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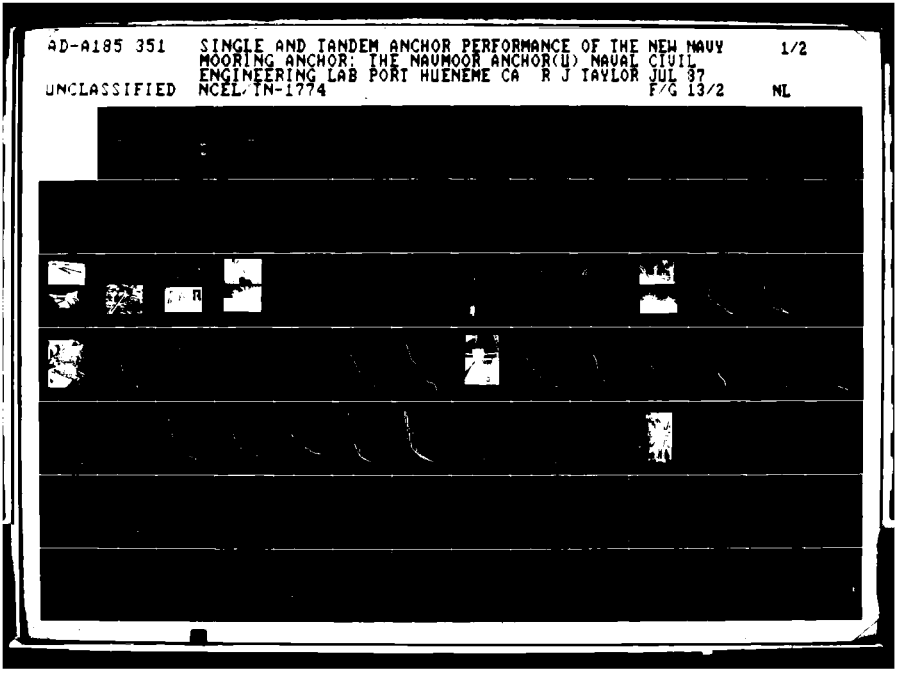

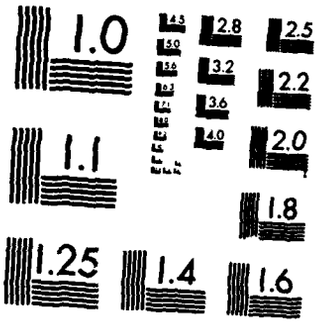

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By Robert J. Taylor

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Technical Note

Single and Tandem Anchor Performance of the New Navy Mooring Anchor: The NAVMOOR Anchor

ABSTRACT A new Navy mooring anchor (NAVMOOR), has been designed to satisfy a variety of Navy anchor applications. Various sizes of anchors have been designed, fabricated, and structurally and operationally proof-tested. This report describes the NAVMOOR Anchor, presents the results of prototype single and tandem anchor tests in sand and mud seafloors, provides anchor performance specifications, and presents Navy fleet mooring anchoring guidelines. The NAVMOOR Anchor was shown to be structurally and operationally superior to the Navy's STATO Anchor which in the past was the most effective general purpose anchor for Navy applications. The NAVMOOR Anchor was effective in dense sand and soft mud seafloors when used in single and tandem anchor leg configurations. Tandem anchor system holding capacity was shown to be at least twice the capacity of a single NAVMOOR Anchor. The Navy's fleet mooring requirements from class C (100-kip capacity) to class AAA (500-kip capacity) can be satisfied with only two sizes of NAVMOOR Anchor, the 10,000-pound and 15,000-pound NAVMOOR, used in various single and tandem anchor leg configurations.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME, CALIFORNIA 93043

METRIC CONVERSION FACTORS

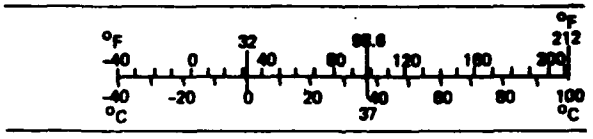
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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A new Navy mooring anchor (NAVMOOR), has been designed to satisfy a variety of Navy anchor applications. Various sizes of anchors have been designed, fabricated, and structurally and operationally proof-tested. This report describes the NAVMOOR Anchor, presents the results of prototype single and tandem anchor tests in sand and mud seafloors, provides anchor performance specifications, and presents Navy fleet mooring anchoring guidelines. The NAVMOOR Anchor was shown to be structurally and operationally superior

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to the Navy's STATO Anchor which in the past was the most effective general purpose anchor for Navy applications. The NAVMOOR Anchor was effective in dense sand and soft mud seafloors when used in single and tandem anchor leg configurations. Tandem anchor system holding capacity was shown to be at least twice the capacity of a single NAVMOOR Anchor. The Navy's fleet mooring requirements from class C (100-kip capacity) to class AAA (500-kip capacity) can be satisfied with only two sizes of NAVMOOR Anchor, the 10,000-pound and 15,000-pound NAVMOOR, used in various single and tandem anchor leg configurations.

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CONTENTS

INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has developed a new anchor suitable for a wide range of mooring applications. The new anchor is called the NAVMOOR Anchor. This development was initiated by the Naval Facilities Engineering Command in response to expanded Navy fleet mooring requirements from 300,000 pounds (class AA) to 500,000 pounds (class AAA). Support for this development was also provided by the Supervisor of Salvage, Naval Sea Systems Command.

This report describes the NAVMOOR Anchor design and operational features and presents the results of small-scale anchor tests on the beach and tests of full-size single and tandem NAVMOOR Anchors in sand and mud. Performance specifications of the NAVMOOR Anchor for sand and mud seafloors are also provided.

BACKGROUND

A program was established at NCEL in 1979 to improve the Navy's fleet mooring capability. Detailed anchor testing programs were conducted at several sites to determine the performance of Navy and commercial anchors (Ref 1 through 5). These tests provided data to support development of improved methods for predicting the performance of drag embedment anchors and methods for improving the performance of anchors (Ref 6 through 11).

Refined mooring load determinations and a reassessment of the Navy's mooring needs resulted in an upgrade in the Navy's mooring requirements to 500,000 pounds maximum. An analysis of high efficiency (high holding capacity to weight ratio) anchor options was performed (Ref 12). The analysis concluded that the Navy's expanded mooring requirements could be satisfied with a structurally and operationally improved version of the Navy's STATO Anchor used in single and tandem anchor leg configurations.

Before proceeding with the new anchor development, a program of model and small-scale tests of anchors was conducted (Ref 13) to evaluate the practicality and effectiveness of using anchors in tandem and to evaluate STATO Anchor configuration changes to enhance performance. Results were positive and justified prototype anchor development and testing to quantify single and tandem anchor performance in sand and mud seafloors.

ANCHOR DESCRIPTION AND OPERATIONAL FEATURES

General

The NAVMOOR Anchor (Figure 1) was designed for single and tandem anchor leg applications. A tandem anchor leg configuration is illustrated in Figure 2 with the NAVMOOR Anchor. In this example, chain is

used to connect the anchors but wire is also acceptable. The NAVMOOR Anchors are designed to structurally tolerate a tandem system capacity of up to 2-1/2 times the capacity of a single anchor. Model and small-scale tests (Ref 13) showed that two anchors of the STATO type (when rigged in tandem) could develop a total system holding capacity of 2-1/2 times the capacity of a single anchor. This design and application approach contrasts with normal commercial practice in the use of tandem anchors.

Normally, when a tandem anchor (also called a piggyback) is used in commercial practice, the primary anchor has failed to hold to its design load. The tandem anchor is added to bring the total capacity of the system up to the capacity originally required of the primary anchor. In contrast, the NAVMOOR Anchor system is structurally designed and operationally capable of being used to satisfy loads associated with much larger single anchors. The fact that anchor efficiency decreases as anchor size increases and that the efficiency of two anchors rigged in tandem is equal to or greater than that of the individually pulled anchors, results in less total weight for a tandem anchor system compared to a single anchor. Also, smaller anchors in a tandem system are easier to handle and recover, particularly in mud seafloors.

Anchor Design

Two views of a NAVMOOR Anchor, 1,000-pound nominal size, are shown in Figure 1. The general configuration of the STATO Anchor was used as the basis for the NAVMOOR Anchor design. For comparison, a STATO Anchor is shown in Figure 3. Plan dimensions of these two anchor types are similar for anchors of comparable nominal weight to ensure at least the same single anchor performance. For reference, design drawings for two versions of the NAVMOOR Anchor are provided in Appendix A. They include the 2,000-pound NAVMOOR Anchor with standard stabilizers designed for causeway mooring applications and the 6,000-pound NAVMOOR Anchor for salvage with folding stabilizers.

There were three principal problems with the STATO Anchor that needed to be corrected to provide an anchor type that would satisfy the Navy's anchoring requirements. The STATO Anchor is not structurally suited to tandem anchor use, has experienced performance problems in hard soil, and has had general structural problems. The NAVMOOR Anchor was designed to eliminate these problems. Other changes were made to simplify construction, improve handling, and expand fabrication options.

The design process began with the design of a 10,000-pound NAVMOOR Anchor for fleet moorings. Finite element analysis techniques were used to optimize the structural integrity of the anchor within a given weight specification. After the design was completed, an exact scale model (about 200 pounds) was designed, constructed, and tested in sand. Some design changes were found to be necessary to simplify construction; otherwise, the design and anchor performance were acceptable. For example, when tested with the 200-pound STATO Anchor (actual weight was 280 pounds), the NAVMOOR Anchor held 25 percent more than the 30 percent heavier STATO Anchor. Next, the 10,000-pound NAVMOOR Anchor was fabricated, instrumented with strain gages, and structurally tested to its design load. The strain gage layout is shown by Figure 4. Twenty single

and rosette gages were used principally in the vicinity of the anchor crown. The anchor was loaded several times at the third point of the fluke (measured from the fluke tip) to its design proof load of 210 kips. The anchor's proof load was established as 70 percent of the total expected anchor holding capacity, which for the 10K NAVMOOR Anchor was 300 kips. Some changes were needed in the anchor stopper design to reduce stress concentrations; otherwise the design was sound. This calibrated design could then be used as a basis for larger or smaller NAVMOOR Anchor designs.

The NAVMOOR Anchor, like most other anchors, is described by a nominal weight which often differs from actual anchor weight. Anchor weight can exceed nominal weight by as much as 10 to 15 percent depending upon fabrication means, anchor application, and the designers choice of plate thickness. External anchor dimensions are controlled to ensure consistent and predictable performance. The nominal weights of the NAVMOOR Anchor were based on the STATO design. The 6,000-pound STATO design was used as the basis for extrapolation of all NAVMOOR Anchor sizes. The STATO Anchor weights were based on anchor weight without mud palms. Mud palms add about 10 percent to the anchor weight; in addition, normal weight variations to accommodate available plate sizes could be as much as 10 percent. As an example, the 6,000-pound NAVMOOR Anchor has two configurations; one for fleet mooring applications and one for salvage applications. The weights of these anchors are 5,940 pounds and 7,200 pounds respectively, even though external dimensions and actual performance are comparable. The higher weight of the salvage anchor results from a strengthened anchor palm to support the stabilizer hinge mechanism and the heavier folding stabilizers.

The principal features of the NAVMOOR Anchor are described in the following paragraphs. Use Figures 1 and 2 as reference for the following discussions.

Anchor Flukes. The plan size of the NAVMOOR and STATO Anchor flukes are similar. The NAVMOOR flukes are of box-like construction to reduce fluke stress and to lighten and streamline the flukes. The STATO flukes are comprised of a central plate with external rib stiffeners. The stiffeners trap sand during penetration in sand resulting in higher penetration resistance and poor hard soil performance. The primary penetration resistance on the anchor during the initial embedment phase is on the flukes; this resistance is a function of fluke roughness. The smooth NAVMOOR flukes cause significantly less penetration resistance than the rough STATO flukes. Model and small-scale tests showed at least a 30 percent improvement in anchor capacity for a smooth-fluked anchor in sand.

The initial design of the NAVMOOR Anchor flukes used internal rib stiffeners located at the folds in the fluke cover plates; this complicated fluke construction. Subsequently, a more refined finite element analysis was performed to see if the ribs could be eliminated without creating an unacceptable weight increase. The ribs could be eliminated with a minor increase in cover plate thickness. All current NAVMOOR Anchor designs employ hollow flukes with no internal rib stiffness.

Stopper Assembly. The stopper assembly consists of a fixed stopper to restrict the fluke angle to 50 degrees for mud use and a welded-on sand wedge to reduce the fluke angle to 32 degrees for sand use. Another restriction to the design is that the anchor penetration angle be 65 degrees to ensure penetration in hard soil. The penetration angle described in Reference 5 is the external angle between the fluke and seafloor when the fluke is open and the fluke tip and shank end are on the seafloor.

The STATO Anchor experienced structural problems, principally because of high stresses occurring at the stopper and trunnion area. The trunnion is the pin located in the anchor crown that connects the shank to the fluke assembly. A finite element analysis that concentrated on this highly stressed area identified specific problem areas and enabled confident design. The analysis was supplemented and calibrated by full-scale instrumented testing of a NAVMOOR Anchor prototype.

Anchor Mud Palms. The NAVMOOR Anchor mud palms are an integral part of the anchor and are used in sand and mud seafloors. The STATO Anchor mud palms are welded add-ons when the anchor is to be used in mud. There is a small performance reduction in sand due to the permanent NAVMOOR Anchor mud palms but this is compensated for by the enhanced performance caused by the smooth flukes.

Anchor Stabilizers. Simple pipes are used for the standard NAVMOOR Anchor stabilizers compared to the welded, tapered construction for the STATO Anchor stabilizers. Model tests showed that the pipe was equal or more effective in controlling anchor roll than the tapered units. The NAVMOOR Anchor stabilizers are bolted or tac-welded in place. They are easily removed for shipping and storage ease.

Shank Assembly. The NAVMOOR Anchor shank is significantly different than the STATO Anchor shank. The STATO shank terminates at the trunnion pin within an enclosed anchor crown as do most anchors. For these anchors, padeyes are connected directly to the anchor crown. The flukes must be fixed open to prevent fluke closure when load is applied by a tandem anchor. The NAVMOOR shank extends through the anchor crown. This enables connection of the tandem anchor directly through the anchor shank. The pinned tandem link (shown in Figure 1 in the lower view) provides the means for the tandem connection and moves independent of anchor fluke movement. Loading by the tandem anchor does not cause fluke closure with resulting loss of primary anchor capacity.

As mentioned earlier, model and small-scale tests demonstrated that two anchors in tandem could develop a capacity 2-1/2 times the capacity of a single anchor. These tests showed that the tandem or piggyback anchor could hold 50 percent more than a single, individually pulled anchor. The anchor shank and connecting hardware are structurally designed to safely hold 2-1/2 times the capacity of a single anchor. The tandem link is sized for a load 1-1/2 times single anchor load.

ANCHOR APPLICATIONS

A variety of NAVMOOR Anchor sizes have been designed to satisfy many anchoring applications. Several of the prototypes are shown in Figure 5.

Navy Fleet Moorings

The Navy maintains about 300 permanent fleet moorings at harbors worldwide. These moorings currently range up to 300,000 pounds in capacity. However, the Navy has designs for and is procuring hardware for storm moorings to 500,000 pound capacity. NAVMOOR Anchor designs were developed to satisfy requirements typically above 300,000 pounds but can be used effectively for lesser capacity moorings. Twelve 10,000 pound (nominal weight) NAVMOOR Anchors (shown to the right in Figure 5) have been fabricated for the Navy's inventory for preproduction evaluation. A design for a 15,000-pound NAVMOOR Anchor was also completed for the fleet mooring program.

To reduce production costs, the 10,000-pound NAVMOOR Anchors were partially cast. The anchor shank and palm were cast and the flukes were fabricated and then welded to the cast palm. The "cast" NAVMOOR Anchor weight was equal to the fully fabricated anchor weight. In addition, anchor stresses, as measured during structural proof testing were also comparable to those of the fabricated anchor.

Navy Salvage

The Navy Supervisor of Salvage identified the need for an improved drag anchor for salvage operations. It had to be compatible with the ARS 50 class ships, hold 100,000 pounds in a broad range of seafloor conditions, and be suitable for free-fall deployment. A 6,000-pound NAVMOOR Anchor satisfied holding requirements but the anchor had to be modified to adapt to stowage in existing anchor pockets on the ARS 50 class ships. A prototype 6,000-pound NAVMOOR Anchor is shown in Figure 5 with one stabilizer in the open position. The stabilizers remain closed while on deck but can open during free fall to the seafloor. The stabilizers fully open on the seafloor from drag force on the plates on the end of the stabilizers when the anchor is proof set.

Tests conducted in soft mud in San Francisco Bay and user tests off the ARS 50, USS SAFEGUARD in sand and coral off Hawaii confirmed the ruggedness of the design and the operation of the folding stabilizers. The 6,000-pound NAVMOOR Anchor is shown in Figure 6 on the SAFEGUARD being released from the forward and after pockets.

As a result of the tests, some design changes were made to ease handling, reduce maintenance, and reduce cost. Based upon the positive results achieved with the cast version of the 10,000-pound NAVMOOR Anchor, the preferred construction method for the NAVMOOR Salvage Anchor is also a combination of cast and fabricated elements.

Amphibious Operations

Three sizes of anchors were designed for anchoring applications associated with amphibious logistics:

1. A 100-pound NAVMOOR Anchor was designed to provide side-stays for a floating fuel line. The anchor replaces a 200-pound STATO Anchor (280 pounds actual weight) which was too heavy for manhandling and a 150-pound LWT which was ineffective in mud. Several hundred 100-pound anchors have been procured.

2. A 1,000-pound NAVMOOR Anchor was designed as a replacement for the 2,500-pound LWT for the Navy's new Powered Causeway Section (PCS) because of space limitations on the PCS. Although lighter, the NAVMOOR Anchor will hold several times more than the LWT in mud and roughly two-thirds as much in sand. To date, 25 PCS's have been outfitted. Some design changes have occurred as a result of inservice use. The anchor shank has been strengthened to better tolerate off-line loading. The sand wedges used to reduce the fluke angle to 32 degrees are now lightly welded in place rather than bolted in place. This last change has been made for all the NAVMOOR Anchors.

3. A 2,000-pound NAVMOOR Anchor was designed as the new mooring anchor for the Army Corps of Engineers causeway system. This anchor replaces the LWT because of the general ineffectiveness of the LWT in mud seafloors. Also, the tandem anchoring capability of the NAVMOOR Anchor allows procurement of a single anchor size to satisfy varying loads along the causeway by using single and tandem anchor leg configurations.

ANCHOR TESTING PROGRAM

Anchor testing progressed through various stages including laboratory model testing, small-scale testing on the beach at Port Hueneme, California, and prototype testing in sand off Port Hueneme and in mud off Hunters Point, San Francisco Bay. The model test program (Ref 14 and 15) will not be discussed in this report. These tests were simply used to guide preliminary design to ensure at least comparable performance of the NAVMOOR Anchor to the proven STATO Anchor design and to evaluate minor configuration changes to enhance anchor performance.

Test Locations

Port Hueneme. The seafloor material at this ocean test site consisted of a dense well-graded gravelly fine sand. A typical grain size curve for a sample is provided in Figure 7. This site has changed considerably since 1981 when prior anchor tests were conducted (Ref 5). At that time, the site consisted of a poorly-graded fine sand. For reference, the 1981 distribution is also plotted on Figure 7. The seafloor material at this site provided a good test of the penetrating capability of the NAVMOOR Anchor in hard seafloor conditions.

San Francisco Bay, Hunters Point. The Hunters Point site was selected because there was a significant amount of historical data on the STATO Anchor (Ref 16) and the site was previously classified as a normally consolidated silty clay (mud). The grain size distribution for the Hunters Point mud is shown in Figure 8. The soil classified as an organic clayey silt. Undrained soil shear strength data taken from three cores are plotted in Figure 9. Historical data from previous NCEL tests (Ref 14) are also plotted for comparison. The historical data was generated from unconfined compression tests whereas the current data came from vane shear testing. Vane shear testing causes less sample disturbance, thus higher average values; nonetheless, results are similar. A reasonable approximation for the strength profile can be stated as the soil strength increases at the rate of 10 psf/ft of depth.

Test Procedures and Equipment

Small Scale Testing. Tests were performed on the beach at Port Hueneme for comparative evaluations of anchor performance prior to prototype testing. The beach material consisted of a poorly graded, medium dense, fine sand. The testing procedure was unsophisticated but very effective. Anchors were pulled with a bulldozer as shown in Figure 10. Total load was recorded using a dynamometer at the bulldozer. Drag distance was visually recorded by observing the travel of a marked line attached to the anchor relative to a fixed point. Other measurements taken at the completion of the test were anchor roll angle, anchor shank pitch angle, anchor chain angle, and anchor depth.

Prototype Testing. The ocean test setups used at Port Hueneme and San Francisco Bay are shown schematically in Figures 11 and 12. The test setups were different but both produced the data needed to establish anchor performance. The test setups and equipment capabilities were suitable for testing either single or tandem anchors.

Each anchor was instrumented to determine anchor depth, anchor shank pitch, anchor roll, and anchor load. A load cell was located between the chain and anchor shackle. An instrument package was strapped to the anchor shank (Figure 13). It contained inclinometers to measure pitch and roll, a pressure transducer to measure anchor depth, all signal conditioning equipment, and load cell amplifiers. A hose attached to the pressure transducer was buoyed off to ensure that it remained in the water column to avoid false readings. The measurement system(s) was connected to the instrumentation onboard the test barge via a 1,000-foot-long electrical well-logging cable. Mooring line load and line angle at the barge and barge displacement relative to a fixed spar buoy were measured. These data were needed to calculate true anchor drag distance as well as to determine the contribution of the bottom resting chain to total anchoring capacity.

At Port Hueneme, anchor loading was accomplished by a 250-ton capacity chain jack that pulled the test barge at about 2 feet per minute toward the restraint mooring that was located on the beach. At San Francisco, a 150-ton capacity winch was leased to speed the testing process. Because of winch capacity limits, the wire was two-parted through a sheave located on another YC barge (Figure 12). The barge system used at Hunters Point

is shown in Figure 14 at the completion of a test series when the barges were near touching. There was sufficient wire to allow barge separation of almost 600 feet which enabled about five tests to be conducted before the wire had to be overhauled.

SINGLE ANCHOR TEST RESULTS AND ANALYSIS

Port Hueneme Beach Tests

General. Before fabricating the prototype 10,000-pound NAVMOOR Anchor, a scale model was constructed to evaluate comparative performance against the STATO Anchor as well as to devise efficient fabrication methods. An anchor of approximately 200-pounds (actual weight was 211 pounds) was desired for comparison to the 200-pound STATO Anchor. It was later discovered that the actual weight of the 200-pound STATO Anchor was 280 pounds; nevertheless, a relative comparison was still possible. The model NAVMOOR Anchor was an exact scaled replica of the prototype. The stress levels in the model at design load are very low compared to the prototype. If the NAVMOOR model had been designed as a working prototype, much smaller steel sections could have been used which would have resulted in a lighter, more streamlined anchor. However, the dual purpose of evaluating anchor constructability would not have been served.

Test Results for 200-Pound Anchors. Five tests each were conducted with the NAVMOOR and STATO Anchors and the results are shown in Figure 15 and 16. To minimize beach variability effects on test results, the anchors were alternately pull tested. The average estimated performance curve for each anchor was plotted on Figure 17. Drag distances were nondimensionalized by reference to anchor fluke length to allow performance comparison to larger or smaller anchors. It is clear from Figure 17 that the NAVMOOR Anchor was more effective than the STATO Anchor in beach sand. The average holding performance advantage of the NAVMOOR anchor was 25 percent. From an anchor efficiency standpoint, the advantage was significantly greater because of the actual weight difference. Anchor efficiency is defined as the ratio of anchor holding capacity to nominal anchor weight.

Figure 18 illustrates one reason why the STATO Anchor is less efficient than the NAVMOOR Anchor in sand even though their general configurations are similar. The external ribs on the STATO Anchor confine and trap sand during the embedment process. This results in higher penetrating resistance that is a function of the friction between the anchor fluke and the penetrated medium. The coefficient of friction between the rough-fluked STATO Anchor and the beach sand is related to the sands intergranular friction, which for a medium density sand equals about 0.7. The coefficient of friction between a smooth steel surface, like the NAVMOOR Anchor fluke, and the beach sand is 0.3 to 0.4. From these preliminary test results it appeared that the goal to improve hard soil performance had been achieved.

Test Results for 100-Pound Anchor. A 100-pound NAVMOOR Anchor was designed for the specific application of side-stay anchor for a floating

fuel line. The 100-pound weight was selected to enable manhandling. Beach tests were conducted to evaluate anchor stability, performance consistency, relative holding capacity, and penetrability. The results of the five tests conducted are shown in Figure 19. Two of the five tests were run in wet dense sand near the water's edge. The remaining three tests were performed in dry sand. Results were indistinguishable. The 100-pound NAVMOOR Anchor had no difficulty penetrating the dense near-shore sand. The average performance was plotted in Figure 17. Interestingly, the 100-pound NAVMOOR Anchor held about 75 percent as much as the nearly 3 times heavier 200-pound STATO Anchor.

Later, in preparation for the final design of a 6,000-pound NAVMOOR Anchor for salvage operations, the 100-pound NAVMOOR Anchor was modified to accept folding stabilizers scaled from the prototype NAVMOOR Salvage Anchor. The test model is shown in Figure 5. Comparative beach tests were performed with the standard 100-pound anchor and the 100-pound anchor with folding stabilizers. Results are not presented, but the performance of these two anchors was indistinguishable and can be represented by the curve of Figure 17. This was a surprise because the larger folding stabilizers were expected to offer greater penetrating resistance which should have caused lower capacity.

Port Hueneme Sand Single Anchor Tests

General. Various sizes of NAVMOOR Anchors (1,000, 6,000 and 10,000 pounds nominal weight) were tested as single anchors. The 1,000-pound size is shown ready for tests as a single anchor in Figure 13. Typical load-drag distance data describing the performance of a single anchor is shown in Figure 20. The cyclic character of the data does not reflect actual anchor performance; rather, it reflects the effect of the test method on the results. The chain jack used to apply the test load hauled in about 3-1/2 feet of chain before it had to be reset to pull again. During the resetting process, up to 1 foot of chain was let out. This caused the large drop in anchor load which was a function of mooring geometry rather than anchor slippage. To simplify evaluation of anchor performance, the data were replotted to show peak values that correctly represent anchor capacity.

NAVMOOR 1,000-Pound Anchor Test Results. The performance of the single 1,000-pound NAVMOOR Anchor is shown in Figures 21 and 22. The test mooring leg from barge to anchor consisted of 36 feet of 2-1/2-inch chain and 45 feet of 1-1/2-inch chain. Total horizontal tension at the deck and tension at the anchor were measured directly. The anchoring tension was determined by subtracting the load caused by the surface resting chain from total tension. The anchoring tension defines the true anchor holding capacity which includes load carried by the anchor and buried chain. In both anchor tests, load was still increasing at a gradual rate when testing was stopped (Figures 21 and 22) so neither anchor reached maximum capacity. The point at which maximum capacity is reached can often be difficult to detect during the test. Also, use of the chain jack was so tedious that tests were often stopped when performance appeared to be peaking. In both tests, the anchoring tension was approximately 30 kips at 40 feet of drag distance.

The anchor was extremely stable during both tests; maximum anchor rotation varied from 2 to 5 degrees. The rotation angle remained near constant during drag suggesting that it was seafloor slope dominated. Anchor shank angle at maximum load was 8 to 9 degrees with the shank tip below the shank crown. This was comparable to past STATO Anchor test results and to NAVMOOR Anchor beach test results.

NAVMOOR 10,000-Pound Anchor Test Results. The results of two tests run with the NAVMOOR 10,000-pound Anchor are shown in Figures 23 and 24. The test mooring consisted of 360 feet of 2-1/2-inch chain. Results were consistent in the dense, gravelly sand. In both tests, all chain was lifted off the seafloor before peak load was achieved. This had little or no effect on performance because the anchor was nearing peak capacity at the time and the chain angle at the seafloor was less than one degree.

When the anchor was recovered after the first test, it was noted that the stabilizers were bent backwards (Figure 25). To solve the problem, the stabilizer pipes were strengthened and shortened by about 15 percent. Shortening of the stabilizers was acceptable because the anchor had demonstrated excellent stability in all laboratory, beach, and prototype testing. Also, note on the anchor in Figure 25 that the paint has been removed from fluke and stabilizer surfaces. This illustrates difficulty of maintaining a painted anchor used in granular seafloors. Maximum roll of the 10,000-pound NAVMOOR Anchor was 5 to 6 degrees, which was consistent during drag again suggesting that it was seafloor slope dominated. Maximum shank angle was 8 to 9 degrees with the shank tip below the anchor crown, which was comparable to the 1,000-pound NAVMOOR Anchor.

An interesting comparison was made between the results of the prototype tests of the 10,000-pound NAVMOOR Anchor and the beach tests of the 200-pound scale model of the 10,000-pound NAVMOOR Anchor. Results were plotted in nondimensional form in Figure 26 as anchor efficiency (holding capacity to weight ratio) versus drag distance/fluke length. Although the beach tests were in dry sand, the average beach test performance curve was remarkably similar to the prototype performance curves. This suggests that more than relative performance evaluations of anchors in sand can be accomplished very inexpensively by conducting tests of moderately sized scale model anchors in beach sand.

NAVMOOR 6,000-Pound Anchor Test Results. The 6,000-pound NAVMOOR Anchor was tested twice and the data are plotted in Figures 27 and 28. The load cell at the anchor did not work reliably in either test; however, anchoring load could still be determined by subtracting the bottom chain effect from horizontal deck load. At the point that all chain is off the seafloor, anchoring load and deck load are equal.

For comparison, a 6,000-pound STATO Anchor was tested and results are presented in Figure 29. Comparative performance of the STATO and NAVMOOR Anchors is shown in Figure 30. All anchors remained very stable during the test, but the STATO Anchor in particular had difficulty penetrating the dense sand. The second NAVMOOR test, 12-85 PH, also showed the effects of the dense seafloor; anchor load built rapidly then

leveled off at about 150 kips. The first NAVMOOR Anchor test showed a more gradual load building during the 80 feet of drag. Load was still increasing when the test was stopped at 174 kips. The more gradual buildup of load and the higher peak capacity for the first test suggested a lower soil density at this test location. When this anchor was recovered, there were no gravel remnants on the anchor as there had been on the other anchors.

Historical STATO Anchor test data (Ref 14) at this site showed consistant load buildup to 180 kips and testing was stopped to avoid anchor damage. Reported soil properties showed a uniform sand of medium density. The character of this site has changed and its effect on STATO Anchor performance has been significant. The performance of the smooth-fluked NAVMOOR Anchor was better than the STATO Anchor in dense sand. The difference in performance in a lower density sand should be less pronounced.

Single Anchor Performance Analysis in Sand. Performance curves for all prototype single NAVMOOR Anchor tests conducted in the dense gravelly sand are provided in Figure 31. There is a common general degradation in anchor performance with increasing anchor size. Nominal rather than actual anchor weight is used to develop the curves. These results should reflect conservative performance of the NAVMOOR Anchor in sand because the data were gathered in dense gravelly sand which is a difficult material to penetrate. These results demonstrate that the NAVMOOR Anchor does improve the Navy's hard soil anchoring capability. The sharp, smooth flukes of the NAVMOOR Anchor enhance penetration in hard soils.

The actual performance curves for the NAVMOOR Anchor, plotted in Figure 31, were used to define an average curve for each anchor size tested. These average performance curves are presented in Figure 32. Even though the trends in Figure 32 showed that maximum capacity was not generally achieved, it was assumed that it was achieved for purposes of defining anchor capacity. The maximum holding capacity for each anchor, from Figure 32, were plotted versus anchor weight in Figure 33. The performance of geometrically similar anchors can normally be represented as a straight line on a log-log plot of holding capacity versus nominal anchor air weight and these data followed that trend. The straight line through the test results is represented by the equation,

$$H_m = 31 W_A^{0.94} \qquad (1)$$

where H_m = anchor holding capacity - kips

W_A = anchor air weight (nominal) - kips

San Francisco Bay Mud Single Anchor Tests

General. The 6,000-pound and 10,000-pound NAVMOOR Anchors were used to evaluate single anchor performance in mud. The 6,000-pound STATO Anchor was also tested to provide a baseline for comparison to NAVMOOR Anchor performance and to historical STATO Anchor test data. Model tests

in soft clay with 1/20 scale models of 6,000-pound anchors showed that performance was comparable. Thus, it was expected that prototype behavior would also be similar in mud.

Single Anchor Test Results. An actual data plot for a 10,000-pound NAVMOOR Anchor test in mud is shown in Figure 34. Horizontal deck load, anchoring load or true anchor holding capacity, and surface chain load are plotted versus anchor drag distance. Anchoring load was determined by subtracting the load caused by the surface resting chain from the deck load. In all of the mud tests, testing was stopped before maximum load was achieved. At about 90 feet of drag the anchor crown buoy was pulled underwater and the instrument cable was near breaking so, the tests were stopped. Actually, achievement of maximum load can take 200 to 300 feet of drag. At about 90 feet of drag, the anchor achieves 70 to 80 percent maximum capacity and ultimate capacity can be projected with reasonable accuracy.

Figure 34 shows that the anchor was very stable throughout drag. Its roll angle oscillated between 5 to 8 degrees from horizontal. Maximum anchor shank pitch was 8.1 degrees (shank shackle above the anchor crown). Based upon an analysis of STATO data from Ref 5, the maximum shank angle for the 6,000-pound STATO Anchor at maximum load and embedment depth is about 24 degrees (shank shackle up). It's obvious from this and all subsequent tests in mud that the NAVMOOR Anchor, whose performance will be shown to be similar to the STATO Anchor, was not at peak capacity.

Results of all 10,000-pound and 6,000-pound NAVMOOR Anchor tests are provided in Figures 35 and 36. Note that all the tests for each size anchor are quite similar. The NAVMOOR Anchor flukes tripped open reliably and the anchor remained stable during the penetration process. Maximum shank angles were far below projected maximum so the anchors would continue to embed.

Single Anchor Performance Analysis. Results of a 6,000-pound STATO Anchor test are superimposed on the NAVMOOR test data in Figure 36 and the results are comparable. With the similarity of the NAVMOOR and STATO data, historical STATO data for the site could be used to estimate maximum NAVMOOR Anchor capacity. This, of course, assumed that the current STATO data agreed with historical data; this comparison is excellent (Figure 37). Historical data for the 6,000-pound and 9,000-pound STATO Anchors were used to define an average performance curve that could be used to project NAVMOOR Anchor test results for the 6,000-pound and 10,000-pound NAVMOOR Anchors, respectively. For example, the estimated average performance of the 9,000-pound STATO Anchor in mud is shown on Figure 38. The selected performance curves for this and the 6,000-pound STATO Anchor conservatively represent anchor performance in mud. Normalized holding capacity-drag distance relationships for the two STATO Anchors were developed (Figure 39) from the average performance curves and were then used to project NAVMOOR Anchor data to determine estimated maximum capacities. Average performance curves for the NAVMOOR Anchors were developed from the test data (Figures 35 and 36) and extrapolated (Figure 40).

The maximum estimated capacities for the 6,000-pound and 10,000-pound NAVMOOR Anchors are 131 kips and 215 kips, respectively. These maximum

values were plotted with historical STATO Anchor data to determine a performance specification in mud (Figure 41). A curve, which reasonably represents the data, is

$$H_m = 25W^{0.94} \quad (2)$$

where H_m = anchor holding capacity - kips

W_A = anchor air weight (nominal) - kips

Summary of Single Anchor Tests

The performance of the NAVMOOR Anchor in sand was defined through a series of small-scale and prototype anchor tests. The NAVMOOR Anchor demonstrated excellent stability throughout the tests and an ability to penetrate and hold consistently in a dense gravelly sand. NAVMOOR Anchor performance exceeded that of the STATO Anchor in dense sand. A goal to improve the Navy's hard soil anchoring capability has been achieved.

Anchor holding capacity in sand can be defined by the equation,

$$H_m = 31W_A^{0.94} \quad (3)$$

where H_m = anchor holding capacity - kips

W_A = anchor air weight (nominal) - kips

NAVMOOR Anchor performance in mud was consistent and comparable to the Navy's STATO Anchor. Excellent anchor stability throughout anchor drag was demonstrated. Anchor holding capacity in mud can be defined by the equation,

$$H_m = 25W_A^{0.94} \quad (4)$$

TANDEM ANCHOR RESULTS AND ANALYSIS

Port Hueneme Sand Tandem Anchor Tests

General. The 1,000-pound and 6,000-pound NAVMOOR Anchors were used to evaluate tandem anchor performance in sand. NAVMOOR 1,000-pound Anchors are shown ready for tandem anchor testing in Figure 42 (the suspended anchor is the tandem anchor). The chain from it is connected to the tandem link at the rear of the primary anchor. This link is pin-connected to the shank, not to the anchor crown.

Tandem Anchor Tests and Analysis. Two tests were performed with 1,000-pound NAVMOOR Anchors and one with 6,000-pound NAVMOOR Anchors. The test with the 6,000-pound NAVMOOR Anchors was stopped because of a

hydraulic power unit failure which also ended the test effort. The second test with the 1,000-pound anchors was also stopped before maximum load because of equipment problems. Nevertheless, the data that was gathered agreed with model and small-scale test results and was suitable for definition of tandem anchor performance in sand.

Results of the 1,000-pound NAVMOOR Anchor tests are shown in Figures 43 and 44. In the first test (test 3-85PH) deck load and load at the tandem anchor were measured. The load cell in front of the primary anchor functioned intermittently. Those data were questionable and are not presented. In the second test, deck load and load at the primary anchor were recorded. The load cell at the tandem anchor did not operate.

The characteristic performance of these anchors in tandem was interesting. Note the dips in the anchor load and deck load curves in Figure 43. At about 20 to 25 feet of drag, the tandem anchor feels the soil disturbed by the forward anchor. Eventually, the tandem anchor begins to embed deeper through the disturbed soil and the load begins to increase at a more rapid rate. This behavior was previously noted in model and small-scale anchor tests. Figure 45 shows the dips, although more pronounced, for 200-pound STATO Anchors tested in tandem. Since soil failure in sand occurs through a zone extending many feet forward of an anchor, the effect of the soil disturbance by the forward anchor would be noticed before the tandem anchor reached the disturbed soil.

The first tandem 1,000-pound NAVMOOR Anchor tests showed that two anchors used in tandem will develop at least twice the capacity of a single anchor. The second test was less conclusive because the test was stopped due to equipment problems. However, the anchoring and deck load curves for both tests were quite similar to the point where the second test was stopped.

Results of the tandem 6,000-pound NAVMOOR Anchor tests are shown in Figure 46. Load increased rapidly until the rear anchor approached the zone disturbed by the forward anchor. Then, the characteristic dip in the load displacement curve occurred similar to all previous tandem anchor tests. (Note the anchor roll plotted above the load displacement curve in Figure 46.) The inboard anchor started to roll slightly when the rear anchor neared the disturbed soil. However, the 6 to 7 degree roll stabilized and then began to decrease. This shows that the NAVMOOR Anchor has good stability and will recover after being perturbed. Anchor load continued to increase at a lesser rate until the test and overall test effort had to be stopped because of a major test equipment failure. The rate of load increase after about 40 feet of drag was about twice that for a single anchor suggesting that both anchors were functioning properly.

The anchor shank angle of the primary anchor started at 7 to 8 degrees (shank shackle down) and gradually decreased to 2 to 3 degrees when the test was stopped. This contrasts to a 10- to 11-degree shank angle (shank shackle down) for the single NAVMOOR Anchor throughout the test. A difference was that a very large load cell requiring 3-inch shackles was needed in the tandem test to handle the expected high load, compared to a load cell 60 percent as wide using 2-1/4-inch shackles for single anchor tests. This added bearing resistance at the shank shackle end will affect anchor performance. Also, at about 145 kips load, all the chain was lifted off the seafloor. Maximum chain angle at the seafloor was 3 to 4 degrees which will slightly affect the primary anchor

performance. The tandem anchor will not be affected. The good stability of the anchors and the uniform load buildup comparable to the sum of two independent anchors shows that the two anchors in tandem will develop a system capacity at least equal to the sum of two individually pulled anchors in sand.

San Francisco Bay Mud Tandem Anchor Tests

General. Tandem anchor tests were conducted with 6,000-pound NAVMOOR Anchors. In these tests, the anchors were separated by a 90-foot length of wire rope. This length of wire rope conveniently allowed each anchor to be handled and placed on the seafloor without disturbing the other anchor and it exceeded the minimum allowable anchor separation of 3 to 4 fluke lengths (Ref 13) to achieve stable performance. Chain could have been used to connect the anchors but wire provides less penetrating resistance and its use should enhance system performance.

Tandem Anchor Tests and Analysis. Performance curves for two tandem anchor tests with 6,000-pound NAVMOOR Anchors are provided in Figures 47 and 48. Similar to the single anchor tests, the maximum drag distance that could be accommodated was about 90 feet. At 90 feet, the total system holding capacity was 210 kips, which is roughly twice the capacity of a single anchor at that drag distance. This suggests that the tandem system was functioning effectively.

At the completion of the first test, the tandem anchor was pulled out of the seafloor and replaced on the seafloor; the primary anchor was left embedded. Figure 48 shows the continuation of the test as if it started at zero drag distance. Anchoring load started at 95 kips, which reflects the capacity of the primary anchor at 90 feet of drag and then increased to 210 kips in 40 feet of additional drag. The tandem anchor was then pulled out of the seafloor and the primary anchor was tested to determine its capacity at test completion. The primary anchor had a capacity of 148 kips.

Figure 49 shows the two NAVMOOR Anchor tests in combination as a single test series. For reference, the average performance curve for a single 6,000-pound NAVMOOR Anchor is plotted for the same total drag distance. At the completion of the first test segment, the primary anchor was holding slightly less than an average single anchor. At the completion of the second test segment, the primary anchor was holding considerably more than an average single anchor. Initially, this was surprising because the embedment of the first anchor was supposed to have been slowed by the drag of the surface resting tandem anchor; rather, it seems that the upward pull on the tandem link caused the anchor shank to pitch forward. This decreases anchor shank angle which effectively increases fluke angle relative to its trajectory and causes more rapid penetration and an accelerated increase in capacity. In fact, the primary anchor's capacity exceeded the predicted ultimate capacity of a single anchor and it was still continuing to increase at a rapid rate. The tandem anchor was also behaving as a normal single anchor. With continued drag, its capacity would exceed single anchor capacity because the anchor is stable and it was being pulled from a point beneath the surface; thus, it did not have to embed a large length of chain during

the process. The capacity of the tandem anchor system in mud will certainly exceed the capacity of the sum of two single anchors. Model tests (Ref 13) showed that a tandem anchor system would hold 20 to 30 percent more than the sum of single anchors. Test results in San Francisco Bay mud indicate that this may be a conservative estimate for prototype anchors.

The key to the effective use of tandem anchors, particularly in mud seafloors, is good anchor stability. Previous tests (Ref 13 and 17) showed that tandem anchor performance depended primarily upon the stability of the primary anchor. Most anchor types become immediately unstable when used in a tandem anchor system and could not develop the full capacities of the individual anchors. As the primary anchor rolls, it can come to the surface and restrict embedment of the rear or tandem anchor. The STATO Anchor type demonstrated good stability during model and small-scale tests in a tandem anchor system. Because of the configuration similarities, the NAVMOOR Anchor was expected to behave similarly. Prototype results have verified that the NAVMOOR Anchor is stable as a single anchor and as the primary anchor in a tandem anchor system. Therefore, each anchor can develop at least its full capacity in a tandem anchor system.

Summary of Tandem Anchor Tests

The NAVMOOR Anchors demonstrated excellent stability when used in tandem. As noted earlier good anchor stability is a key element in the proper functioning of anchors in tandem. Test results in sand and mud seafloors showed that two NAVMOOR Anchors connected in tandem will develop at least twice the capacity of a single anchor. While the test data suggest that this is a conservative estimate, particularly in mud seafloors, the recommended ultimate capacity of a tandem anchor system in sand and mud seafloors is twice the capacity of a single anchor.

Since the performance relationships provided for the NAVMOOR Anchors in sand and mud seafloors show that anchor efficiency decreases as anchor size increases, there are advantages to using two anchors in tandem compared to the use of a single large anchor. The anchors are lighter and easier to handle and recover, and the tandem system is more efficient resulting in a lighter system.

NAVMOOR ANCHOR SIZE GUIDELINES FOR NAVY FLEET MOORINGS

Using the NAVMOOR Anchor performance relationships presented in this report, anchor size requirements for various mooring classes could be determined. Actual calculated anchor sizes based on a safety factor of two are provided in Table 1. Recommended sizes established by rounding up or down while remaining within an allowable factor of safety range of 1.75 to 2.25 are provided in Table 2. Acceptance of a factor of safety of less than 2 is reasonable because anchor performance criteria and methods used to establish mooring loads are conservative.

Mooring classes below class C in mud and class B in sand were not considered because standard stockless anchors available in Navy inventory can be used to readily satisfy these needs. The approximate maximum anchor size considered was 15,000 pounds, which is based upon a

recovery limitation in mud seafloors. The Navy's ability to recover an anchor is generally limited to about 200,000 pounds which approximates the pullout load for a 15,000 pound NAVMOOR Anchor set to its safe working load in mud.

Four ground leg options with the NAVMOOR Anchor are provided. These options are standard within the Navy. The four ground leg options listed in decreasing order of desirability are:

(1) Single chain, single anchor. This is the simplest ground leg option consisting of a single anchor on a single mooring chain.

(2) Single chain, tandem anchor. This consists of two anchors connected in tandem on a single mooring leg. Minimum recommended anchor separation referenced to the length of the anchors fluke is 3 fluke lengths. Larger lengths would commonly be used to simplify handling.

(3) Twin chain, single anchor. This consists of two single anchor legs connected to a common point e.g., ground ring, buoy, etc. To avoid anchor interference when the anchors are dragged, the anchors are staggered by a minimum of 3 fluke lengths.

(4) Twin chain, tandem anchor. This consists of two tandem anchor legs connected to a common point. The anchors are staggered by a minimum of 3 fluke lengths to avoid interference.

Table 2 shows that the Navy's fleet mooring requirements from class C (100 kips) to AAA (500 kips) can be satisfied with only two sizes of anchors, the 10,000-pound and 15,000-pound NAVMOOR Anchors. Actually, with the 15,000-pound anchor in the twin chain tandem anchor leg configuration, moorings to 650-kip capacity in mud and 800-kip capacity in sand could be established.

SUMMARY AND CONCLUSIONS

A new Navy mooring anchor (NAVMOOR) has been developed to satisfy a variety of Navy anchor applications. Various sizes of anchors have been designed, fabricated, and structurally and operationally proof-tested. Prototype testing of single anchors and of anchors in tandem were completed in sand and mud seafloors. Results have shown that the NAVMOOR Anchor is structurally and operationally superior to the Navy's STATO Anchor which in the past was the most effective general purpose anchor for Navy applications. The NAVMOOR Anchor demonstrated its effectiveness in dense sand and soft mud seafloors when used in single or tandem anchor leg configurations. The NAVMOOR Anchor has enhanced the Navy's capability to anchor in harder seafloors and has provided a means to satisfy its expanded fleet mooring requirements to a 500-kip capacity.

The holding capacity of a single NAVMOOR Anchor can be defined by the equations:

$$H_m = 25W_A^{0.94} \text{ - mud}$$

and

$$H_m = 31W_A^{0.94} \text{ - sand}$$

where H_m = anchor holding capacity - kips

W_A = anchor air weight (nominal) - kips

In a tandem anchor system each anchor will develop at least its full rated holding capacity. Tandem anchor system capacity is defined as twice the capacity of a single anchor.

The ability of the NAVMOOR Anchor to be used in single and tandem anchor configurations and to function effectively in a broad range of seafloor conditions minimizes the Navy's anchor inventory needs while satisfying high capacity mooring requirements.

The Navy's fleet mooring requirements from class C (100 kip capacity) to class AAA (500 kips) can be satisfied with only two sizes of NAVMOOR Anchor, the 10,000-pound and 15,000-pound NAVMOOR, used in various single and tandem anchor leg configurations.

Because the tandem anchor system employs smaller anchors to satisfy new mooring requirements, the Navy's existing equipment assets are adequate for installation and recovery of the new moorings.

Various size NAVMOOR Anchors have been designed, fabricated, and employed for Navy mooring applications. These include anchors for amphibious logistics applications, salvage, and fleet moorings. The NAVMOOR Anchor design is flexible and can be adapted as needed for other applications as well.

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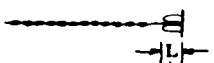
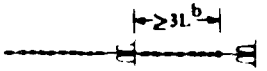
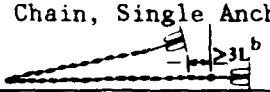
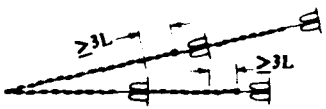
Table 1. Calculated NAVMOOR Anchor Size[a] for Navy Fleet Moorings

Mooring Class	Mooring Capacity (kips)	Anchor Weight (Nominal) for Ground Leg Options (lb)					
		1. Single Chain, Single Anchor 		2. Single Chain, Tandem Anchor  3. Twin Chain, Single Anchor 		4. Twin Chain, Tandem Anchor 	
		Mud[c]	Sand[d]	Mud	Sand	Mud	Sand
AAA	500					11,580	9,340
BBB	400				15,400	9,130	
AA	300			14,060	11,340		
BB	250			11,580	9,340		
CC	200		15,190	9,130			
DD	175	16,560	13,180				
A	150	14,060	11,340				
B	125	11,580	9,340				
C	100	9,130					

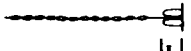
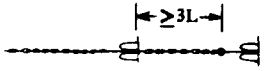
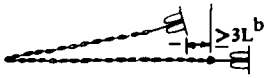
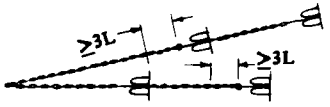
[a]Calculated anchor size based upon system factor of safety of 2.

[b]Minimum anchor separations related to fluke length (L).

[c]Includes very soft to soft silt and clay seafloors.

[d]Includes sands and medium to stiff clay seafloors.

Table 2. Recommended NAVMOOR Anchor Size[a] for Navy Fleet Moorings

Mooring Class	Mooring Capacity (kips)	Anchor Weight (Nominal) for Ground Leg Options (lb)					
		1. Single Chain, Single Anchor 		2. Single Chain, Tandem Anchor  3. Twin Chain, Single Anchor 		4. Twin Chain, Tandem Anchor 	
		Mud[c]	Sand[d]	Mud	Sand	Mud	Sand
AAA	500					10,000	10,000
BBB	400				15,000	10,000	
AA	300			15,000	10,000		
BB	250			10,000	10,000		
CC	200		15,000	10,000			
DD	175	15,000	15,000				
A	150	15,000	10,000				
B	125	10,000	10,000				
C	100	10,000					

[a]Recommended anchor sizes provide system factor of safety of 1.75 to 2.25.

[b]Minimum anchor separations related to fluke length (L).

[c]Includes very soft to soft silt and clay seafloors.

[d]Includes sands and medium to stiff clay seafloors.

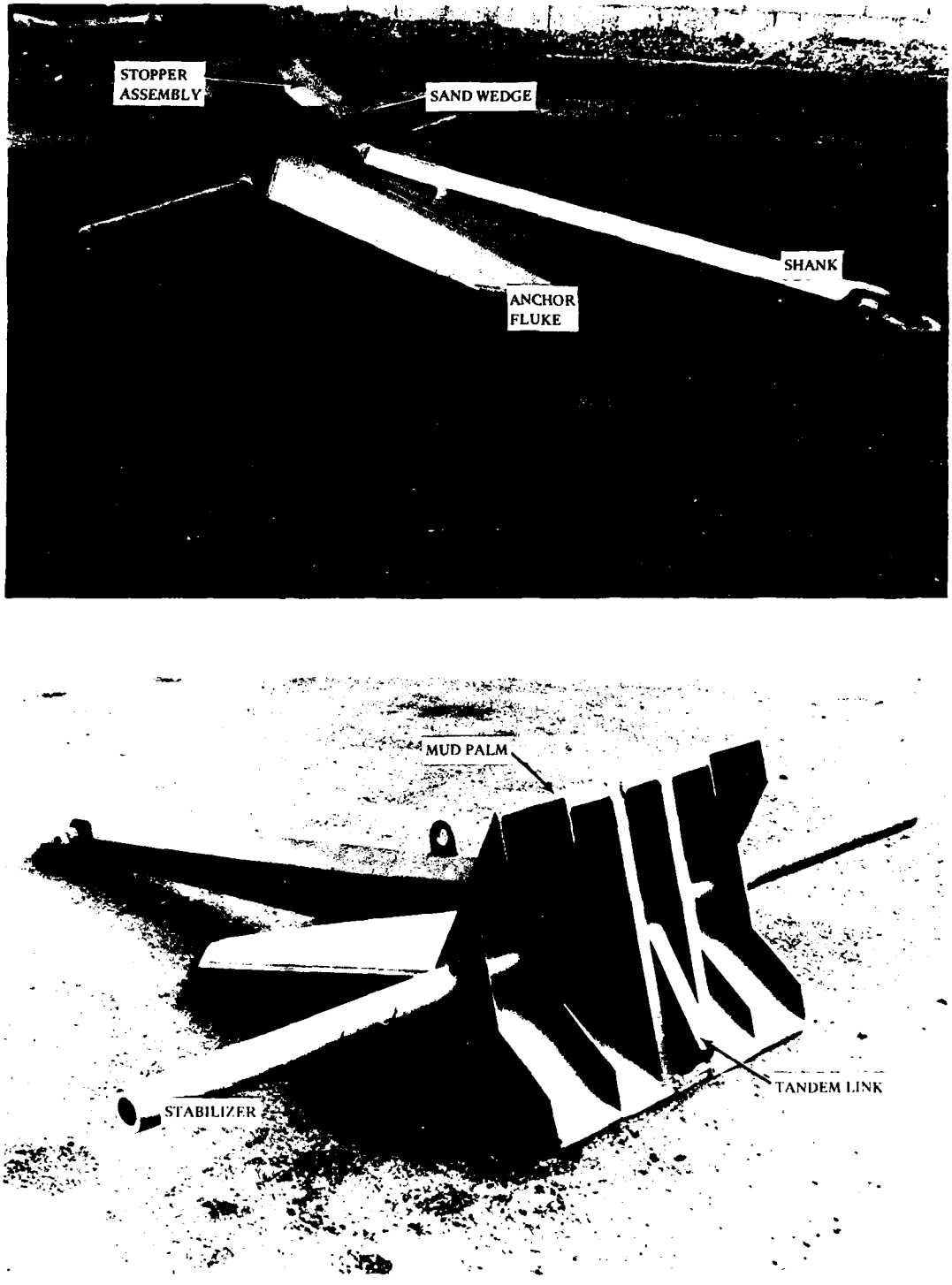


Figure 1. 1,000-pound NAVMOOR Anchor.

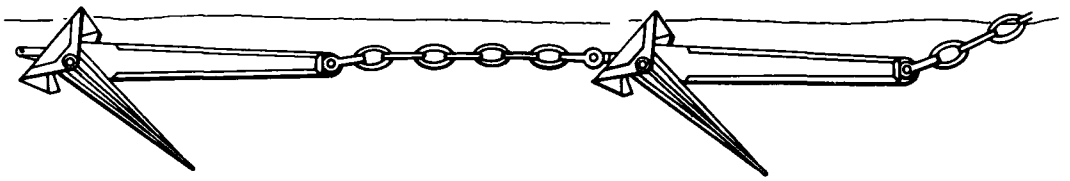


Figure 2. NAVMOOR Anchors shown rigged in tandem.

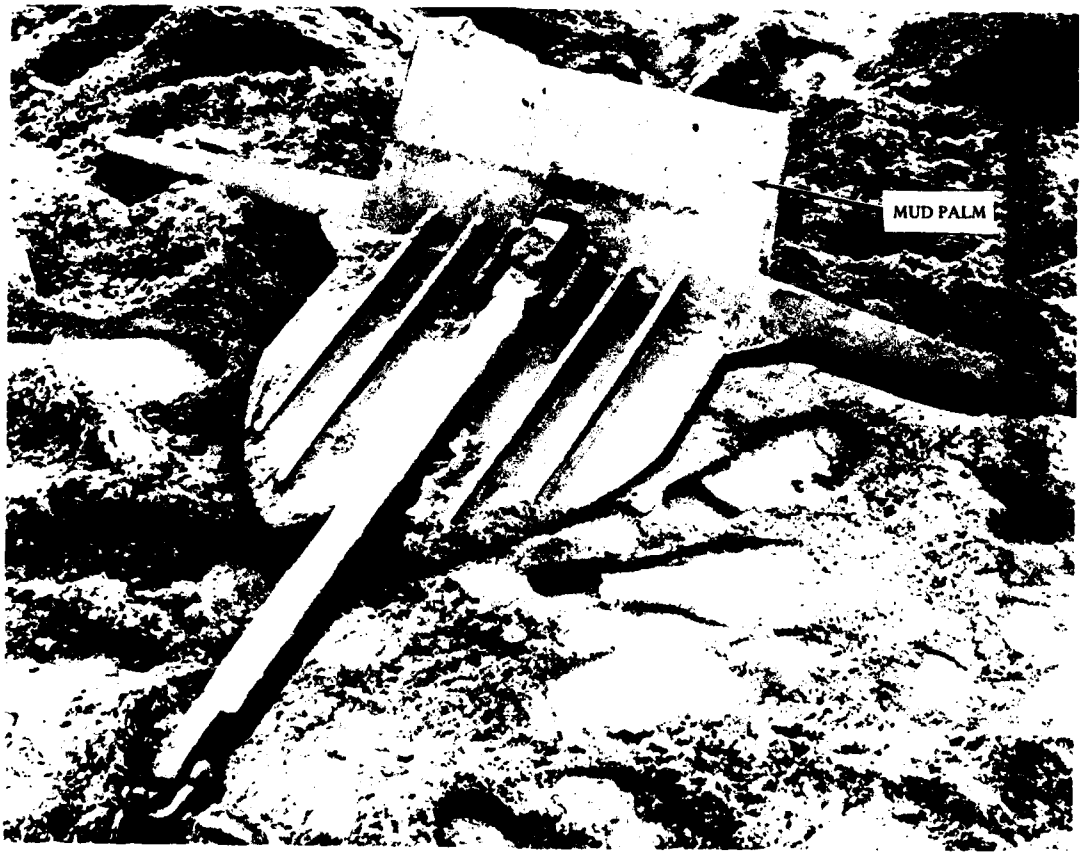


Figure 3. 200-pound STATO Anchor.

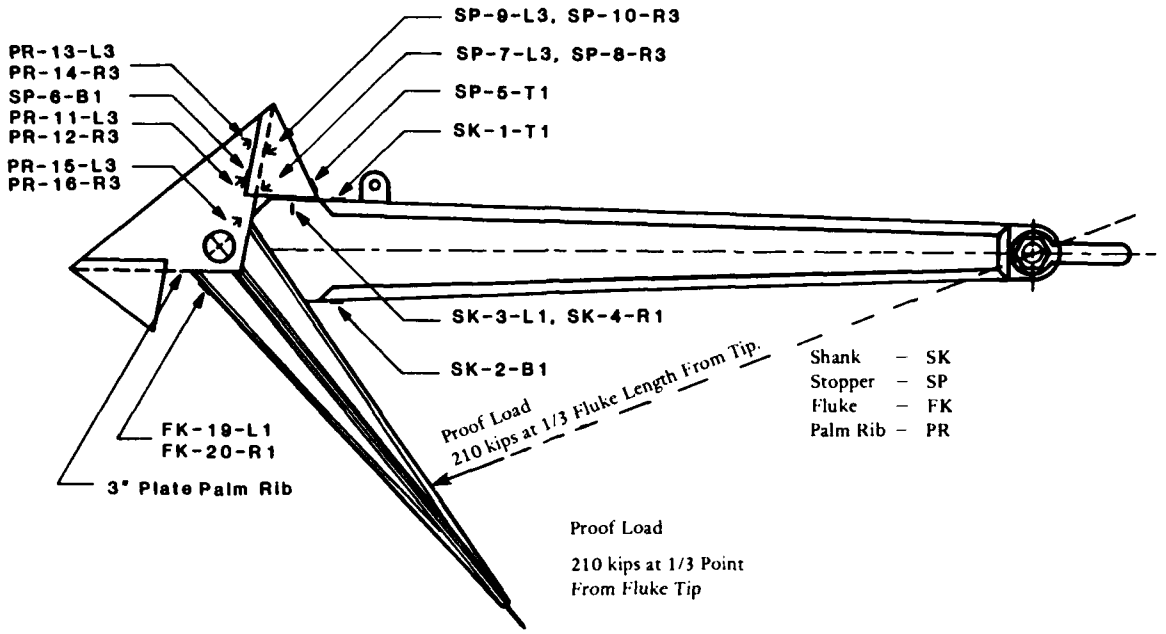
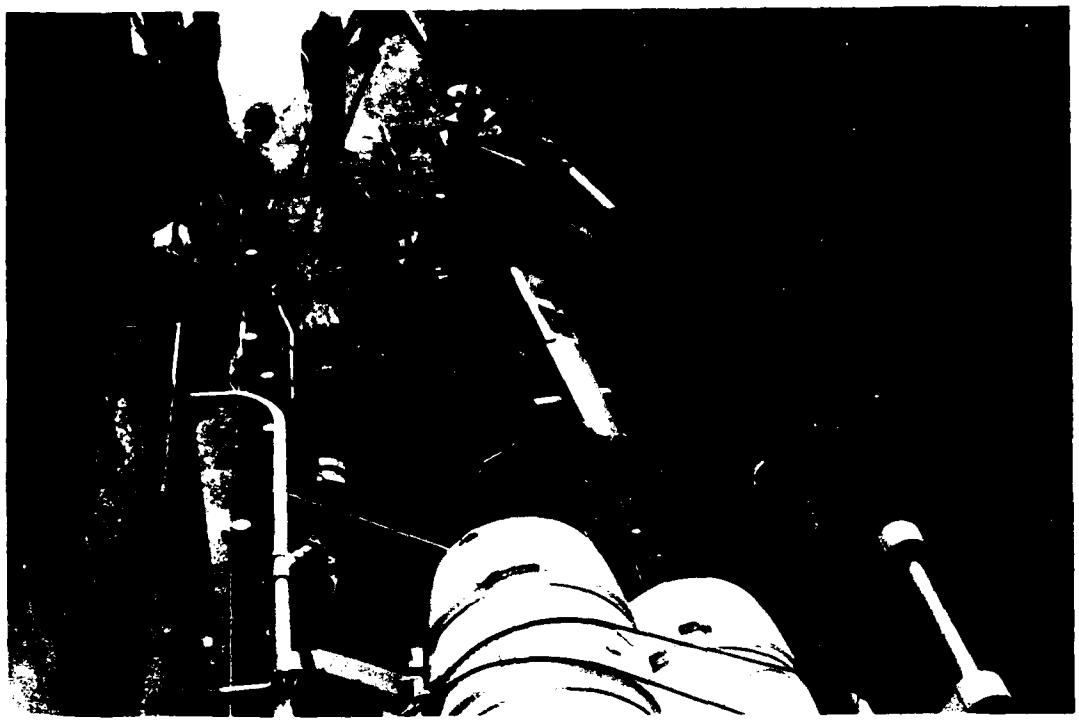
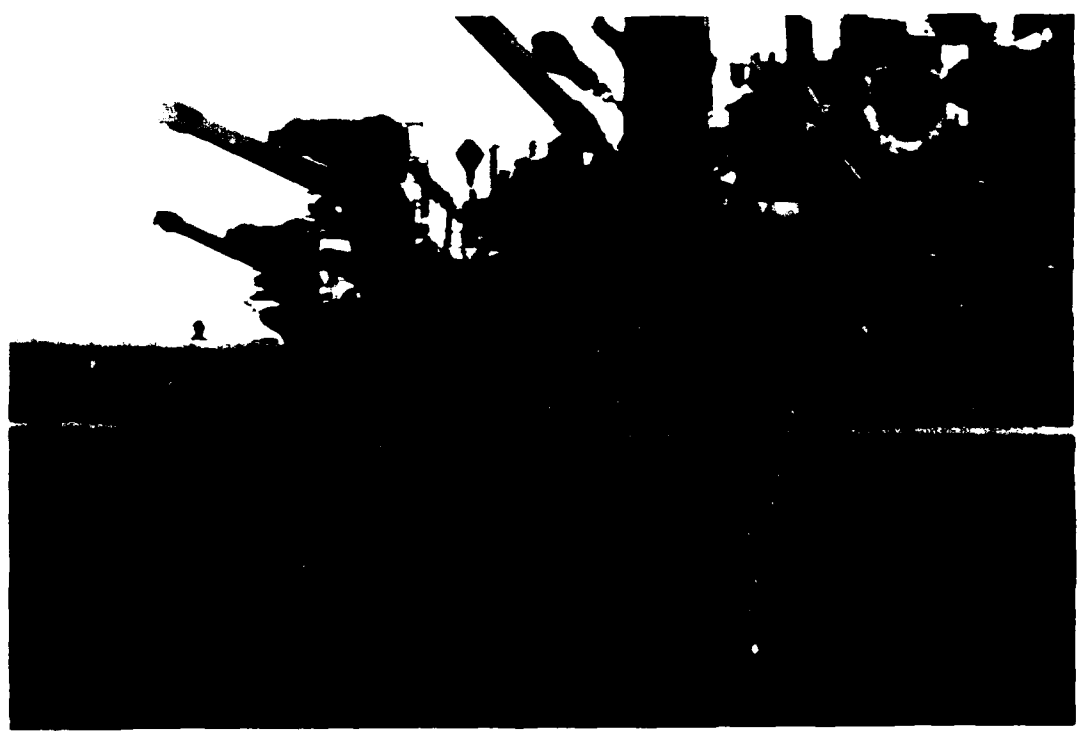


Figure 4. Plan view - strain gage locations for 10K NAVMOOR Anchor proof tests.

Figure 5. NAVMOOR Anchors. Left to right: (1) 1,000-pound, (2) 200-pound, (3) 6,000-pound with folding stabilizers, (4) 100-pound model with folding stabilizers, (5) 100-pound, and (6) 10,000 pound.



a. Anchor mounted horizontally in forward pocket.



b. Anchor mounted vertically in after pocket.

Figure 6. NAVMOOR Anchors for salvage being deployed from the USS SAFEGUARD, ARS 50.

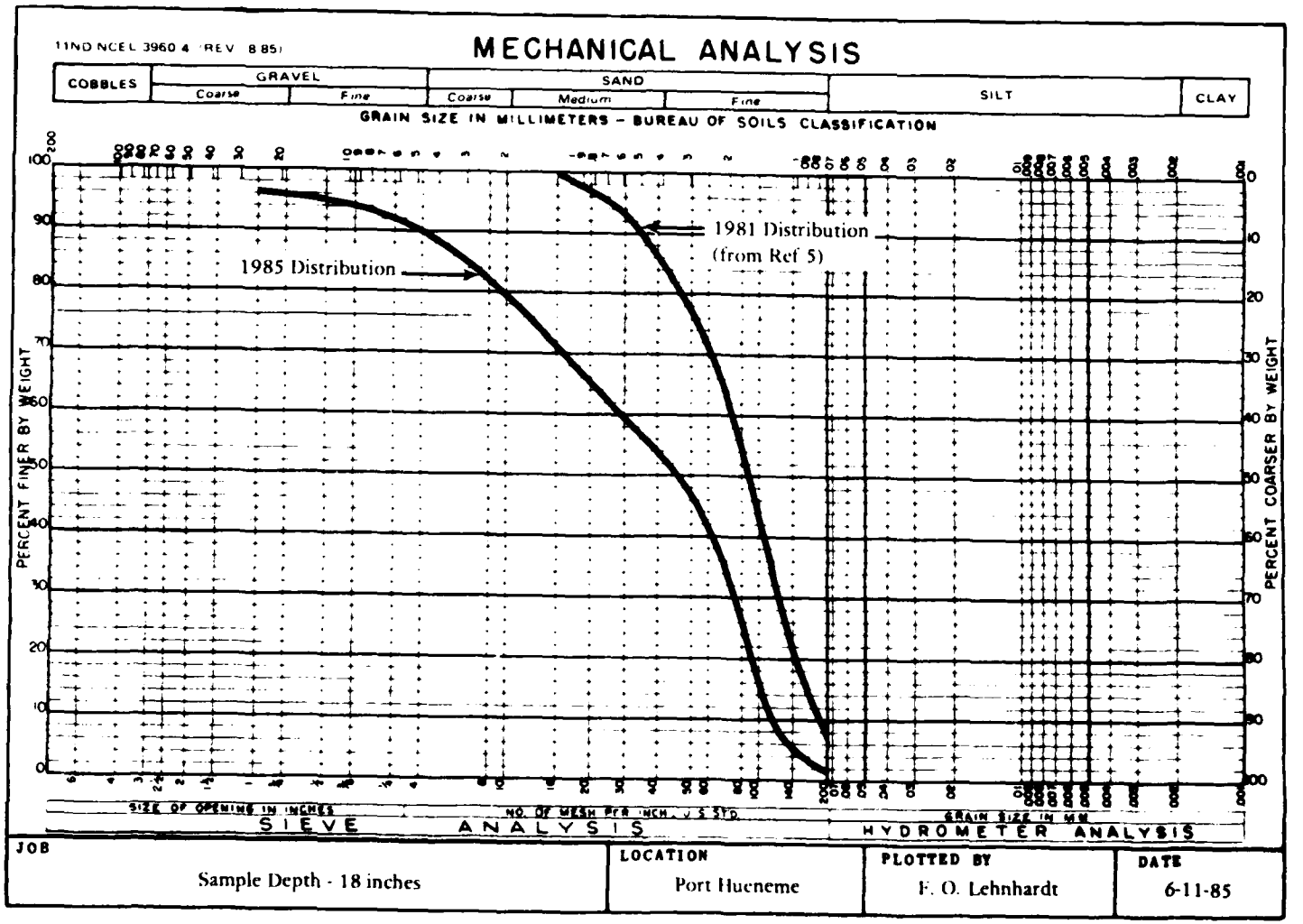


Figure 7. Grain size distribution for Port Hueneme sand, west jetty.

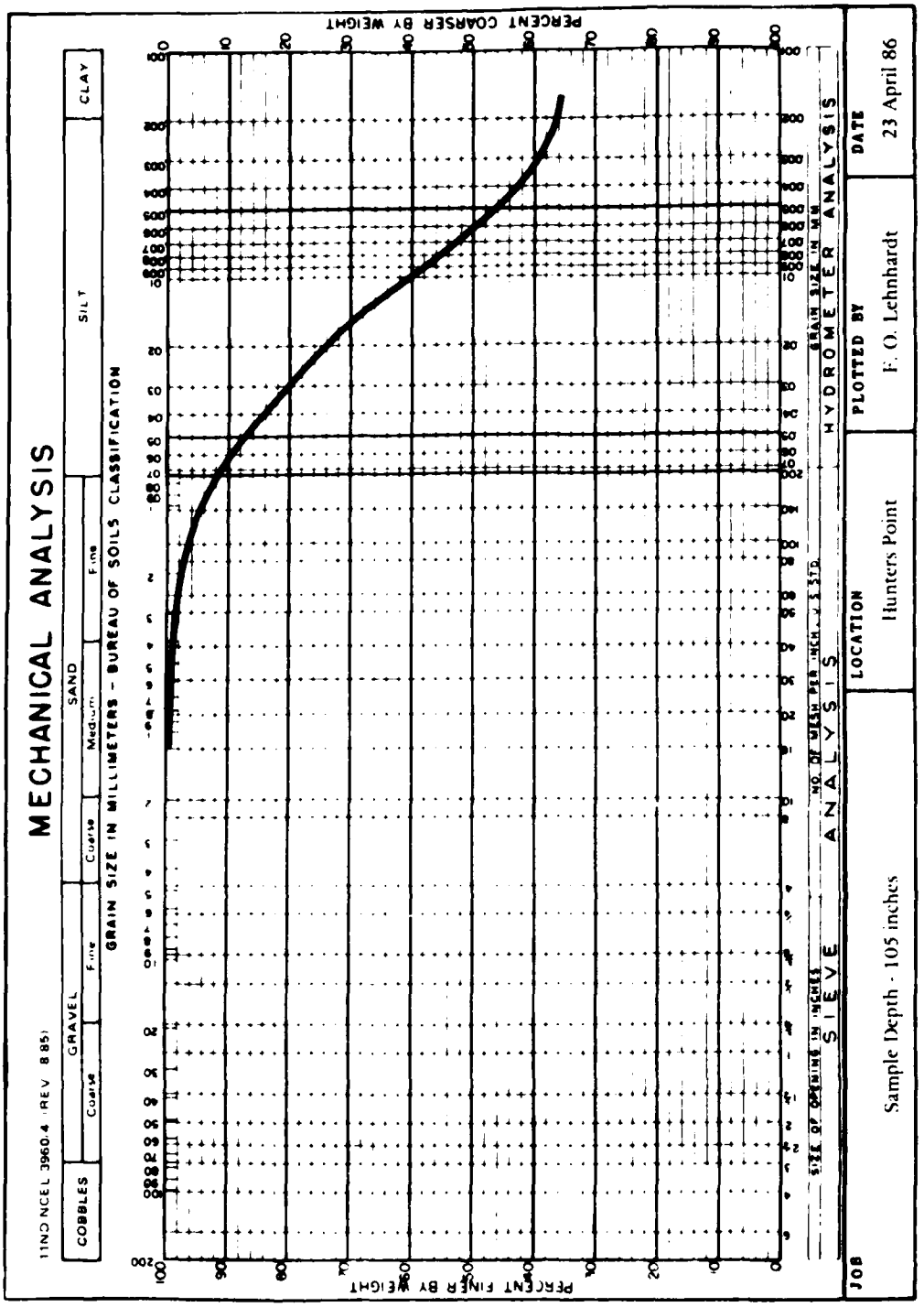


Figure 8. Grain size distribution for San Francisco Bay mud at Hunters Point.

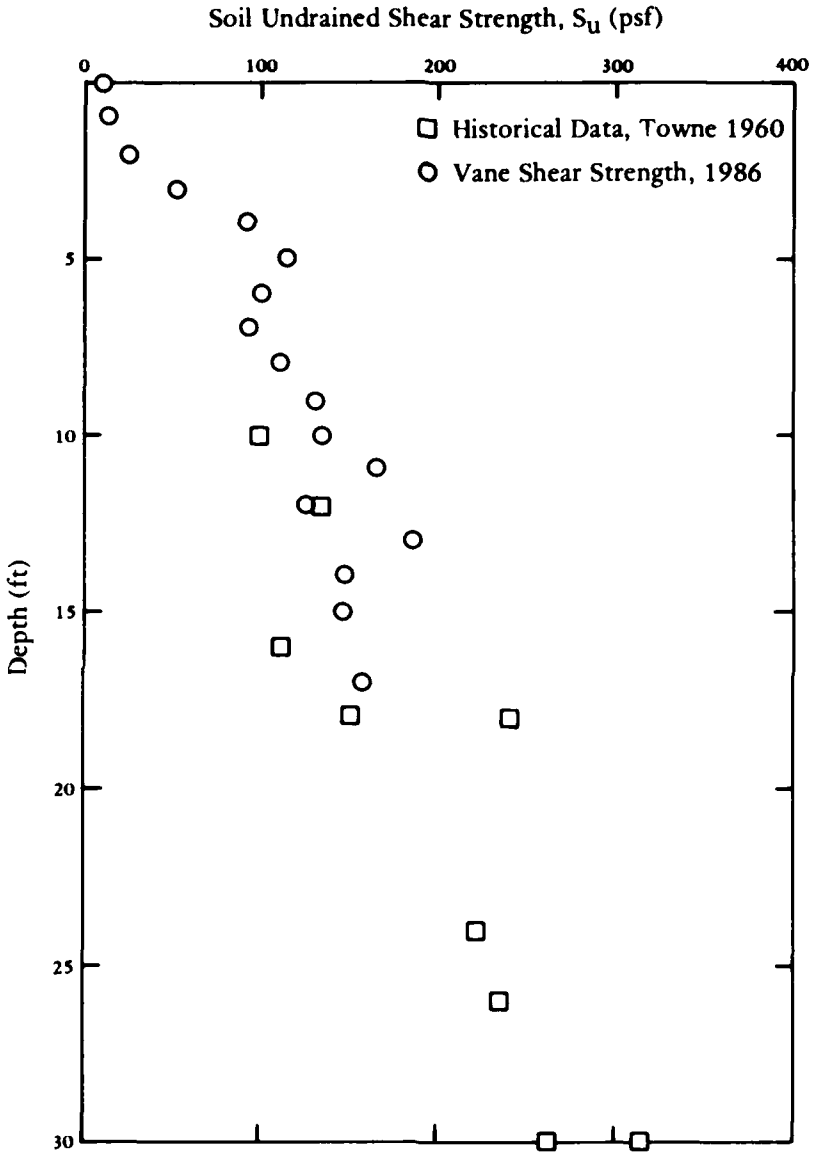
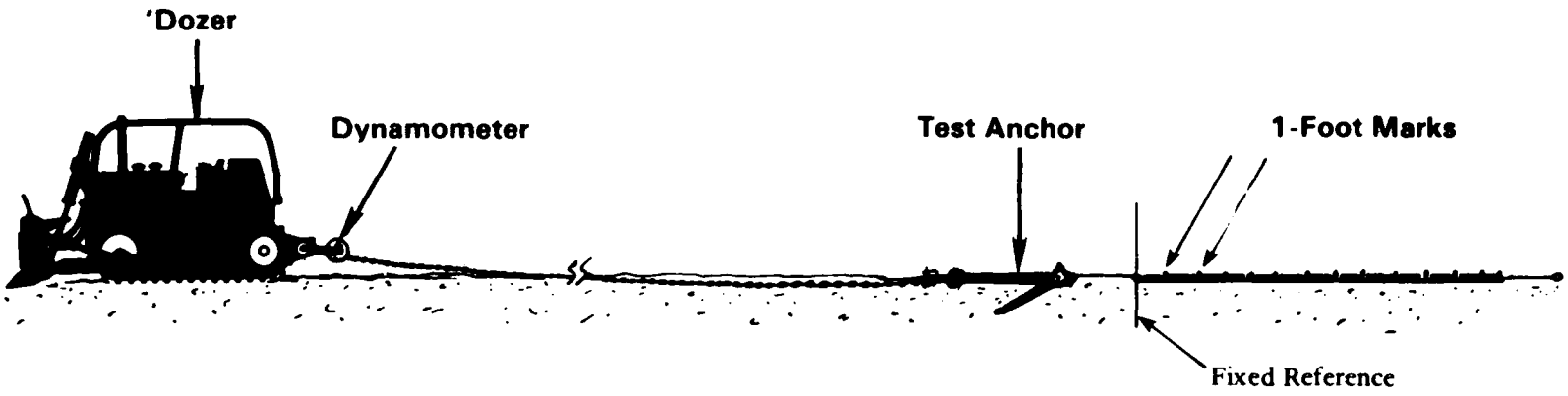


Figure 9. Soil undrained shear strength profile for San Francisco Bay mud, Hunters Point.



Test Measurements

Total anchor tension
Anchor drag distance
Anchor roll angle (final)
Anchor shank pitch angle (final)
Anchor chain angle (final)
Anchor depth (final)

Figure 10. Small-scale test arrangement used for NAVMOOR Anchor beach tests.

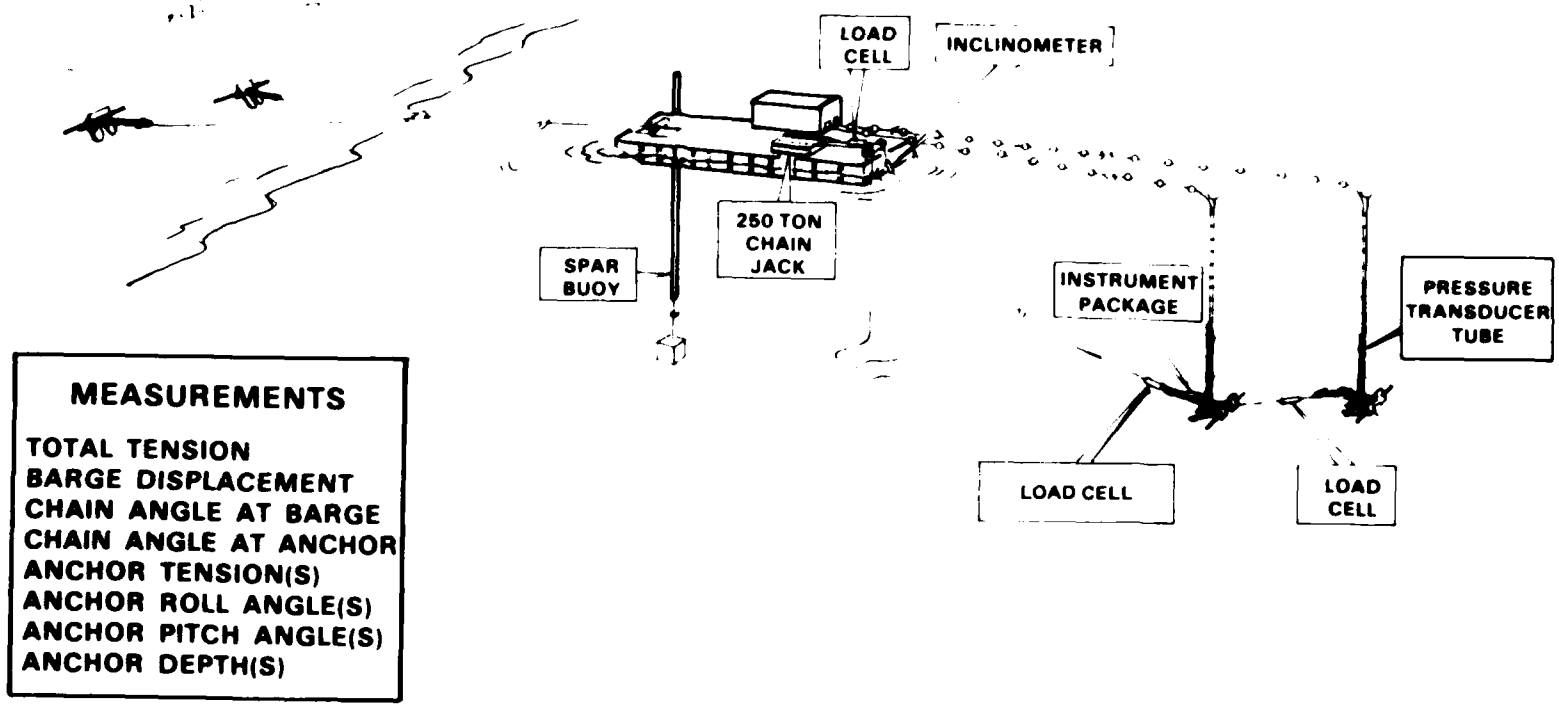


Figure 11. Test configuration for NAVMOOR Anchor tests in sand at Port Hueneme.

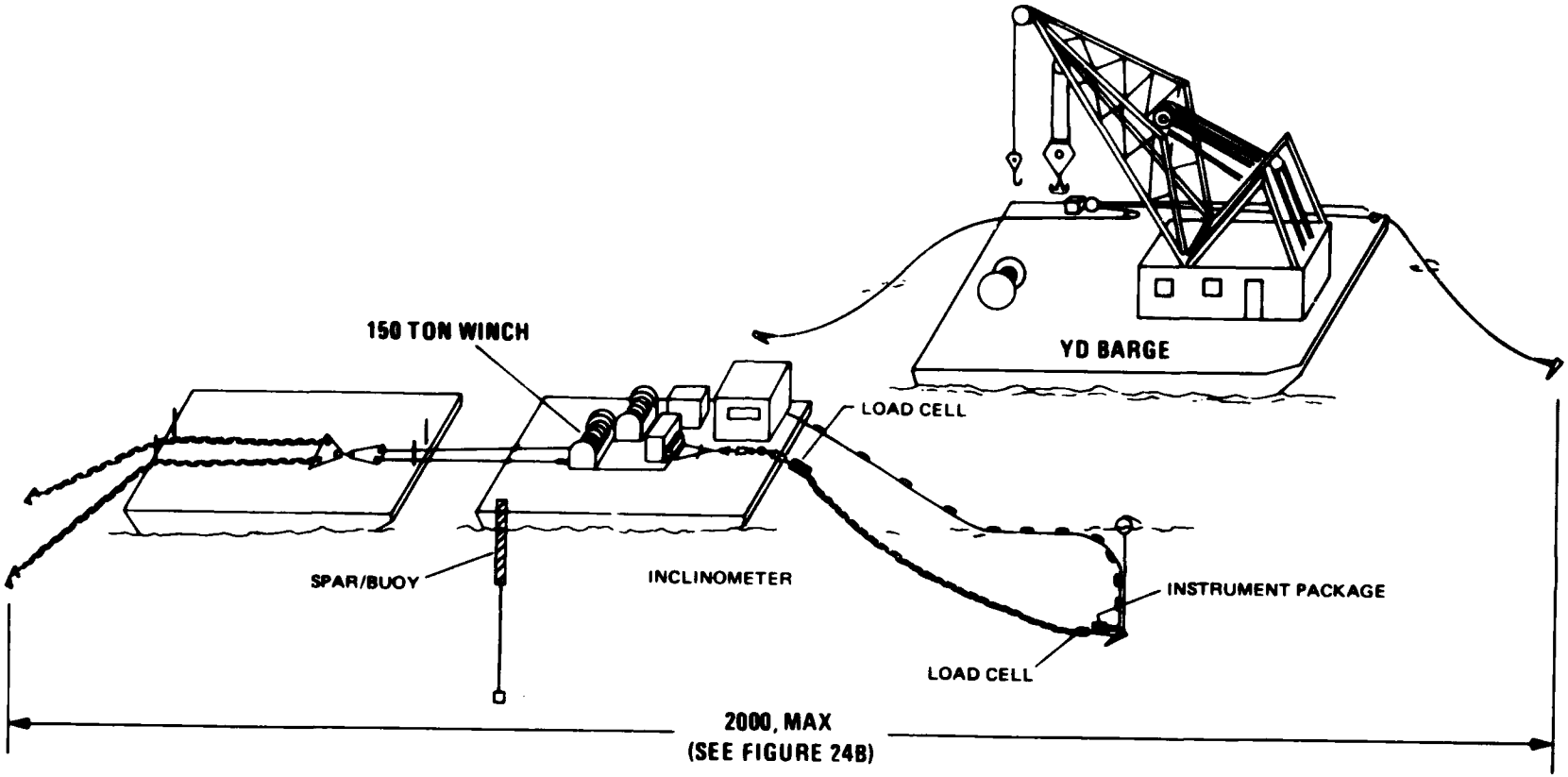


Figure 12. Test configuration for NAVMOOR Anchor tests in mud at Hunters Point, San Francisco Bay.

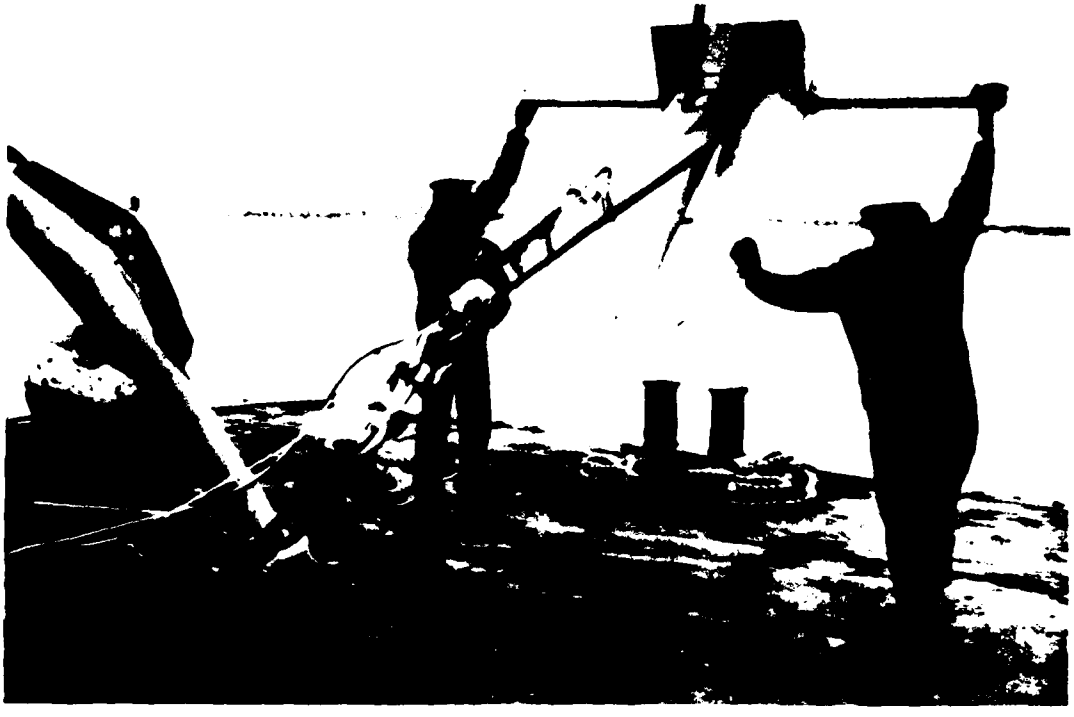


Figure 13. 1,000-pound NAVMOOR Anchor with instrumentation system.

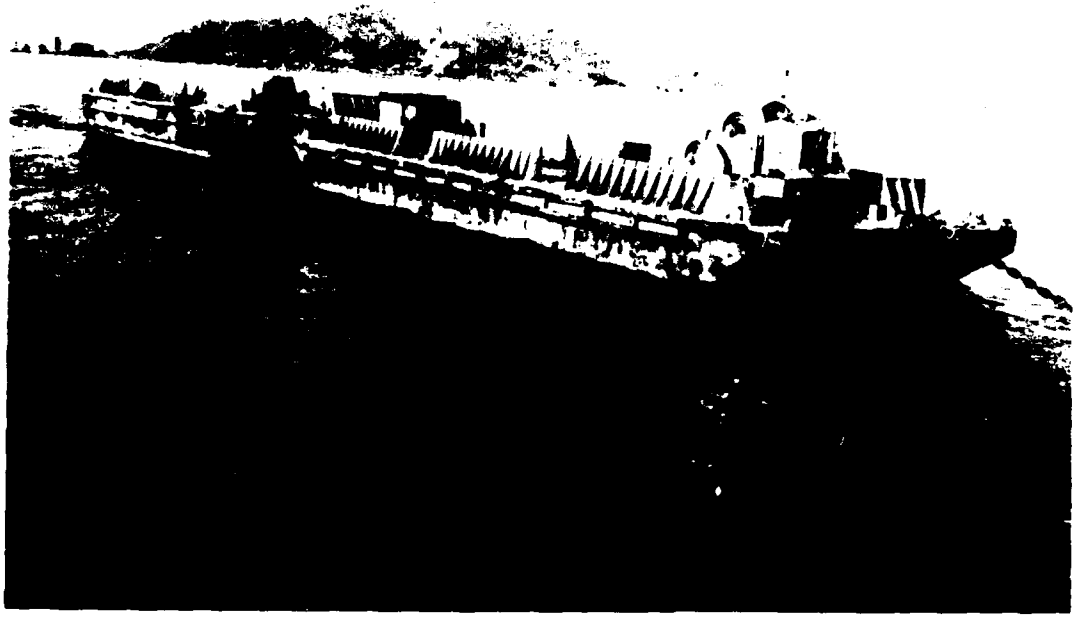


Figure 14. Test barge setup used for NAVMOOR Anchor testing in San Francisco Bay mud, Hunters Point.

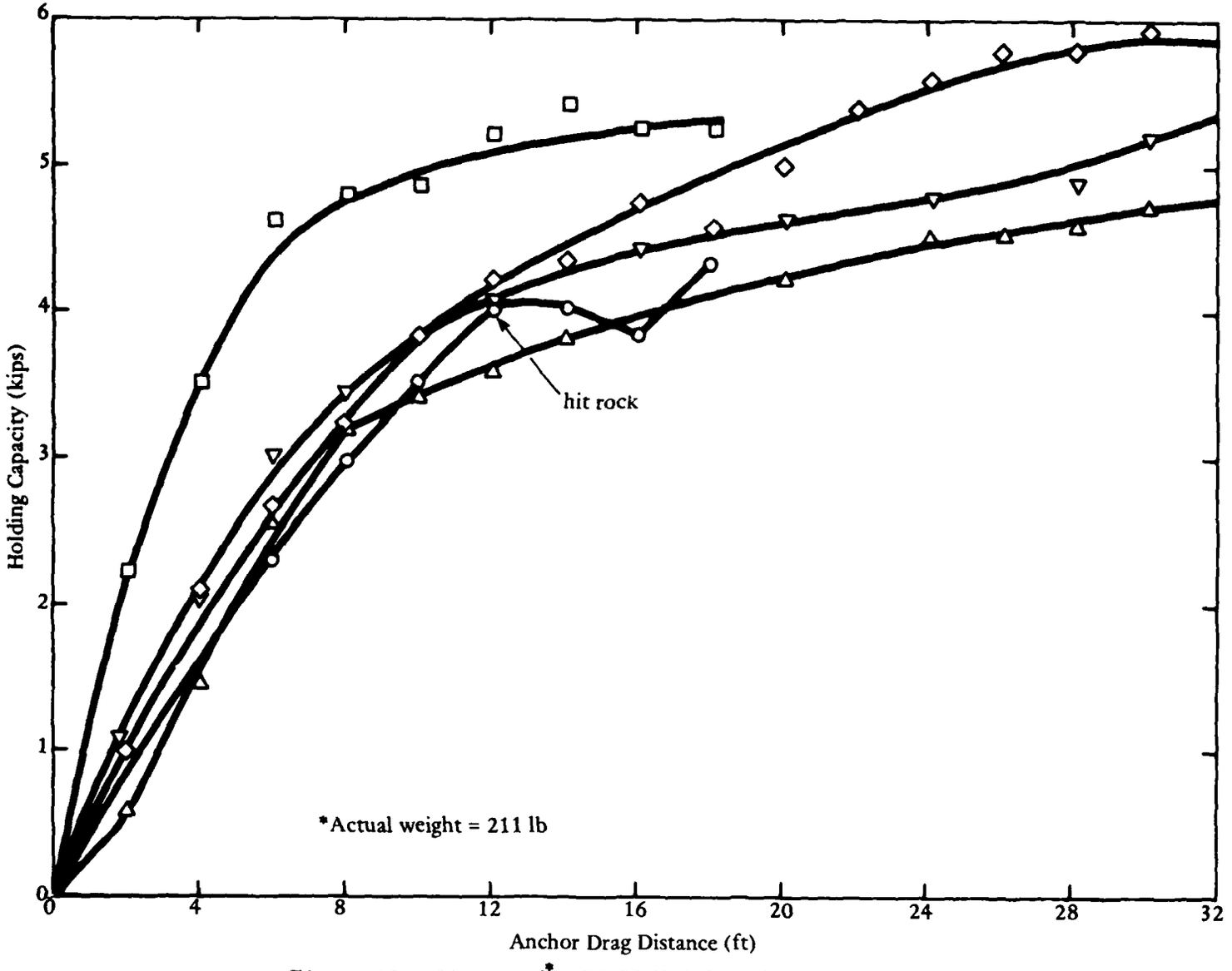


Figure 15. 200-pound* NAVMOOR Model Anchor performance in dry Port Hueneme beach sand.

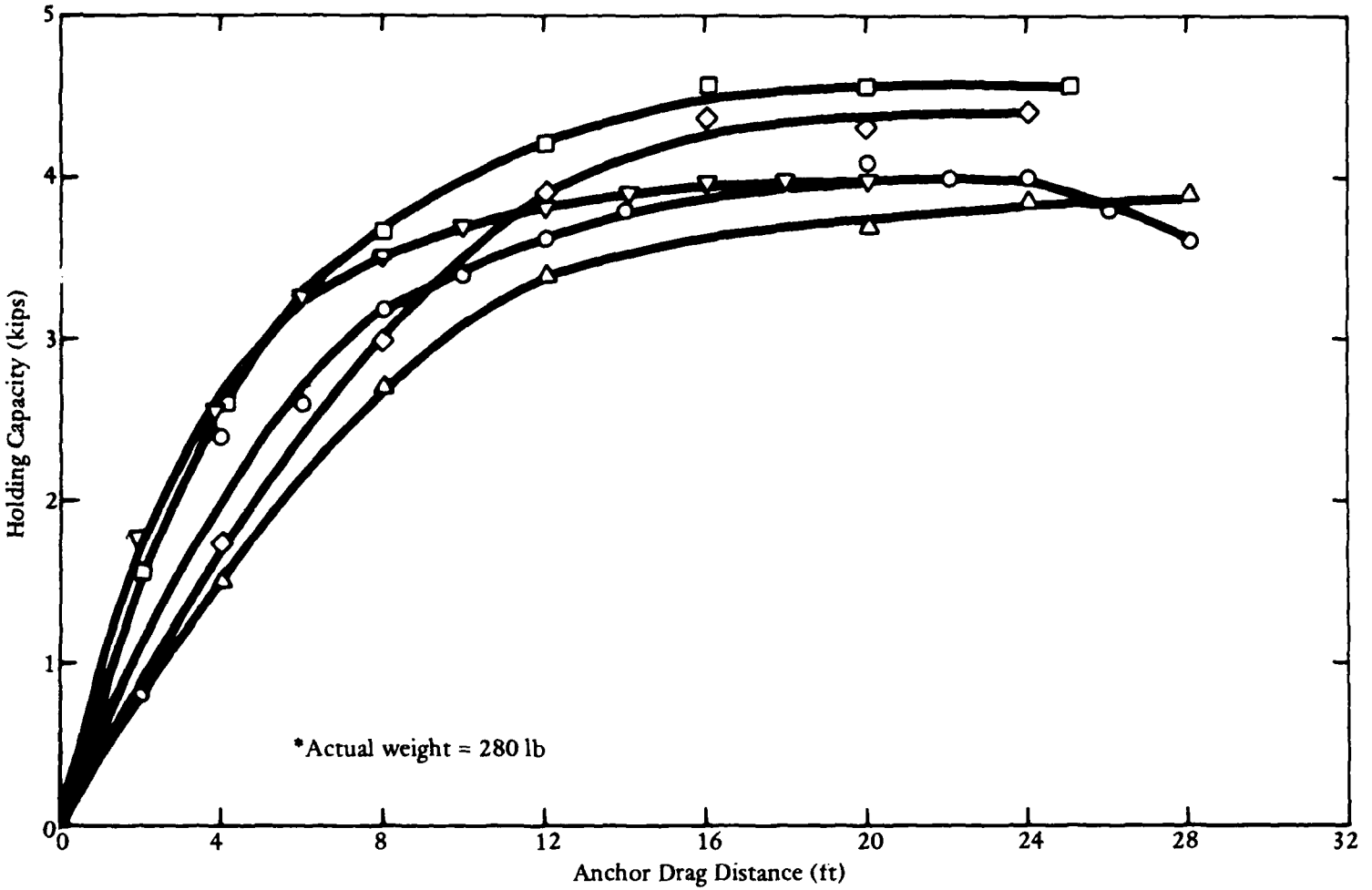


Figure 16. 200-pound* STATO Anchor performance in dry Port Hueneme beach sand.

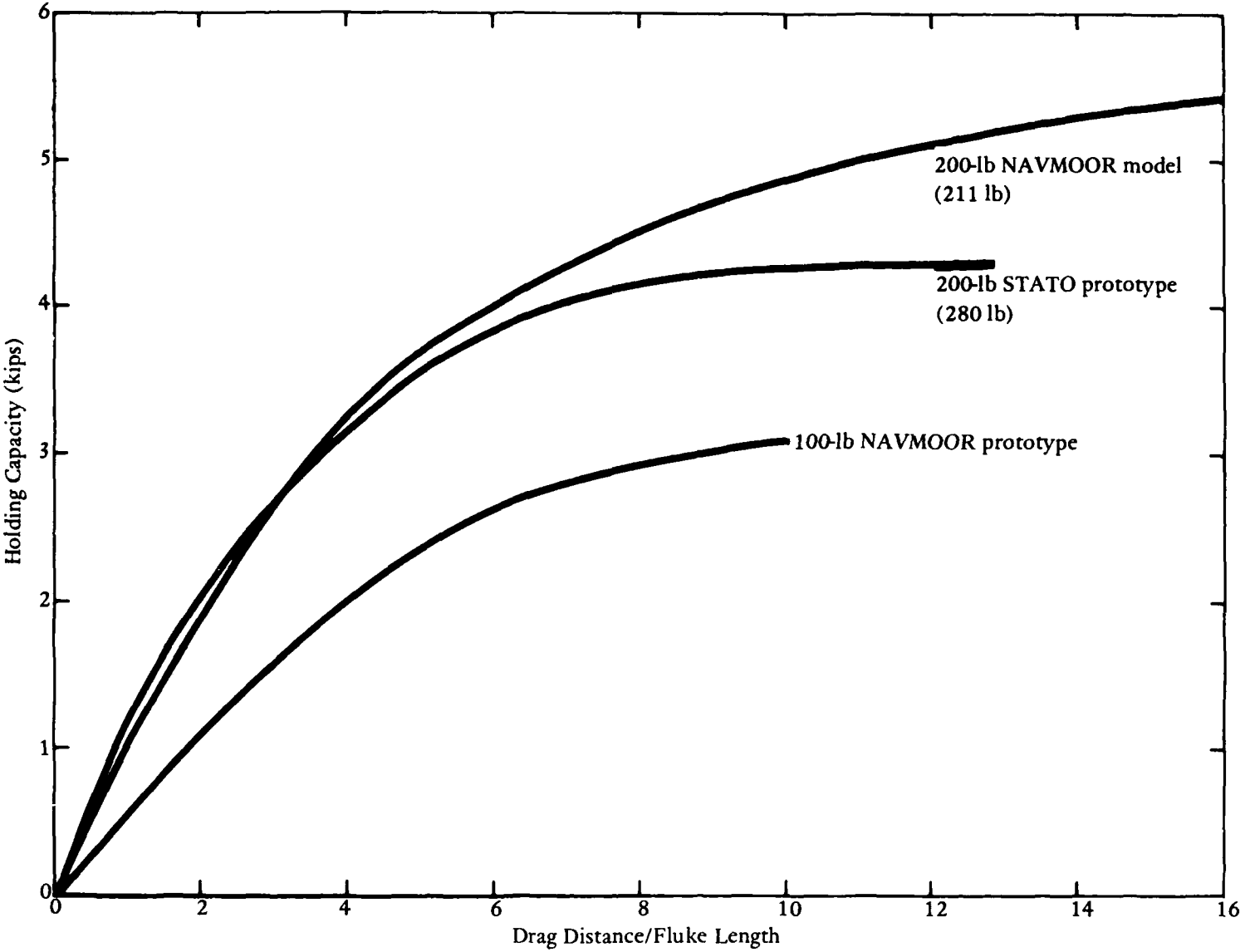


Figure 17. Average performance curves for small NAVMOOR Anchors in dry beach sand.

Figure 18. STATO Anchor flukes showing sand trapped between flukes ribs.

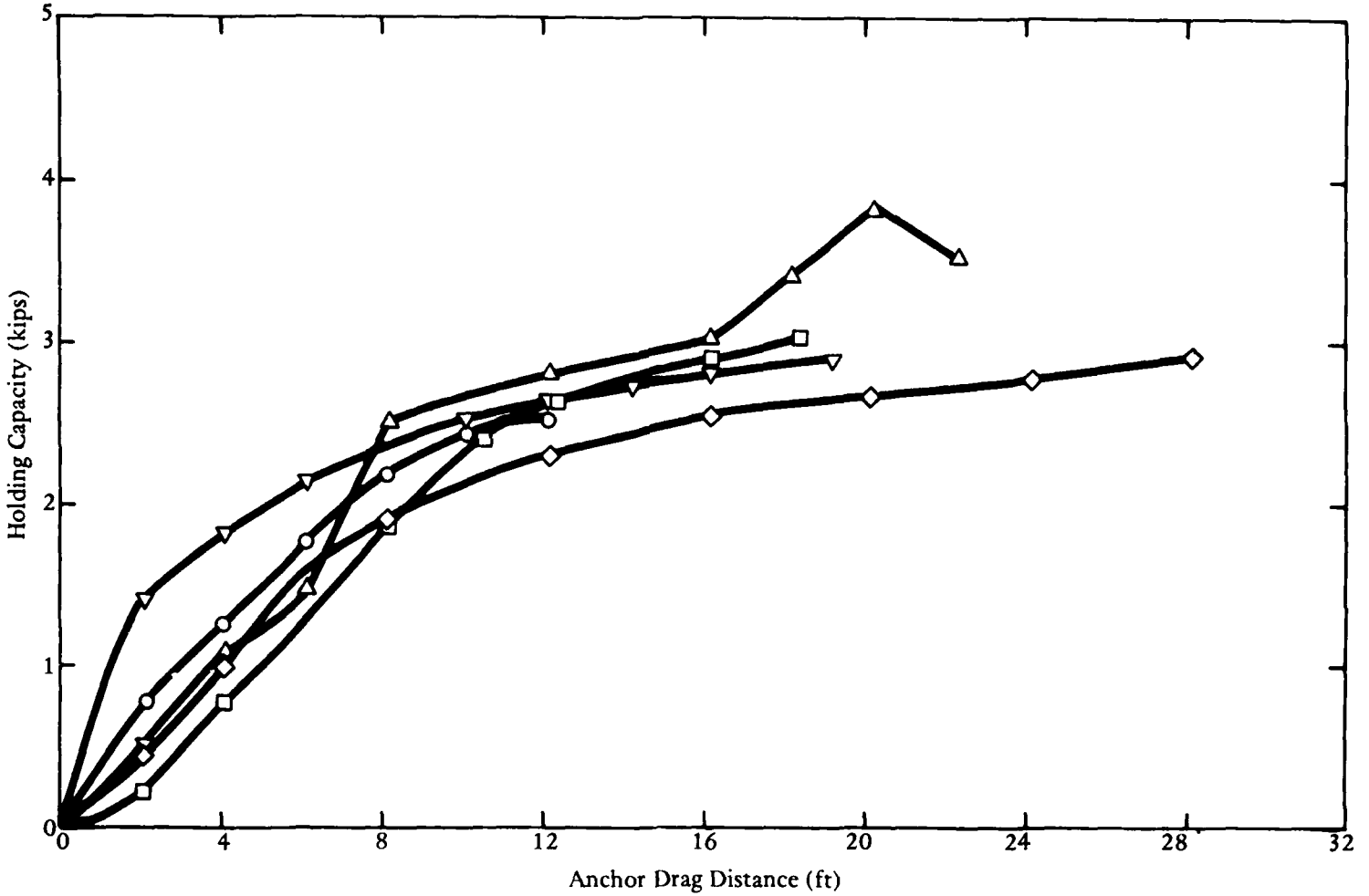


Figure 19. 100-pound NAVMOOR Anchor performance in dry Port Hueneme beach sand.

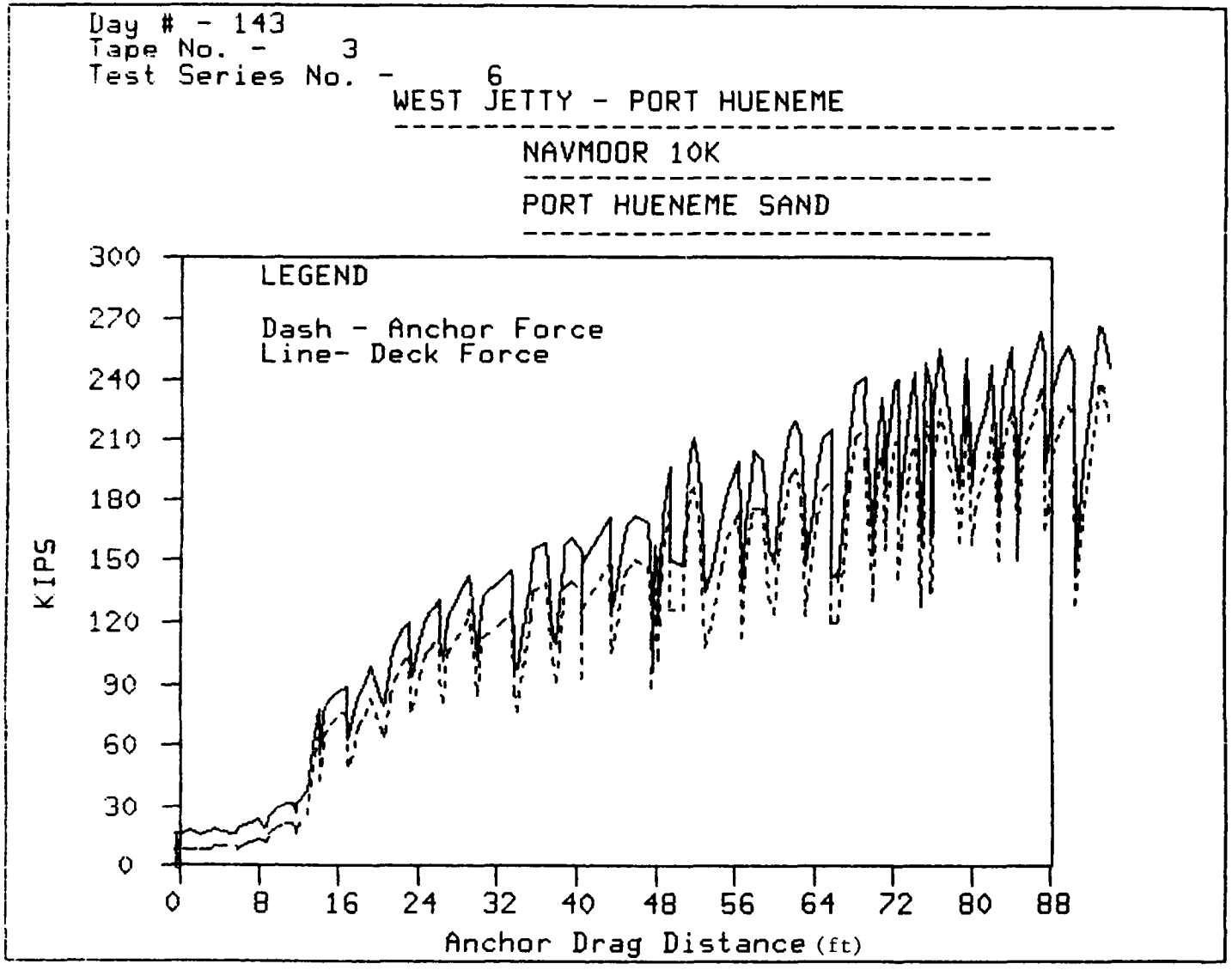


Figure 20. Typical load-drag distance test data for the NAVMOOR Anchor in Port Hueneme sand.

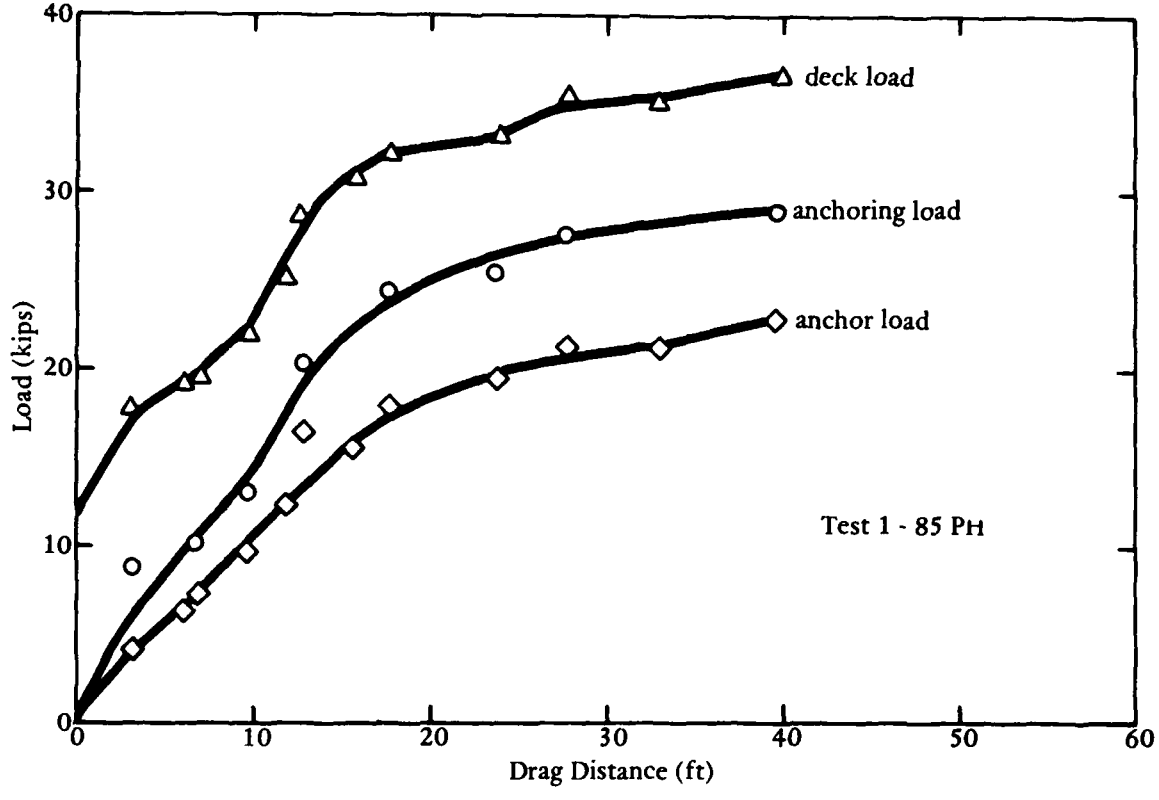


Figure 21. 1,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

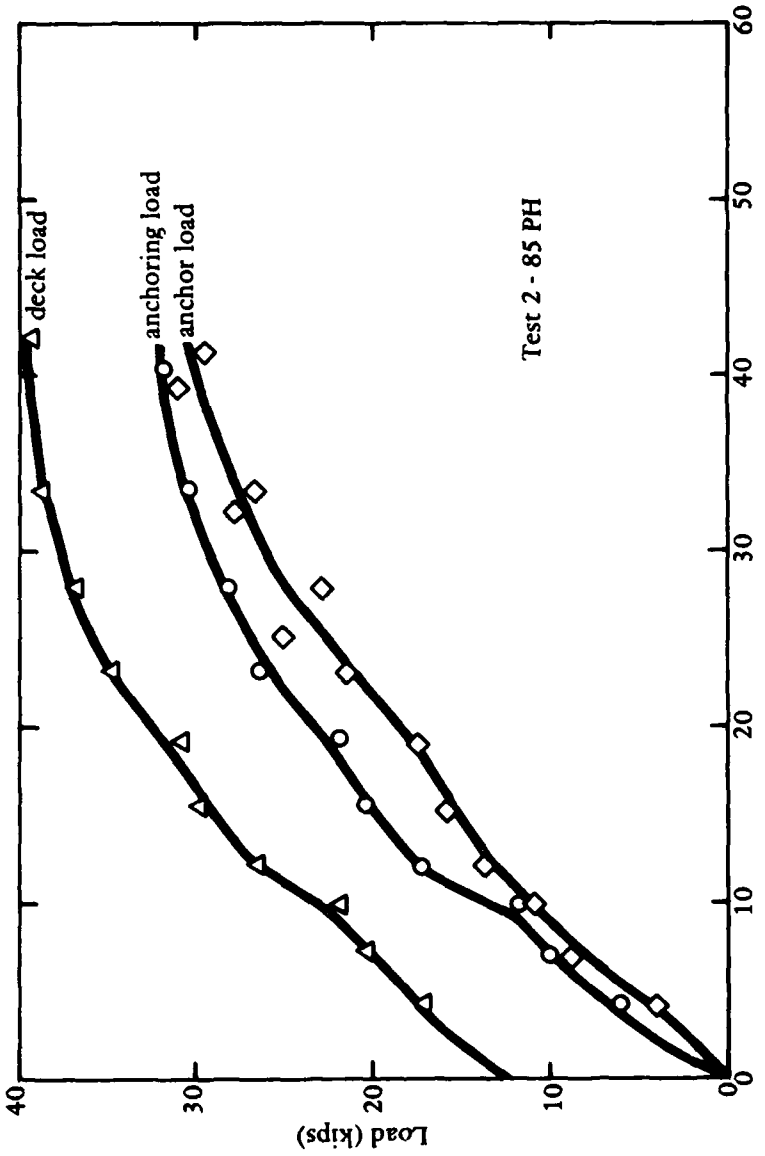


Figure 22. 1,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

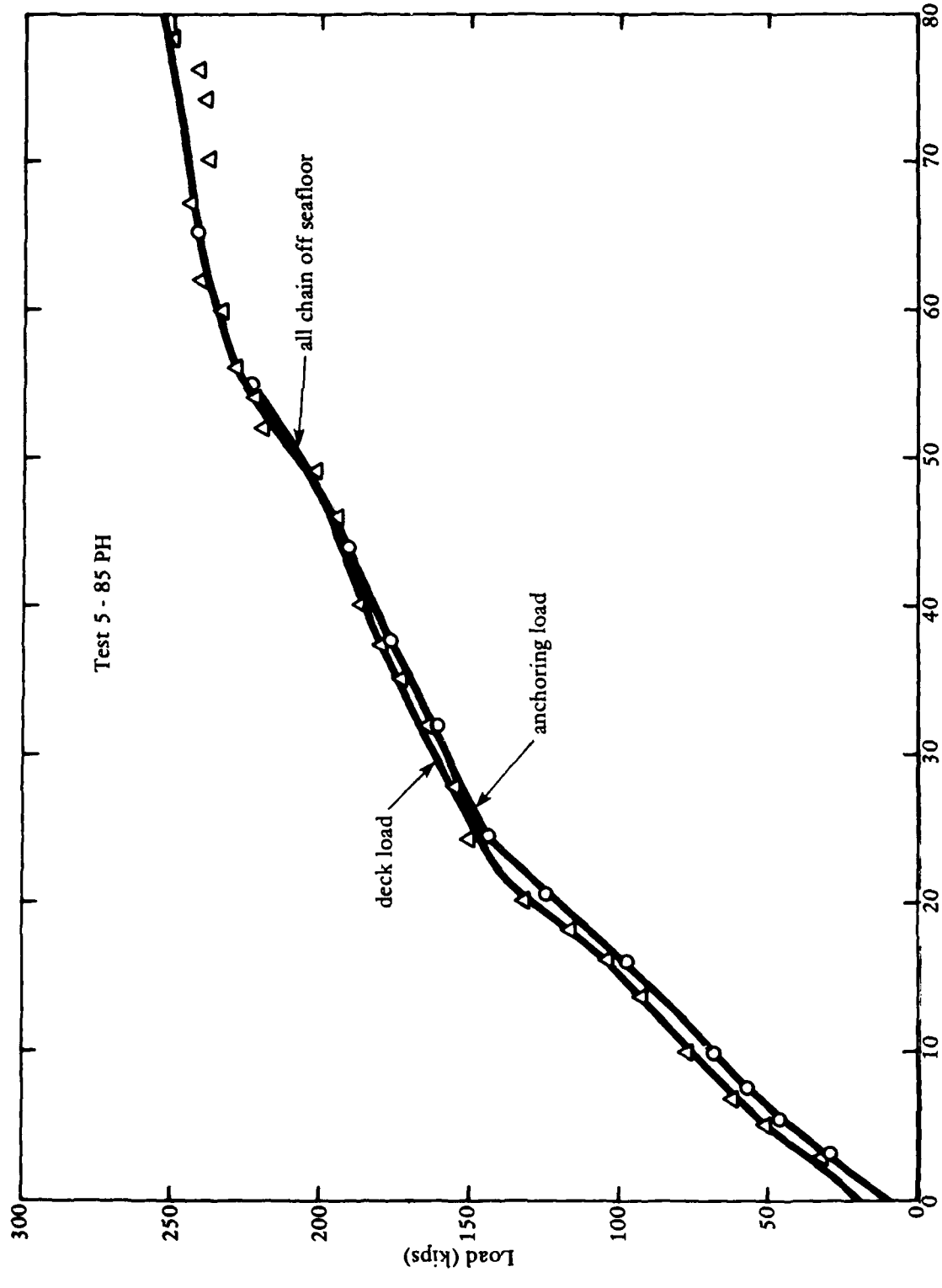


Figure 23. 10,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

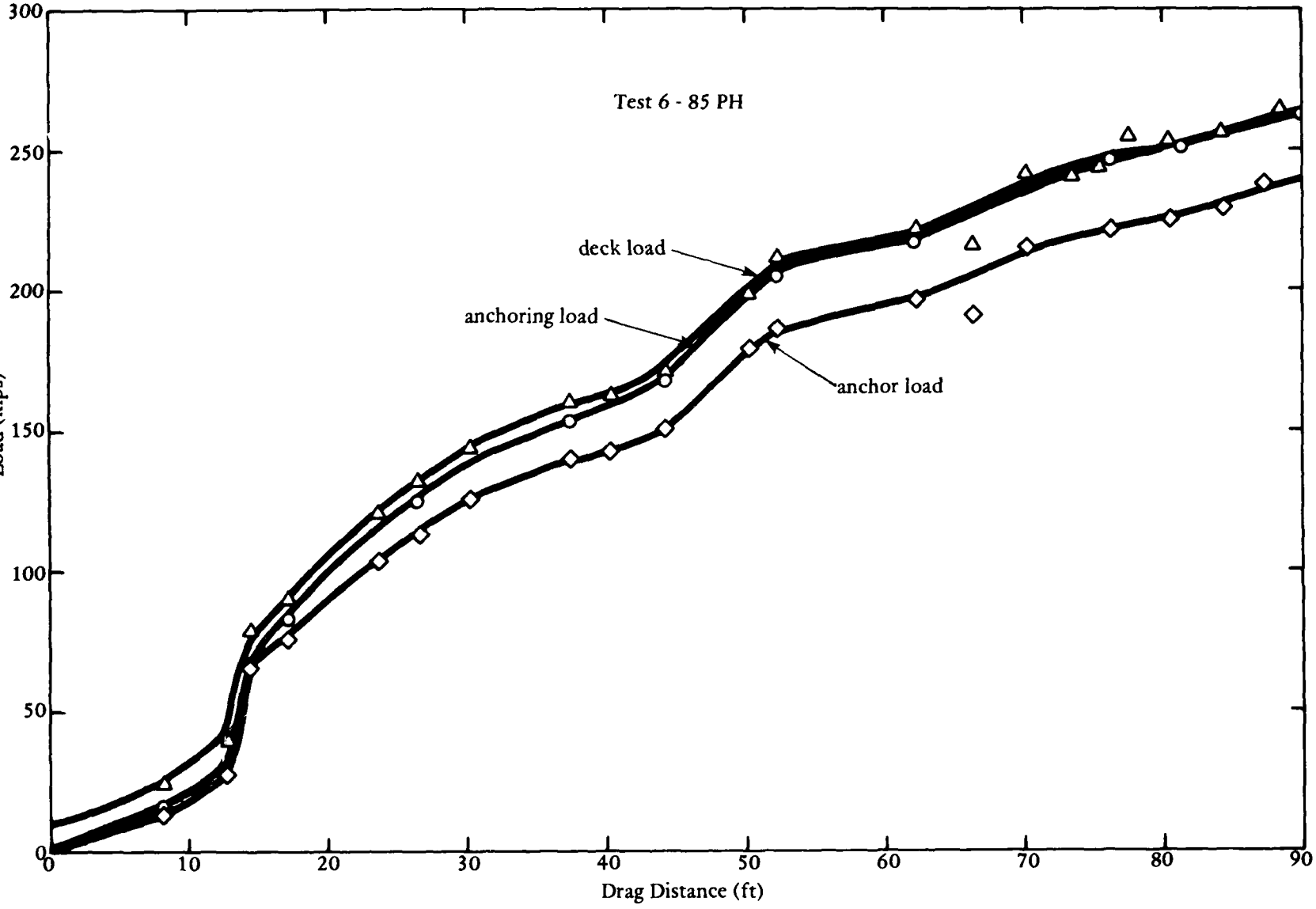


Figure 24. 10,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

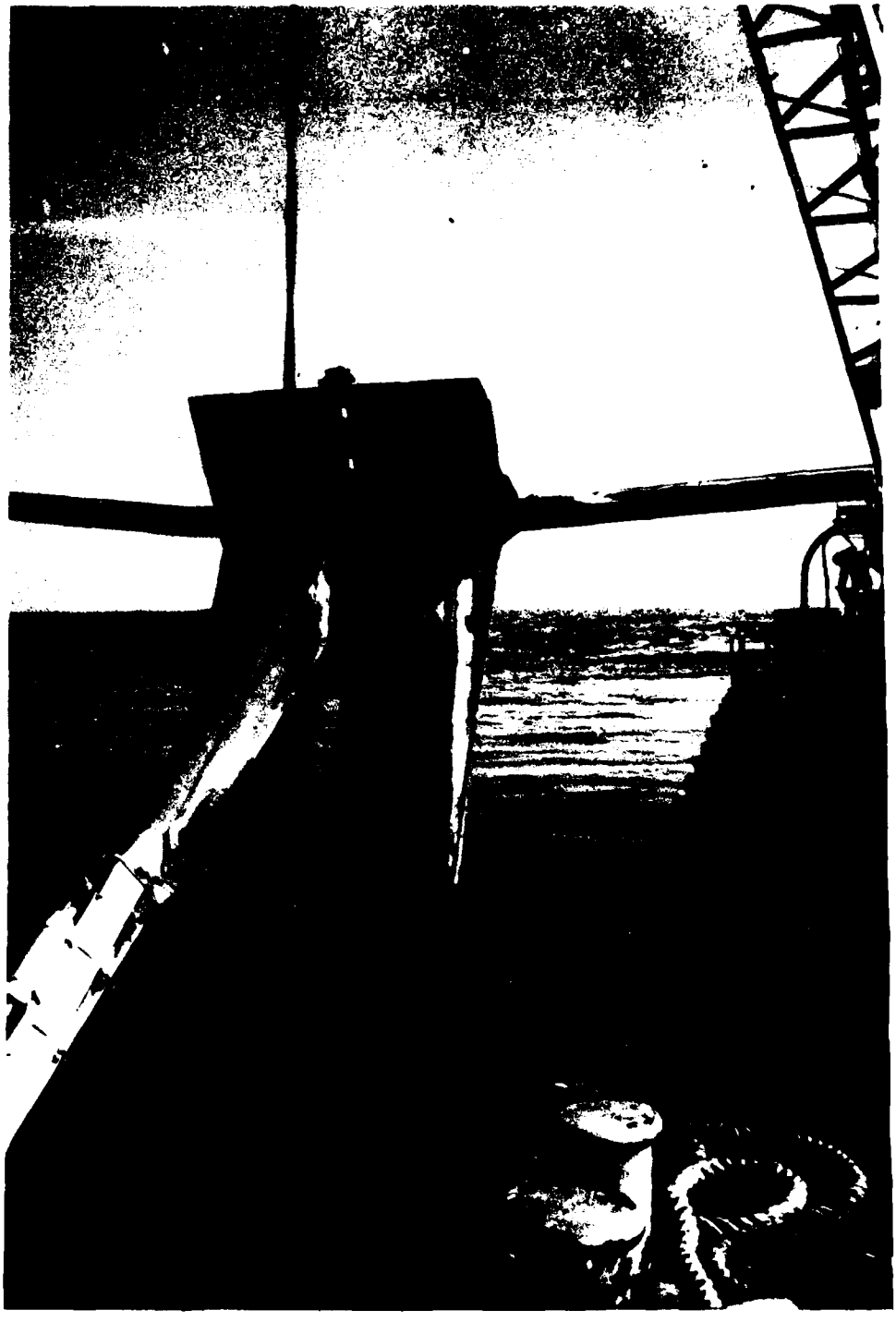


Figure 25. 10,000-pound NAVMOOR Anchor after testing showing bent stabilizers.

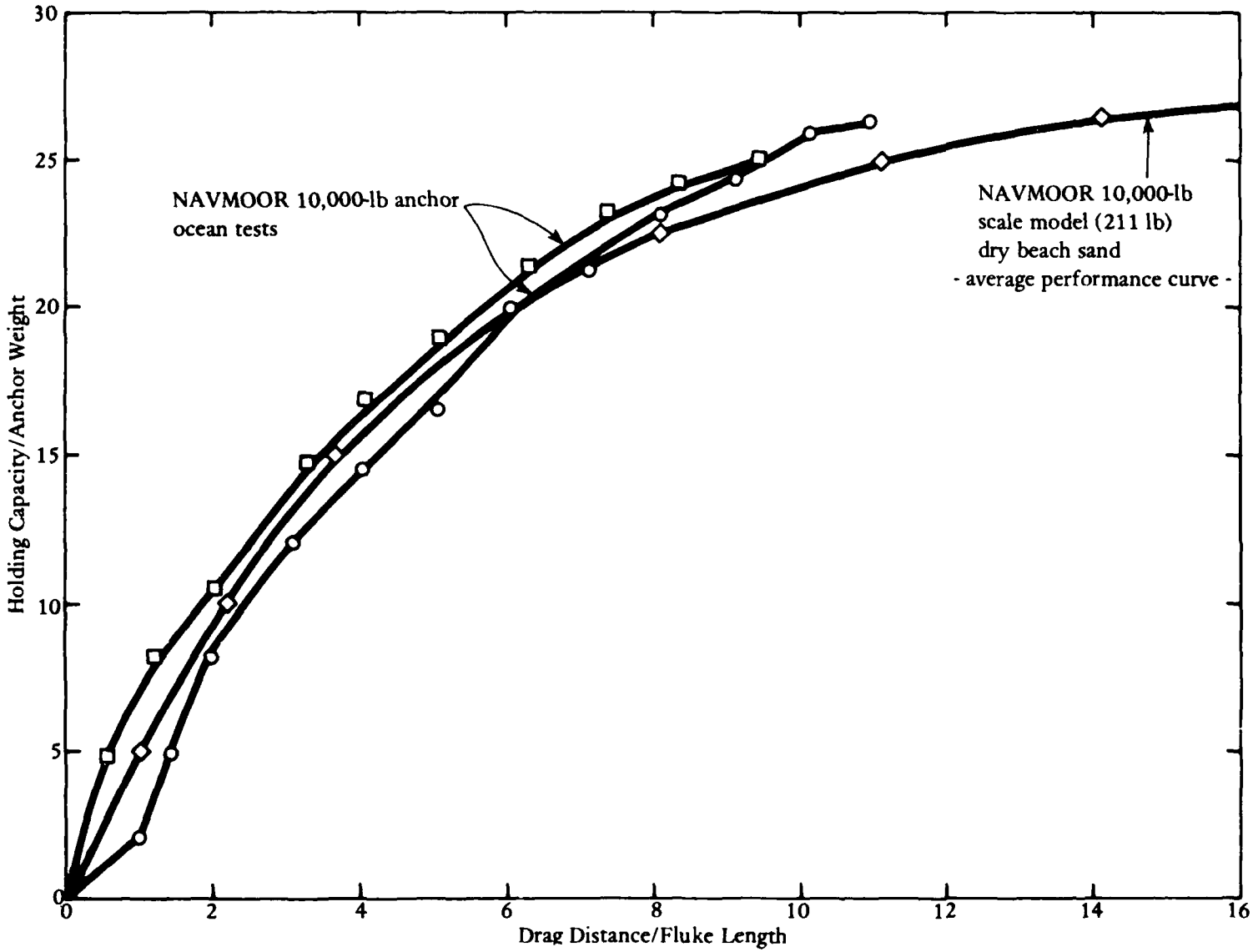


Figure 26. Performance curves of prototype and scale model NAVMOOR Anchors.

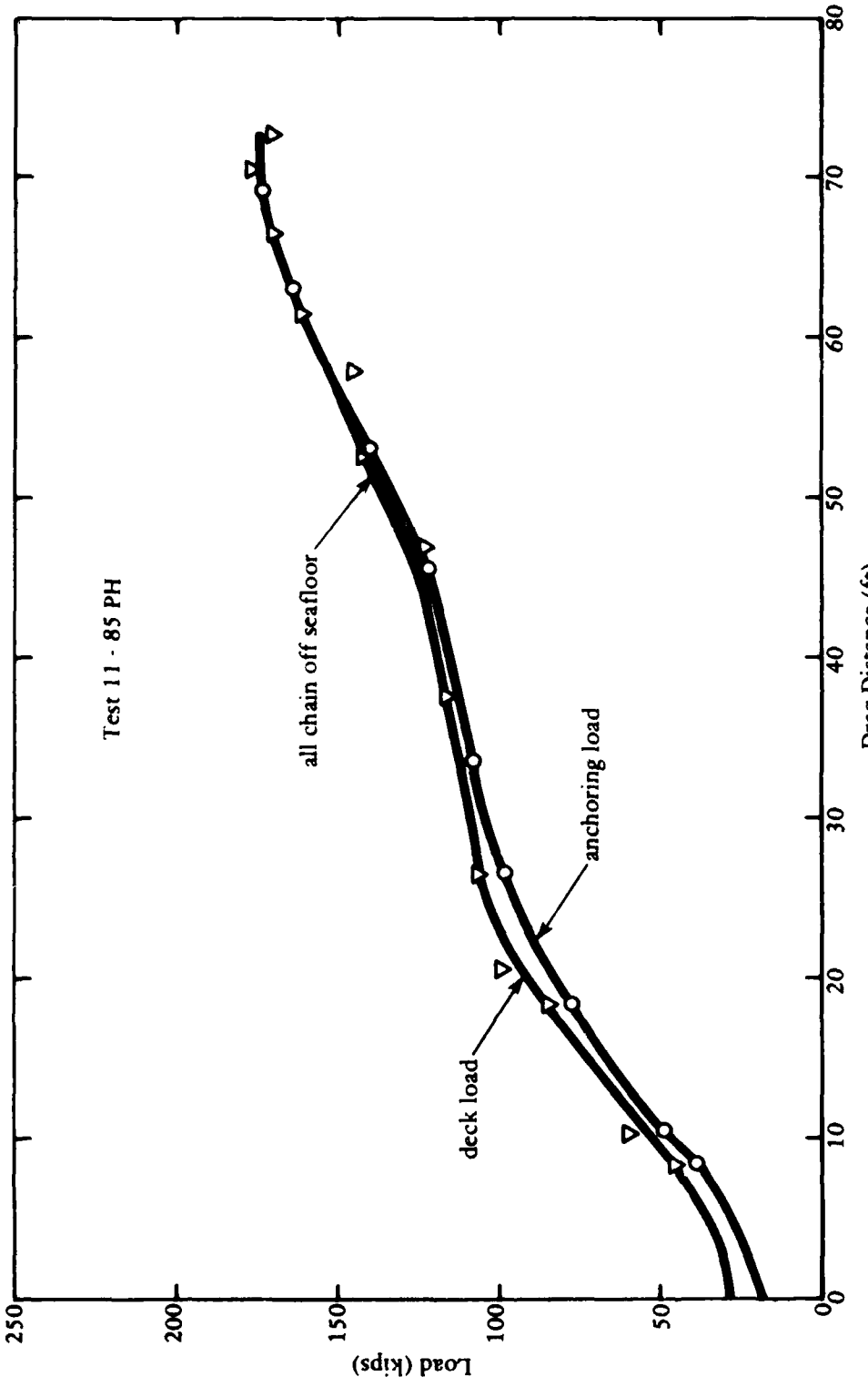


Figure 27. 6,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

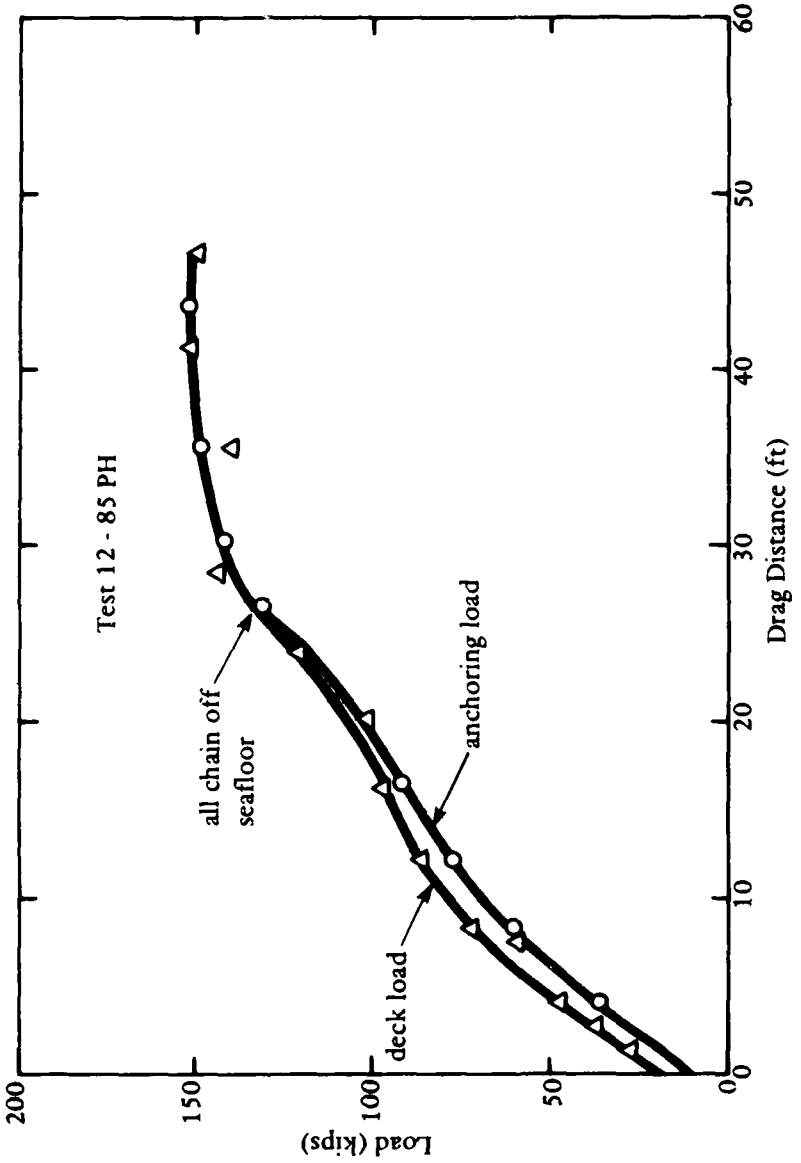


Figure 28. 6,000-pound NAVMOOR Anchor performance in Port Hueneme sand.

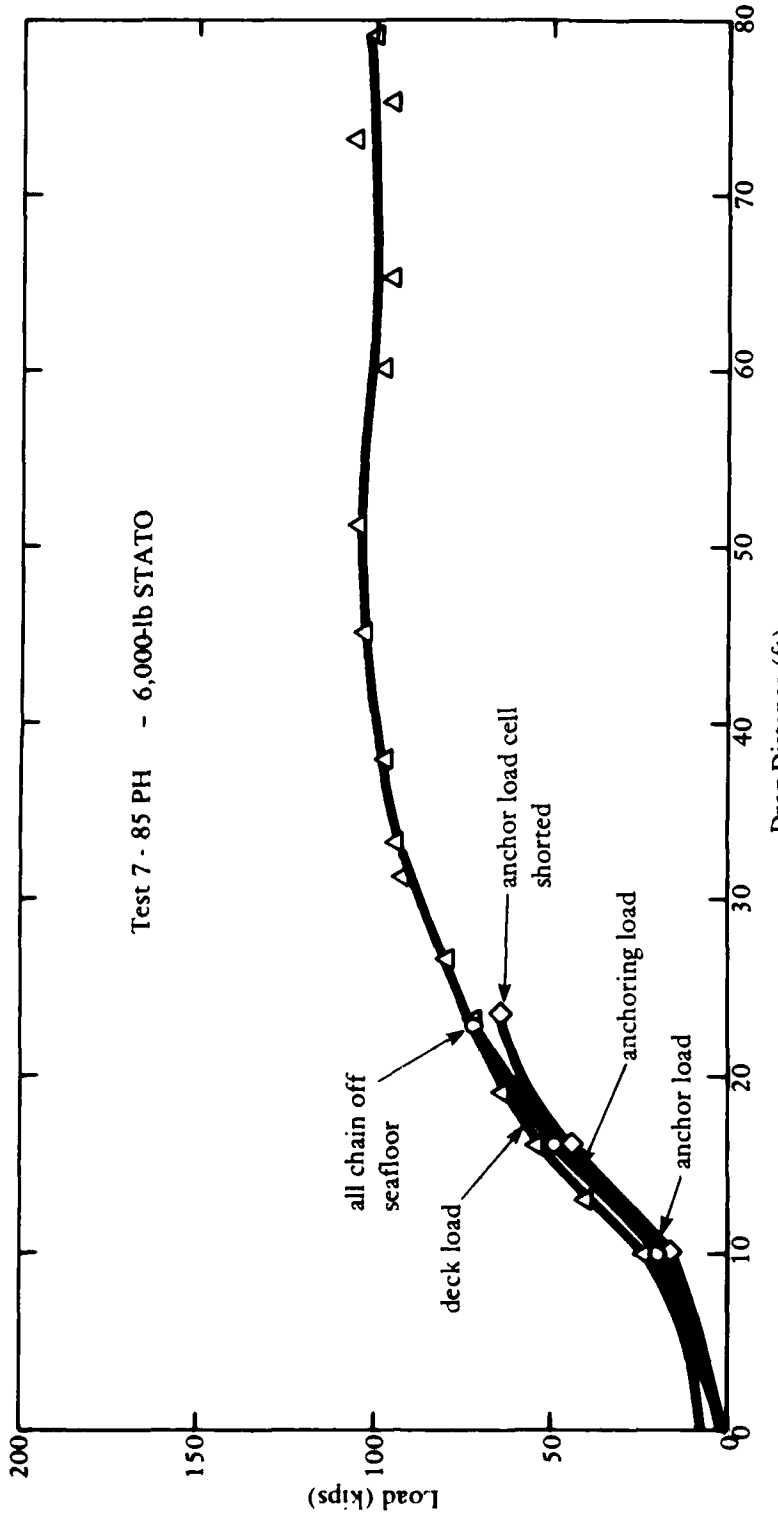


Figure 29. 6,000-pound STATO Anchor performance in Port Hueneme sand.

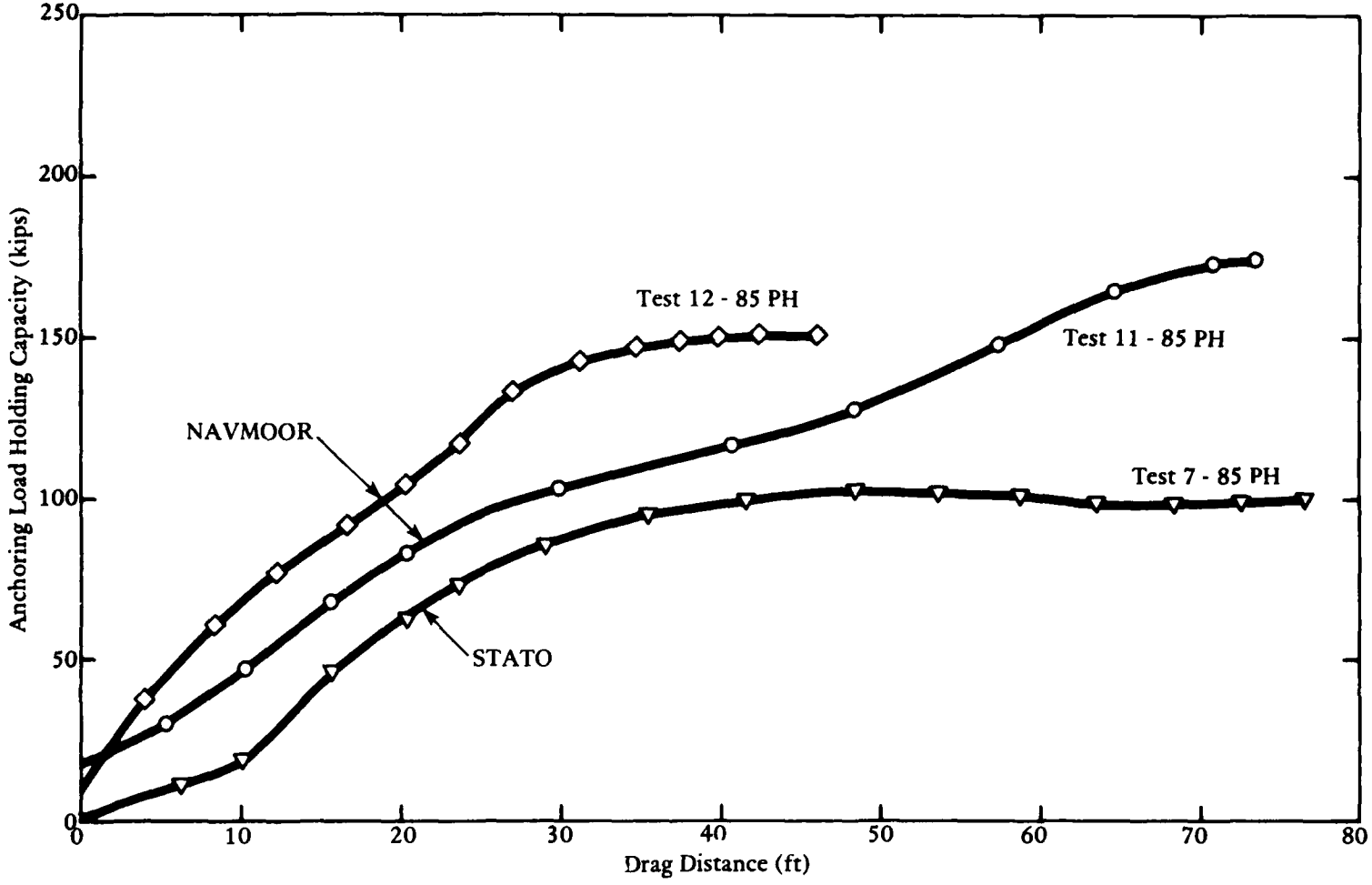


Figure 30. Comparative performance of 6,000-pound NAVMOOR and STATO Anchors in dense gravelly Port Hueneme sand.

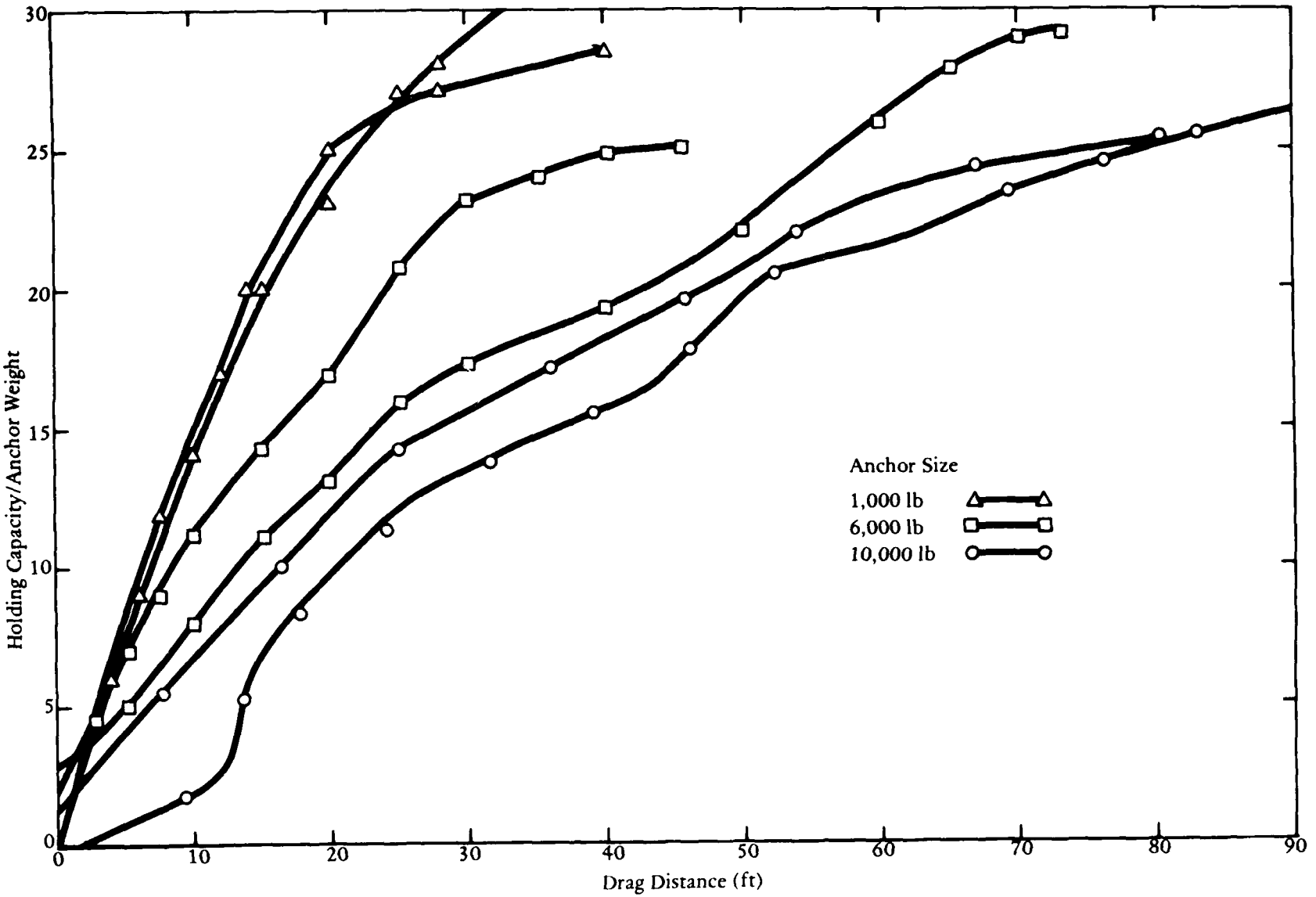


Figure 31. Performance curves for NAVMOOR Anchors in dense gravelly sand at Port Hueneme.

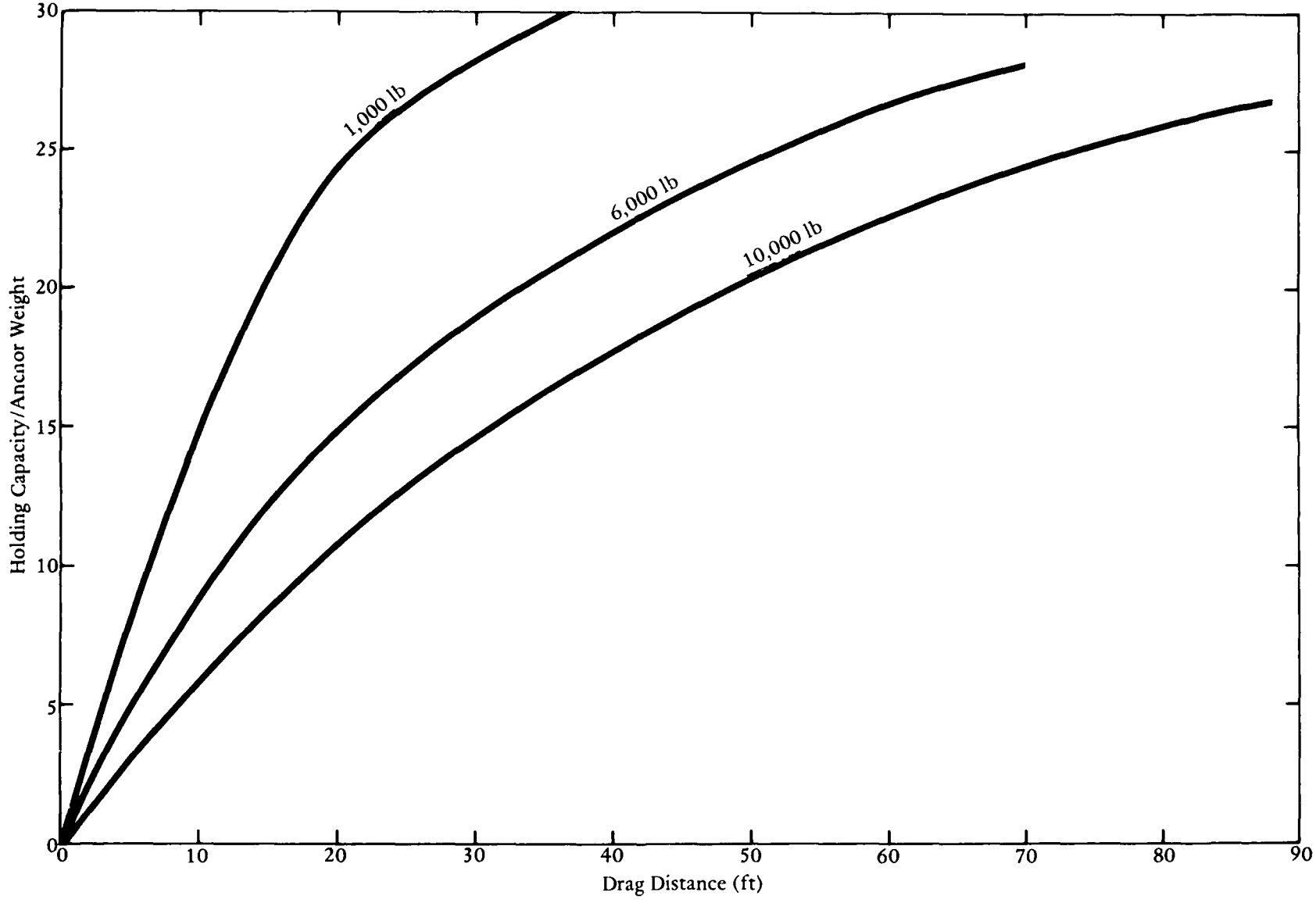


Figure 32. Average performance curves for NAVMOOR Anchors in dense gravelly sand at Port Hueneme.

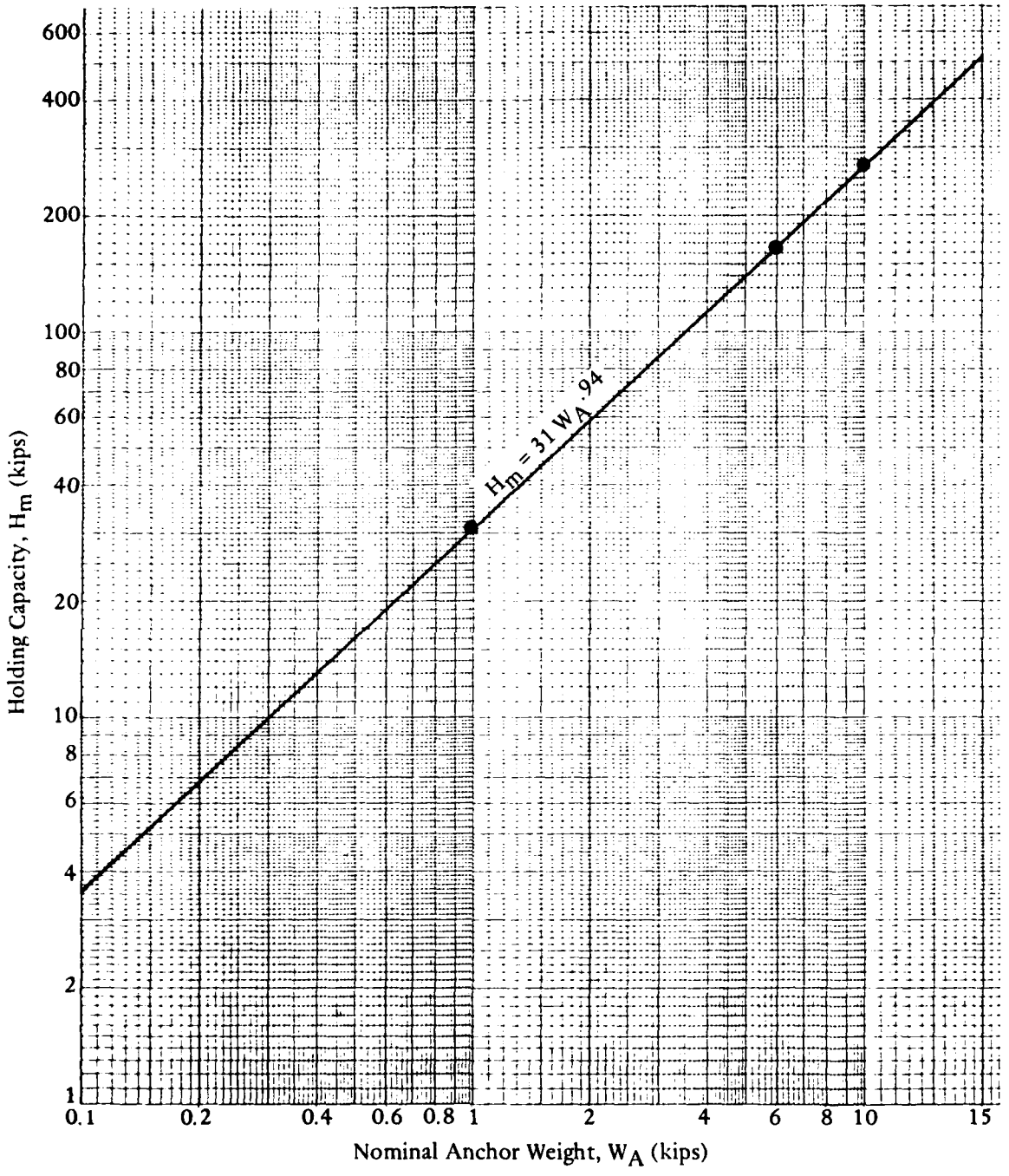


Figure 33. NAVMOOR Anchor performance specification in sand.

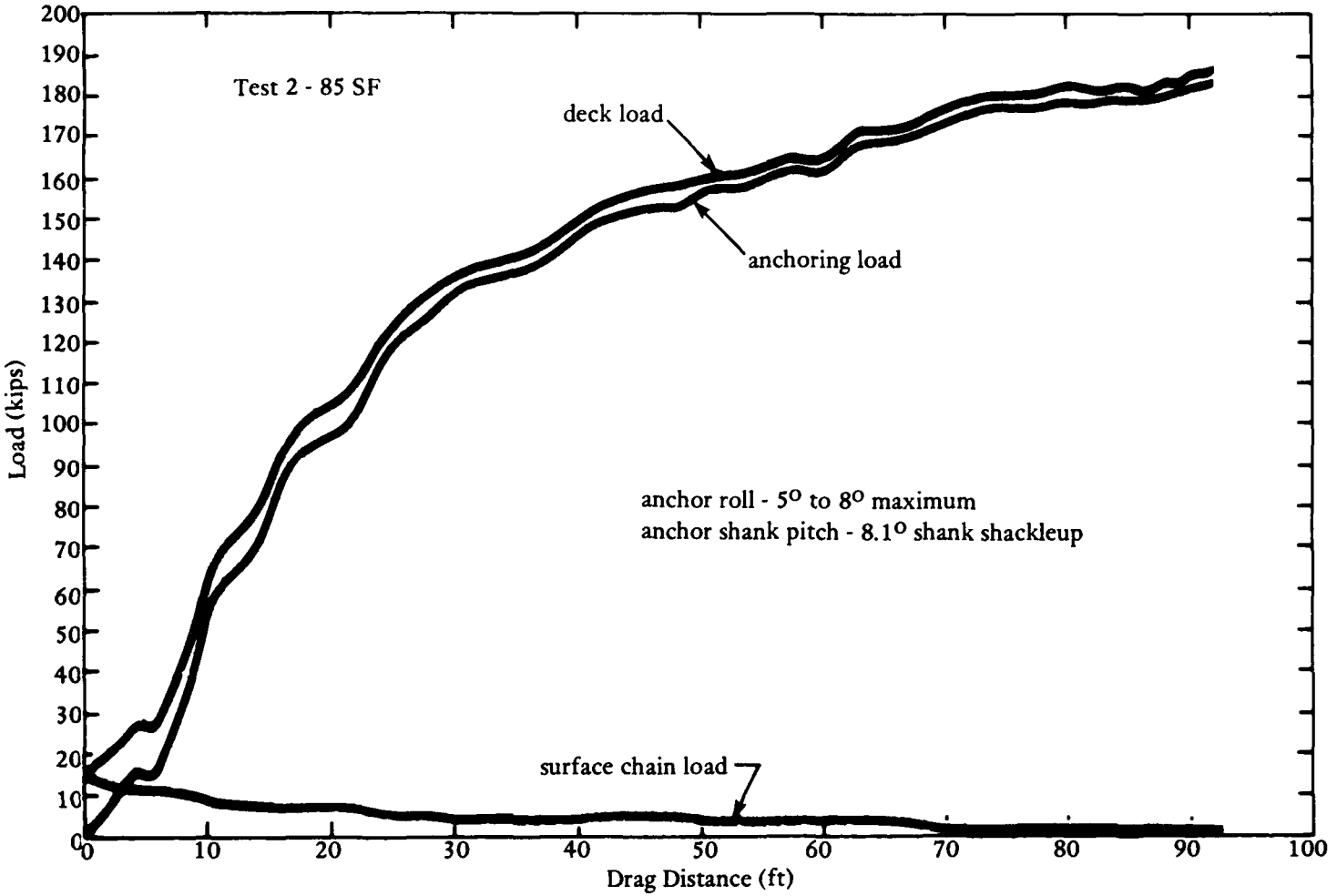


Figure 34. 10,000-pound NAVMOOR Anchor performance in San Francisco Bay mud.

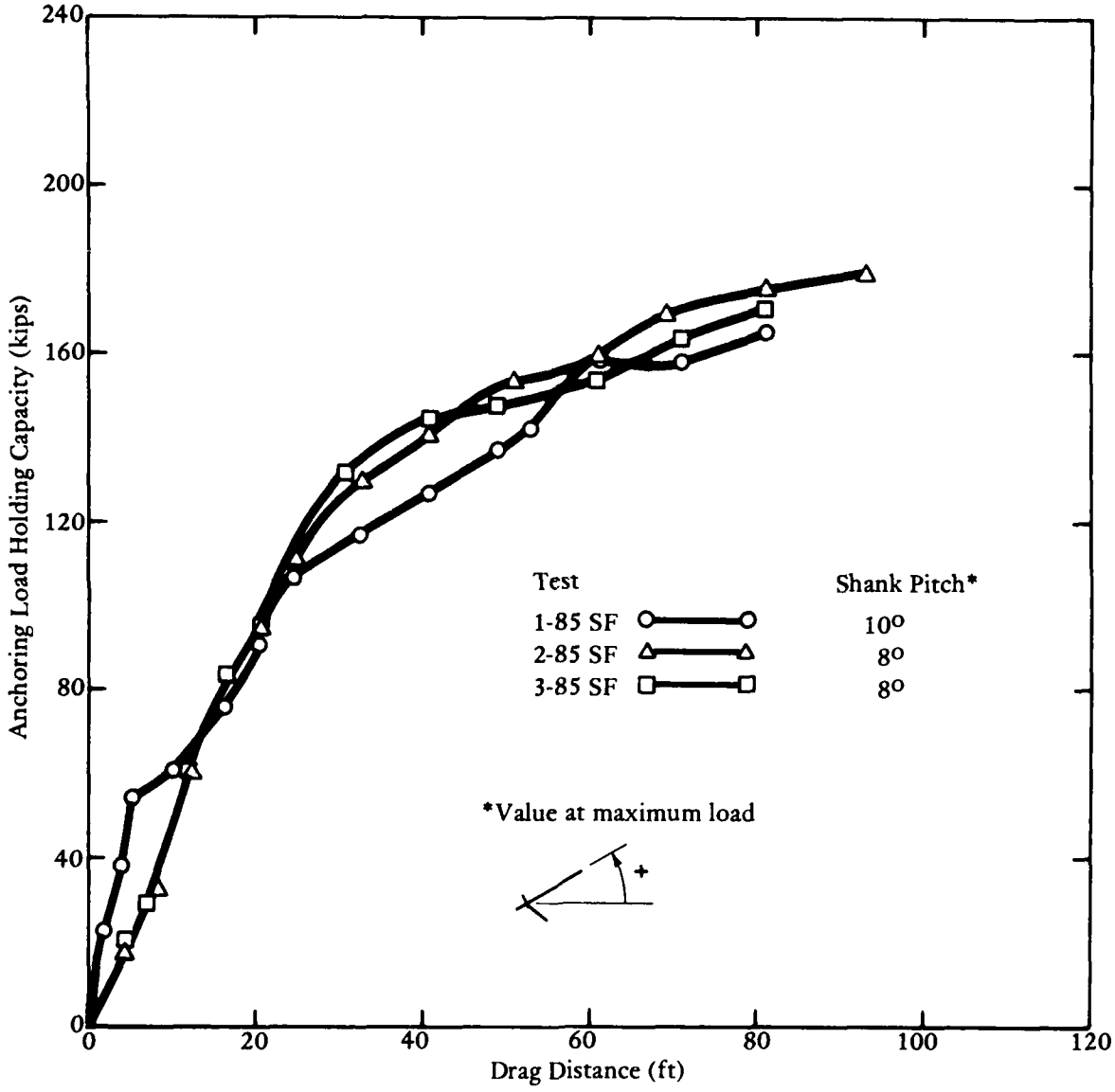


Figure 35. 10,000-pound NAVMOOR Anchor performance curves in San Francisco Bay mud.

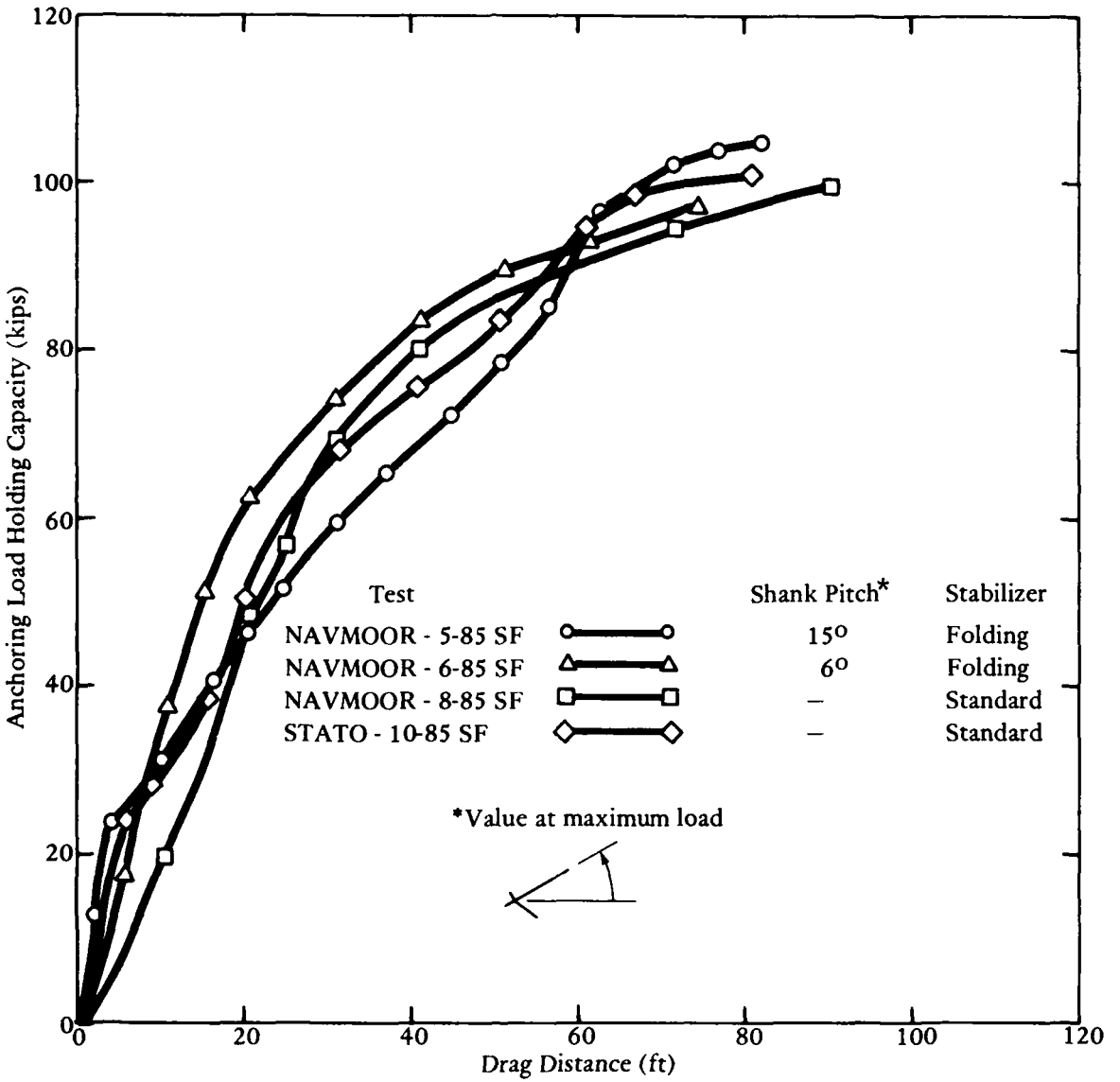


Figure 36. 6,000-pound NAVMOOR and STATO Anchor performance curves in San Francisco Bay mud.

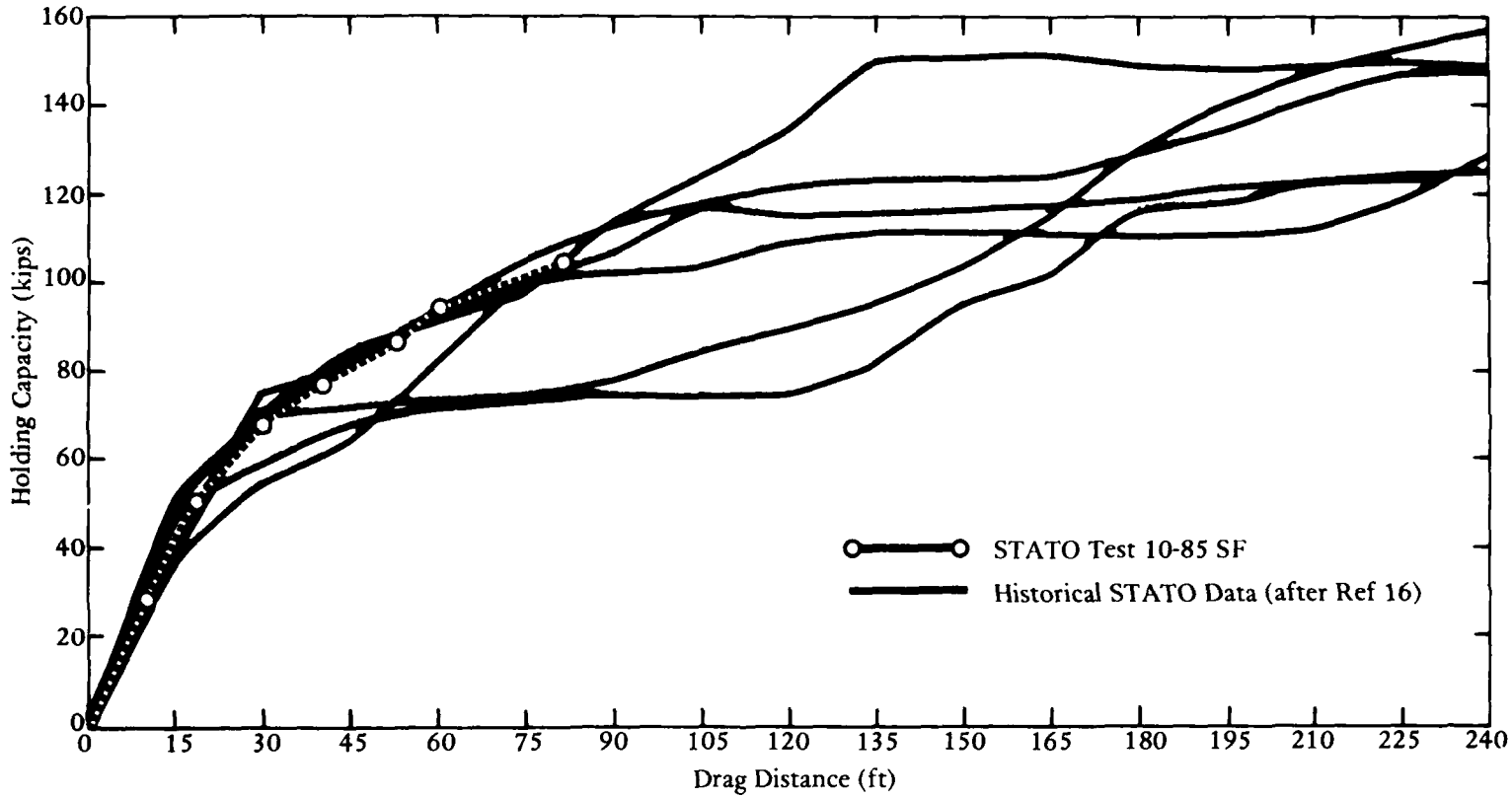


Figure 37. Comparison of recent and historical 6,000-pound STATO Anchor test data.

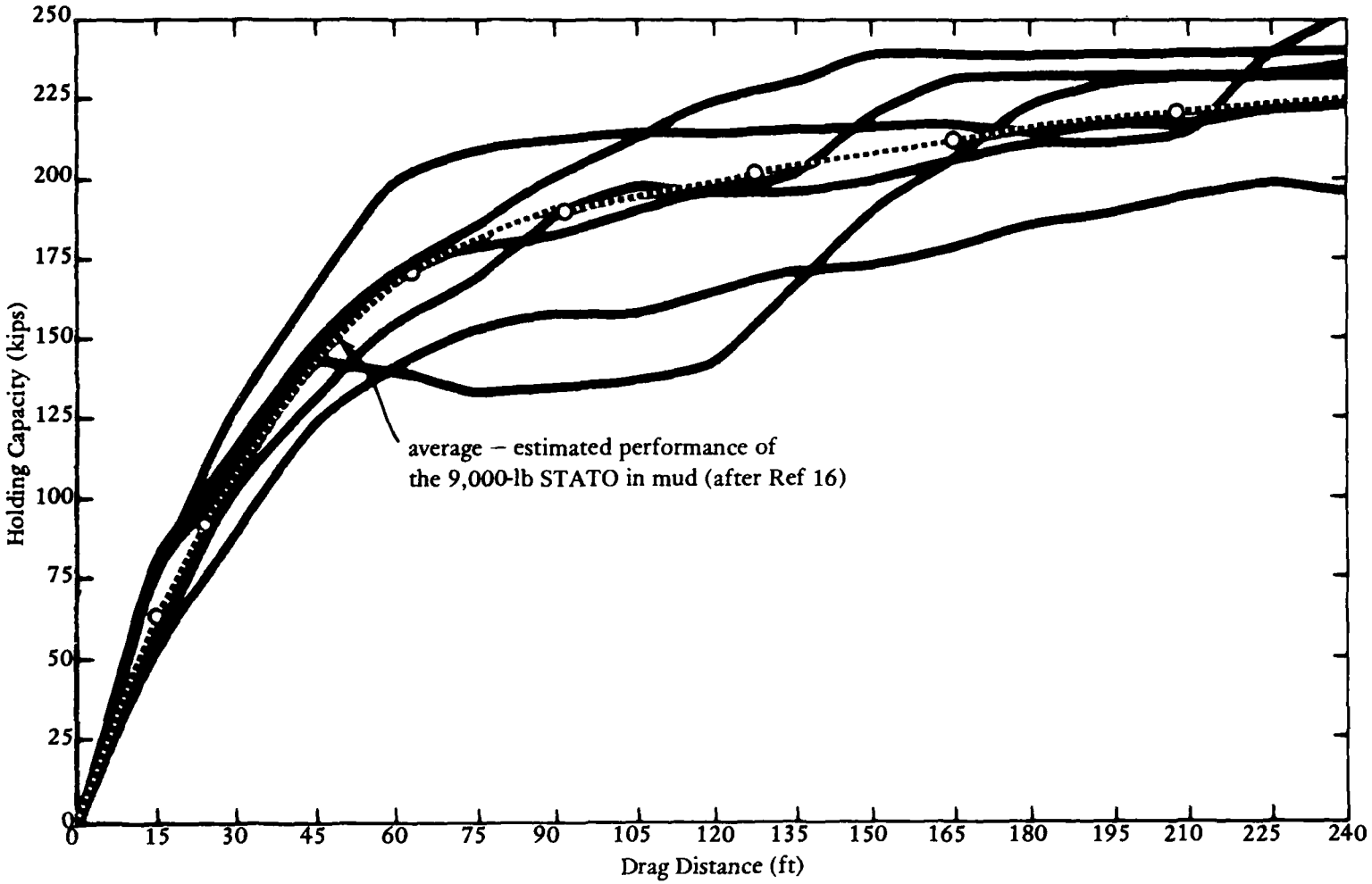


Figure 38. Historical 9,000-pound STATO Anchor data for San Francisco Bay mud.

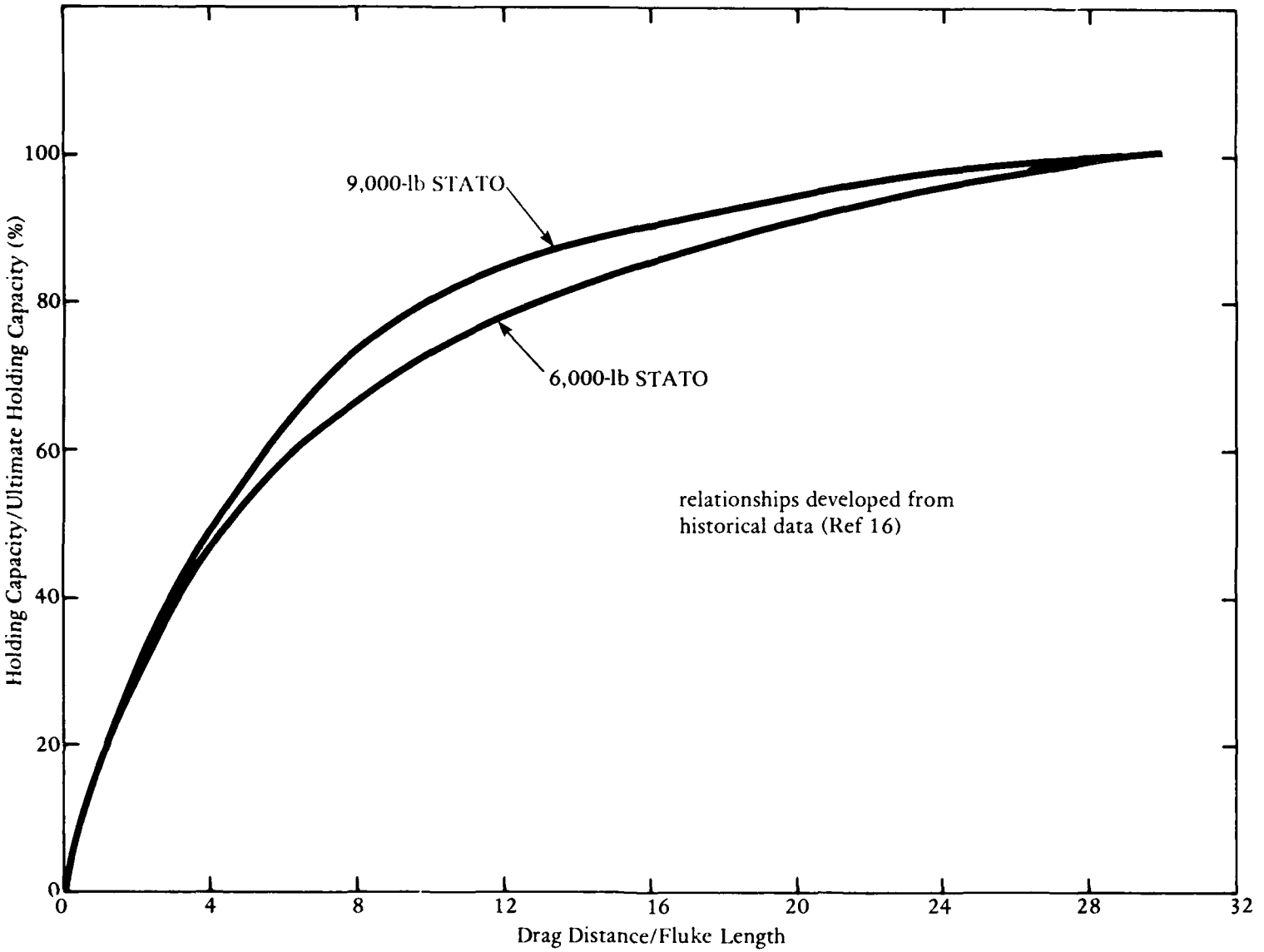


Figure 39. Normalized holding capacity-drag relationships for STATO (NAVMOOR) Anchors in San Francisco Bay mud.

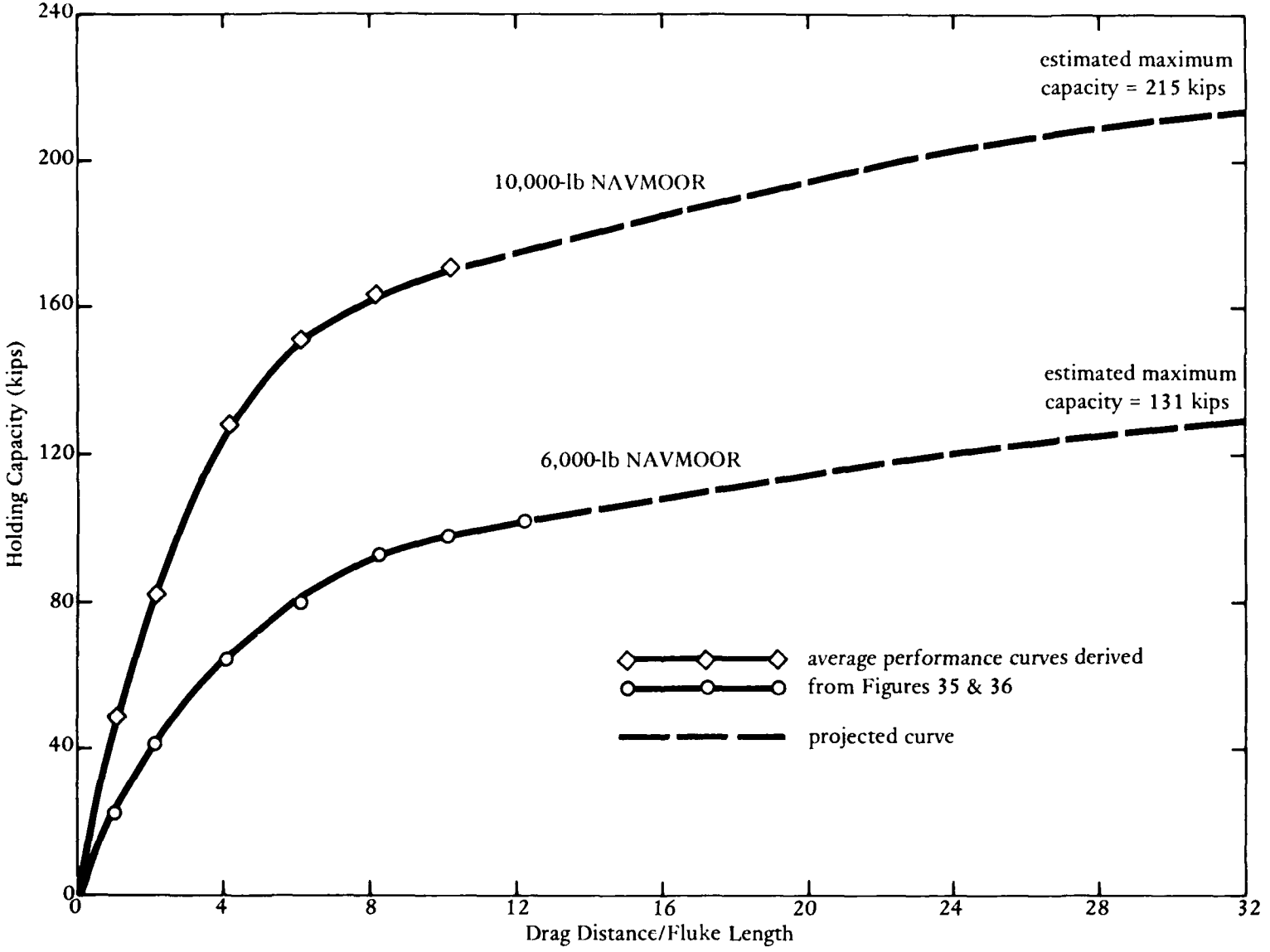


Figure 40. Average performance curves for NAVMOOR Anchors in San Francisco Bay mud.

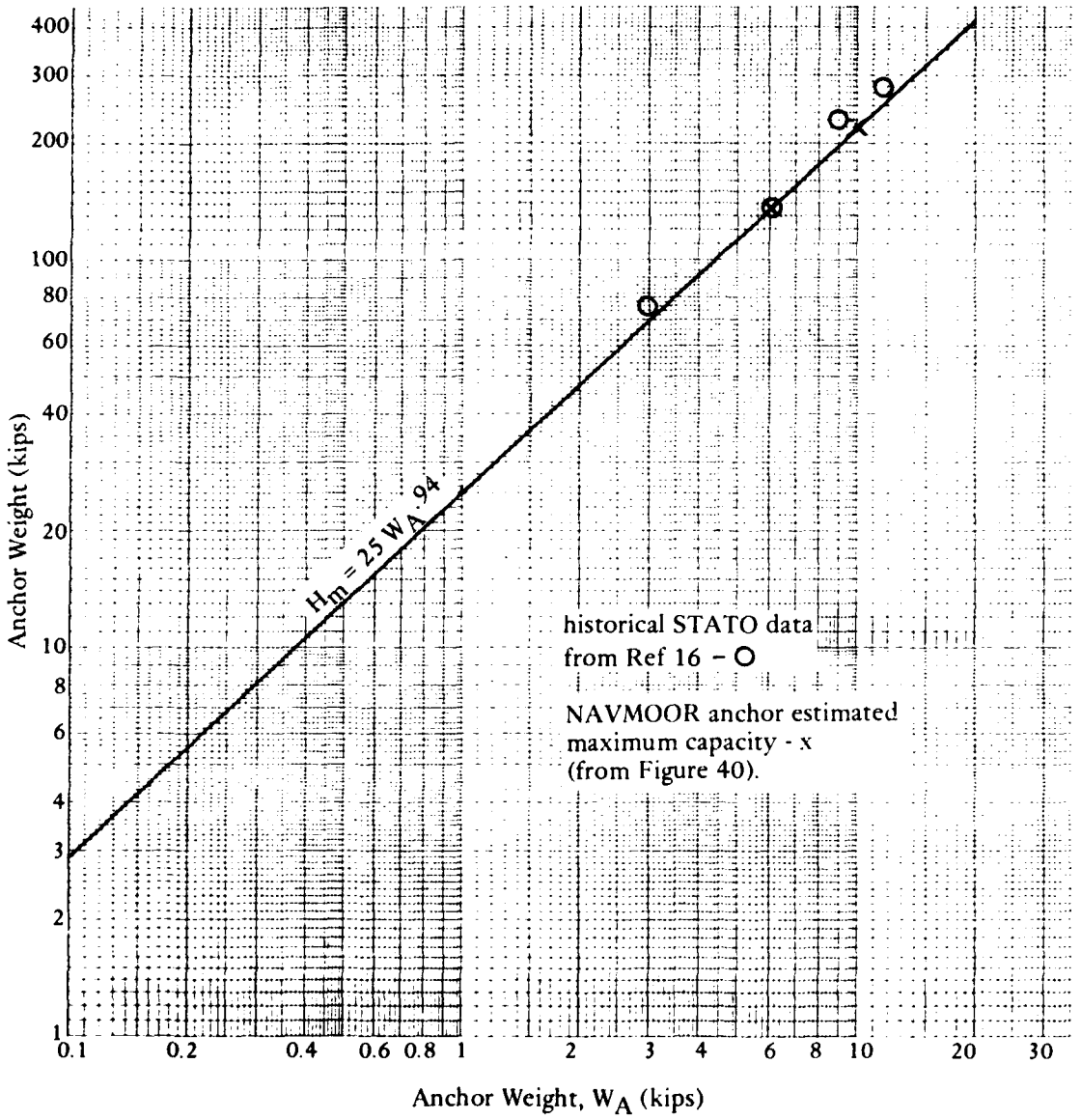


Figure 41. NAVMOOR Anchor performance specification in mud.

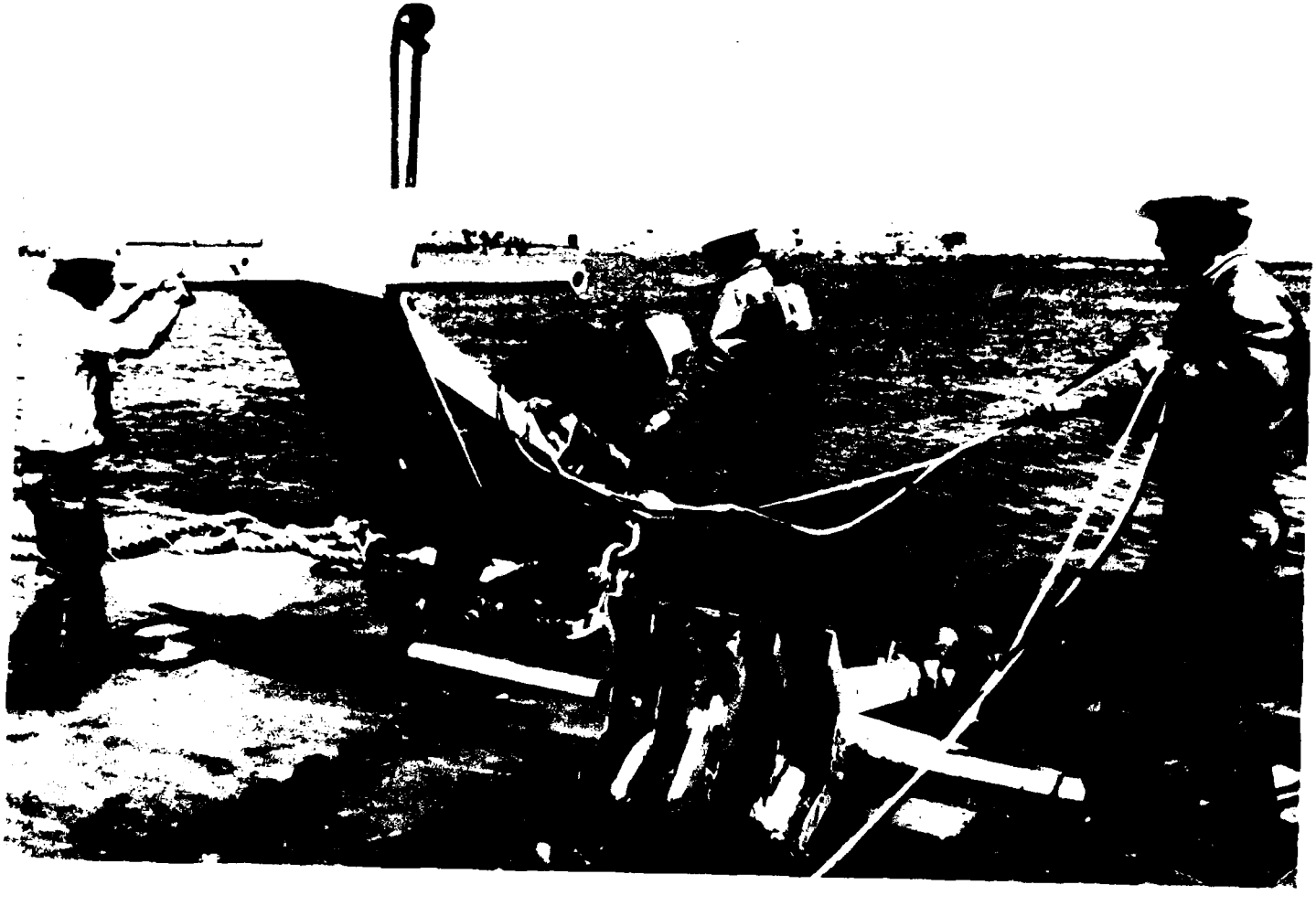


Figure 42. 1,000-pound NAVMOOR Anchors being deployed for tandem anchor testing in Port Hueneme sand.

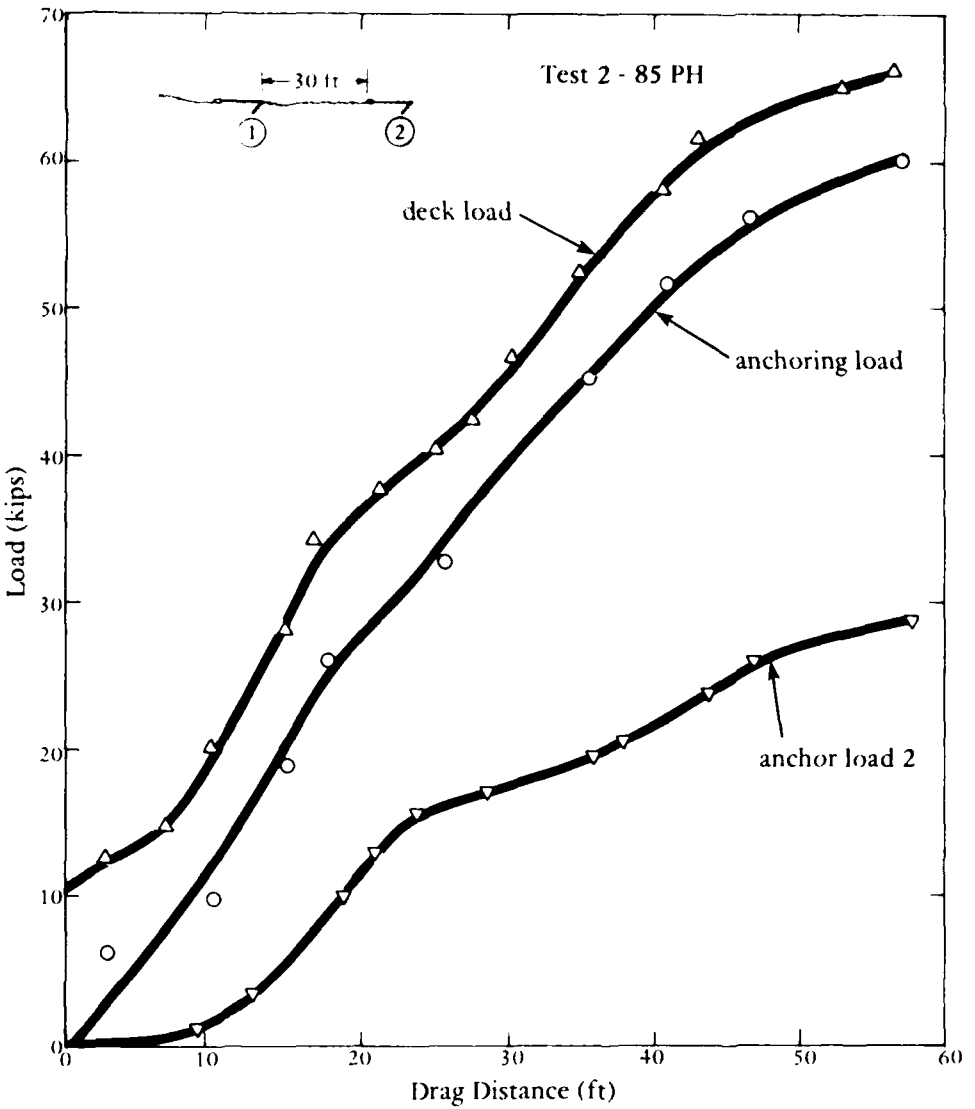


Figure 43. 1,000-pound tandem NAVMOOR Anchor performance in dense gravelly sand at Port Hueneme.

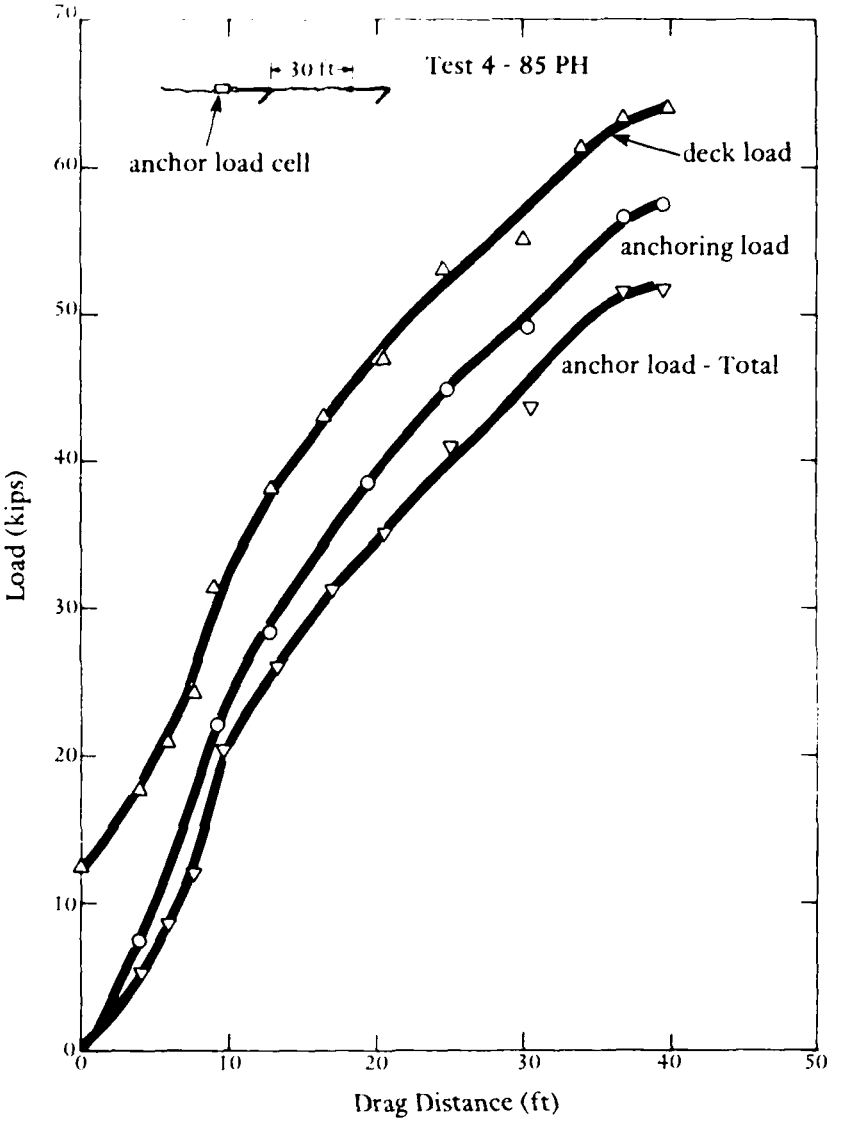


Figure 44. 1,000-pound tandem NAVMOOR Anchor performance in dense gravelly sand at Port Hueneme.

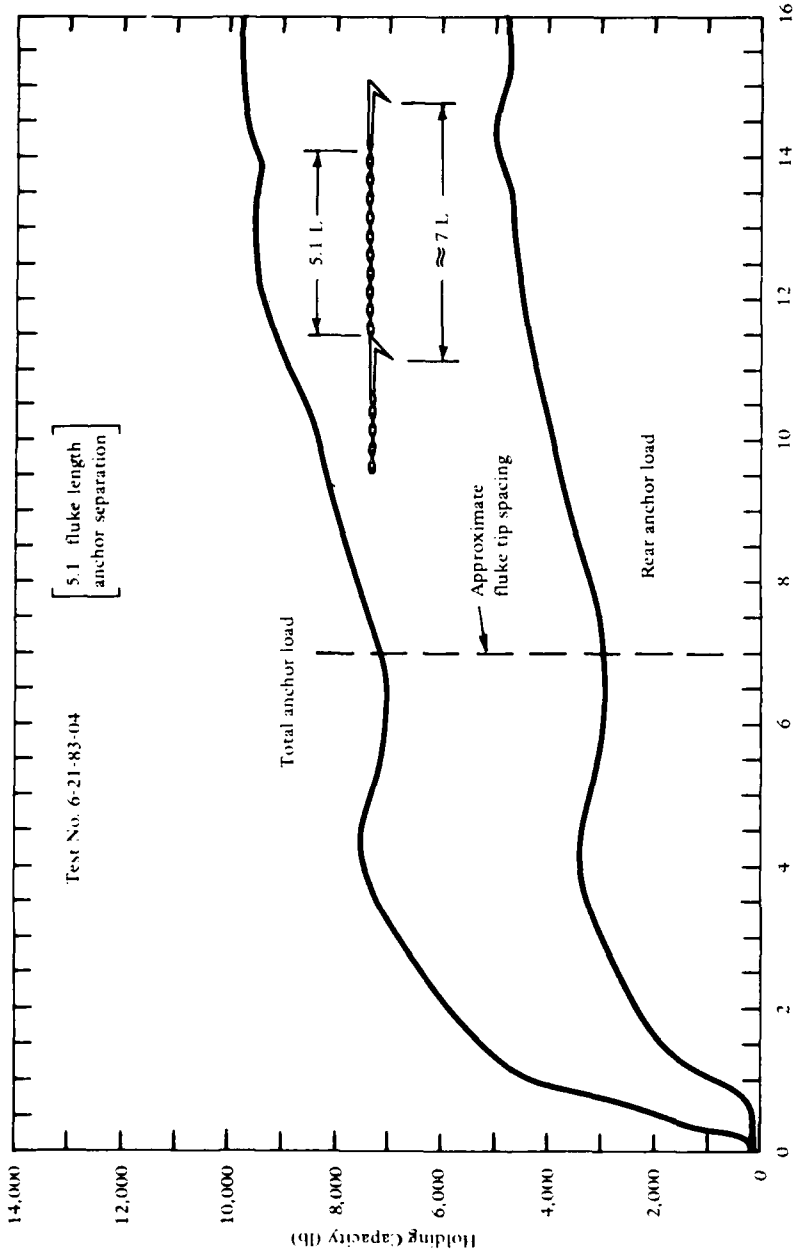


Figure 45. Holding capacity versus drag distance for 200-pound STATO Anchors in tandem, in sand (from Ref 13).

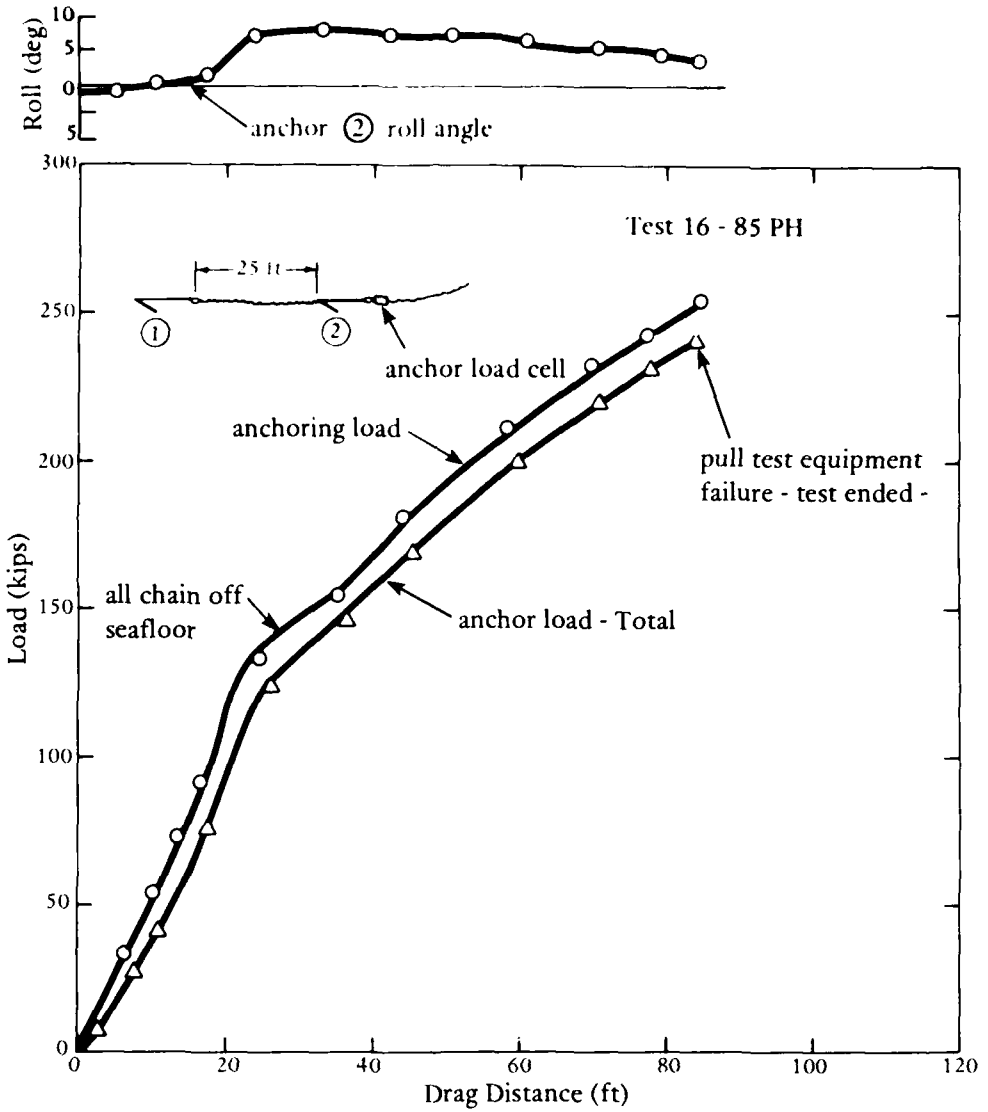


Figure 46. 6,000-pound tandem NAVMOOR Anchor performance in dense gravelly sand at Port Hueneme.

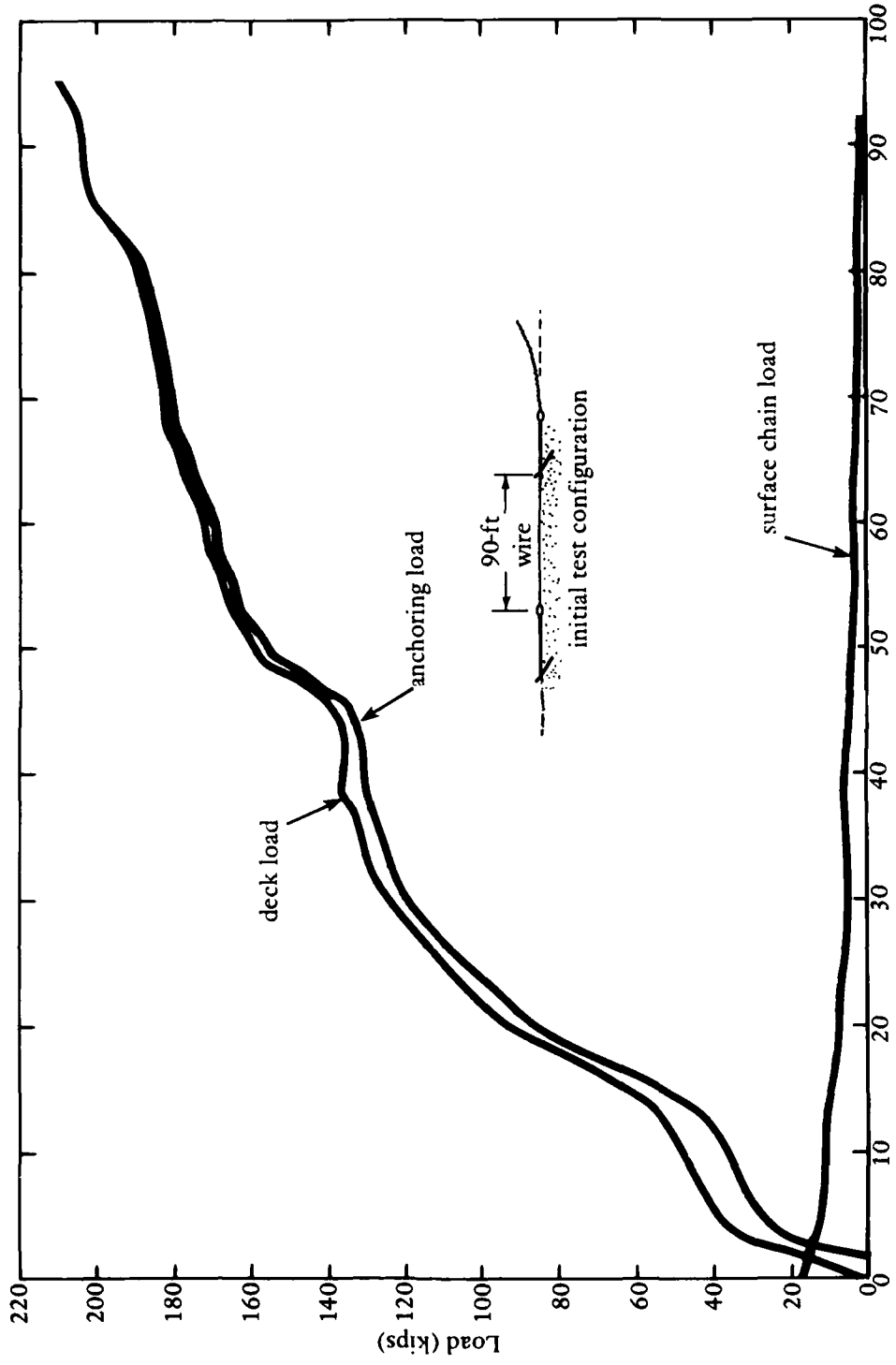


Figure 47. 6,000-pound tandem NAVMOOR Anchor performance in San Francisco Bay mud.

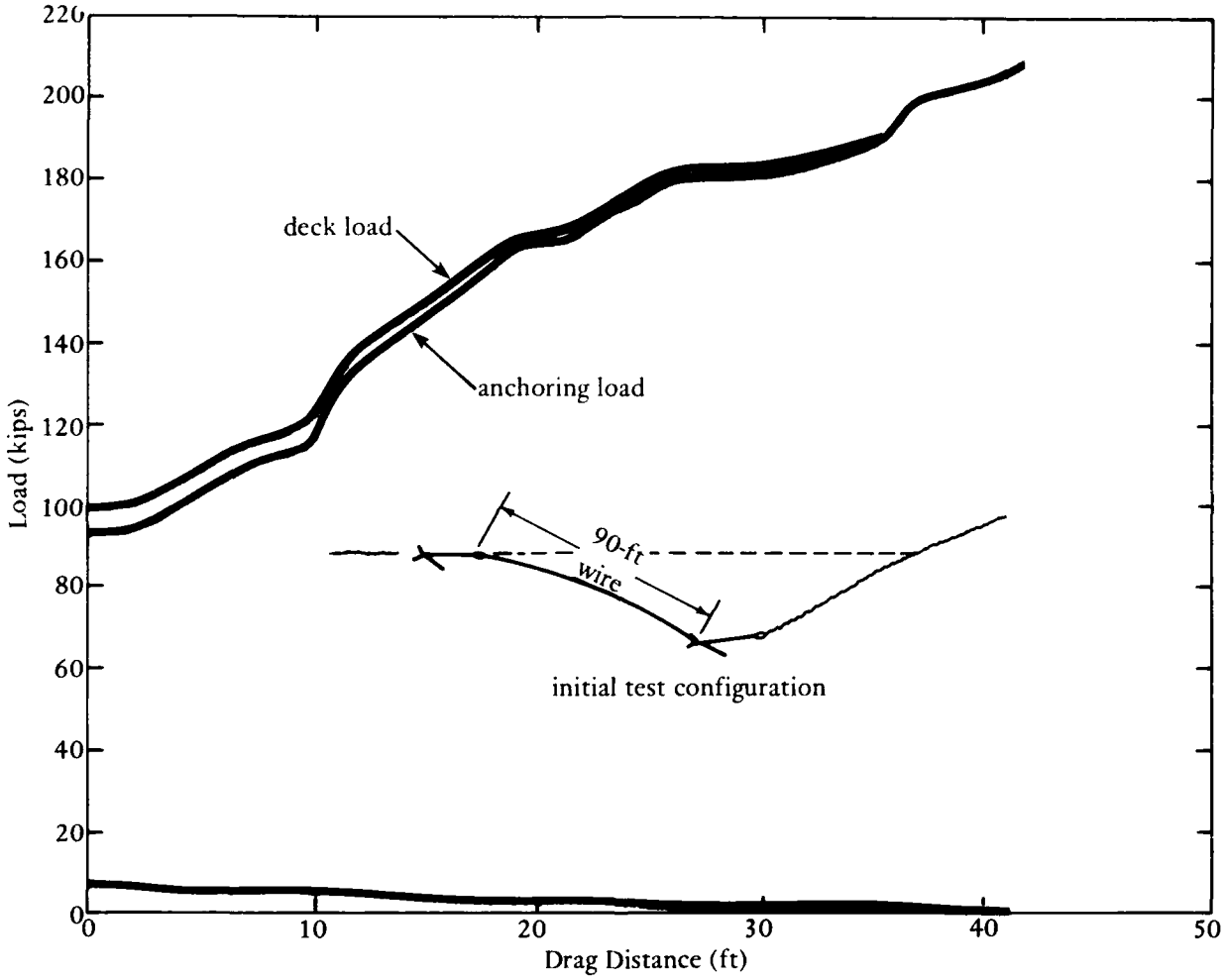


Figure 48. 6 000-pound tandem NAVMOOR Anchor performance in San Francisco Bay mud.

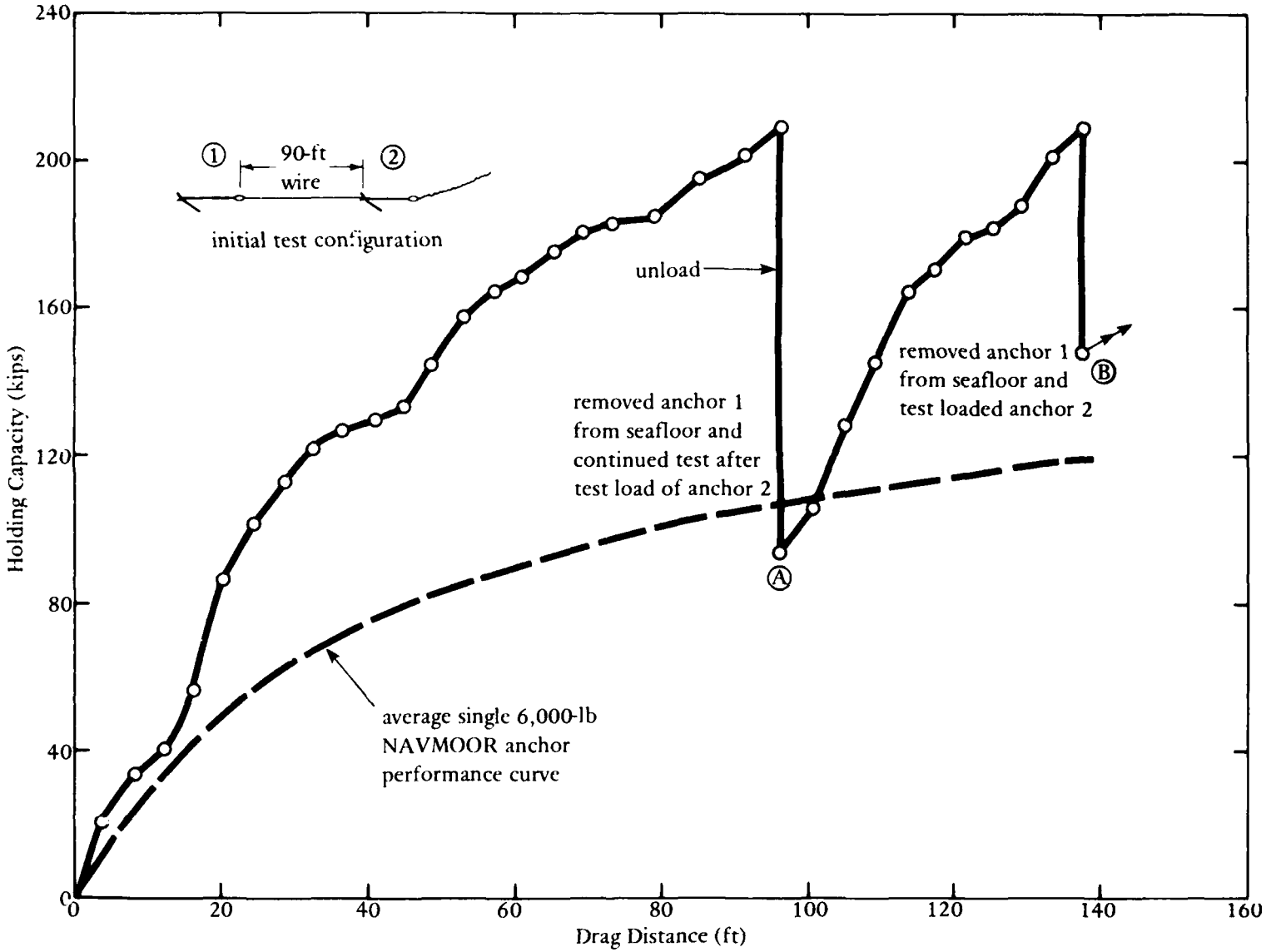


Figure 49. 6,000-pound tandem NAVMOOR Anchor performance in San Francisco Bay mud, showing results of sequential testing.

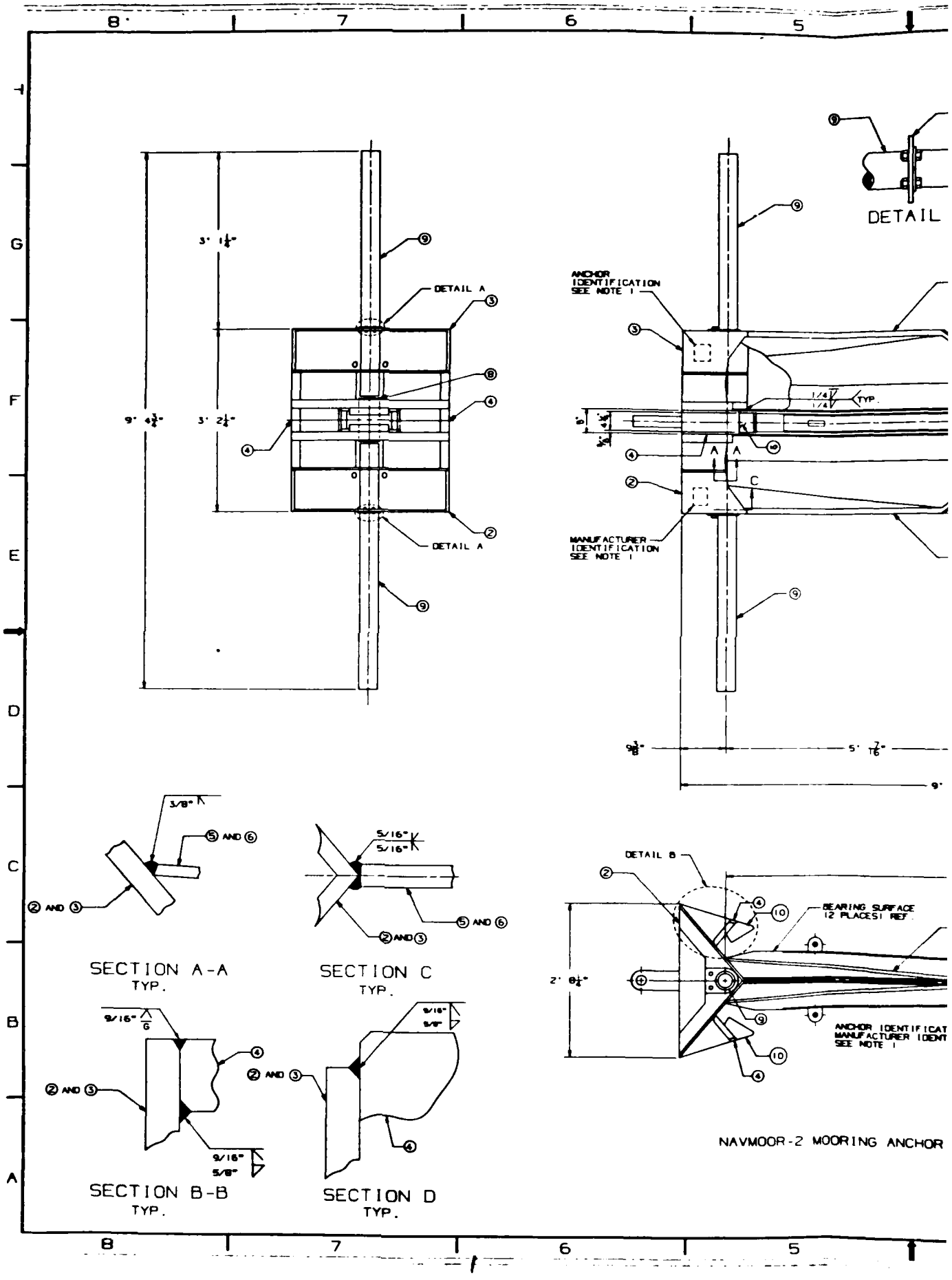
APPENDIX

DESIGN DRAWINGS FOR NAVMOOR ANCHORS

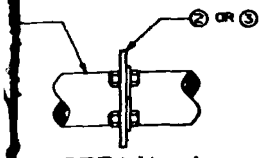
The design drawings for two general types of NAVMOOR Anchors are provided.

The 2,000-pound NAVMOOR Anchor design drawings represent anchors designed for amphibious logistics use. The principal difference between this anchor and anchors designed specifically for fleet mooring applications is the shank design. Shank taper is nearly nonexistant at the crown end to increase shank bending resistance to lateral loading. The shank of fleet mooring anchors can be more tapered to improve anchor penetrability because these anchors are rarely subjected to significant off-line loading.

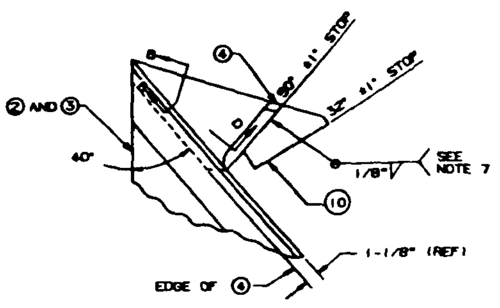
The 6,000-pound NAVMOOR Anchor for salvage employs folding stabilizers to enable anchor stowage in existing pockets on Navy ARS ships. The anchor crown has been strengthened to accommodate the folding stabilizers. The anchor shank is also less tapered than fleet mooring anchors to simplify anchor recovery through ARS ship stern chutes. Other minor differences exist for this anchor to ease handling on board ship and to reduce anchor maintainability.



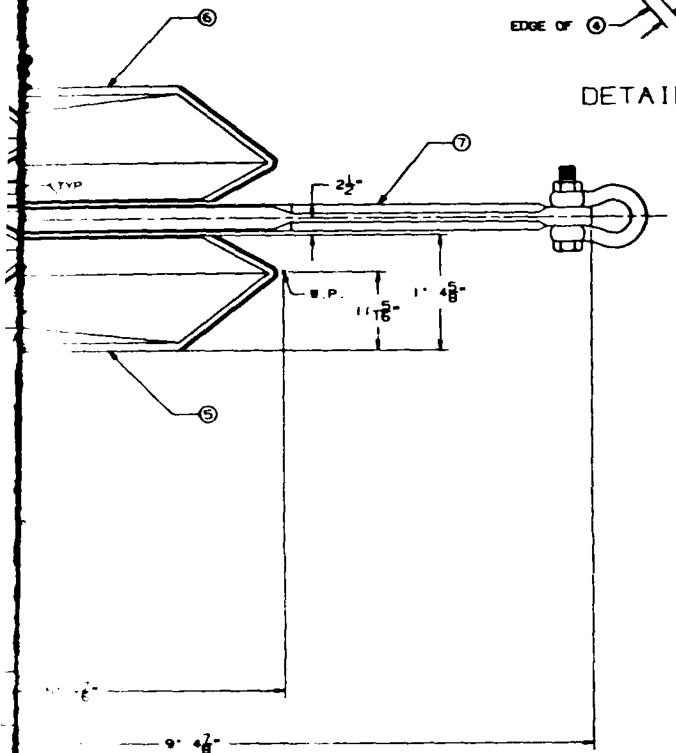
NAVMOOR-2 MOORING ANCHOR

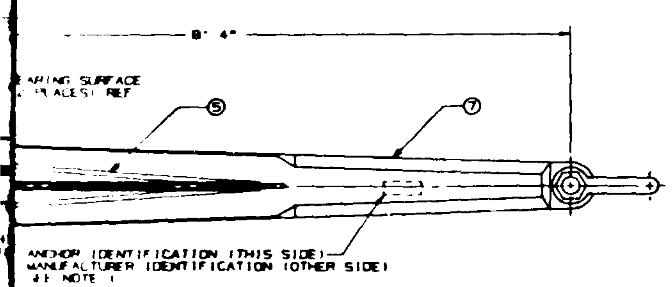


DETAIL A



DETAIL B





GENERAL NOTES :

1. SEE SPECIFICATION (MOST RECENT ISSUE, ENTITLED: "PURCHASE DESCRIPTION, PROTOTYPE NAVMOOR-2 MOORING ANCHOR") FOR ADDITIONAL REQUIREMENTS.
2. ALL STRUCTURAL STEEL SHALL CONFORM TO ASTM SPECIFICATION A36, OR FORGED STEEL CONFORMING TO A668 CLASS D, OR CAST STEEL CONFORMING TO A27, GRADE 70-36 OF THE MOST RECENT ISSUE UNLESS OTHERWISE NOTED.
3. SHANK AND DOUBLER SHALL BE EITHER CUT FROM STRUCTURAL STEEL CONFORMING TO COR-TEN B (ASTM A588) FY = 50 KSI, OR FORGED STEEL CONFORMING TO ASTM A668 CLASS F, OR CAST STEEL CONFORMING TO ASTM A148, GRADE 80-50.
4. FLUKE ASSEMBLY SHALL BE FABRICATED. ALL WELDING SHALL CONFORM TO THE STRUCTURAL WELDING CODE OF THE AMERICAN WELDING SOCIETY AWS D1.1 OF THE MOST RECENT ISSUE.
5. FILLER MATERIAL FOR WELDING SHALL CONFORM TO AWS A5.1 OR A5.5 E70XX.
6. DIMENSIONS SHOWN ON THIS SHEET ARE FOR REFERENCE ONLY.
7. RECOMMENDED WELDING PROCEDURES (MAY BE USED WHEN PALM IS A WELDMENT) :
   (i) COMPLETE ITEMS (2) AND (3) SEPARATELY.
   (ii) WELD ITEMS (a) AND (c) OF (5) AND (6) TO (2) AND (3).
   (iii) WELD ITEMS (b) OF (5) AND (6).
   (iv) WELD ITEMS (4) TO (2) AND (3). BOTH BEARING SURFACES OF (7) SHALL BE FLUSHED TO (4) AND (10) AT SPECIFIED OPENING ANGLES.
   (v) WELD ITEM (10) TO (4).
8. SPECIFIED WELD SIZES SHALL BE REPLACED BY SECTION WITH EQUIVALENT RADII IN THE EVENT OF CASTING THE COMPONENT.

DRING ANCHOR GENERAL ASSEMBLY ①

QUANTITY FOR EACH ASSEMBLY	ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
2	10	6155315-2S2	32° STOPPER	
2	9	6155317-4S2	STABILIZER ASSEMBLY	
1	8	6155317-4T1	TRUNNION ASSEMBLY	
1	7	6155317-4S1	SHANK ASSEMBLY	
1	6	6155316-3F1 L	FLUKE ASSEMBLY (OPPOSITE HAND)	
1	5	6155316-3F R	FLUKE ASSEMBLY (AS SHOWN)	
2	4	6155315-2S1	90° STOPPER	
1	3	6155315-2P1 L	PALM ASSEMBLY (OPPOSITE HAND)	
1	2	6155315-2P1 R	PALM ASSEMBLY (AS SHOWN)	
X	1	6155314-1	NAVMOOR-2 MOORING ANCHOR GENERAL ASSEMBLY	

PARTS LIST

[illegible]	
TOLERANCES: ±	
X DECIMAL ±	
TOLERANCES: ±	SEE NOTE 6
X DECIMALS ±	
XX DECIMALS ±	
FRACTIONS ±	
ANGLES ±	

MCA ENGINEERS, INC.

DES JC | DR HMP | CHK DB

SUBMITTED BY [illegible] 11/10/86 DATE

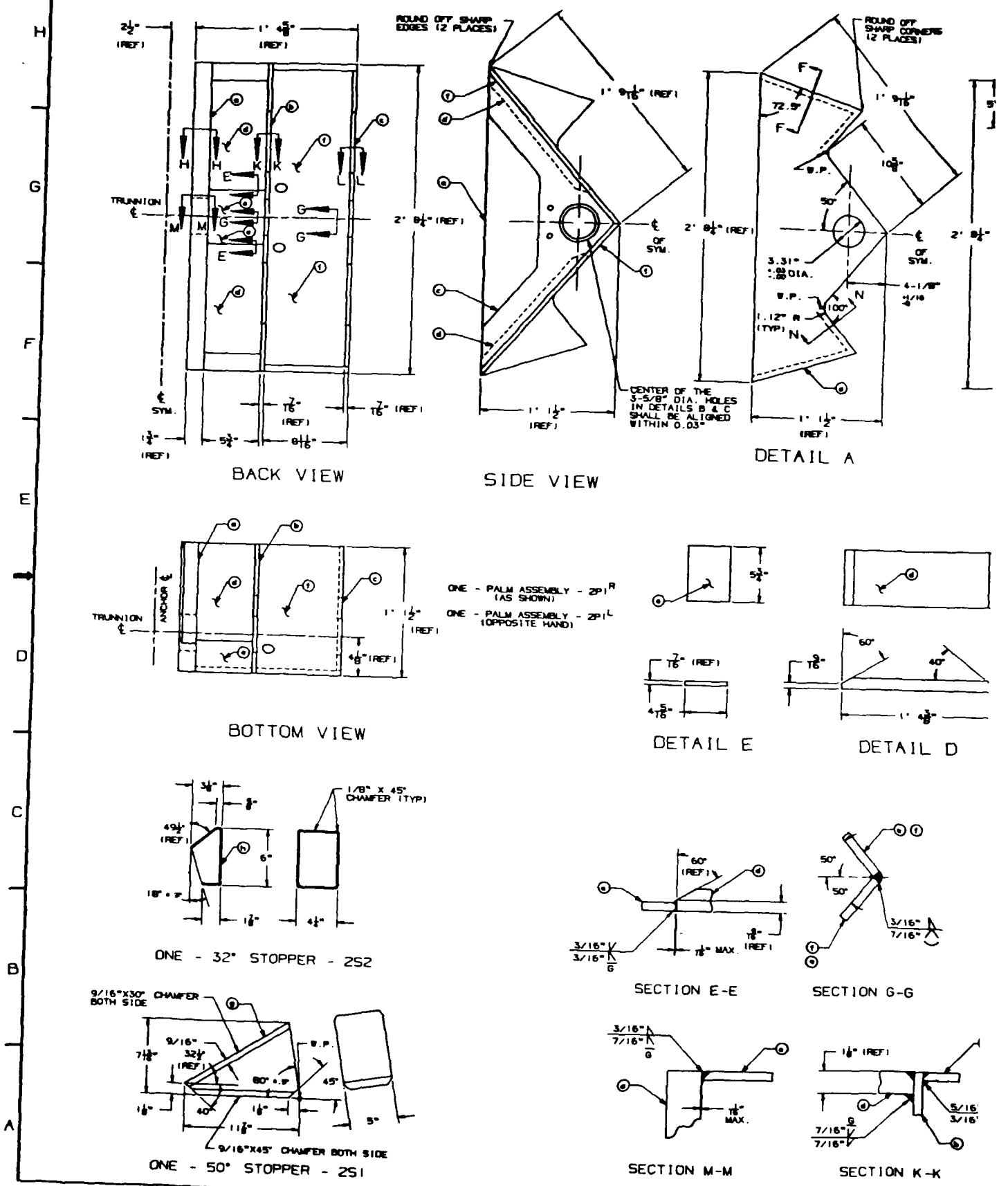
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

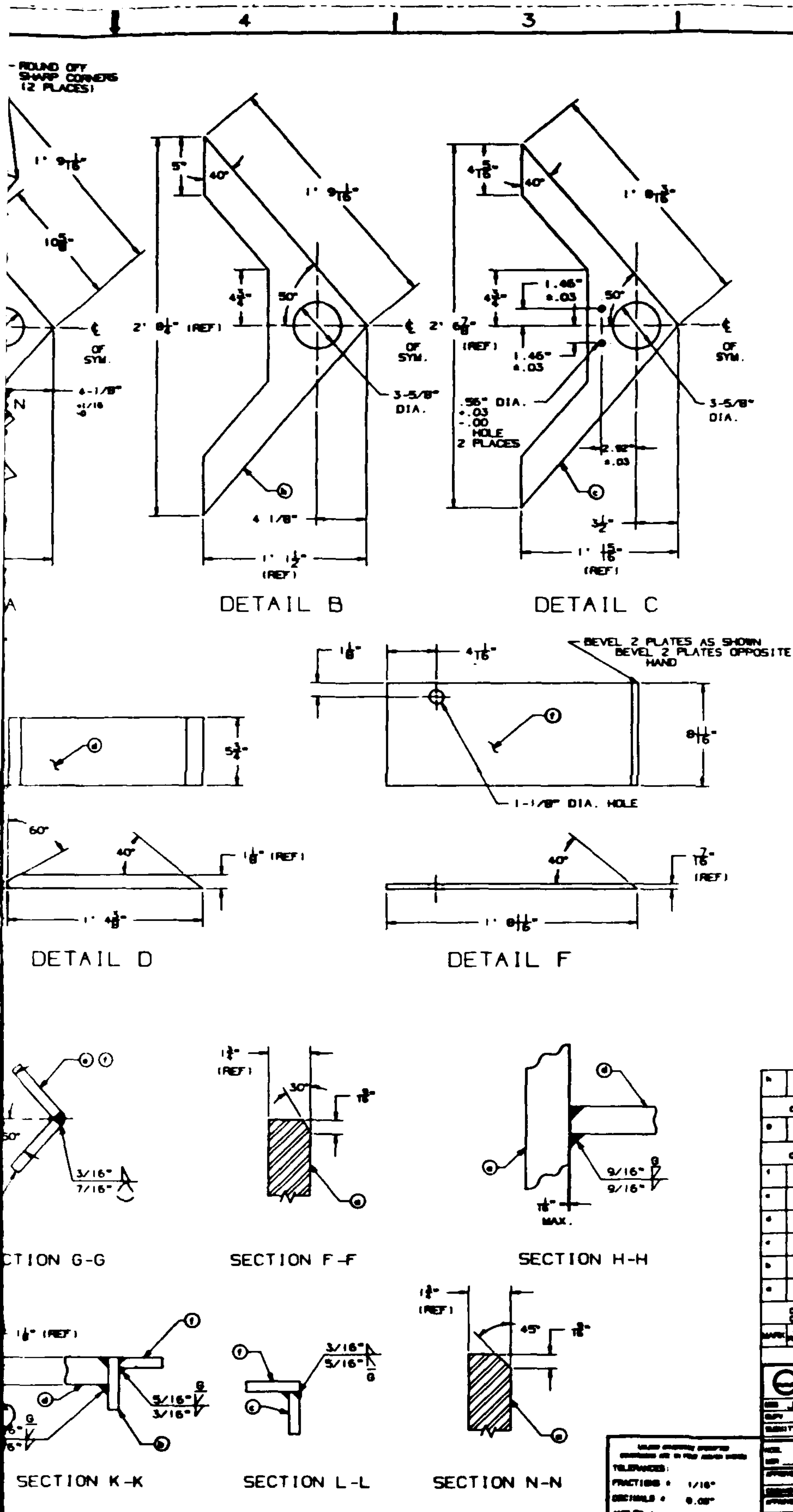
NAVMOOR-2 MOORING ANCHOR
2,400 LBS. (WT.)
GENERAL ASSEMBLY

SIZE F | CODE IDENT NO 80091 | NAVFAC DRAWING NO 6155314

SCALE NONE | SHEET 1 OF 4

86-17-1F


BACK VIEW
SIDE VIEW
DETAIL A
BOTTOM VIEW
DETAIL E
DETAIL D
ONE - 32° STOPPER - 2S2
SECTION E-E
SECTION G-G
ONE - 50° STOPPER - 2S1
SECTION M-M
SECTION K-K
ROUND OFF SHARP EDGES (2 PLACES)
ROUND OFF SHARP CORNERS (2 PLACES)
TRUNNION ℄
ANCHOR ℄
℄ SYM.
℄ OF SYM.
CENTER OF THE 3-5/8" DIA. HOLES IN DETAILS B & C SHALL BE ALIGNED WITHIN 0.03"
ONE - PALM ASSEMBLY - 2P1R (AS SHOWN)
ONE - PALM ASSEMBLY - 2P1L (OPPOSITE HAND)
1/8" X 45° CHAMFER (TYP)
9/16"X30° BOTH SIDE CHAMFER
9/16"X45° CHAMFER BOTH SIDE
1.12" R (TYP)
(REF)
(TYP)
B.P.



Mark	No. Req'd	Size	Length FT	Length IN	Remarks
h	1	PL 3-1/8" X 4-1/4"	0	6	
ONE - 32" STOPPER - 252					
g	1	PL 5" X 7-13/16"	0	11-7/8	
ONE - 60" STOPPER - 251					
f	4	PL 7/16" X 8-11/16"	1	8-11/16	PALM COVER #3 DETAIL F
e	4	PL 7/16" X 4-5/16"	0	5-3/4	PALM COVER #2 DETAIL E
d	4	PL 1-1/8" X 5-3/4"	1	4-3/8	PALM COVER #1 DETAIL D
c	2	PL 7/16" X 1' 15/16"	2	6-7/8	PALM SPAR #3 DETAIL C
b	2	PL 7/16" X 1' 1-1/2"	2	8-1/4	PALM SPAR #2 DETAIL B
a	2	PL 1-3/4" X 1' 1-1/2"	2	8-1/4	PALM SPAR #1 DETAIL A
ONE - PALM ASSEMBLY -2P1R (AS SHOWN)					
ONE - PALM ASSEMBLY -2P1L (OPPOSITE HAND)					

BILL OF MATERIAL

TOLERANCES:

FRACTIONS ±	1/16"
DECIMALS ±	0.03"
ANGLES ±	1°

MCA ENGINEERS, INC.

JC HNP DB

SUBMITTED BY D.B. 11/10/86

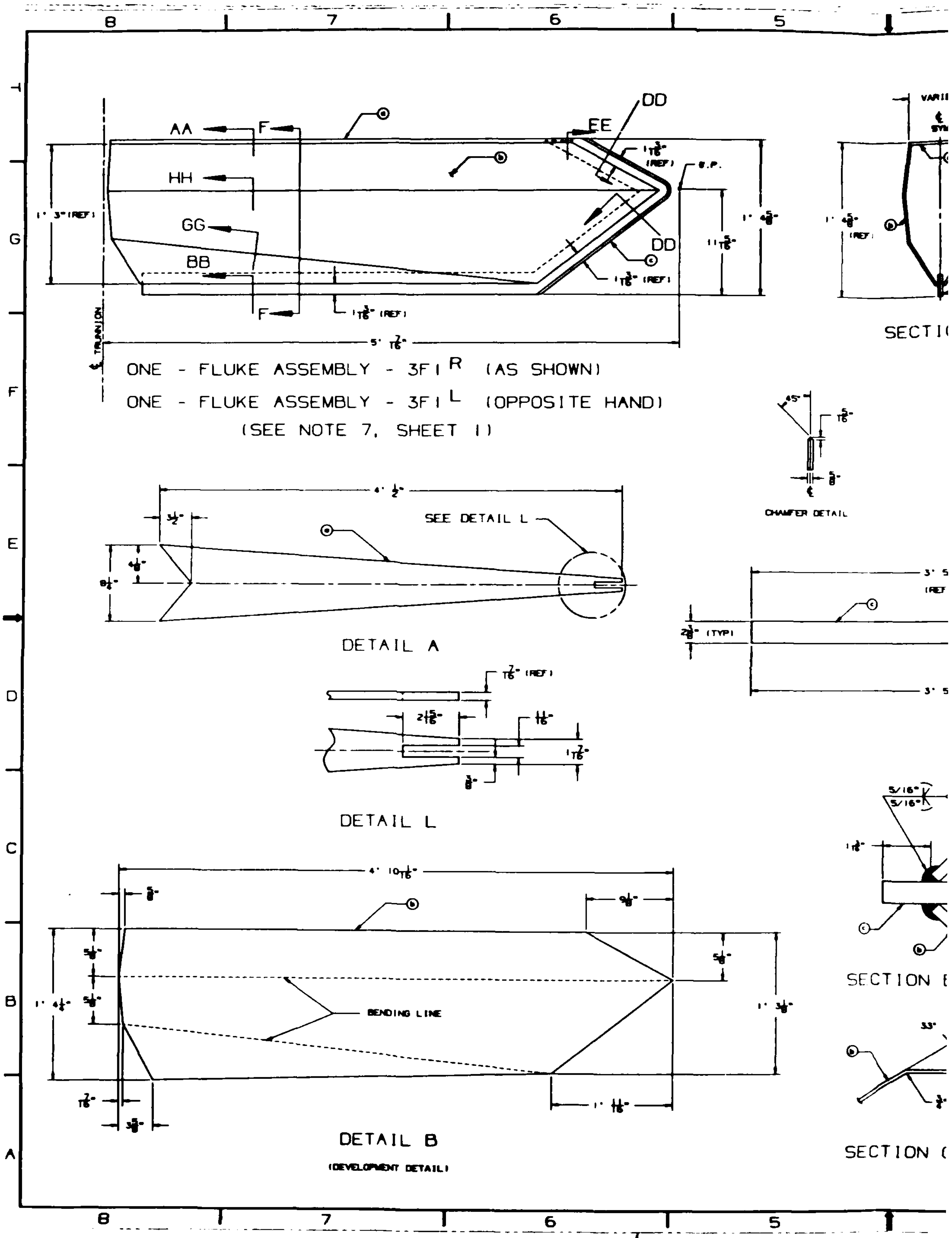
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

NAVMOOR-2 MOORING ANCHOR
2,400 LBS. (WT.)
PALM ASSEMBLY, STOPPER ASSEMBLY

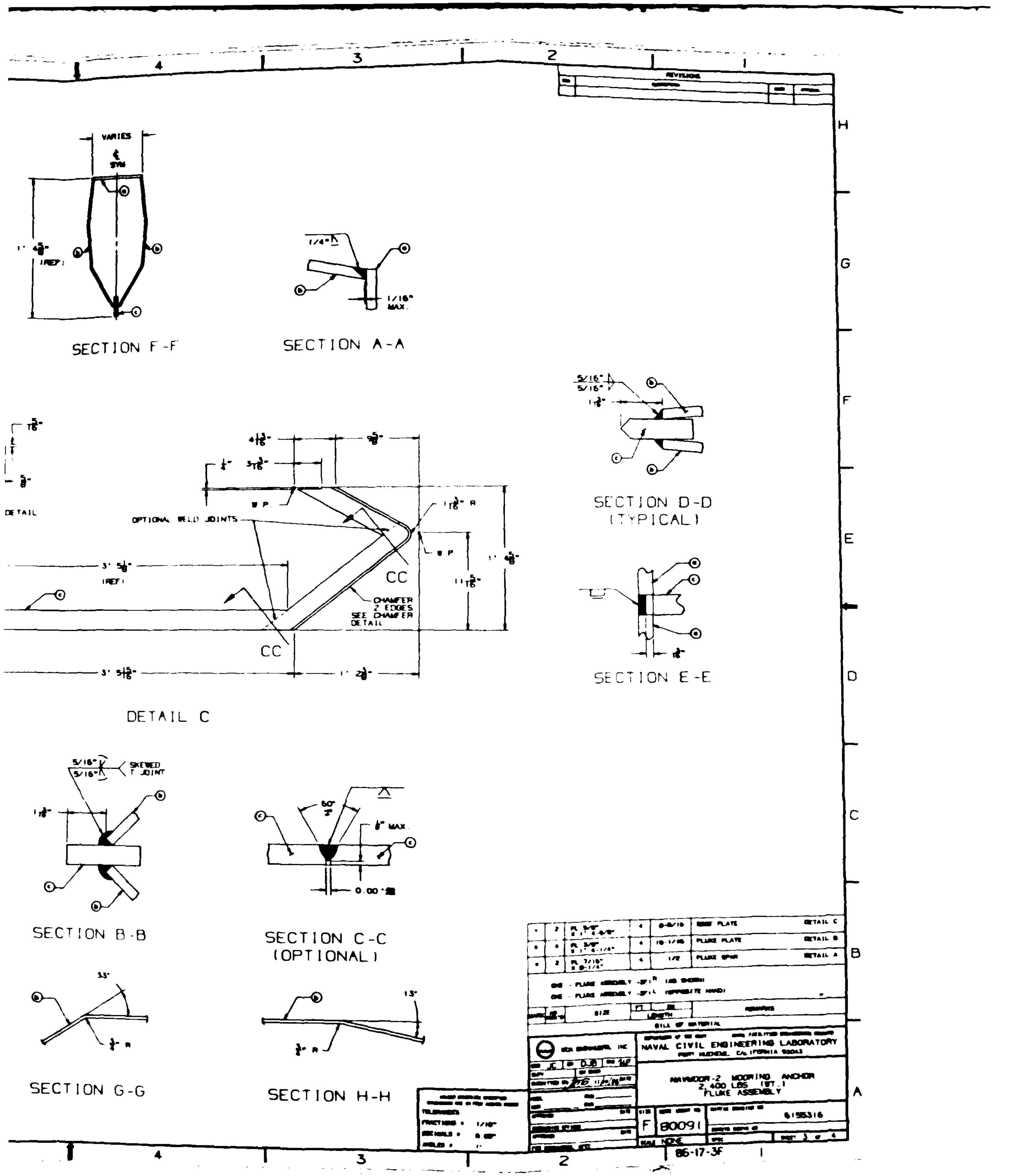
SIZE F 80091 6155315

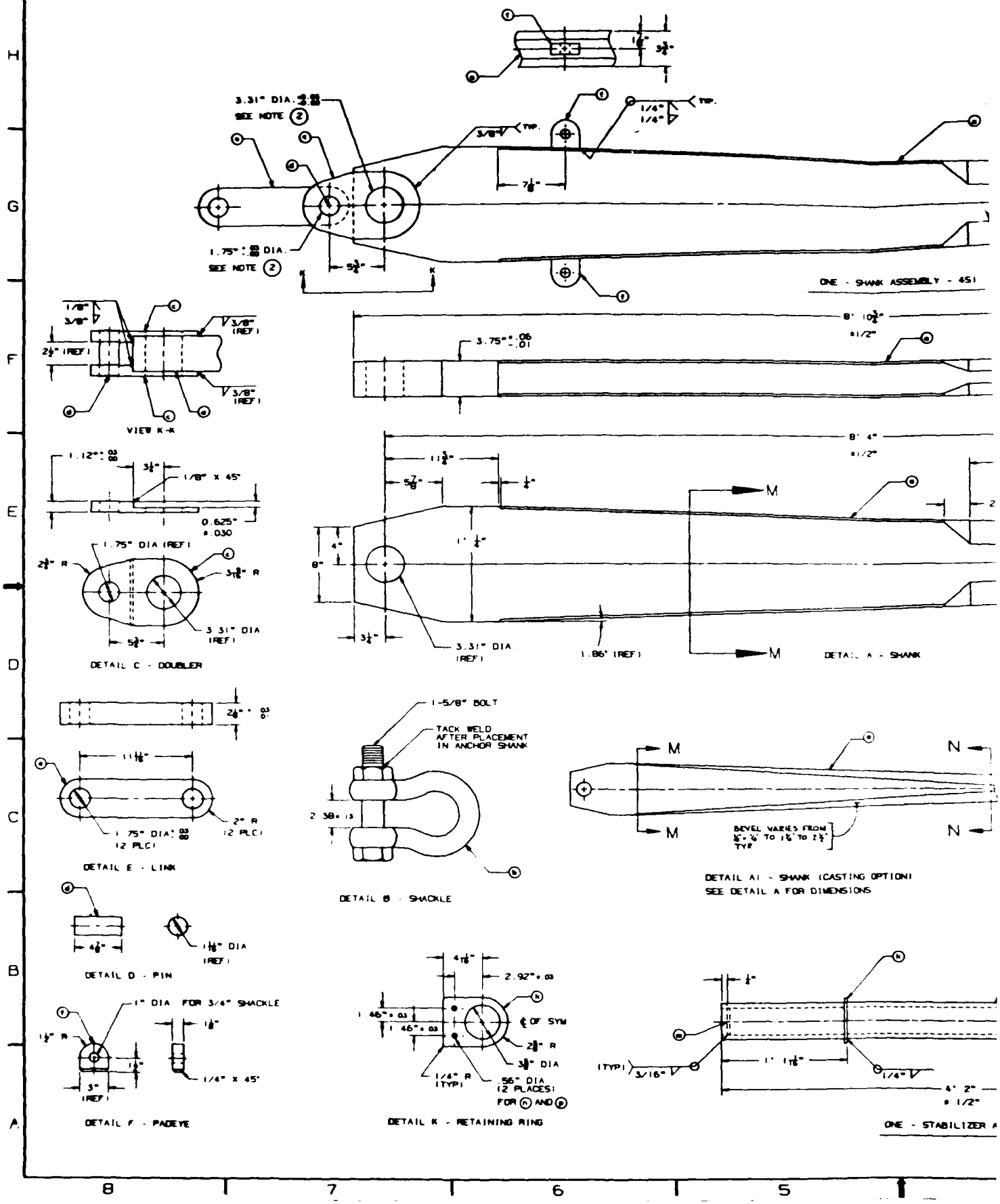
SCALE NONE SHEET 2 OF 4

86-17-2F

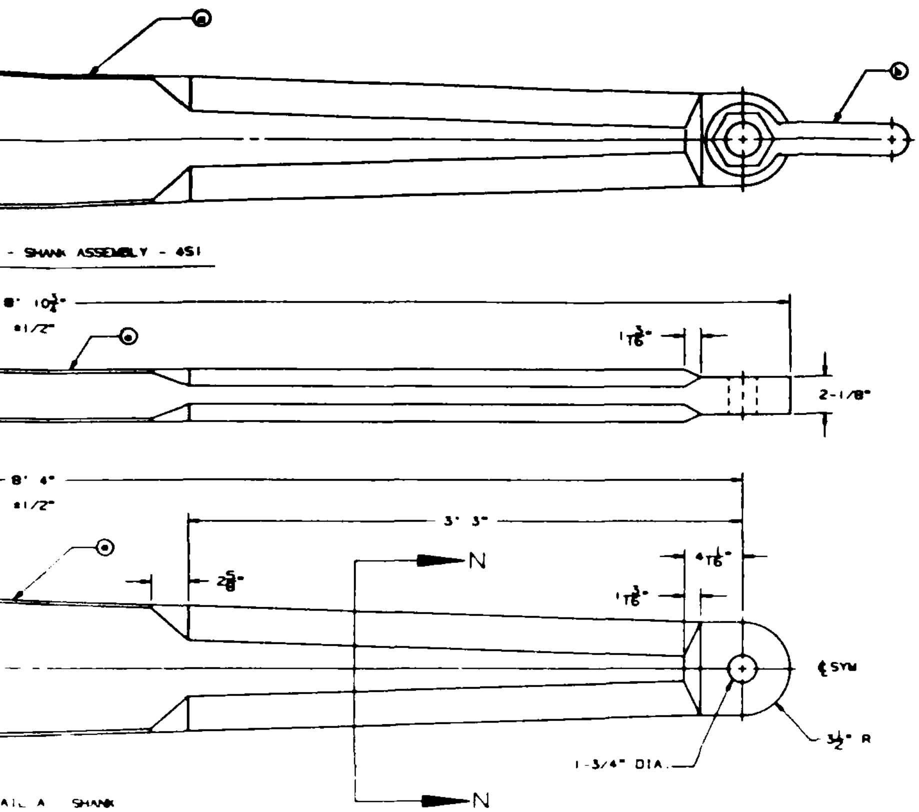


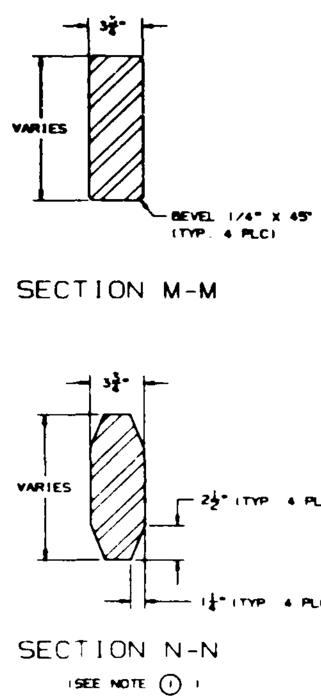
AA
F
HH
GG
BB
DD
EE
(REF)
1' 3" (REF)
TRUNNION
ONE - FLUKE ASSEMBLY - 3F1 R (AS SHOWN)
ONE - FLUKE ASSEMBLY - 3F1 L (OPPOSITE HAND)
(SEE NOTE 7, SHEET 1)
SECTI
45°
CHAMFER DETAIL
SEE DETAIL L
DETAIL A
(TYP)
3' 5
DETAIL L
5/16"
5/16"
SECTION E
BENDING LINE
33°
DETAIL B
(DEVELOPMENT DETAIL)
SECTION C

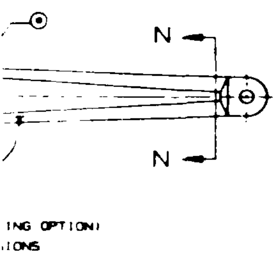

SECTION F-F
SECTION A-A
SECTION D-D
(TYPICAL)
SECTION E-E
DETAIL C
OPTIONAL WELD JOINTS
CHAMFER
2 EDGES
SEE CHAMFER
DETAIL
SECTION B-B
SKEWED
T JOINT
SECTION C-C
(OPTIONAL)
SECTION G-G
SECTION H-H
NAVAL CIVIL ENGINEERING LABORATORY
NAVMOOR-2 MOORING ANCHOR
2,400 LBS (WT.)
FLUKE ASSEMBLY
F
80091
6155316
NONE
86-17-3F

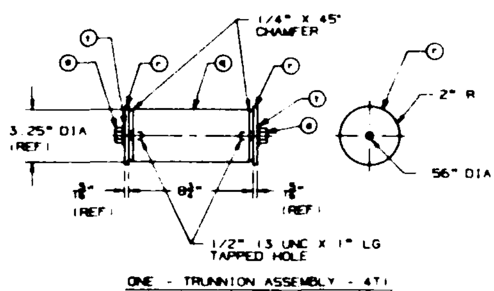

3.31" DIA
SEE NOTE (2)
1.75" DIA
SEE NOTE (2)
1/4" TYP.
3/8" TYP.
ONE - SHANK ASSEMBLY - 451
VIEW K-K
3.75"
8' 4"
±1/2"
1.12"
1/8" X 45°
0.625"
±.030
1.75" DIA (REF)
3.31" DIA (REF)
DETAIL C - DOUBLER
3.31" DIA (REF)
1.86" (REF)
DETAIL A - SHANK
DETAIL E - LINK
1-5/8" BOLT
TACK WELD AFTER PLACEMENT IN ANCHOR SHANK
DETAIL B - SHACKLE
BEVEL VARIES FROM 1/8" TO 1 1/8" TO 2 1/2" TYP
DETAIL A1 - SHANK (CASTING OPTION)
SEE DETAIL A FOR DIMENSIONS
DETAIL D - PIN
1" DIA FOR 3/4" SHACKLE
1/4" X 45°
DETAIL F - PADEYE
2.92"
1.46"
2-3/8" R
3-3/8" DIA
1/4" R (TYP)
.56" DIA (2 PLACES) FOR (N) AND (P)
DETAIL K - RETAINING RING
(TYP) 3/16"
ONE - STABILIZER

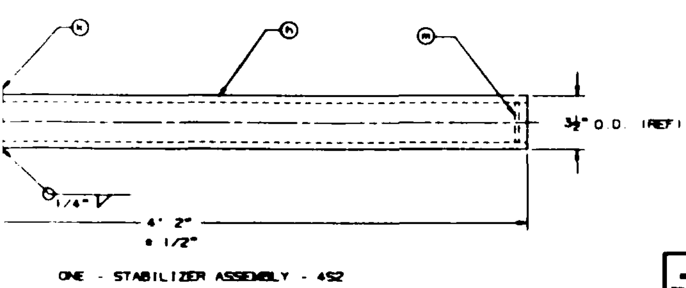
REVISIONS











NOTE
1. THE TOLERANCE OF THE CROSS SECTION DIMENSIONS SHALL BE ± 1/8"
2. PART (c) WELDED TO (a) BEFORE HOLES ARE DRILLED

MARK	NO REQ'D	SIZE	LENGTH FT	LENGTH IN	REMARKS
t	2	1/2" DIA	-	-	HEAVY DUTY HELICAL SPRING LOCK WASHER, CORROSION RESISTANT
s	2	1/2" - 13 UNC	0	1-1/4	HEX HEAD BOLT, ASTM A325 CORROSION RESISTANT TYPE 3
r	2	5/16" PL 4" OD 9/16" ID	-	-	KEEPER PLATE
q	1	3-1/4" DIA	0	8-3/4	TRUNNION PIN, COLD DRAWN AISI 1018, FY = 54 KSI
ONE - TRUNNION ASSEMBLY - 4T1					
p	2	1/2" DIA	-	-	HEAVY DUTY HELICAL SPRING LOCK WASHER, CORROSION RESISTANT
n	2	1/2" - 13 UNC	0	1-1/4	HEX HEAD BOLT WITH NUT, ASTM A325 CORROSION RESISTANT TYPE 3
m	2	5/16" PL 2-1/4" OD	-	-	END PLATE
k	1	5/16" PL X 5-1/4"	0	6-11/16	RETAINING RING DETAIL K
h	1	3" PIPE (XXS)	4	2	ASTM A53 GRADE B
ONE - STABILIZER ASSEMBLY - 4S2					
f	2	1-1/8" X 3" PL	0	3	PADEYE DETAIL F
e	1	2-1/8" X 4" PL	1	3-11/16	LINK, ASTM A588 MOD FY = 60 KSI DETAIL E
d	1	1-11/16" DIA BAR	0	4-7/8	PIN, COLD DRAWN AISI 4340, FY = 90 KSI DETAIL D
c	2	1-1/8" PL X 7-1/8"	1	1/16	DOUBLER SEE NOTE 3 SHT 1 DETAIL C
b	1	1-1/2" DIA NOM	-	-	BOLT TYPE ANCHOR SHACKLE 300,000 LBS BREAKING STRENGTH DETAIL B
a	1	3-3/4" PL X 12-1/4"	8	10-3/4	SHANK SEE NOTE 3 SHT. 1 DETAIL A DETAIL A1
ONE - SHANK ASSEMBLY - 4S1					

BILL OF MATERIAL

TOLERANCES:
FRACTIONS ± 1/16"
DECIMALS ± 0.08"
ANGLES ± 1°

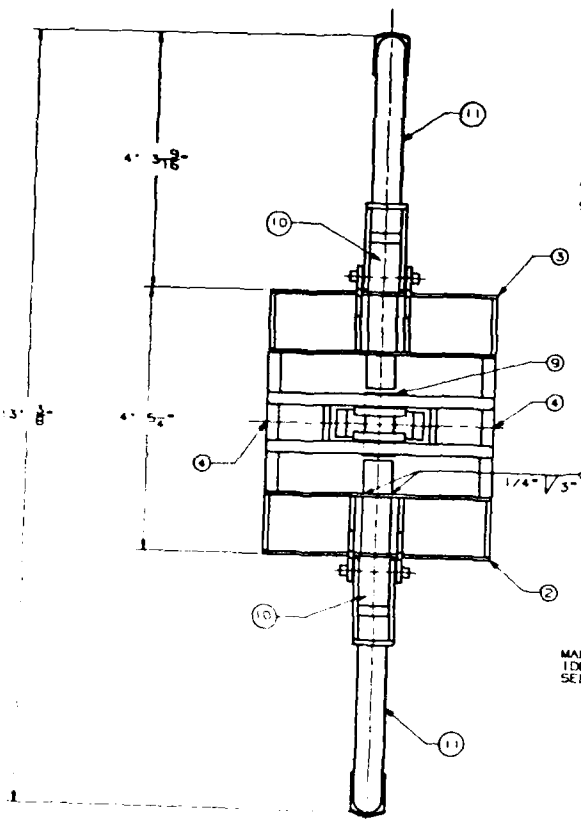
MCA ENGINEERS, INC
DES JC | DR DJB | CHK HP
SUBMITTED BY 11.10.86 DATE

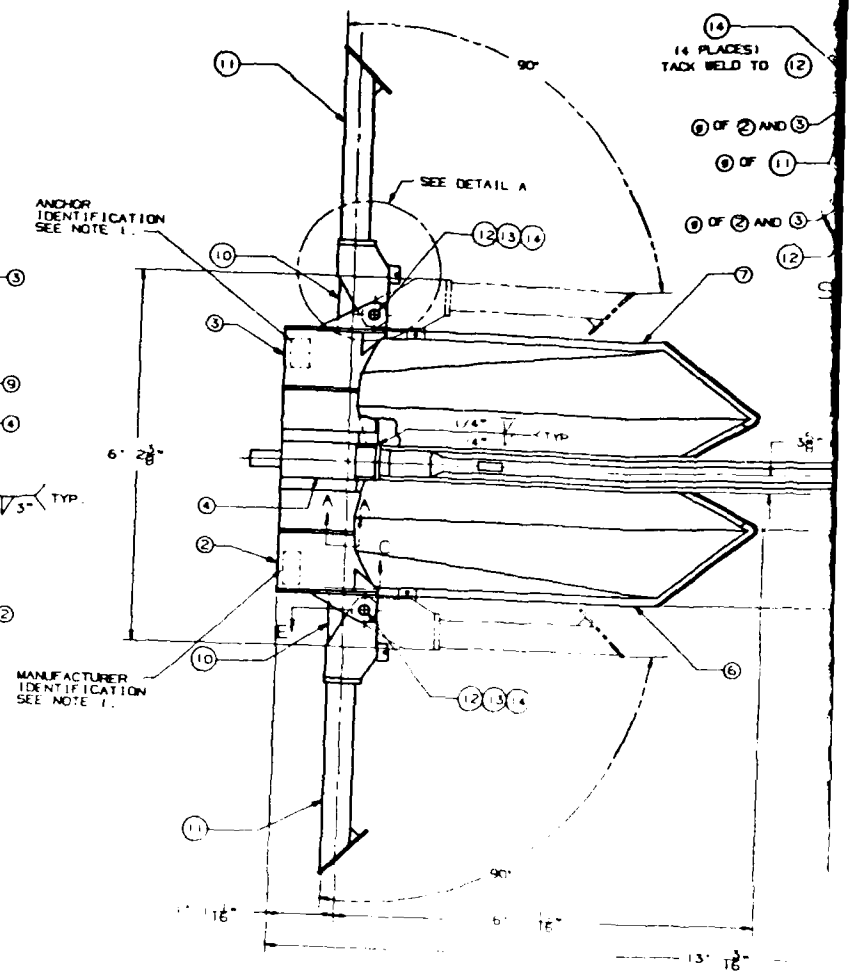
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

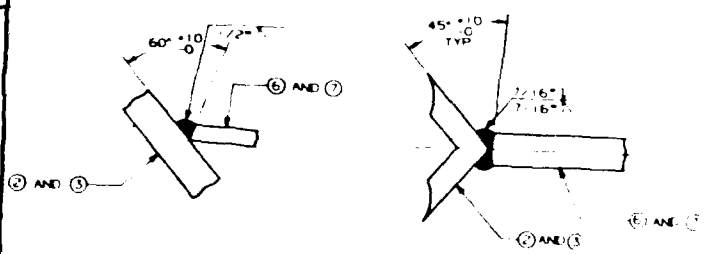
NAVMOOR-2 MOORING ANCHOR
2,400 LBS. (WT.)
SHANK ASSEMBLY, TRUNNION ASSEMBLY,
STABILIZER ASSEMBLY

SIZE F | CODE IDENT NO 80091 | NAVFAC DRAWING NO 6155317
SCALE NONE | SHEET 4 OF 4

86-17-4F

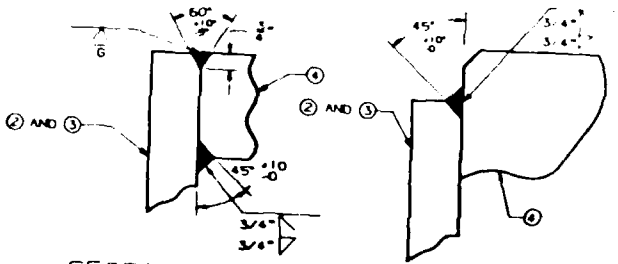






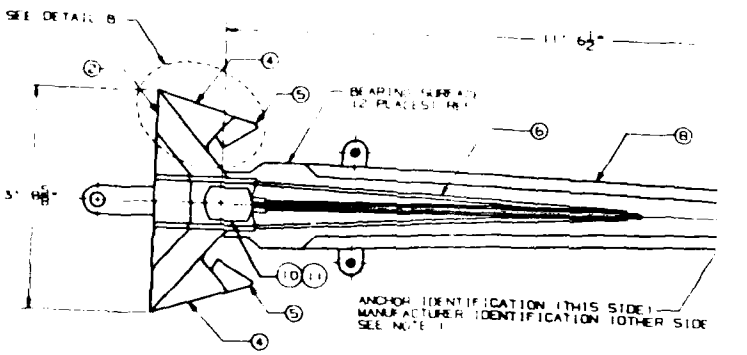
SECTION A-A
TYP.

SECTION C
TYP.

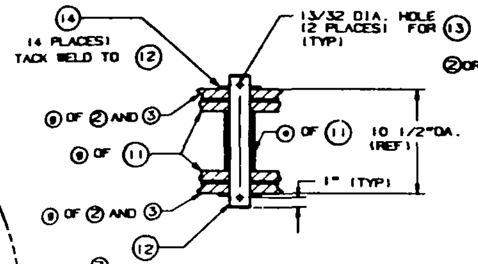


SECTION B-B
TYP.

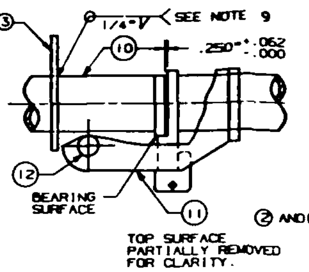
SECTION D
TYP.



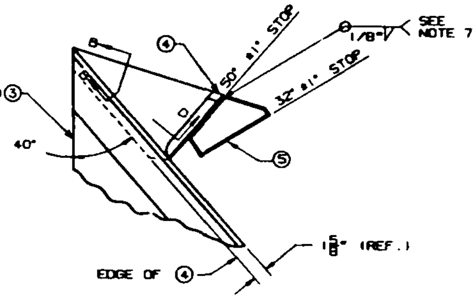
NAVMOOR-6 SALVAGE ANCHOR (FOLDABLE STABILIZER)



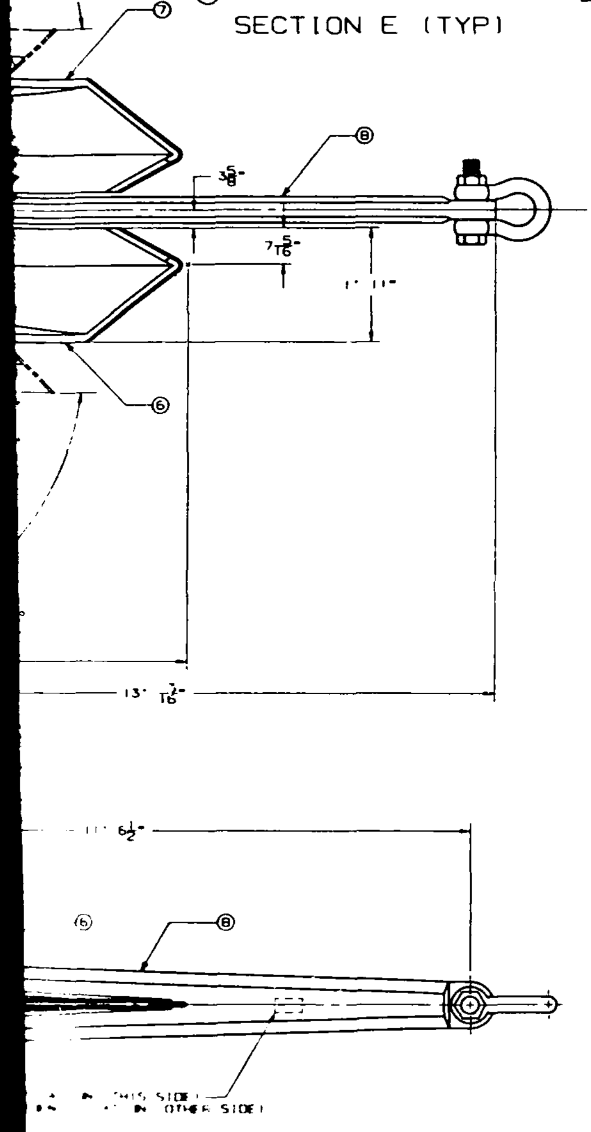
SECTION E (TYP)



DETAIL A



DETAIL B



GENERAL ASSEMBLY (1)

GENERAL NOTES :

1. SEE SPECIFICATION (MOST RECENT ISSUE, ENTITLED: "PURCHASE DESCRIPTION, PROTOTYPE NAVMOOR-6 SALVAGE ANCHOR") FOR ADDITIONAL REQUIREMENTS.
2. ALL STRUCTURAL STEEL SHALL CONFORM TO ASTM SPECIFICATION A 36 OF MOST RECENT ISSUE UNLESS OTHERWISE NOTED.
3. SHANK, STOPPERS AND DOUBLER SHALL BE EITHER CUT FROM STRUCTURAL STEEL CONFORMING TO ASTM A 36, FORGED STEEL CONFORMING TO ASTM A 668 CLASS D, OR CAST STEEL CONFORMING TO ASTM A27, GRADE 70-36.
4. WELDING SHALL CONFORM TO THE STRUCTURAL WELDING CODE OF THE AMERICAN WELDING SOCIETY AWS D1.1 OF THE MOST RECENT ISSUE.
5. FILLER MATERIAL FOR WELDING SHALL CONFORM TO AWS A5.1 OR A5.5 E70XX.
6. UNLESS OTHERWISE NOTED, DIMENSIONS SHOWN ON THIS SHEET ARE FOR REFERENCE ONLY.
7. RECOMMENDED WELDING PROCEDURES (MAY BE USED WHEN PALM IS A WELDMENT) :
   - (i) COMPLETE ITEMS (2) AND (3) SEPARATELY.
   - (ii) WELD ITEMS (a), (c) AND (d) OF (6) AND (7) TO (2) AND (3).
   - (iii) WELD ITEMS (b) OF (6) AND (7).
   - (iv) WELD ITEMS (4) TO (2) AND (3). BOTH BEARING SURFACES OF (8) SHALL BE FLUSH TO (4) AND (5) AT SPECIFIED OPENING ANGLES.
   - (v) WELD ITEM (5) TO (4).
8. SPECIFIED WELD SIZES SHALL BE REPLACED BY SECTION WITH EQUIVALENT RADII IN THE EVENT OF CASTING THE COMPONENT.
9. PROPERLY INSTALL SHANK (8) AND TRUNNION PIN (9). WELD (10) TO (2) OR (3) WHILE MAINTAINING THE SPECIFIED SPACING AND ALIGNMENT OF THE BEARING SURFACES. INJECT GREASE THROUGH ITEM (m) OF (11) UNTIL GREASE SHOWS UP BETWEEN (11) AND (12). THEN REPLACE ITEM (m) OF (11) BY ITEM (n) OF (11).

QUANTITY FOR EACH ASSEMBLY	ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
8	14	6155301-14	WASHER 4" O.D. X 2-1/16" X 1/4" THK. (NOM.) MACHINE THICKNESS TO HOLD OVER ALL DIMENSIONS AS REQ'D.	316 S.S.
4	13	6155301-13	3/8" X 3" COTTER PIN	316 S.S.
2	12	6155301-12	HINGE PIN 2" DIA. X 13-7/16" LG. FY = 90 KSI	AISI 4140
2	11	6155305-5S2	MOVABLE STABILIZER ASSEMBLY	
2	10	6155305-5S1	FIXED-STABILIZER ASSEMBLY	
1	9	6155304-4T1	TRUNNION PIN	
1	8	6155304-4S1	SHANK ASSEMBLY	
1	7	6155303-3F1 L	FLUKE ASSEMBLY (OPPOSITE HAND)	
1	6	6155303-3F1 R	FLUKE ASSEMBLY (AS SHOWN)	
2	5	6155305-5S4	32° STOPPER	
2	4	6155305-5S3	50° STOPPER	
1	3	6155302-2P1 L	PALM ASSEMBLY (OPPOSITE HAND)	
1	2	6155302-2P1 R	PALM ASSEMBLY (AS SHOWN)	
X	1	6155301-1	NAVMOOR-6 SALVAGE ANCHOR (FOLDABLE STABILIZER) GENERAL ASSEMBLY	
1	ITEM NO.	PART NO.	DESCRIPTION	MATERIAL

PARTS LIST

TOLERANCES: X DECIMAL, XX DECIMALS, XXX DECIMALS, FRACTIONS, ANGLES — SEE NOTE 6

MCA ENGINEERS, INC.

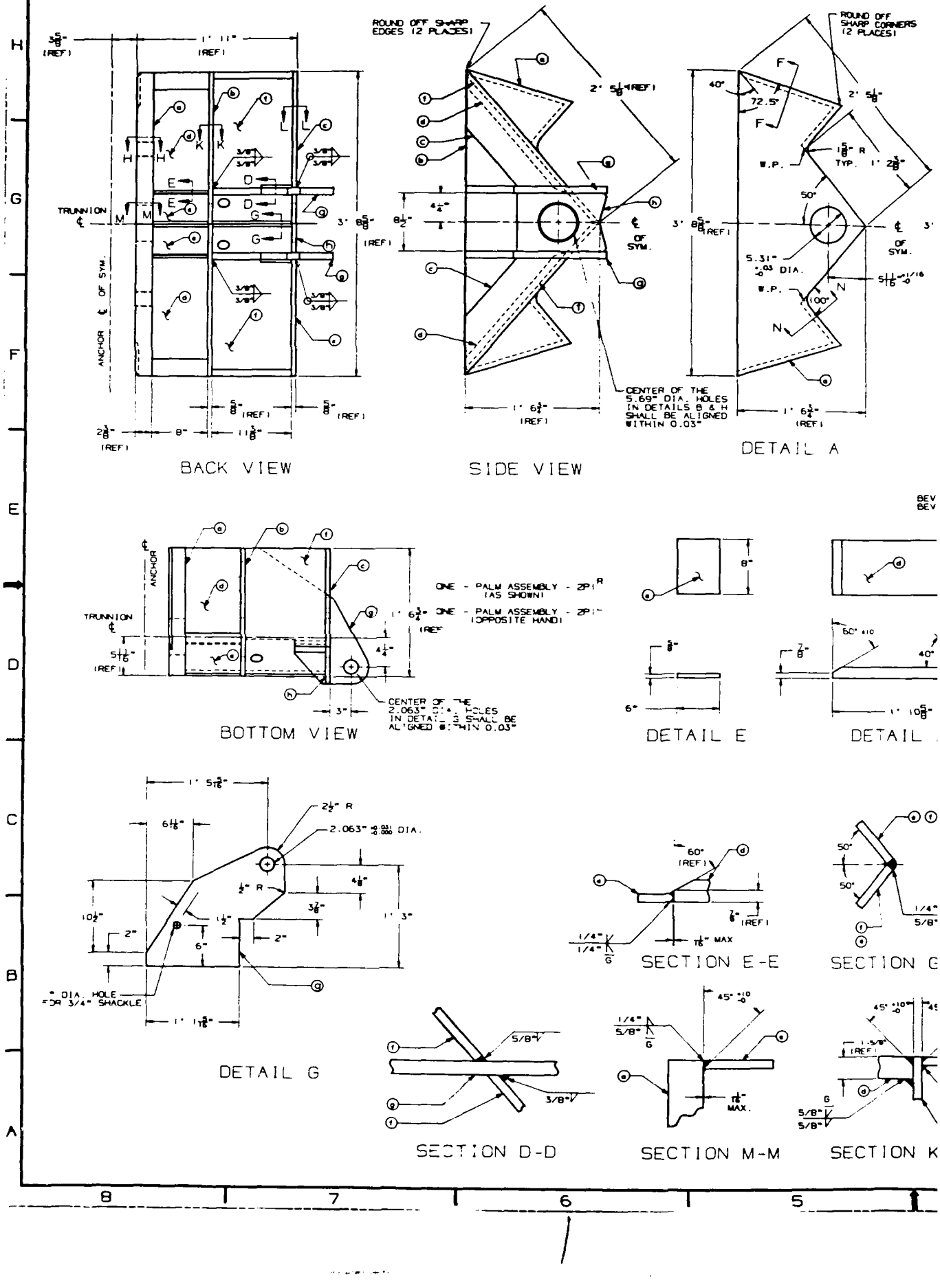
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

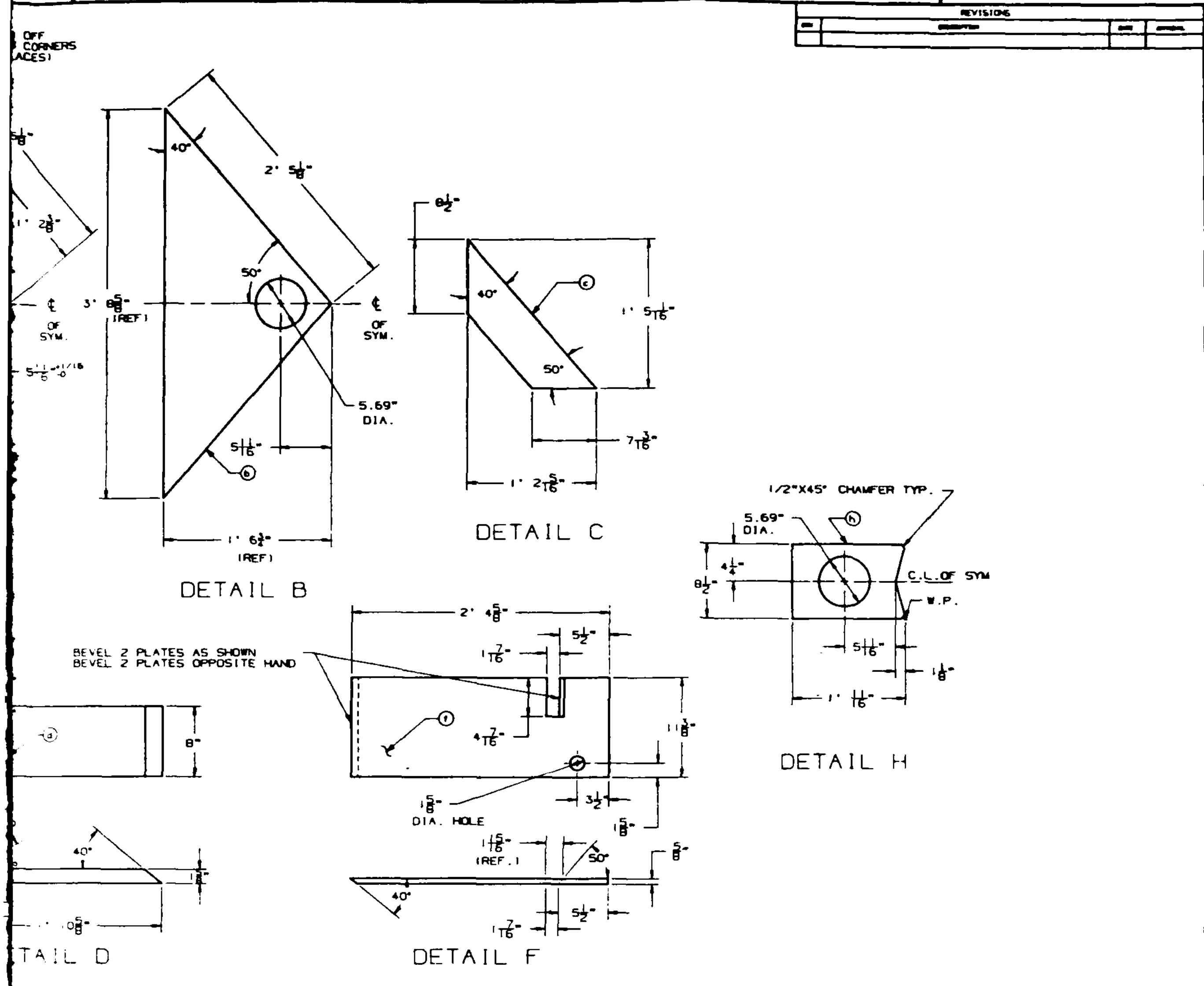
NAVM YR-6 SALVAGE ANCHOR
7,200 LBS. (WT.)
GENERAL ASSEMBLY

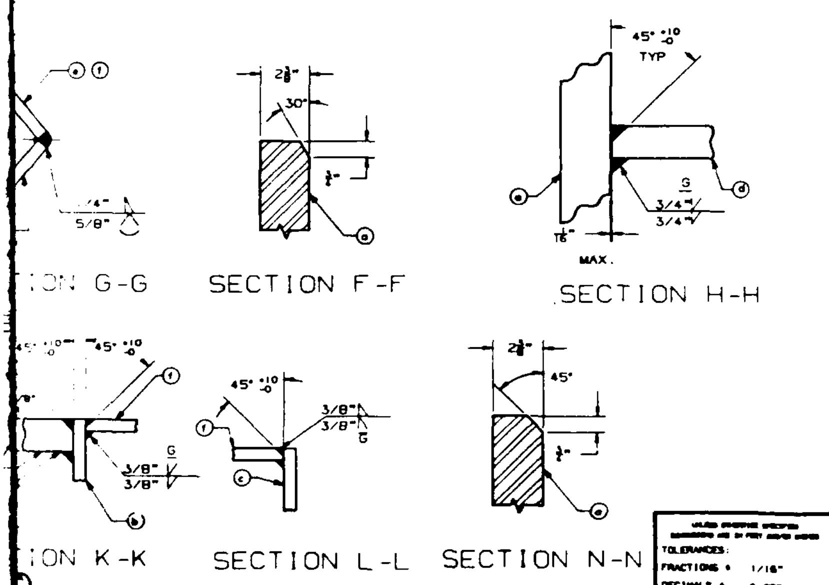
SIZE	CODE IDENT NO	FEC DRAWING NO
F	80091	6155301

SCALE NONE — SHEET 1 OF 5

85-45-1F


ROUND OFF SHARP EDGES (2 PLACES)
ROUND OFF SHARP CORNERS (2 PLACES)
TRUNNION ℄
ANCHOR ℄ OF SYM.
℄ OF SYM.
CENTER OF THE 5.69" DIA. HOLES IN DETAILS B & H SHALL BE ALIGNED WITHIN 0.03"
W.P.
TYP.
ONE - PALM ASSEMBLY - ZP1R (AS SHOWN)
ONE - PALM ASSEMBLY - ZP1L (OPPOSITE HAND)
CENTER OF THE 2.063" DIA. HOLES IN DETAIL G SHALL BE ALIGNED WITHIN 0.03"
2.063" DIA.
" DIA. HOLE FOR 3/4" SHACKLE
BACK VIEW
SIDE VIEW
DETAIL A
BOTTOM VIEW
DETAIL E
DETAIL G
SECTION E-E
SECTION G
SECTION D-D
SECTION M-M
SECTION K





NOTE :

RECOMMENDED WELDING PROCEDURES (MAY BE USED WHEN PALM IS A WELDMENT) :

(I) WELD ITEMS (a), (b), (d), AND (e) FIRST

(II) THEN WELD ITEMS (g) AND (h).

(III) WELD COVER PLATES (f).

(IV) WELD ITEMS (c) LAST.

MARK	NO. REQ'D	SIZE	LENGTH FT	LENGTH IN	REMARKS	
h	2	PL 5/8" X 8-1/2"	1	11/16	PALM SPAR #4	DETAIL H
g	4	PL 1" X 1'-5-1/2"	1	7-13/16	PALM CLEVIS	DETAIL G
f	4	PL 5/8" X 11-3/8"	2	4-5/8	PALM COVER #3	DETAIL F
e	4	PL 5/8" X -6"	0	8	PALM COVER #2	DETAIL E
d	6	PL 1-5/8" X 8"	1	10-5/8	PALM COVER #1	DETAIL D
c	4	PL 5/8" X 5-9/16"	1	10-5/16	PALM SPAR #3	DETAIL C
b	2	PL 5/8" X 1'-6-3/4"	3	8-5/8	PALM SPAR #2	DETAIL B
a	2	PL 2-3/8" X 1'-6-3/4"	3	8-5/8	PALM SPAR #1	DETAIL A

ONE - PALM ASSEMBLY -2P(R) (AS SHOWN)
ONE - PALM ASSEMBLY -2P(L) (OPPOSITE HAND)

BILL OF MATERIAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES
TOLERANCES:
FRACTIONS ± 1/16"
DECIMALS ± 0.08"
ANGLES ± 1°

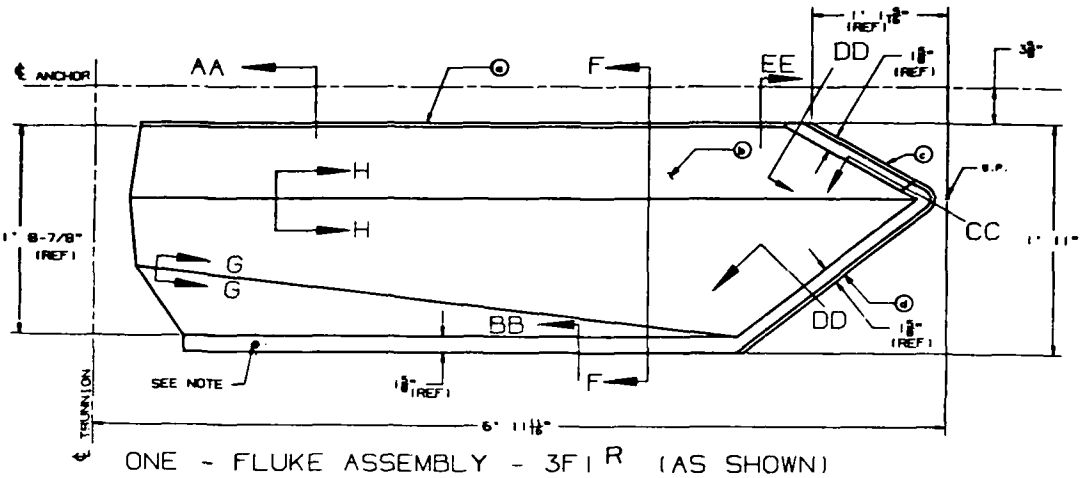
MCA ENGINEERS, INC.
DES JC | DR HNP | CHK MC
SUPV | CH ENGR
SUBMITTED BY [signature] 10/31/85 DATE
NCEL | END
NEP | DIR
APPROVED | DATE
COMMANDING OFFICER
APPROVED | DATE
FOR COMMANDER, NFEC

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

NAVMOOR-6 SALVAGE ANCHOR
7,200 LBS. (WT.)
PALM ASSEMBLY

SIZE F | CODE IDENT NO 80091 | FEC DRAWING NO 6155302
SCALE NONE | SPEC | SHEET 2 OF 5

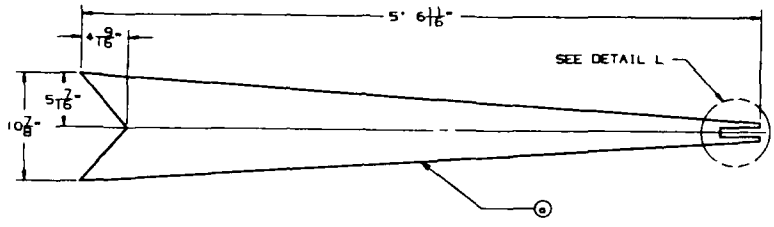
85-45-2F



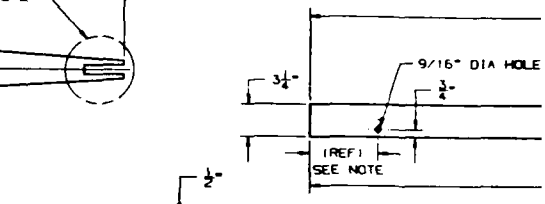
ONE - FLUKE ASSEMBLY - 3F1 R (AS SHOWN)

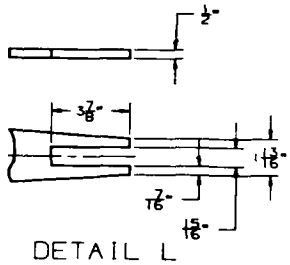
ONE - FLUKE ASSEMBLY - 3F1 L (OPPOSITE HAND)

(SEE NOTE 7, SHEET 1)

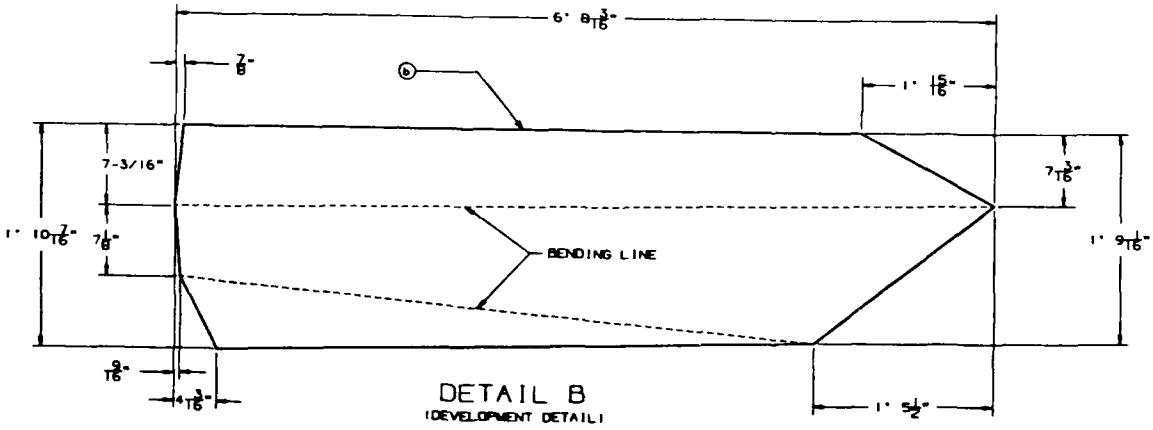


DETAIL A

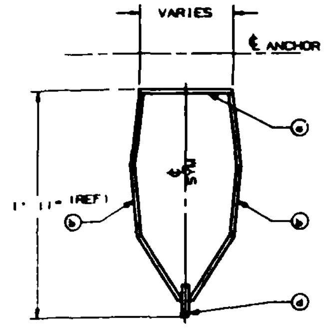




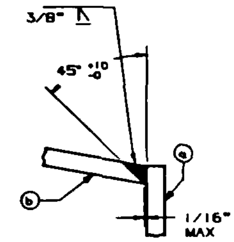
DETAIL L



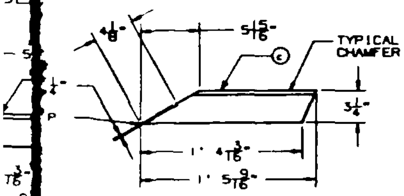
DETAIL B
(DEVELOPMENT DETAIL)



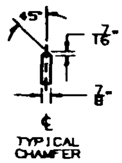
SECTION F-F

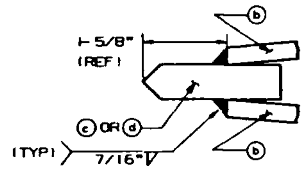


SECTION A-A

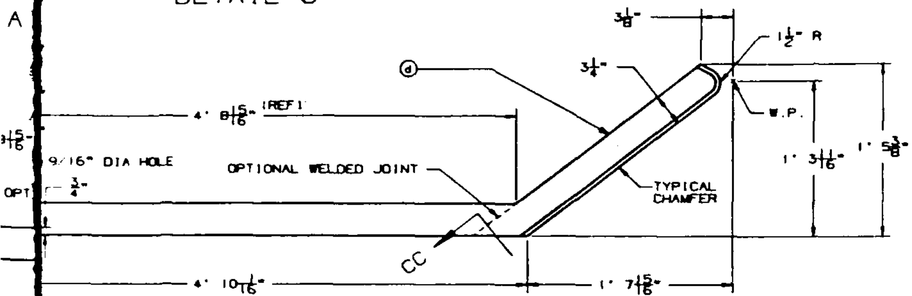


DETAIL C

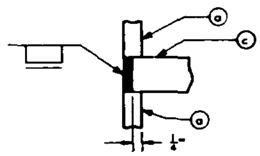




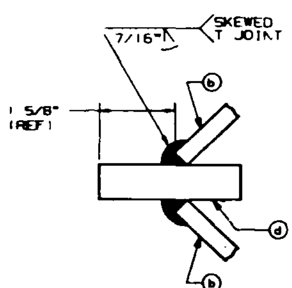
SECTION D-D (TYPICAL)



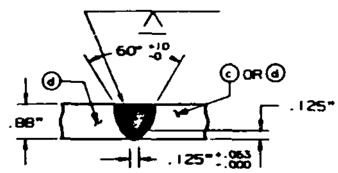
DETAIL D



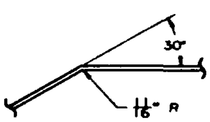
SECTION E-E



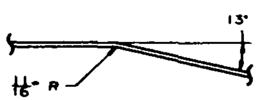
SECTION B-B



SECTION C-C



SECTION G-G



SECTION H-H

NOTE: LOCATE HOLE TO MATCH SIMILAR HOLE OF ITEM (N) SHEET 5 AFTER STABILIZER ASSEMBLY IS PIN-CONNECTED TO THE PALM ASSEMBLY AS SHOWN ON SHEET 1.

MARK	NO REQ'D	SIZE	LENGTH FT	LENGTH IN	REMARKS	
d	2	PL 7/8" X 1' 5-3/8"	6	6	EDGE PLATE #2	DETAIL D
c	2	PL 7/8" X 3-1/4"	1	5-9/16	EDGE PLATE #1	DETAIL C
b	4	PL 1/2" X 1' 10-7/16"	6	8-3/16	FLUKE PLATE	DETAIL B
a	2	PL 1/2" X 10-7/8"	5	6-11/16	FLUKE SPAR	DETAIL A

ONE - FLUKE ASSEMBLY -3F1 R (AS SHOWN)
ONE - FLUKE ASSEMBLY -3F1 L (OPPOSITE HAND)

BILL OF MATERIAL

TOLERANCES:
FRACTIONS ± 1/16"
DECIMALS ± 0.05"
ANGLES ± 1°

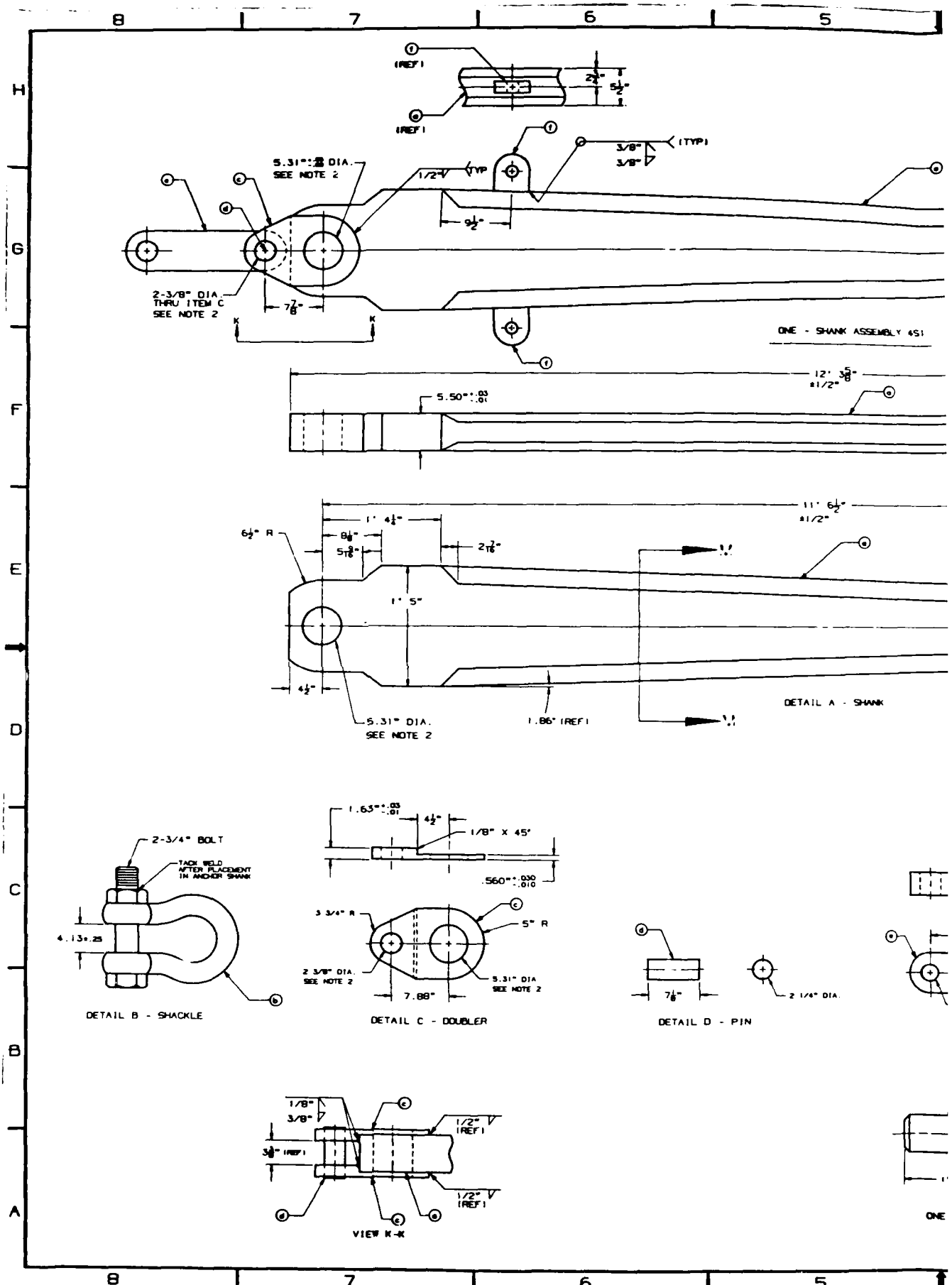
MCA ENGINEERS, INC.
DES JC | DR DJB | CHK
SUBMITTED BY 10/81

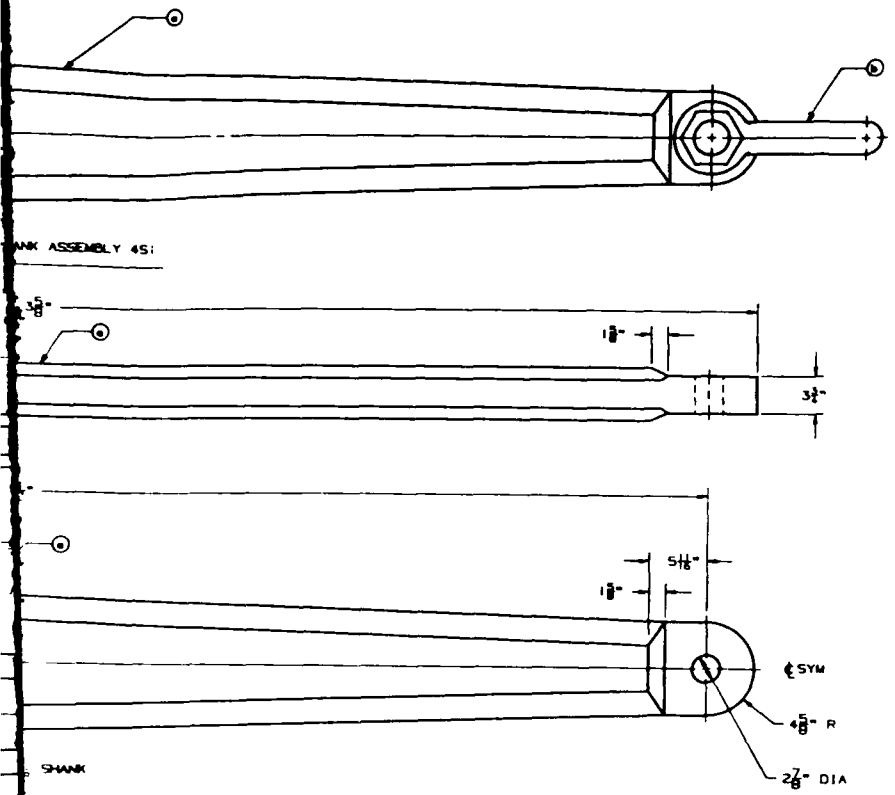
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

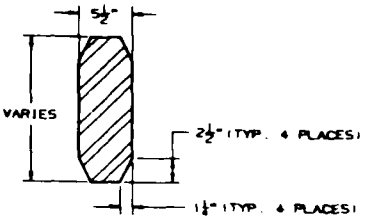
NAVMOOR-6 SALVAGE ANCHOR
7,200 LBS. (WT.)
FLUKE ASSEMBLY

SIZE F | CODE IDENT NO 80091 | FEC DRAWING NO 6155303
SCALE NONE | SHEET 3 OF 5

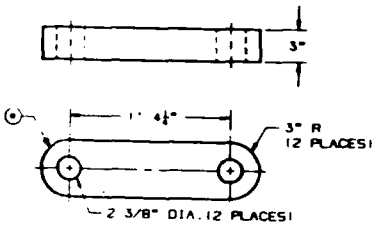
85-45-3F


(REF)
(REF)
5.31" DIA.
SEE NOTE 2
(TYP)
(TYP)
2-3/8" DIA.
THRU ITEM C
SEE NOTE 2
ONE - SHANK ASSEMBLY 451
5.50"
DETAIL A - SHANK
5.31" DIA.
SEE NOTE 2
1.86" (REF)
2-3/4" BOLT
TACK WELD
AFTER PLACEMENT
IN ANCHOR SHANK
DETAIL B - SHACKLE
1/8" X 45°
DETAIL C - DOUBLER
DETAIL D - PIN
VIEW K-K

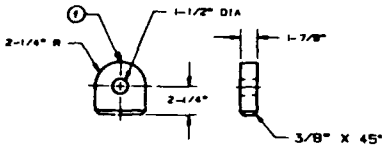




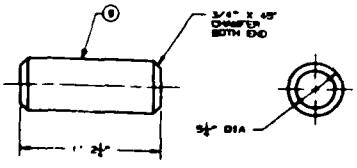
SECTION M-M
(SEE NOTE ①)



DETAIL E - LINK



DETAIL F - PADEYE



ONE TRUNNION PIN - 4T

NOTE: ① THE TOLERANCE OF THE SHANK'S CROSS SECTION DIMENSIONS AT THE CHAMFERED PORTION SHALL BE ± 1/4"
② PART ⓔ WELDED TO ⓓ BEFORE HOLES ARE DRILLED

MARK	NO REQ'D	SIZE	FT	IN LENGTH	REMARKS
g	1	5-1/4" DIA	1	2-1/4	TRUNNION PIN (COLD DRAWN) AISI 1018 FY = 54 KSI
		ONE - TRUNNION PIN -4T			
f	2	1-7/8" X 4-1/2" PL	0	4-1/2	PADEYE DETAIL F
e	1	3" X 6" PL	1	10-1/4	LINK ASTM A 5[illegible] MOD. FY = 60 KSI DETAIL E
d	1	2-1/4" DIA BAR	0	7-1/8	PIN (COLD DRAWN) AISI 4340 FY = 99 KSI DETAIL D
c	2	1-5/8" - 10" PL	1	4-5/8	DOUBLER SEE NOTE 3 SHT. 1 DETAIL C
b	1	2-1/2" NOM. DIA	-	-	BOLT TYPE ANCHOR SHACKLE 950,000 LBS BREAKING STRENGTH DETAIL B
a	1	5-1/2" x 17" PL	12	3-5/8	SHANK SEE NOTE 3 SHT. 1 DETAIL A
		ONE - SHANK ASSEMBLY -4S			

BILL OF MATERIAL

MCA ENGINEERS, INC.

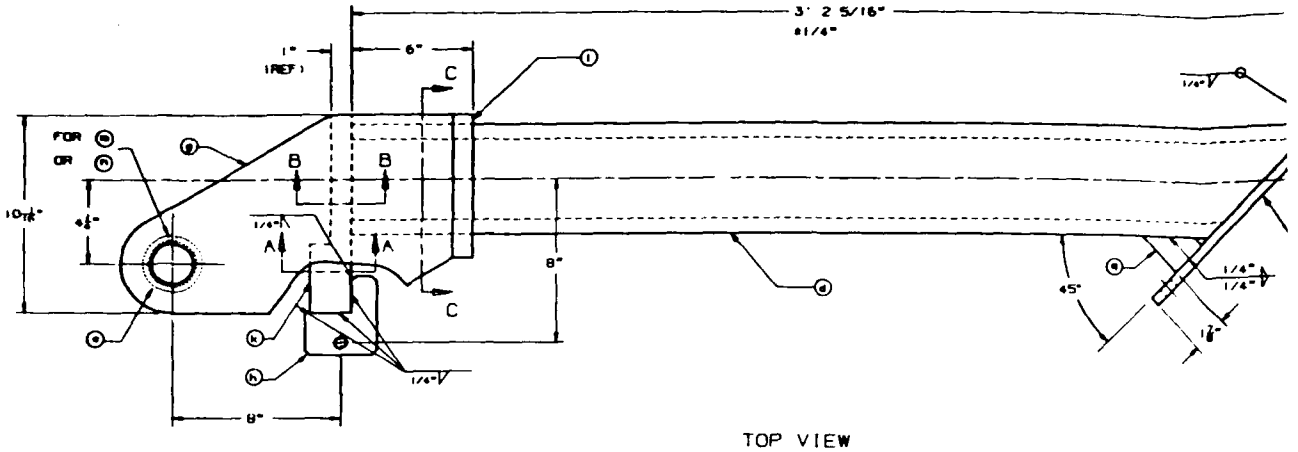
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

NAVMOOR-6 SALVAGE ANCHOR
7,200 LBS. (WT.)
SHANK ASSEMBLY, TRUNNION PIN

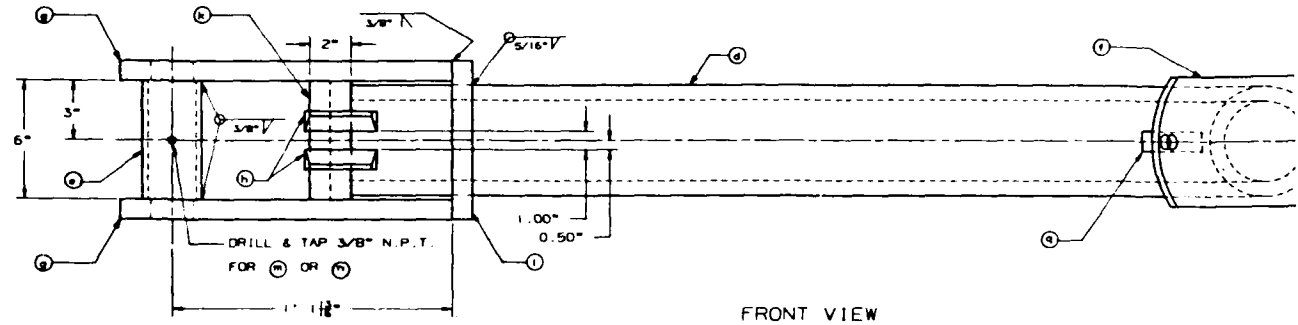
TOLERANCES:	
FRACTIONS ±	1/16"
DECIMALS ±	0.02"
ANGLES ±	1°

SIZE F | CODE IDENT NO 80091 | FSC DRAWING NO 6155304 | SCALE NONE | SHEET 4 OF 5

85-45-4F

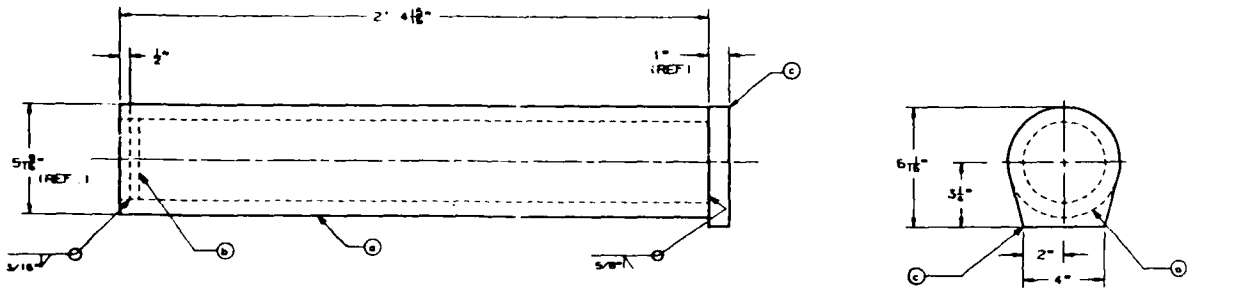


TOP VIEW



FRONT VIEW

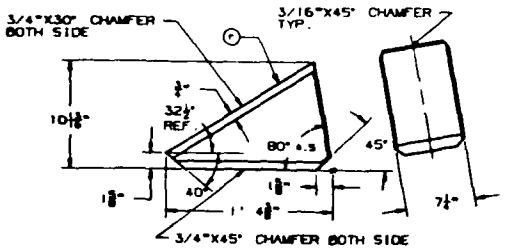
ONE - FOLDABLE STABILIZER ASSEMBLY - 552



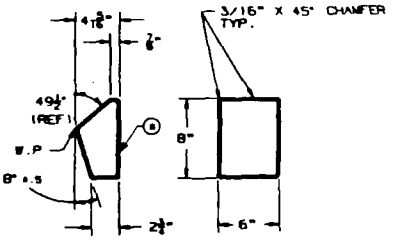
TOP VIEW

SIDE VIEW

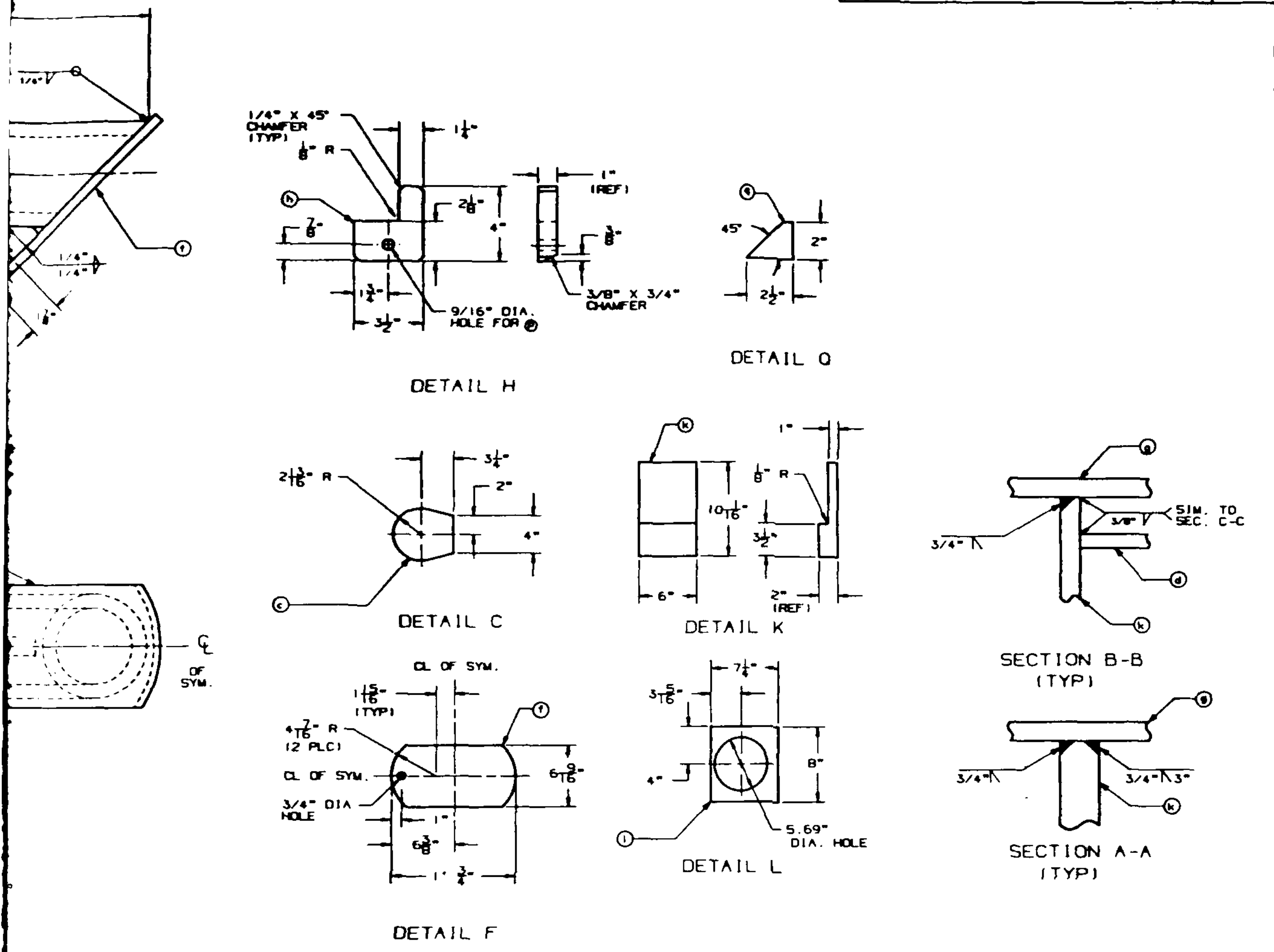
ONE - FIXED STABILIZER ASSEMBLY - 551

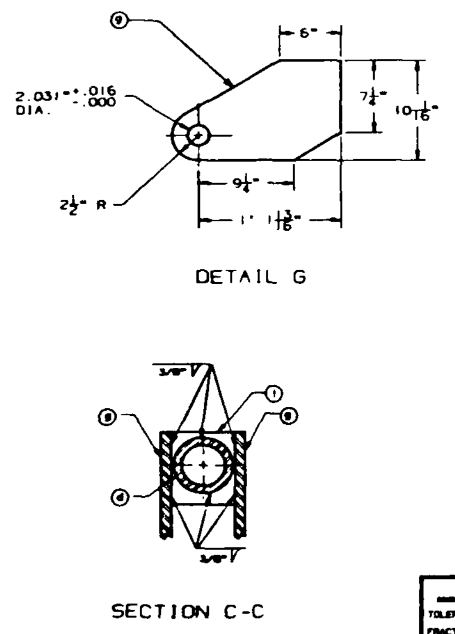


ONE - 50° STOPPER - 553



ONE - 32° STOPPER - 554





MARK	NO. REQ'D	SIZE	LENGTH FT	LENGTH IN	REMARKS
s	1	PL 4-5/16" X 8"	0	8	SEE NOTE 3, SHEET 1
		ONE 32" STOPPER - S54			
r	1	PL 7-1/4" X 10-13/16"	1	4-3/8	SEE NOTE 3, SHEET 1
		ONE 50" STOPPER - S53			
q	1	PL 1/2" X 2"	0	2-1/2	STIFFENER DETAIL Q
p	1	1/2" - 13 UNC	0	4	HEX HEAD BOLT WITH NUT AND WASHER STAINLESS STEEL
n	1	3/8"	-	-	PIPE PLUG
m	1	3/8"	-	-	GREASE FITTING
l	1	PL 1" X 7-1/4"	0	8	STABILIZER CLEVIS END PLATE DETAIL L
k	1	PL 2" X 6"	0	10-1/16	SHEAR CHOCK DETAIL K
h	2	PL 1" X 3-1/2"	0	4	LOCK PIN BRACKET DETAIL H
g	2	PL 1" X 10-1/16"	1	4-5/16	STABILIZER CLEVIS DETAIL G
f	1	PL 1/2" X 6-9/16"	1	3/4	FLOW PLATE DETAIL F
e	1	2-1/2" PIPE XS	0	6	ASTM A53 GRADE B
d	1	5" PIPE XXS	3	2-5/16	ASTM A53 GRADE B
		ONE - FOLDABLE STABILIZER ASSEMBLY - S52			
c	1	PL 1" X 5-5/8"	0	6-1/16	HEAD PLATE DETAIL C
b	1	PL 1/2" X 4" OD	-	-	END PLATE
a	1	5" PIPE XXS	2	4-15/16	ASTM A53 GRADE B
		ONE - FIXED STABILIZER ASSEMBLY - S51			

BILL OF MATERIAL

TOLERANCES:
FRACTIONS ± 1/16"
DECIMALS ± 0.08"
ANGLES ± 1°

MCA ENGINEERS, INC.
DES JC DR HNP CHK M.C.
SUBMITTED BY

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

NAVMOOR-6 SALVAGE ANCHOR
7,200 LBS. (WT.)
STABILIZER ASSEMBLY, STOPPERS

SIZE F | CODE IDENT NO 80091 | NAVFAC DRAWING NO 6155305
SCALE NONE | SHEET 5 OF 5

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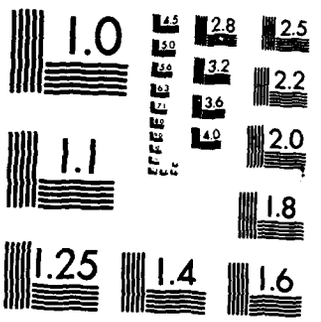

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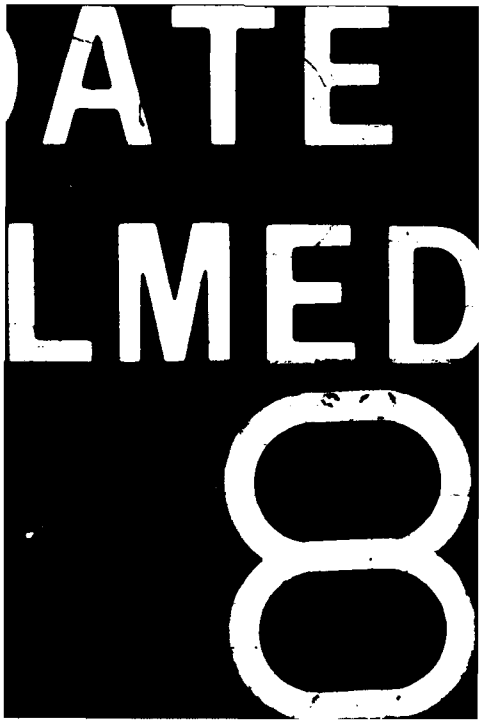
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