R 598

Technical Report

OPERATIONAL EVALUATION OF THE STATO MOORING ANCHOR

September 1968

NAVAL FACILITIES ENGINEERING COMMAND

NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

OPERATIONAL EVALUATION OF THE STATO MOORING ANCHOR

Technical Report R-598

Y-F015-20-02-002

by

R. C. Towne and R. A. Bliss

ABSTRACT

The STATO mooring anchors were designed to be used in (1) permanent moorings such as Fleet moorings, or (2) in situations where large holding powers are required such as in salvage operations, or (3) in the temporary mooring of large barges or vessels. In-service tests were requested by the Naval Facilities Engineering Command to determine any adverse operational characteristics which might become apparent through varying or continuous operational use. STATO anchors were substituted for Navy Stockless anchors of equivalent holding power already attached to two Fleet mooring assemblies of different capacities in the Navy Harbor Complex in San Diego Bay during the regular Public Works Center inspection of moorings. This report describes the fabrication and installation of the anchors and the results of a 1-year operation. The anchors were removed from the water and inspected after the test period. The results of the evaluation showed no adverse operational characteristics and that the anchors performed satisfactorily.

CONTENTS

INTRODUCTION

The STATO anchor was designed by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, at the request of the Naval Facilities Engineering Command (NFEC), Washington, D.C. The anchor design was the result of a comprehensive program initiated in November 1947 to improve the efficiency of the Navy Stockless anchors and to develop a more suitable design criteria for mooring anchors. The "family" of STATO anchors was developed during the period 1955-1958 and met the proposed design criteria of light weight, rotational stability, mild steel construction, and relative high holding power to anchor weight in both sand and mud bottoms. These advantages were achieved with a minimum of anchor sizes, that is with anchors having nominal weights of 200, 3,000, 6,000, 9,000, 12,000, and 15,000 pounds and providing design holding powers of 6,000 to 320,000 pounds in sand bottoms and 4,500 to 240,000 pounds in mud bottoms.[1,2] A small, 100-pound STATO, developing 3,000 pounds holding power in sand, was fabricated at a later date for ship-to-shore mooring of the assault fuel line.

In July 1966, NFEC directed that in-service tests of the STATO anchor be conducted at San Diego Bay. Two mooring sites were selected which had different capacities and were scheduled for regular periodic inspection during FY 1967.

MOORING TEST SITES

The two sites selected were Barge Mooring No. 18 (BM 18) and Fleet Buoy Mooring No. 45 (M 45) in the central bay of the Navy Harbor Complex, San Diego, California (Figure 1). The scheduled inspection for these moorings fit the time frame of the proposed in-service test schedule, and the sites were normally used to moor LST class ships. BM 18, a class D mooring, has a rated holding capacity of 75,000 pounds and consists of a 3-legged anchorage with a single riser chain attached to a 10-foot 6-inch-diameter buoy. Each of three 13,000-pound Navy Stockless anchors were joined to the riser chain by 2 shots of 2-inch-diameter anchor chain. Depth of water at the site is 34 feet,

with a normal tide of 6 feet. The position of mooring BM 18 was established by sighting on three prominent markers as indicated in Figure 1. The positions of the anchors and ground lines are shown in Figure 2.

Mooring 45, a class C mooring, has a rated capacity of 100,000 pounds and utilized three 20,000-pound Stockless anchors with 2-1/2 shots of 2-1/4-inch-diameter anchor chain on each of the three legs. Location is fixed by sighting on three targets as shown in Figure 1. The anchor positions are detailed in Figure 3. Precise location of the moorings was for use at a later date to establish any movement of the anchorages.

No soil sample borings were taken of the proposed mooring sites because of existing soil data. The Public Works Center (PWC), San Diego defined the bottom as a mixture of decomposed granite, coarse sand and shell, over-laid by approximately 2 feet of silt.

The triennial inspection and overhaul of the two moorings at the selected sites were scheduled in September 1966 for BM 18 and March 1967 for M 45. To allow sufficient time for fabrication and delivery of the first anchors, the inspection of BM 18 was deferred until November 1966.

STATO ANCHORS

One 3,000-pound (nominal weight) STATO was selected to replace each 13,000-pound Navy Stockless anchor in BM 18. Fabrication was accomplished in the NCEL shops. Each of the three anchors weighed about 3,430 pounds, required 185 man-hours to fabricate and cost $2,300. The fluke angle was set for 34 degrees by the wedge inserts, and because of the reported 2 feet of silt overlying the site bottom, mud palm extension plates were installed on the anchors. These extension plates increased the normal anchor weight by 280 pounds, from 3,150 pounds to 3,430 pounds. This additional work to fabricate and install the plates is included in the previously mentioned cost of the anchor.

Each anchor was test pulled in sand at NCEL to check its operation and structural strength. Figure 4 is a graph of the test results showing each anchor was pulled to a holding power of about 82,000 pounds before the test was stopped. The maximum required holding power of this anchor is 60,000 pounds at 50 feet of drag.

The anchors were delivered by truck to the PWC, San Diego on 3 November 1966 and were installed in BM 18 on 9 November 1966 by PWC floating crane and pontoon barge (Figure 5).

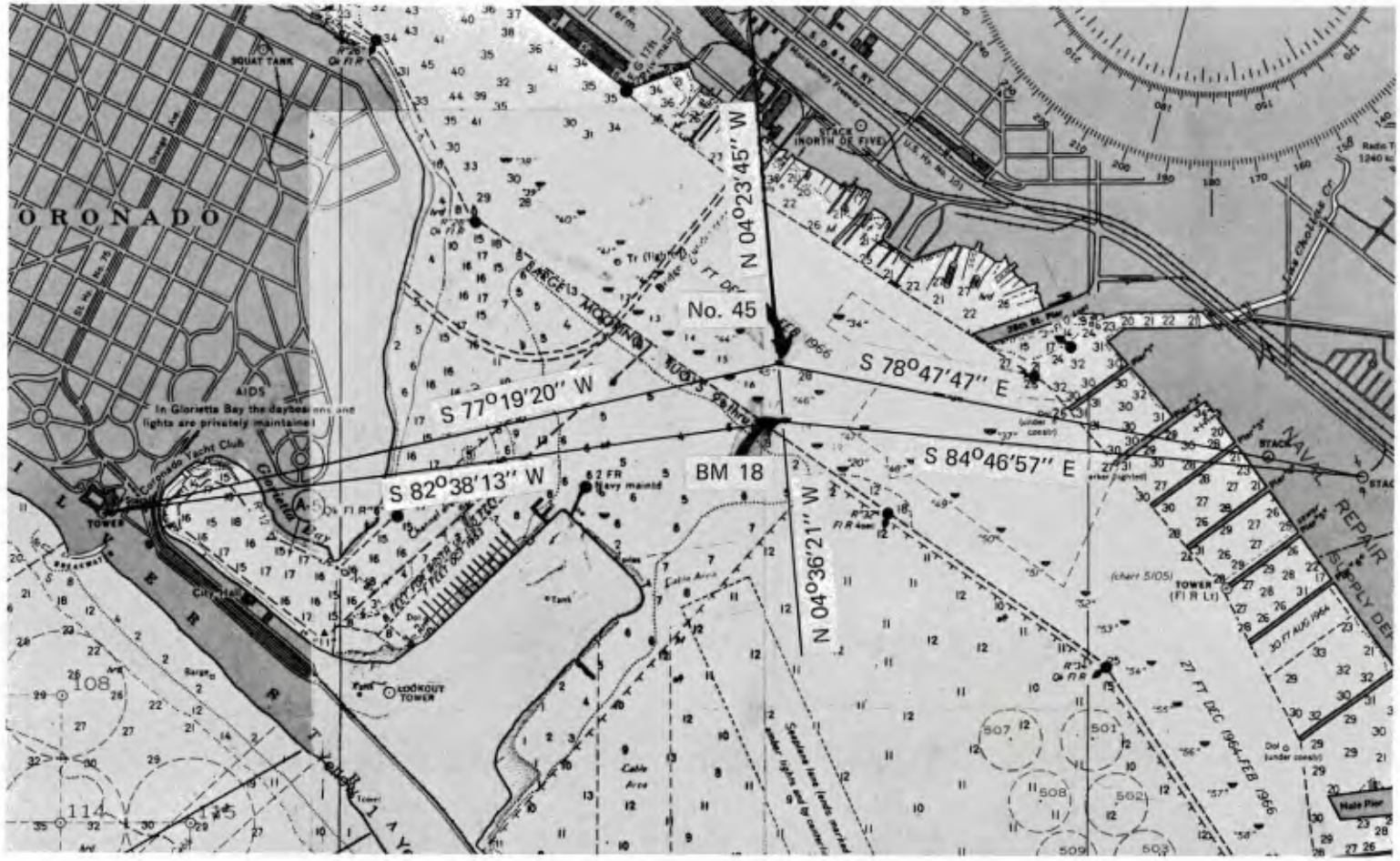


Figure 1. Fleet mooring site at San Diego Bay.

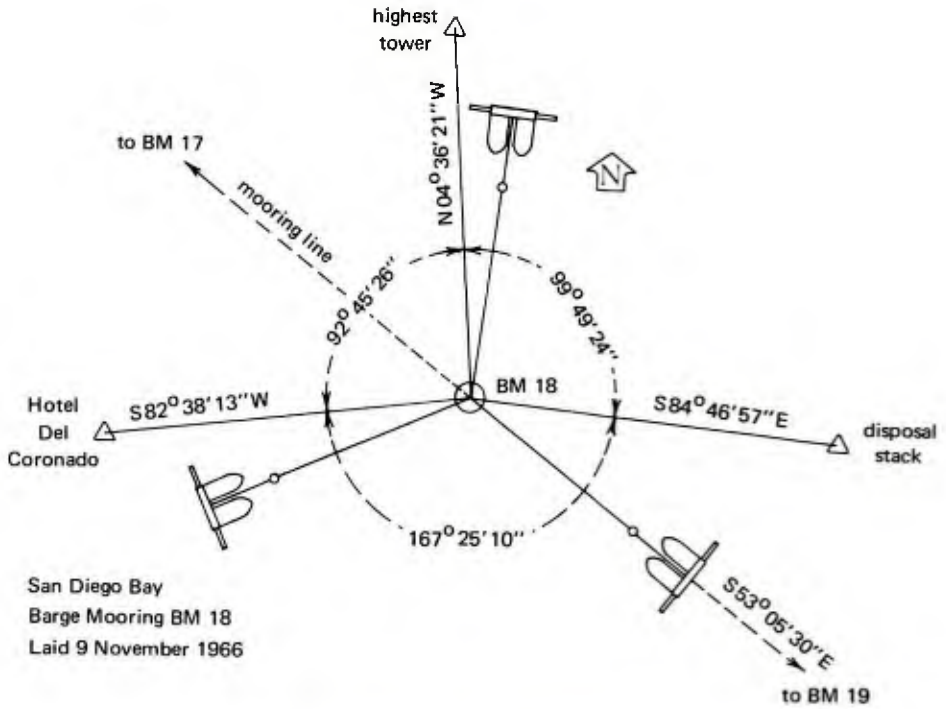


Figure 2. Mooring site for 3,000-pound STATO anchors.

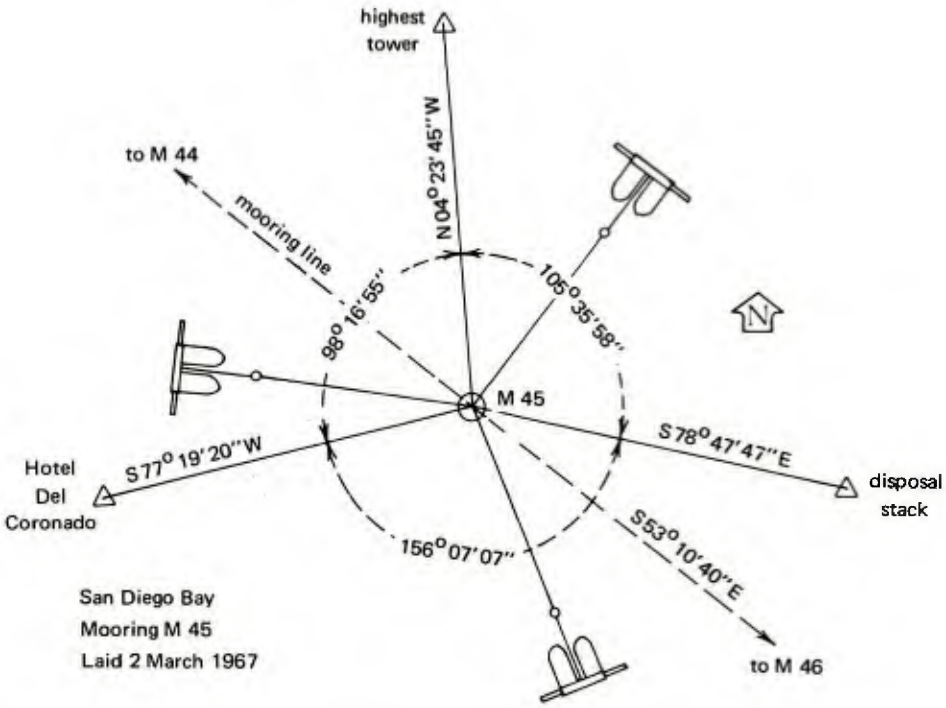


Figure 3. Mooring site for 6,000-pound STATO anchors.

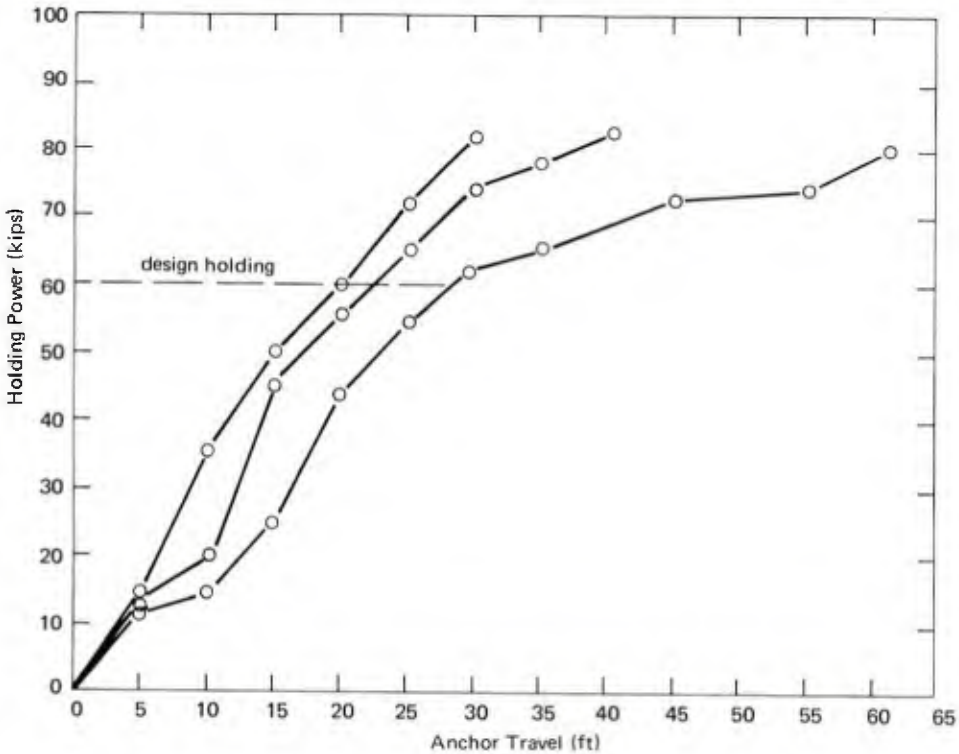


Figure 4. Results of test pulls on sand beach with 3,000-pound STATO anchors having palm extensions.

Figure 5. Installing 3,000-pound anchors in BM 18 at San Diego Bay.

The 6,000-pound (nominal weight) STATO anchors were fabricated to supplant the 20,000-pound Navy Stockless anchors in Mooring 45. Each of the three STATO anchors weighed approximately 6,750 pounds, required 220 man-hours to fabricate, and cost $3,500. As with the 3,000-pound STATO, wedge inserts were installed to restrict the fluke angle to 34 degrees, and palm extension plates were installed. Without palm extension plates, the anchor weight, including shackle, was 6,200 pounds.

Each 6,000-pound anchor (Figure 6) was test-pulled in sand at NCEL to check its operation and structural strength. Figure 7 is a graph of the test results. The average maximum load applied was 155,000 pounds. The maximum required holding power of the anchor is 120,000 pounds at 50 feet of drag.

The anchors were delivered to the Public Works Center, San Diego on 27 February 1967 by truck, and installed in Mooring M 45 on 2 March 1967. Figure 8 shows the anchors with hinged stabilizers folded to facilitate transport by truck.

A preliminary report[3] describing the fabrication and test of the anchors was issued in April 1967.

Figure 6. 6,000-pound STATO anchor. The light portion under man's hand is a palm extension plate for mud operation.

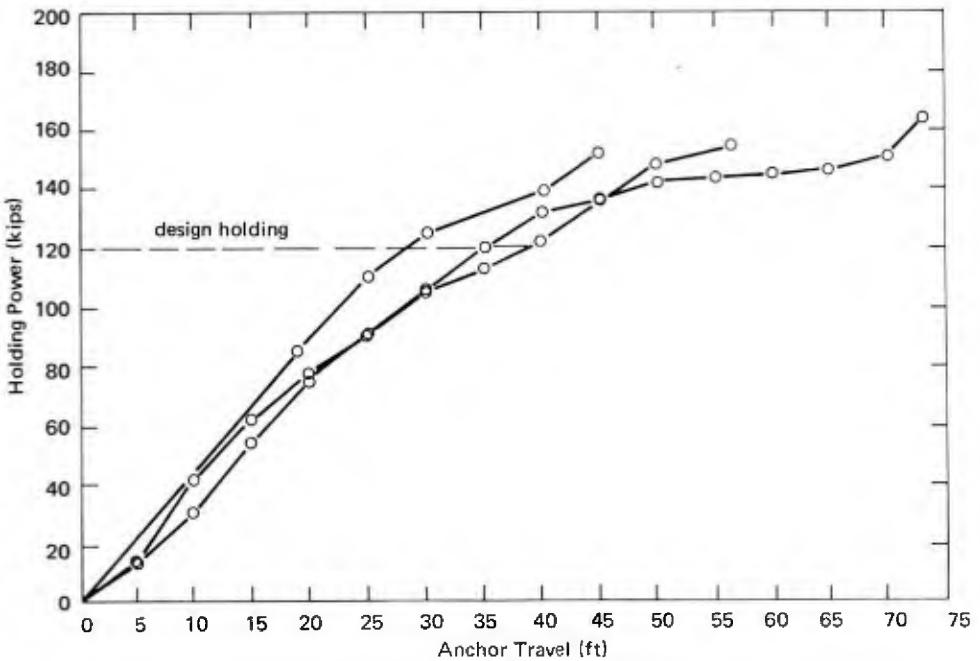


Figure 7. Results of test pulls on sand beach with 6,000-pound STATO anchors having palm extensions.

Figure 8. 6,000-pound STATO anchors with stabilizers folded to facilitate truck shipment.

EVALUATION RESULTS

In February 1967, NCEL was informed by PWC, San Diego of an apparent shift of BM 18. During the period of January 20-23, two LSTs were secured abreast between moorings 17 and 18 and one LST was tied between moorings 18 and 19. A strong SSE wind had been blowing for several days. The apparent shift was reported because of a visual misalignment of moorings 14, 15, 16, 17, 18, 19, and 20. BM 18 was rechecked using the bearings detailed in Figure 1 and was found to be on station. The visual misalignment was caused by movement of moorings 15, 16, 19, and 20 (Figure 9). The 12- to 14-foot dislocation of moorings 17 and 18 recorded during the inspection was within the normal free traverse of the mooring buoys. Moorings 15, 16, 19, and 20 had moved 30 to 50 feet.

A record of the ship types and numbers tied to the moorings during the test period was accumulated from logs maintained at San Diego. Wind forces and directions for the same period were obtained, and both types of data are listed in Tables 1 and 2.

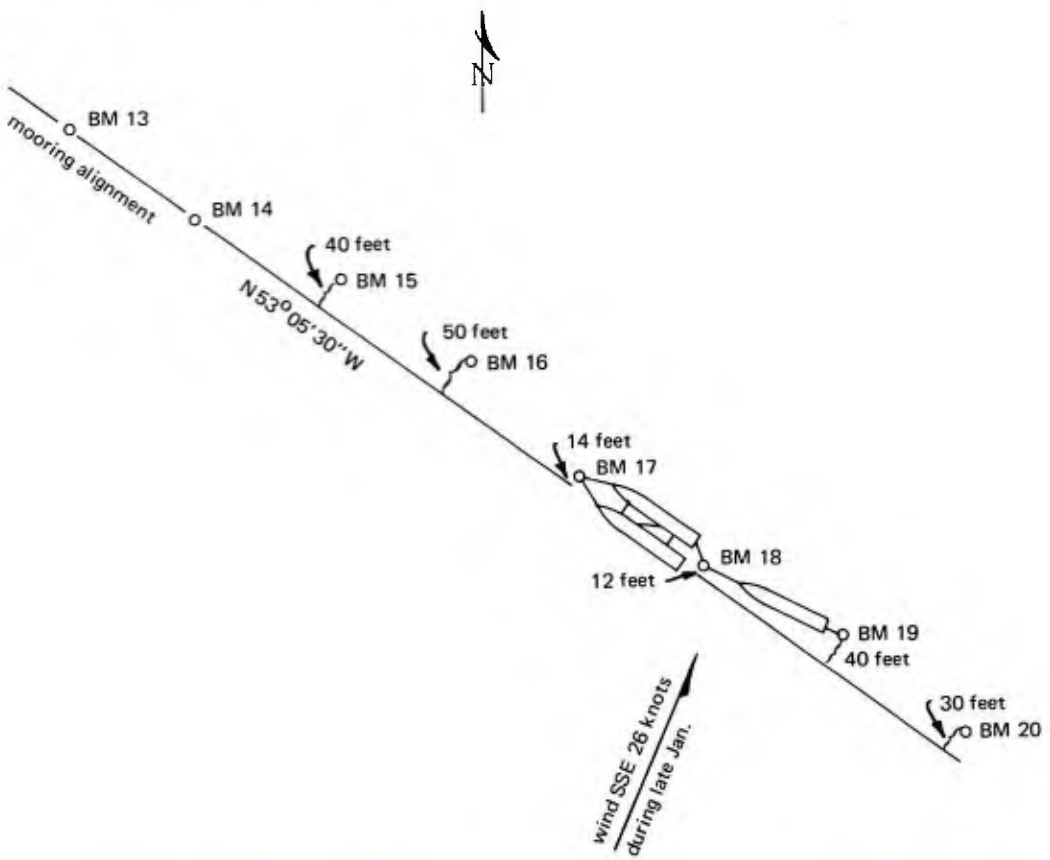


Figure 9. Mooring positions in February 1967. Distances indicate displacements from original locations.

Table 1. Ship Mooring Data

Date	Type of Ship—	
	Anchorage BM 18	Anchorage M 45
4-5 Jan 1967	LST[1]	
20-23 Jan 1967[2]	LST	
24 Jan 1967	LST	
6 Feb 1967	LST	
14-15 Feb 1967	LST	
10 Mar 1967	LST	
2 May 1967	LST	
20-21 May 1967	—	AFS-4
14 Jun 1967	LST	
21 Jun 1967	LST	
28 Jun 1967	LST	
1 Aug 1967	LST	
22 Nov 1967	LST	
4 Dec 1967[3]	LST	
12 Feb 1968	LST	

[1] Displacement 4,000 tons.

[2] Two LSTs abreast; one LST astern.

[3] Two LSTs abreast; one LST astern.

In December 1967, the 3,000-pound anchors were raised and inspected. The condition of these anchors at time of lifting is shown in Figure 10. No deleterious conditions were apparent which would limit the anchors operational capabilities. Likewise the 6,000-pound anchors (Figure 11) were inspected in March 1968 with satisfactory results. All of the anchors were returned to their respective positions in the moorings.

DISCUSSION

The anchors performed satisfactorily during the 1-year in-service period, but the number of ships tied to one of the moorings (M 45) was considered subnormal. Most of the ships assigned to this test mooring were operating in Southeast Asian waters.

Figure 10. STATO (3,000 pound) after 1 year of operation.

Figure 11. STATO (6,000 pound) after 1 year of operation.

Table 2. Wind Velocity and Direction

Date	Peak Winds		Prevailing Winds	
	Maximum Velocity (knots)	Direction	Average Velocity (knots)	Direction
7 Nov 1966	38	WSW	17	NW
30 Dec 1966	33	SW	30	W
22 Jan 1967	26	SSE	14	NW
1 Feb 1967	20	NW	14	NW
29 Mar 1967	31	WNW	16	WNW
11 Apr 1967	32	WNW	19	WNW
5 May 1967	21	W	16	W
2 Jun 1967	24	WNW	16	WNW
19 Jul 1967	19	WNW	14	W
10 Aug 1967	22	WNW	15	W
1 & 13 Sep 1967	22	WNW	15	WNW
6 Oct 1967	22	NW	15	WNW
21 Nov 1967	34	S	16	WNW
18 Dec 1967	31	S	15	WNW
3 Jan 1968	22	NW	14	NW
18 Feb 1968	31	WNW	15	WNW
8 Mar 1968	32	SE	19	WNW

The difference in costs and weights of initially using STATO anchors in place of the Navy Stockless anchors would be about $2,400 and 70,000 pounds, based on catalog prices for the Navy Stockless anchors at $0.20 per pound. No changes were made in the chain size or other ground tackle. Commercial procurement of forty 6,000-pound STATO anchors for Southeast Asia resulted in a price of $2,314 each or a 30% cost reduction. This is a cost per pound of about $0.35 as opposed to a cost per pound of $0.52 for more limited production.

Additional operational use of other STATO anchors was investigated during the test period. A 12,000-pound STATO anchor was used to moor a 150-foot work ship in the mud bottom of the Gulf of Mexico off the coast of Morgan City, Louisiana. The anchor buried about 20 feet into the bottom and moored the ship securely for 2 months (November–December 1967).

One proposed field service operation of the STATO anchors is a mooring installation using the 15,000-pound anchors in a bottom composed primarily of volcanic ash. No soil analysis data are available presently, but it is presumed that the anchor action will be similar to its action in the soft mud bottom at San Francisco Bay.

Hinged Stabilizers

In the early program planning phase, the problem of shipment of the anchors was considered. The problem which exists in shipping stabilized anchors is the large width required for the stabilizers. Some lightweight anchors are designed to permit the stabilizers to be disassembled but require a fork truck, crane, or auxiliary equipment to reassemble the anchor at the delivery site. The solution proposed for the STATO anchors was to hinge each stabilizer (Figure 12), thus reducing the anchor width by over 60%. The stabilizers can be repositioned at the delivery site by one man without the necessity for auxiliary equipment. The anchor width was reduced from over 12 feet to under 6 feet. All of the anchors fabricated for the in-service tests were equipped with hinged stabilizers.

Figure 12. STATO (6,000 pound) anchors with hinged stabilizers.

It was also envisioned that the hinged stabilizers would facilitate stowage of the anchors aboard ships, such as salvage vessels, thus reducing the required deck space. This hinged stabilizer (Figure 13) is being included in the Design Manual NAVDOCKS DM-26, Harbor and Coastal Facilities, under Mooring System Components. Drawings of the hinged stabilizers are contained in the Appendix.

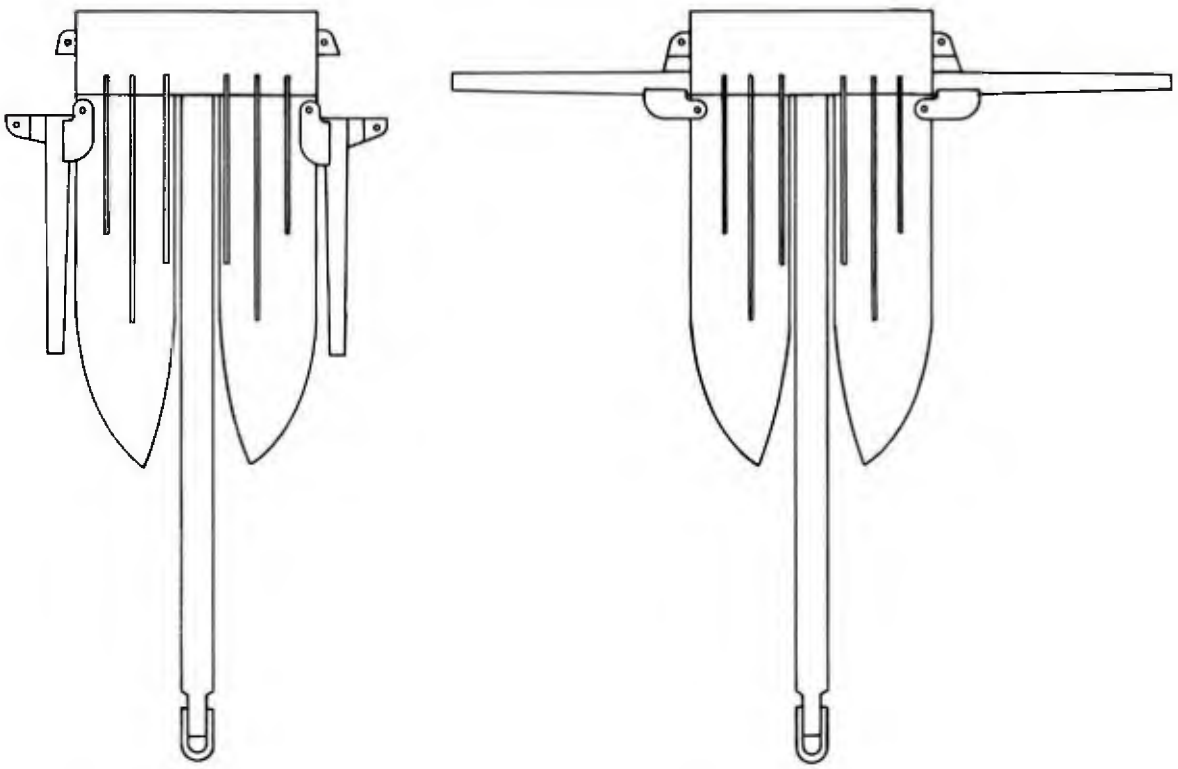
Palm Extension Plates

The STATO anchor can be provided with palm extension plates (Figure 6) which are installed when the anchor is to be used in a soft mud bottom. In the situation where a mud layer overlies a sand bottom, such as occurred at San Diego Bay, it is necessary to have the mud plates installed. This assures that the flukes will trip, penetrate through the soft mud layer and bury into the underlying sand. The anchors were tested in the sand at NCEL with the mud plates installed. No problems were encountered by the use of the extra plates in a sand bottom and it appears that some additional holding power was obtained in a shorter drag distance. No detailed tests were made to determine the exact amount of increase in holding power. It does seem that consideration should be given to installing the mud plates on most STATO anchors even though some additional cost and weight is involved. Installation of the mud plates at the time of anchor fabrication will eliminate the problem of field assembly and will assure proper fluke operation in either sand, mud, or combination of mud—sand layers.

Holding Power

The relatively large holding power/anchor weight ratio of the STATO anchor, especially in the larger sizes and in mud bottom, make this anchor attractive for use in mooring sites having a soft or unstable soil. Data from previous anchor tests[1-6] reflect the relative holding power of various type anchors (Figures 14 and 15). All of the anchors shown on the graphs were tested in the same areas and under the same conditions. The data presented in the graphs are the maximum holding powers measured during the tests.

A commercial company conducted several comparative tests between a STATO anchor and an LWT anchor during 1967. The anchors were in the 700-to-800-pound range, and tests were made in two different mud bottoms and one sand bottom location. The STATO anchors were reported to have a more uniform performance and a more reliable operation in the mud bottoms. Results of the tests are shown in Table 3. Tests were conducted using 1,200 feet of 1-3/8-inch-diameter wire rope in about 75 feet of water.



Anchor Weight (lb)	Stabilizer Length (one) (in.)	Hinge Padeye Thickness (in.)	Bolt Diam* (in.)	Y&D Dwg. No.
3,000	34	5/8	3/4	813584
6,000	44	3/4	1	813583
9,000	54	7/8	1-1/4	813561
12,000	67	1	1-1/2	879085
15,000	74	1-1/8	1-3/4	813464

* ASTM A325

Figure 13. Hinged stabilizer for STATO anchor.

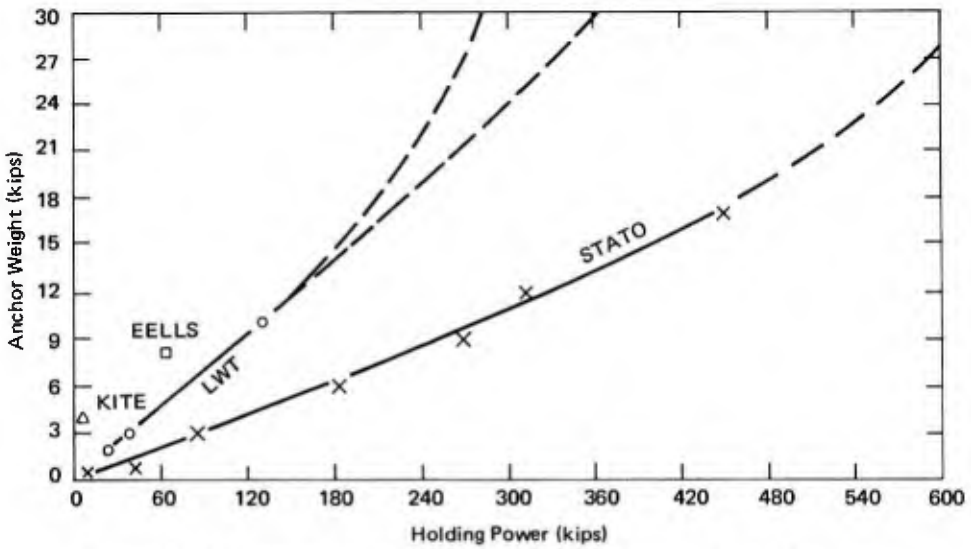


Figure 14. Maximum holding powers in sand for various types of anchors.

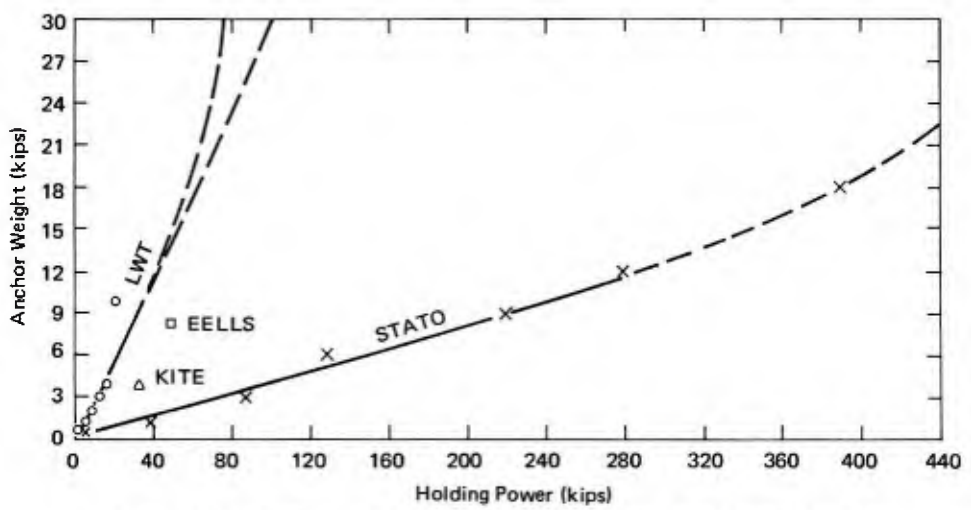


Figure 15. Maximum holding powers in mud of various types of anchors.

Table 3. Anchor Holding Power Tests

Bottom	STATO Holding Power (lb)			LWT Holding Power (lb)		
	At 100-Foot Drag	Average During Test	Highest Average for 25-Foot Drag	At 100-Foot Drag	Average During Test	Highest Average for 25-Foot Drag
Mud #1	30,800[1]	29,400[1]	39,200[1]	16,000[2]	15,300[2]	20,400[2]
Mud #2[3]	28,000[1]	26,000[1]	34,700[1]	2,400[1]	–	–
Sand	28,700[4]	26,800[4]	35,700[4]	18,000[2]	17,100[2]	22,800[2]

[1] Fluke angle 50 degrees.

[2] Fluke angle 30 degrees.

[3] Mud #2 was reported to have a lower shear value than Mud #1.

[4] Fluke angle 34 degrees.

STATO Design Criteria

The STATO anchors are designed to be fabricated from mild steel plate entirely by cutting and welding. These materials and construction techniques were specified for anchor operation in sand and mud bottoms. Use of mild steel may result in damage to the fluke tips if the anchors are operated in a rock or coral bottom. However, the anchor design may be altered to increase the fluke tip strength, and where equipment is available the shank may be forged rather than cut from plate to reduce costs and to expedite fabrication of the anchors in quantity.

CONCLUSIONS

1. The STATO anchors are satisfactory for use in Fleet type moorings.

2. The savings in cost and weight are dependent upon the mooring size but are substantial. In addition the added holding power is significant.

3. Hinged stabilizers will effectively reduce the anchor width and facilitate shipment and stowage.

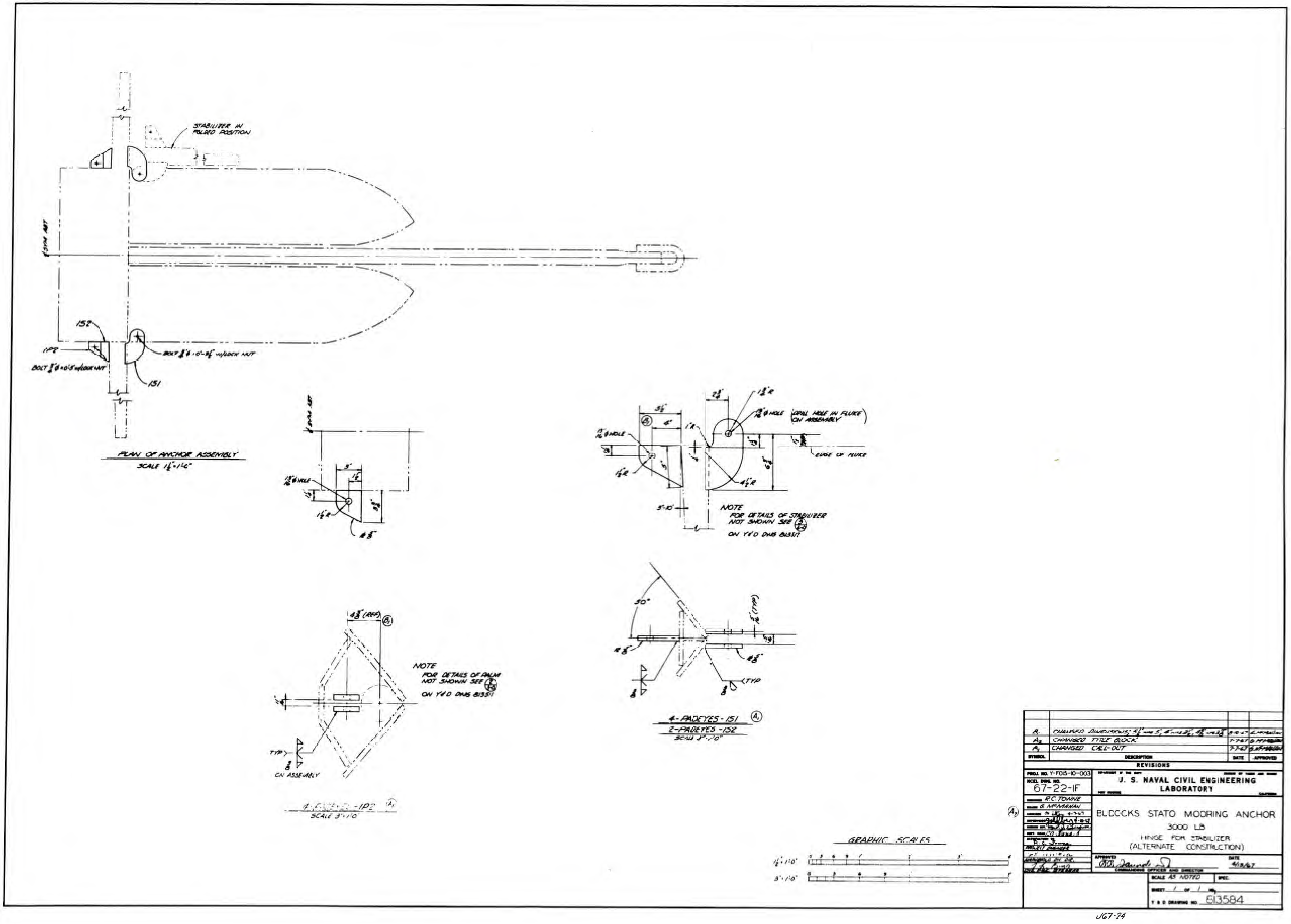
4. Palm extension plates assure fluke operation in sand bottoms overlain with mud and do not adversely affect holding power in sand.

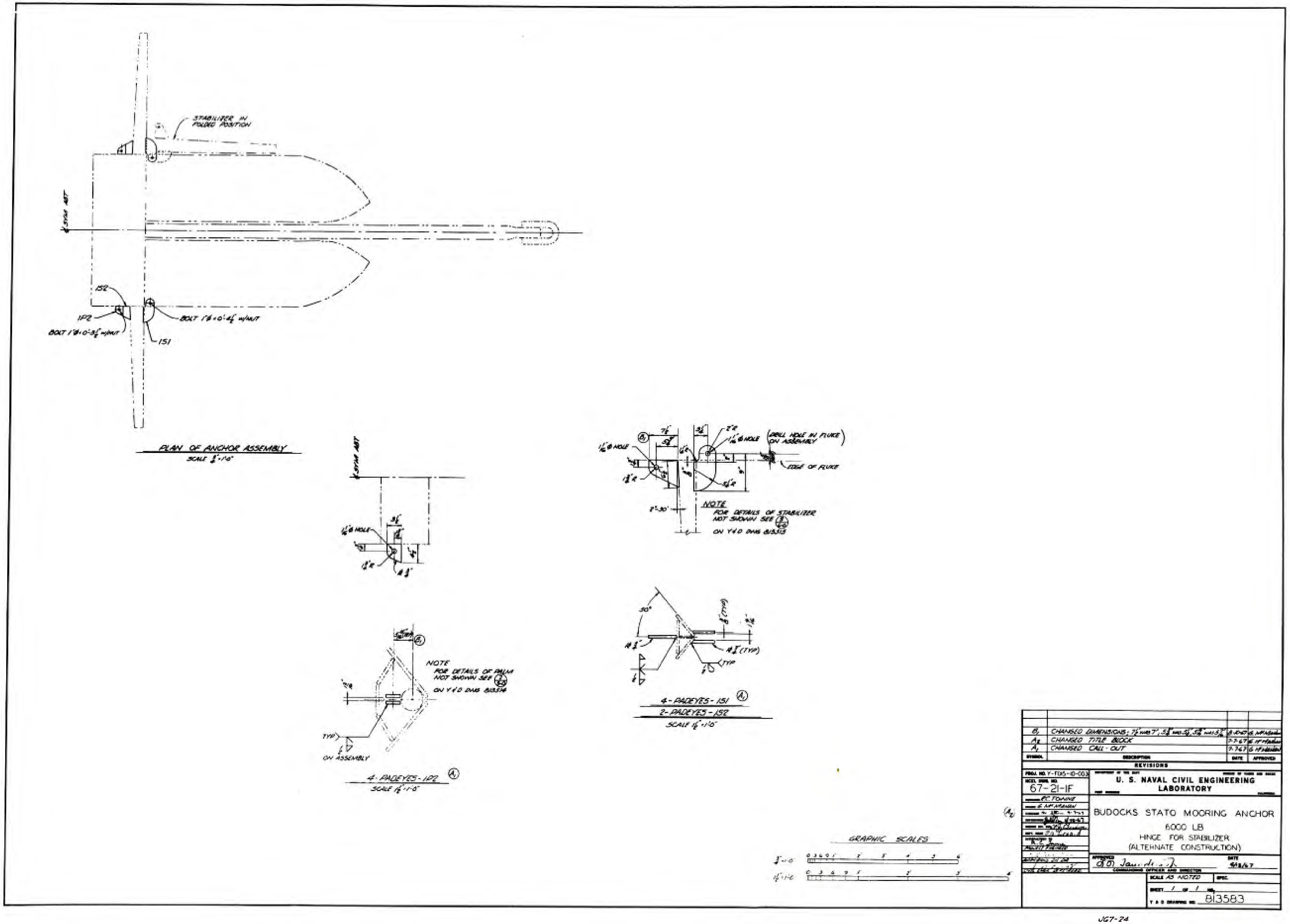
RECOMMENDATION

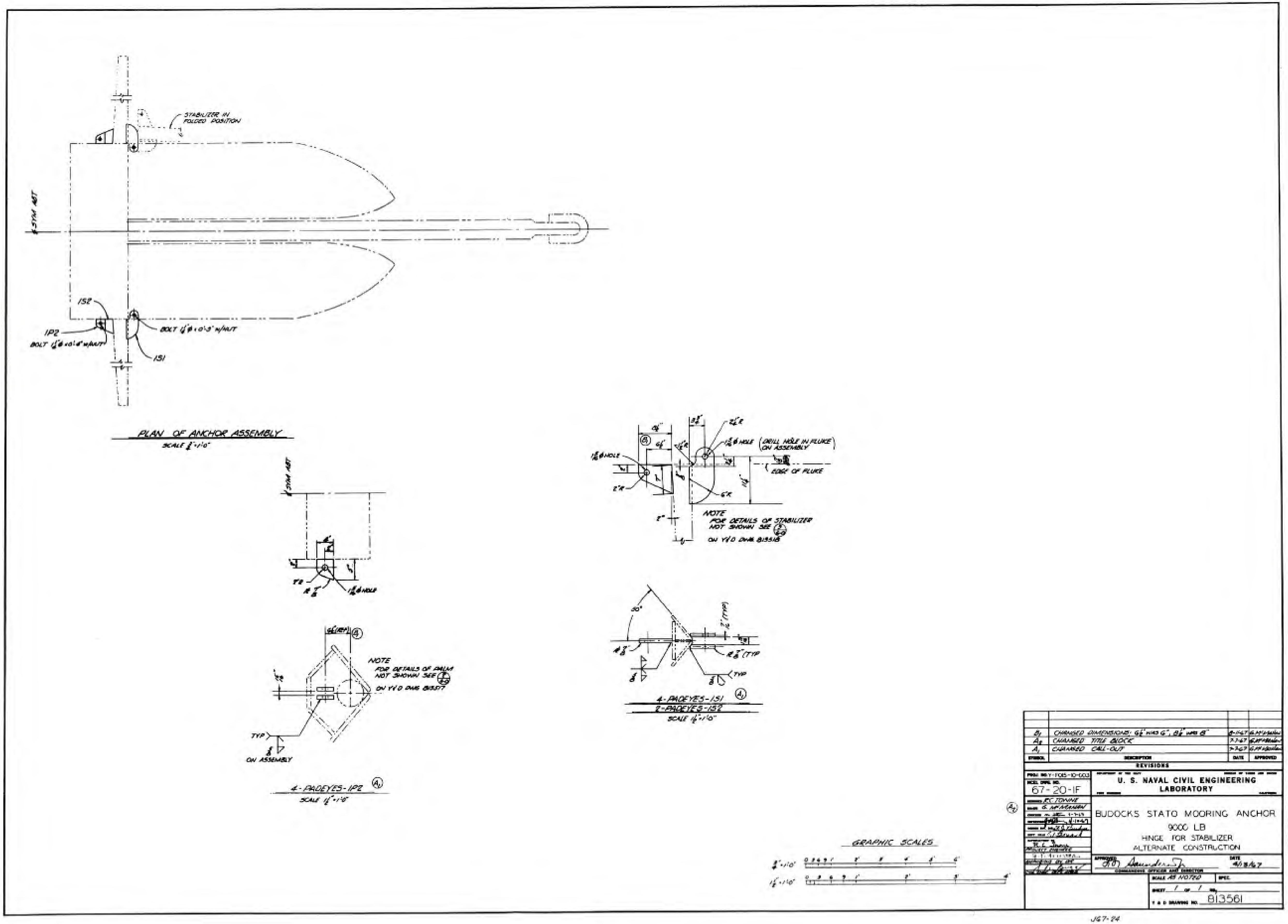
It is recommended that future anchorages requiring conventional anchors utilize the STATO anchors, especially in mud or unstable soil bottoms, or where mud or organic material overlies a sand bottom.

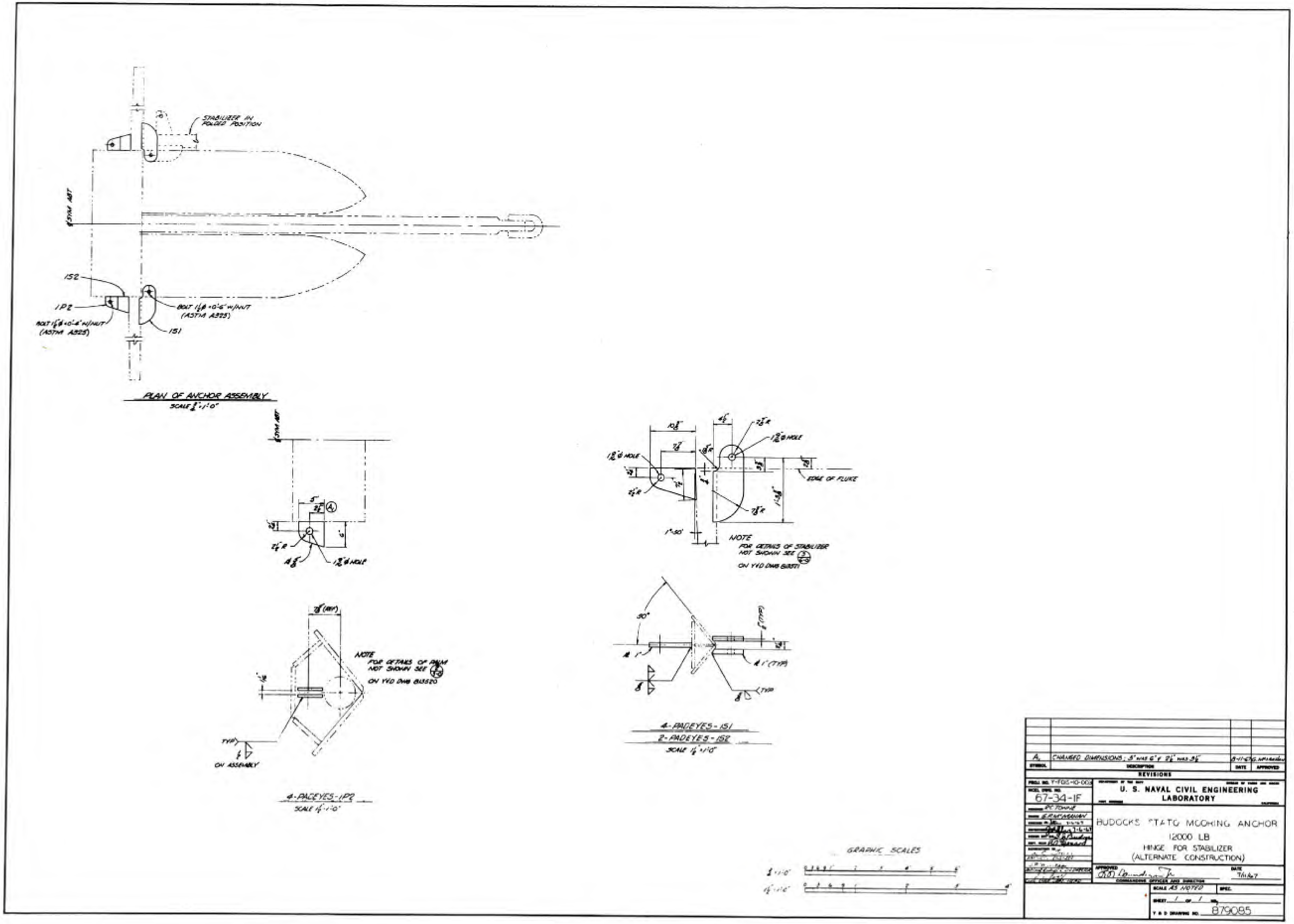
Appendix

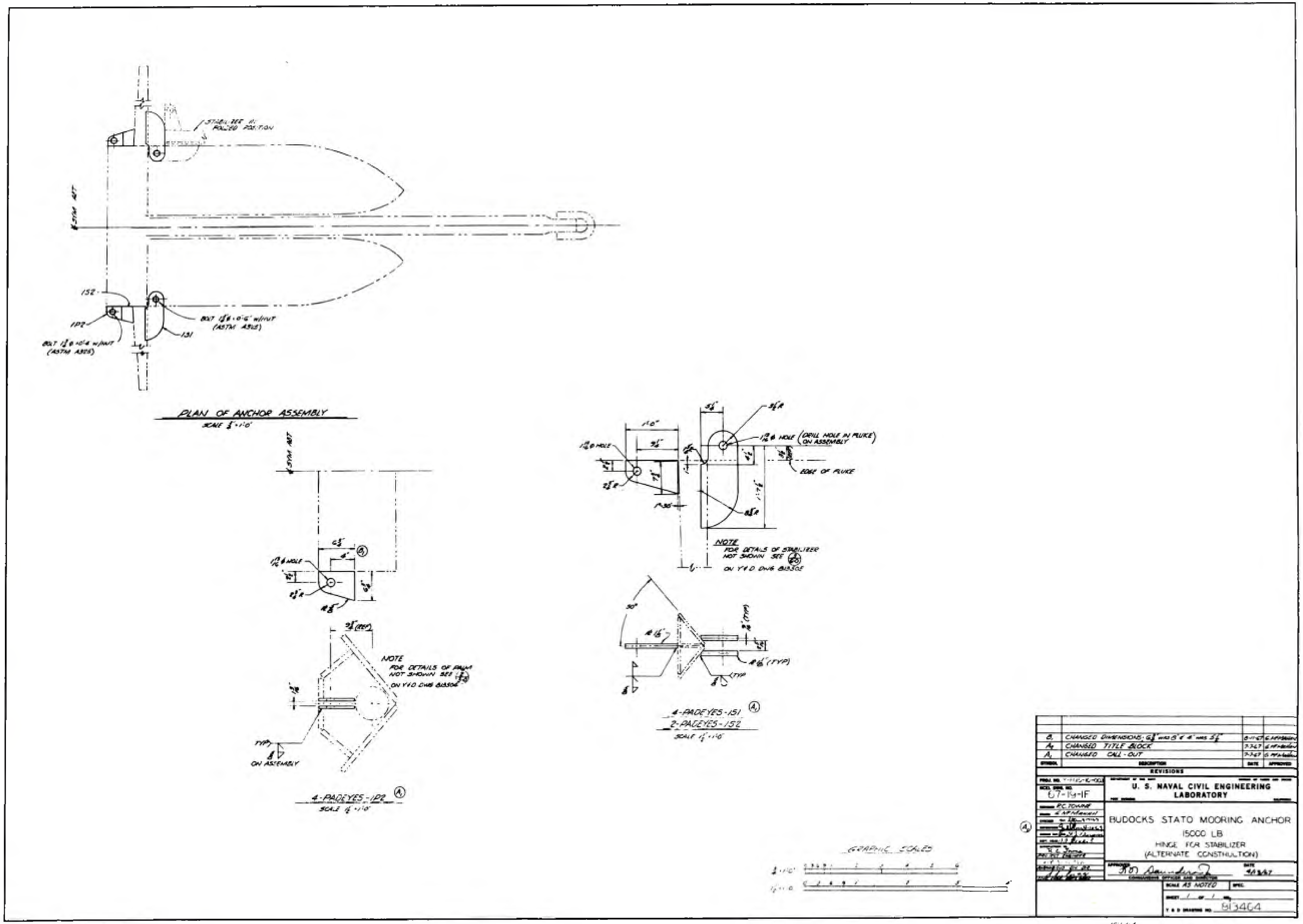
DRAWINGS OF HINGED STABILIZERS


STABILIZER IN FOLDED POSITION
BOLT 5/8" Ø x 0'-3 3/4" w/LOCK NUT
152
1P2
151
PLAN OF ANCHOR ASSEMBLY
SCALE 1 1/2"=1'-0"
NOTE
FOR DETAILS OF PALM NOT SHOWN SEE ON Y&D DWG 813511
4-PADEYES-1P2
SCALE 3"=1'-0"
ON ASSEMBLY
NOTE
FOR DETAILS OF STABILIZER NOT SHOWN SEE ON Y&D DWG 813512
EDGE OF FLUKE
(DRILL HOLE IN FLUKE ON ASSEMBLY)
4-PADEYES-151
2-PADEYES-152
SCALE 3"=1'-0"
GRAPHIC SCALES
A1 CHANGED CALL-OUT
A2 CHANGED TITLE BLOCK
REVISIONS
U. S. NAVAL CIVIL ENGINEERING LABORATORY
67-22-IF
BUDOCKS STATO MOORING ANCHOR
3000 LB
HINGE FOR STABILIZER
(ALTERNATE CONSTRUCTION)
SCALE AS NOTED
813584
JG7-24


STABILIZER IN FOLDED POSITION
PLAN OF ANCHOR ASSEMBLY
4-PADEYES-151
2-PADEYES-152
4-PADEYES-1P2
GRAPHIC SCALES
U. S. NAVAL CIVIL ENGINEERING LABORATORY
BUDOCKS STATO MOORING ANCHOR
6000 LB
HINGE FOR STABILIZER
(ALTERNATE CONSTRUCTION)
67-21-1F
813583
JG7-24


STABILIZER IN FOLDED POSITION
BOLT 1⅛" ø x 0'-3" W/NUT
151
152
1P2
PLAN OF ANCHOR ASSEMBLY
NOTE FOR DETAILS OF STABILIZER NOT SHOWN SEE ON Y&D DWG 813518
EDGE OF FLUKE
4-PADEYES-151
2-PADEYES-152
NOTE FOR DETAILS OF PALM NOT SHOWN SEE ON Y&D DWG 813517
ON ASSEMBLY
4-PADEYES-1P2
GRAPHIC SCALES
B1 CHANGED DIMENSIONS
A2 CHANGED TITLE BLOCK
A1 CHANGED CALL-OUT
REVISIONS
U. S. NAVAL CIVIL ENGINEERING LABORATORY
67-20-1F
BUDOCKS STATO MOORING ANCHOR
9000 LB
HINGE FOR STABILIZER
ALTERNATE CONSTRUCTION
COMMANDING OFFICER AND DIRECTOR
SCALE AS NOTED
SHEET 1 OF 1
813561
J67-24


STABILIZER IN FOLDED POSITION
BOLT 1¼"⌀ x 0'-6" W/NUT (ASTM A325)
151
152
1P2
PLAN OF ANCHOR ASSEMBLY
SCALE ⅜"=1'-0"
NOTE
FOR DETAILS OF PALM NOT SHOWN SEE
ON Y&D DWG 813520
ON ASSEMBLY
4-PADEYES-1P2
SCALE 1½"=1'-0"
EDGE OF FLUKE
NOTE
FOR DETAILS OF STABILIZER NOT SHOWN SEE
4-PADEYES-151
2-PADEYES-152
SCALE 1½"=1'-0"
GRAPHIC SCALES
A | CHANGED DIMENSIONS, 5" WAS 6" & 3¼" WAS 3½"
REVISIONS
67-34-1F
U. S. NAVAL CIVIL ENGINEERING LABORATORY
BUDOCKS "STATO" MOORING ANCHOR
12000 LB
HINGE FOR STABILIZER
(ALTERNATE CONSTRUCTION)
SCALE AS NOTED
SHEET 1 OF 1
Y & D DRAWING NO. 879085
J67-24


STABILIZER IN FOLDED POSITION
152
1P2
131
PLAN OF ANCHOR ASSEMBLY
4-PADEYES-1P2
NOTE FOR DETAILS OF PALM NOT SHOWN SEE ON Y&D DWG
ON ASSEMBLY
EDGE OF FLUKE
NOTE FOR DETAILS OF STABILIZER NOT SHOWN SEE ON Y&D DWG
4-PADEYES-151
2-PADEYES-152
GRAPHIC SCALES
B. CHANGED DIMENSIONS
A2 CHANGED TITLE BLOCK
A1 CHANGED CALL-OUT
REVISIONS
U. S. NAVAL CIVIL ENGINEERING LABORATORY
BUDOCKS STATO MOORING ANCHOR
15000 LB
HINGE FOR STABILIZER
(ALTERNATE CONSTRUCTION)
SCALE AS NOTED
813464

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5.————. Technical Memorandum M-097: Test of anchors for moorings and ground tackle design in mud bottom, by R. C. Towne and J. V. Stalcup. Port Hueneme, Calif., Dec. 1954. (AD 72623L)

6.————. Technical Note N-195: Tests of BuShips anchors in mud and sand bottoms, by R. C. Towne and J. V. Stalcup. Port Hueneme, Calif., Aug. 1954. (AD 81213L; PB 154662)

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1. Mooring anchors—In-service tests I. Y-F015-20-02-002

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OPERATIONAL EVALUATION OF THE STATO MOORING ANCHOR, by R. C. Towne and R. A. Bliss

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