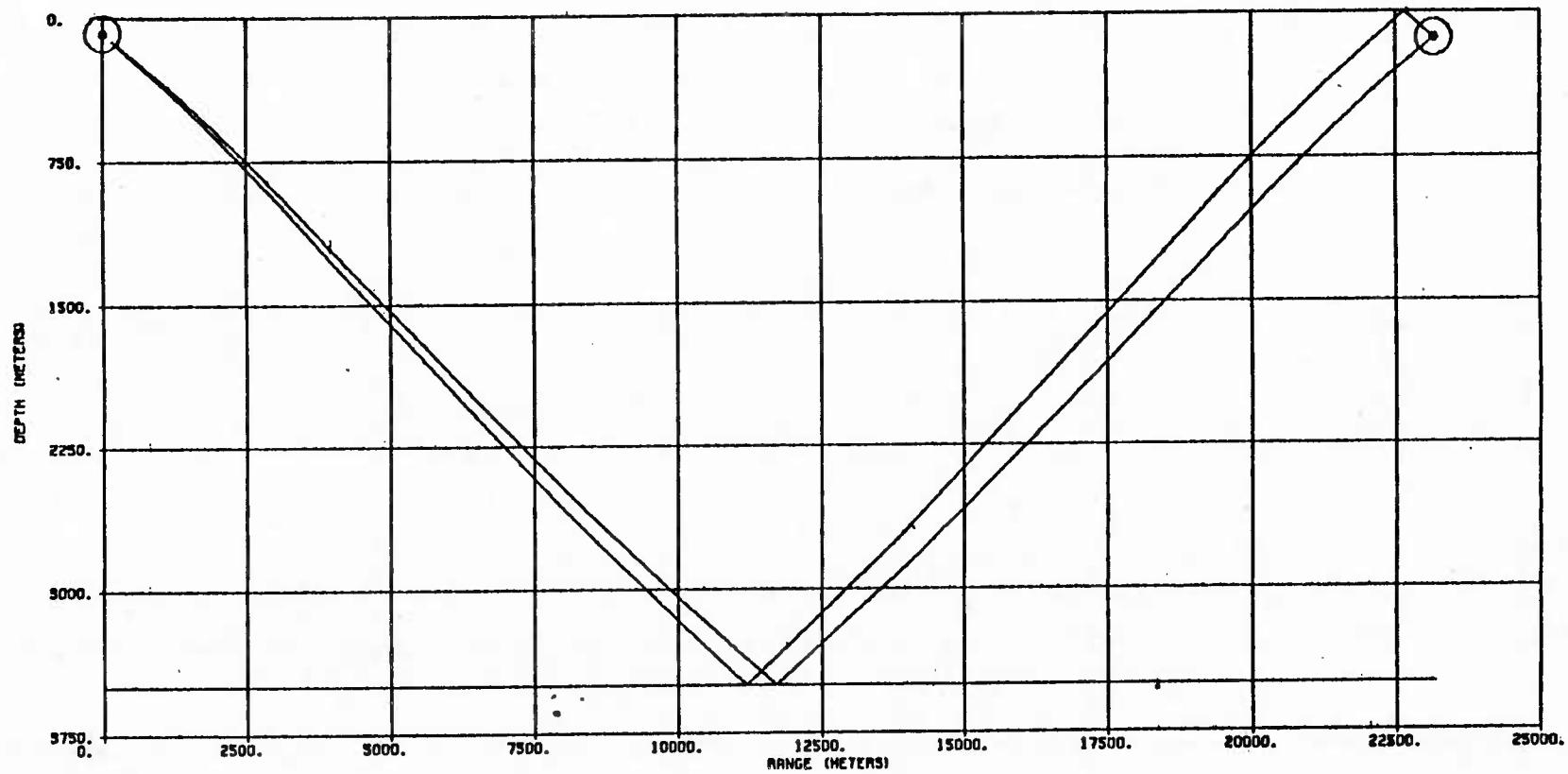
TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
29.7	-29.6	17.891	-29.8	29.9	88.23	3

TM NO. 811061

TM No. 811061

C16

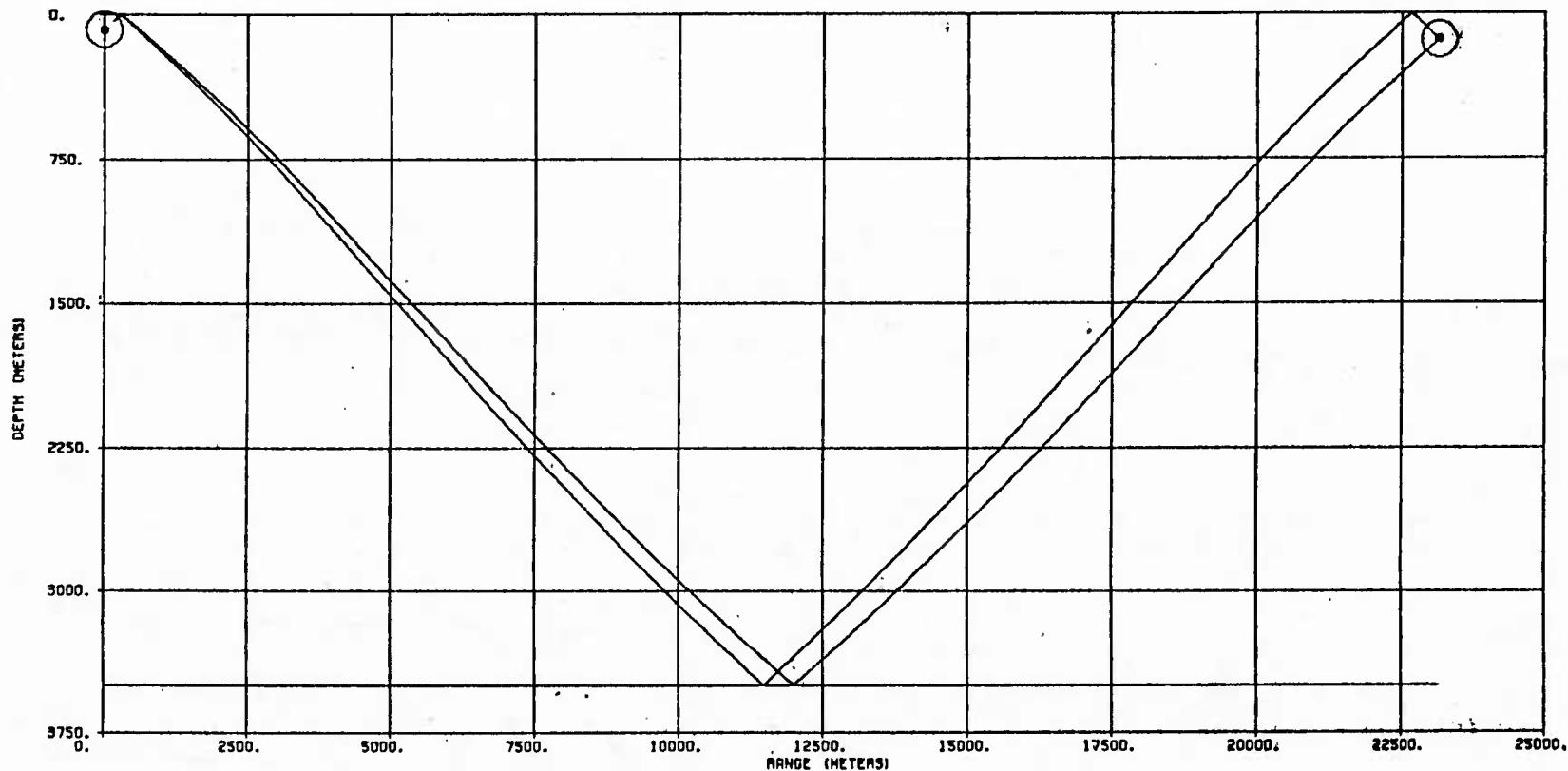


RUN FOR BT56C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
14.1 14.9	-14.0 14.8	16.021 16.066	0.0 -15.1	14.6 15.4	86.93 86.53	1 2



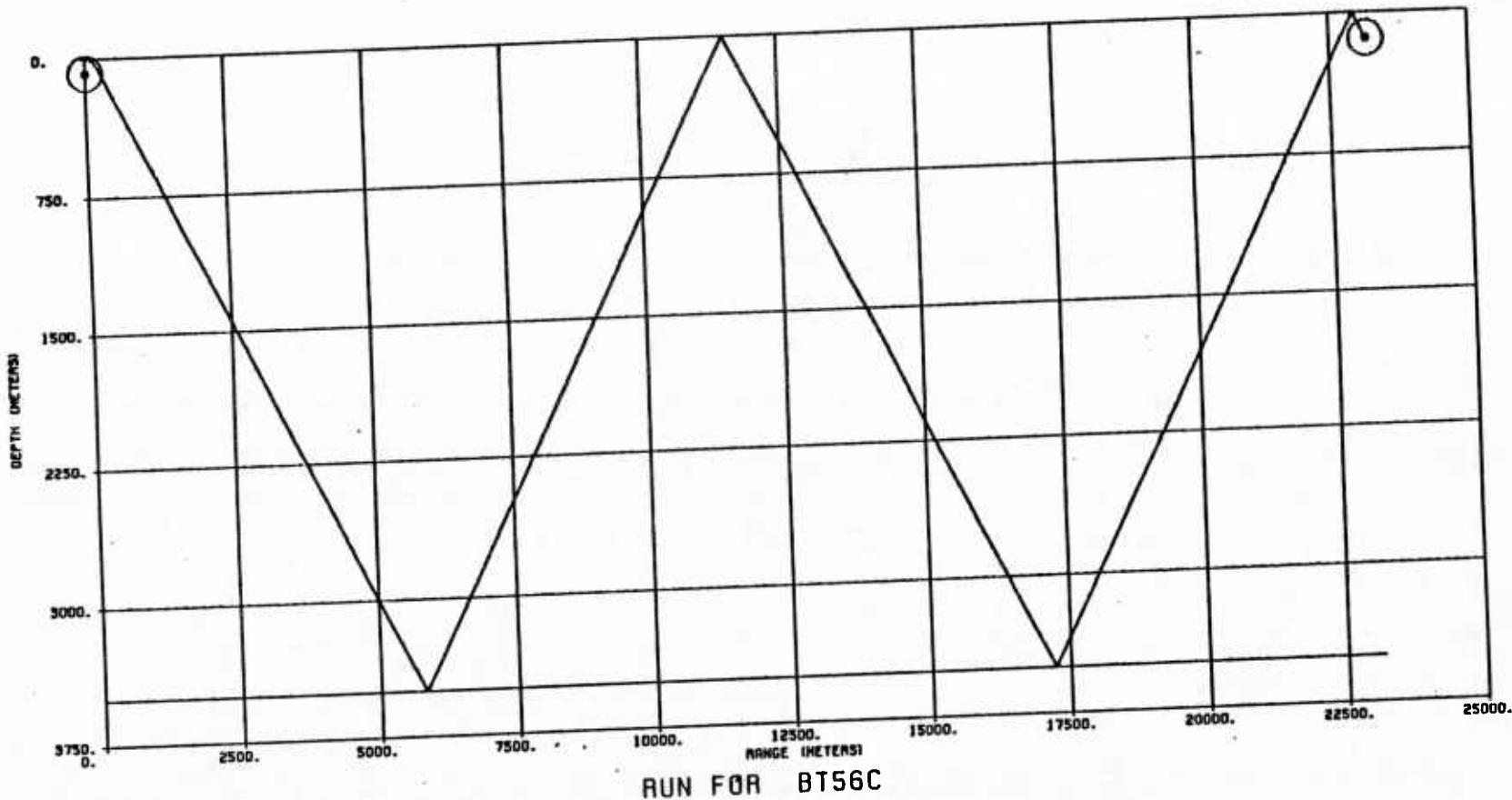
SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-14.5	-14.4	16.048	-14.8	15.0	66.45	2
-15.3	15.2	16.093	-15.5	15.8	66.62	3

TM No. 811061

C18



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 23166.37 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-30.5	30.5	16.092	-30.8	30.7	88.33	5

TM No. 811061

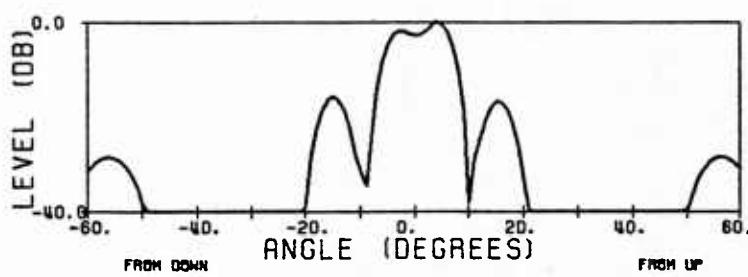
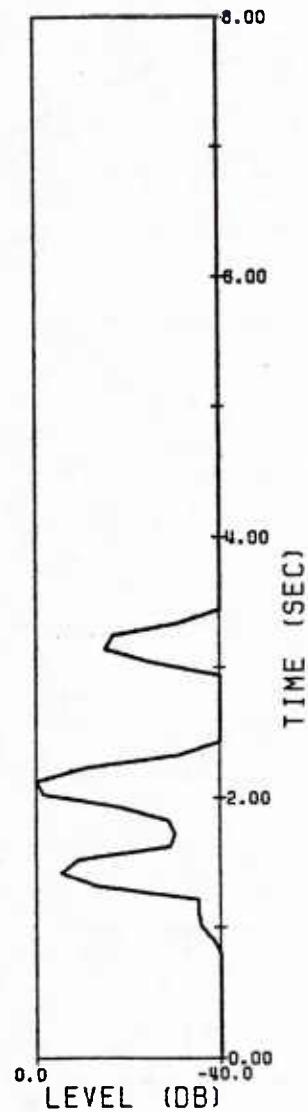
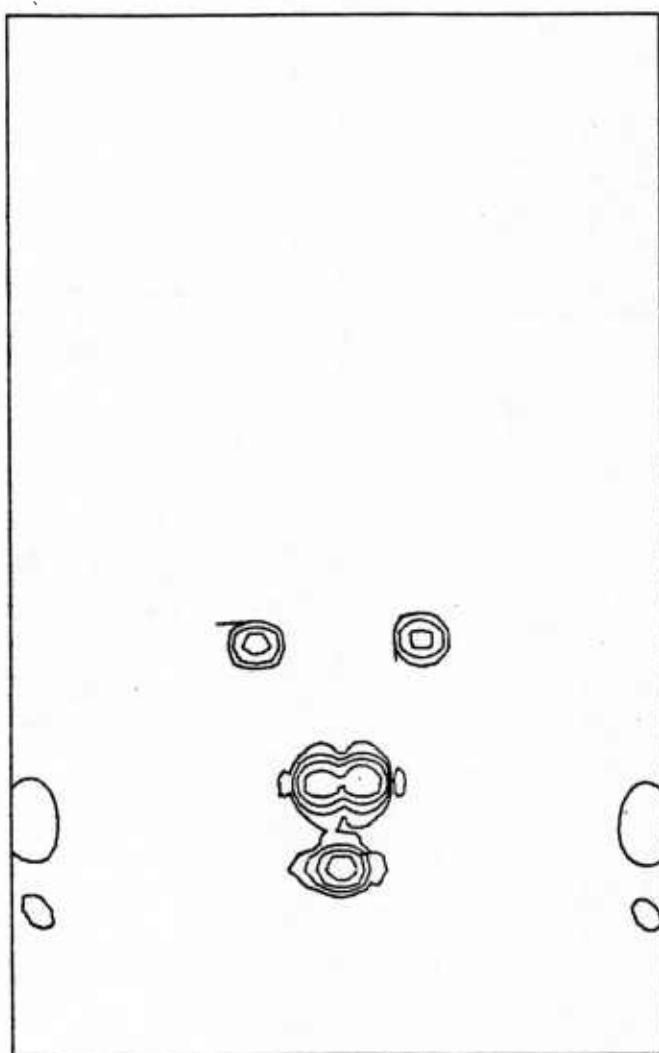
RANGE = 25 MILES

C19/C20

REVERSE BLANK

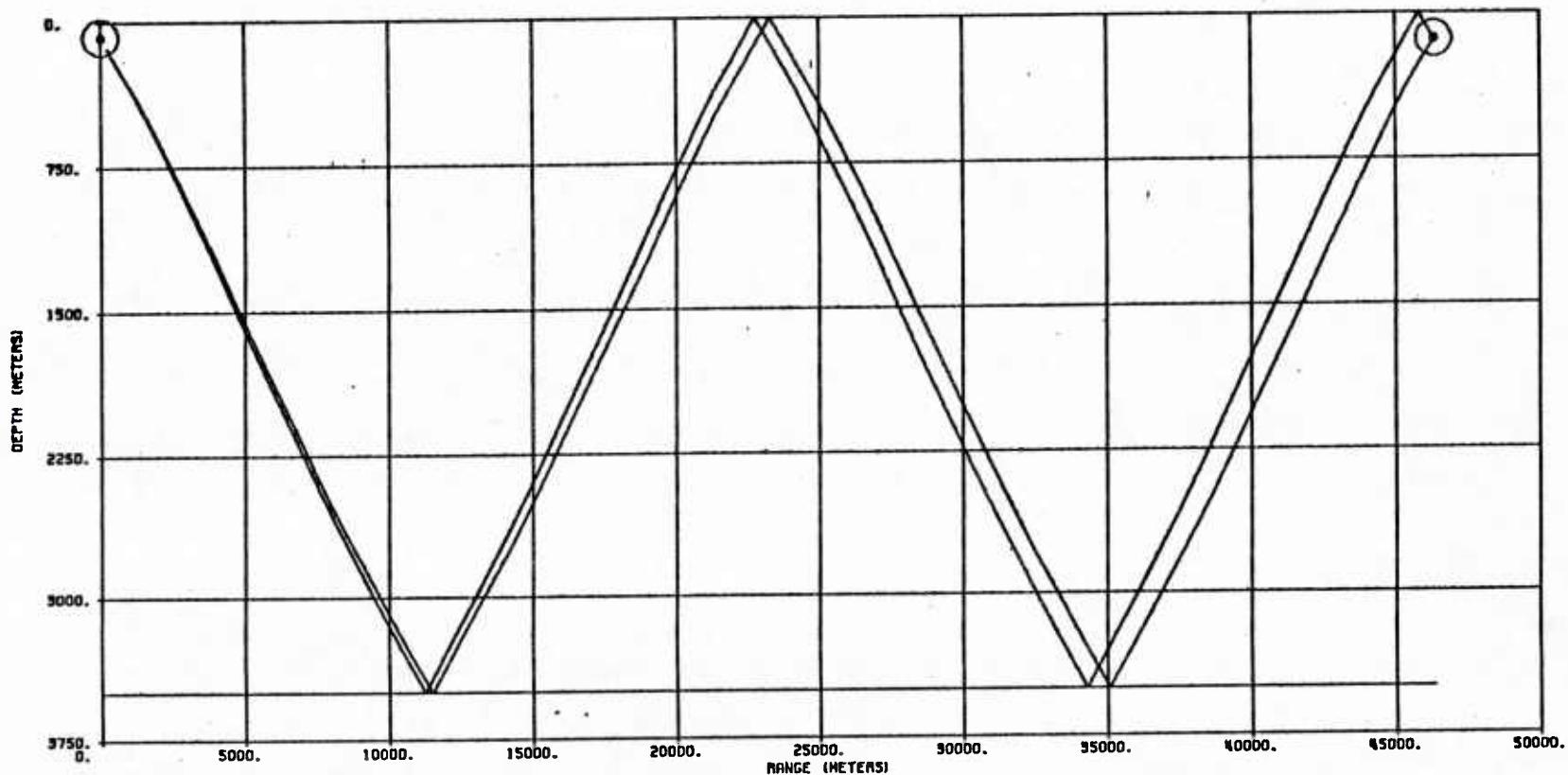
TM No. 811061

## E11MAR35 RIDGE



ANGLE,DELAY MAX=-90.25 DB  
 ANGLE MAX=-87.75 DB  
 DELAY MAX=-81.99 DB  
 DESIRED RANGE= 25.0 NAUTICAL MILES  
 STARTING FREQUENCY= 495. HZ.  
 STOPPING FREQUENCY= 505. HZ.  
 STARTING DEPTH= 102.98 METERS  
 STOPPING DEPTH= 162.60 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 10.0 METERS  
 SOURCE AIM= 15.0 DEGREES

C22



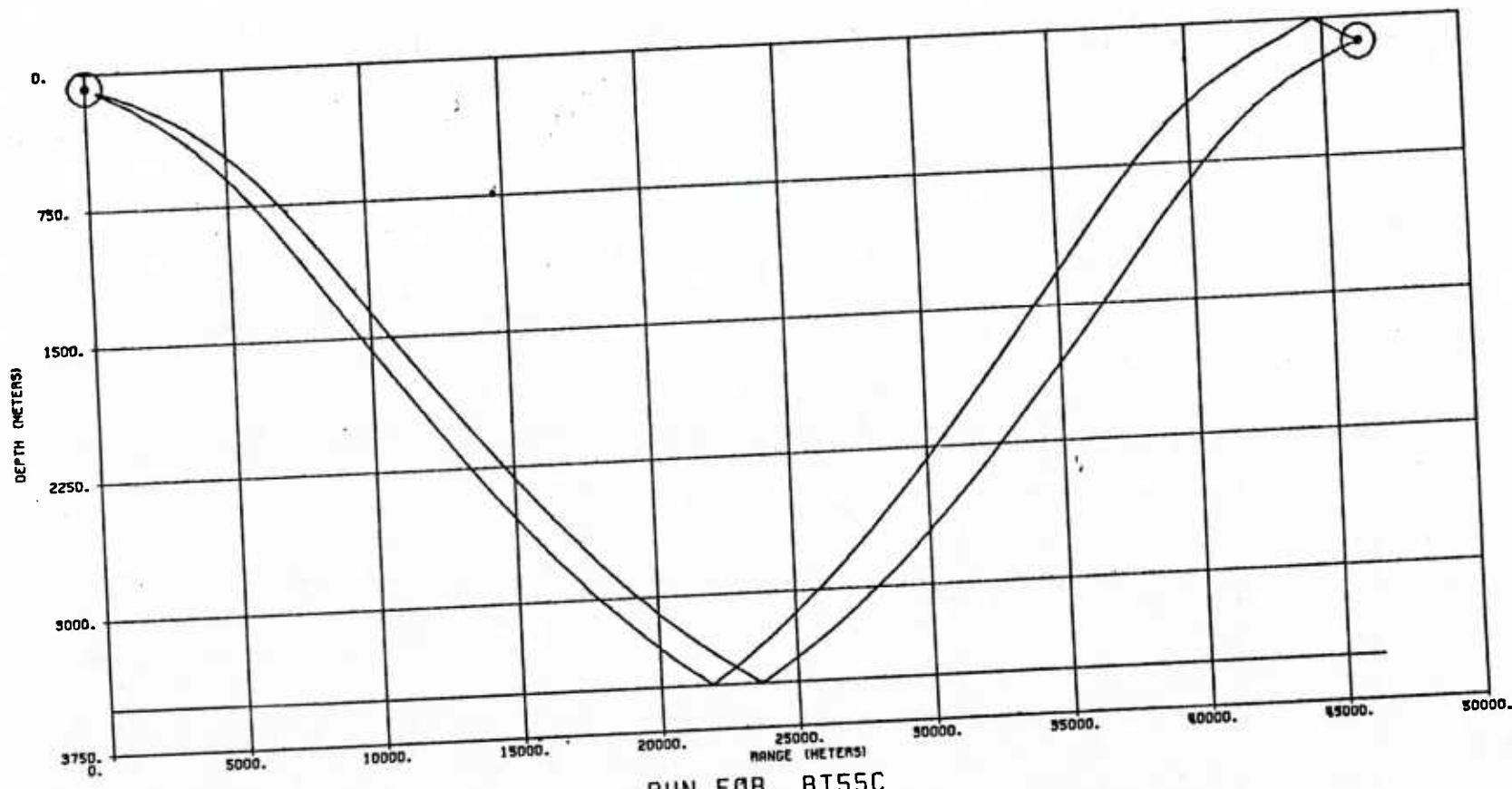
## RUN FOR BT55C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (dB)	NUMBER OF REVERSALS
14.4	-14.3	52.076	-14.6	14.9	92.43	3
14.6	14.7	32.122	-15.0	15.9	92.55	4

C23

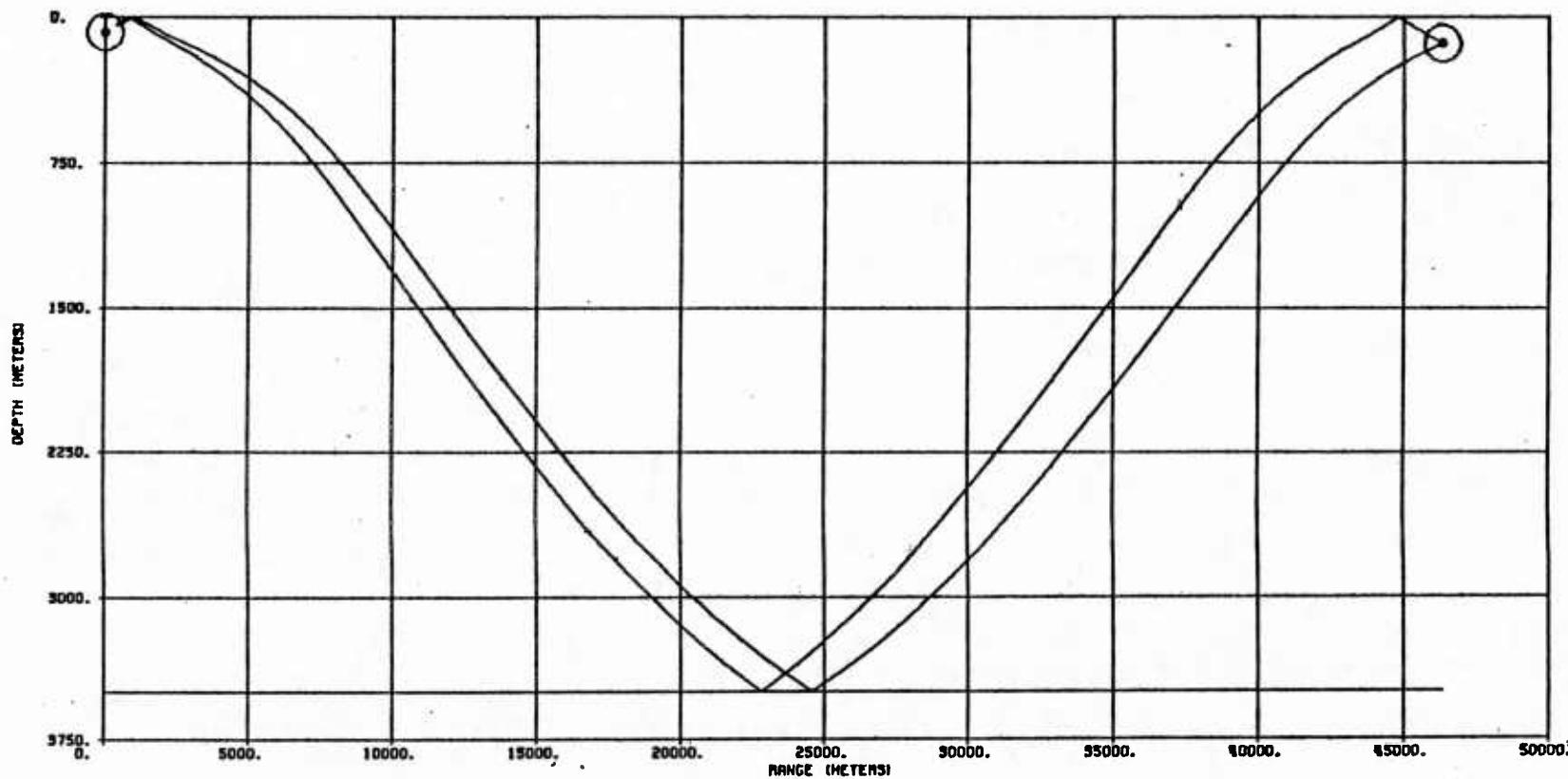


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
3.6	-3.2	31.059	0.0	5.5	87.30	1
4.6	4.2	31.072	-5.3	6.0	86.89	2

C24

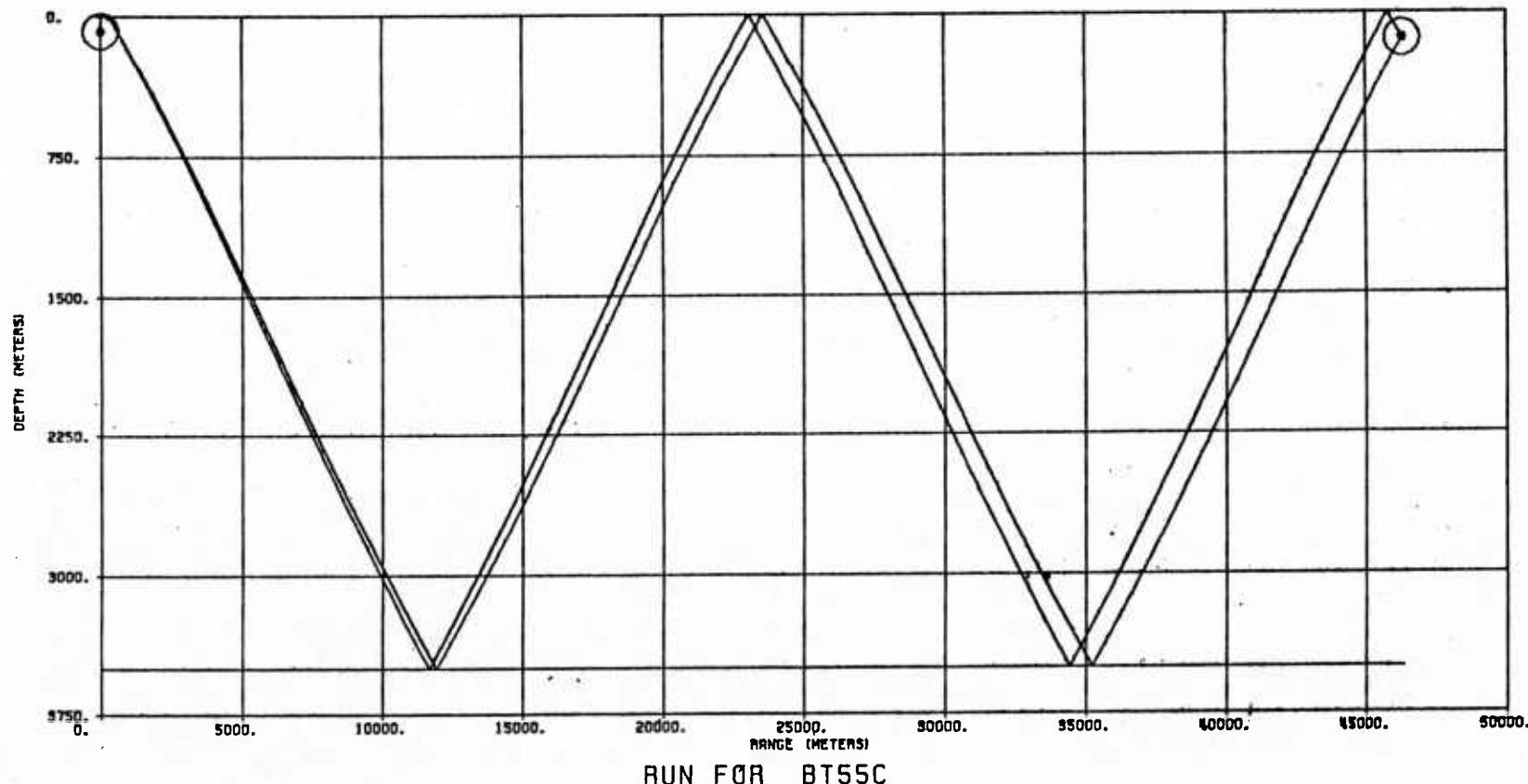


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-4.2 -5.1	-3.8 4.7	31.066 31.081	-4.9 -5.7	5.7 6.4	88.21 89.37	2

C25/C26  
REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 46332.74 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (dB)	NUMBER OF REVERSALS
-14.6	-14.5	92.102	-14.9	15.1	82.49	4
-15.0	14.0	32.148	-15.2	15.5	92.57	5

TM No. 811061

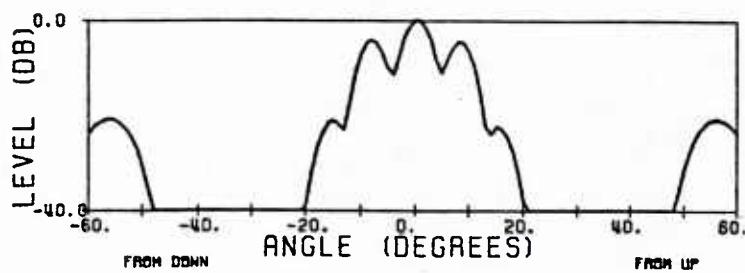
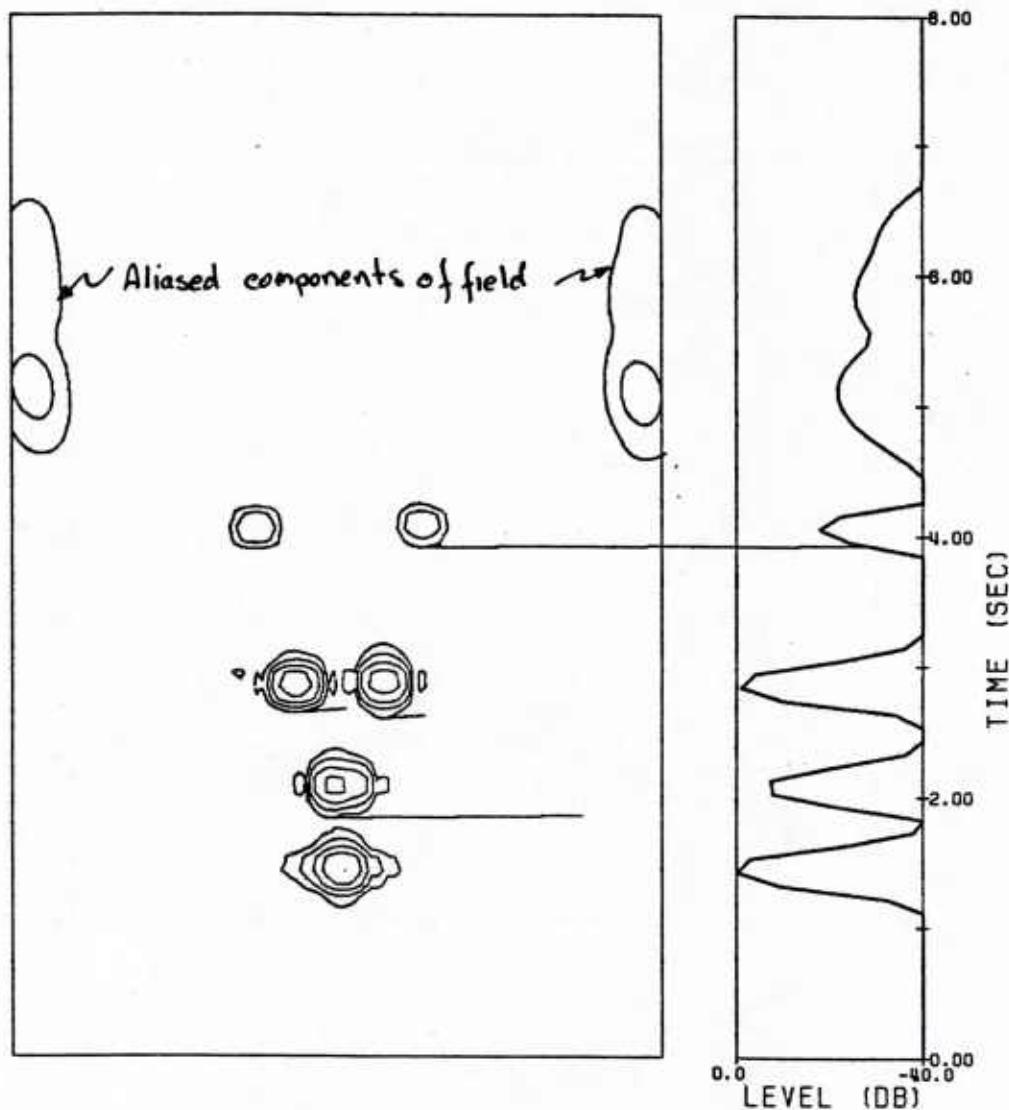
TM No. 811061

RANGE = 37.5 MILES

C27/C28

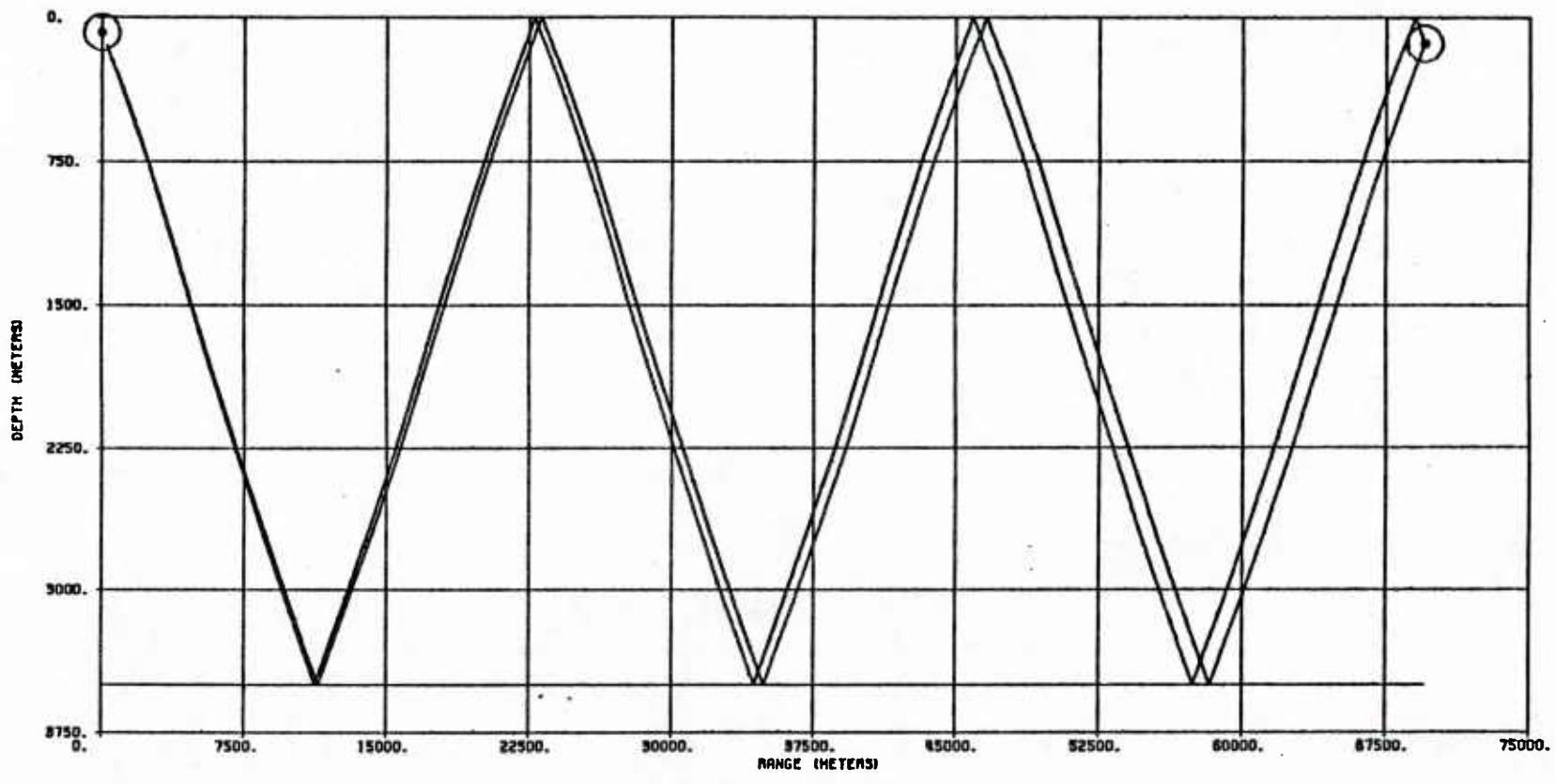
REVERSE BLANK

## E11MAR35 RIDGE



ANGLE,DELAY MAX=-99.27 DB  
 ANGLE MAX=-96.57 DB  
 DELAY MAX=-92.88 DB  
 DESIRED RANGE= 37. NAUTICAL MILES  
 STARTING FREQUENCY= 495. HZ.  
 STOPPING FREQUENCY= 505. HZ.  
 STARTING DEPTH= 102.98 METERS  
 STOPPING DEPTH= 162.60 METERS  
 SOURCE DEPTH= 76.0 METERS  
 SOURCE WIDTH= 10.0 METERS  
 SOURCE AIM= 15.0 DEGREES

C30

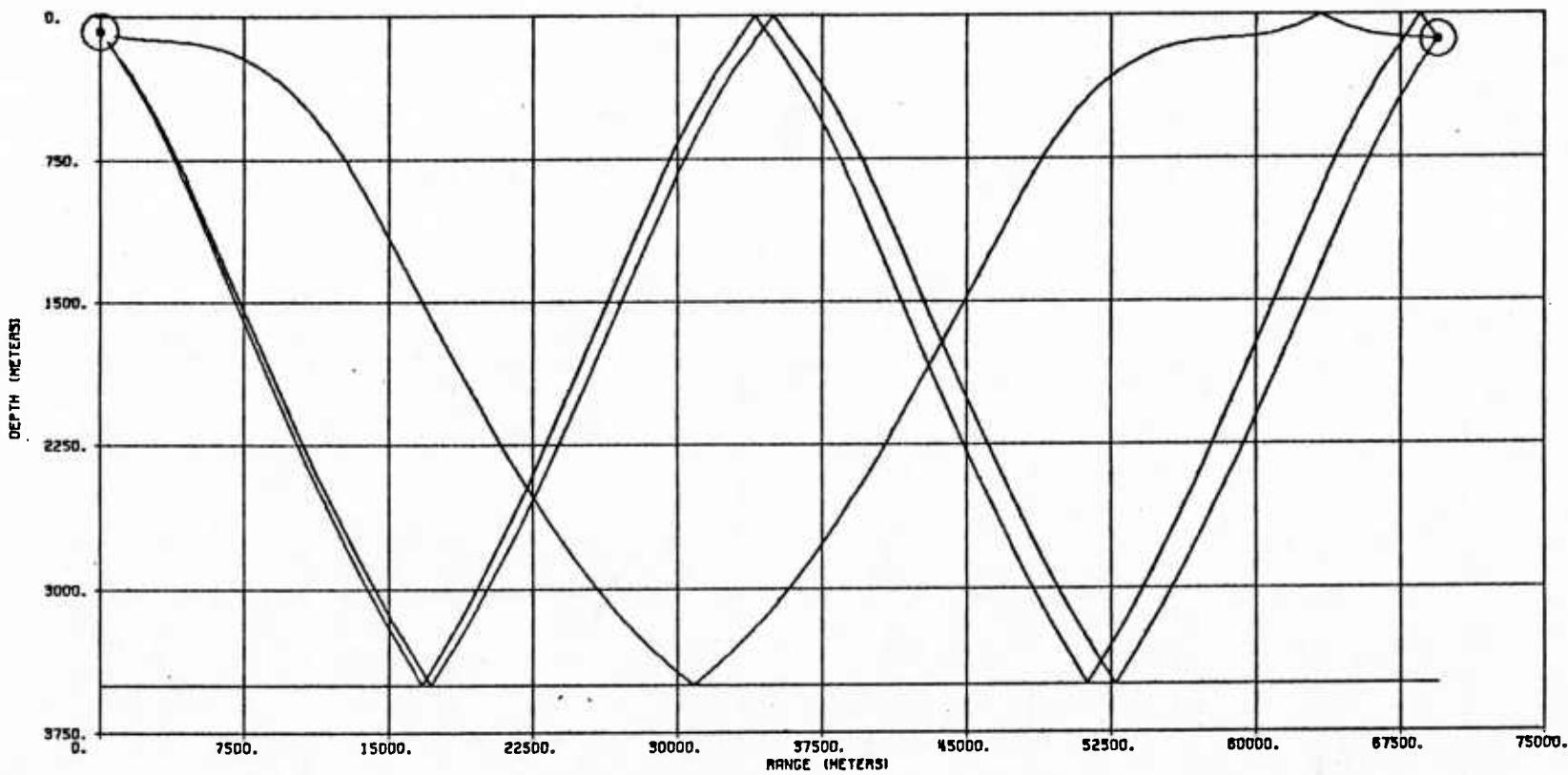


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (dB)	NUMBER OF REVERSALS
14.5 14.8	-14.4 14.7	48.152 48.177	-14.7 -15.0	15.0 15.9	85.98 86.04	5

C31



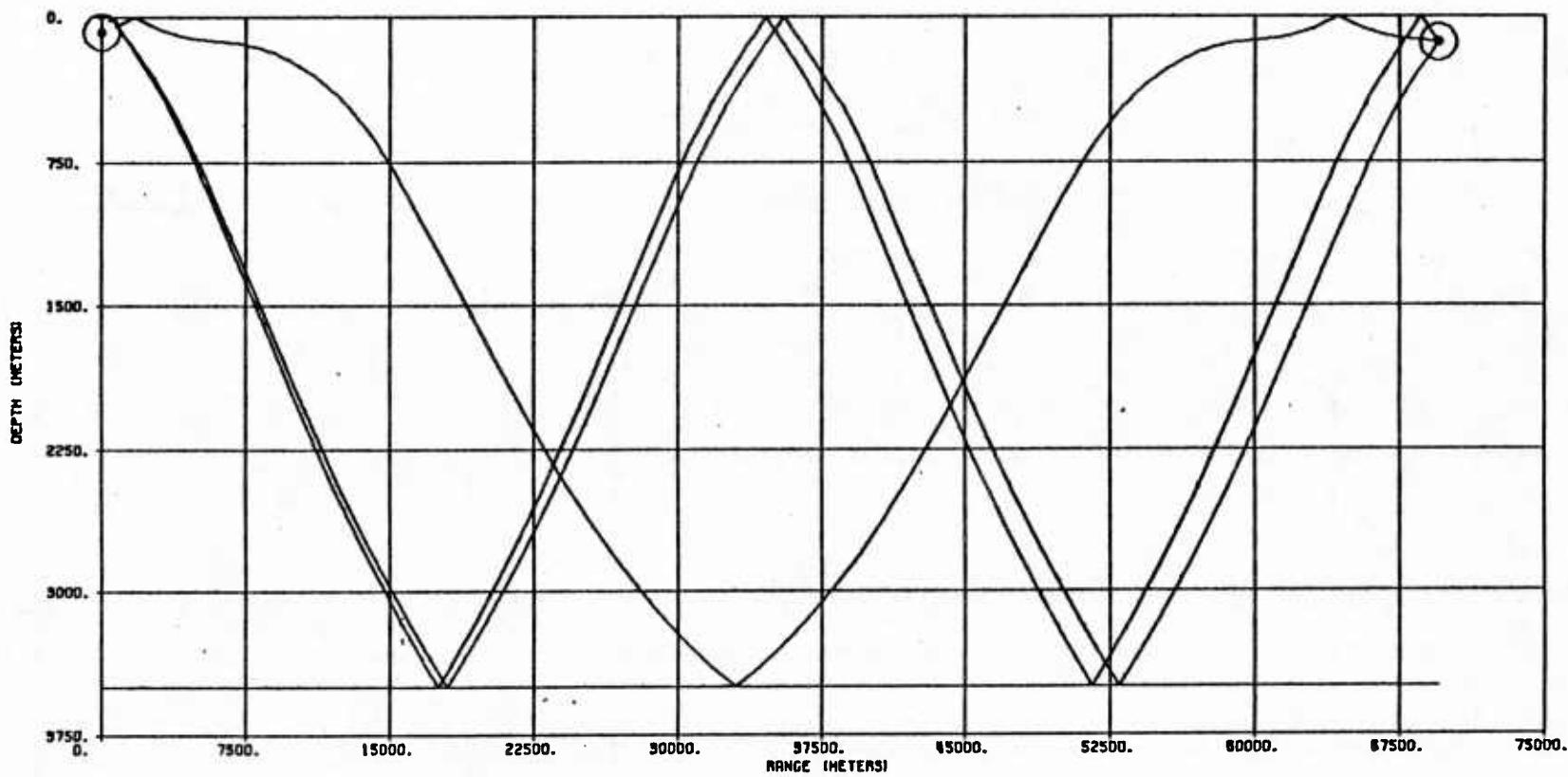
RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
2.0	0.7	46.258	-3.2	4.4	97.23	2
7.9	-7.7	47.004	-8.3	8.0	94.16	3
8.3	8.1	47.029	-8.7	9.2	94.42	4

C32

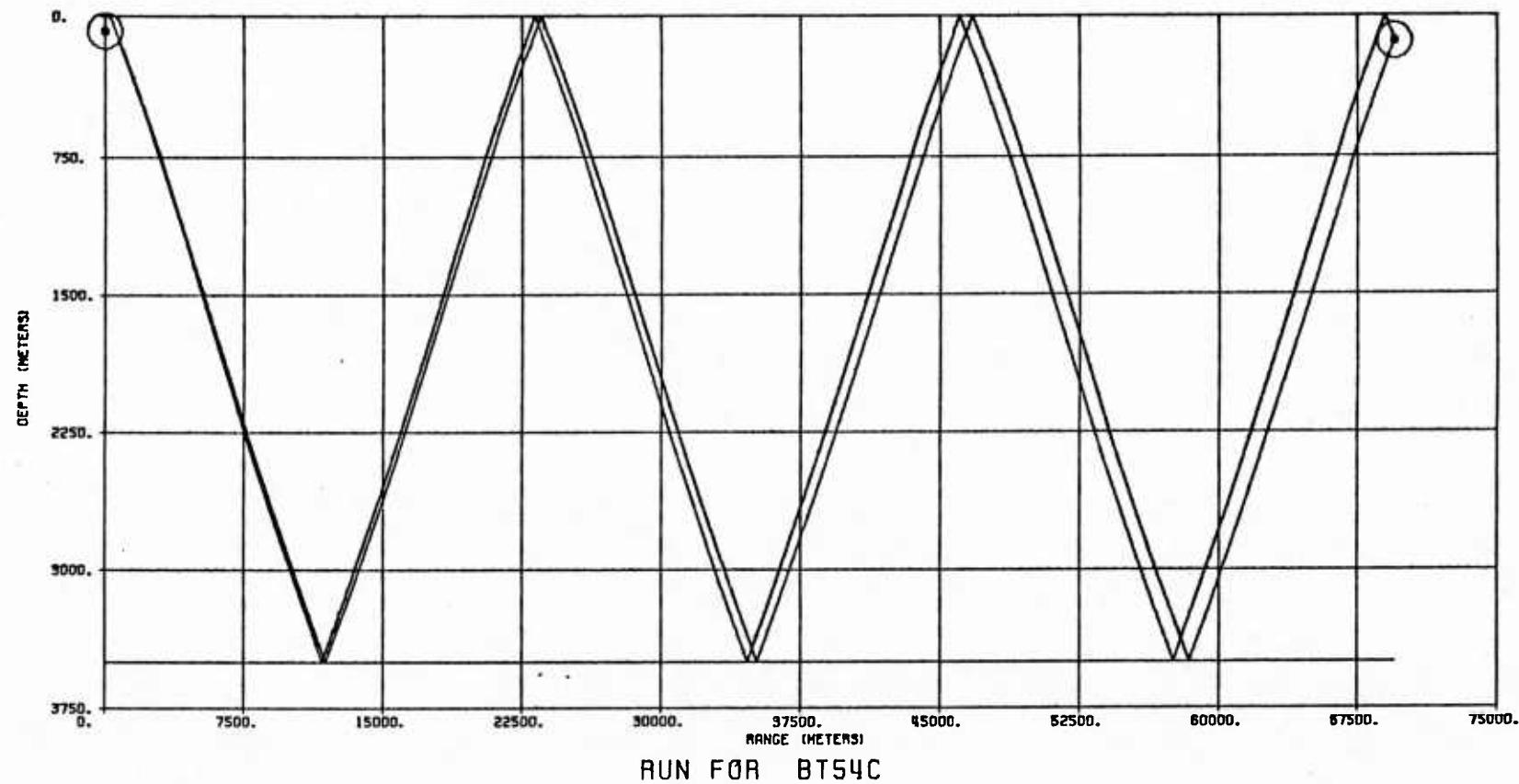


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	0.8	46.263	-3.3	4.4	93.84	3
-8.1	-7.9	47.018	-8.5	9.0	94.31	4
-8.5	8.3	47.044	-8.9	9.4	94.53	5

C33/C34  
REVERSE BLANK



RUN FOR BT54C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 69499.11 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-14.7	-14.5	48.158	-14.9	15.2	86.02	6
-14.9	14.6	48.204	-15.1	15.4	96.08	7

TM No. 811061

RANGE = 50 MILES

C35/C36

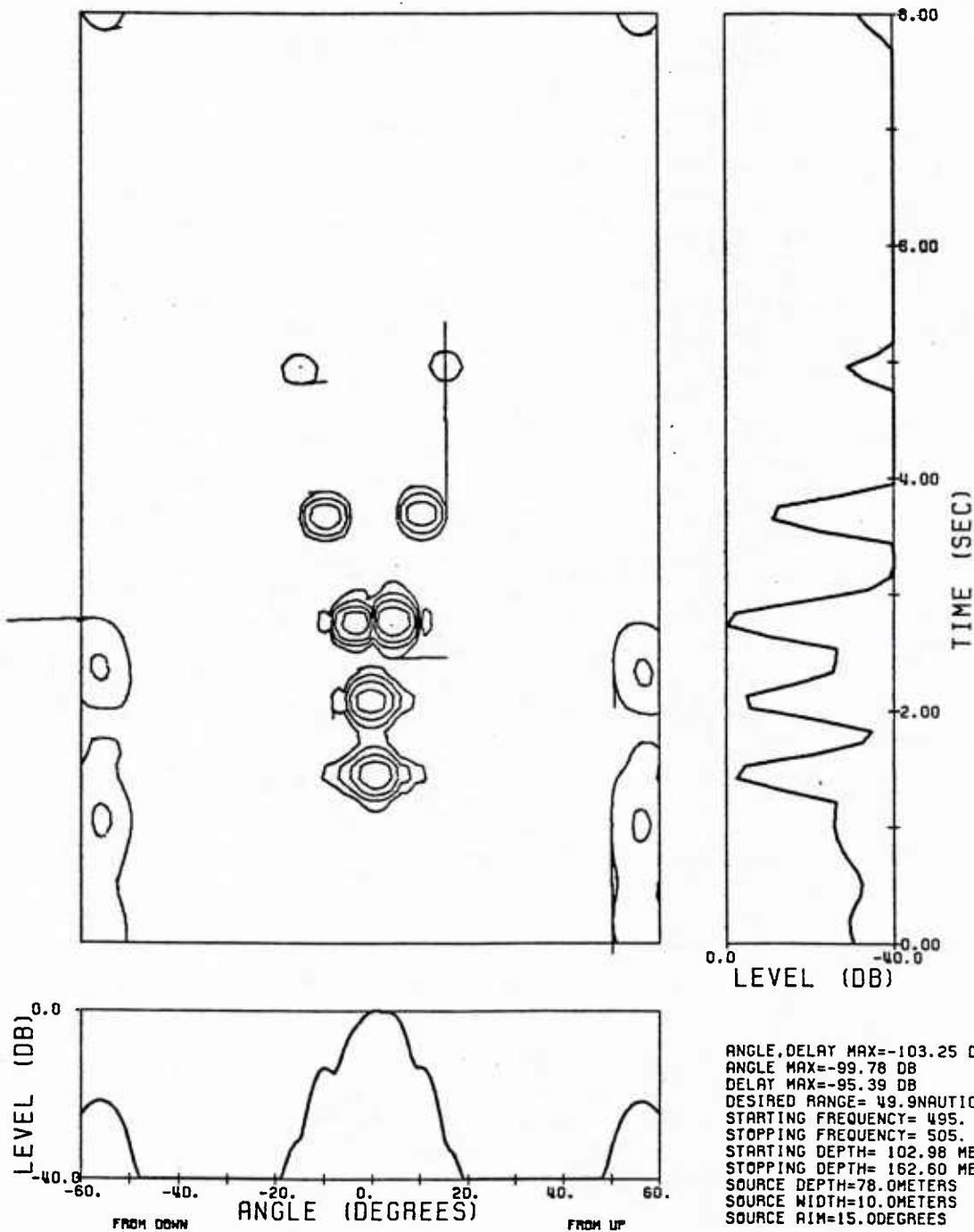
REVERSE BLANK

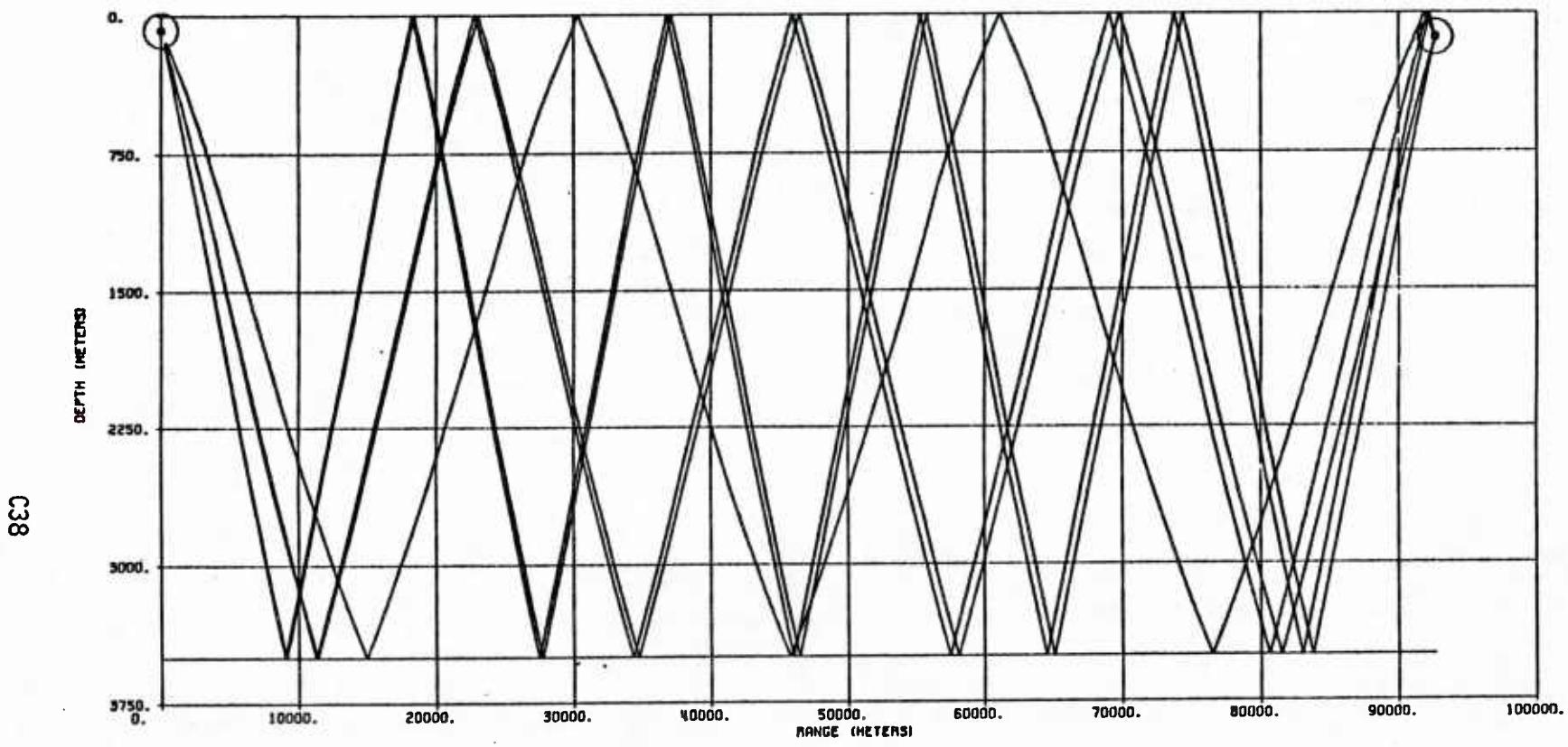
PEMF: 30-AUG-80 02:03:53

8-SEP-80 14:40:27

TM No. 811061

# E11MAR35 RIDGE



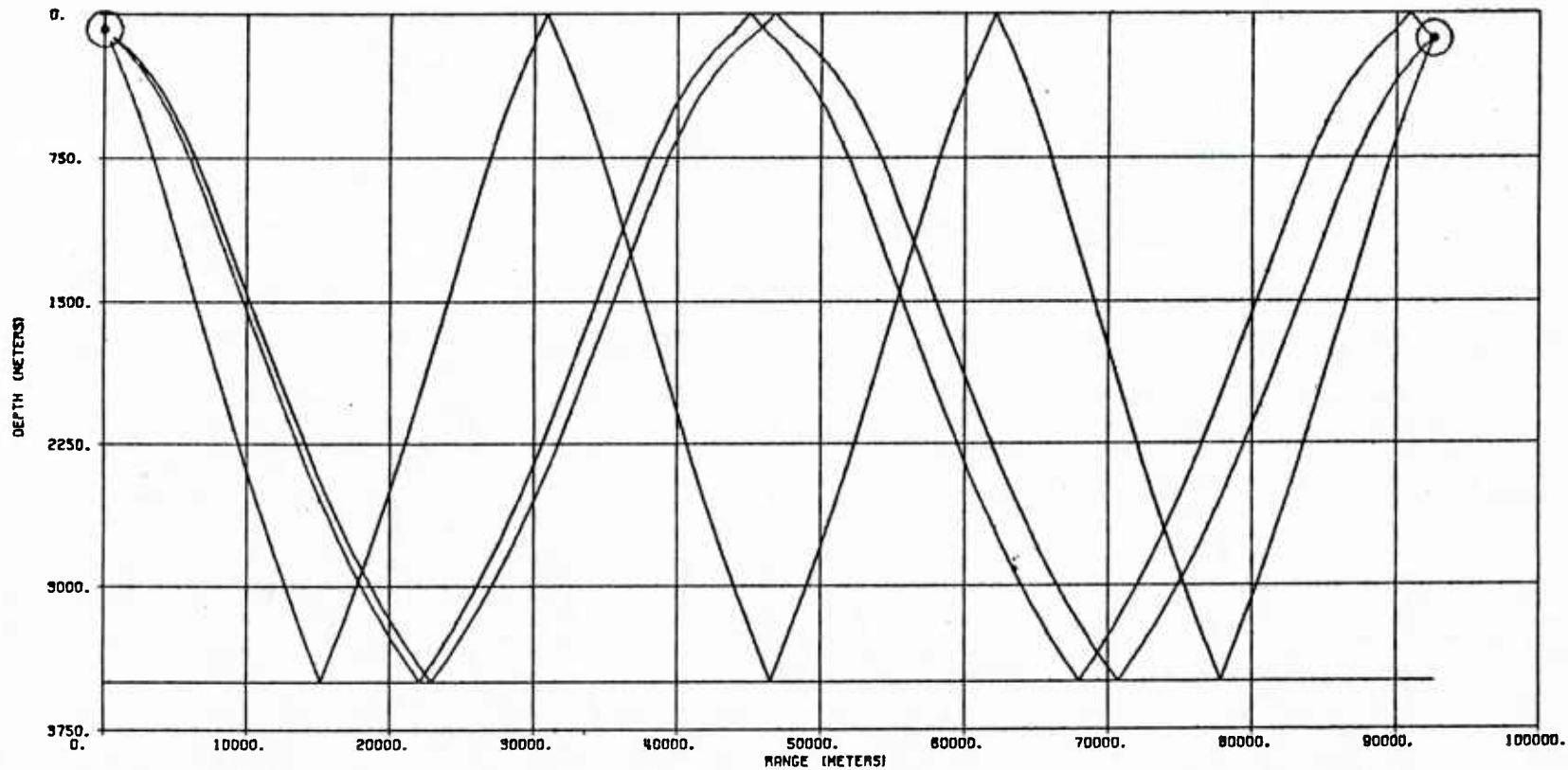


SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
10.0	9.8	63.035	-10.3	10.7	97.49	6
14.6	-14.4	64.188	-14.8	15.1	98.49	7
14.8	14.6	64.233	-15.0	15.3	98.54	8
16.9	-16.8	65.676	-10.1	19.9	99.11	9
19.1	19.0	65.734	-10.2	19.4	99.14	10

C39



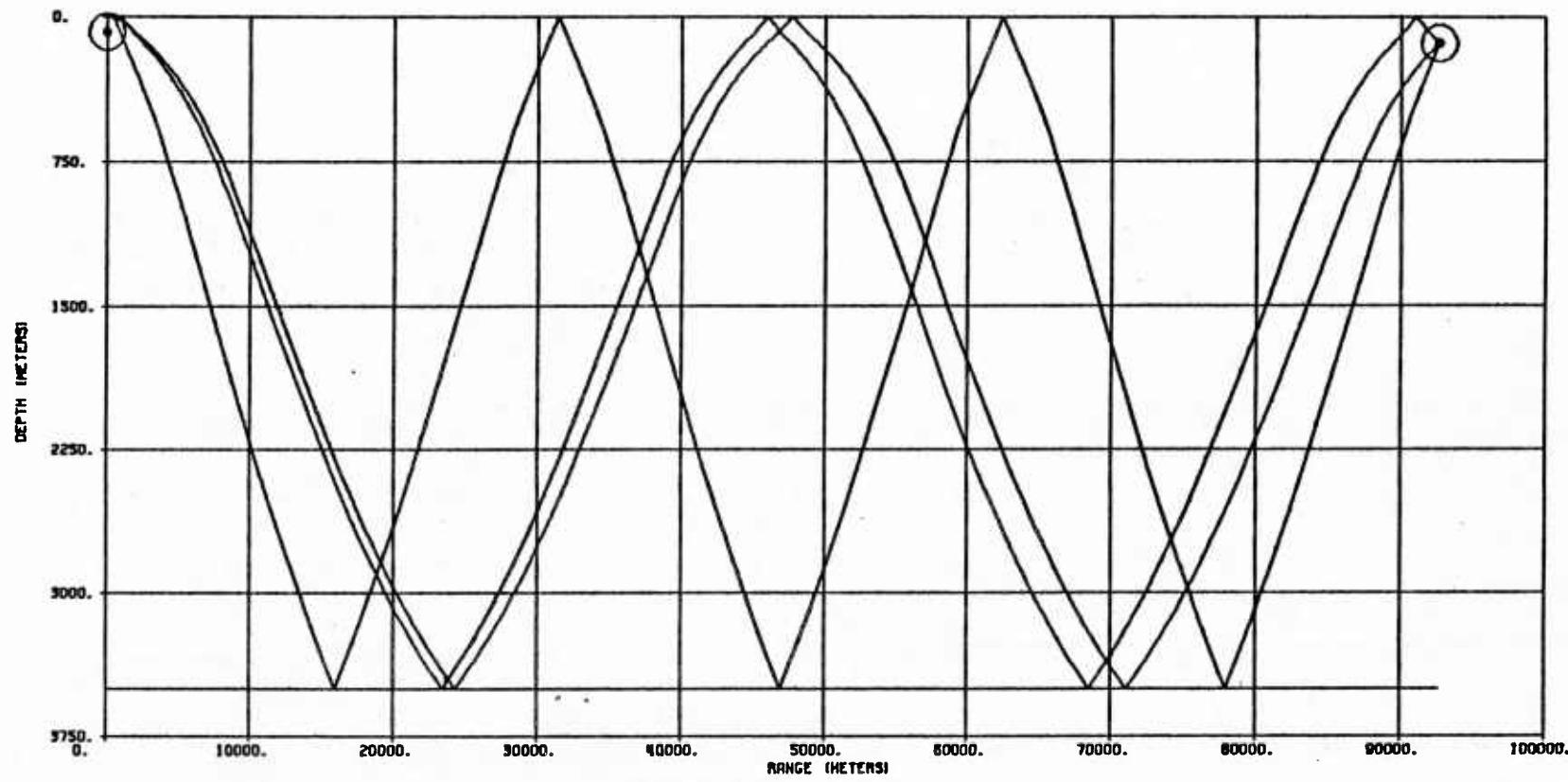
RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
4.1	-3.6	62.127	-4.8	5.6	94.06	3
4.5	4.1	62.141	-5.2	6.0	94.77	4
9.8	-9.5	63.004	-10.1	10.5	97.37	5

C40



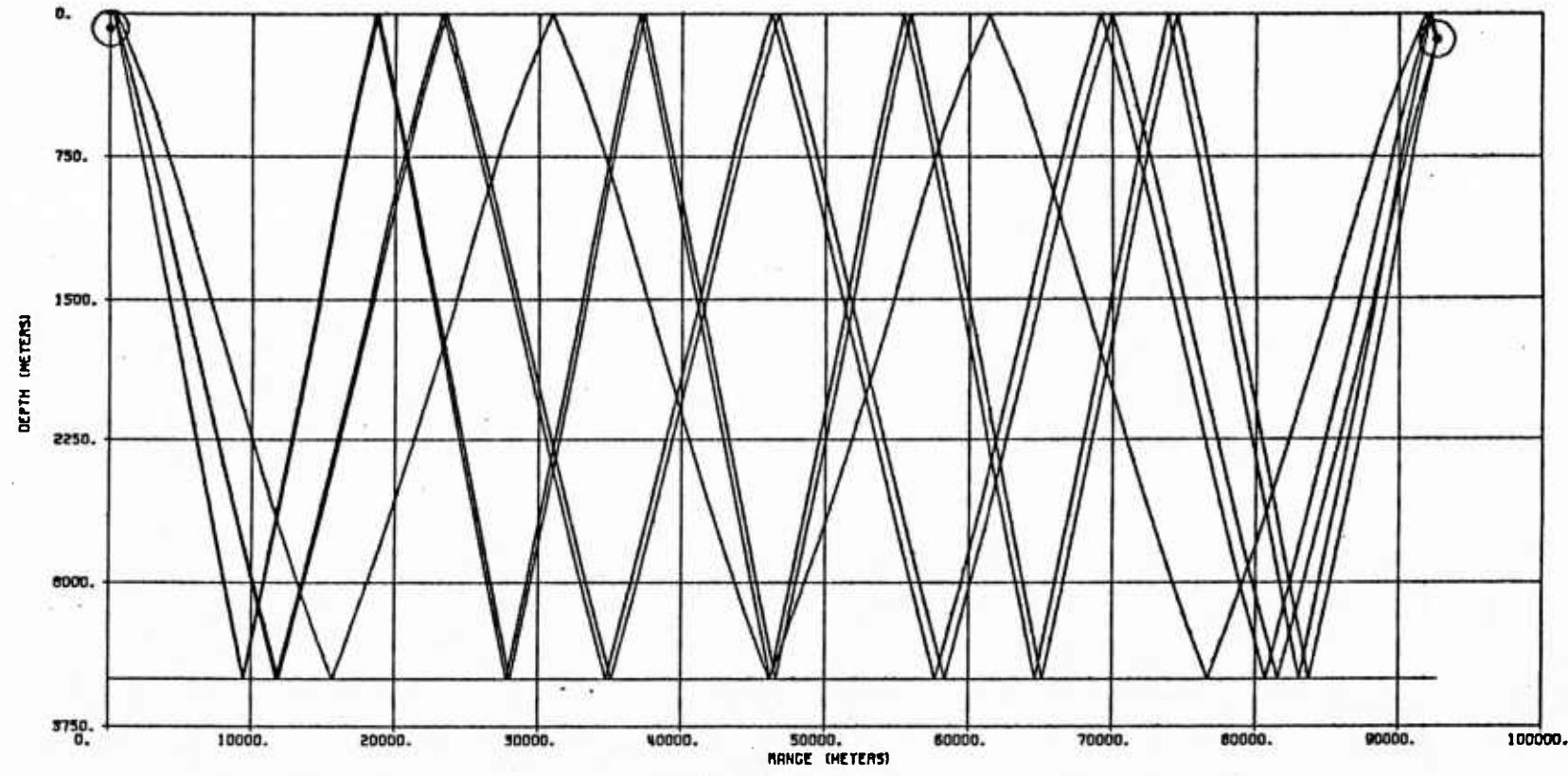
## RUN FOR BT53C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-4.3	-3.0	62.136	-5.0	5.8	94.42	4
-4.6	4.4	62.150	-5.4	6.1	95.02	5
-9.9	-9.7	63.022	-10.2	10.6	97.44	6

C41/C42  
REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 92665.49 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-10.2	10.0	63.059	-10.5	10.9	97.56	7
-14.7	-14.6	64.214	-14.9	15.2	98.52	8
-14.8	14.8	64.260	-15.1	15.4	98.56	9
-19.0	-18.9	65.710	-19.2	19.4	99.12	10
-19.2	19.1	65.768	-19.3	19.5	99.15	11

TM No. 811061

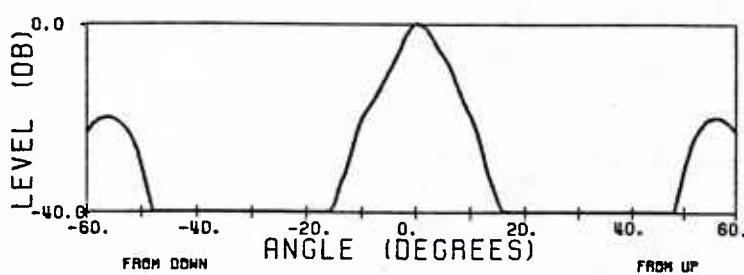
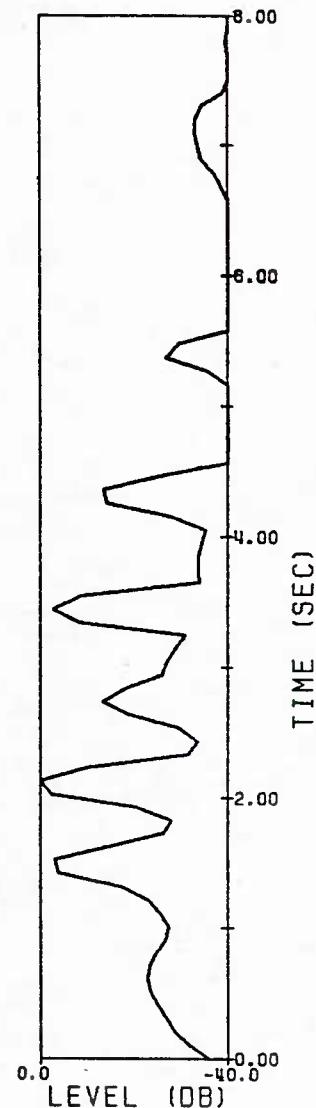
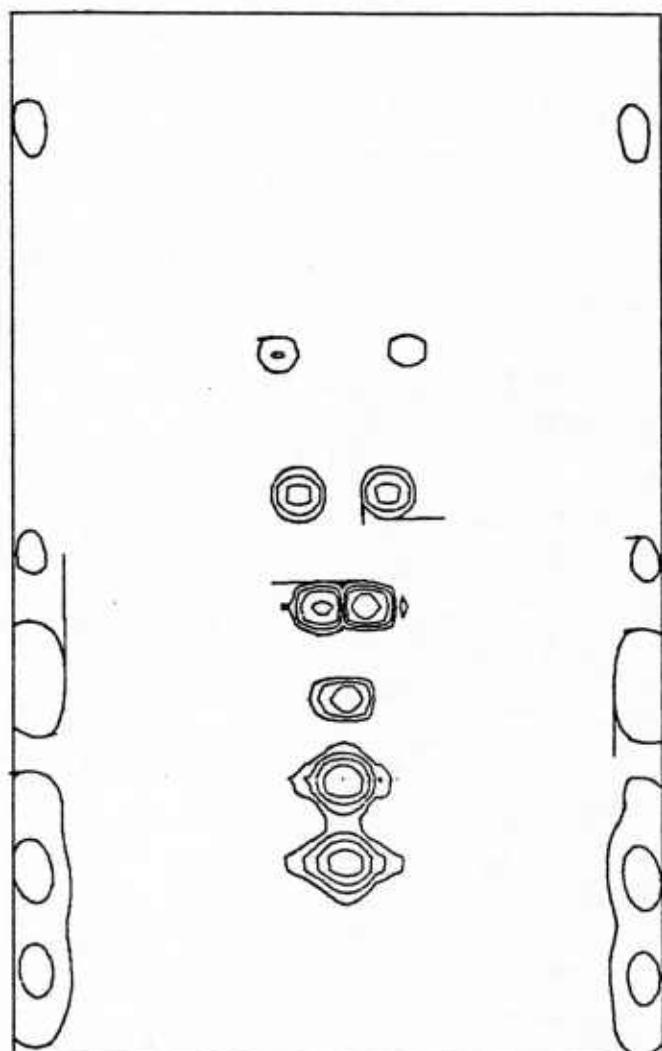
TM No. 811061

RANGE = 75 MILES

C43/C44

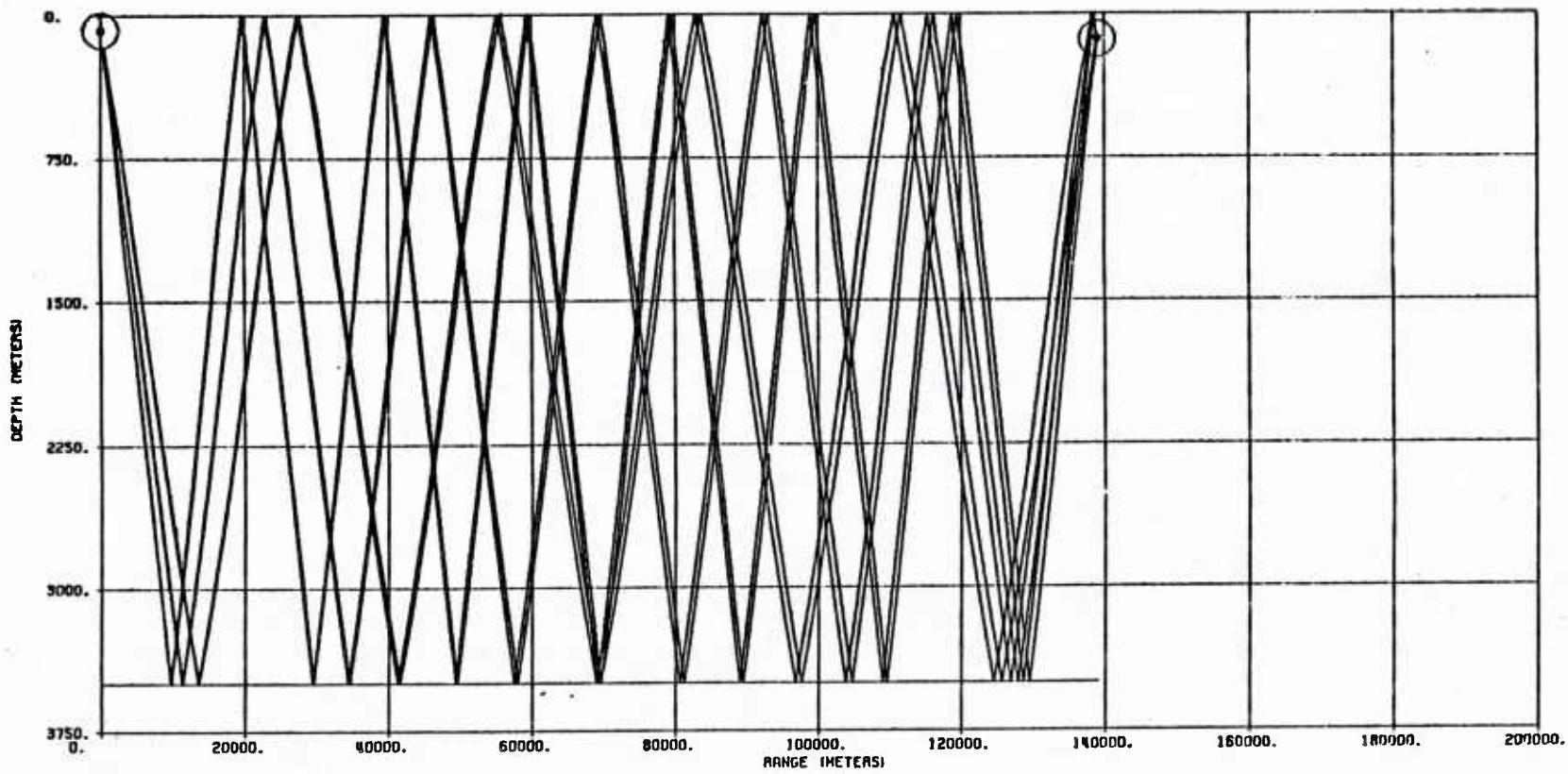
REVERSE BLANK

## E11MAR35 RIDGE



ANGLE, DELAY MAX=-109.08 DB  
 ANGLE MAX=-104.89 DB  
 DELAY MAX=-102.65 DB  
 DESIRED RANGE= 74.9 NAUTICAL MILES  
 STARTING FREQUENCY= 495. HZ.  
 STOPPING FREQUENCY= 505. HZ.  
 STARTING DEPTH= 102.98 METERS  
 STOPPING DEPTH= 162.60 METERS  
 SOURCE DEPTH= 78.0 METERS  
 SOURCE WIDTH= 10.0 METERS  
 SOURCE AIM= 15.0 DEGREES

C46

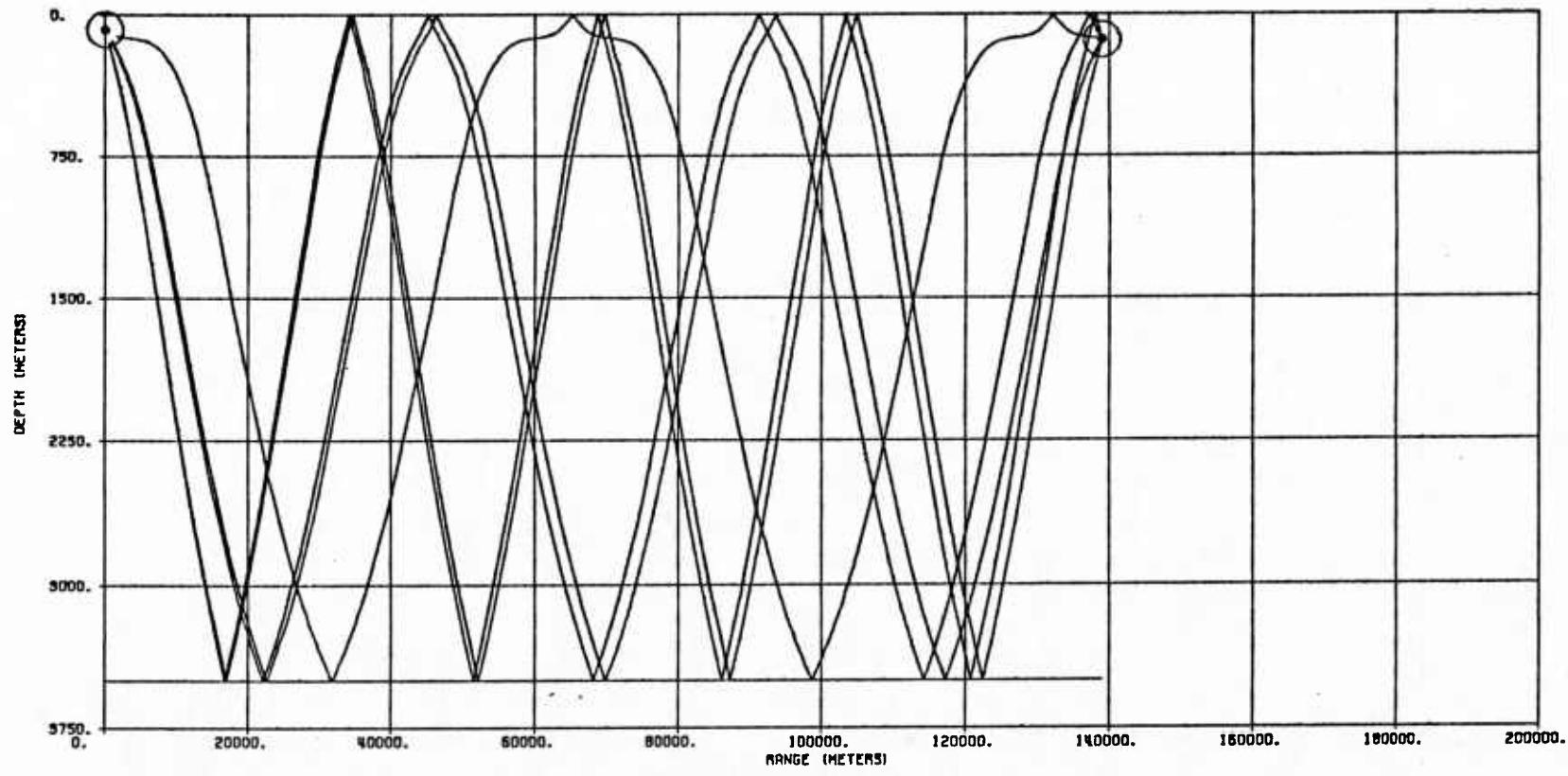


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 136998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
11.5	-11.3	95.060	-11.8	12.1	101.39	8
11.6	11.5	95.096	-11.9	12.3	101.44	10
14.6	-14.5	96.300	-14.8	15.1	102.03	11
14.7	14.6	96.345	-15.0	15.2	102.06	12
17.5	-17.4	97.742	-17.7	17.0	102.46	13
17.7	17.6	97.796	-17.8	18.1	102.48	14

C47



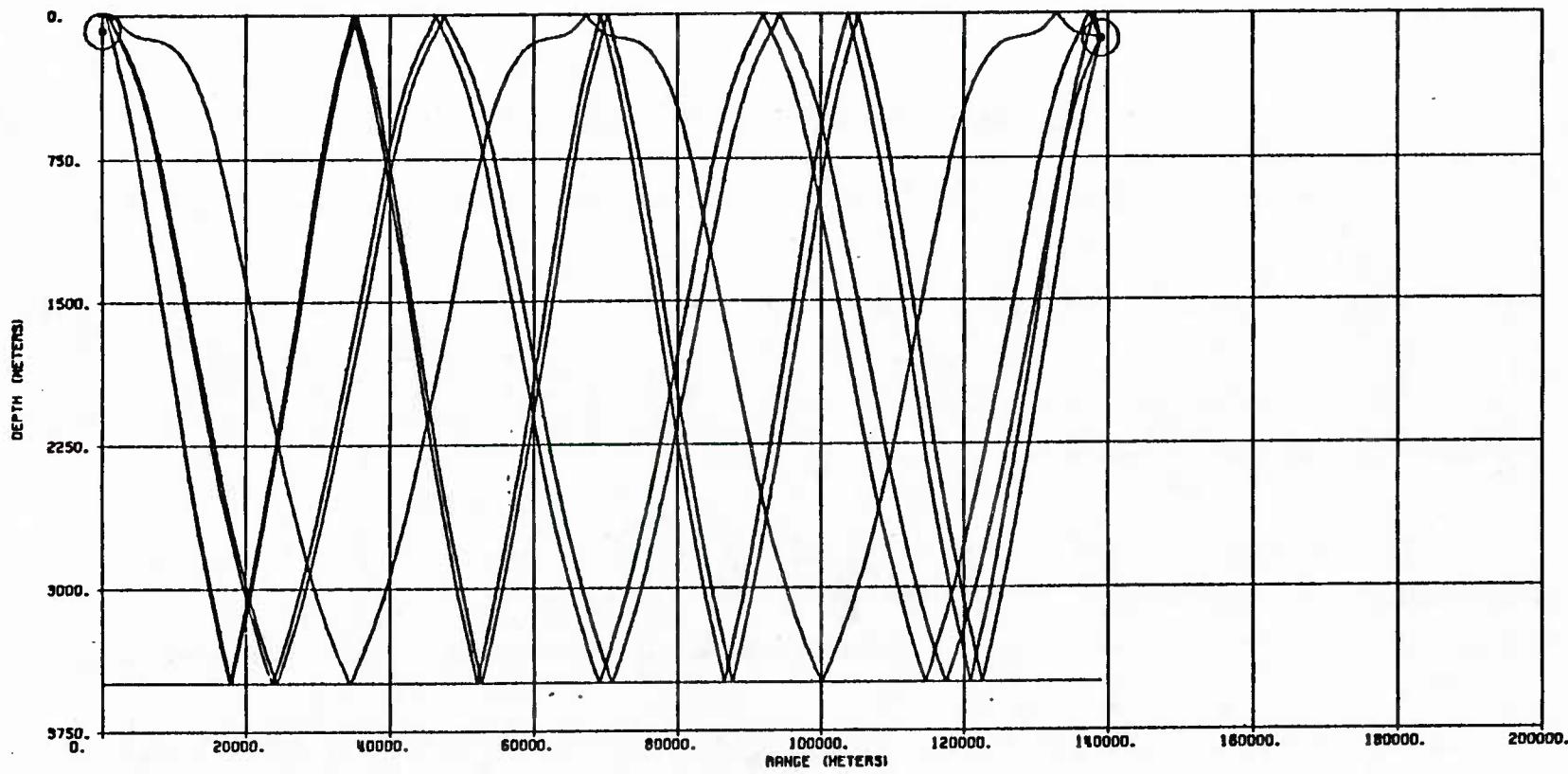
SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
1.8	0.6	92.516	-3.2	4.4	108.50	4
4.2	-3.8	93.196	-4.8	5.7	97.77	5
4.5	4.1	93.210	-5.2	5.9	98.26	6
8.1	-7.9	94.027	-8.5	9.0	100.28	7
8.3	8.1	94.053	-8.7	9.1	100.40	8

TM NO. 811061

C48

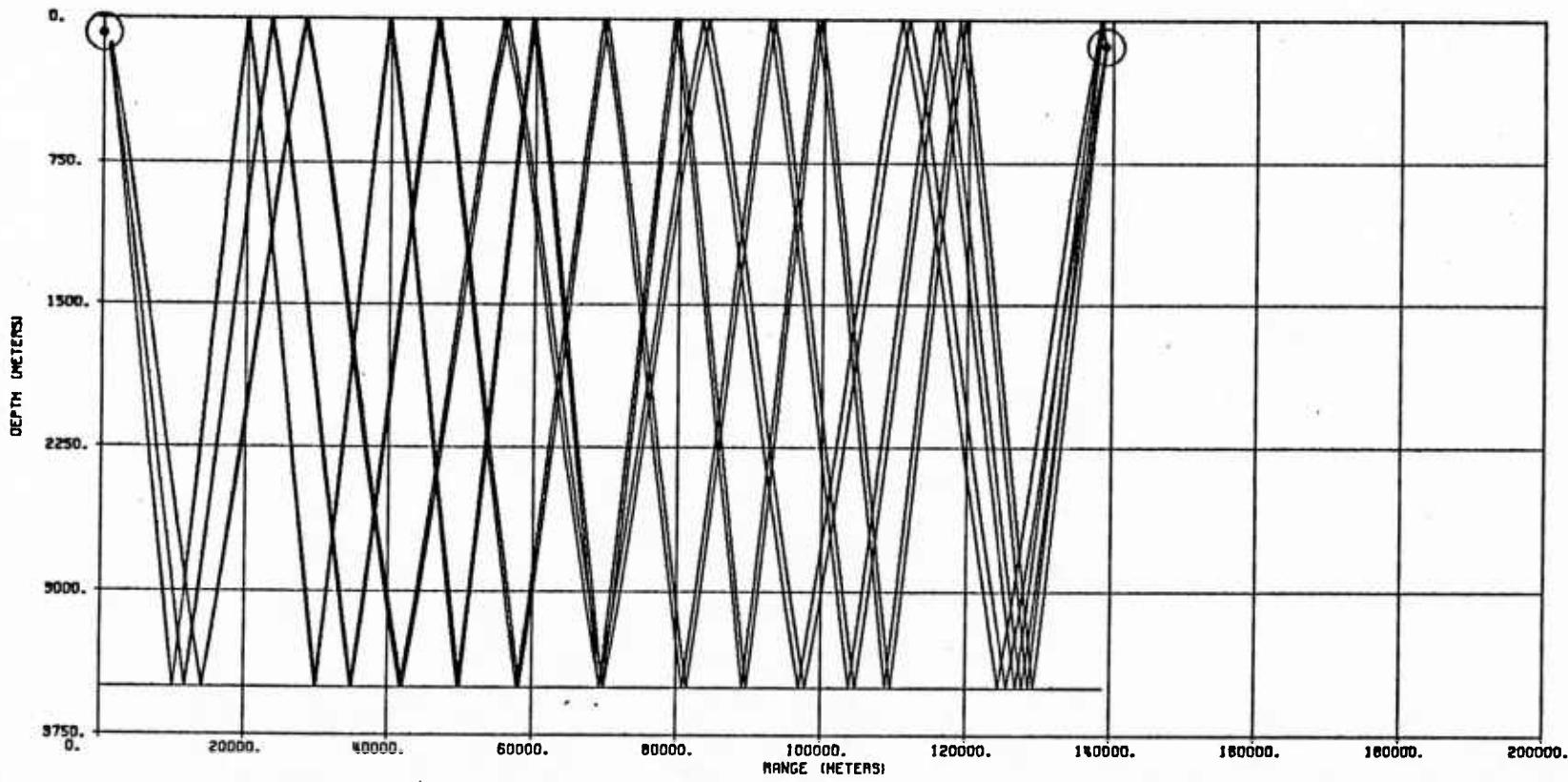


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	0.7	92.521	-3.2	4.4	102.44	5
-4.4	-3.9	93.205	-5.1	5.8	98.02	6
-4.6	4.3	93.219	-5.3	6.1	98.45	7
-8.2	-8.0	94.042	-8.6	9.1	100.35	8
-8.4	8.2	94.068	-8.8	9.2	100.40	9

C49/C50 REVERSE BLANK



RUN FOR BT52C

SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 138998.21 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-11.6	-11.4	95.081	-11.9	12.2	101.43	10
-11.7	11.6	95.117	-12.0	12.4	101.47	11
-14.7	-14.6	96.326	-14.9	15.2	102.05	12
-14.8	14.7	96.372	-15.0	15.3	102.08	13
-17.6	-17.5	97.779	-17.8	18.0	102.47	14
-17.7	17.6	97.828	-17.9	18.1	102.49	15

TM No. 811061

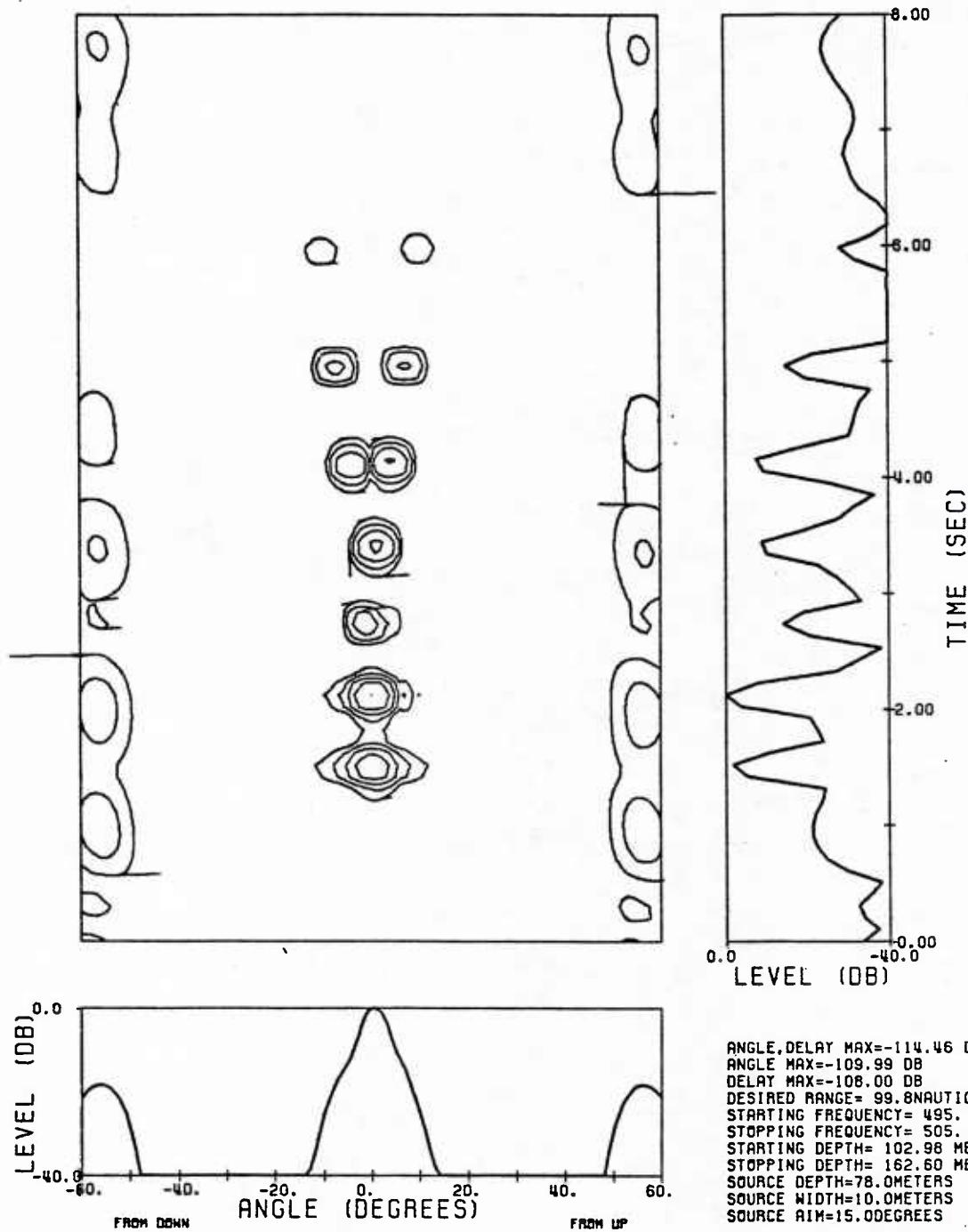
RANGE = 100 MILES

C51/C52

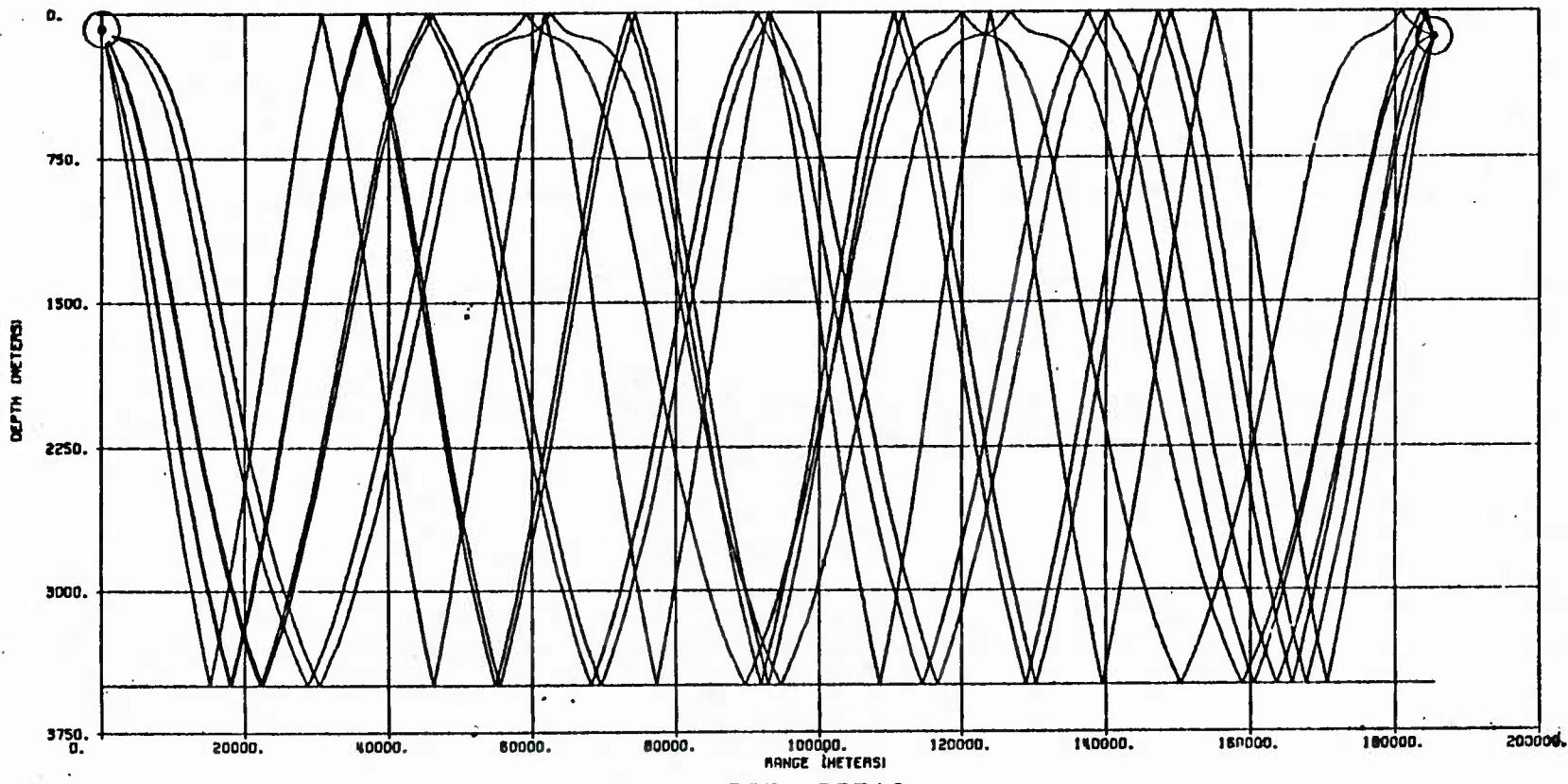
REVERSE BLANK

TM No. 811061

## E11MAR35 RIDGE



C54

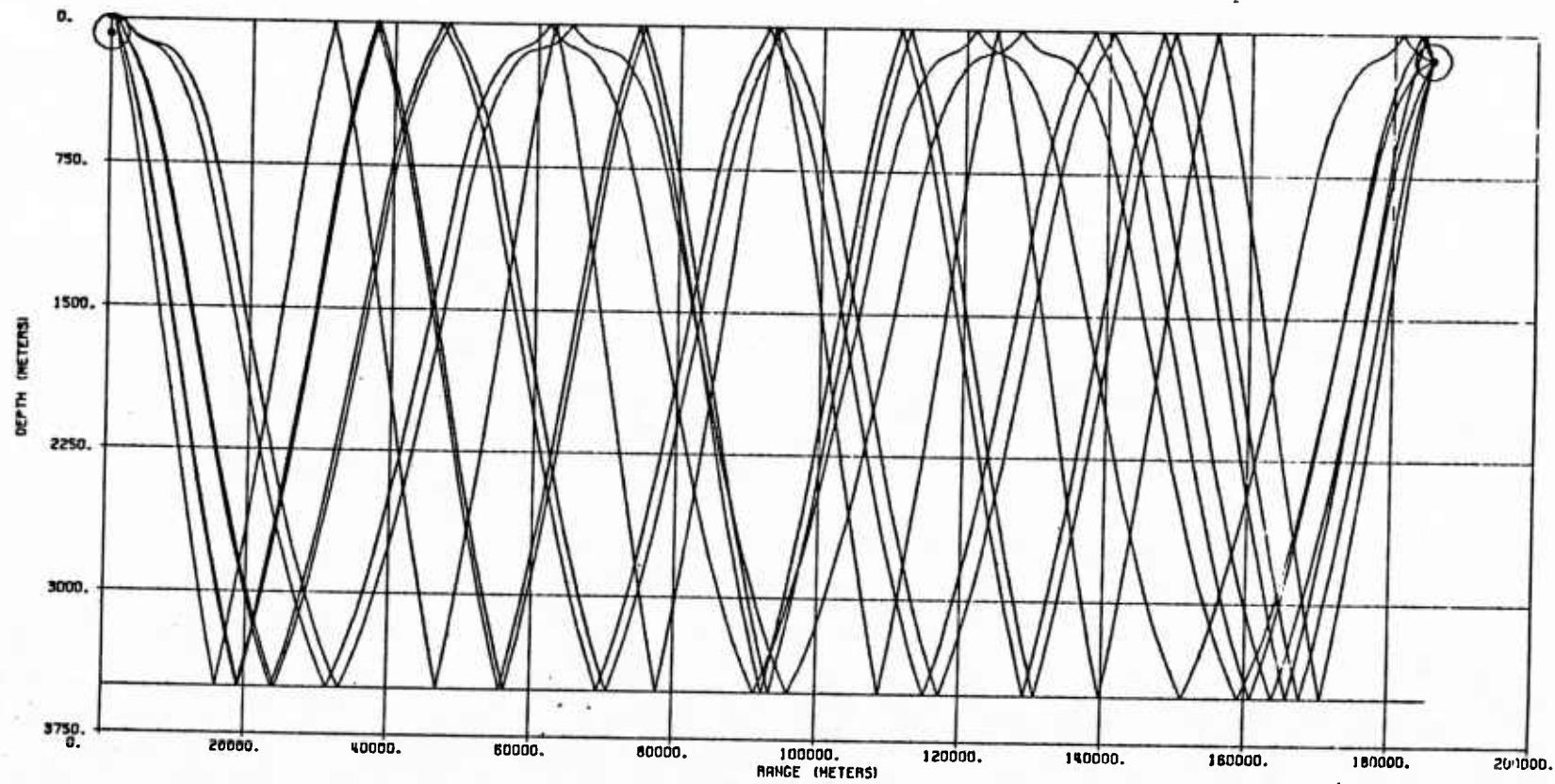


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 185330.96 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
2.0	-0.7	123.571	-3.2	4.4	104.27	5
2.1	1.0	123.577	-3.3	4.4	100.82	6
4.2	-3.8	124.266	-5.0	5.6	100.97	7
4.5	4.1	124.279	-5.2	5.9	100.72	8
7.2	-7.0	125.074	-7.6	8.2	102.39	9
7.4	7.1	125.097	-7.8	8.5	102.51	10
9.8	-9.7	126.032	-10.2	10.6	103.44	11

C55/C56  
REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 185330.96 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DB)	NUMBER OF REVERSALS
-2.0	-0.8	123.576	-5.3	4.4	100.66	6
-2.1	1.1	123.582	-5.3	4.4	99.86	7
-4.4	-4.0	124.274	-5.1	5.9	100.54	8
-4.6	4.2	124.288	-5.3	6.0	100.84	9
-7.3	-7.1	125.008	-7.7	8.3	102.45	10
-7.4	7.2	125.111	-7.9	8.4	102.56	11
-9.9	-9.8	126.050	-10.3	10.7	103.47	12

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TM No. 811061

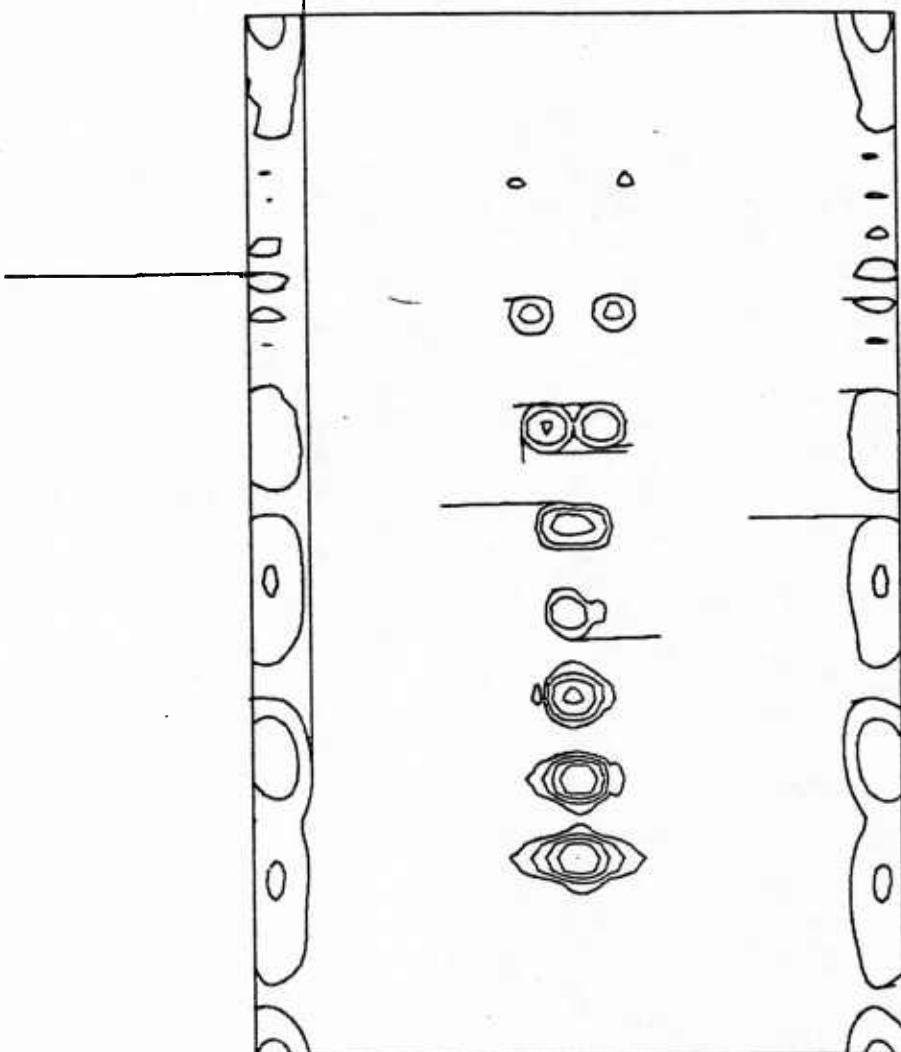
RANGE = 117 MILES

C57/C58

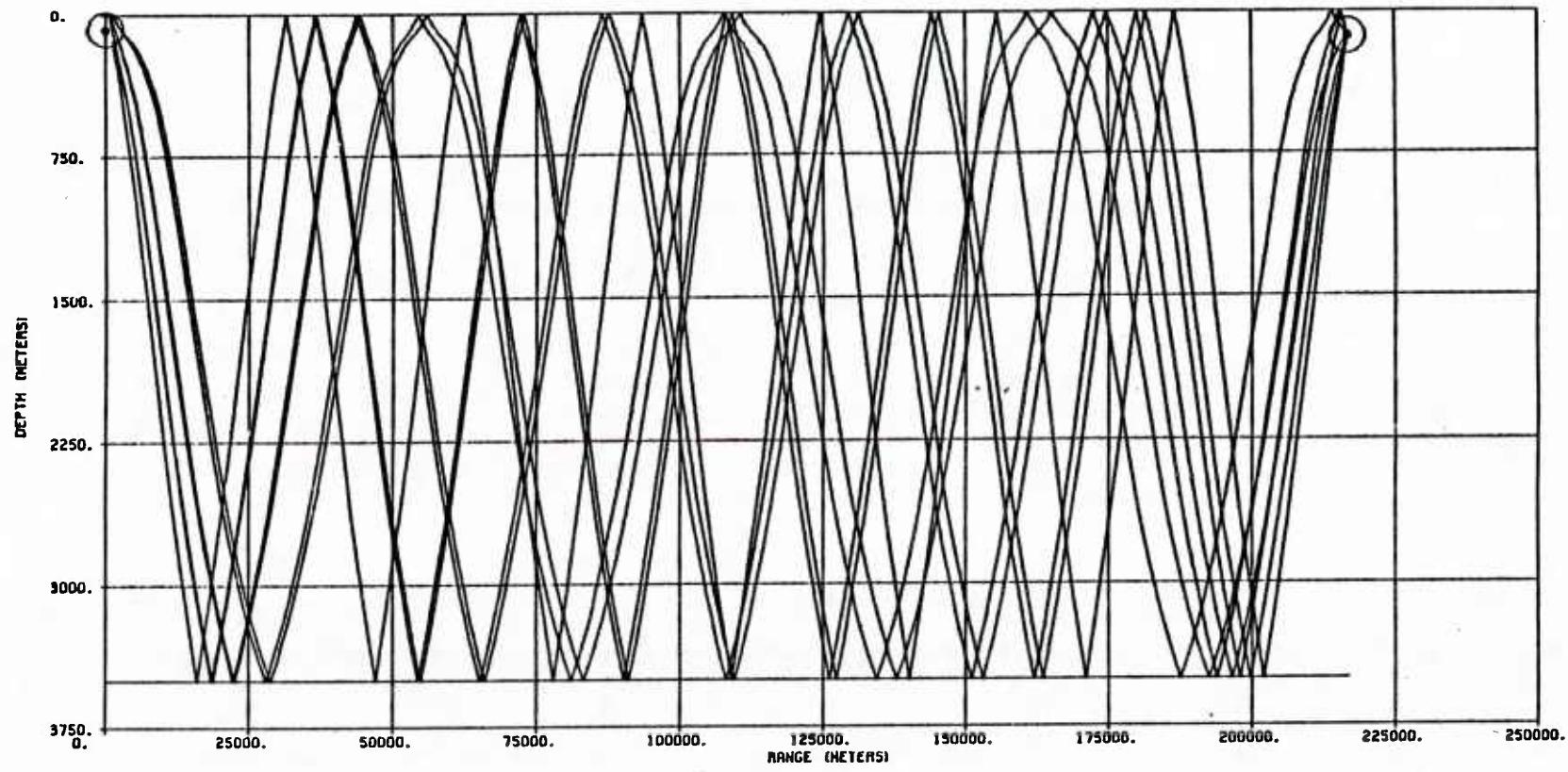
REVERSE BLANK

TM No. 811061

E 11MAR35 RIDGE



C60

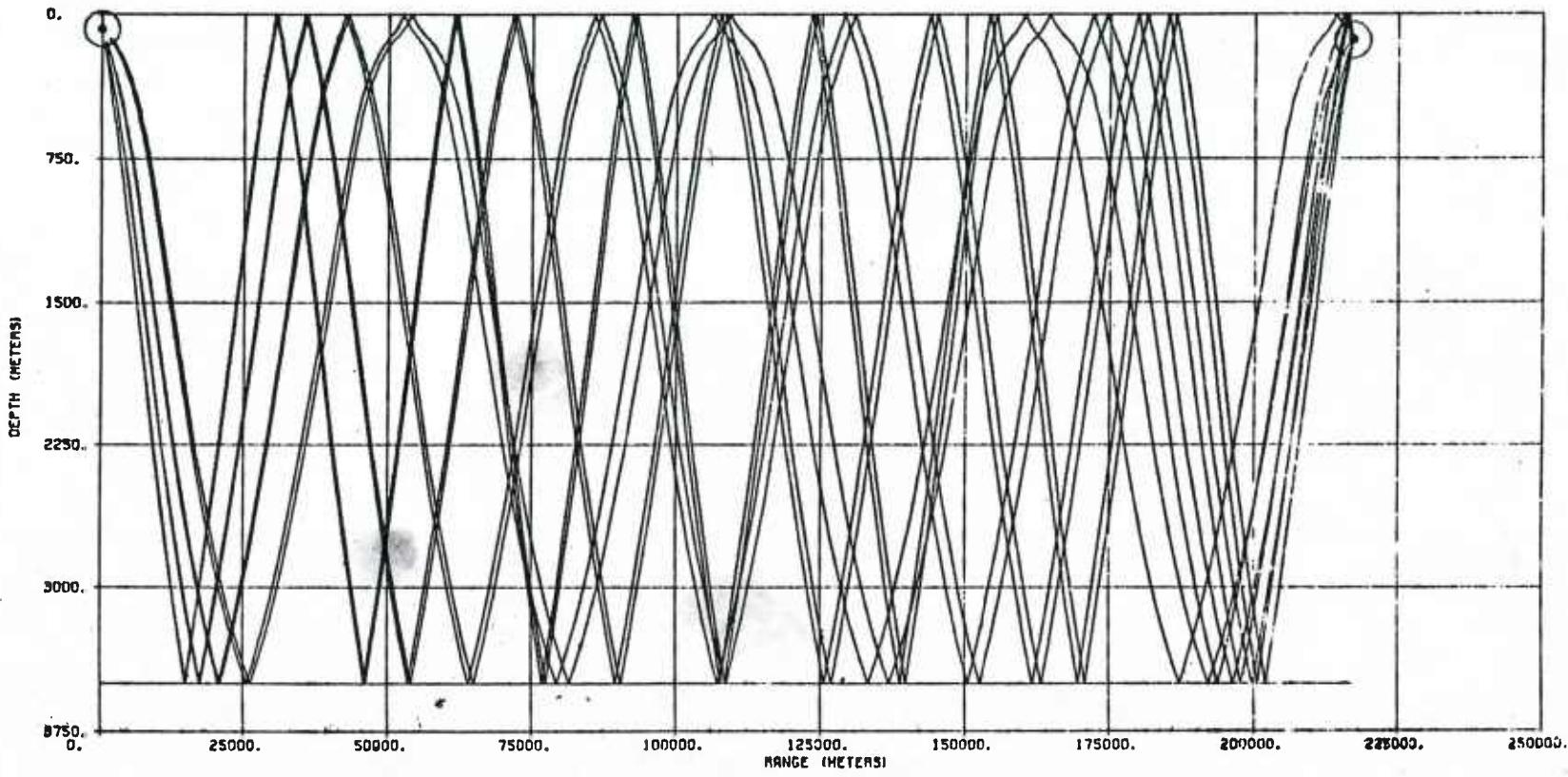


SOURCE DEPTH = 78.00 METERS  
 SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
 TARGET RANGE = 216837.23 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE ANGLE	BOTTOM ANGLE	PROPAGATION LOSS (DBI)	NUMBER OF REVERSALS
-2.7	-2.0	144.915	-3.7	4.7	100.38	8
-2.9	2.3	144.924	-3.9	4.9	100.76	9
-5.2	-4.9	145.645	-5.8	6.5	102.57	10
-5.4	5.0	145.662	-6.0	6.6	102.77	11
-7.6	-7.4	146.488	-8.1	8.6	104.00	12
-7.8	7.6	146.512	-8.2	8.7	104.06	13
-9.9	-9.7	147.459	-10.2	10.6	104.83	14

C61/C62 REVERSE BLANK



SOURCE DEPTH = 78.00 METERS  
SOURCE RANGE = 0.00 METERS

TARGET DEPTH = 136.00 METERS  
TARGET RANGE = 216837.23 METERS

TRANSMIT ANGLE	RECEIVE ANGLE	TRAVEL TIME (SECONDS)	SURFACE INCLINE	BOTTOM ANGLE	PROPAGATION LOSS (dB)	NUMBER OF REVERSALS
2.6	-1.6	144.909	-3.7	4.7	100.18	7
2.6	2.1	144.918	-3.6	4.8	100.67	6
5.1	-4.8	145.636	-5.7	6.4	102.45	9
5.3	4.9	145.652	-5.9	6.6	102.66	10
7.6	-7.5	146.474	-8.0	8.5	103.93	11
7.7	7.5	146.498	-8.1	8.6	104.05	12
9.8	-9.7	147.441	-10.2	10.6	104.80	13
9.9	9.8	147.472	-10.3	10.7	104.96	14

TM No. 811061

A COMPARISON OF MULTIPATH ARRIVAL STRUCTUES OBSERVED IN THE PRESENCE  
OF SURFACE DUCT WITH PREDICTIONS OBTAINED USING CLASSICAL RAY  
TECHNIQUES AND THE PARABOLIC EQUATIONS METHOD

Herbert A. Freese

Formally Of The Submarine Sonar Department

TM NO. 811061

Issued By The Surface Ship Sonar Department

14 February 1985

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