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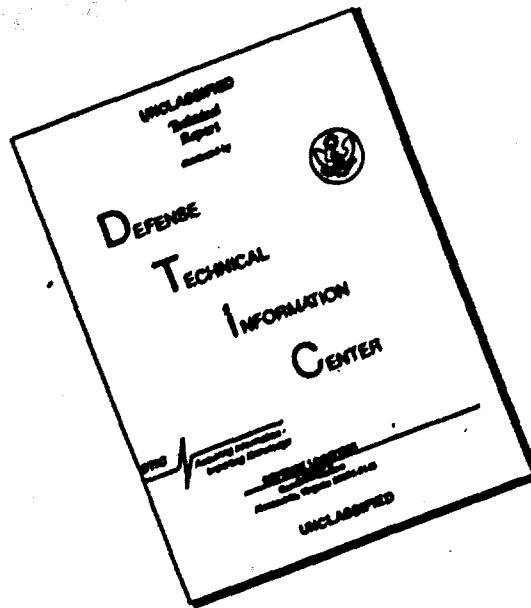
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Project NY 420 010
Technical Note N-195
5 August 1954

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technical note

TESTS OF CUSHIPS ANCHORS IN MUD AND SAND BOTTOMS

R. C. Towne and J. V. Stalcup

U. S. Naval Civil Engineering Research and Evaluation Laboratory
Port Hueneme, California

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Figure 1. Mud Bottom Test Site in San Francisco Bay.

INTRODUCTION

These anchor tests were conducted by the U. S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, California at the request of the Bureau of Ships. The tests were made in the mud bottom of San Francisco Bay at the San Francisco Naval Shipyard, Hunters Point, California, and in a sand bottom at Port Hueneme, California.

The purpose of the tests was to provide comparative holding power data of several lightweight and Navy stockless anchors presently being utilized by the Bureau of Ships.

This report contains a description of the tests together with the results and observations.

ANCHOR TEST APPARATUS

The test apparatus for mud bottom tests consisted of two 5 x 12 pontoon barges, used to carry the test equipment, and a 5 x 12 pontoon varying tug, used to drop and retrieve the anchors. The test equipment was composed of a 400,000-lb. capacity electric dynamometer to measure the holding power of the anchors and a model BU-140 Skagit winch with a six-part line for dragging the anchors. The winch was spooled with 2,500-ft of 1-3/8 in. diameter wire rope, and the wire rope was reeved through sheaves mounted on the two barges to form the six-part line. One of the 5 x 12 pontoon barges was anchored with two 30,000-lb. Navy Stockless anchors and the other barge was attached to the test anchor with suitable lengths of anchor chain. Figure 1 shows a general view of the barges at Hunters Point during the tests. In this view the test anchor is located beneath the buoy between the two furthest barges and the buoy in the right foreground locates one of the 30,000-lb. stockless anchors used to hold the barges in position.

The vertical force required to break the test anchor loose from the mud bottom at the end of each pull was measured by means of a strain gage mounted on the varying tug winch line. See Figure 2. Depth of water was approximately 30-ft at the test site.

The test apparatus for sand bottom tests consisted of a 20-ft gage railway, 300-ft in length, the open end of which is 100-ft above mean low tide; a 20,000-lb. gross weight, traveling instrument car; and a winch mounted on a stationary platform at the in-shore end. See Figure 3. The instrument car was fabricated to simulate the movement of a ship dragging its anchor and to carry a 400,000-lb. capacity electric dynamometer. Figure 4, to measure the holding power of the anchors. A portable, dry-cell battery powered, indicator was used to record the holding power.

SOIL SAMPLES

Samples of the mud were taken in the path of the test pulls down to a depth of 20-ft. A mechanical analysis was conducted by the Soils Division of the Laboratory. See Table I. A soil shear strength and water content analysis of the bay mud are shown in Table II.

A mechanical analysis of the sand at the Port Huenehue test site showed 95 per cent sand particles, 92 per cent of which was finer than 0.6 mm, the remainder being less than 2.0 mm in size.

TEST ANCHORS

The test anchors consisted of a 2,000-lb., 3,000-lb., 4,000-lb. and 10,000-lb. Lightweight; a 4,000-lb., 8,000-lb. and 17,000-lb. Navy stockless; and a 2,110-lb. British Mulock. The Mulock anchor is equipped with a 12-in. long stabilizer fabricated from 2-in. steel round stock. See Figures 5, 6, 7, 8, 9, and 10. In order to improve the holding power of the LWT anchors, the 2,000-lb., 3,000-lb., and 4,000-lb. LWT anchors were modified as per BuShips instructions to a full fluke shape by welding fluke extension plates to the base of the conventional fluke and these anchors were retested in both mud and sand. See Figure 11. Two new design Baldt anchors, 3,170-lb. and 3,650-lb., and a 3,060-lb. Croseck anchor were also tested. See Figures 12, 13, and 14.

TEST RESULTS, MUD BOTTOM

The 2,000-lb., 3,000-lb., and 4,000-lb. Lightweight and 4,000-lb., and 8,000-lb. Navy stockless anchors were pulled at chain angles of 0-, 6-, and 12-degrees. The proper chain lengths for 0-, 6-, and 12-degree chain angles were obtained by the formula presented in the U. S. Navy Technical Publication entitled "Mooring Guide" NavDocks TP-pv-2. The remainder of the anchors were pulled at a zero degree chain angle only. Six tests were conducted with each anchor at each chain angle. Results of these tests are contained in Table III. Figs. 15 through 38 are graphs of the six test pulls on each anchor showing holding power versus anchor travel. Figures 33, 34, and 35 are the graphs of the 2,000-lb., 3,000-lb., and 4,000-lb. LWT anchors with fluke extension plates. The holding power, breakout force, and chain angles for each anchor are shown in the table.

Initial tests on the 3,170-lb. new design Baldt anchor showed a holding power to anchor weight ratio of 2.36 to 1 at a zero degree chain angle. This low ratio, for an anchor of this design, indicated that the flukes were not opening properly as the chain length was shortened, to lift the shank slightly thus opening the flukes, and the anchor was retested. Holding power ratio was increased to 6.62 to 1.

Test pulls of the anchor chain alone were made at 10° to determine the resistance of the chain dragging through the sand bottom. The average holding power of 210-ft of 2-3/4 in. anchor chain was 11.1 kips and for 180-ft of 1-1/2 in. anchor chain, 1.7 kips.

TEST RESULTS, SAND BOTTOM

Six tests were conducted with each anchor at zero degree chain angle only. Results of these tests are contained in Table IV. Figures 24 through 31 are graphs of the six test pulls on each anchor showing holding power versus anchor travel.

Test pulls of the anchor chain alone showed an average holding power of 23.3 kips for 210-ft of 2-3/4 in. anchor chain and 3.0 kips for 180-ft of 1-1/2 in. anchor chain.

The tests conducted in the beach sand above the water line indicate a higher holding power than the same anchors will produce in sand under water. This is due to the different in-place densities of the sands above and below water. The sand being less dense under water¹. The indicated holding powers on the beach are approximately 33 per cent higher than under water.

OBSERVATIONS

The holding power of individual anchors may be low when pulled in a mud or sand bottom due to the failure of the flukes to open in mud or because the flukes open too wide in sand. The flukes fail to open in mud bottom due to insufficient area in the tripping plates in relation to the large area in the flukes. In the initial setting of the anchor, the flukes are normally parallel to the bottom and are supported underneath by the mud. In this position there is nothing of sufficient resistance to cause them to drop down and dig into the mud.

In sand bottom the anchors which have a large fluke opening, approximately 49-degrees, will open up but will not bury into the sand due to the incorrect angle of pull on shank and flukes. This condition has been observed while testing on the beach where the anchors are visible and is also indicated in the comparison of the holding powers when the chain angle is changed from zero degrees to six and twelve degrees in mud bottom. For the Lightweight anchors, the holding power at 12-degree chain angle was actually higher in two instances than at 6-degree chain angle. See Table III. For the Stockless anchors, the increase of holding power from zero degree chain angle to 6-, and 12-degrees is only slight after dragging 50-ft and becomes greater as the anchor is dragged further. The larger chain angle

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1. NAVFACRELAB Technical Memorandum M-266, Test of Anchors for Mooring and Ground Tackle Design by R. E. Towne, 10 June 1953, p. 13 and BUDOCKS Soils Laboratory Report, Sand Samples, Anchor Tests, Steel & Concrete-Steel Anchors, by L. A. Palmer, 5 January 1950.
-

apparently tends to lift the anchor shank and thereby open the flukes and permit them to start digging into the mud. This was shown in the tests on the new design 3,170-lb. Baldt anchor when the chain length was shortened and the holding power ratio to anchor weight was increased from 2.35 to 1 up to 6.62 to 1.

Stockless anchors have been tested in mud bottom with the flukes fixed at their maximum fluke opening and the holding power to weight ratio averaged 4.24 to 1, compared to 2.49 to 1 for the same anchors without the flukes fixed in an open position, indicating further the inability of the anchor flukes to assume an open position. Anchors utilized in these particular tests were a 6,000-, 10,000-, and 20,000-lb Navy stockless.

The Mulock anchor stabilizer is of insufficient length, 12-in., to prevent rotation, thereby reducing its maximum holding power. The anchor started to penetrate the sand bottom rapidly but would rotate 180-degrees and pull out in a short distance.

The new design Baldt anchors were designed primarily for mud bottom and due to the large fluke opening, 50-degrees, would not penetrate the sand bottom properly and resulted in a lower holding power than would normally be expected from an anchor of this design.

Previous tests made in sand bottom have shown that a fluke angle of 35-degrees produces the maximum holding power for the anchors in sand bottom and preliminary tests in mud have indicated that a larger fluke angle of approximately 50 to 70 degrees will produce the maximum holding power. These fluke angle tests in mud bottom are being continued.

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1. (See page 3.)
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TABLE I
MECHANICAL ANALYSIS
Hunters Point Mud

Depth - ft	Very Fine Sand .05 - .075 mm	Silt* .005 - .075 mm	Clay* .001 - .005 mm
0-1	40	30	30
10-11	2	48	50
19-20	--	40	60

* Per cent by weight

TABLE II
SOIL SHEAR STRENGTH AND WATER CONTENT *
Hunters Point Mud

Depth - ft	Unconfined Compressive Strength - psf	Shear - psf (1/2 U.C.S.)	Cohesion - psf	Natural Water Content - %
12	195	97.5	97	61.4
22	325	162.5	162	71.0
32.5	504	252.0	252	75.0
42.5	230	115.0	115	79.0
52.5	80	40.0	40	72.0

* From KAWCERLAB Technical Memorandum H-049, Grouting in Soft Soils by Philip P. Brown dated 21 May 1953.

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TABLE III

Holding Power Data of Steel Anchors tested in Mud Bottom at Hunters Point

Anchor	Wt.-lb	Fluke Angle	Average Holding Power length of drag		Minimum Holding Power length of drag		Chain Angle Degrees	Average Break-off Force-lb
			50-ft	100-ft	50-ft	100-ft		
Lightweight	2000	29	7500	7900	5000	5700	0	5300
"	2000		5400	6700	4200	5300	6	3500
"	2000		5800	6800	4800	5700	12	3100
Lightweight	3000	30	11700	12600	8600	8600	0	8900
"	3000		10000	12600	7700	8600	6	7500
"	3000		8400	10200	4800	6700	12	8300
Lightweight	4000	30	11400	13200	7700	9600	0	7100
"	4000		8700	13500	5700	9600	6	6200
"	4000		9500	12200	6700	8600	12	9700
Lightweight	10000	30	18800	20900	13100	17700	0	12700
Navy Stockless	4000	45	10800	12900	5700	7700	0	5800
"	4000		10000	11400	5700	6700	6	5200
"	4000		8000	8800	6700	7700	12	5000
Navy Stockless	8000	49	15900	18800	15300	14400	0	15000
"	8000		15900	18600	14400	15300	6	14000
"	8000		13200	14300	11500	13400	12	14300
Navy Stockless	17000	49	33300	41600	30600	38300	0	34000
British Willock	2110	33	5700	6500	4700	4700	0	—
Lightweight w/ fluke extension plates	2000	29	8400	9400	7700	7700	0	8100
	3000	30	11700	14900	9600	13400	0	9900
	4000	30	17300	20400	12400	15300	0	11200
New Design Balldt	3170	50	21000	30200	12100	14000	0	17400
"	3650	50	12800	14900	9300	8400	0	8500
Croceck	3060	51	23500	35600	14300	21000	0	17300

TABLE IV

Holding Power Data of Steel Anchors Tested in Beach Sand at Port Huereze

Anchor	Wt.-lb	Fluke Angle	Average Holding Power length of drag 50-ft	Average Holding Power length of drag 90-ft	Minimum Holding Power length of drag 50-ft	Minimum Holding Power length of drag 90-ft
Lightweight	2000	29	26400	24500	21000	21000
"	3000	30	42000	43900	38200	40100
"	4000	30	52800	54500	49700	47800
"	10000	30	109600	127300	93500	120500
Navy Stockless	4000	45	8500	19400	5700	5700
"	8000	49	28300	27400	22900	15300
"	17000	49	66300	60800	57400	59300
British Mulock	2110	33	8500	9800	5700	5700
Lightweight w/ fluke extension	2000	29	31200	32400	30500	24800
"	3000	30	42400	49700	40100	45300
"	4000	30	62400	73700	59300	65000
New Design Baldt	3170	50	31100	27700	22900	17300
"	3650	50	43000	41400	11400	5700
Crooseck	3060	51	18700	12300	13500	11400

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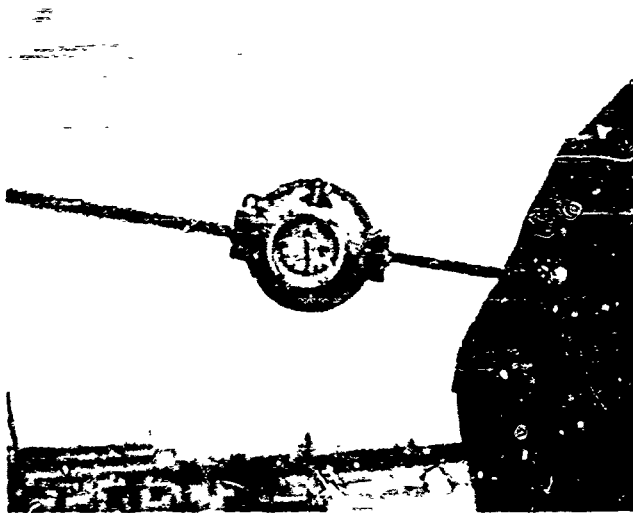


Figure 2. Strain gage used to measure break-out force of anchors in mud bottom.

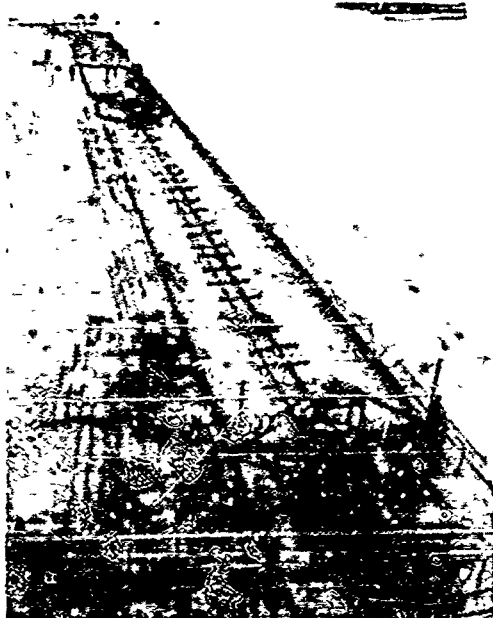


Figure 3. Test apparatus used to pull anchors in beach sand.



Figure 4. 500,000-lb. capacity electrical dynamometer.

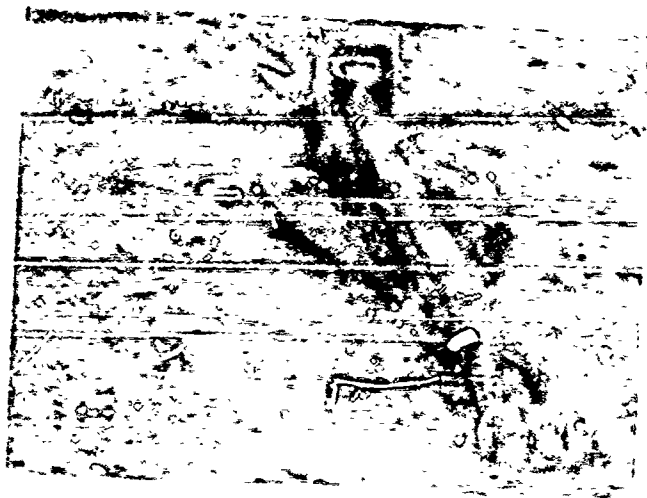


Figure 5. Typical LWT anchor. Note curved shape of the upper portion of flukes between the stock and the flukes.

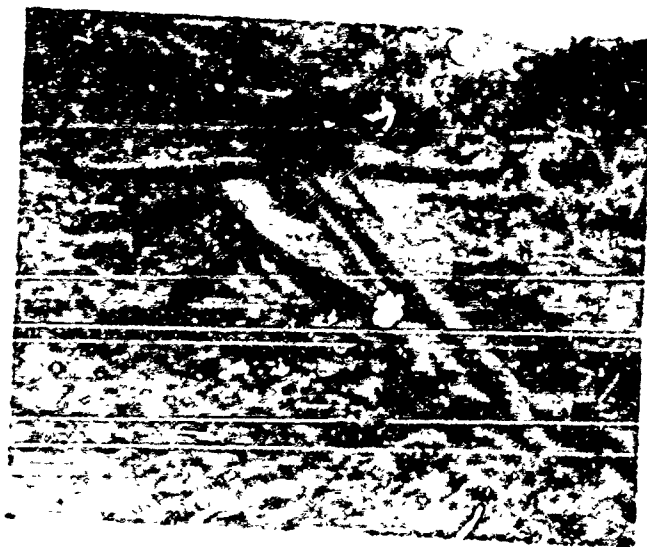


Figure 6. 10,000-lb. LWT anchor.

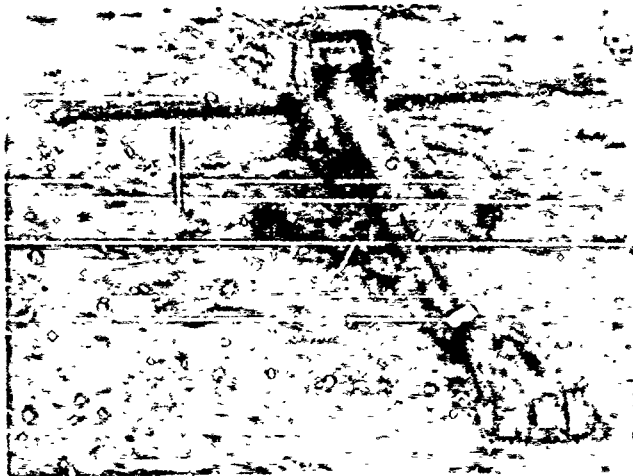


Figure 5. Typical LWT anchor. Note curved shape of the upper portion of flukes between the stock and the flukes.

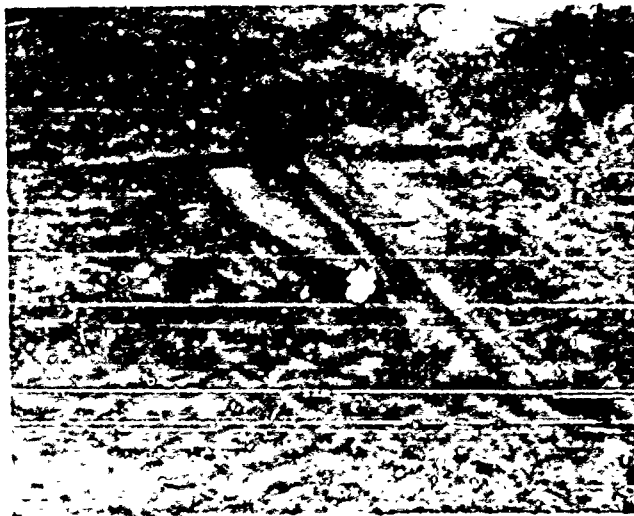


Figure 6. 10,000-lb. LWT anchor.

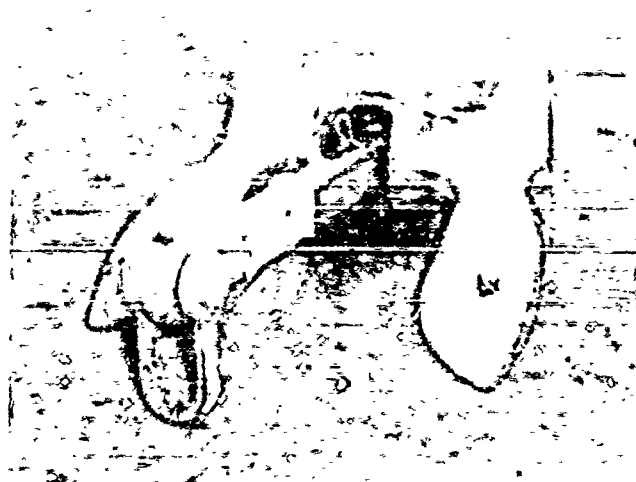


Figure 7. 4,000-lb. Navy Stockless anchor.

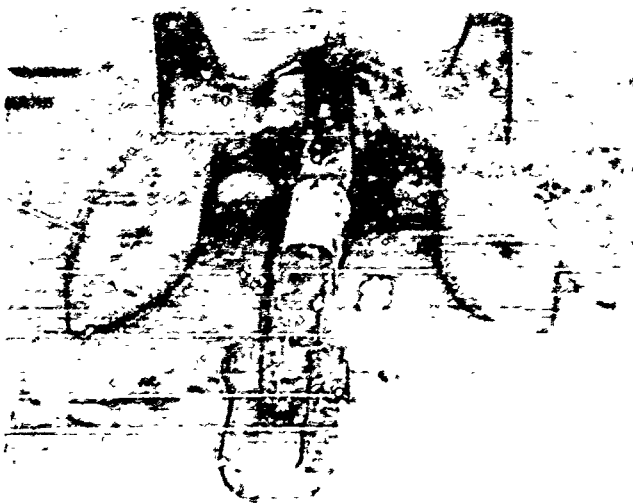


Figure 8. 8,000-lb. Navy Stockless anchor.

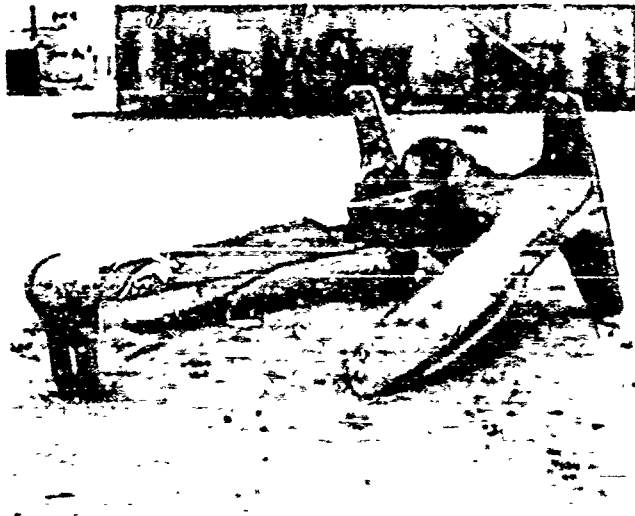


Figure 9. 17,000-lb. Navy Stockless anchor.

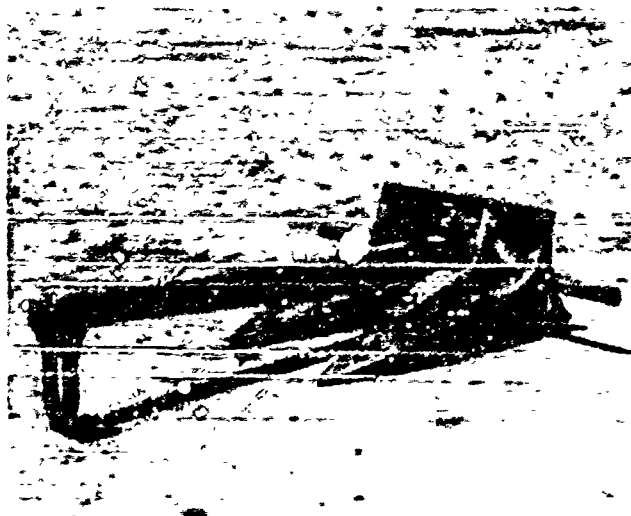


Figure 10. 2,110-lb Mulock anchor.



Figure 11. Typical LWT anchor, with fluke extension plates.

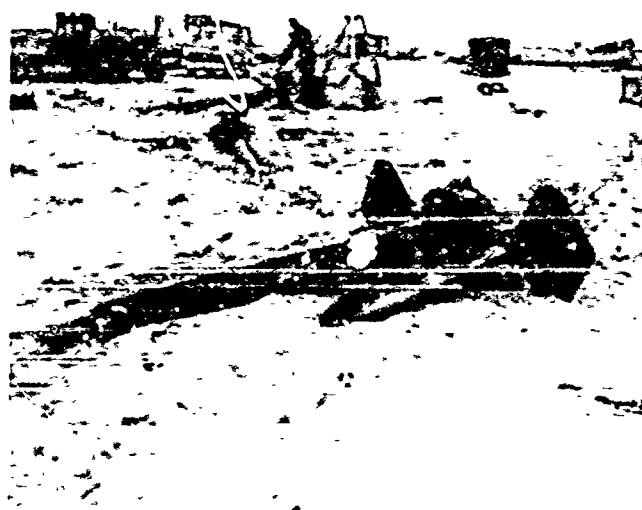


Figure 12. New design Baldt mud anchor.

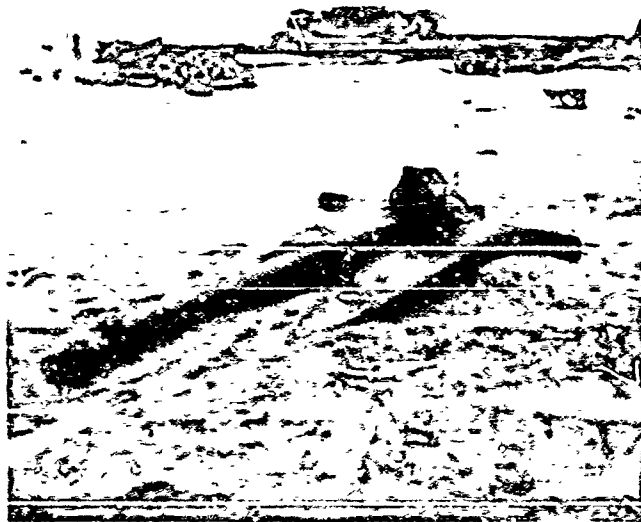


Figure 13. New design 3,650-lb. Baldt mud anchor.

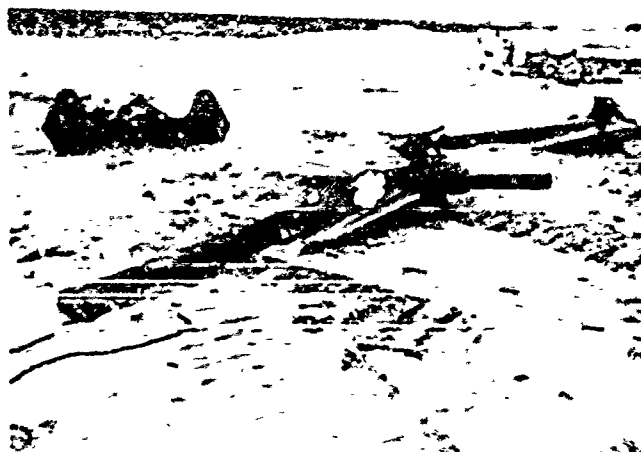


Figure 14. Croseck anchor, 3,060-lb.

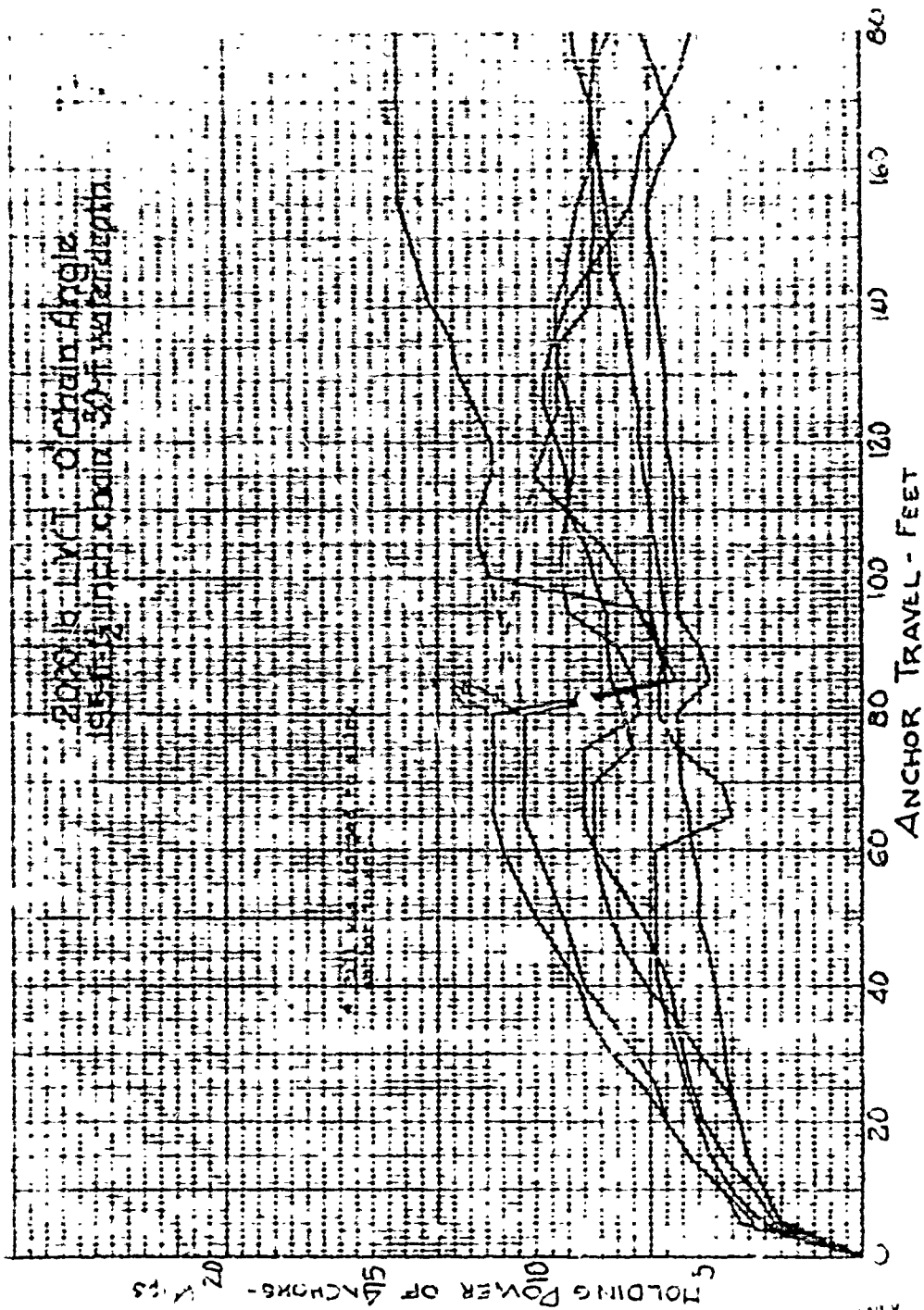
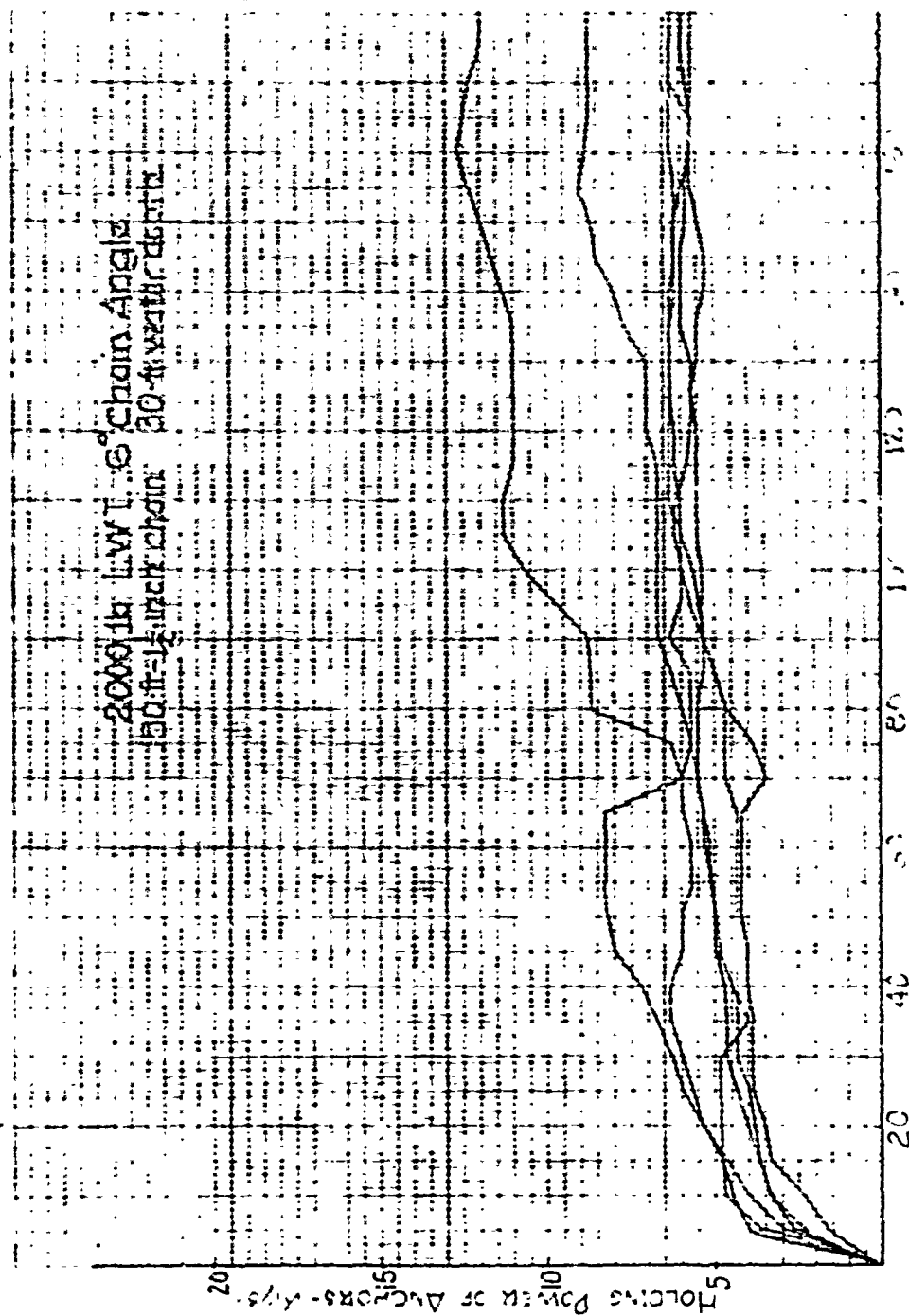
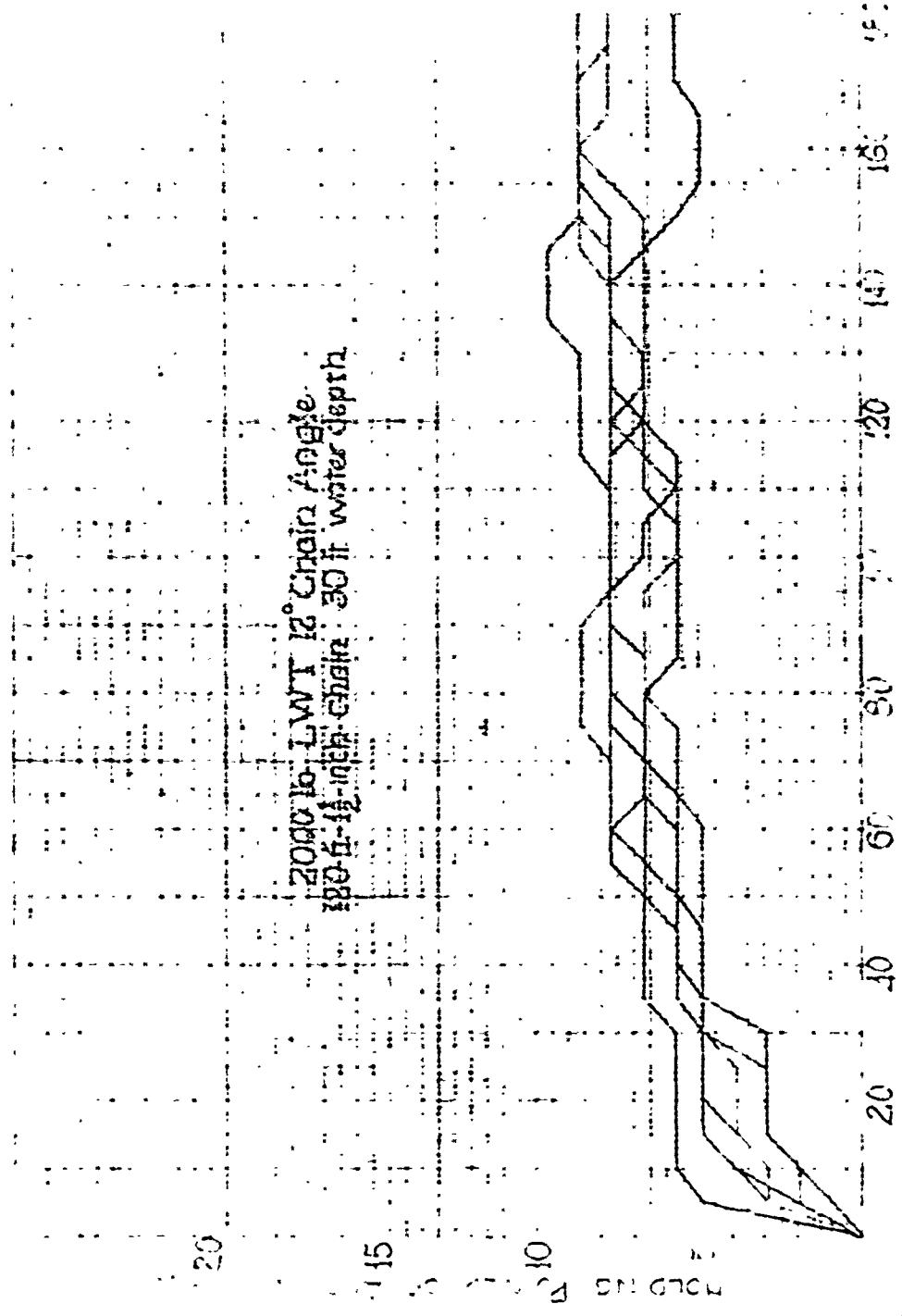


Figure 15

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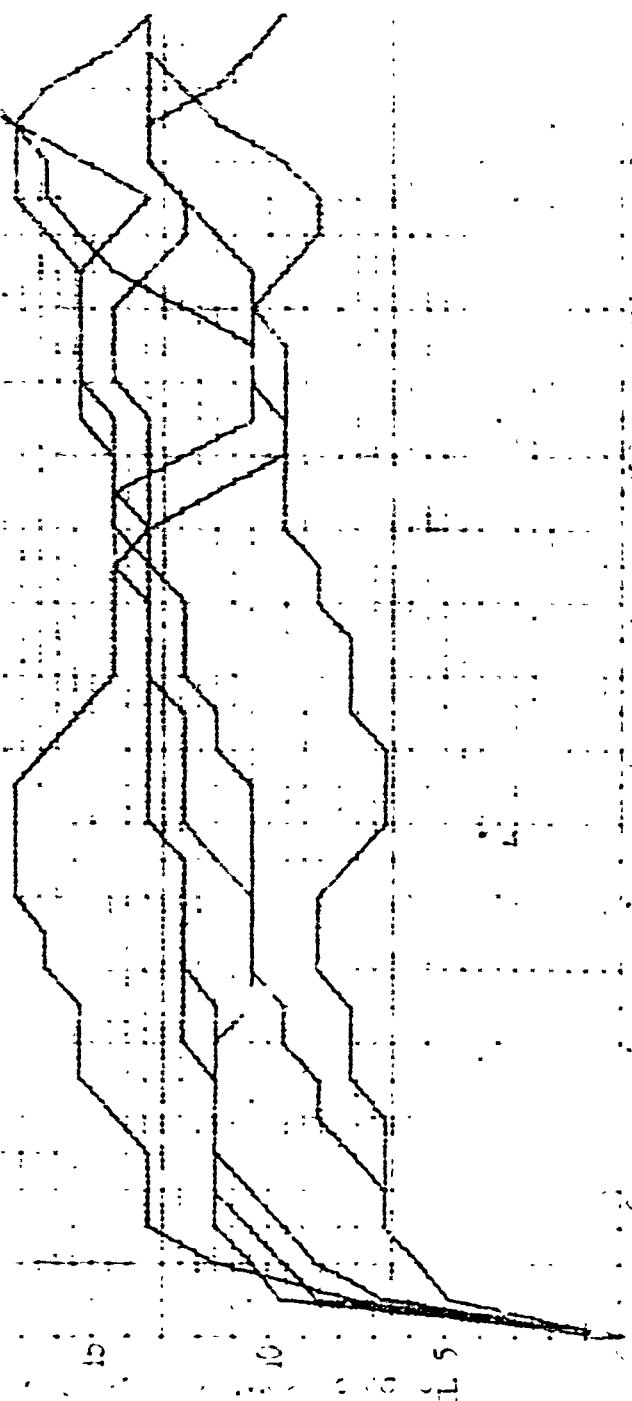


2000 lb. LWT 12° Chain Angle
 180 ft. 1 1/2 inch chain 30 ft water depth

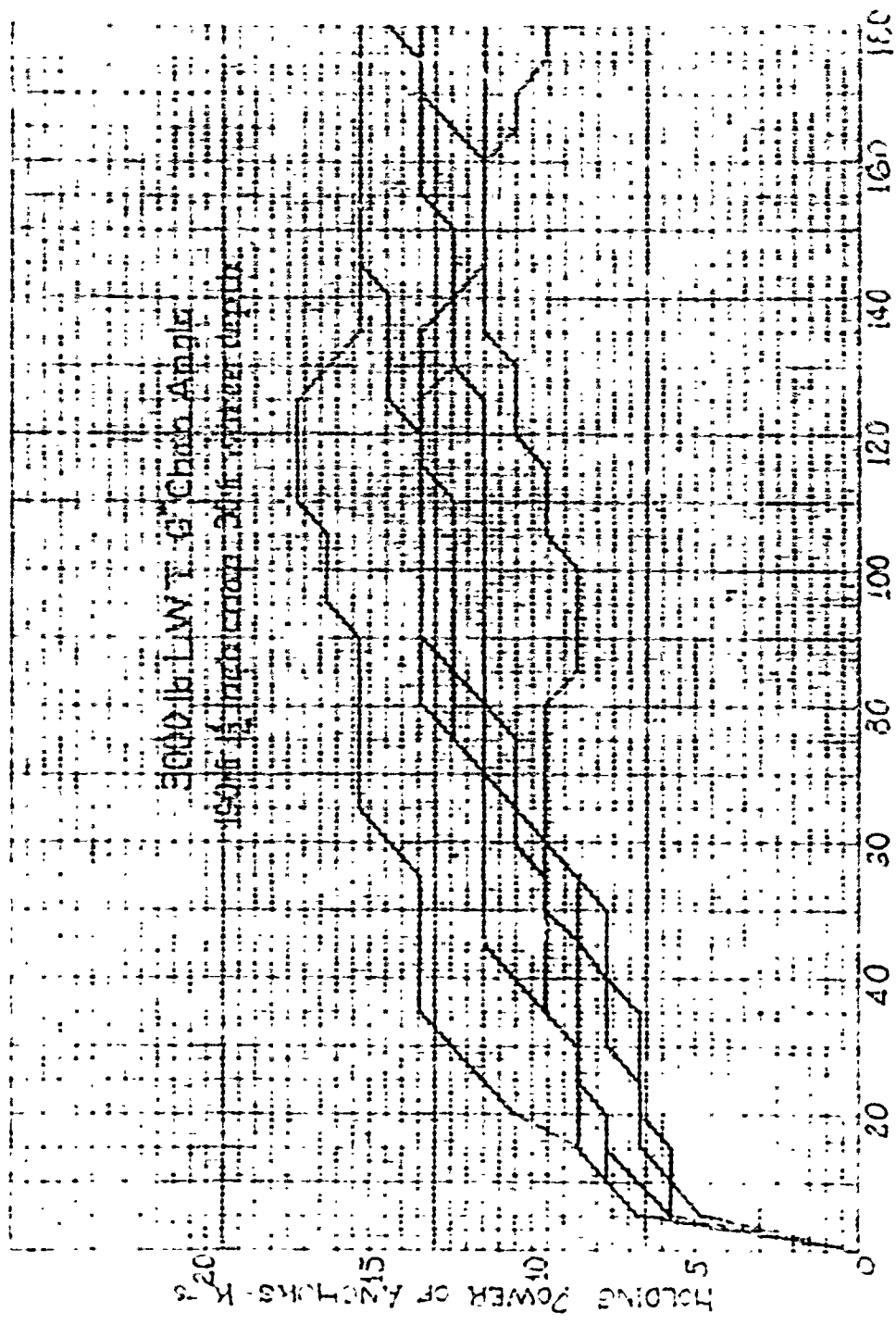
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300 to L.W.I. 0' from Angle

270 ft. 1/2 inch diam. 3 1/4 inch apart



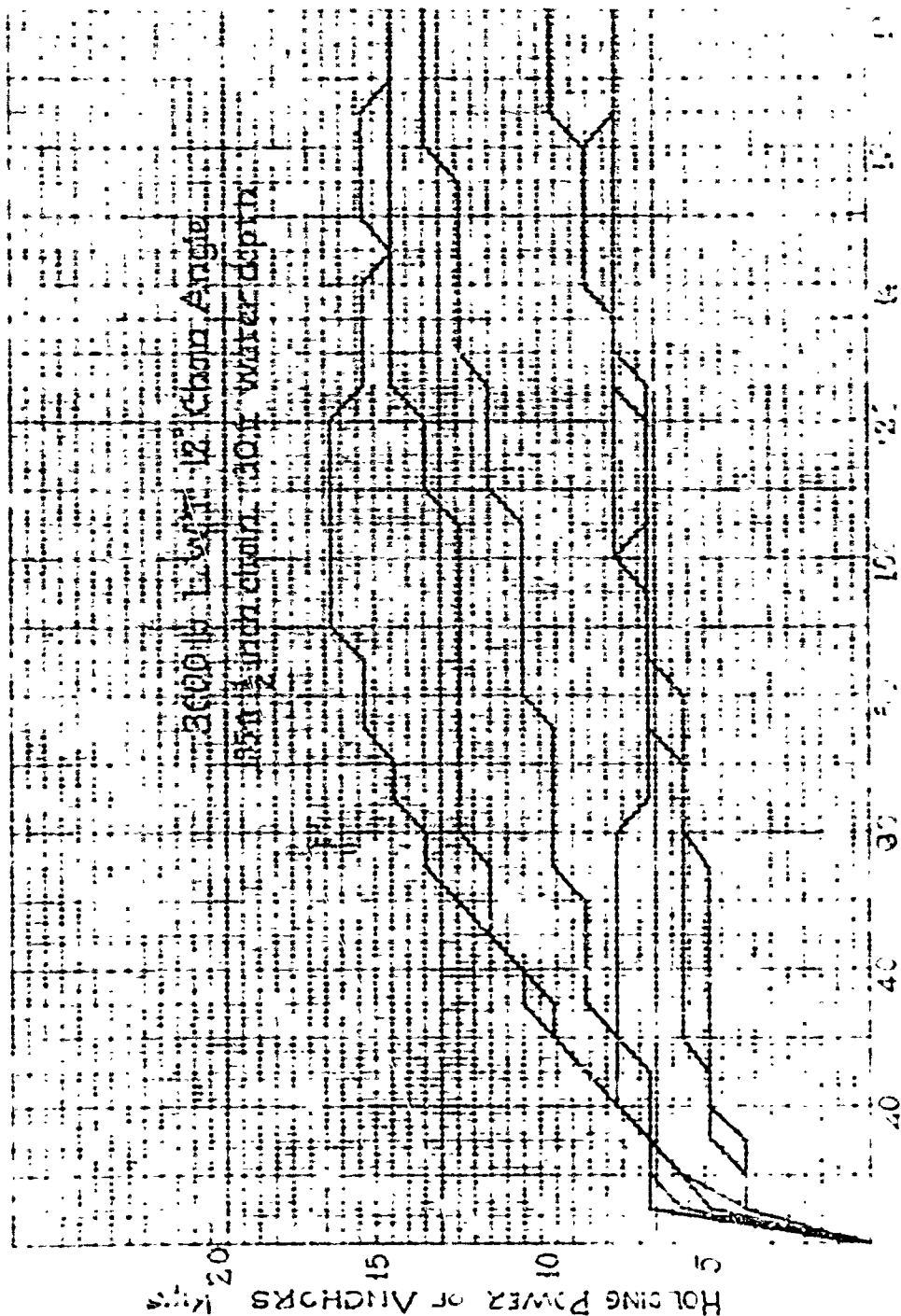
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HOLDING POWER OF ANCHORS - KG

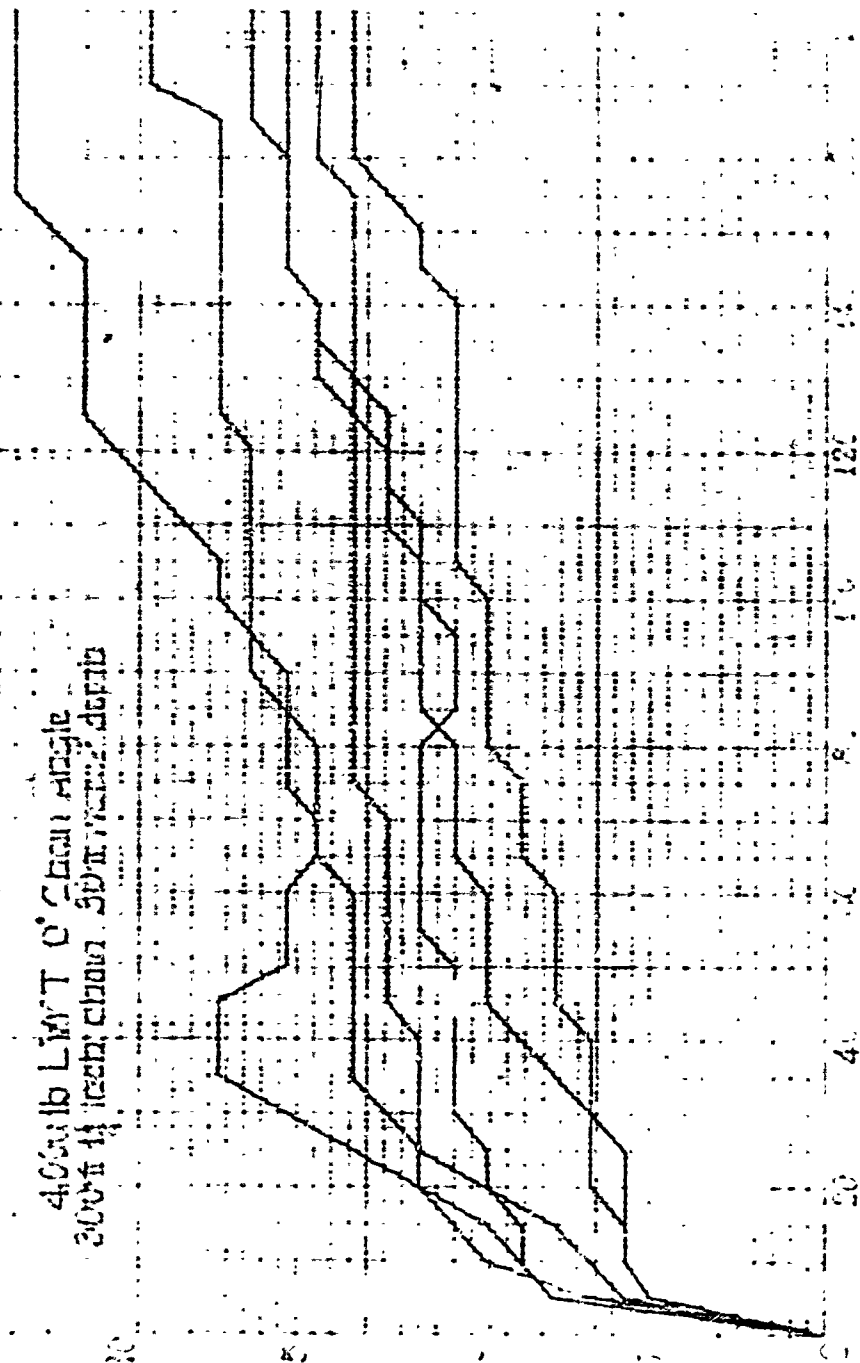
ANCHOR TRAVEL - FEET

UNITED STATES NAVY



ANCHOR TRAVEL - Meters

ANCHOR TRAVEL - Feet



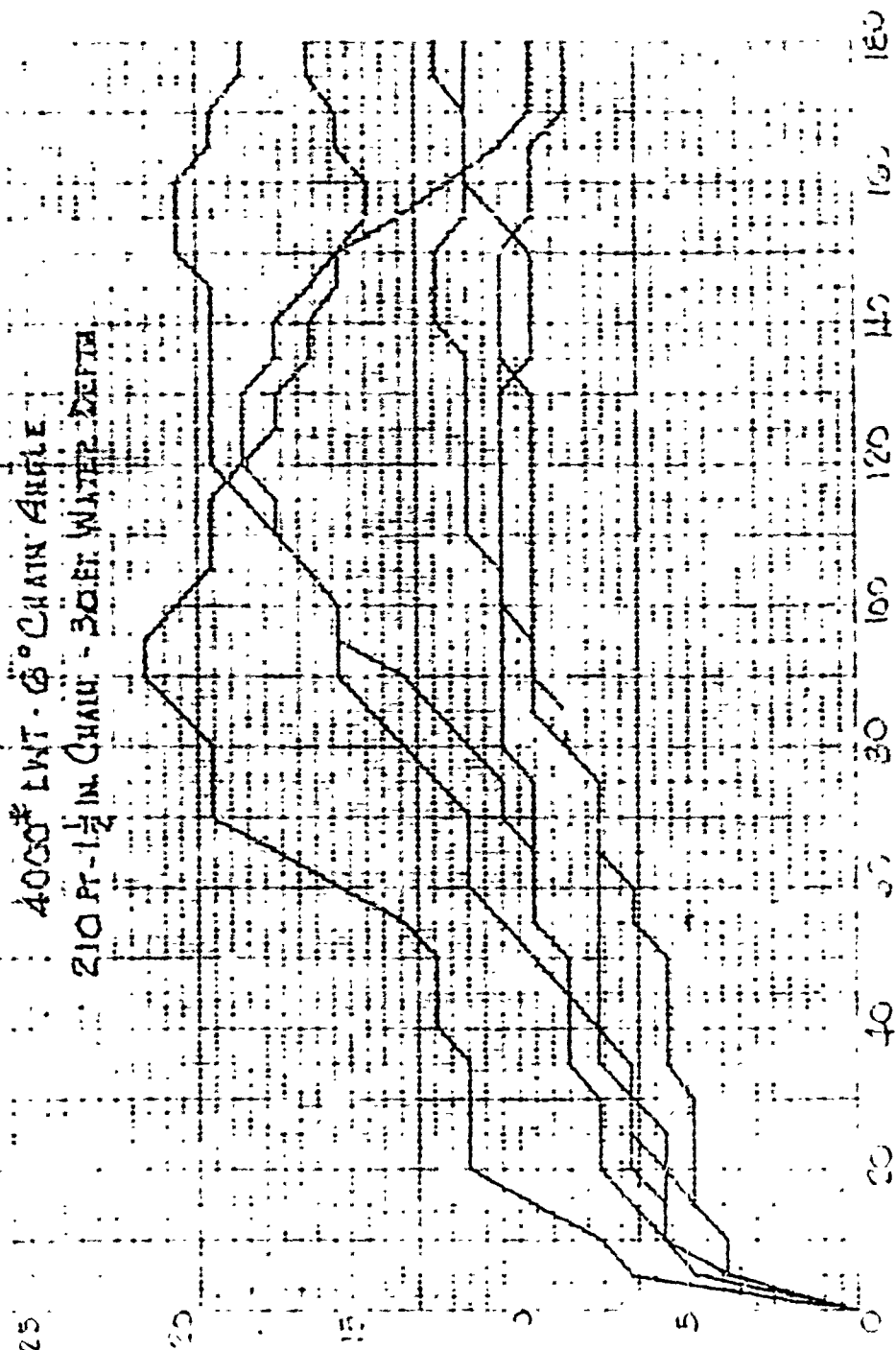
4000 lb LWT 0° beam angle
 300 ft 1/4 inch chord 30 ft 1/2 inch depth

AN - 014 PRO. E. - F. 127
 0. 0. 0.

OPTIONAL USE ONLY

4000' LWT - 6° CHAIN ANGLE

210 FT - 1 1/2" IN CHAIN - 30' BT. WATER DEPTH



ALONG 300 - 2110 HOURS - TOWER OF HARBOR - LIPS

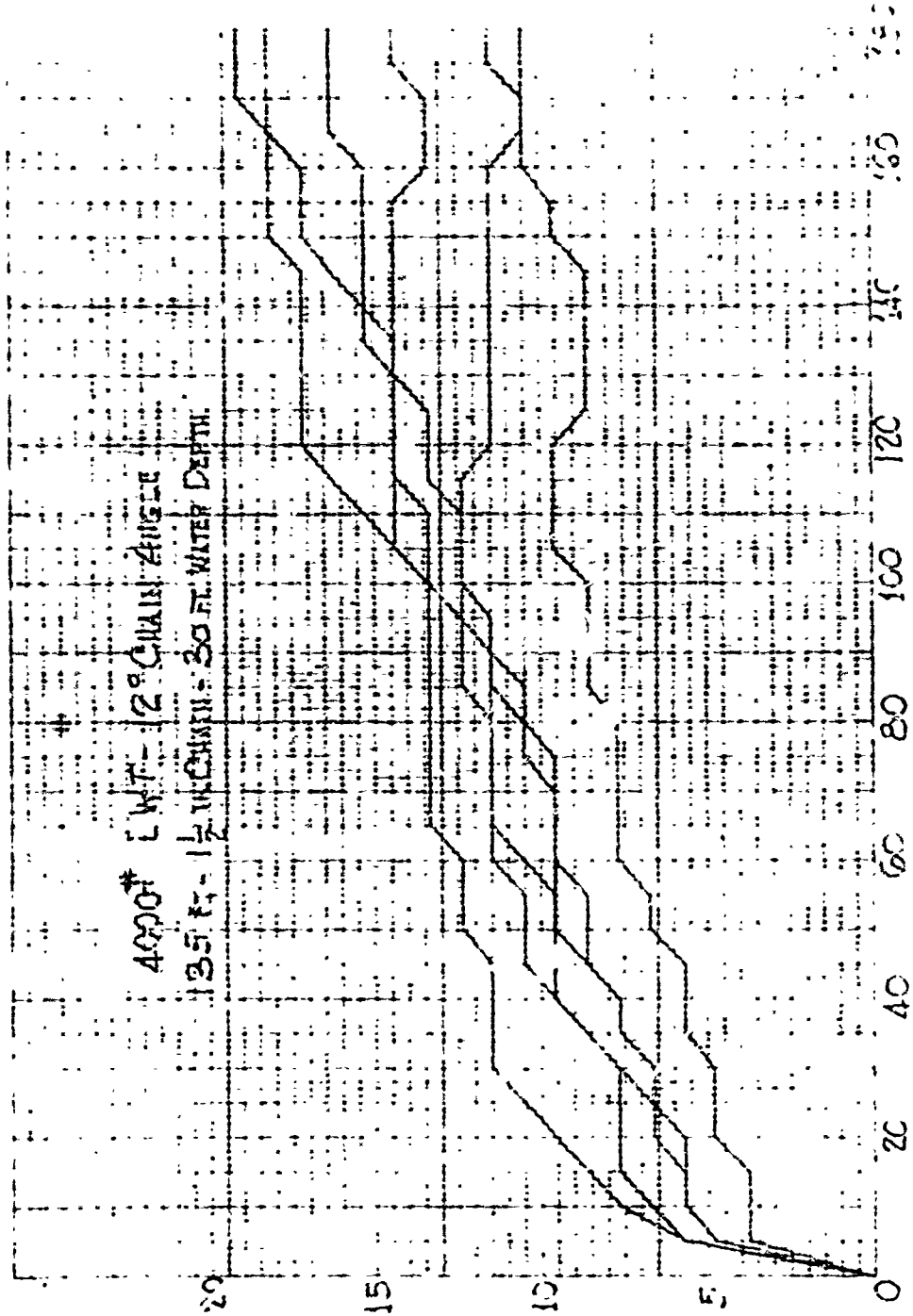
ALONG 300 - 2110 HOURS - TOWER OF HARBOR - LIPS

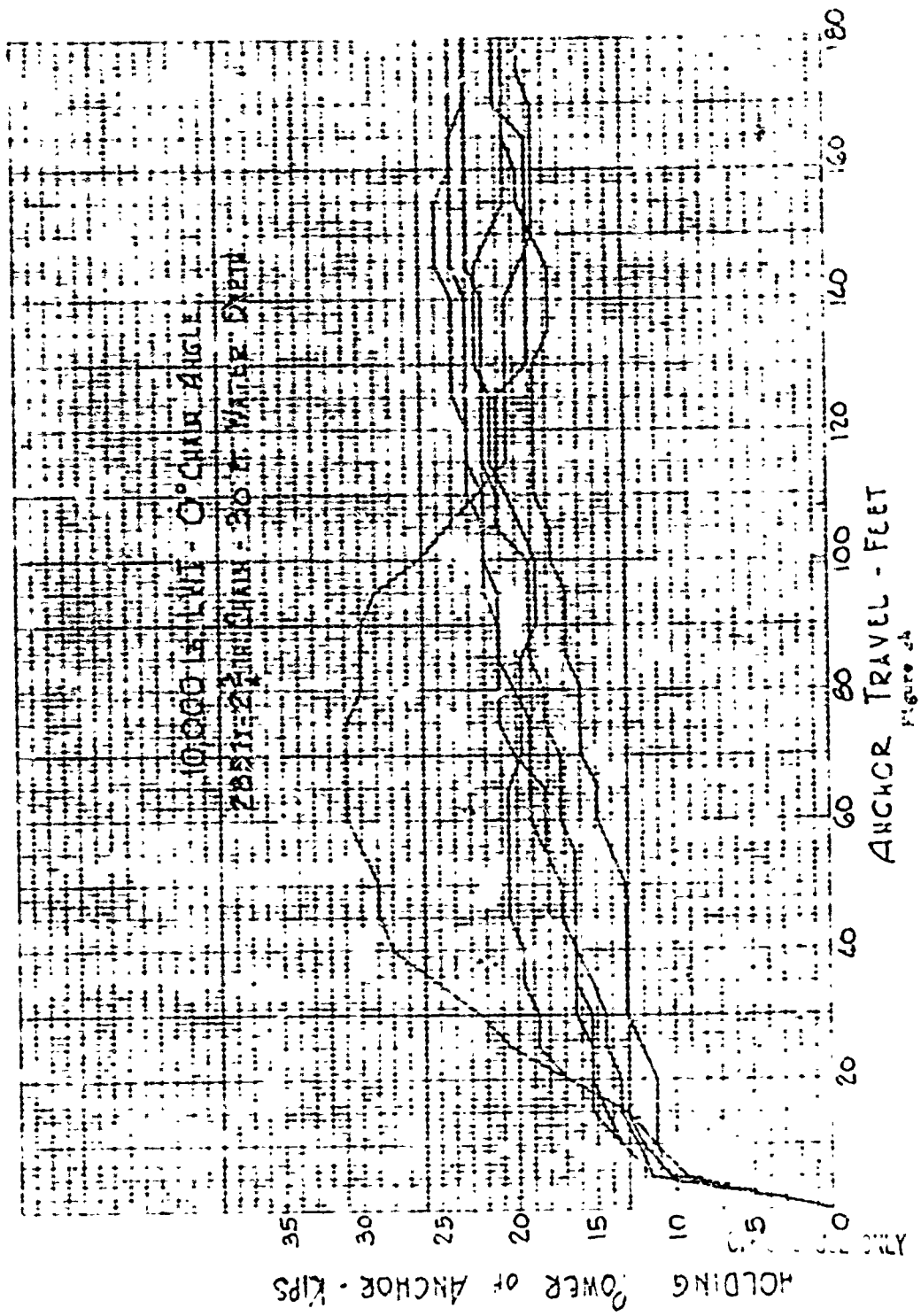
HOLDING POWER OF ANCHOR LBS

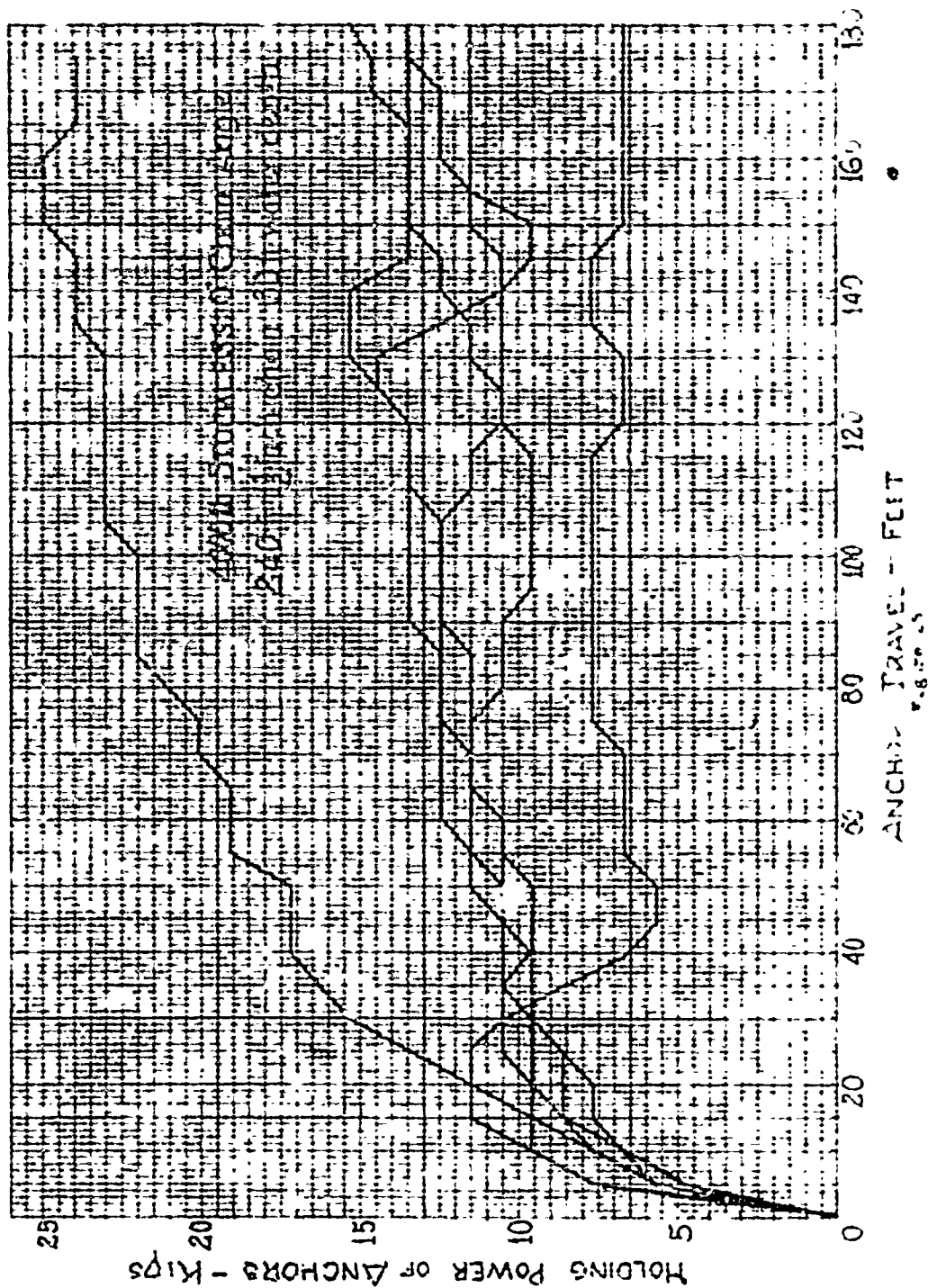
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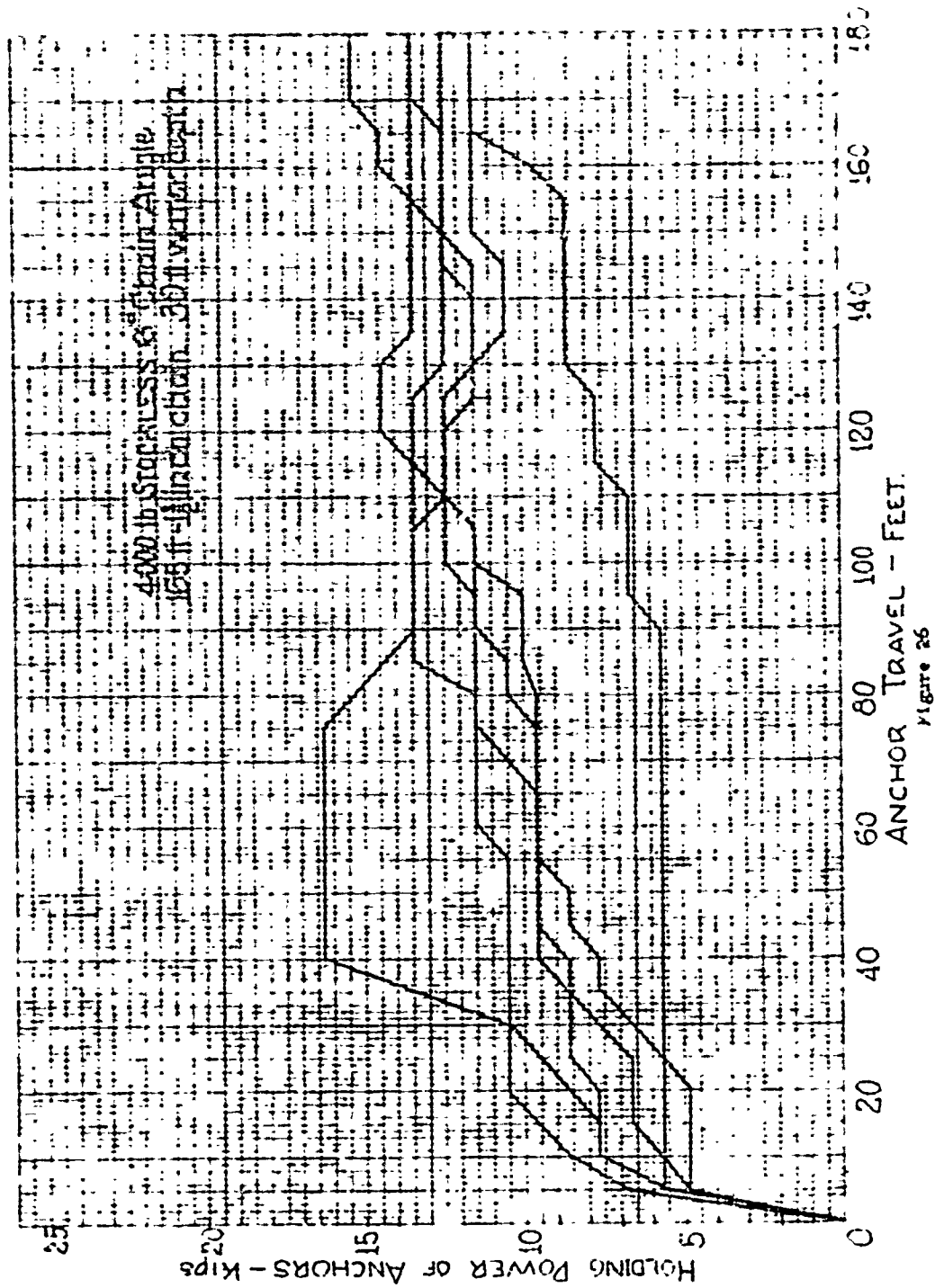
4000# LWT - 12° CHAIN ANGLE
135 ft - 1 1/2" CHAIN - 30 FT. WATER DEPTH

ANCHOR TRAVEL - FEET



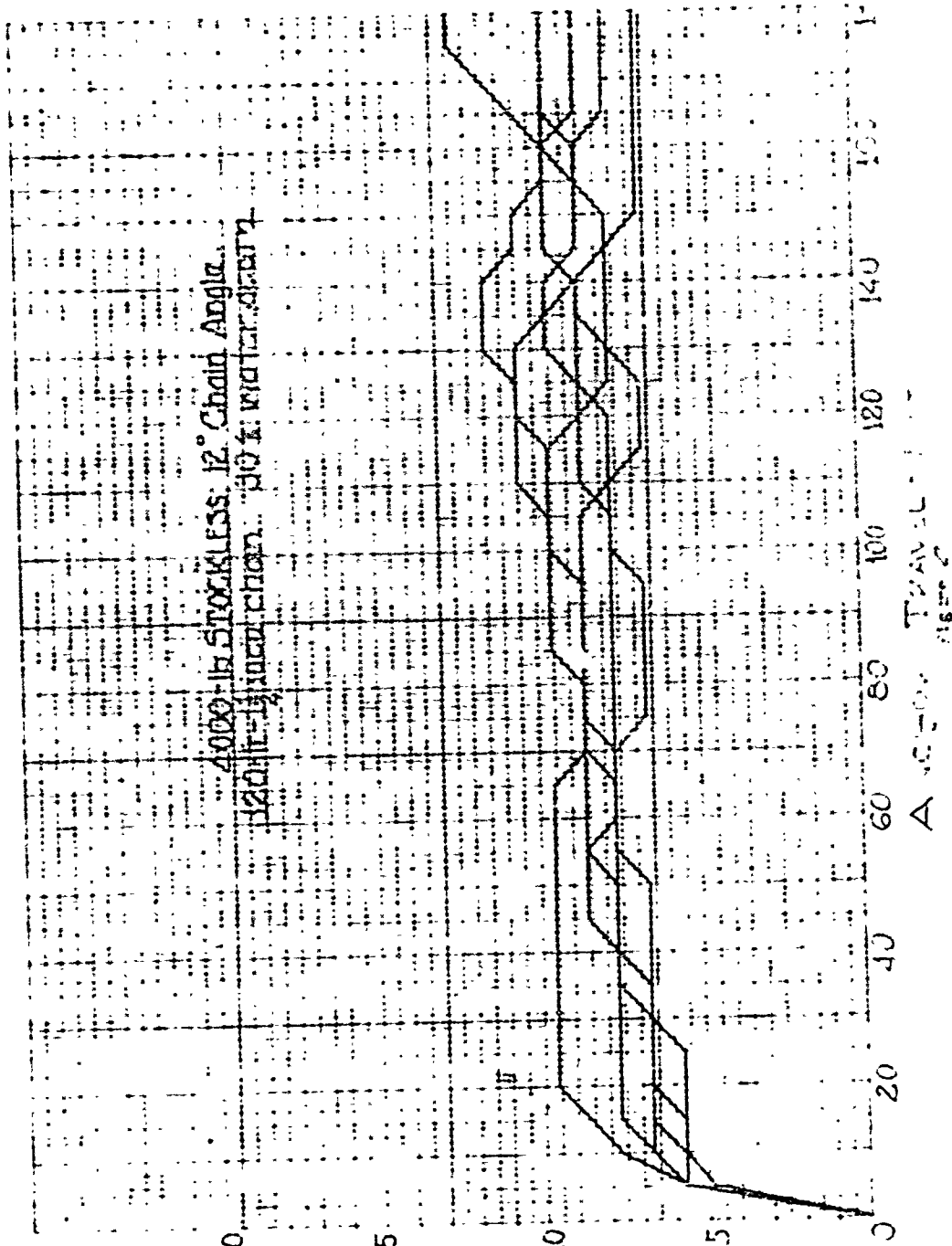






4000-lb STOCKLESS 12° Chain Angle
 120 ft - 13 ft in chain 30 ft water depth

HOLDING POWER OF ANCHORS - T



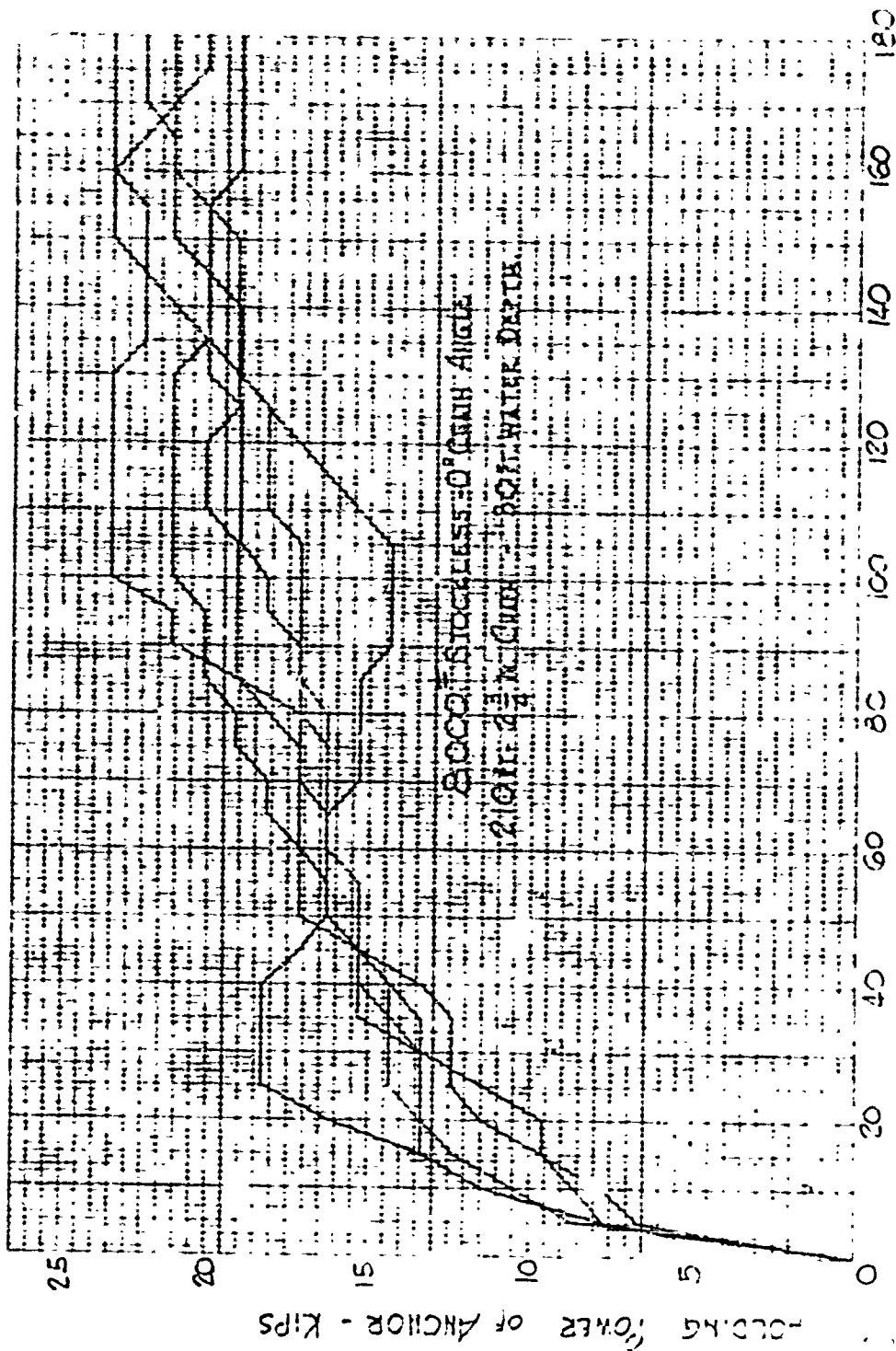
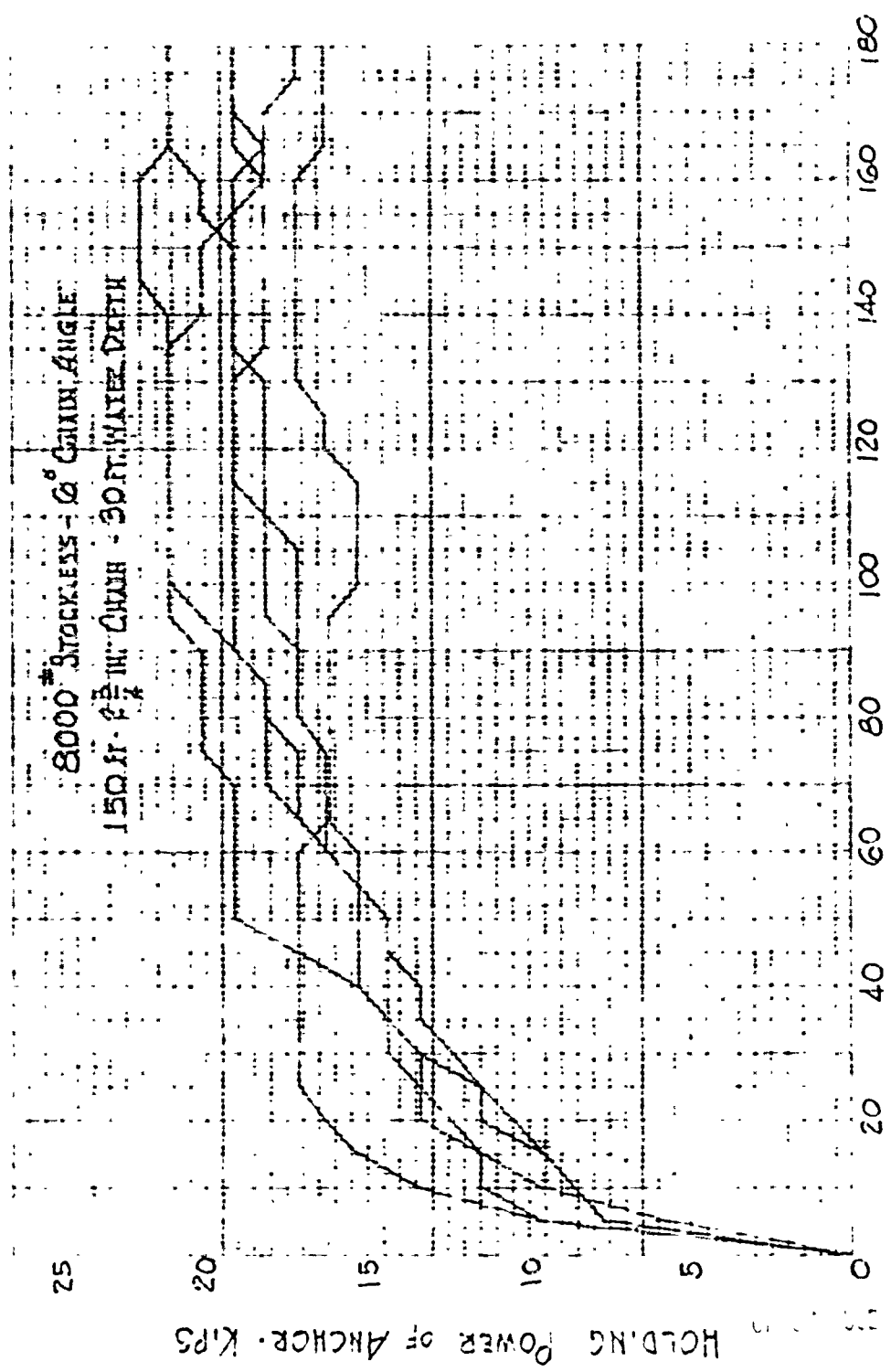


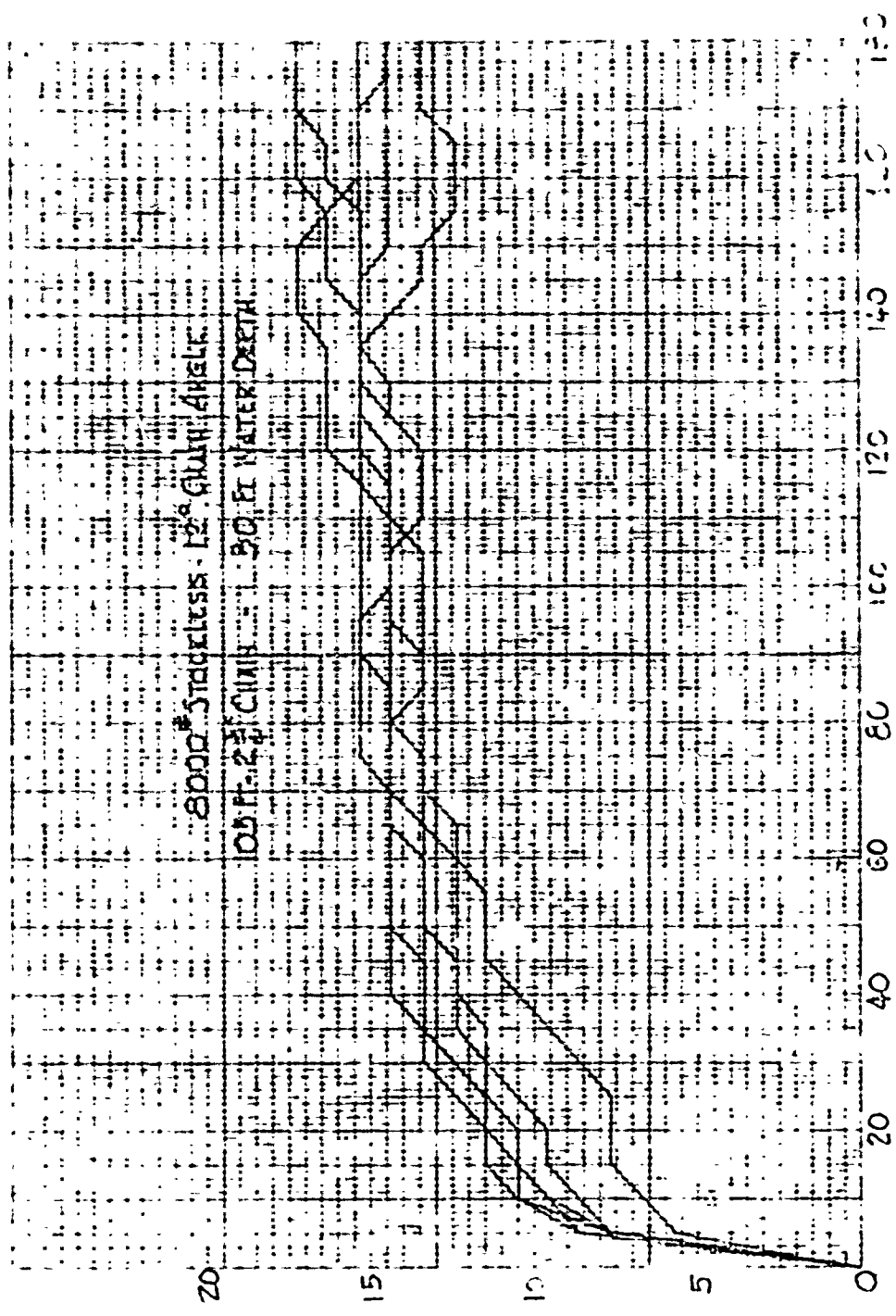
Figure 28
ANCHOR TRAVEL-Feet



ANCHOR TRAVEL - FEET
FIG. 100-29

HOLDING POWER OF ANCHOR - KIIPS

AND 3500 - HOLDING POWER OF ANCHOR - KIPS



ANCHOR TRAVEL - FEET

Figure 30

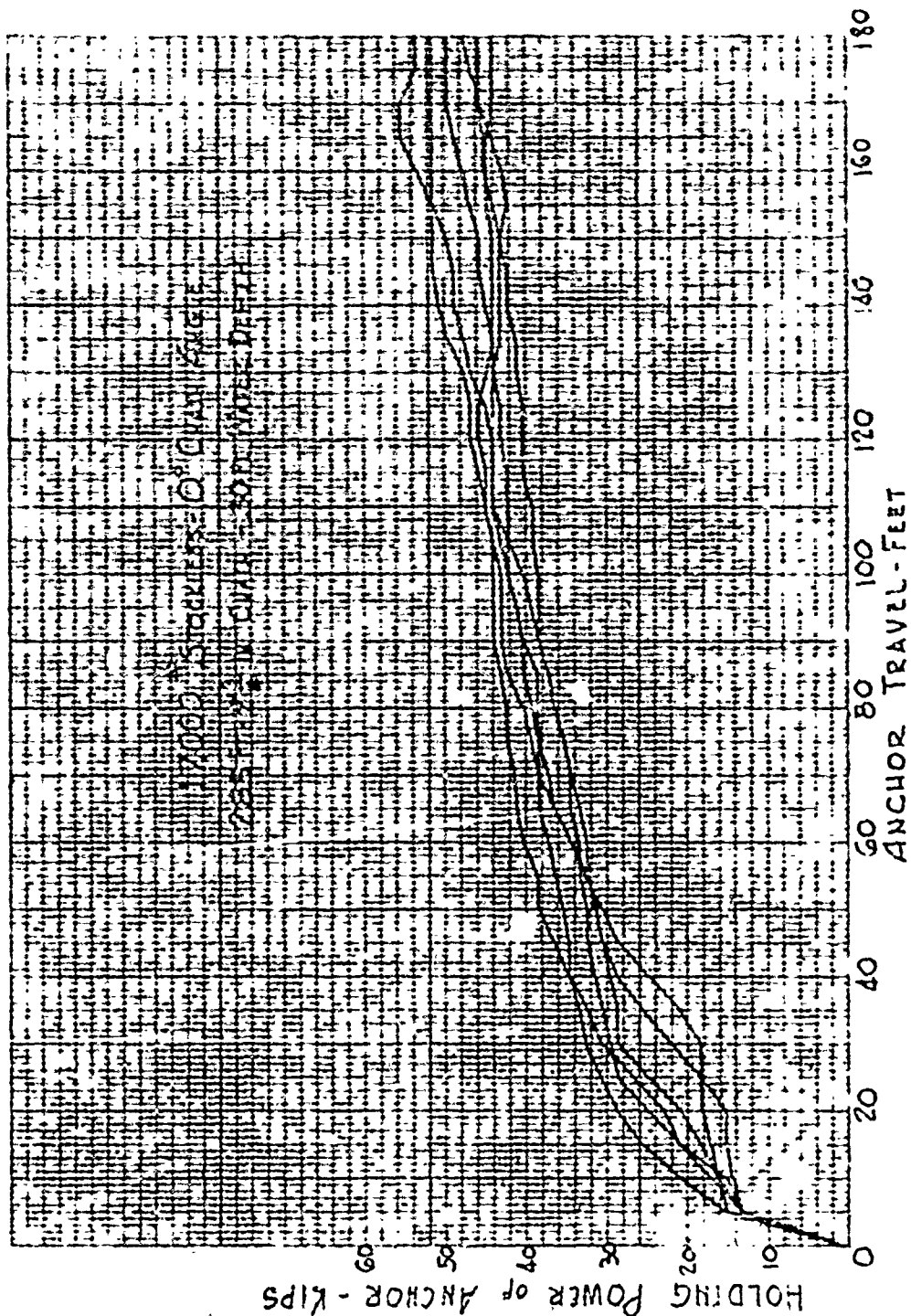
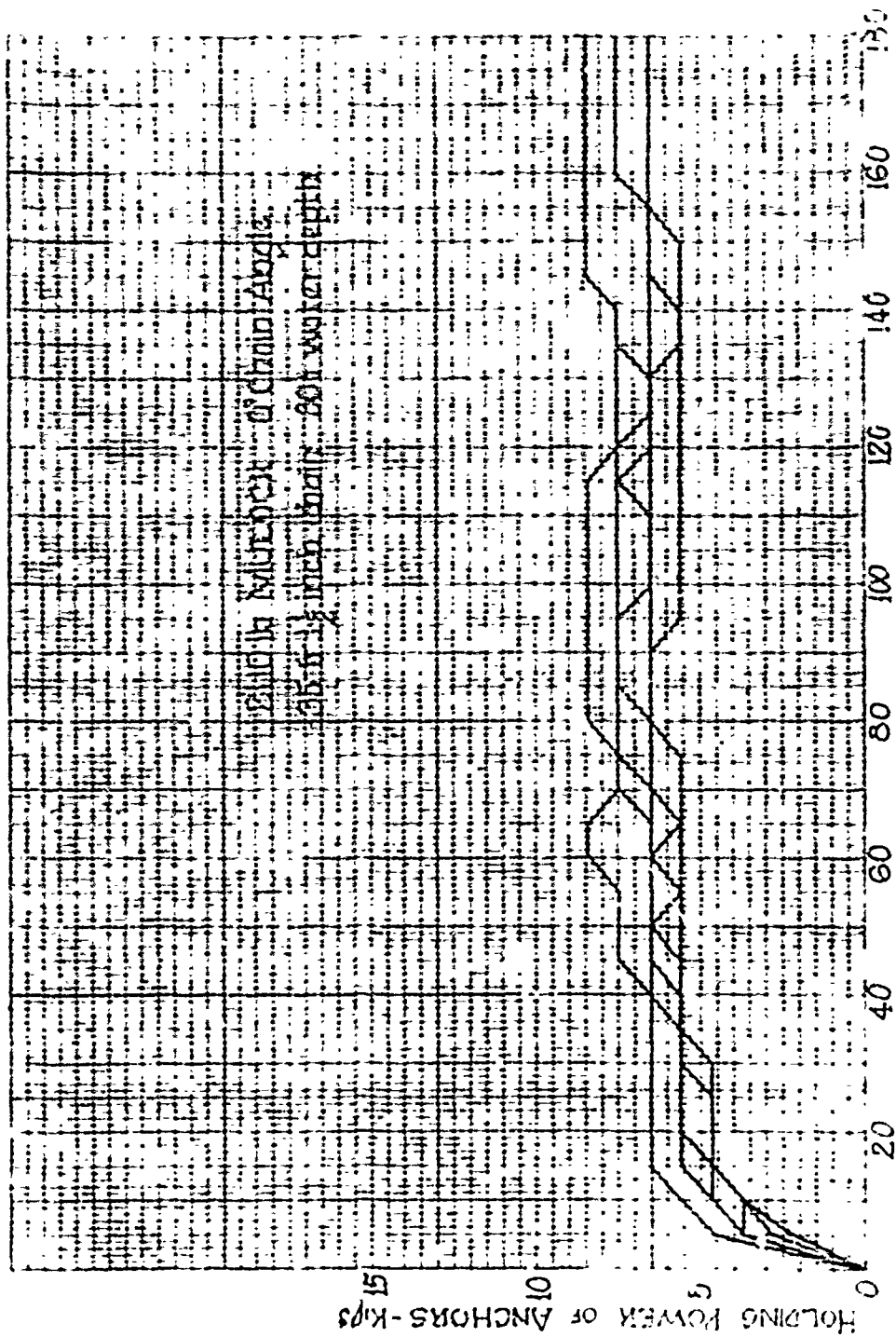


FIGURE 31

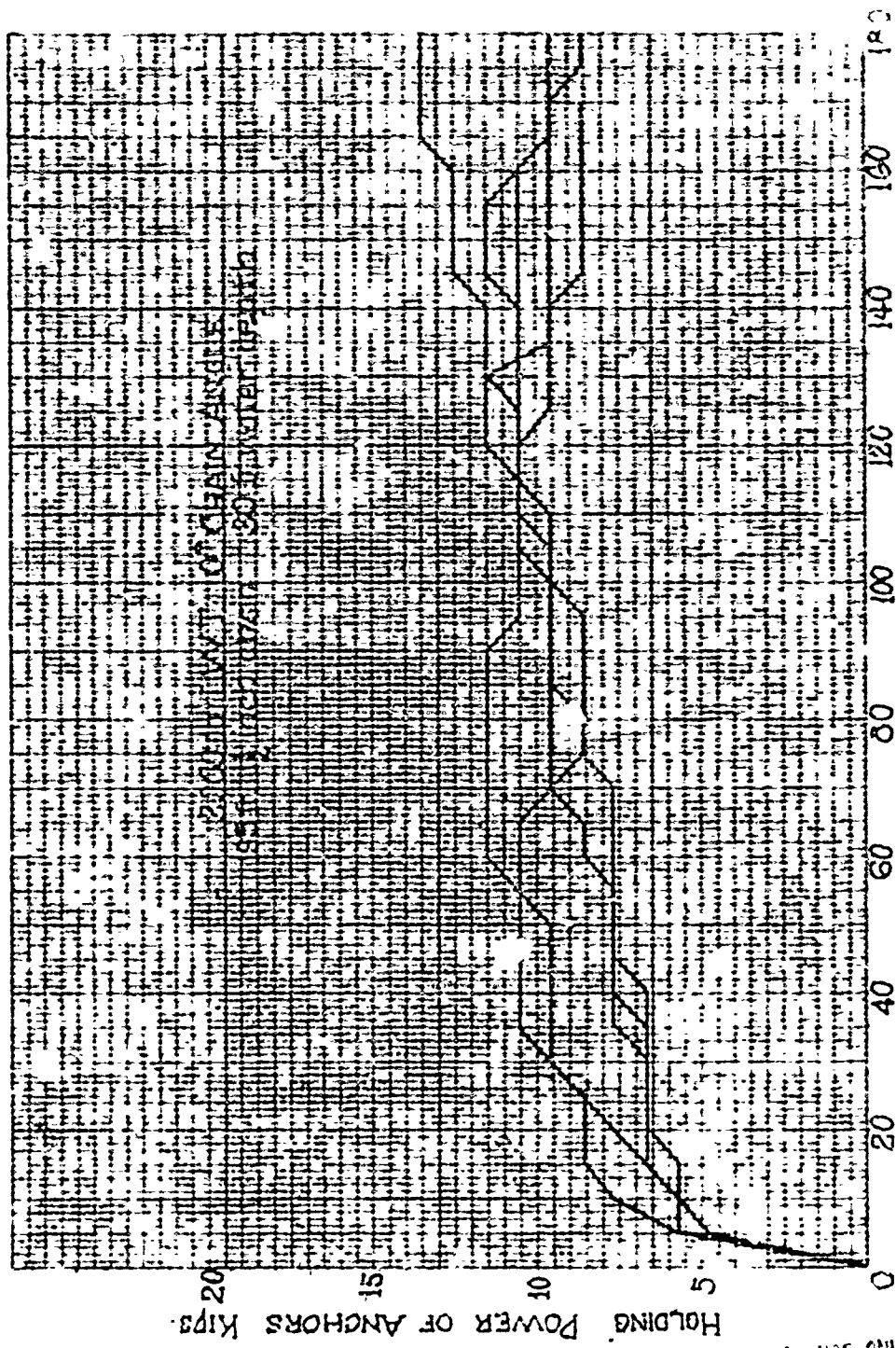
ANCHOR 3/4\"/>



ANCHOR TRAVEL - FEET

Figure 2

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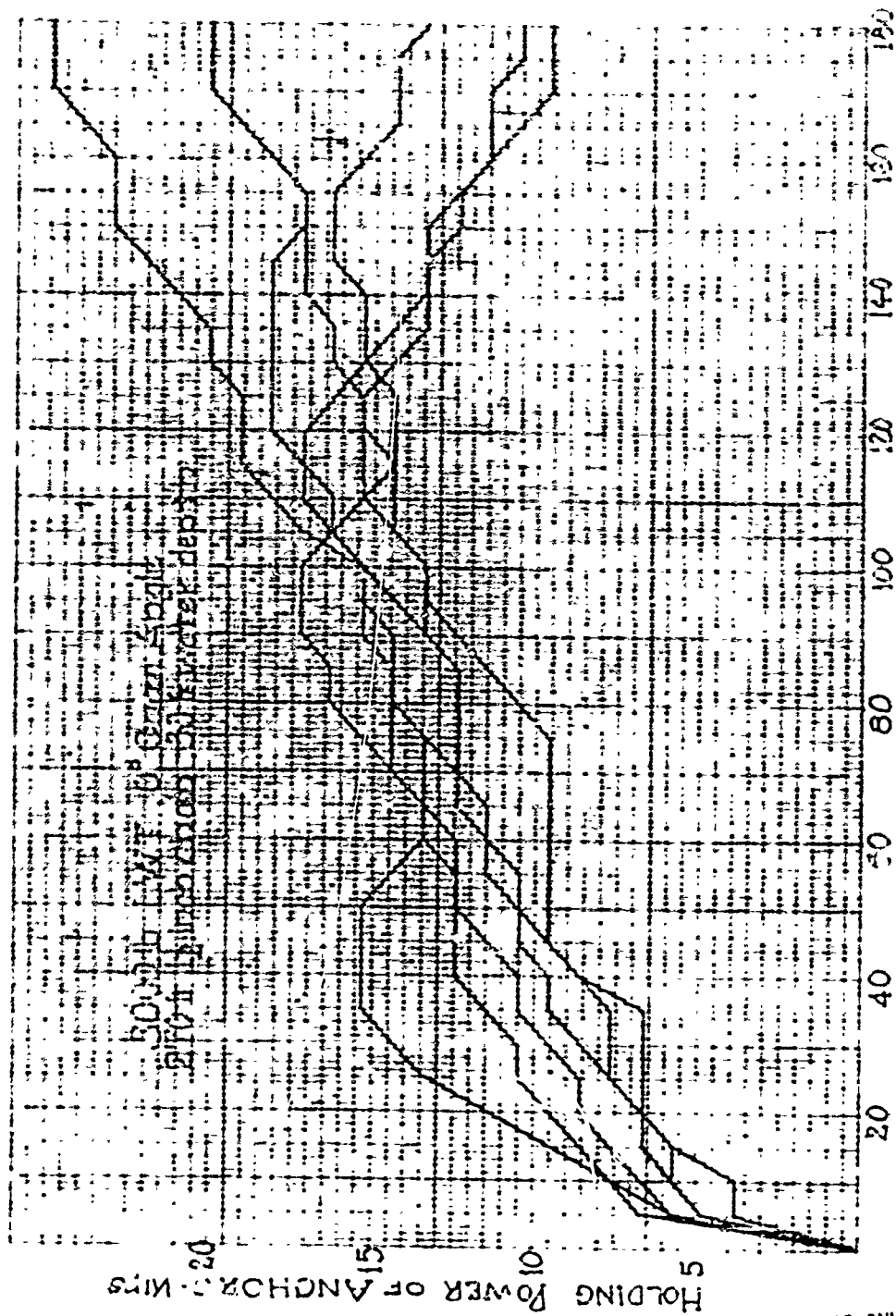


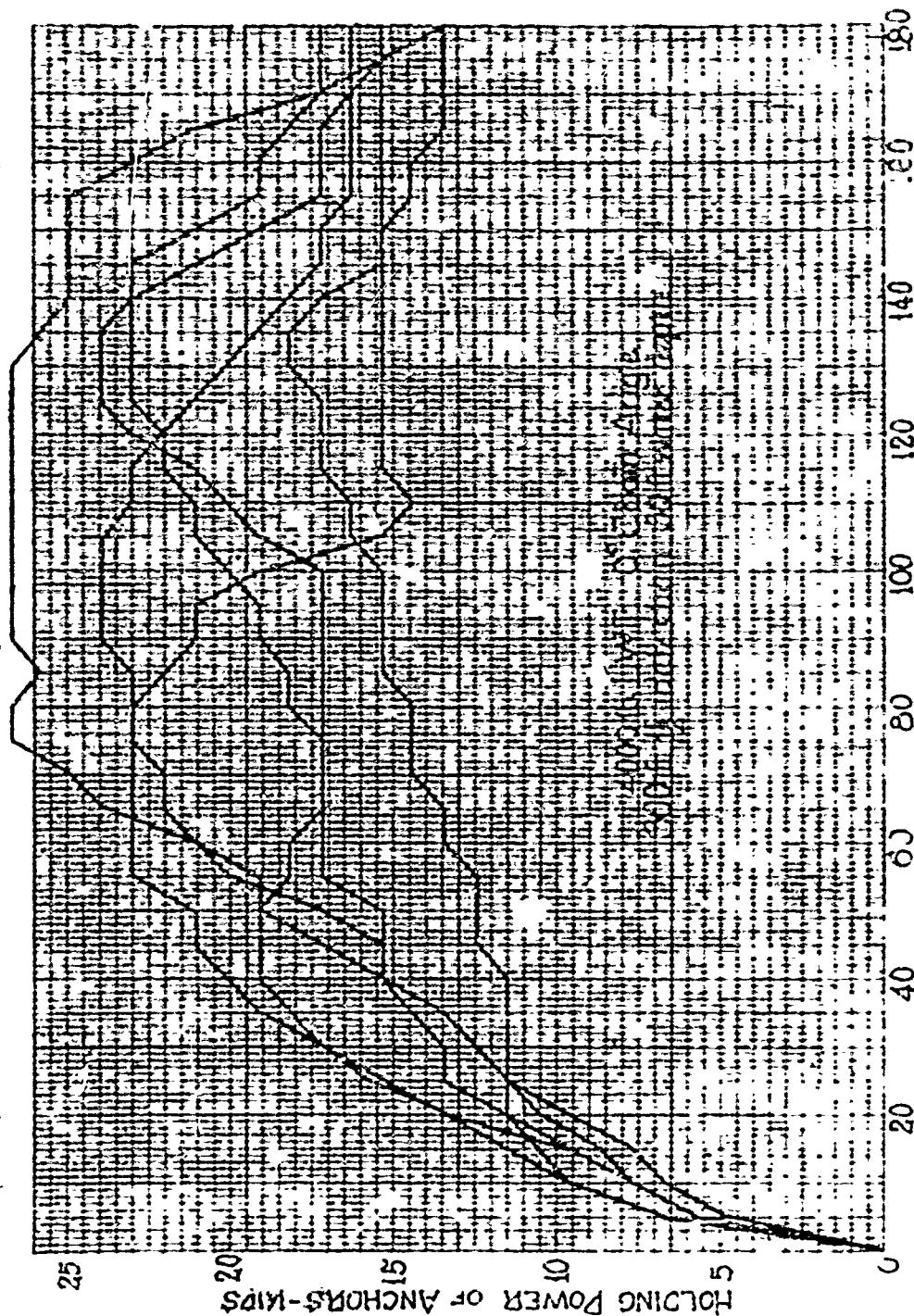
ANCHOR TRAVEL FEET

Figure 33

HOLDING POWER OF ANCHORS KIIPS

ATMS 300 : 11110





ANCHOR TRAVEL- FEET

Figure 35

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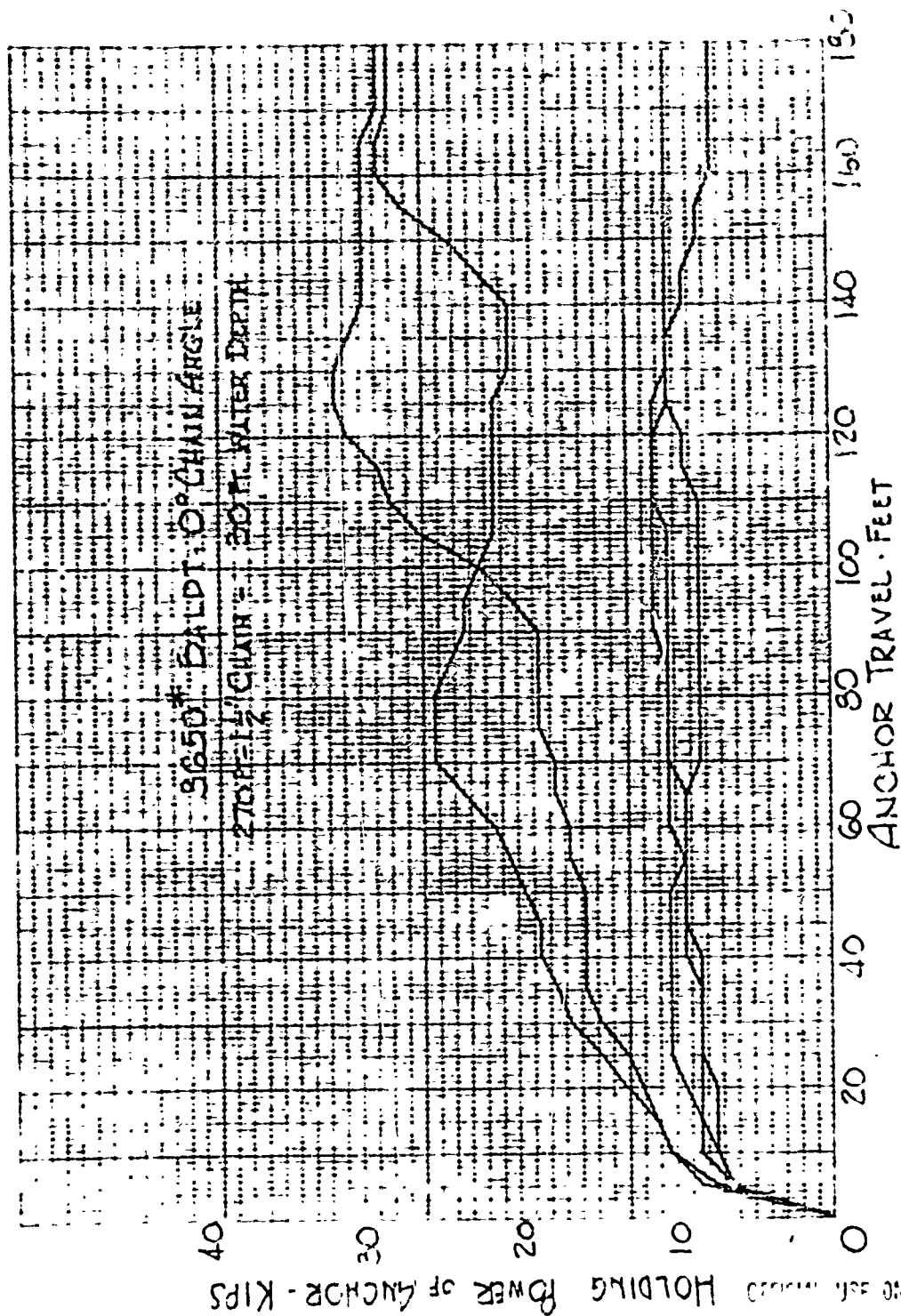


Figure 36

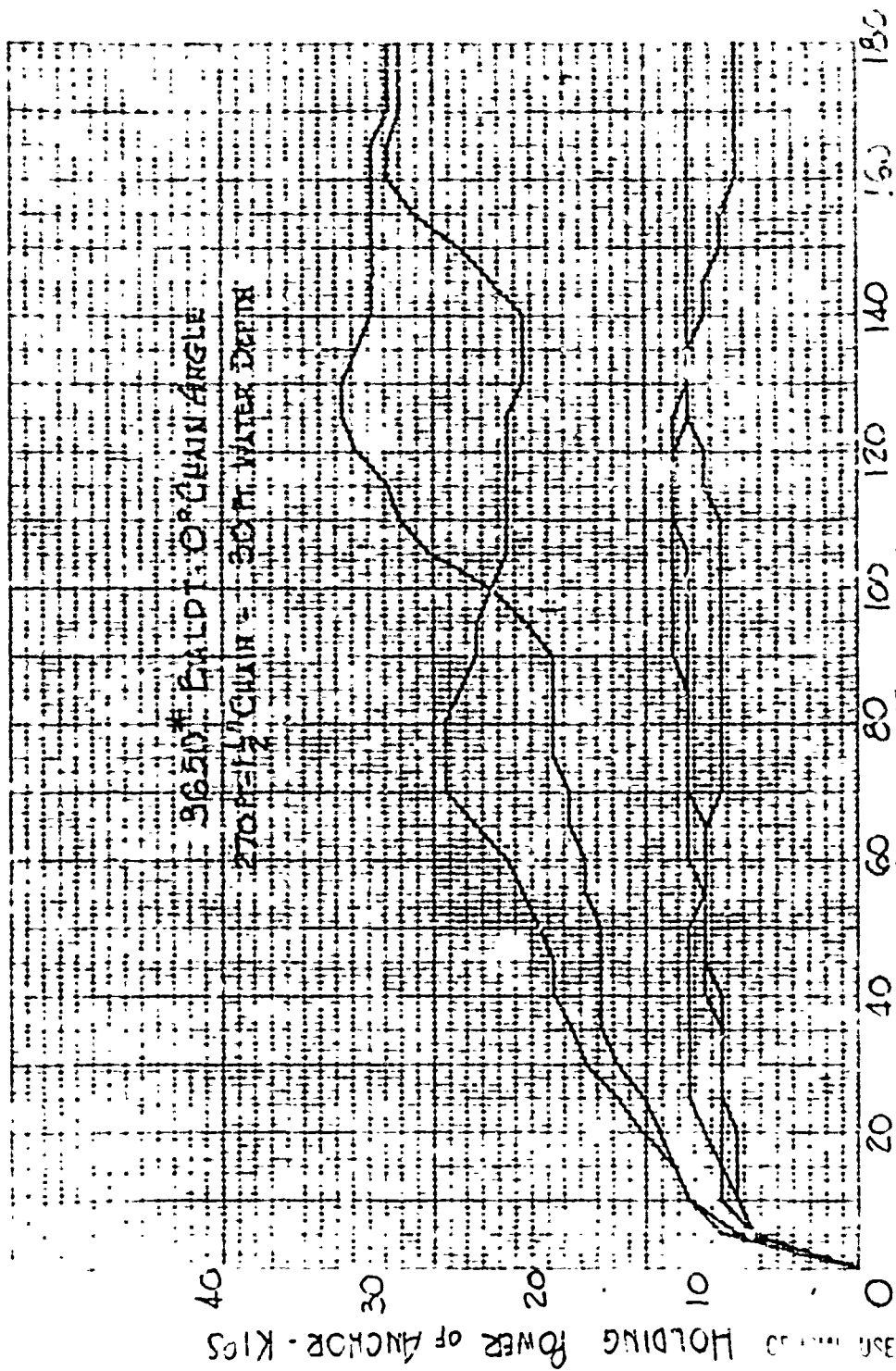
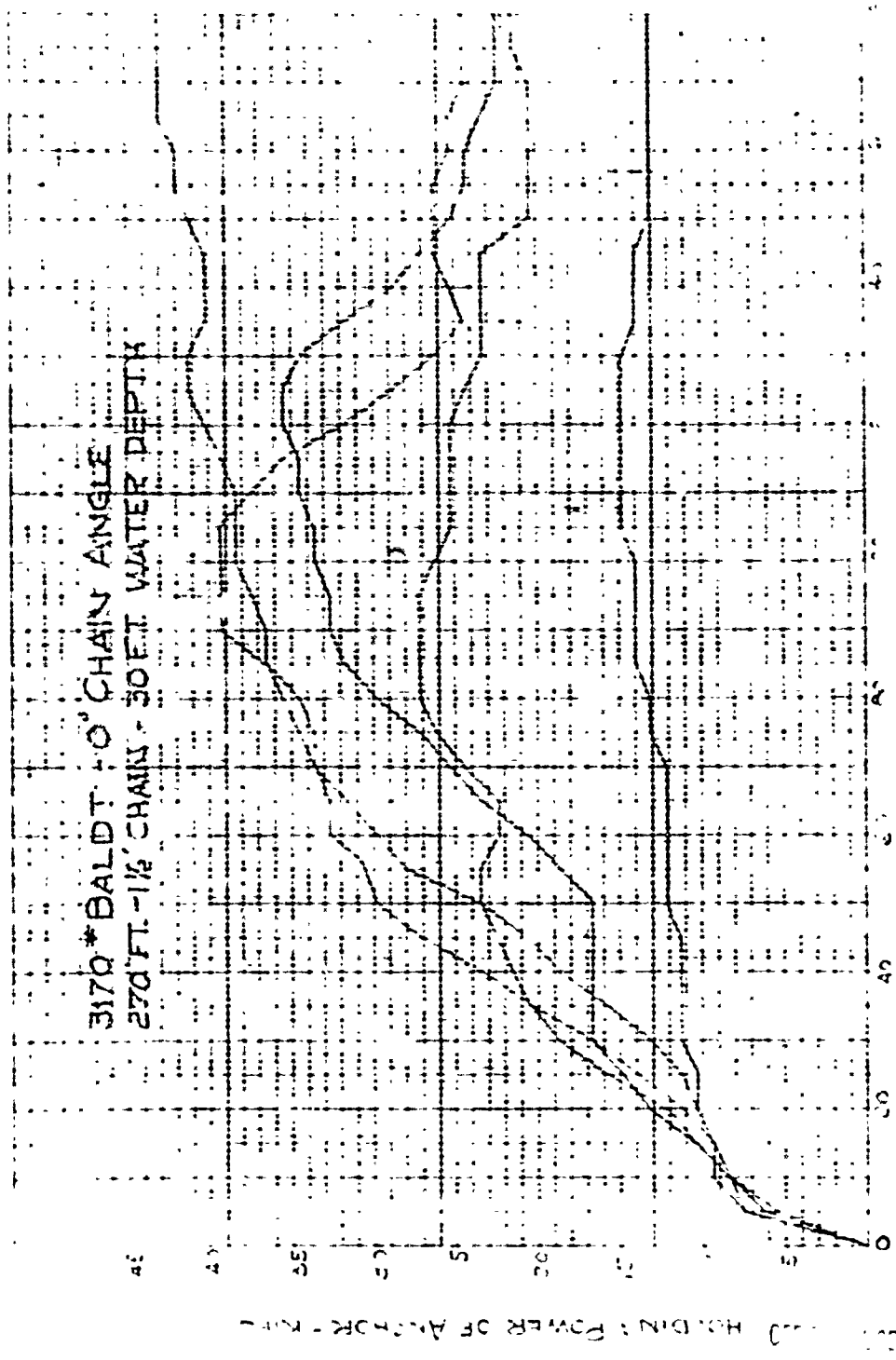
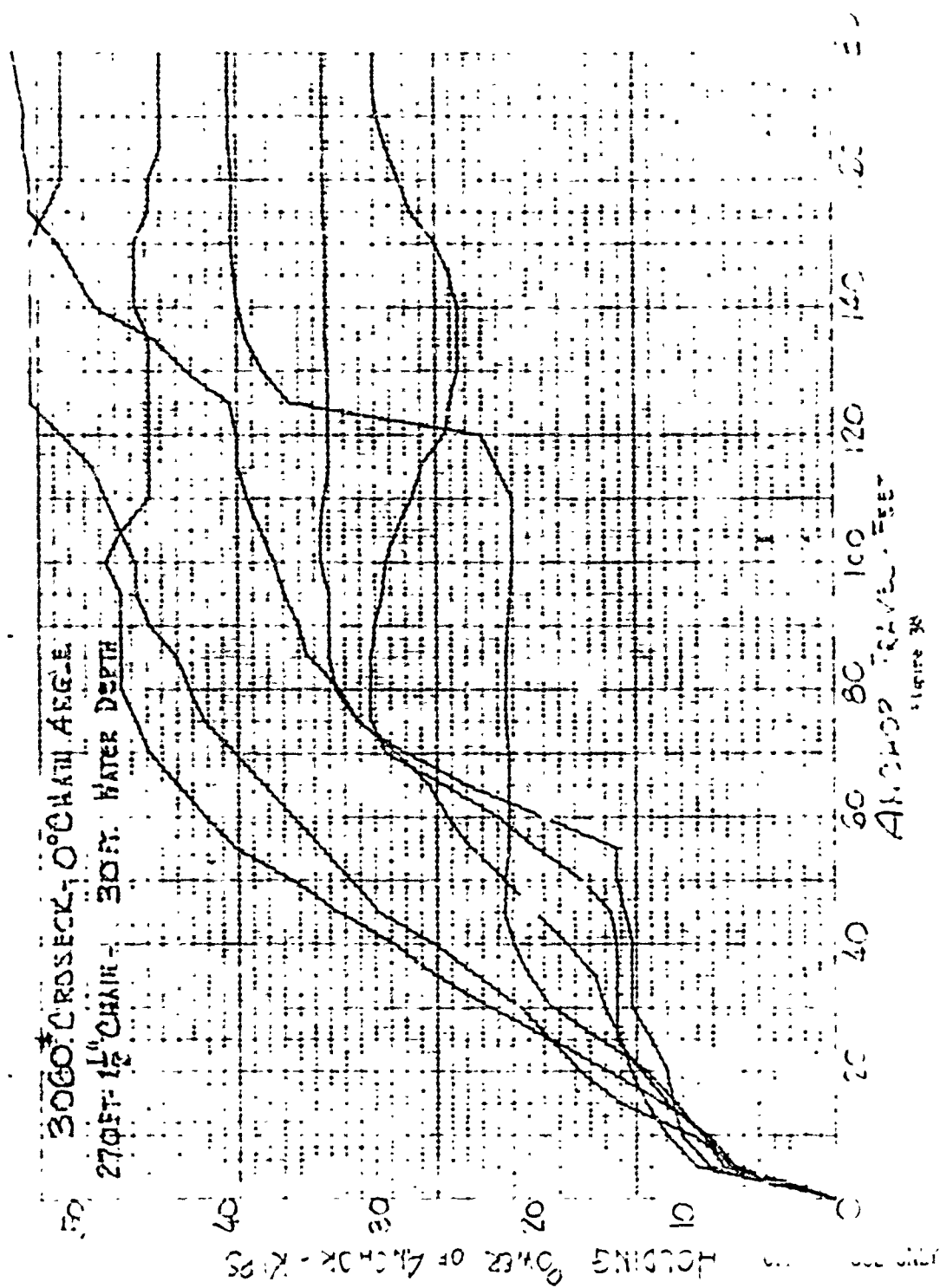


Figure 36



ANCHOR TRAVEL - FEET

FIGURE 37



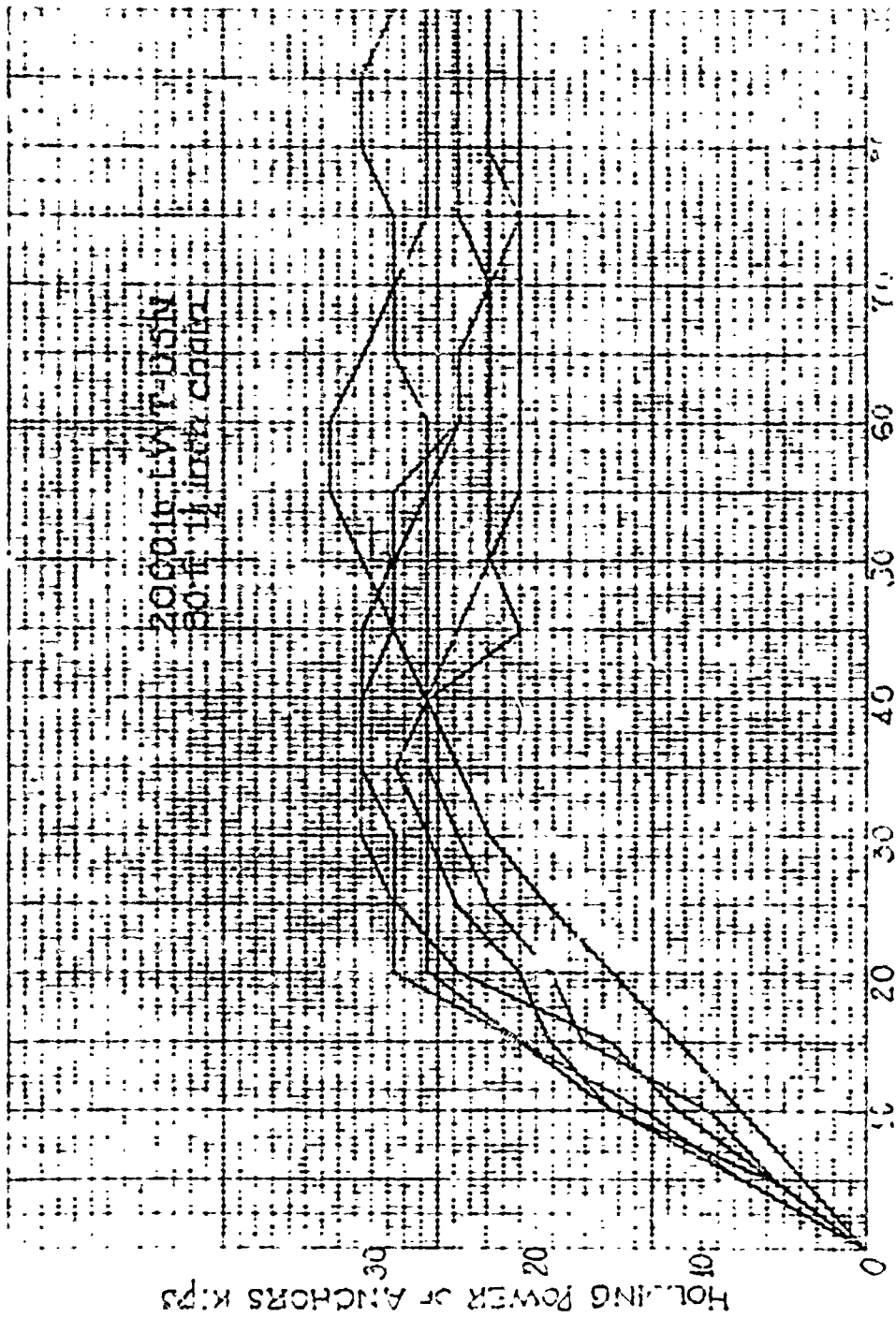


Figure 39

ANCHOR TRAVEL- FEET

HOLDING POWER OF ANCHORS KIPS

AND 3000 LBS ONLY

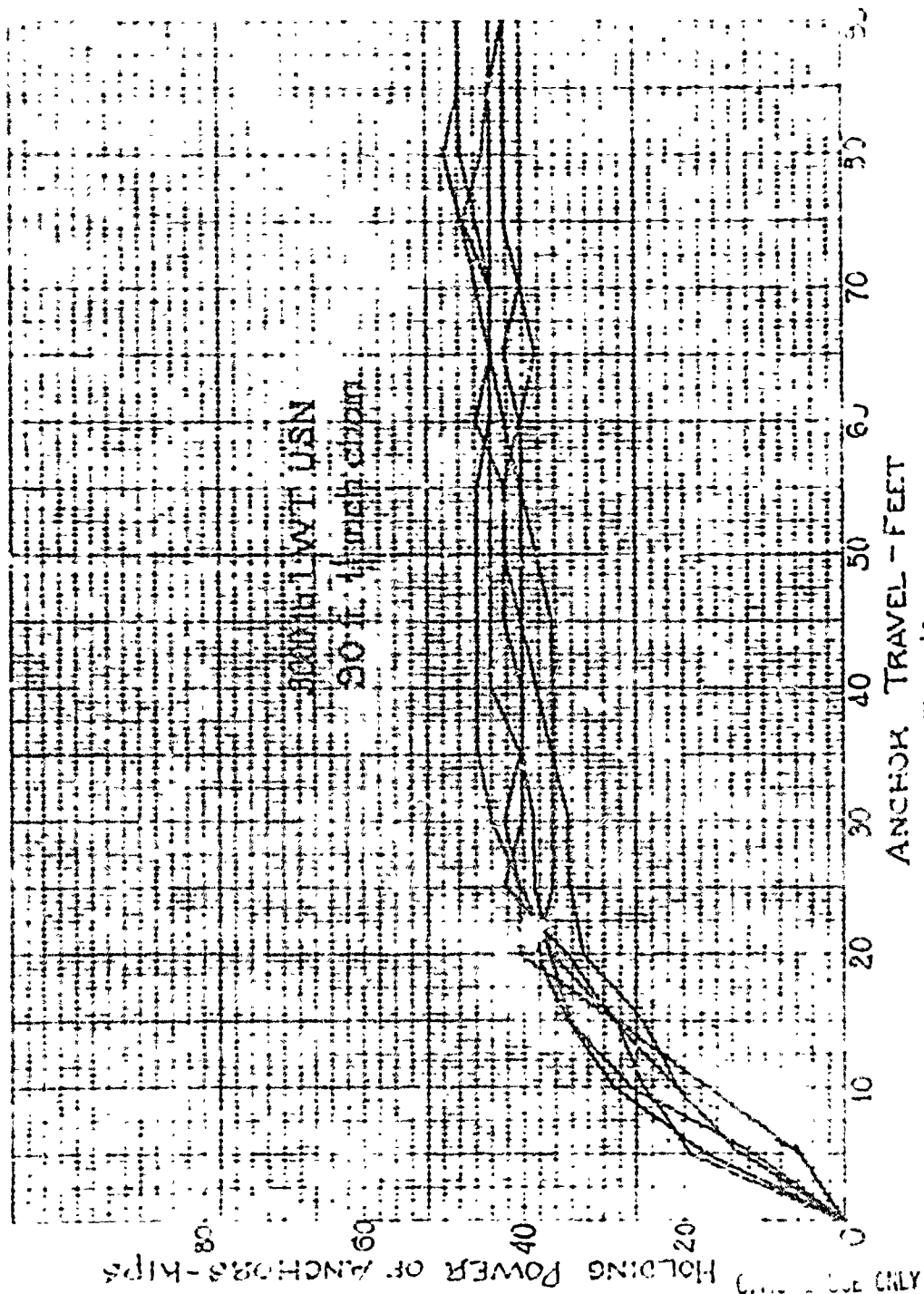


Figure 30

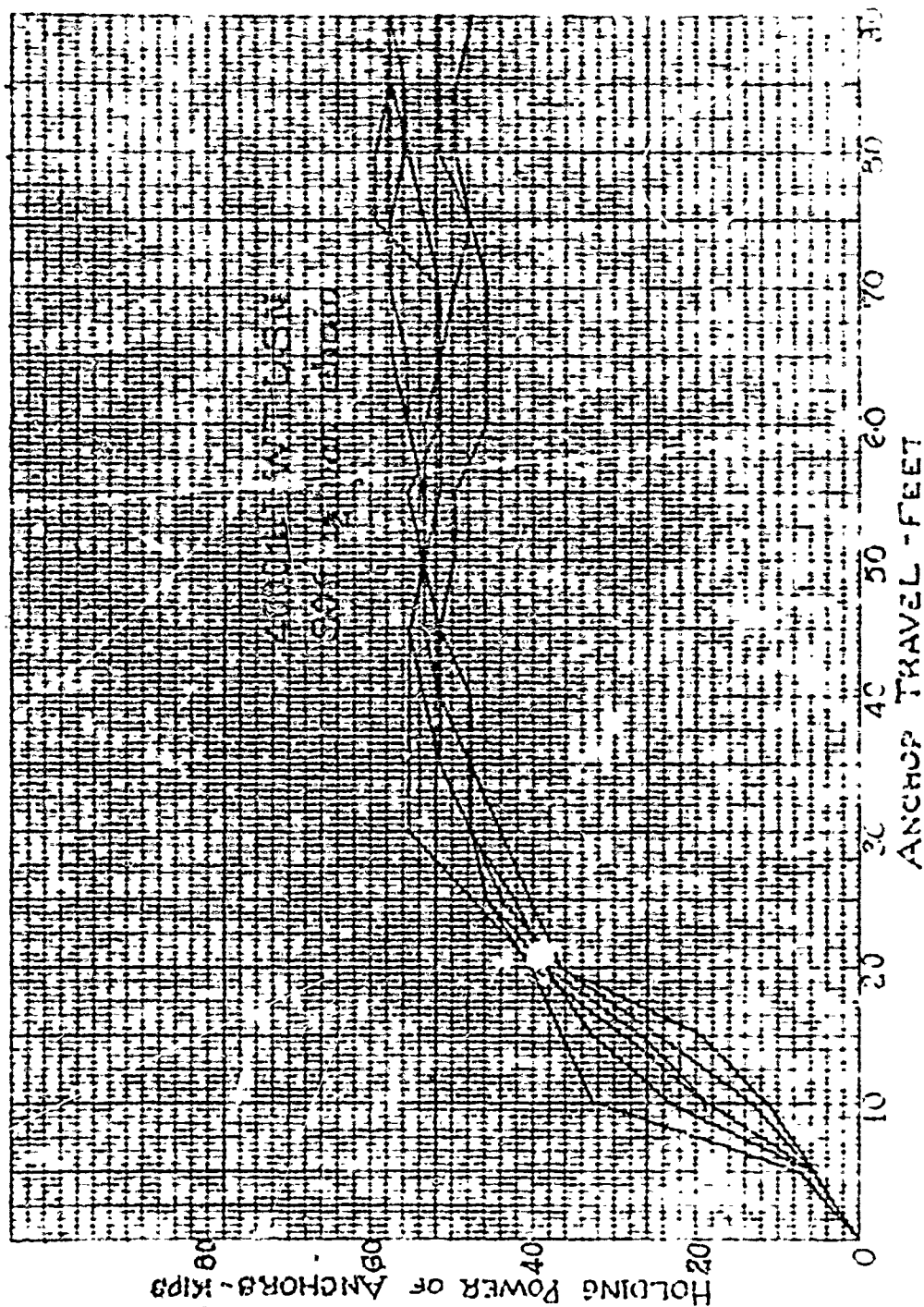
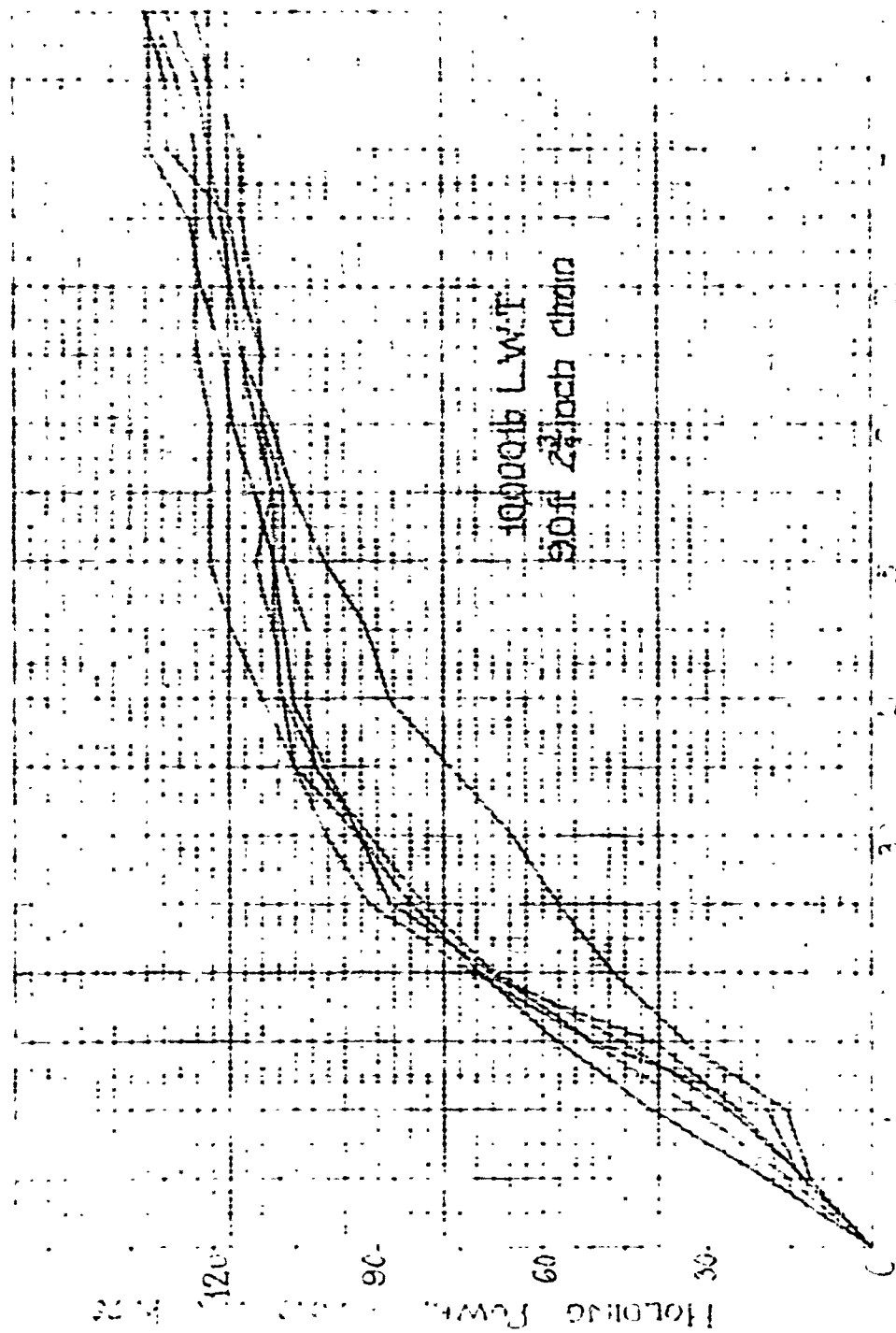


FIGURE 81

OFFICIAL USE ONLY



ANCHOR TRAWL - FIVE

Figure 2

OFFICIAL USE ONLY

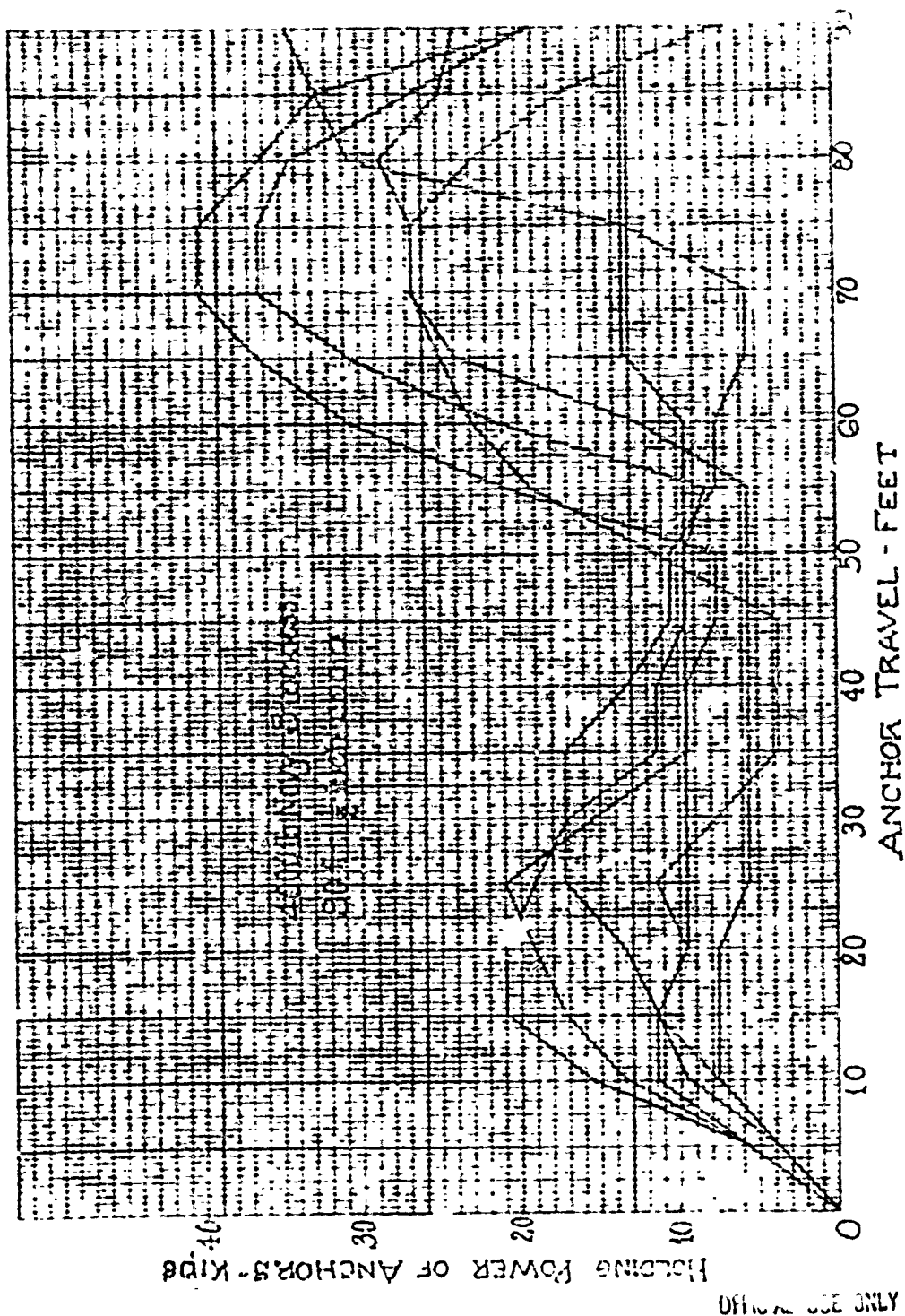
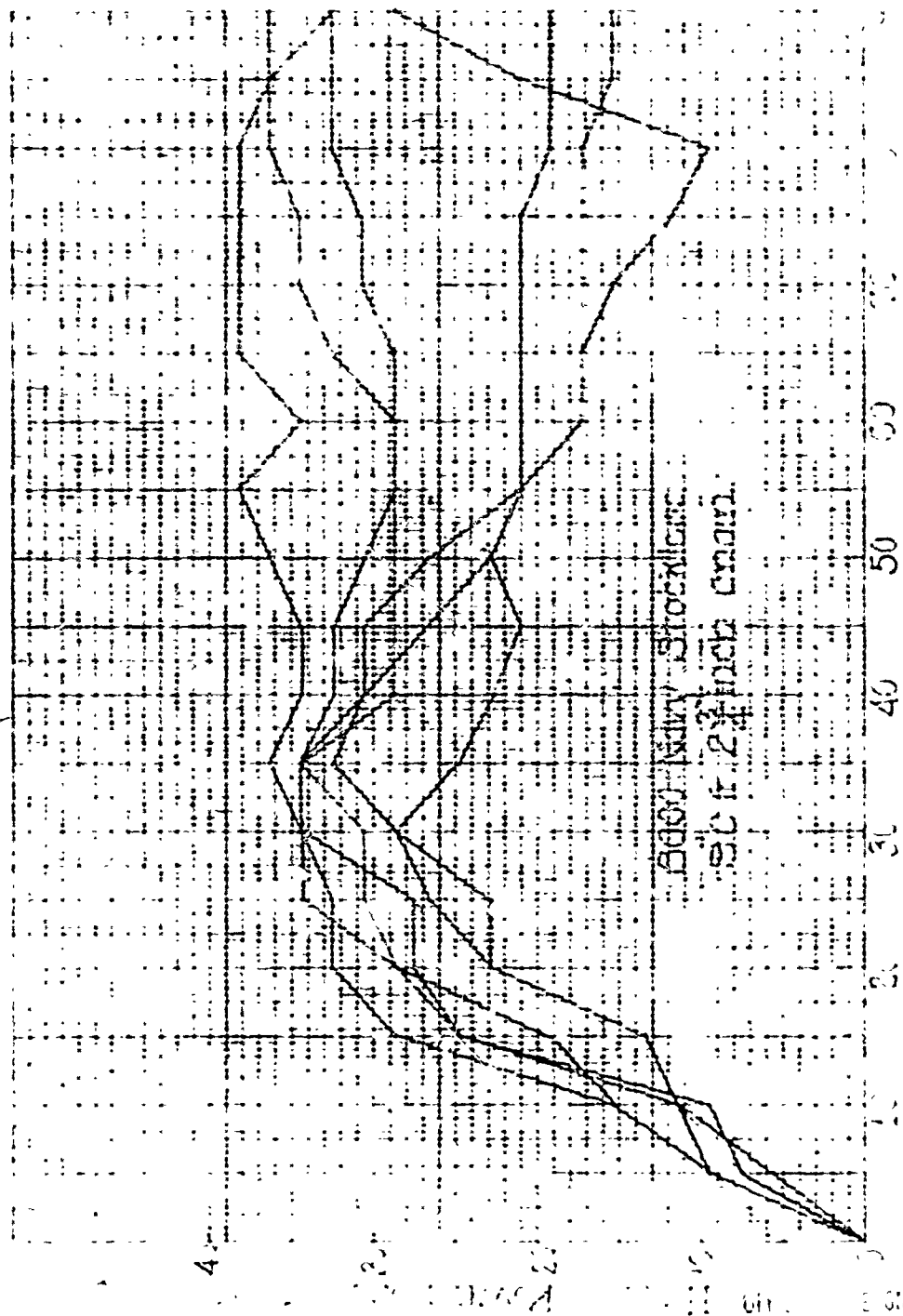


Figure 17



6000 lb dry strength

50 ft 2 1/2 inch diam.

ANCHOR TRAVEL - FEET

Figure 14

4
3
2
1
ON ONLY

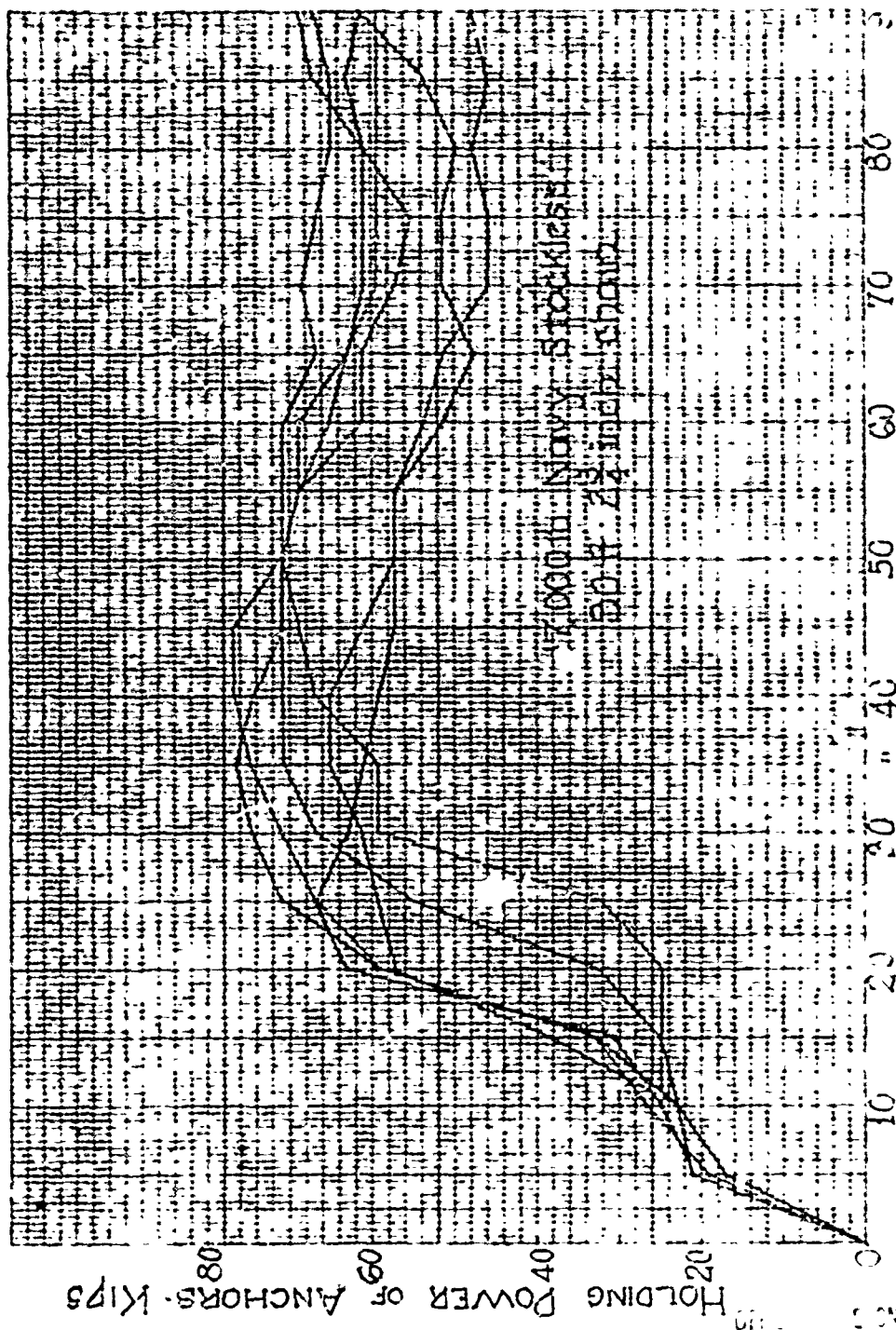
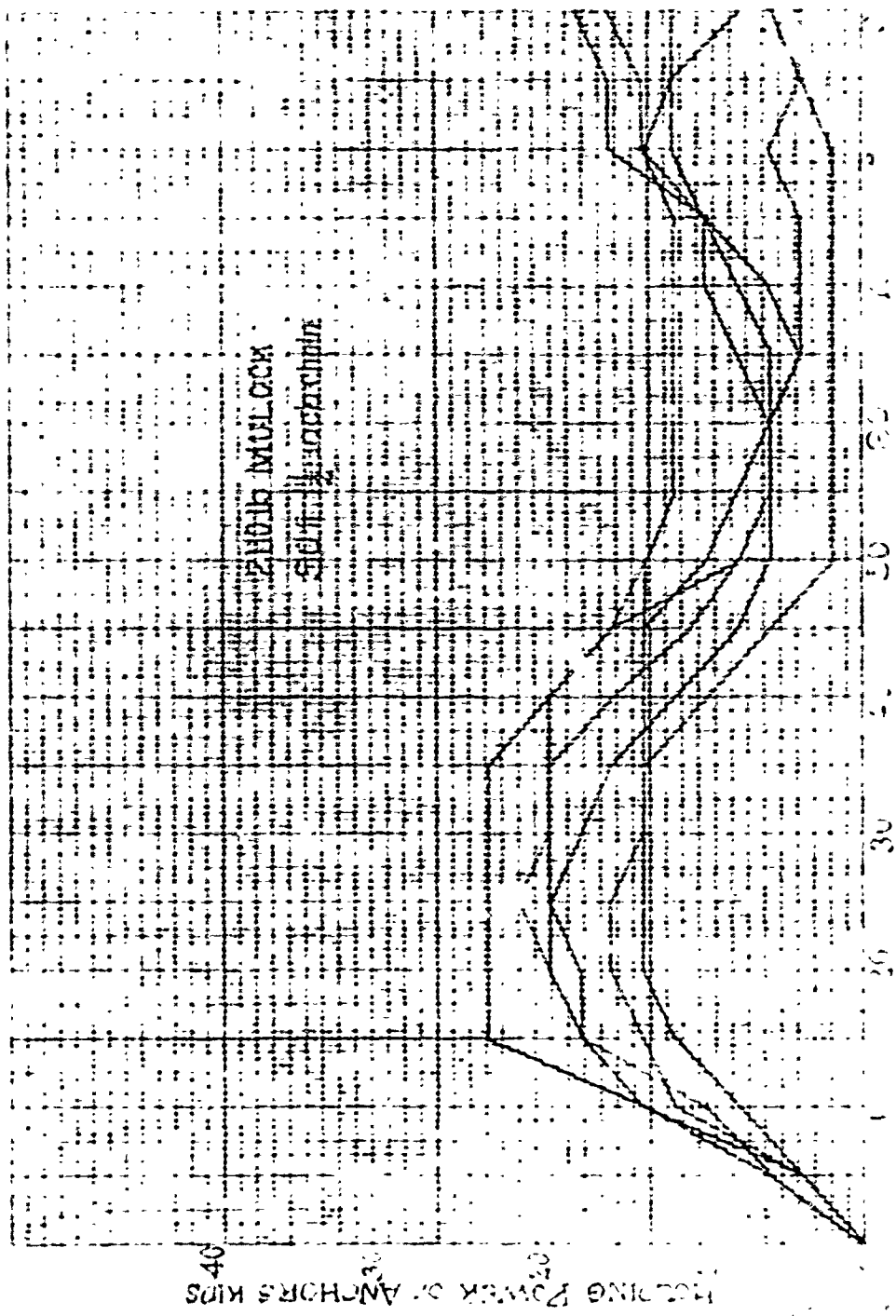


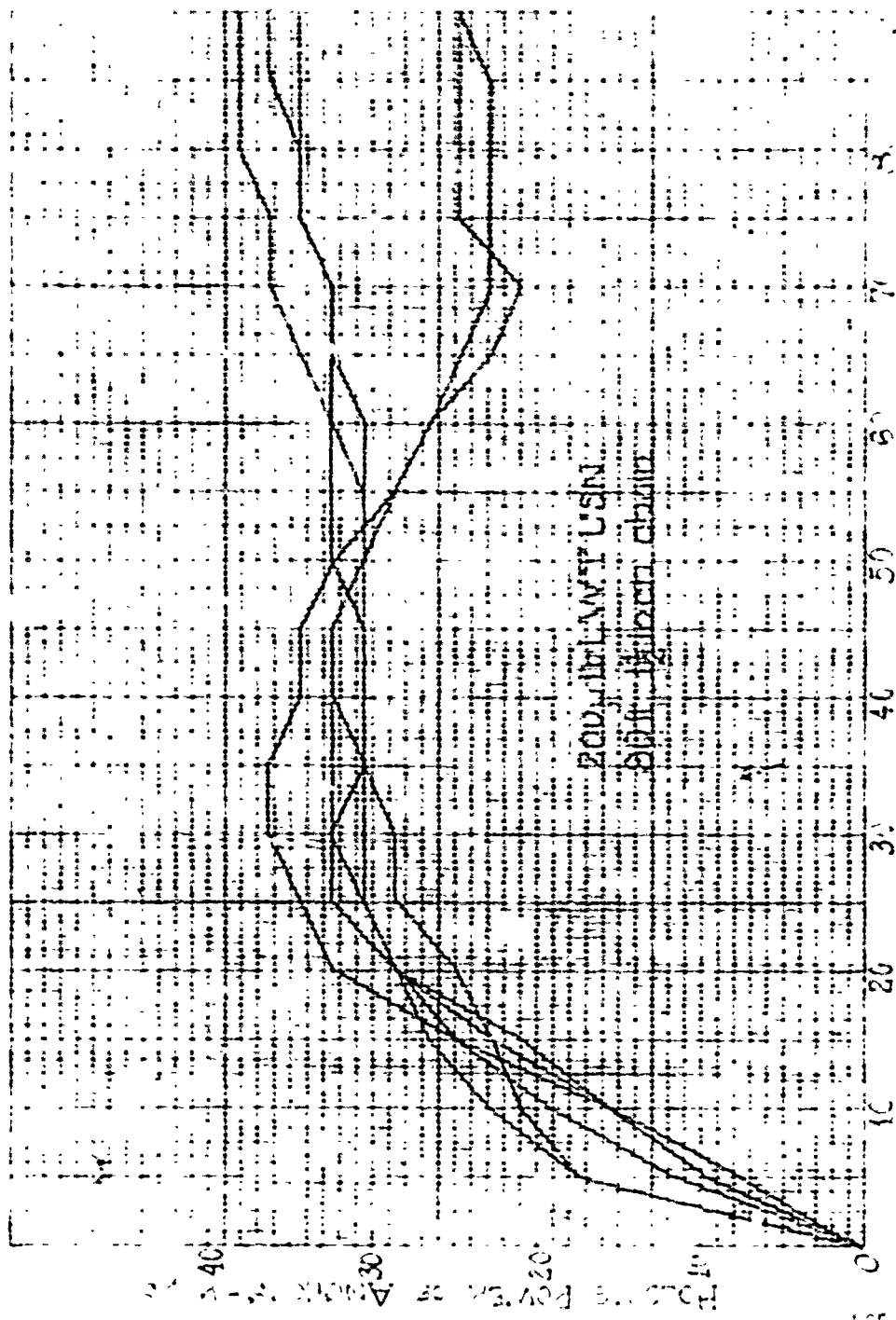
Fig. 35

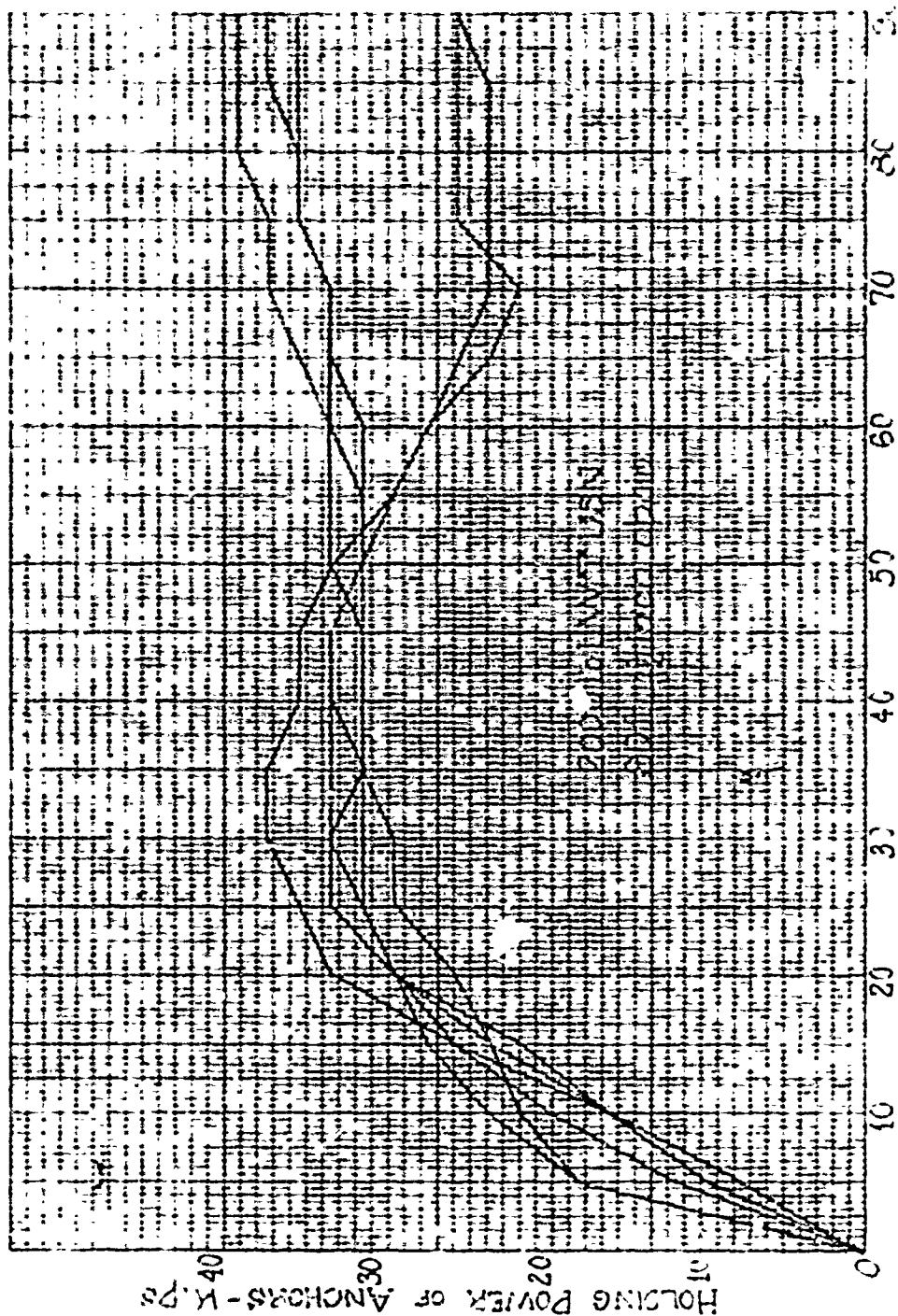


ANCHOR TRAVEL FEET

Figure 16

HOLDING POWER OF ANCHORS KIDS

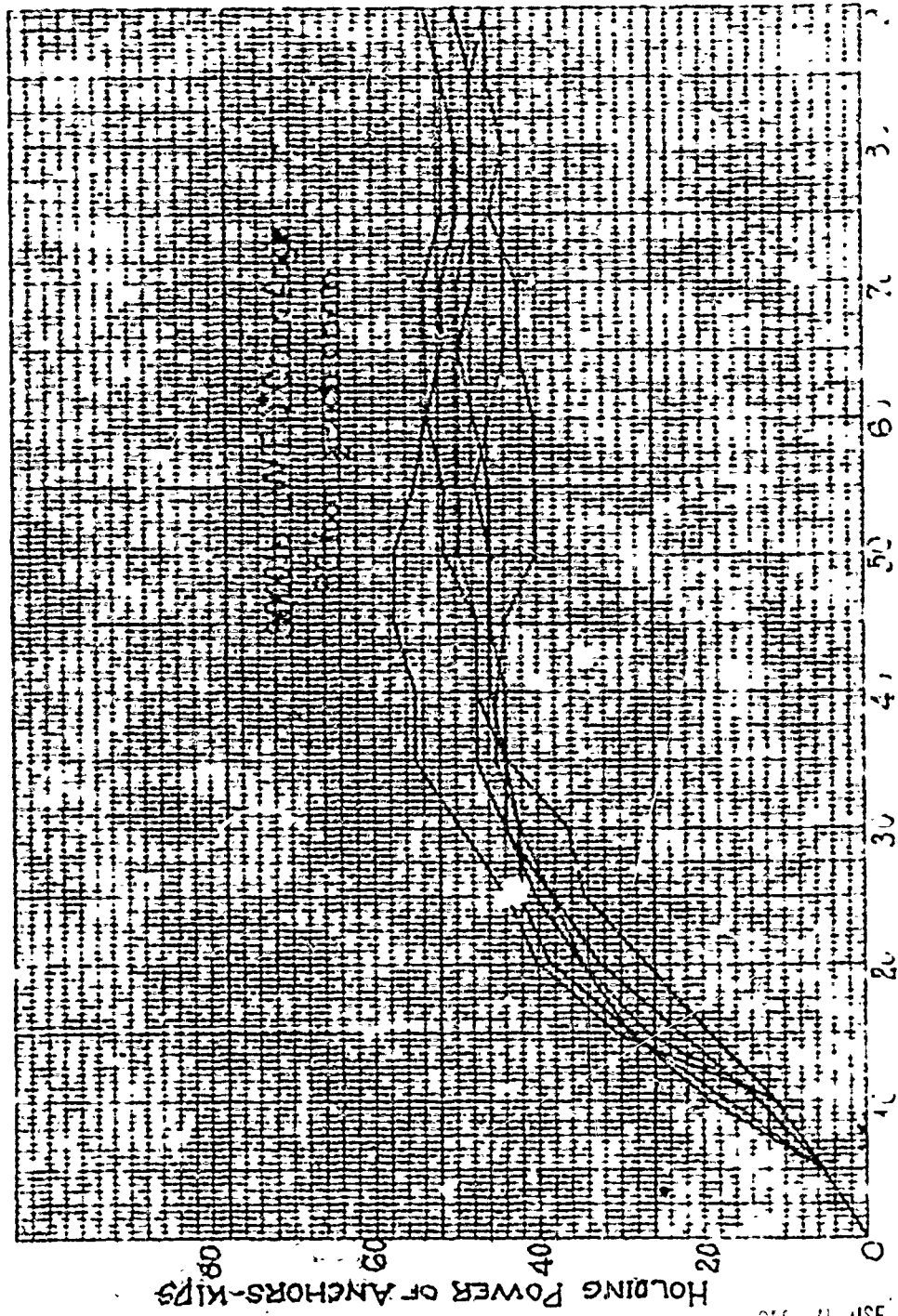




OFFICE USE ONLY

ANCHOR TRAVEL- FEET

Figure 47



ANCHOR TRAVERSE, FEET
FIGURE 48

17NO 550 117110

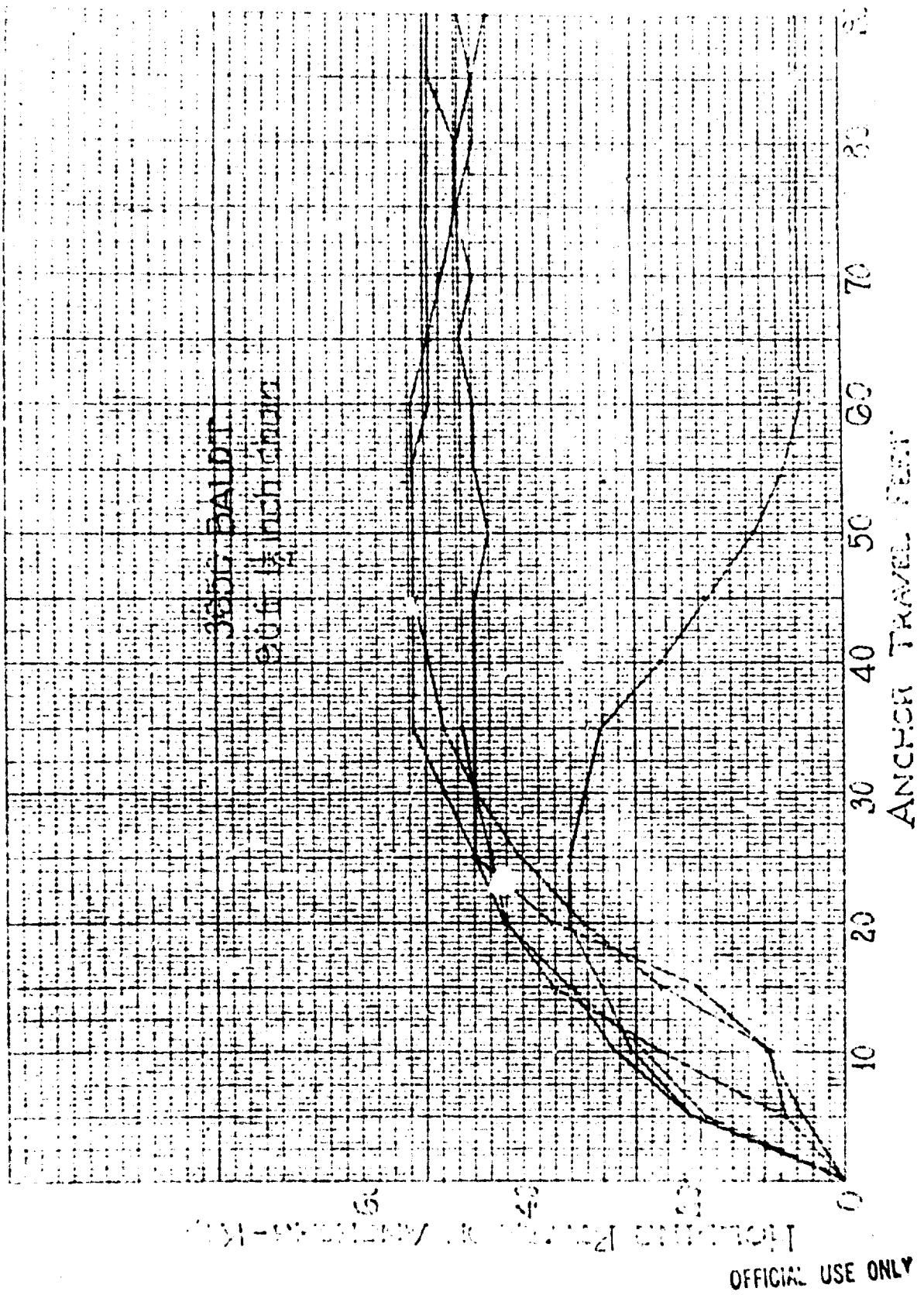


Figure 50

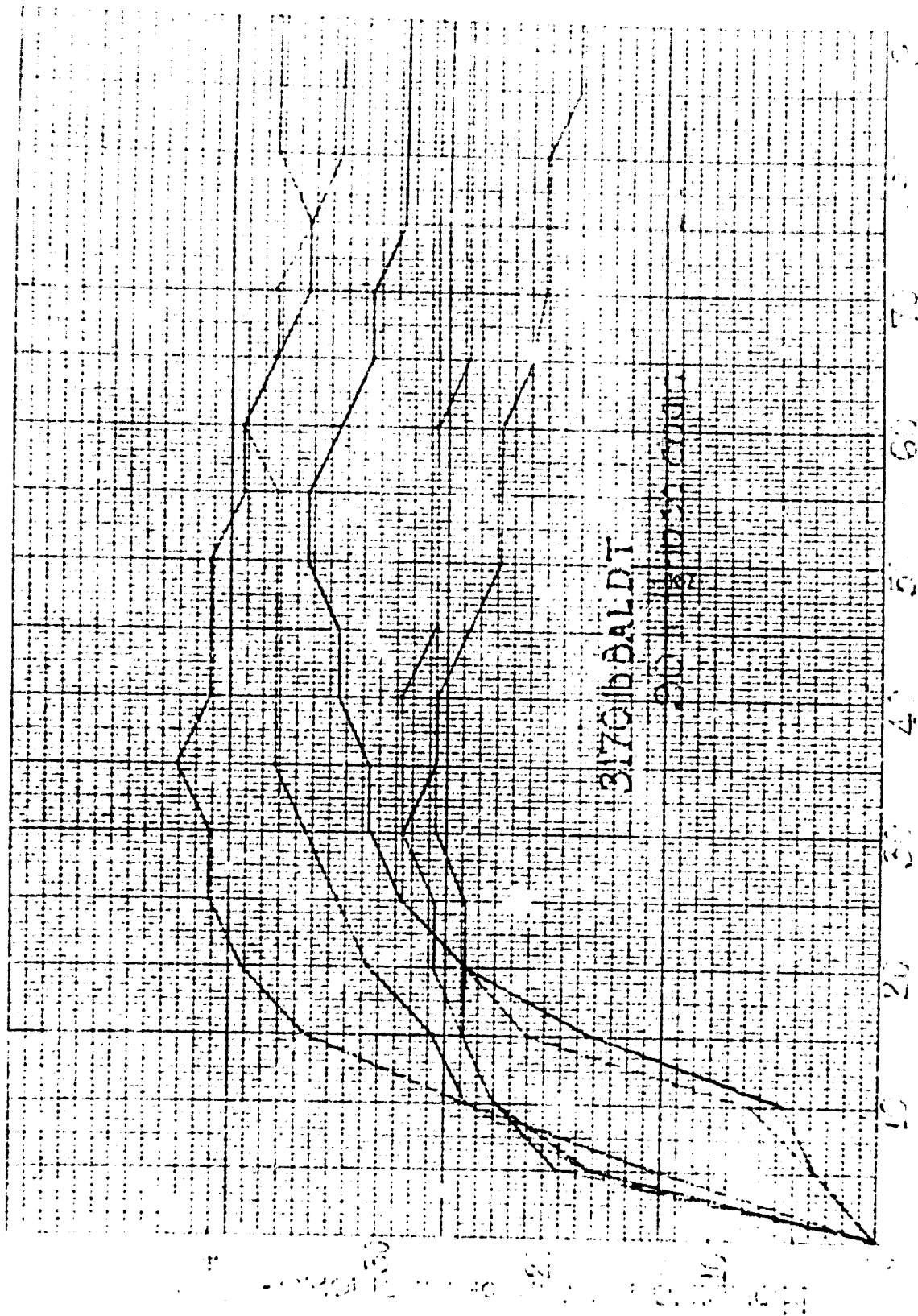


Figure 51

OFFICIAL USE ONLY

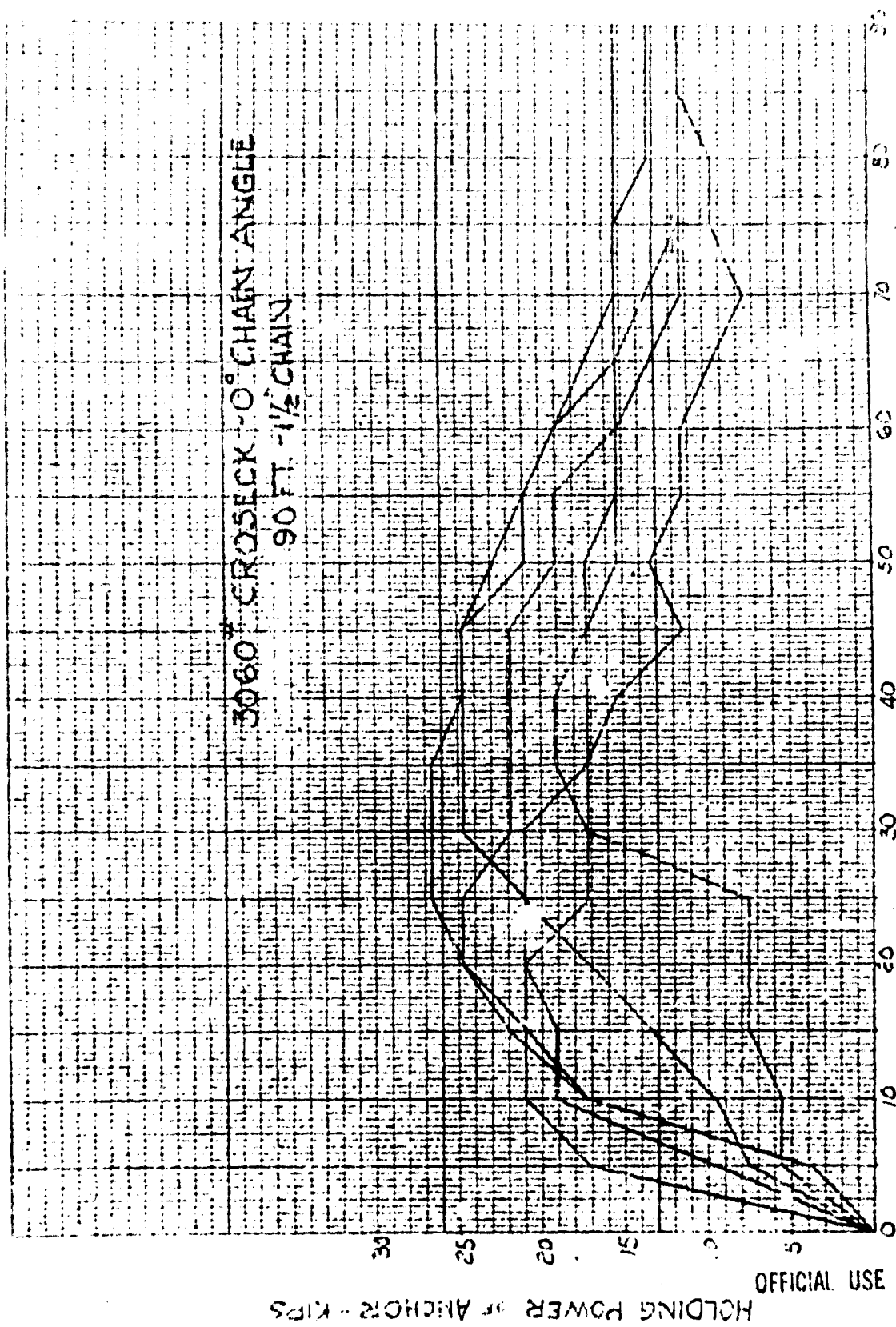


Figure 52