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RESULTS FROM UNDERWATER SOUND INTENSITY CALCULATIONS FOR SPECIF--ETC(U)
AUG 60 M A PEDERSEN, D F GORDON
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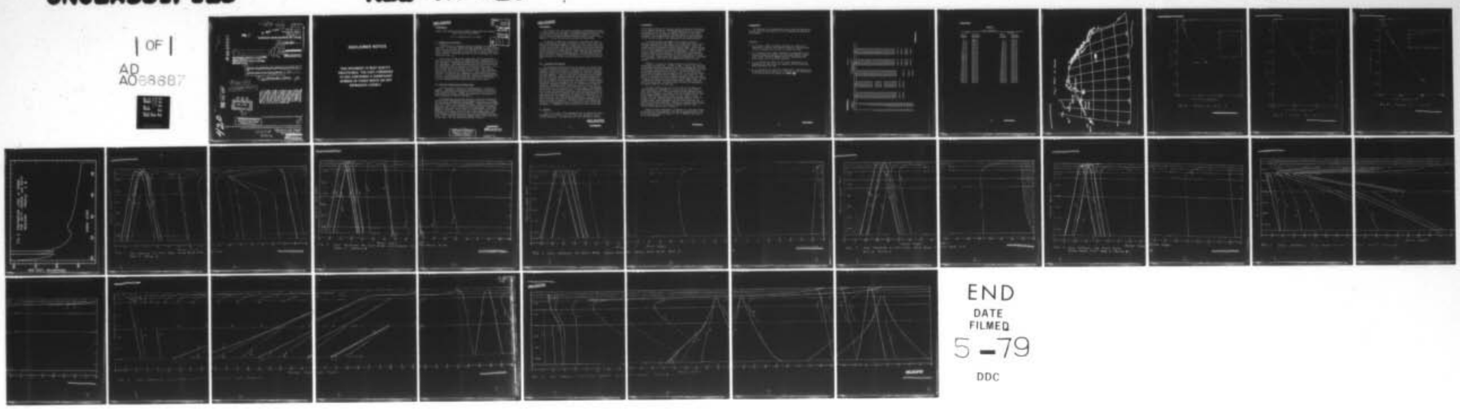

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RESULTS FROM UNDERWATER SOUND INTENSITY CALCULATIONS FOR SPECIFIC AREAS BY USE OF RAY ACOUSTICS

by M. A. Pedersen and D. F. Gordon

I Introduction and Purpose

A new method for computing acoustic intensities has ~~just~~ been completed. Preliminary computations ~~have been~~ were made for three northern areas in which sea tests are to be conducted in July and August 1960. These computations were made in order to test our current ability to predict acoustic intensities and also for use in designing the forthcoming sea tests.

Due to lack of time, these computations have not been made in sufficient detail to present a complete picture. Nonetheless it was felt advisable to summarize and present these preliminary results in this memorandum. Thus computed predictions will be on record before any experimental data on acoustics is known from these areas. It is also believed that these results will be useful in this form to others at NEL and to a few groups outside of NEL. This memorandum should not be construed as a report as its only functions are to record and to present for the information of others these preliminary results. A forthcoming NEL report will compare the experimental data to these predicted intensities and also give further calculations based on oceanographic data collected during the sea tests.

II Velocity Profiles for the Three Areas

The three areas of interest are designated as C, D, and E in figure 1. Temperature and salinity data from Nansen casts taken in these areas was used to calculate the sound velocities, using equations derived by Wilson[1]. Depths were converted to pressures by a method discussed by Fofonoff and Tabata[2].

The temperature and salinity data were taken from observations made by Pacific Oceanographic Group (Canada), University of Washington, and Scripps Institute of Oceanography. Observation dates ranged from 1950 to 1959. The resulting velocities seemed to fall into two groups for area C and E, representing for area E slightly different geographic locations, and for area C a time difference. These five groups of velocities, C type I and II, D, and E type I and II, each consisting of an average of from seven to nine observations, gave velocity-depth profiles which were felt to be representative of the areas. Data below 2500 meters was obtained from a single observation in each area. The five profiles are given in Table I.

The profiles were then altered slightly to approximate the effect of earth curvature on ray paths. The method given by Watson[3] was used to calculate the apparent depth and velocity to give this effect. Table 2 gives the true and altered velocity profile for area C type I. Figures 2 - 4 show the profiles as altered for curved earth.

An analytic function was then fitted to the points in order to give a mathematical statement of velocity vs depth. Each profile was broken into convenient segments or layers and the function was fitted to each layer in such a way that the derivative for any two adjoining layers was matched at their junction points, giving a smooth function closely fitting the altered profile. These curve fitting techniques will be discussed in a forthcoming article. The Burroughs 220 Computer was used to calculate the velocities, to alter the profiles for earth curvature, to do the curve fitting, and to compute the intensities.

III Intensity Calculations

The intensity calculations follow the general ray theory method discussed by Pedersen and Keith[4]. However, they differ in that here a profile consisting of curved line segments is used, while Pedersen and Keith discuss the details of the method for a profile consisting of linear segments. About 250 rays were calculated for each profile. These 250 rays were refracted upward at various depths ranging from the axis of minimum velocity to the bottom. Bottom reflected rays were not included in the computations. Computations including bottom reflections could be performed in the same manner, but, would require assumptions regarding reflection loss as a function of the angle of incidence. Computations were carried out for six receiver and six source depths, for the first three convergence zones. The intensity outputs were stored on magnetic tape. A second program then selected from the tape the data for a particular source and receiver combination and interpolated to determine the intensity contributions at all ranges which are even multiples of 100 yards. The intensities at a given range were then added assuming random phase. This sum was converted to decibel loss, and an attenuation factor depending on frequency and range was added in. The final output of the machine was a listing of the propagation loss as a function of range for 100 yard increments. A frequency of 1300 c/s was used in these calculations.

IV Results

Figure 5 is a plot of the propagation loss vs range in the first convergent zone of area E, type II. The source and receiver depth are both fifty feet. The three vertical lines extending to the top of the figure indicate the caustics, which, according to this theory, are of infinite intensity. The maximum range here at 67.5 kiloyards is attained by the ray that just grazes the bottom of the ocean. Discontinuities in the slope of this plot appear at 51, 54, and 62 kiloyards. These imperfections occur because the second derivative of the velocity profile is not continuous at the junction points.

To further condense and summarize the results, acoustic-intensity sections have been drawn. For a given source depth, loss vs range tabulations for six receivers were available. Thus, six points along an iso-intensity contour could be found. Those sections which have been completed or partially completed are shown in figures 6 - 13. Cross-hatched areas indicate shadow zones. Caustics are indicated by heavy lines marked C. The horizontal lines extending across the page indicate the depths at which calculations for receivers were made. Broken lines were used for extrapolations. Following is a discussion of several of the significant features of these results.

Figures 6 - 10 show the acoustic field for each profile for a source depth of fifty feet. In area C (figs. 6 and 7), the rapid drop in intensity near sixty kiloyards is due to the dropping out of bottom limited rays. Rays are bottom limited near seventy kiloyards for area E, the depth being greater in this area. The low intensity sound field beyond the bottom limited range in area C is due to the configuration of the profiles near the surface (see inset figure 2). The sign of the gradient for both C profiles changes near ten yards depth. As this is not the case in area D and E (see the insets figs. 3 and 4), a shadow zone follows the bottom limited range, marking a distinct end to the first zone. The greater depth of area D is reflected in the greater width of the first zone.

The source depth in fig. 11 is at the axis of the channel for area E profile II. Caustics for a receiver at this depth appear about every 1500 yards. This trend would probably continue if more zones were calculated. The source in fig. 12 is again near the axis of the deeper channel in area C type II. This channel is much broader than that noted above and the caustics occur at a wider interval, but with a similar pattern for the upper portion of the caustics shown. These intensities are due to rays that have not, in general, been surface reflected. However, the caustics beyond forty-eight kiloyards in fig. 12 are due to surface reflected rays. A similar pattern may be seen in figure 13.

Figure 13 may be considered to be typical of a very deep source, as the source is deep compared to the axis of minimum velocity. For the various deep sources in figs. 11 - 13, no separate zone effects can be distinguished.

The drafting of the illustrations by Mrs. Grace Wofford and the critical review of this paper by Dr. E. R. Anderson are gratefully acknowledged.

REFERENCES

1. W. D. Wilson, "Speed of Sound in Sea Water as a Function of Temperature, Pressure, and Salinity" Journal of the Acoustical Society of America, Vol. 32, No. 6, pp 641, June 1960

2. N. P. Fofonoff and S. Tabata "Program for Oceanographic Computations and Data Processing on the Electronic Digital Computer ALWAC III-E", Fisheries Research Board of Canada Manuscript Report Series No. 25, pp 18-25, Aug 1958

3. A. C. D. Watson "The Effect of the Earth's Sphericity in the Propagation of Sound in the Sea" Admiralty Research Laboratory Report ARL/N29/L, Dec 1958

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TABLE I

	Depth (Meters)	Velocity by Areas (Yards/Sec)				
		CI	CII	D	EI	EII
1	0	1638.43	1640.33	1625.40	1628.47	1631.50
2	10	1638.47	1640.33	1623.70	1628.30	1631.20
3	20	1638.16	1639.23	1622.40	1627.77	1627.67
4	30	1635.67	1630.47	1618.70	1619.60	1622.50
5	50	1625.40	1619.37	1608.90	1610.33	1606.17
6	75	1617.67	1612.80	1604.00	1609.40	1601.67
7	100	1616.10	1610.83	1603.50	1609.00	1602.60
8	150	1616.43	1612.07	1605.50	1610.97	1605.77
9	200	1614.83	1612.43	1606.70	1611.77	1606.50
10	250	1613.33		1607.00	1611.47	1607.10
11	300	1612.57	1611.33	1608.00	1611.07	1607.73
12	400	1612.13	1611.23	1608.80	1611.10	1608.97
13	500	1612.67	1611.97	1610.00	1611.97	1610.07
14	600	1613.43	1613.33	1611.00	1612.57	1611.13
15	700	1614.20		1611.90	1613.97	1612.17
16	800	1615.13	1615.17	1613.30	1614.83	1613.33
17	1000	1617.13	1616.60	1615.40	1616.90	1615.53
18	1200	1619.43	1619.10	1617.80	1619.07	1617.93
19	1500	1623.13	1623.10	1622.00	1623.03	1622.13
20	2000	1630.53	1630.53	1629.90	1630.57	1630.07
21	2500	1639.00	1639.00	1638.40	1638.93	1638.90
22	3000	1647.83	1647.83	1647.40		
23	3247				1652.40	1652.40
24	3500	1657.17	1657.17			
25	3786				1662.63	1662.63
26	4000	1666.83	1666.83	1666.40		
27	4321				1673.10	1673.10
28	4699				1680.23	1680.23
29	5000			1686.20		
30	5383				1694.20	1694.20
31	6000			1706.60		

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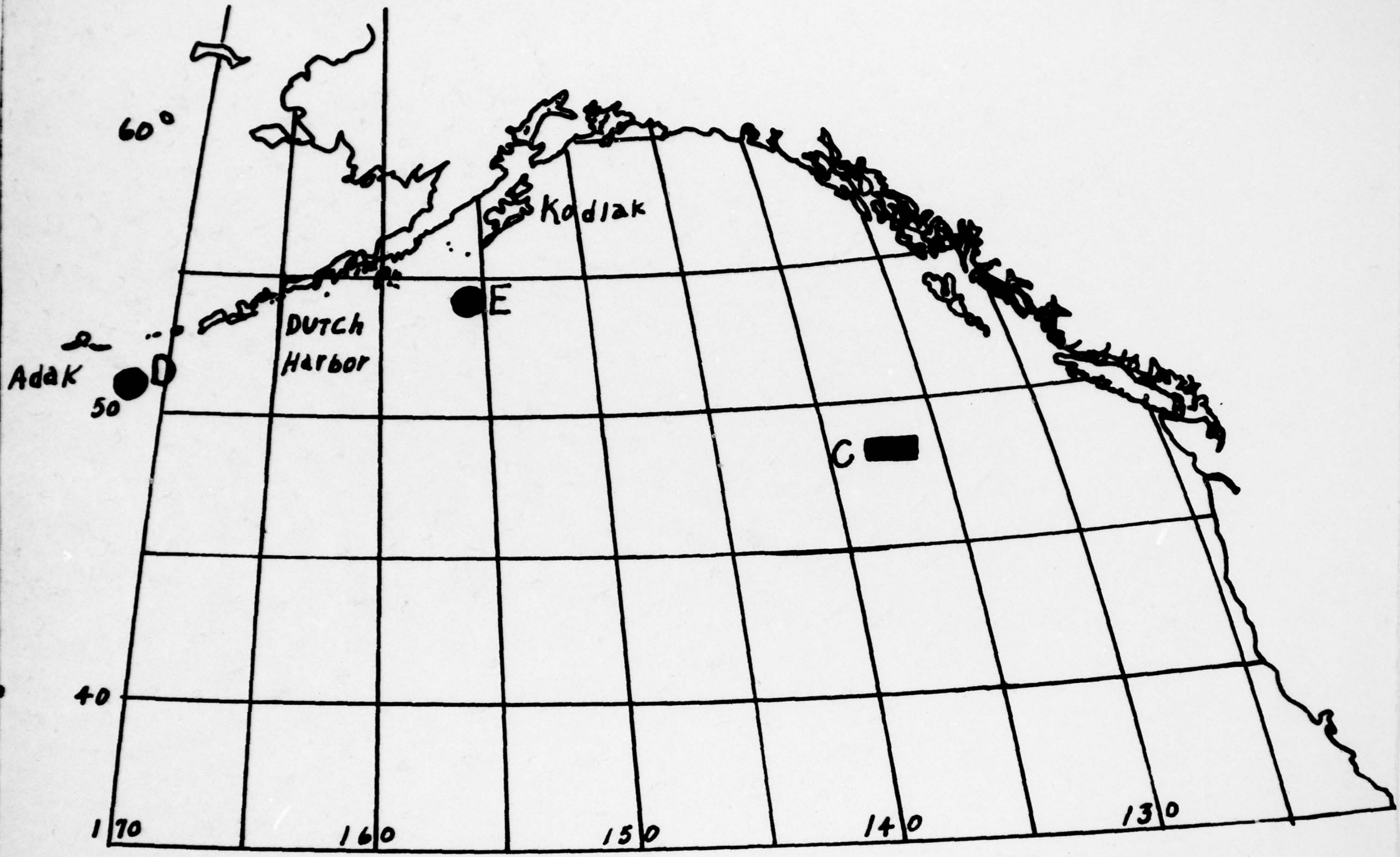
TABLE II

Area C Profile I

True		Altered	
Depth (Yards)	Velocity (Yds/Sec)	Depth (Yards)	Velocity (Yds/Sec)
0	1638.43	0	1638.43
21.09	1638.47	21.09	1638.47
21.87	1638.17	21.87	1638.17
32.80	1635.67	32.80	1635.67
54.68	1625.40	54.68	1625.41
82.02	1617.67	82.02	1617.69
109.36	1616.10	109.36	1616.13
164.04	1616.43	164.04	1616.47
218.72	1614.83	218.73	1614.88
273.40	1613.33	273.41	1613.40
328.08	1612.57	328.09	1612.64
437.44	1612.13	437.46	1612.23
546.81	1612.67	546.83	1612.79
656.17	1613.43	656.20	1613.59
765.53	1614.20	765.57	1614.38
874.89	1615.13	874.94	1615.34
1093.61	1617.13	1093.70	1617.39
1312.33	1619.43	1312.47	1619.74
1640.42	1623.13	1640.61	1623.52
2187.22	1630.53	2187.57	1631.05
2734.03	1639.00	2734.56	1639.64
3280.83	1647.83	3281.61	1648.61
3827.64	1657.17	3828.69	1658.08
4374.44	1666.83	4375.82	1667.88

Fig.1 Map of Areas



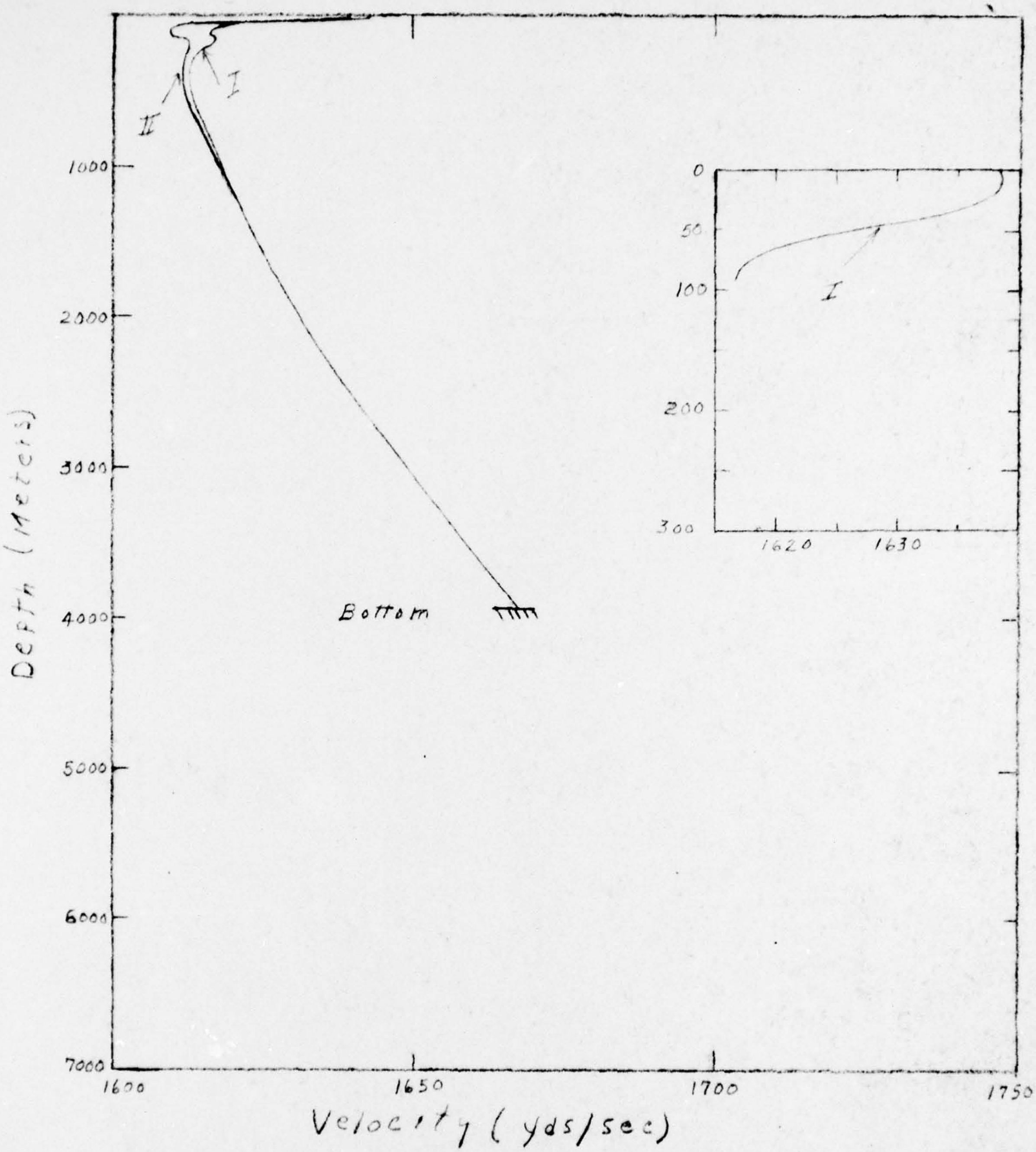


FIG 2 Profiles for Area C

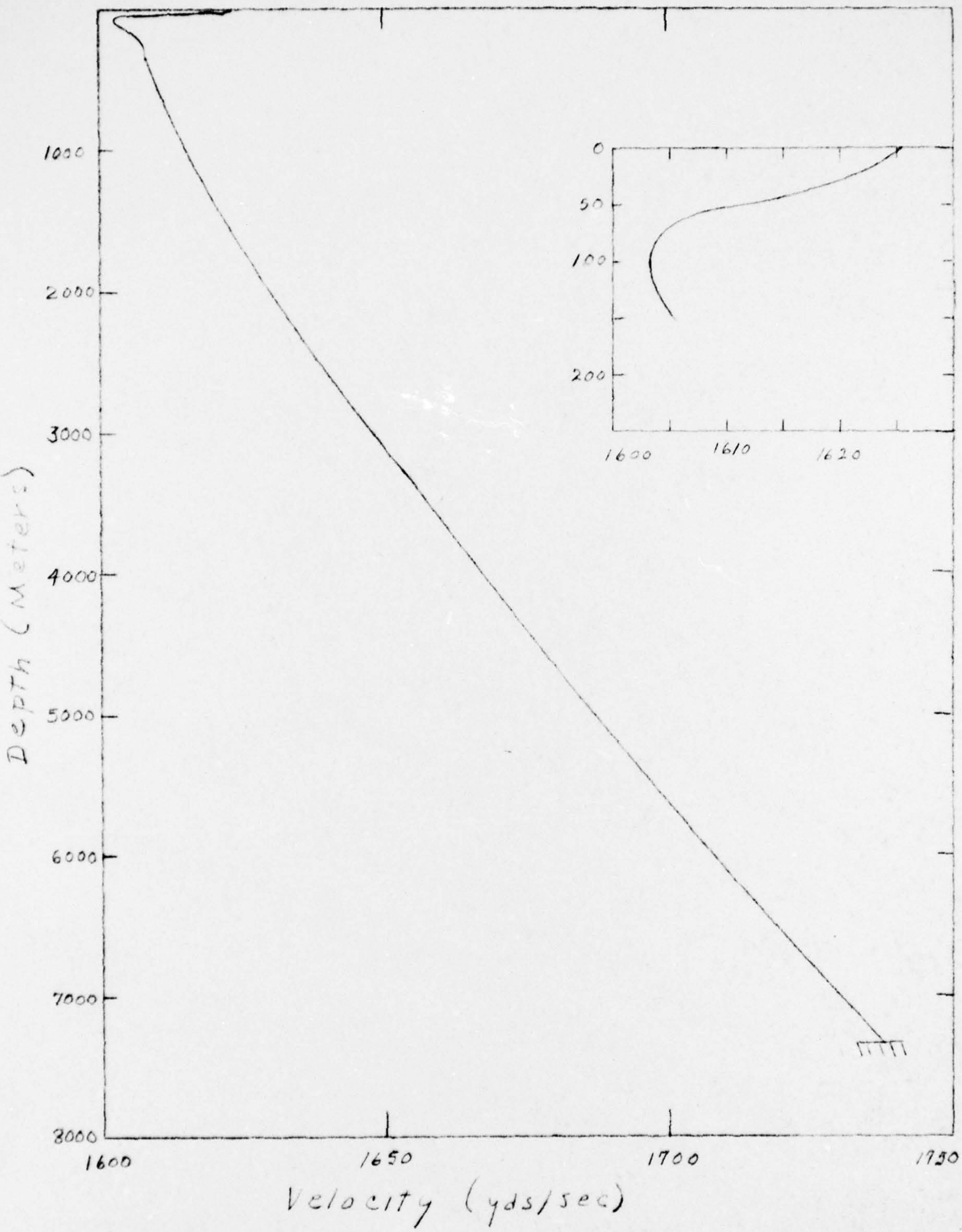


FIG 3 Profile for AREA D

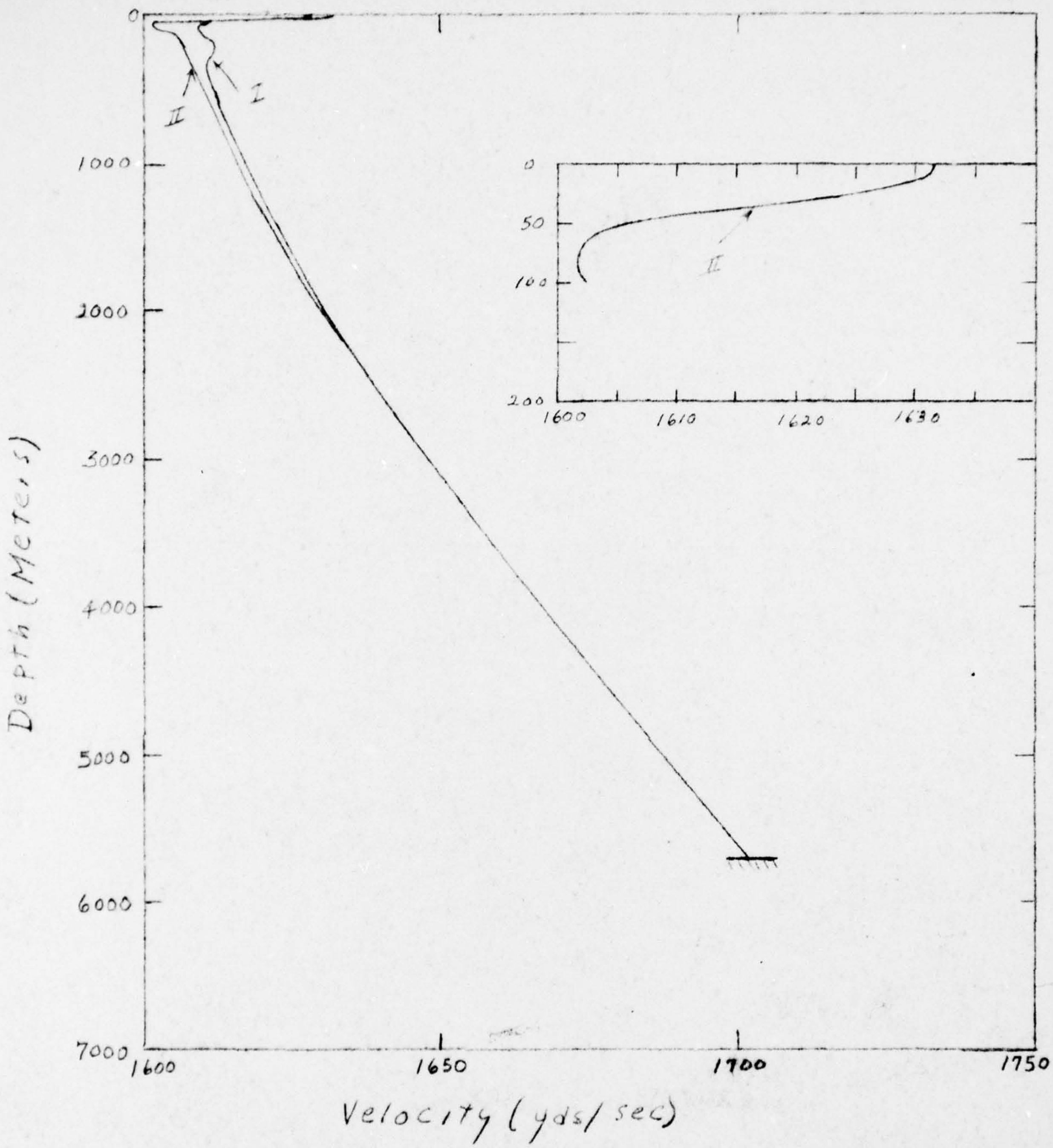


FIG 4 Profiles for Area E

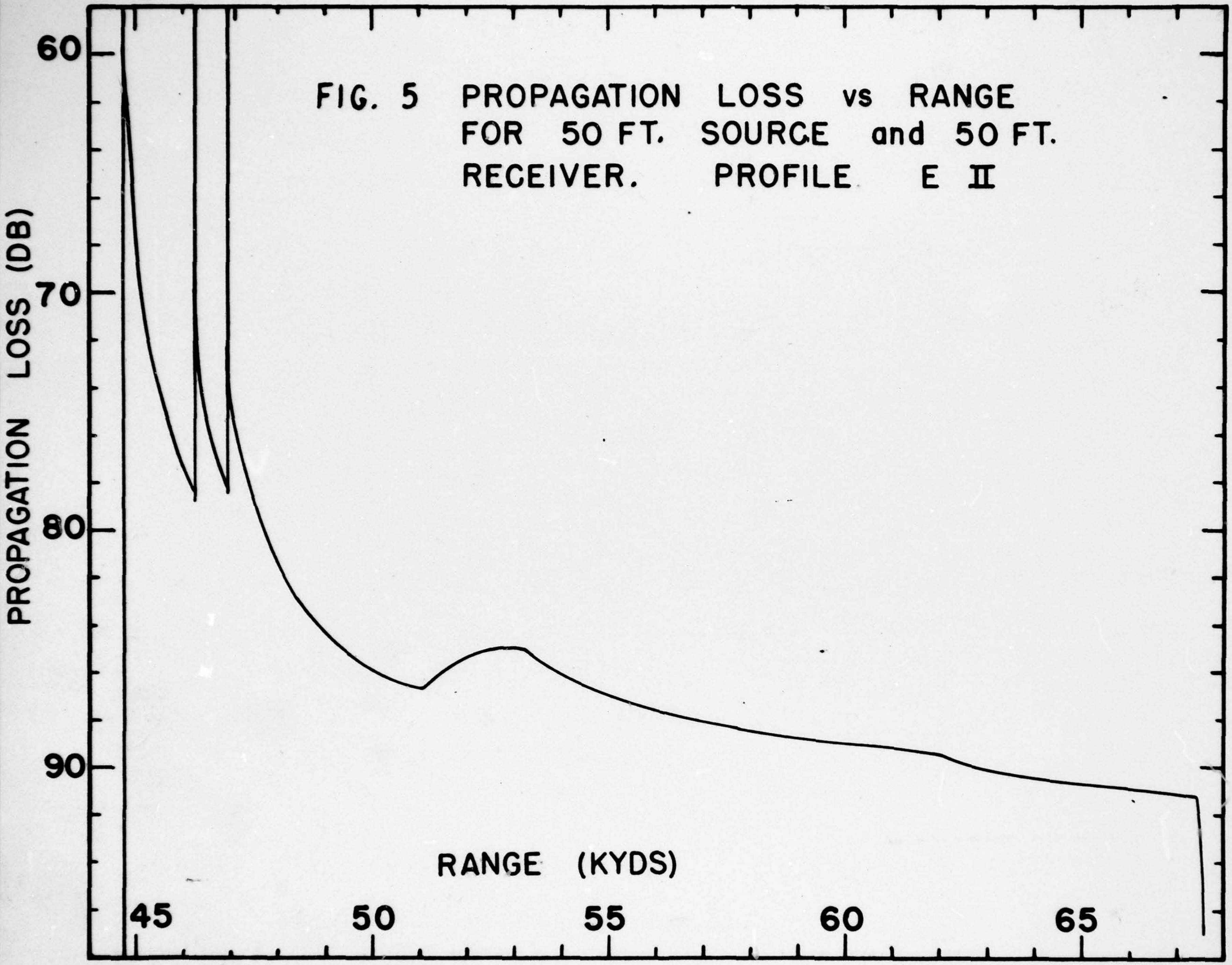


FIG. 5 PROPAGATION LOSS vs RANGE FOR 50 FT. SOURCE and 50 FT. RECEIVER. PROFILE E II

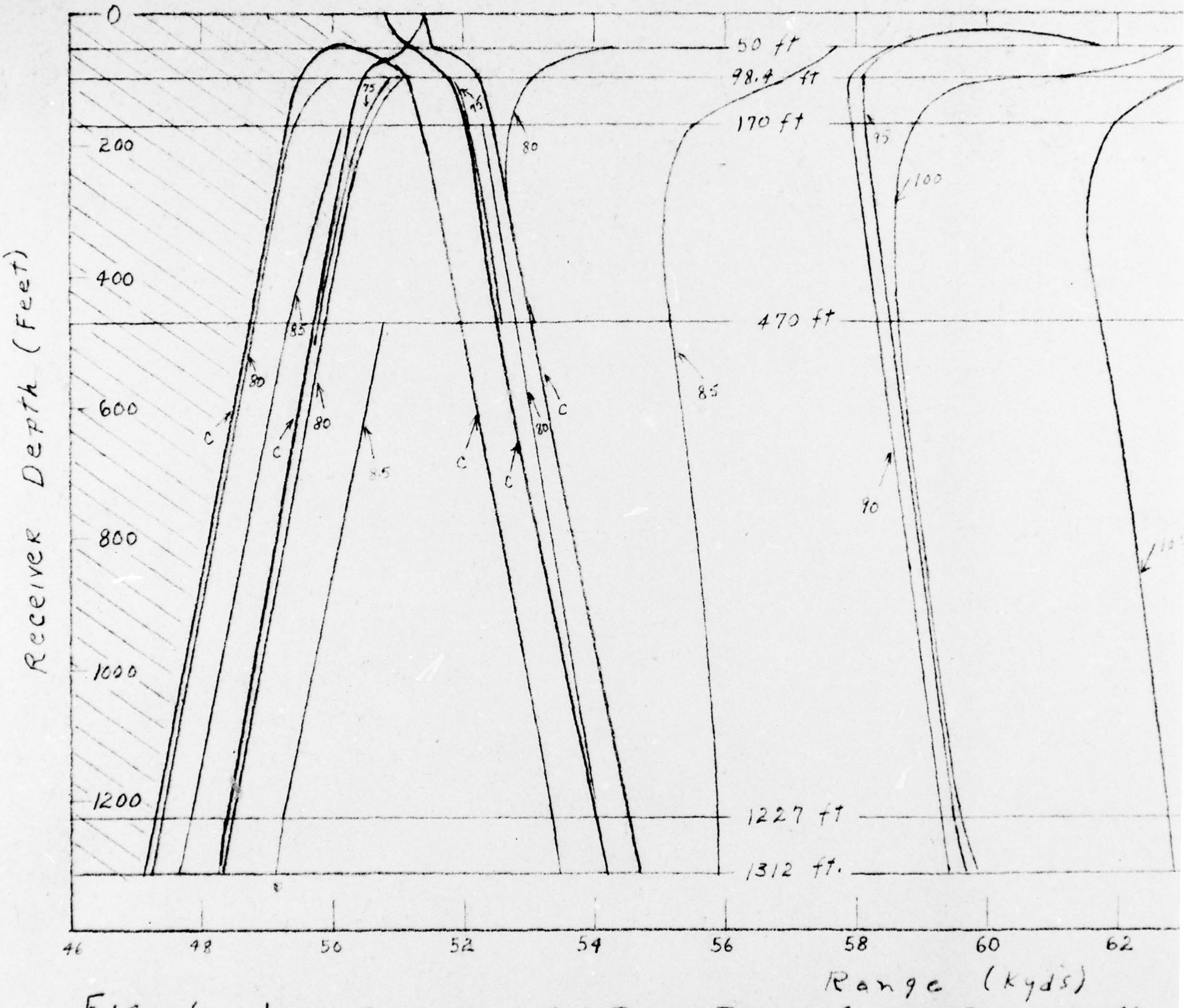
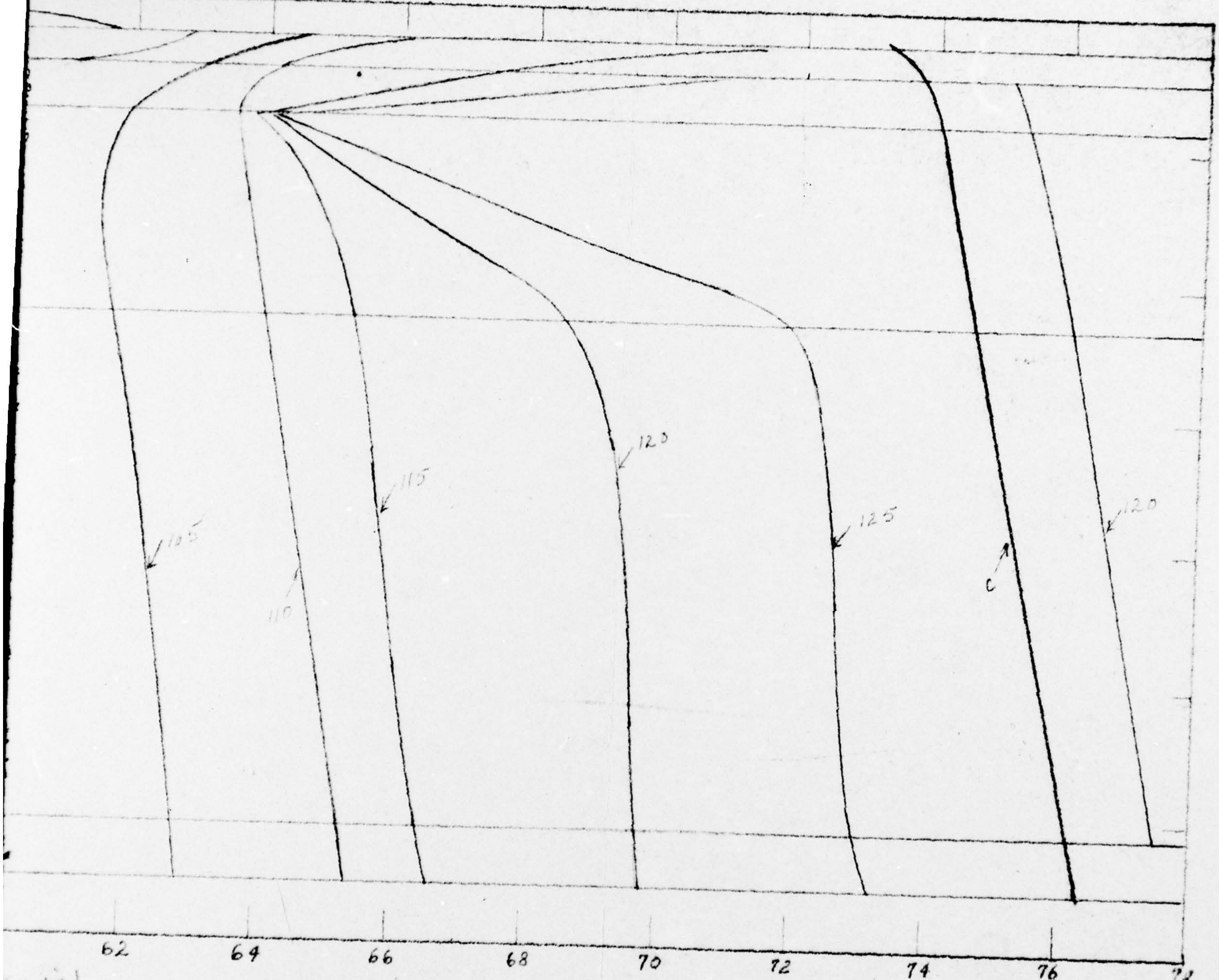


FIG. 6 LOSS CONTOURS for FIRST ZONE. SOURCE DEPTH 50 ft
AREA C PROFILE I



(yds)

th 50 ft

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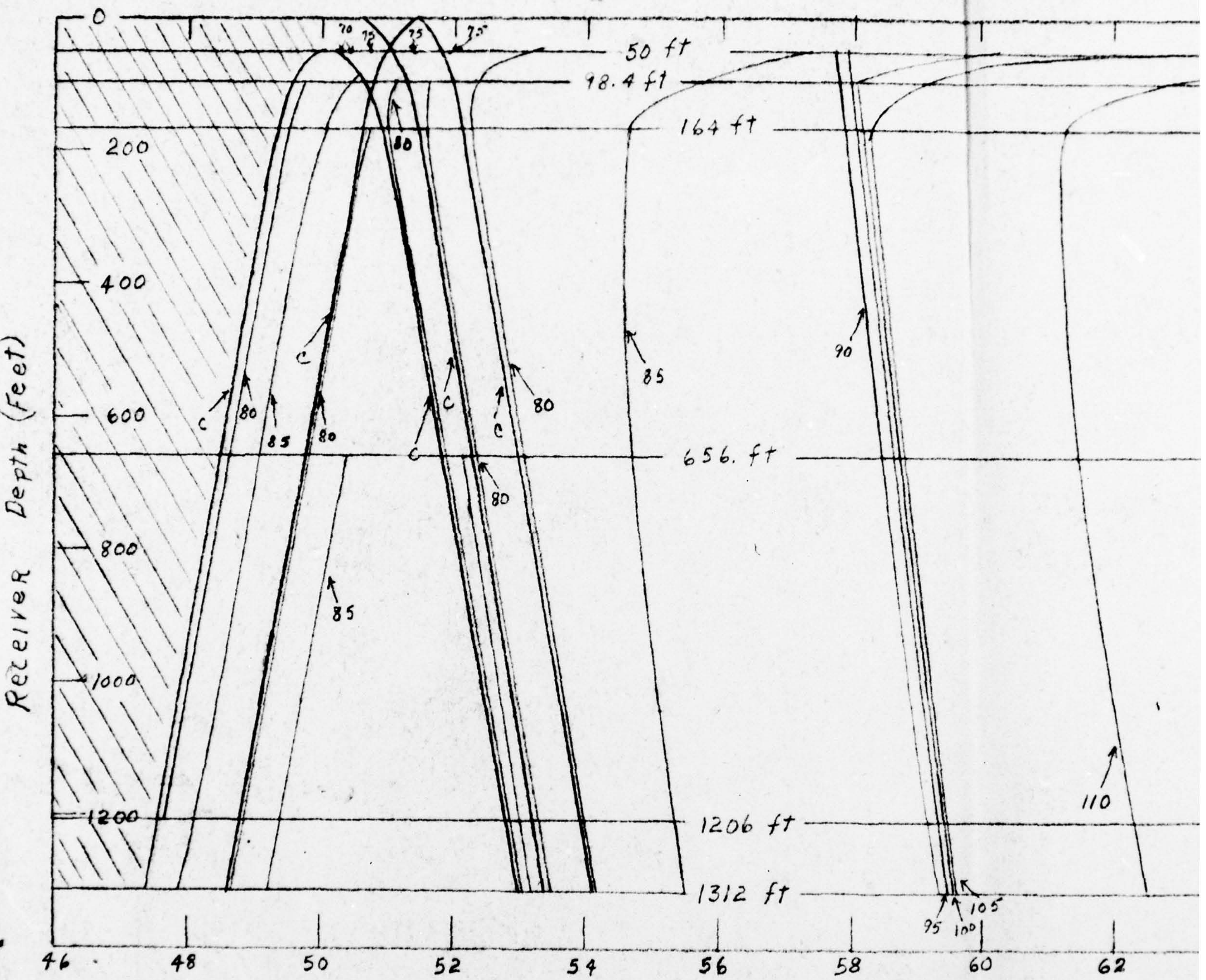
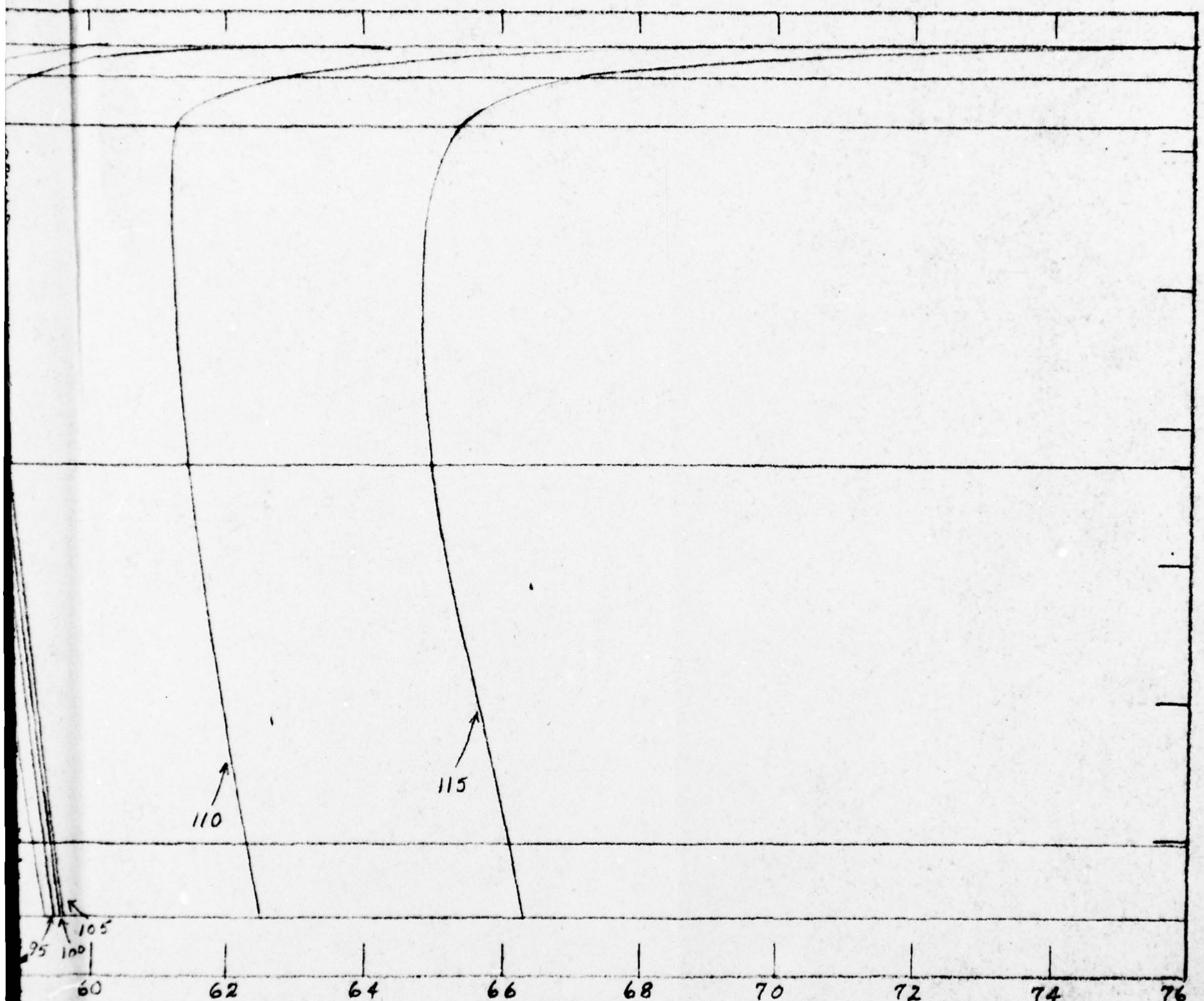


FIG. 7 LOSS CONTOURS for FIRST ZONE. SOURCE DEPTH 50
AREA C PROFILE II



(Kyds)
ource Depth 50 ft.

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2

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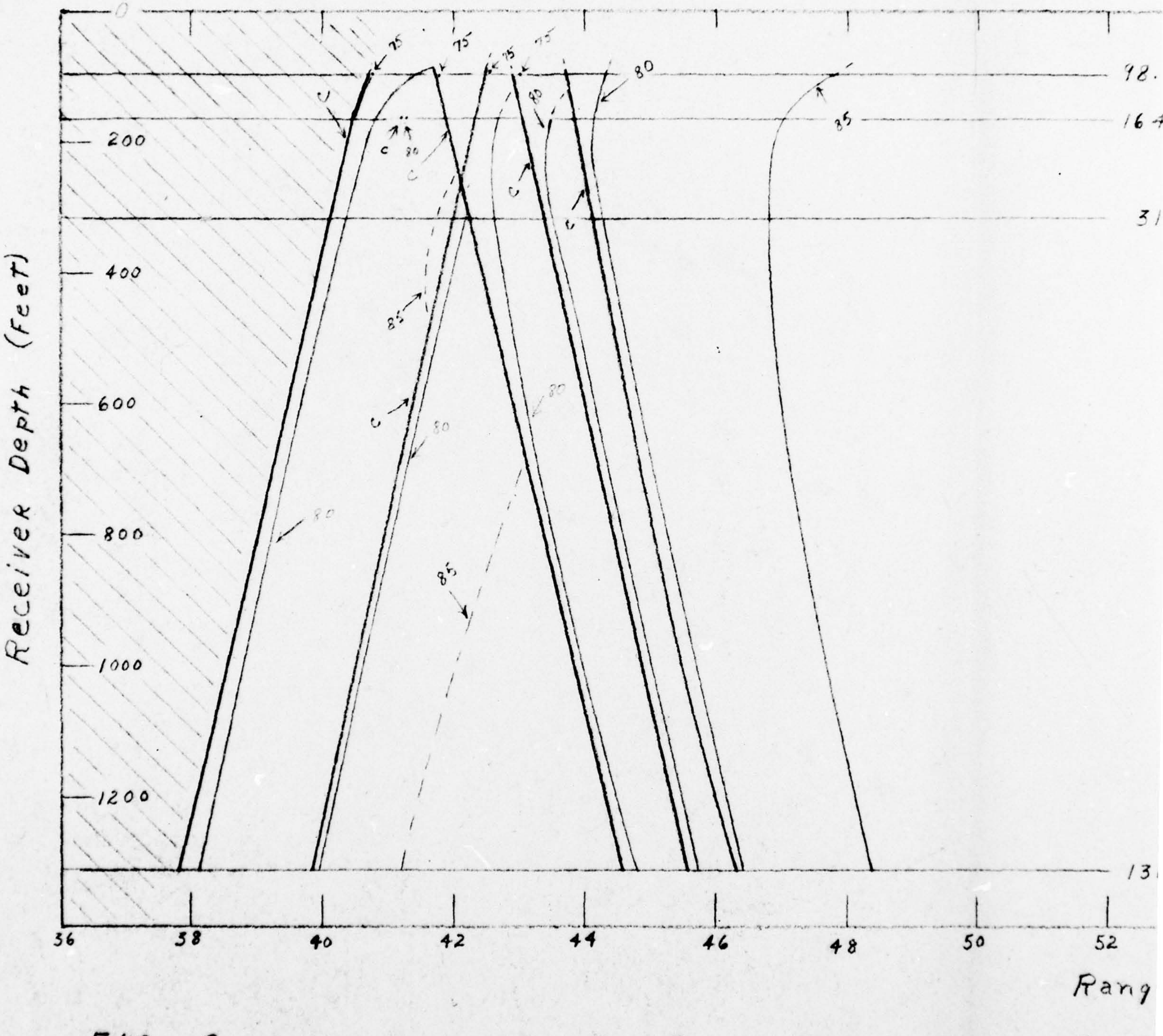
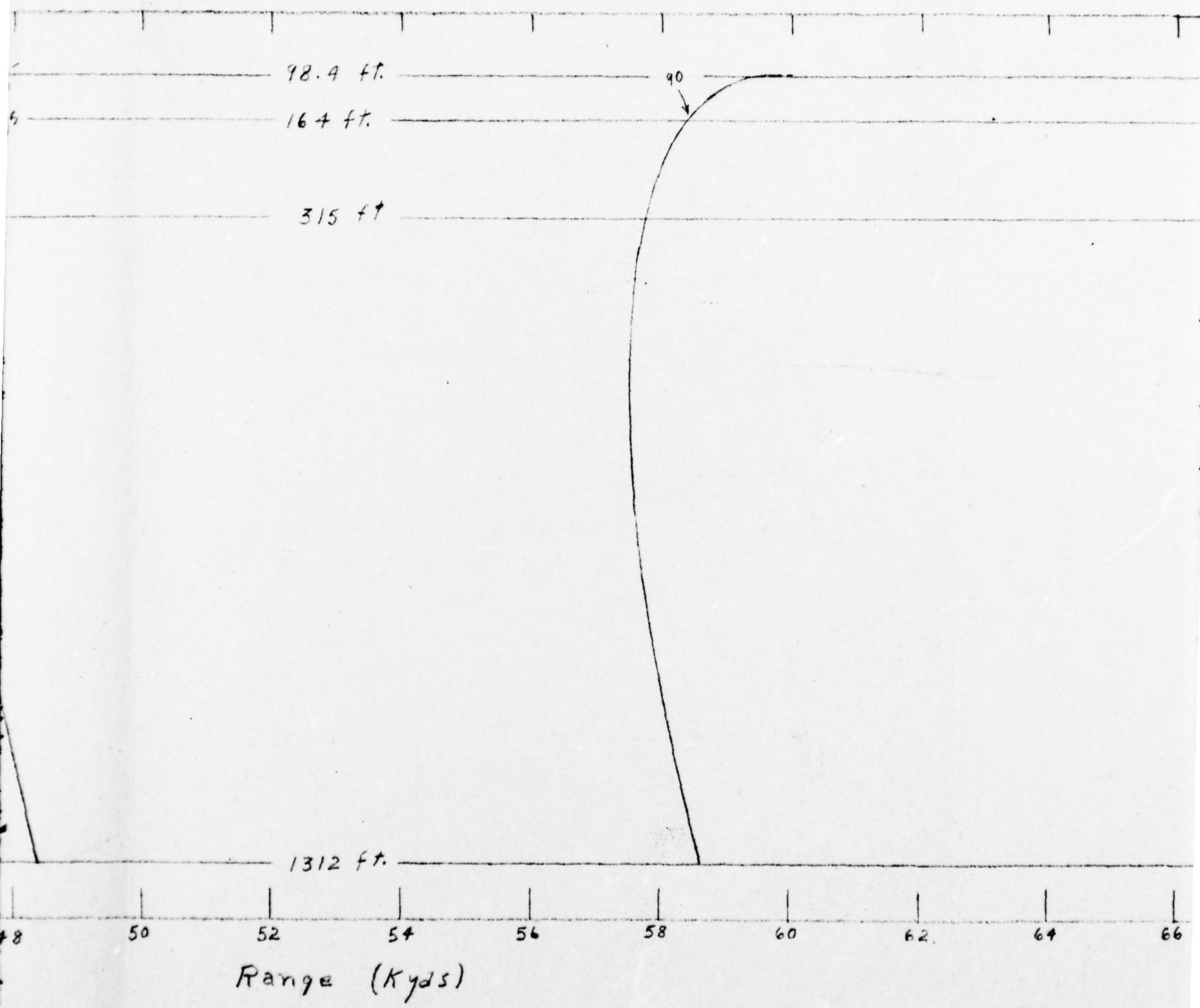
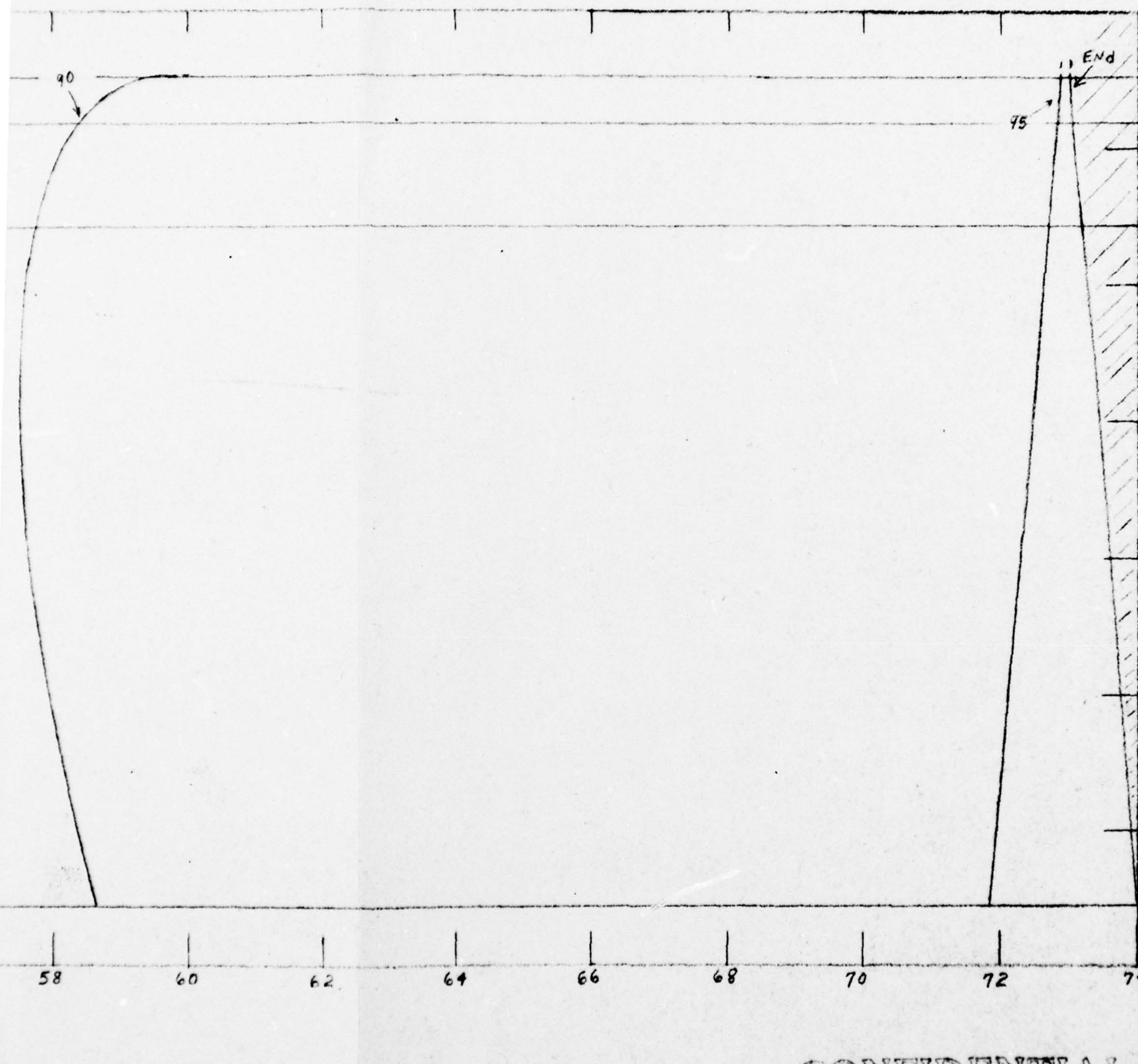


FiG. 8 LOSS CONTOURS FOR FIRST. ZONE. SOURCE Dept



NE. SOURCE Depth 50 ft. AREA D



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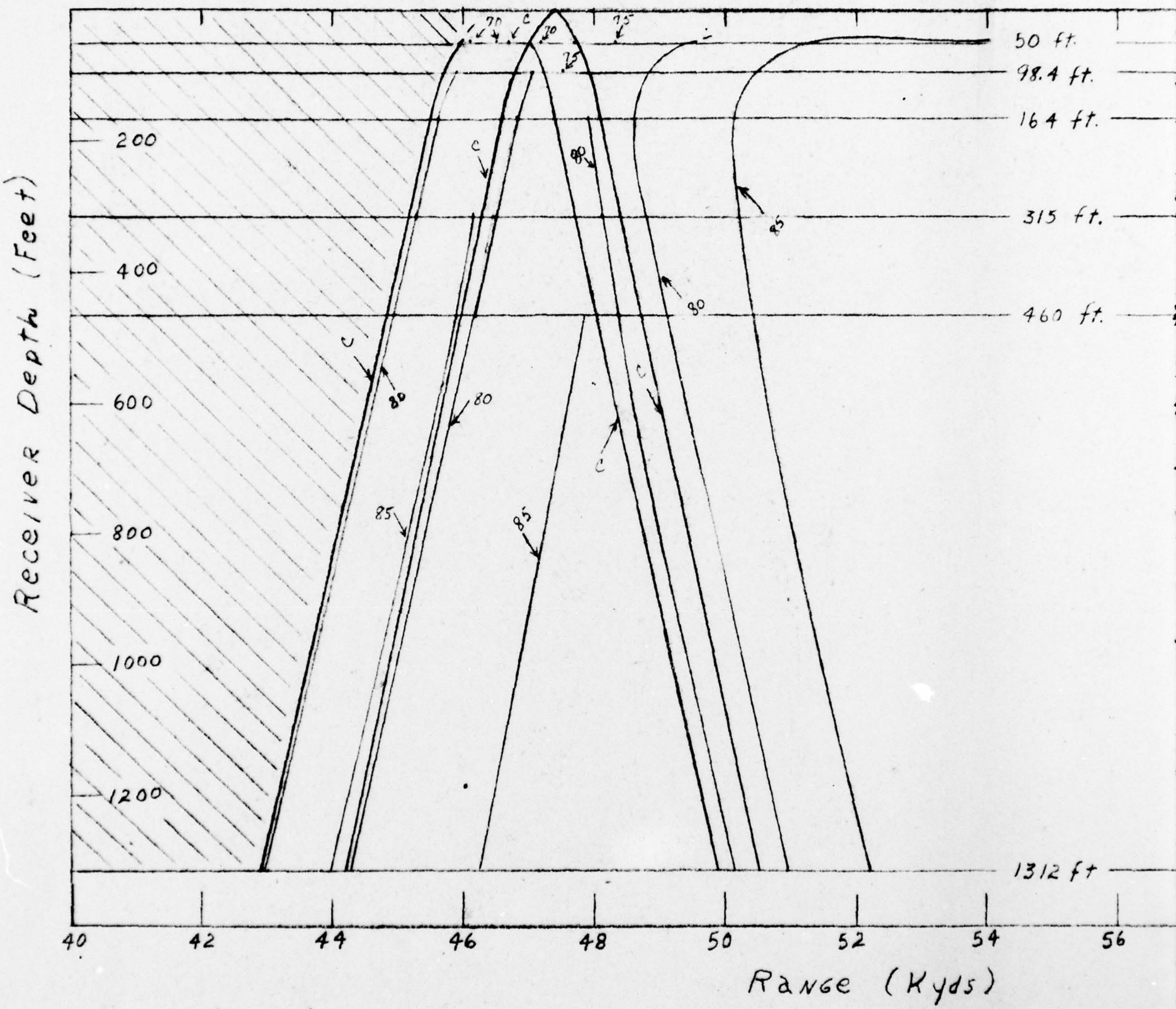
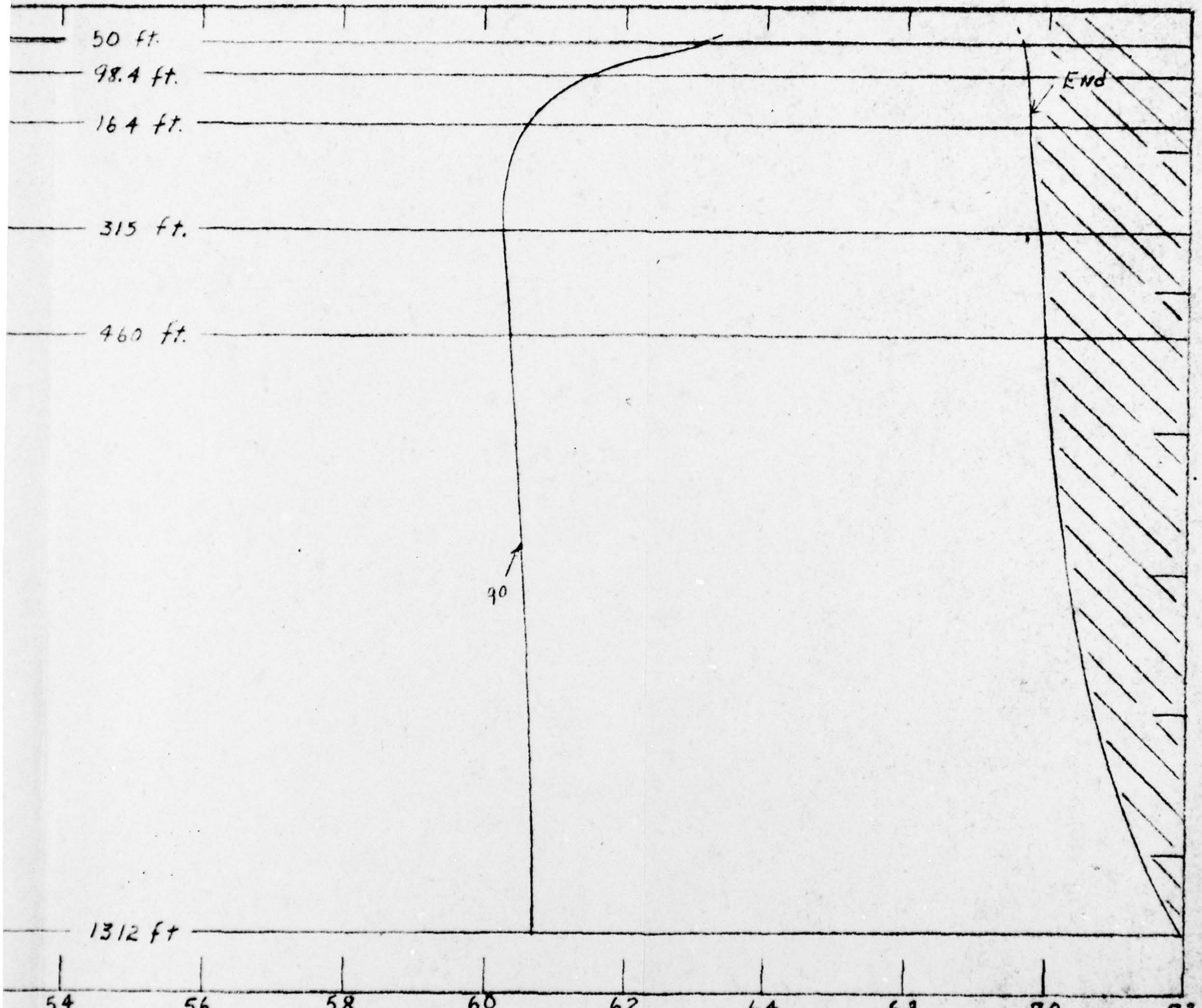


FIG. 9 LOSS CONTOURS for FIRST ZONE. Source Depth 50 Area E. Profile I.



yds)
urce Depth 50 ft.

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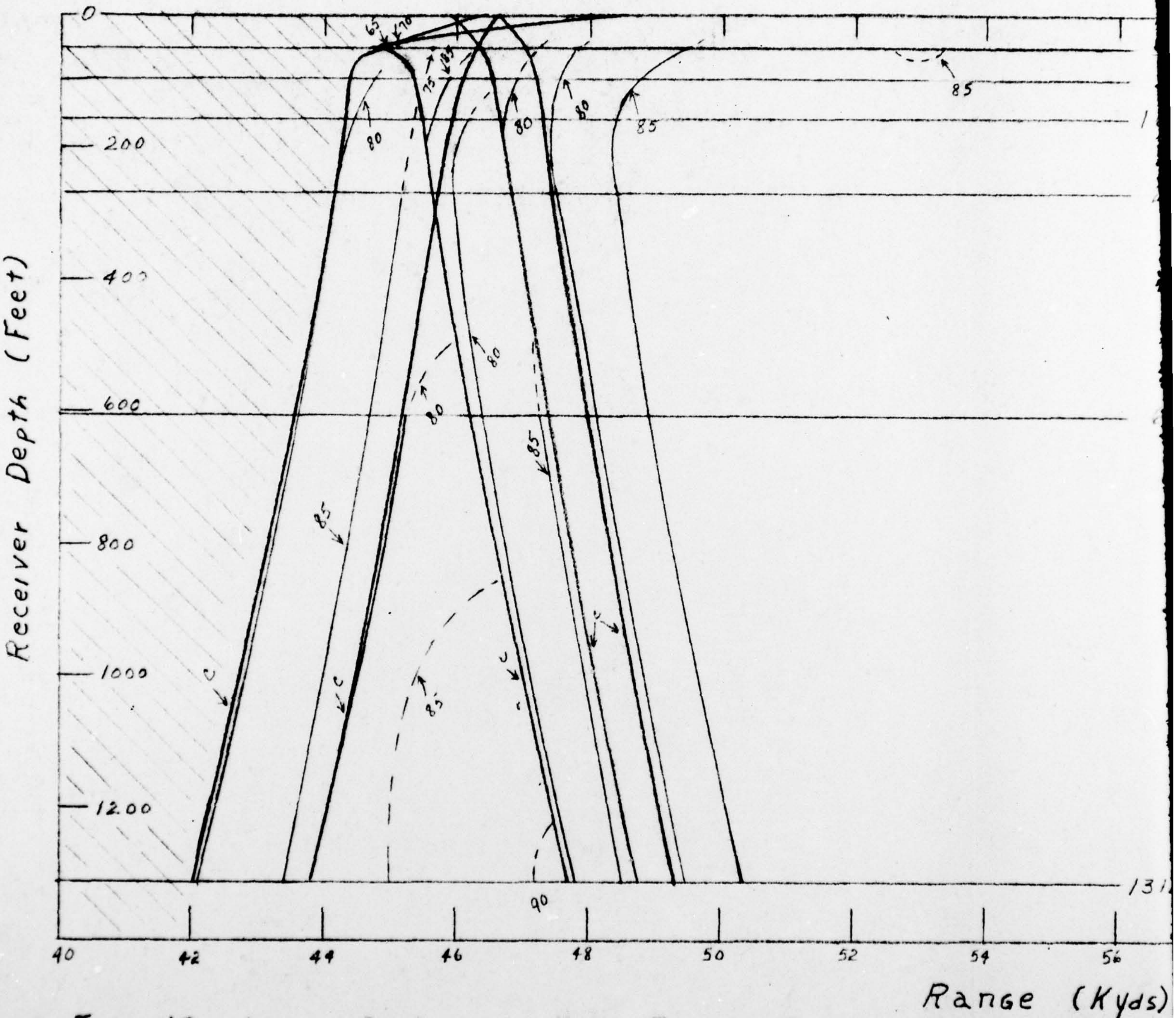
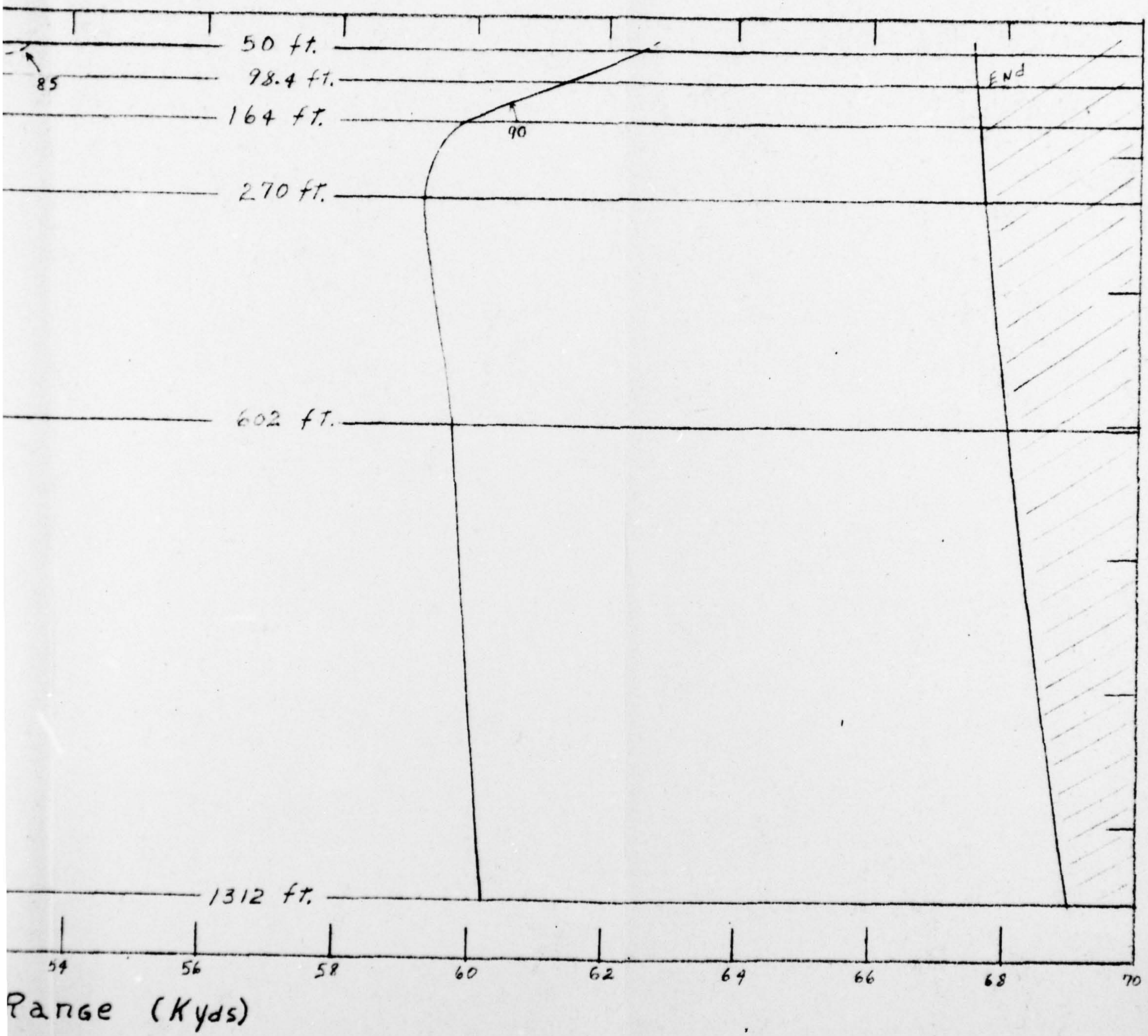


FIG. 10 LOSS CONTOURS FOR FIRST ZONE.
SOURCE DEPTH, 50 FT. AREA E. PROFILE II.


50 ft.
98.4 ft.
164 ft.
270 ft.
602 ft.
1312 ft.
85
90
End
54
56
58
60
62
64
66
68
70
Range (Kyds)

II.

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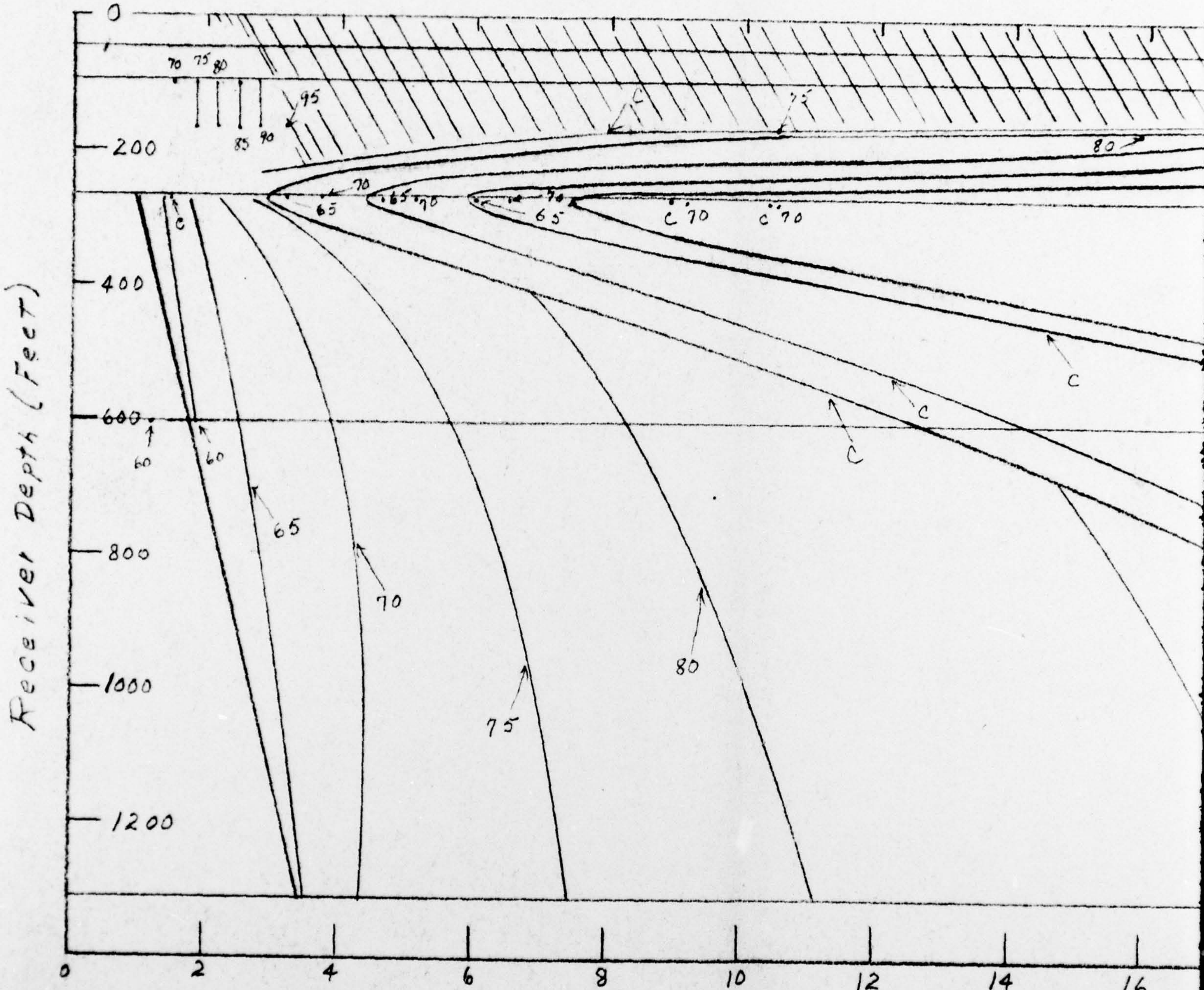
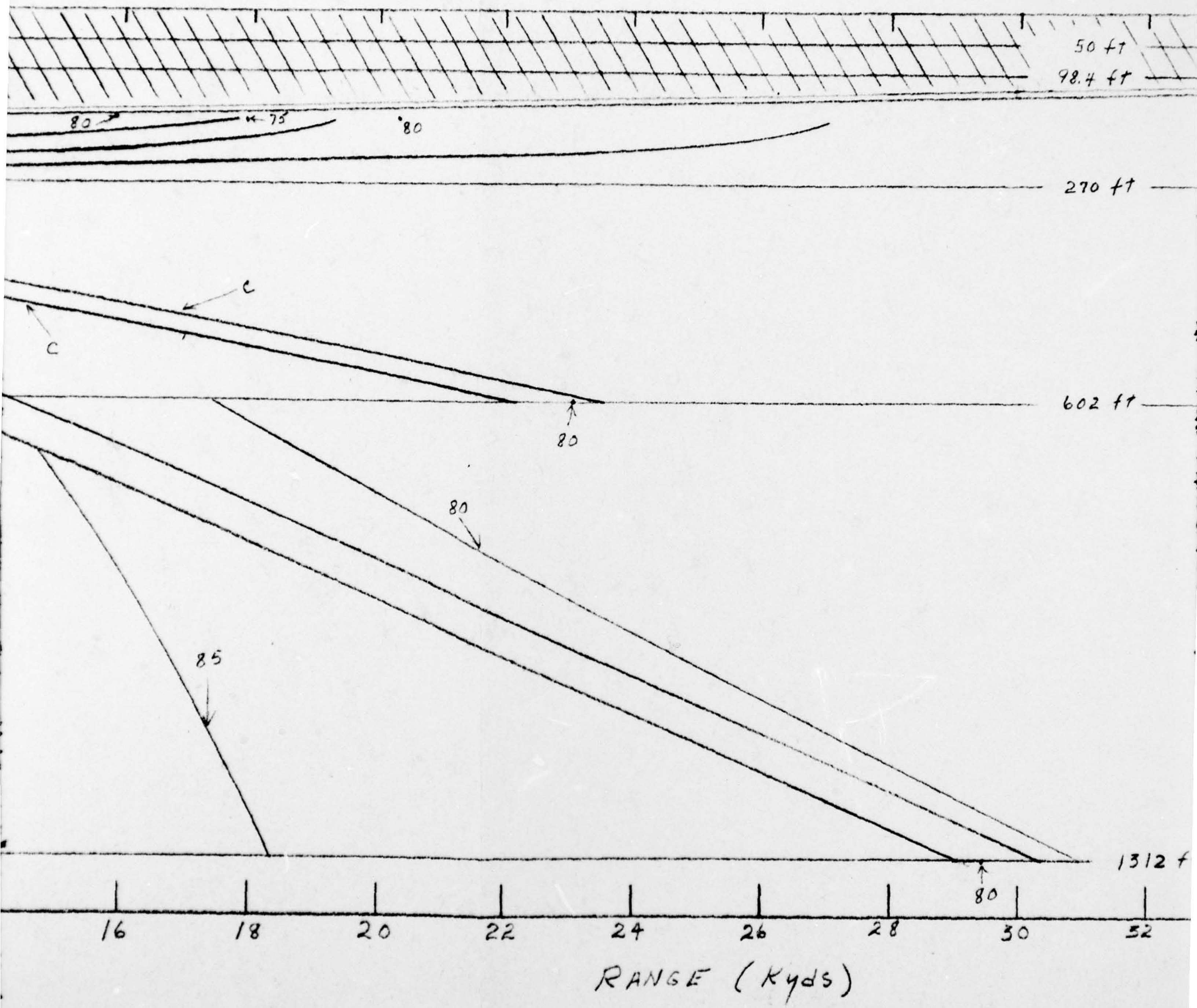
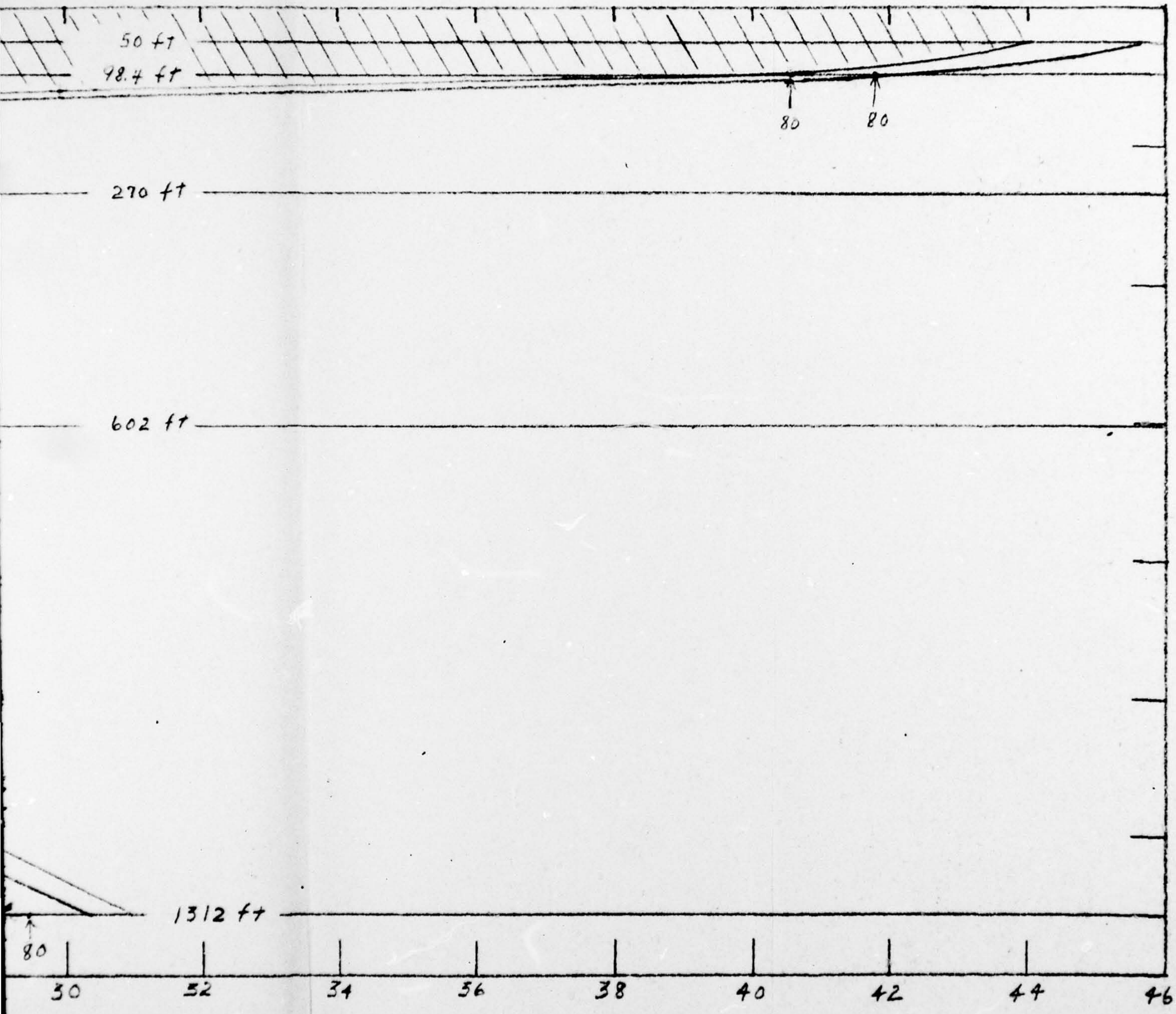


FIG. 11 LOSS CONTOURS. Source Depth 270 Feet H



Feet Area E · Profile II

2



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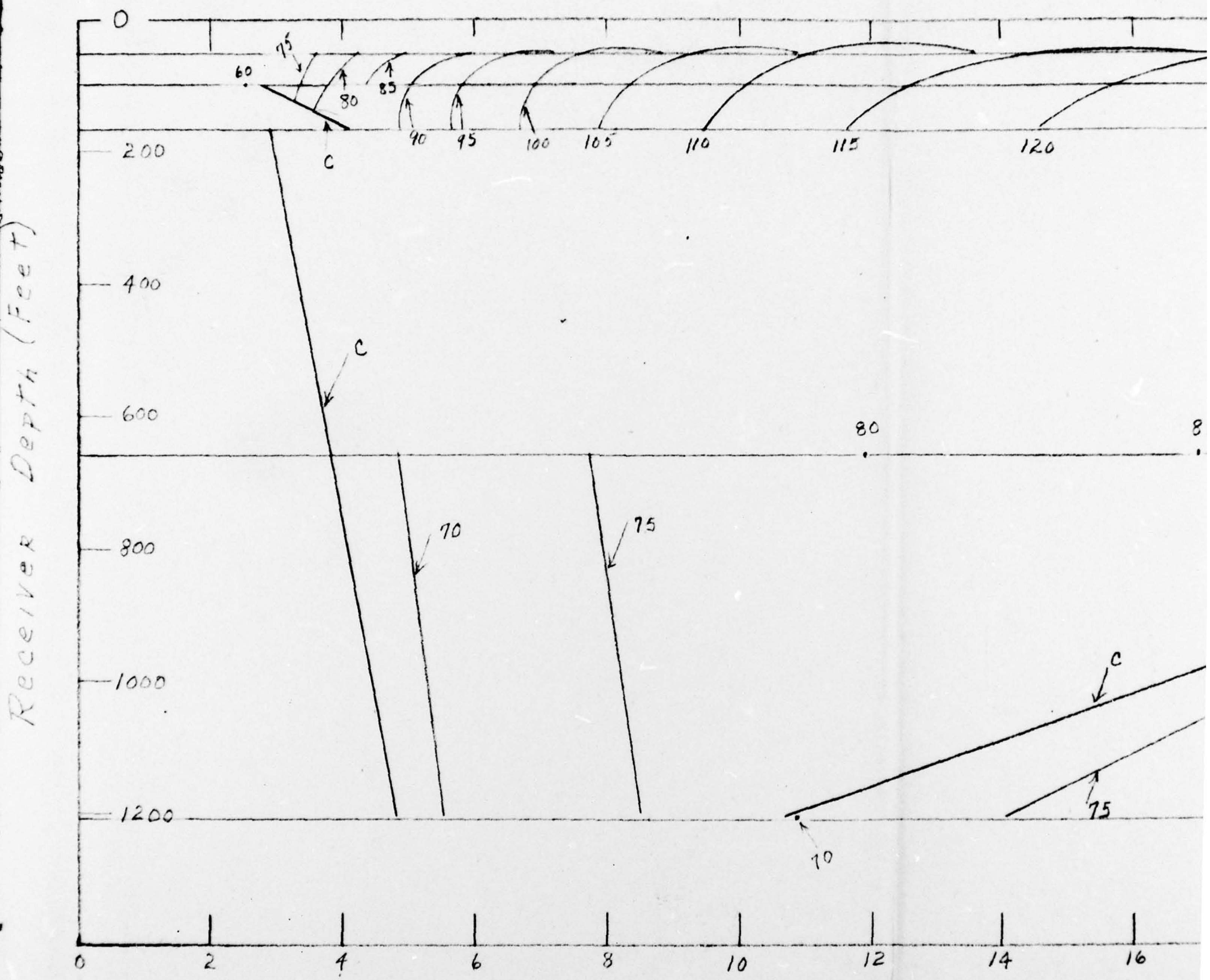
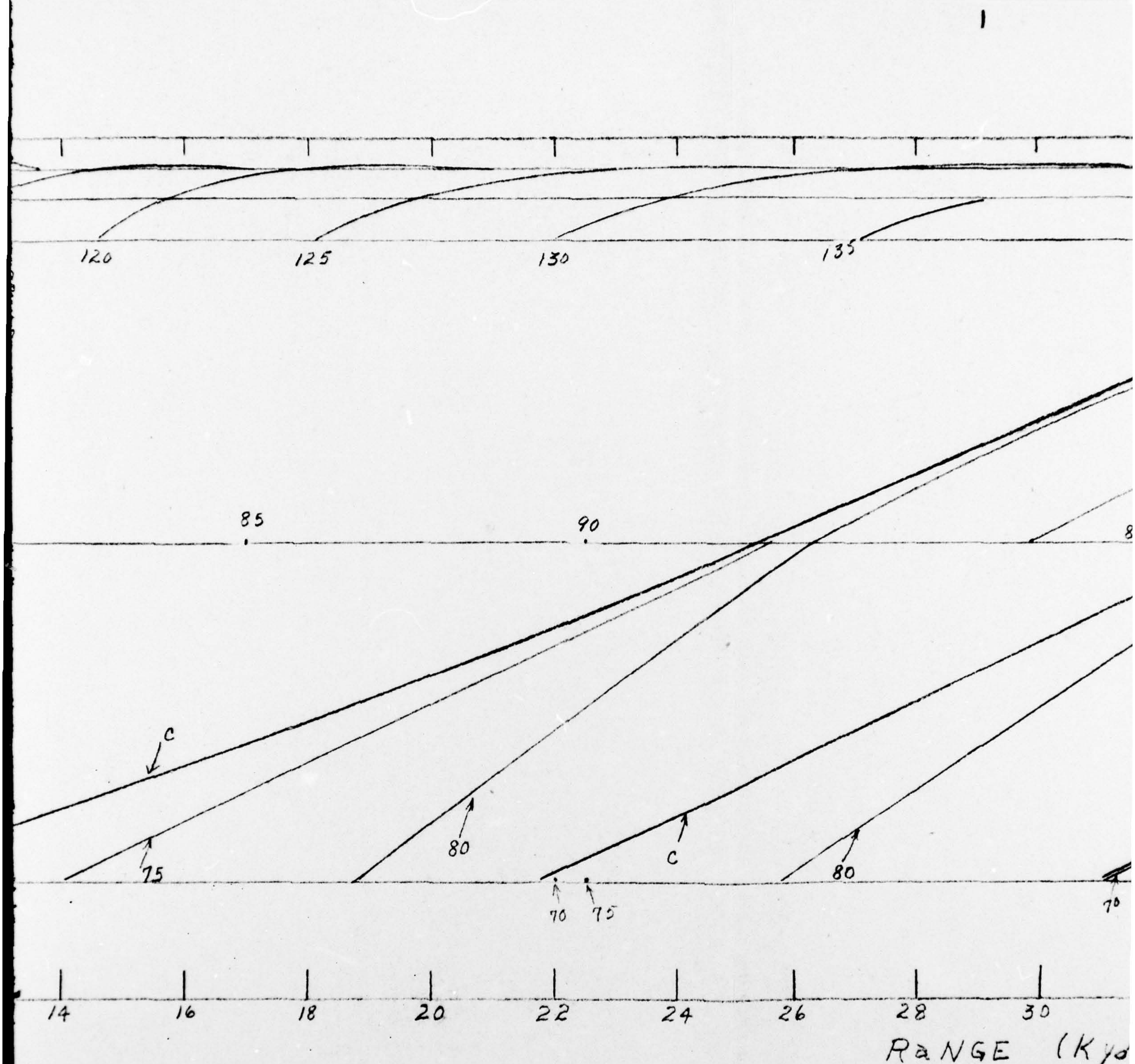
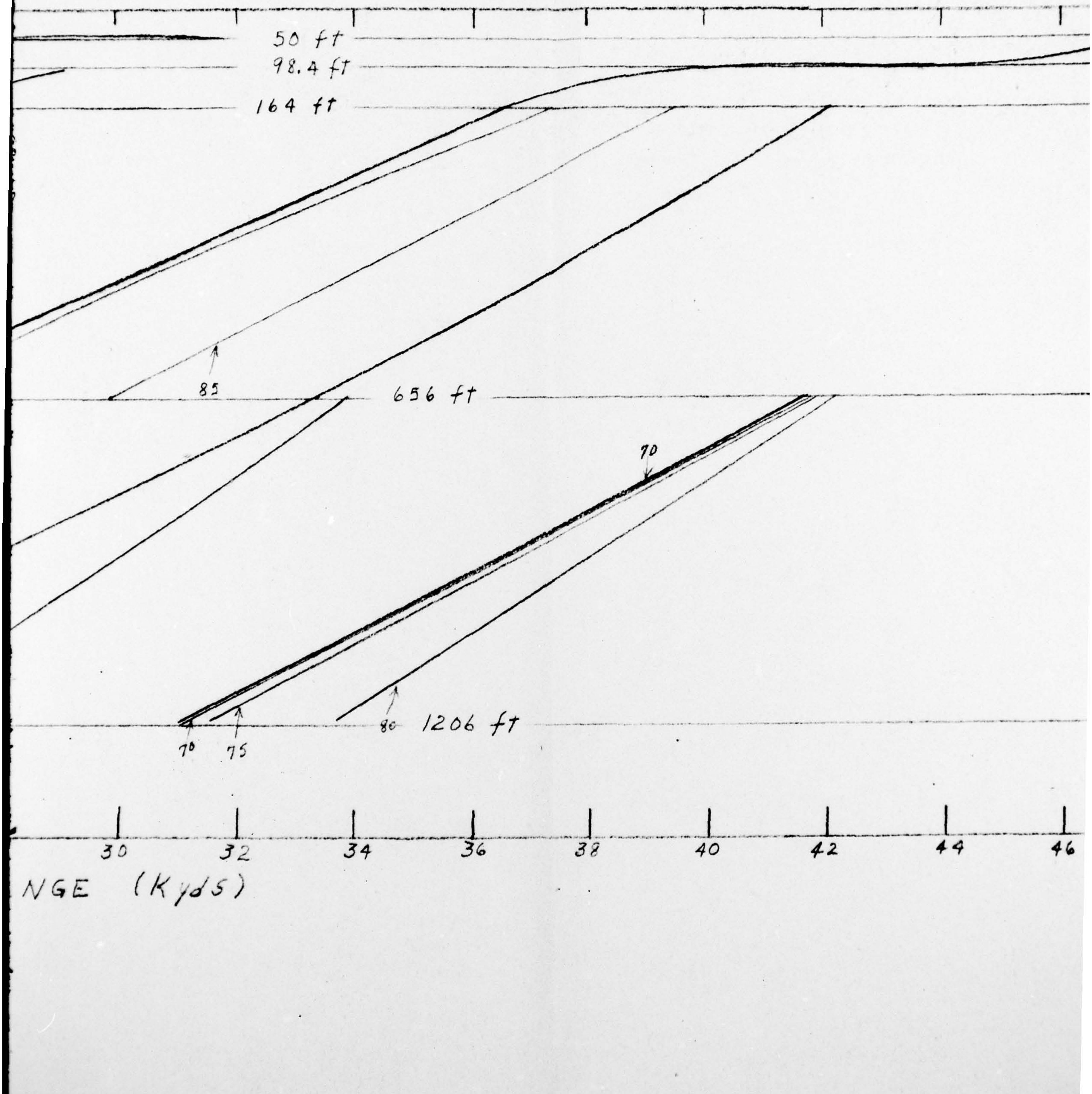


FIG. 12 LOSS CONTOURS. Source Depth 1312 Feet



1312 Feet Area C Profile II



50 ft
98.4 ft
164 ft
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1206 ft
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36
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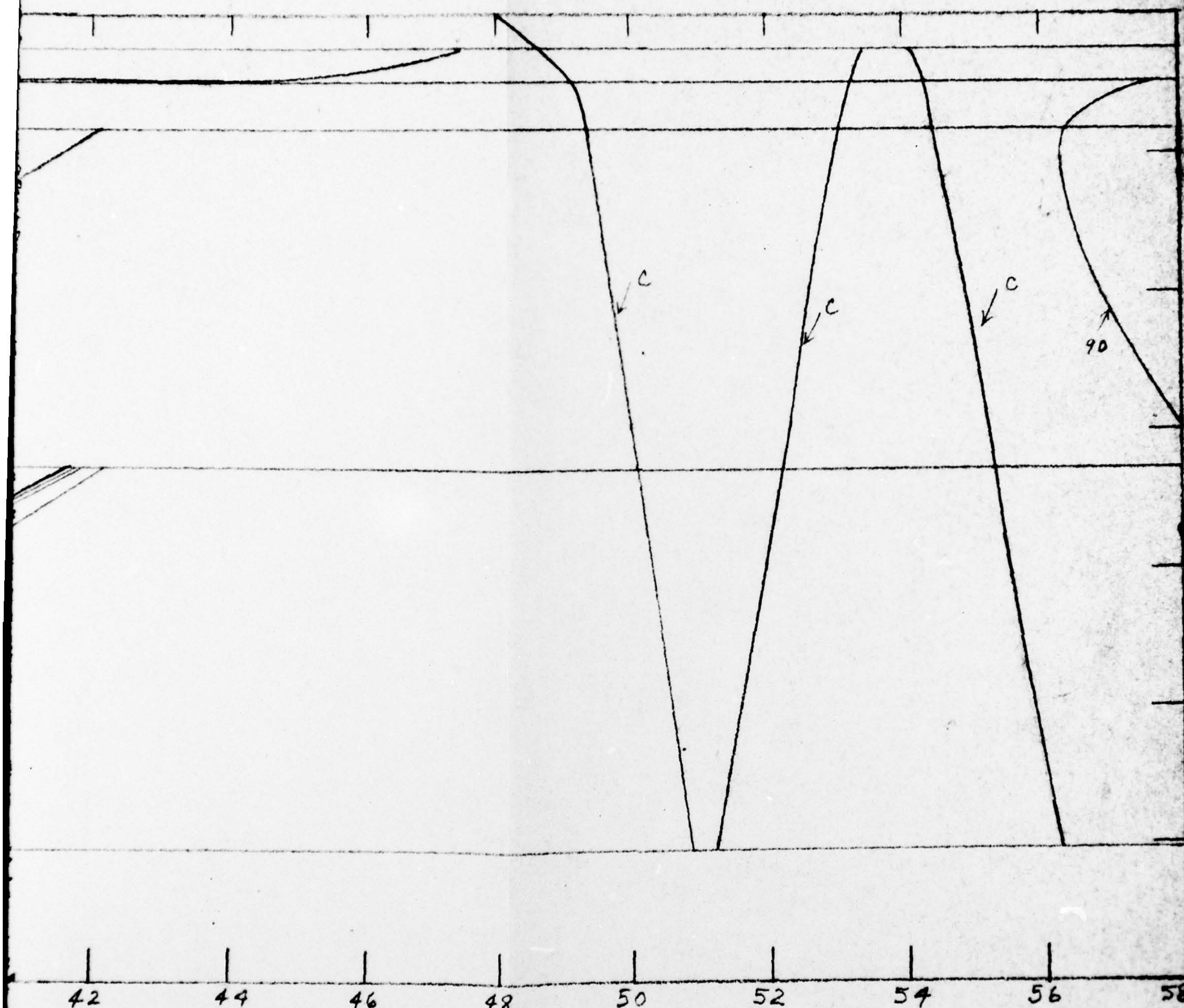
42
44
46
NGE (Kyds)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90
42
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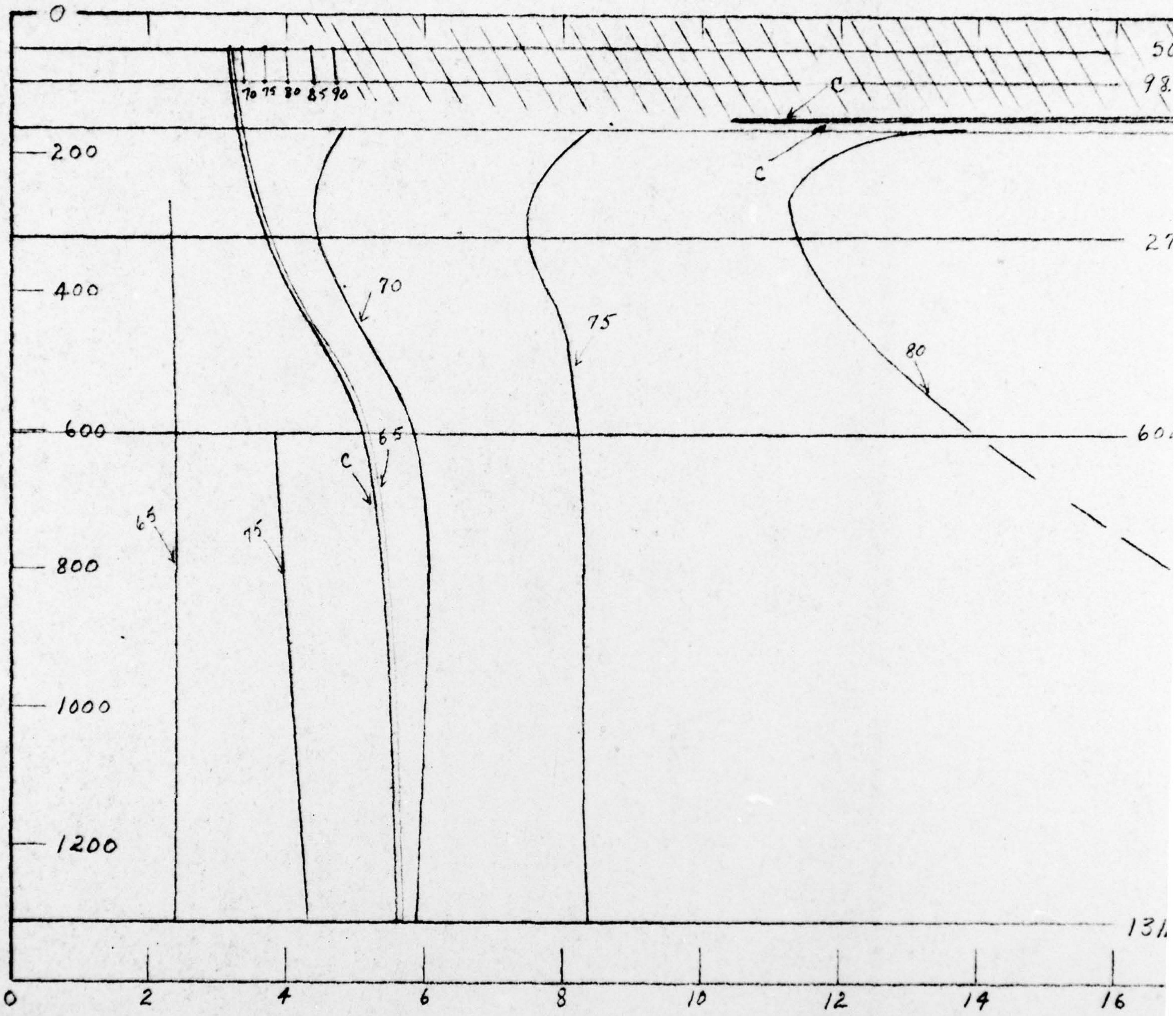
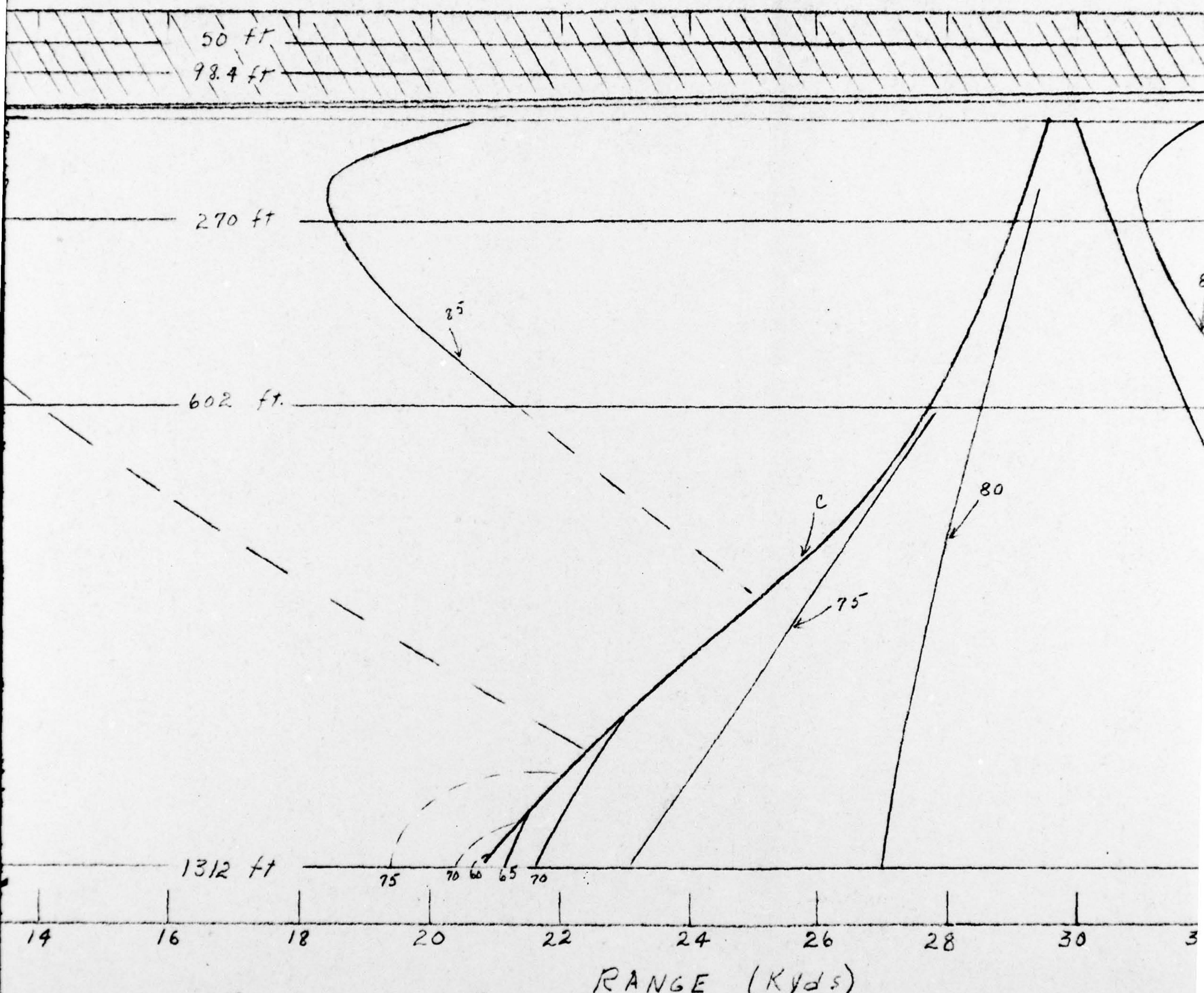
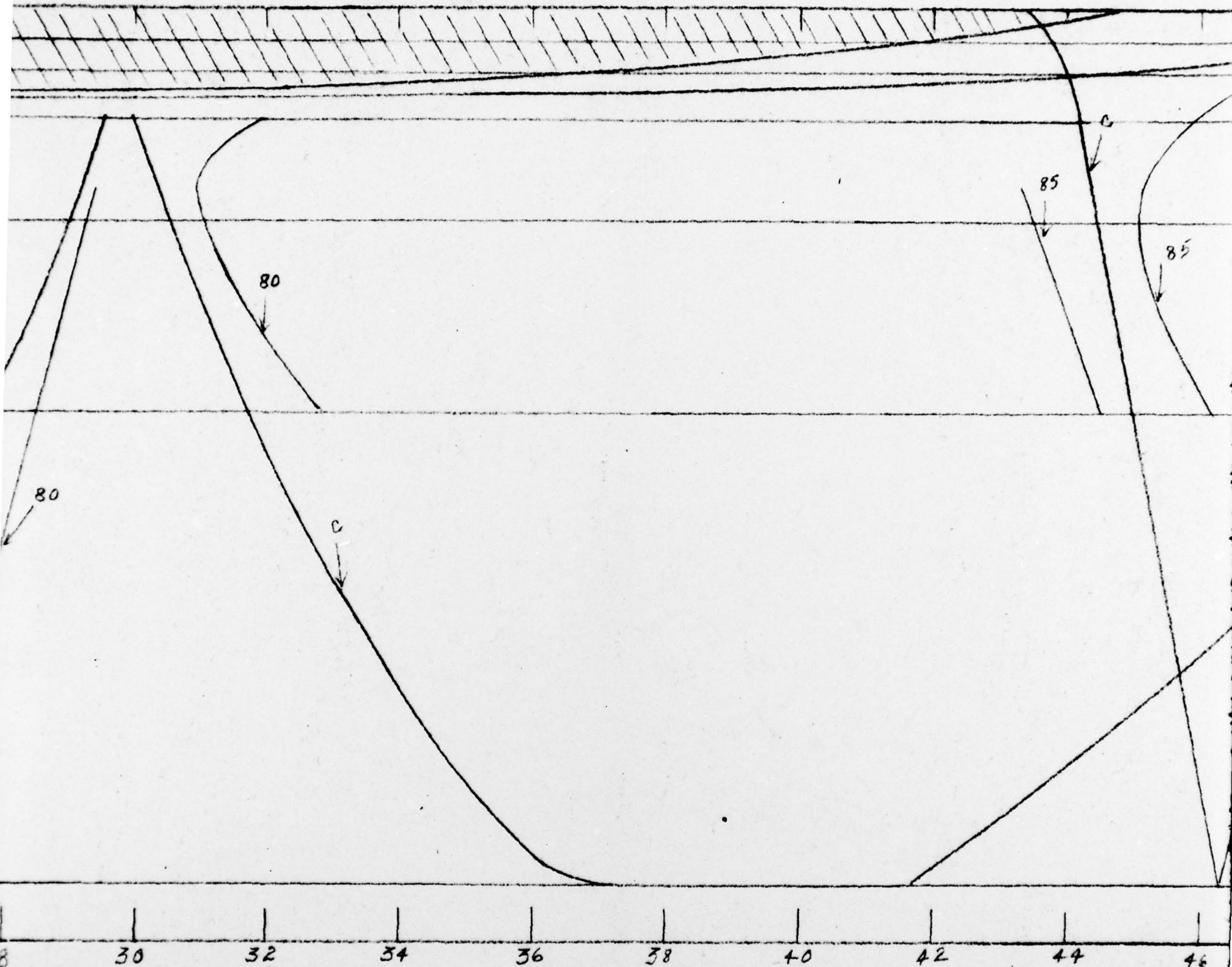


FIG 13 LOSS CONTOURS. SOURCE DEPTH 1312 Feet Area



Feet Area E Profile II



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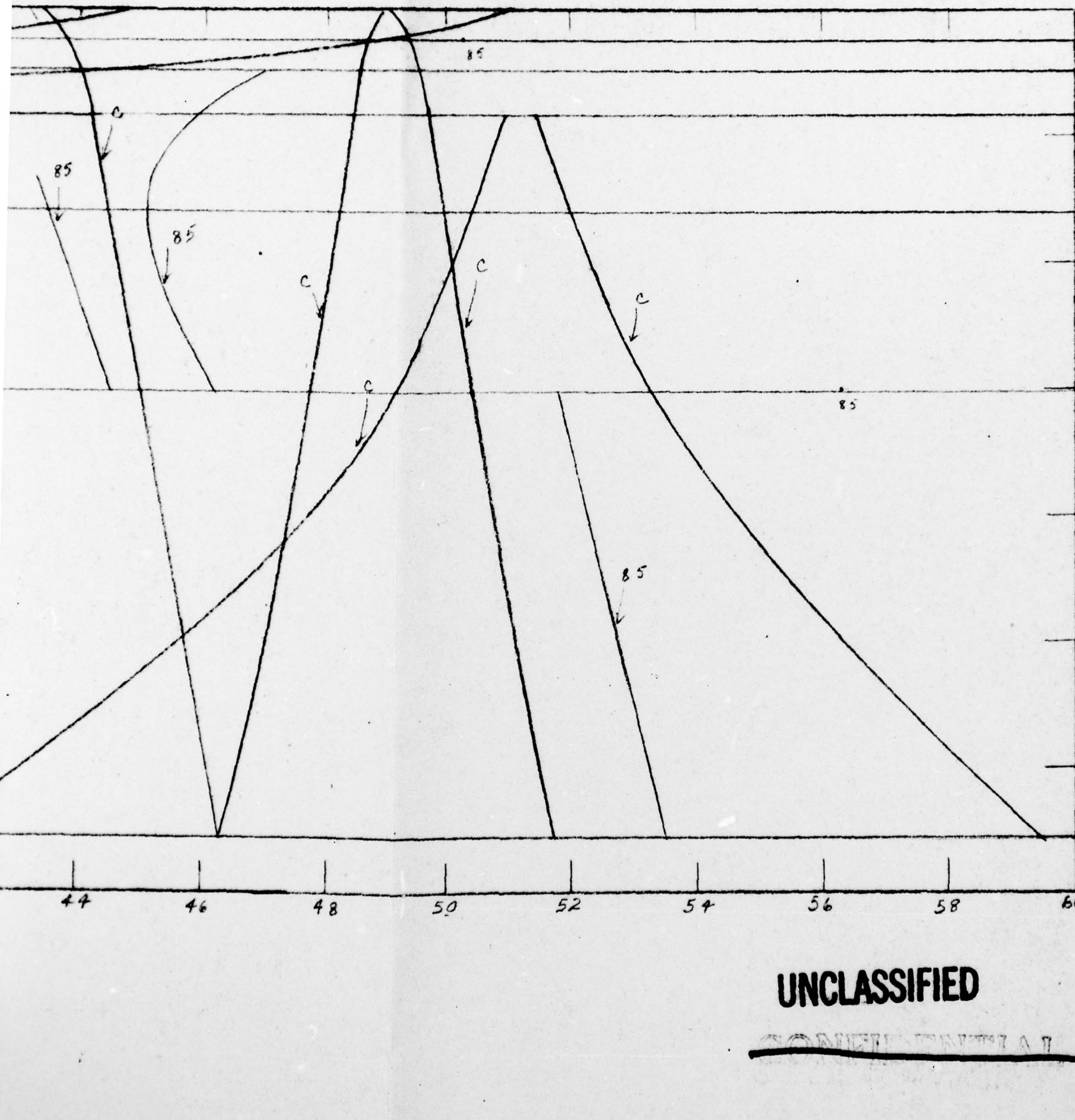

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