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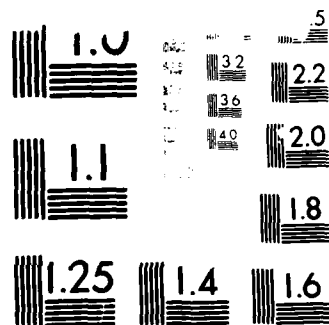
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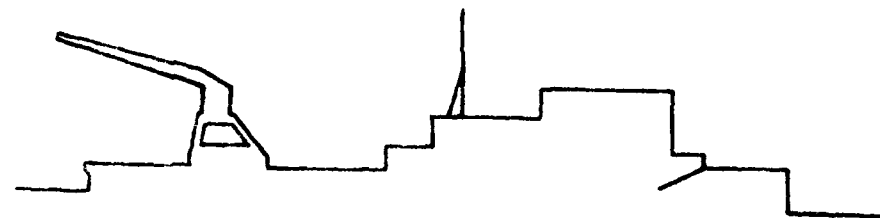
ST. CROIX MOORING DESIGN

by

William N. Seelig

FPO-1-84 (47)

December 1984



Ocean Engineering

CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON NAVY YARD
WASHINGTON, DC 20374

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This report presents the design of a mooring to service surface ships and submarines operating off the west coast of the island of St. Croix, West Indies. This emergency mooring is required because the nearby Frederiksted Pier was damaged during tropical storm "Klaus" on 1 November 1984 (Con't)

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Little geologic or environmental data are available for the site and the emergency mooring is needed quickly, so the following approach is used in design:

1. The mooring will accommodate large submarines ("Lafayette" SSBN 616 or smaller) and a wide variety of surface ships ("Spruance" DD 963 was selected as typical). These vessels have the following characteristics:

Ship Class	Ship Length (ft)	Max. Nav. Draft (ft)	Mooring Swing Circle (ft)
DD 963 "Spruance"	564.	30.	750.
SSBN 616 "Lafayette"	421.	32.	560.

2. Both static and dynamic ship/mooring forces and interactions are considered and a Class A mooring with 100 kips working holding capacity was selected. This corresponds to a maximum 2.0 knots current with a simultaneous 50 knot, 30-second duration wind. The surface ships control the design forces. The buoy is to be located 500 yards north of the pier in a water depth of 60 feet.

3. Because of the great uncertainty in bottom conditions the mooring will be installed and tested and the rating of the mooring will be re-evaluated.

4. A site survey is planned in January 1985. Design adjustment may be made based on those survey results and/or installation experiences. Drag anchors as well as Propellant Embedment Anchors will be mobilized to cover installation contingencies.

St. Croix Mooring Design

EXECUTIVE SUMMARY

This report presents the design of a mooring to service surface ships and submarines operating off the west coast of the island of St. Croix, West Indies. This emergency mooring is required because the nearby Frederiksted Pier was damaged during tropical storm "Klaus" on 1 November 1984.

Little geologic or environmental data are available for the site and the emergency mooring is needed quickly, so the following approach is used in design:

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DESIGN OF THE ST. CROIX MOORING

by

William N. Seelig, P.E.

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DESIGN OF THE ST. CROIX MOORING

by

William N. Seelig, P.E.

INTRODUCTION

The purpose of this mooring is to service submarines and surface vessels operating off the western coast of St. Croix, West Indies. The mooring is needed because the Frederiksted Pier was damaged in a storm (Figure 1).

The approach taken in this design is to custom design a mooring for the site using mostly standard materials available in U. S. Navy Fleet Mooring Inventory. Both static and dynamic behavior of ships in the mooring are considered. Propellant Embedment Anchors (PEA) are specified as the primary anchor type, due to the poor bottom conditions in the area. A "soft" buoy and protective collar around the chain riser are used to protect contact with a submarine coming close to the mooring. A sinker and three ground legs are used to provide dynamic energy absorption in the mooring.

DESIGN CONDITIONS

1. Vessels. It is not known exactly what vessels may use the mooring, so the design is tailored to service all submarines of "Lafayette Class" (SSBN 616) and smaller. The "Spruance Class" DD 963 was taken as representative of U. S. NAVY surface combatants. A list of vessels authorized to use the mooring will be made once the mooring is installed, tested and rated.
2. Environment. A 50.0 knot wind with a 30-second duration was selected for design based on engineering judgement. Note that this operational wind speed may have to be adjusted based on the rating assigned to the as-built mooring.
3. Tide. The normal tide range at the site is 0.8 feet with an extreme tide range of 1.8 feet.
4. Currents. Little is known about the currents in the area. Howard Kelly (LANTDIV, phonecon of 12/10/84) states that current speed varies with location, but could be up to 2 knots. A design current of 2.0 knots is therefore specified. More information on currents should become available as a result of a planned site survey and based on observations made during mooring installation.

5. Bathymetry Data. Chart Number 25644 (May 1975) and NOAA survey files (personnel communication, National Ocean Survey) provided water depth and bottom conditions data. National Ocean Survey study of the area shows that the bottom is a combination of coral and sand (Figure 2).

6. Additional Data. An Underwater Construction Team One (UCT-1) is being planned for January 1985 which should provide additional information on bottom type, sediment thickness, bottom slope, water depths and current speeds.

DESIGN FORCES

The mooring design is based on static and dynamic design forces. A ship in a mooring may have much different motions than an unmoored vessel at the same site. This dynamic behavior depends on characteristics of the mooring and ship. Therefore, an iterative design procedure was used and many alternative designs considered. Only the selected design is presented in this report.

1. STATIC FORCES.

Methods in Design Manual 26.5 "Fleet Mooring" (95% Submittal) were used to calculate static mooring forces. In this method the design current speed of 2.0 knots was used. Thirty second wind speeds of both 35 and 50 knots were used to obtain data on the sensitivity of forces on wind speeds. Calculation in Appendices A and B were then used, together with a computer program, to find the equilibrium position of the vessel (Figure 3). Once the equilibrium position is known the required static mooring hawser tension (Figure 3) is also calculated using the computer program. Calculation procedures are described in great detail in DM 26.5, so they are not repeated here.

Little is known about the direction of currents and winds at the design site. Therefore, the approach taken here was to assume that the winds and currents could come from any direction. Relative wind/current directions at 10 degree angle increments were all analyzed and the combination of directions that gave the highest mooring force were selected for design. These static design equilibrium forces are given in Table 1.

2. SHIP DYNAMICS - YAW.

Even in relatively steady wind and current conditions a vessel moored to a single point mooring may experience dynamic action. Many references document this "fish-tailing" illustrated in Figure 4 (see Chrenshaw, R. S., Naval Shiphandling, Naval Institute Press, Annapolis, Md., 1975). "Fish-tailing" occurs because the total moment curve of the ship in the mooring may have a flat slope near the "equilibrium" position. Even a very small perturbation in forcing causes the ship to yaw from equilibrium (Figure 5). Ship inertia together with the flat sloped moment curve means that the ship may have ± 20 degree of yaw from equilibrium before the ship is brought back towards equilibrium. The main consequence of this yawing action is that mooring hawser forces are greatly increased. For example, the DD 963 calculations shown in Figure 5 indicate a 42 kip static mooring load at equilibrium that jumps to 96 kips at ± 20 degrees yaw (wind and current azimuth both 270 degrees for the example shown). Design forces including the ± 20 degree yaw are shown in Table 1 for the DD 963. Values at ± 10 degree yaw are used for the SSBN 616 (Figure 6 and Table 1). The smaller value of yaw for the submarine is justified based on the fact that the total restoring moment on a SSBN 616 is higher than for a DD 963.

3. DYNAMIC FORCES - SURGE.

A ship may also surge while in a mooring. Surge may be especially important, even if it is small, because (a) moorings may be highly non-linear and a small change in ship deflection away from the ground ring will produce a large increase in mooring force and (b) the ship and mooring (if poorly designed) may get into a resonance condition where motions and forces can be amplified.

Surge dynamics are investigated in this report by use of a one-dimensional computer program that simulates important aspects of the mooring, ship and forcing. Details of this numerical model are too complex to present here. The following gives a summary of important computer program components:

a. The mooring is represented by the non-linear load/deflection curves shown in Figure 7. Deflection (surge) of the bow of the ship away from the ground ring is shown on the x-axis and restoring force in the mooring shown on the y-axis. The load/deflection curve includes non-linear stretch of the mooring hawser (if any), submergence and rotation of the buoy, displacement of the riser catenary, lifting of the sinker, lifting and the catenary of ground legs.

b. The forcing wind is generated by the computer using the wind spectrum presented in Vellozzi, J. et al, "Gust Response Factors", ASCE, Structural Division, June 1968, pp. 1295-1313. This generalized wind spectral shape was developed by analyzing records from 90 storms under a wide variety of conditions. The computer takes the spectrum, uses wind energy components with periods between 5 seconds and one hour and generates the instantaneous wind acting on the vessel at one second intervals. A sample wind time history is given in Figure 8.

c. Hydraulic forcing on the vessel includes a steady current and reversing current component due to long waves.

d. Ship response/forcing includes: ship mass; added mass; damping; non-linear wind forcing; non-linear current forcing including the effects of the ship motion; and non-linear restoring forcing of the mooring. The solution is a time-marching scheme that updates the forcing and ship conditions at one-second intervals. Conditions are modeled for 1000 seconds and the highest predicted mooring hawser tension reported.

Sample computer plots of mooring hawser tension are given in Figure 9 (DD 963) and Figure 10 (SSBN 616). The destroyer is predicted to experience significant dynamics during a storm, while the submarine remains relatively static. These and many other computer plots show that the ship/mooring combination is well matched and that yaw action produces the highest total mooring force (Table 1).

MOORING DESIGN

The selected mooring design (Figure 11) was evolved after considering many factors:

- a. A Class "A" mooring with 100 kips restoring force is desirable.
- b. The SEACON will be used for installation.
- c. The SEACON can easily mobilize any materials from the inventory of Fleet Mooring Materials in San Diego.
- d. Installation is planned for early 1985.
- e. The mooring will be used for surface ships, which require moorings with good energy absorption characteristics.
- f. Submarines will use the mooring, therefore the buoy should be soft and the riser chain will be protected to minimize the possibility of metal contact with the submarine.
- g. Propellant Embedment Anchors are used as the best and most cost effective method of providing anchoring considering the bottom type. However, since bottom conditions are poorly known, Stockless Anchors will also be mobilized as a contingency.

Predicted characteristics of the mooring with some notes are shown in Figure 12. Note that the energy absorption characteristics of the mooring are good throughout the working range of the mooring.

Materials to be mobilized for this mooring are given in Table 2. This list includes some spare materials. Cathodic protection for the chain is illustrated in Appendix D. Three 20-kip Stockless Anchors are also specified. These anchors could be used in various combination, if one or more of the PEA placements are unsuccessful. Another advantage of mobilizing these anchors is that they are needed for other projects on the U. S. East Coast, if the PEA's are successful.

MOORING LOCATION

A study of the required swing circles (Table 3), required water depths, bottom slopes and use of the mooring suggests that the site shown in Figure 13 is by far the best location for the mooring. Figure 14 shows the ships in the mooring at scale with the ship perpendicular to shore.

INSTALLATION SEQUENCE

The following general installation sequence is recommended. More detailed installation plans will be formulated by the FPO-1 Construction Division as the project progresses.

1. Mobilize to the site with materials.
2. Locate the mooring site.
3. Locate the exact position of two of the PEA's.
4. Install, set and test the two PEA's.
5. Attach one ground leg to each of the two PEA's, attach riser, buoy, sinker and ground ring. Also attach the third ground leg.
6. Put the mooring in the water.
7. Tighten the mooring by pulling the mooring towards the third anchor site.
8. Locate, install and test the third PEA.
9. Attach the third PEA.

SUMMARY

A mooring design is presented for western St. Croix to service submarines and surface ships. Mooring use, performance characteristics, environmental conditions, the site, installation equipment and available Fleet Mooring Inventory materials were all considered in formulating the design.

Unique features of this mooring are that a "Soft" mooring buoy and covering riser chain are provided to minimize the possibility of damage to a moored submarine.

This mooring should be installed and each anchor leg tested. At that time the capacity and use of the mooring will have to be re-evaluated. This procedure is recommended due to the uncertain conditions at the site.

CHESAPEAKE		DIVISION	PROJECT: <u>St. Croix Mooring</u>
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: <u>W. Seelig</u>		date: <u>12/21/84</u>	Calculations for: <u>Compare CGN 38 "Virginia"</u> <u>and DD963</u>
Calcs ck'd by: <u>At</u>		date: _____	

DD963 "Spruance" was used as the basis of design as a typical surface vessel. How does the CGN 38 compare? Under what conditions could it use the mooring?

	<u>L(H)</u>	<u>B(H)</u>	<u>Max Drift</u>	<u>Front Wind Area</u>	<u>Disp</u>
"Spruance" DD963	529.	55.	30.0	4350.	6450. LT
"Virginia" CGN 38	586.	61.	32.6	4430.	9220. LT

Frontal wind areas are about the same, so both vessels are good to about 50 knots of wind (as a first approximation). Exact conditions will be determined after mooring is installed and tested.

Water depth in the swing circle of the mooring site is at least 40 feet (to be verified by a UCT-1 inspection). Therefore, water depth is adequate.

Conclusion: "Virginia" CGN 38 could safely use the as-designed mooring.

CHESAPEAKE	DIVISION	PROJECT: <u>St. Cas. Mooring</u>
Naval Facilities Engineering Command	NDW	Station: _____
DISCIPLINE		E S R: _____ Contract: _____
Calcs made by: <u>W. Seelig</u>	date: <u>12/19/84</u>	Calculations for: <u>Compare LPD-4</u>
Calcs ck'd by: <u>AT</u>	date: _____	<u>and DD963</u>

	Max Nav. Draft			Wind Area End	Disp.
	L (ft)	B (ft)	T (ft)	(ft ²)	(L.T.)
"Spruce" DD963	529	55.	300	4350.	6,450.
LPD-4	570.	84.	27.0	8100.	11,480.

The LPD-4 has 86% more frontal wind area than the DD963. The mooring is designed for 100 kips, which corresponds to a 50 knot wind with the DD963. Wind Controls, so the max winds that an LPD-4 could use the mooring is approximately:

$$\text{Wind} = \frac{4350}{8100} \times 50 \text{ knots} \approx 27 \text{ knots}$$

Dynamics, etc. will have to be checked to verify this estimate.

page ____ of ____

Conclusion: The LPD-4 could only use the as-designed mooring in relatively calm conditions.

Table 1. DESIGN FORCES

30-second duration design wind speed = 50 knots
 design current speed = 2.0 knots*

Design Load Between Ship & Mooring
 (Kips)

<u>Condition</u>	"Spruance" DD 963 L = 564 ft	"Lafayette" SSBN 616 L = 421 ft
Static Equilibrium	42	7.5
Static + Dynamic Yaw	100 (+/-20 deg)	31 (+/-10 deg)
Static + Dynamic Surge	56	8.2

*Relative direction between wind and current selected for each case to give the highest load.

Table 2. Mooring Materials to Mobilize to the Site

<u>Item</u>	<u>Total Number (including spares)</u>
2 1/4" Chain	13 shots (or 12 shots + short sections)
2 1/4" Shackles	6
2 1/4" Detachable Links	17
2 1/4" Anchor Joining Links	10
2 1/2" Anchor Joining Links	3
2 1/4" Size Ground Ring	1
2 1/4" Sinker Shackle	3
16 Kip Stockless Anchor	1
20 Kip Stockless Anchor	3
100 Kip PEA Package	4
20 Kip Reserve Buoyancy Buoy (soft type)	1
2 1/4" Pelican Hooks	2
Chain Cathodic Protection Assemblies	10
2 1/4" Pear Links	4
Tires	As Needed

Table 3. Ship/Mooring Characteristics

Ship Class	Ship Length (ft)	Approx. Hawser Length (ft)	Max. Nav. Draft (ft)	Mooring Swing Circle
"Spruance" DD 963	564.	150.	30.	750.
"Lafayette" SSBN 616	421.	100.	32.	560.

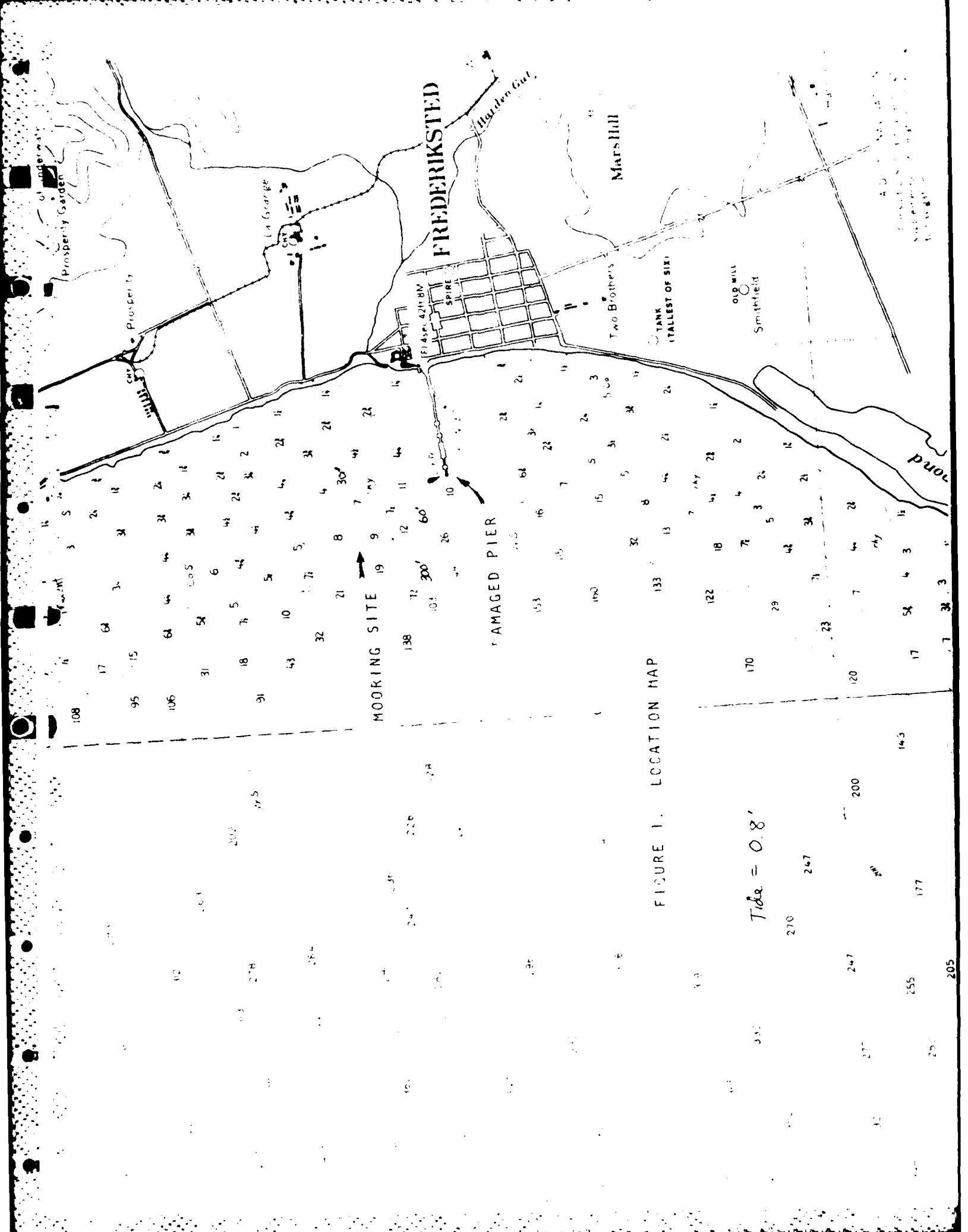


FIGURE 1. LOCATION MAP

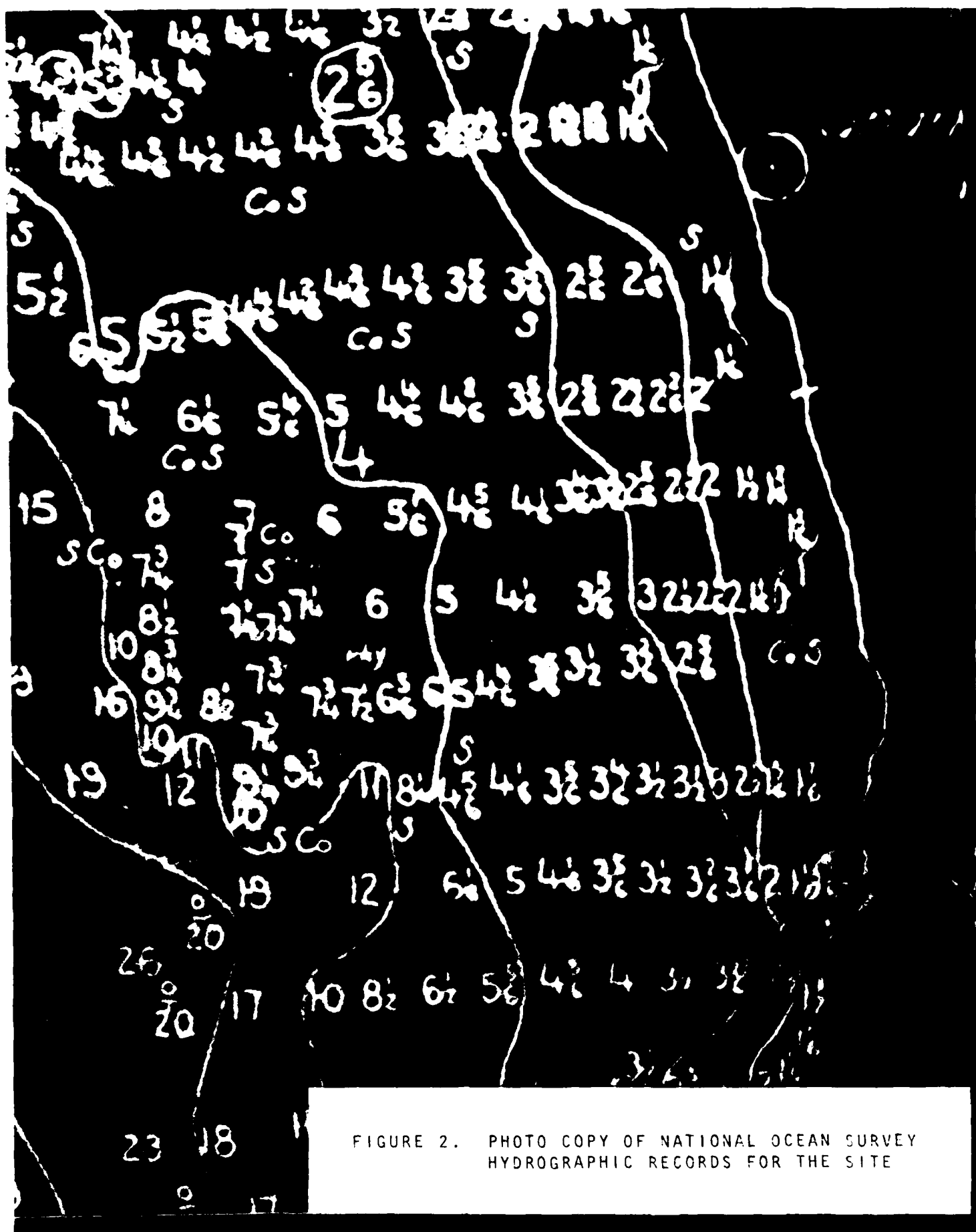


FIGURE 2. PHOTO COPY OF NATIONAL OCEAN SURVEY
HYDROGRAPHIC RECORDS FOR THE SITE

CHESAPEAKE		DIVISION	PROJECT: <u>St. Croix Mooring</u>
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE		E S R: _____	Contract: _____
Calcs made by: <u>W. SEELIG</u>	date: <u>12/14/84</u>	Calculations for: <u>Ship in Mooring</u>	
Calcs ck'd by: <u>CA</u>	date: _____	_____	

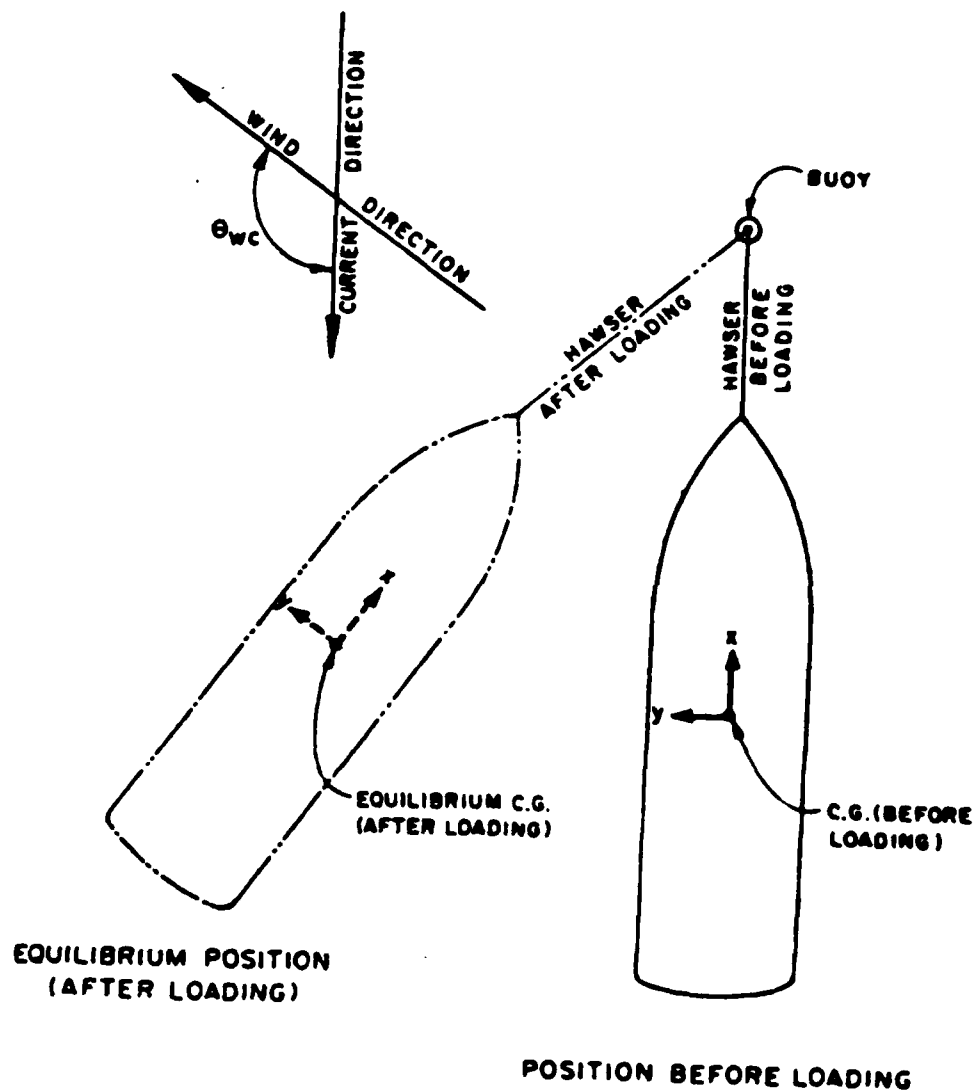


Figure 3. SHIP IN A SINGLE POINT MOORING

CHESAPEAKE**DIVISION****PROJECT:** St. Croix Mooring

Naval Facilities Engineering Command

NDW**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____Calcs made by: W. Seelindate: 12/14/84Calculations for: "Fish Tailing"

Calcs ck'd by: _____

date: _____

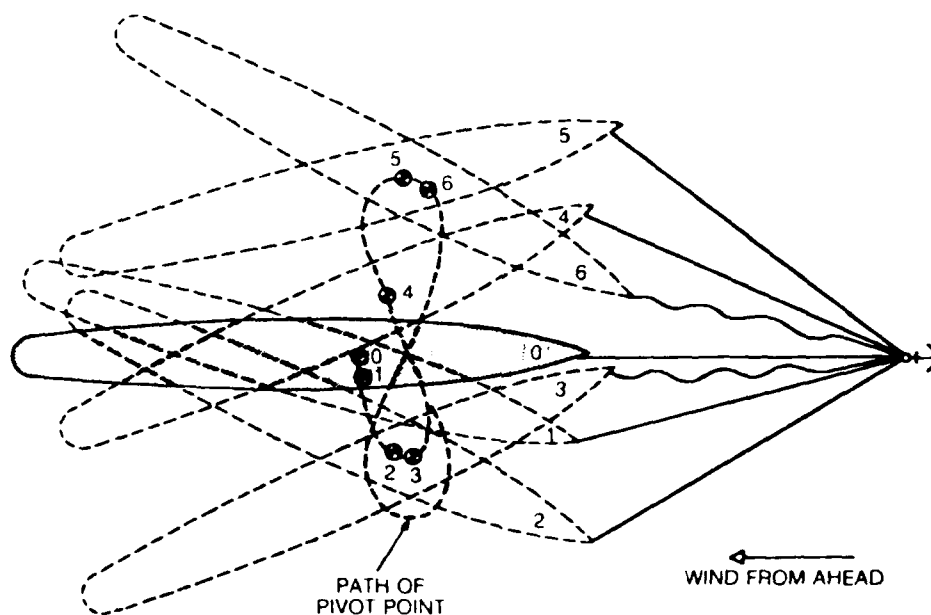


FIGURE 4. A SHIP FISH TAILING IN A
SINGLE POINT MOORING

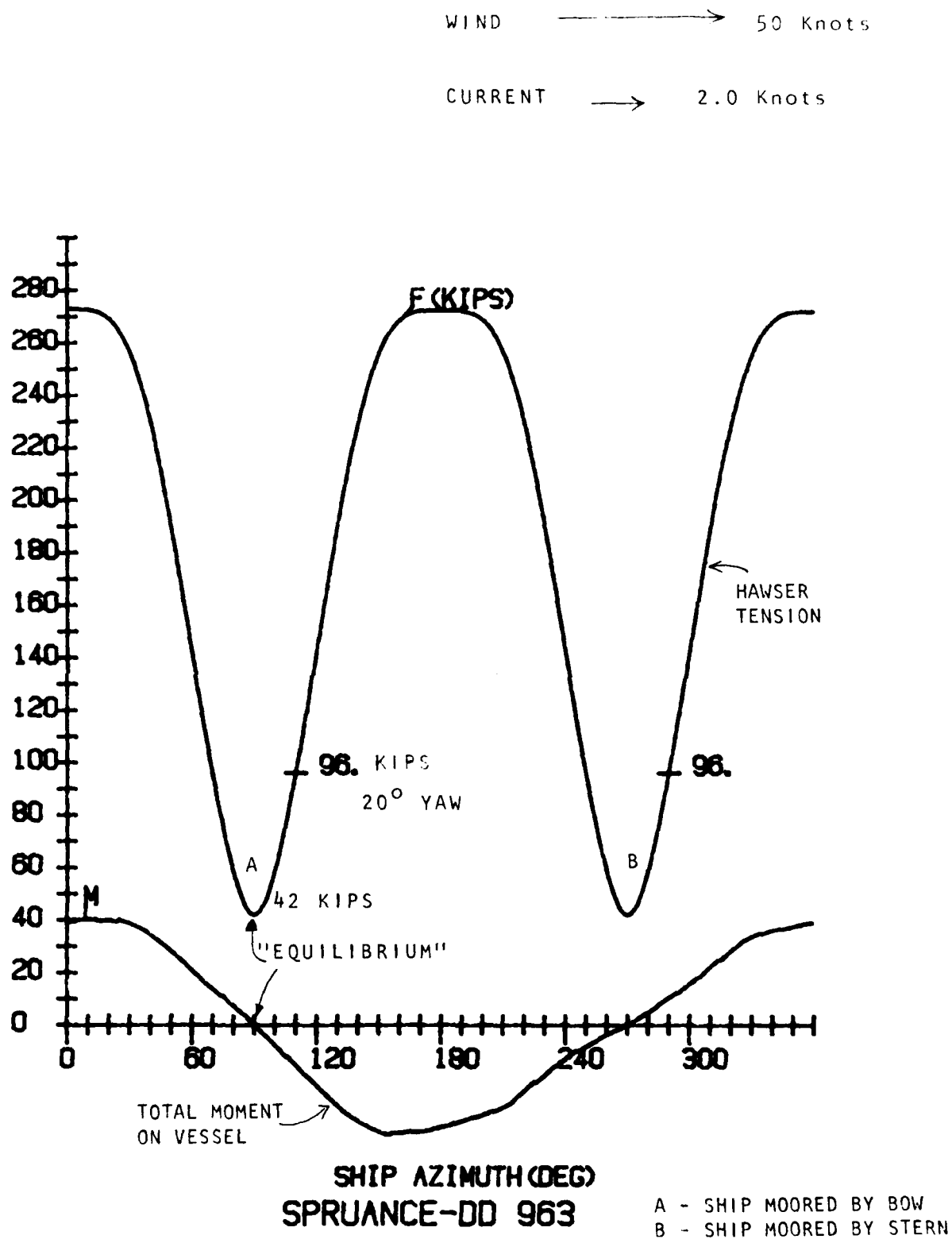
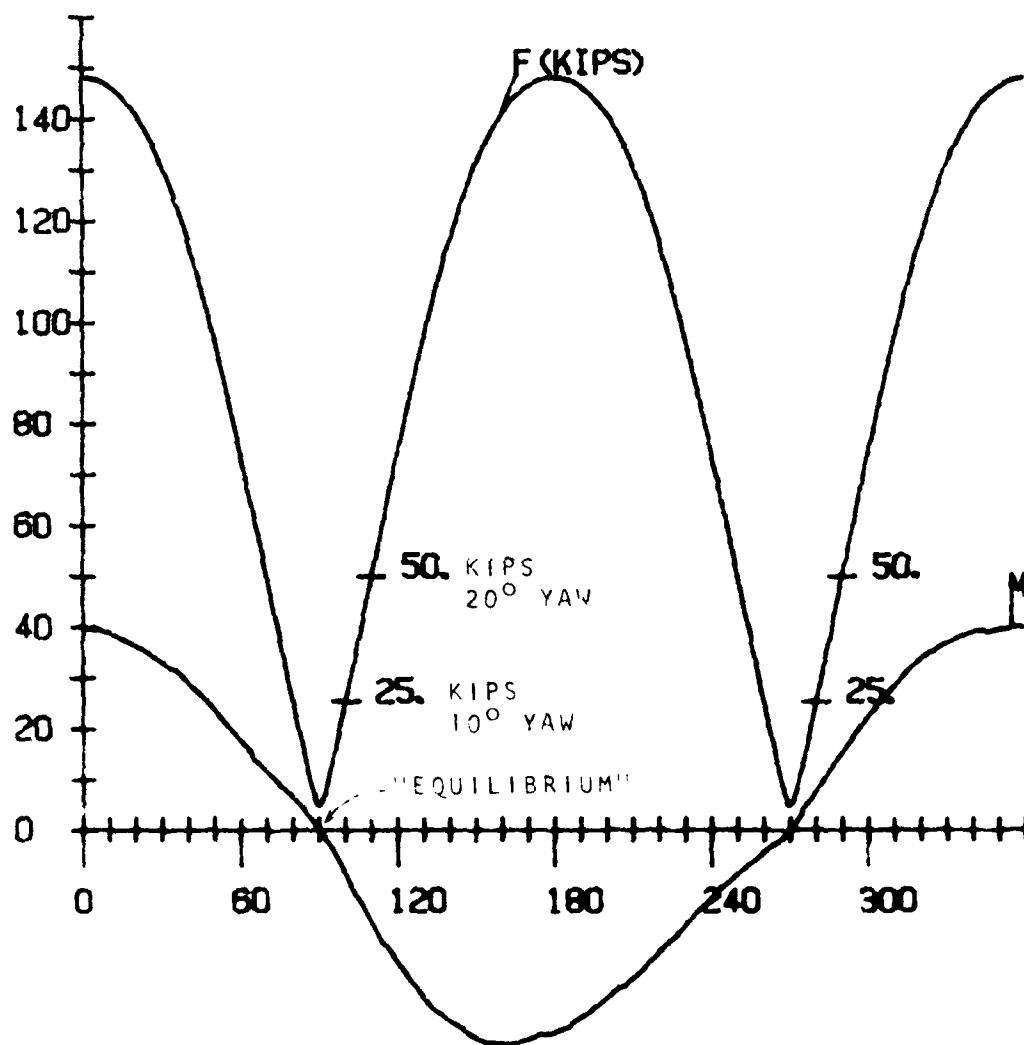


FIGURE 5. MOORING HAWSER TENSION FOR A DD 963
AT A SINGLE POINT MOOR UNDER
"EQUILIBRIUM" AND VARIOUS AMOUNTS OF YAW

WIND → 50 Knots

CURRENT → 2.0 Knots



SHIP AZIMUTH (DEG)
LAFAYETTE - SSBN 616

FIGURE 6. MOORING HAWSER TENSION FOR A SSBN 616
AT A SINGLE POINT MOOR UNDER
"EQUILIBRIUM" AND VARIOUS AMOUNTS OF YAW

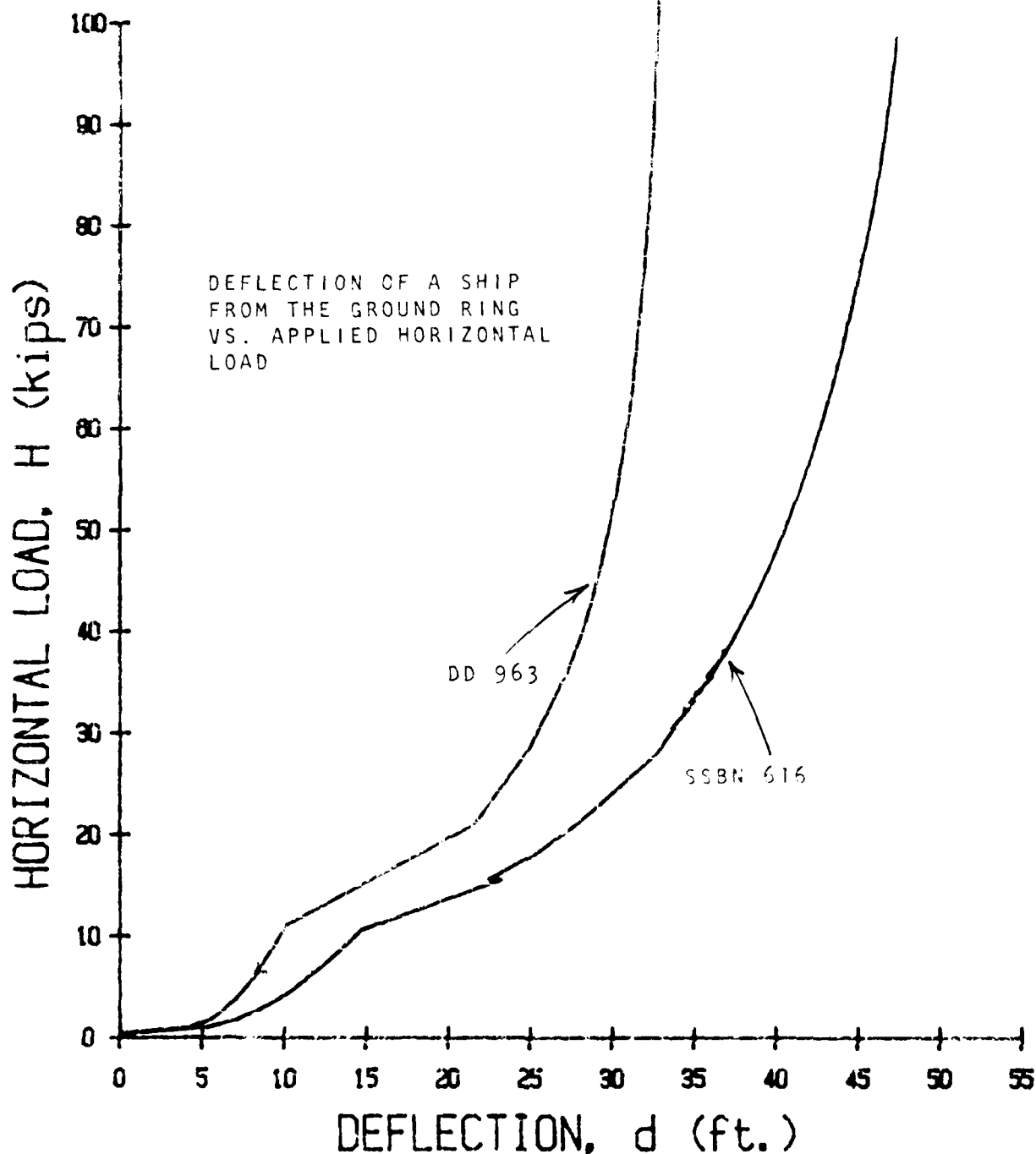
CHESAPEAKE**DIVISION****PROJECT:** St. Croix Mooring

Naval Facilities Engineering Command

NDW**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____Calcs made by: W. SEELIGdate: 12/14/84Calculations for: Load/Deflection Curves
Ships in the Mooring

Calcs ck'd by: _____

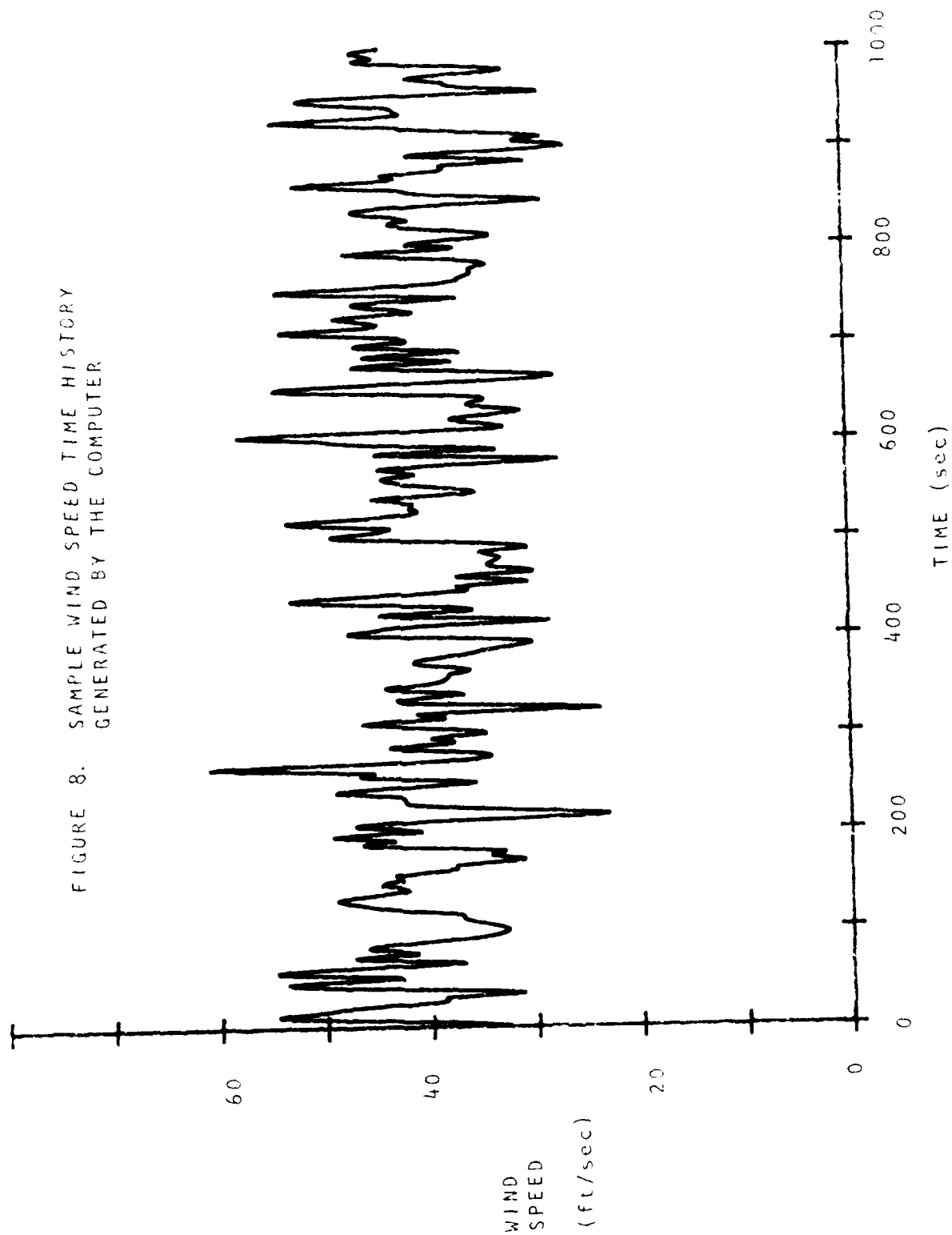
date: _____



page ____ of ____

FIGURE 7. LOAD DEFLECTION CURVES FOR SHIPS IN THE MOORING

FIGURE 8. SAMPLE WIND SPEED TIME HISTORY
GENERATED BY THE COMPUTER



30-second wind speed 57 mph
steady current 2.0 knots

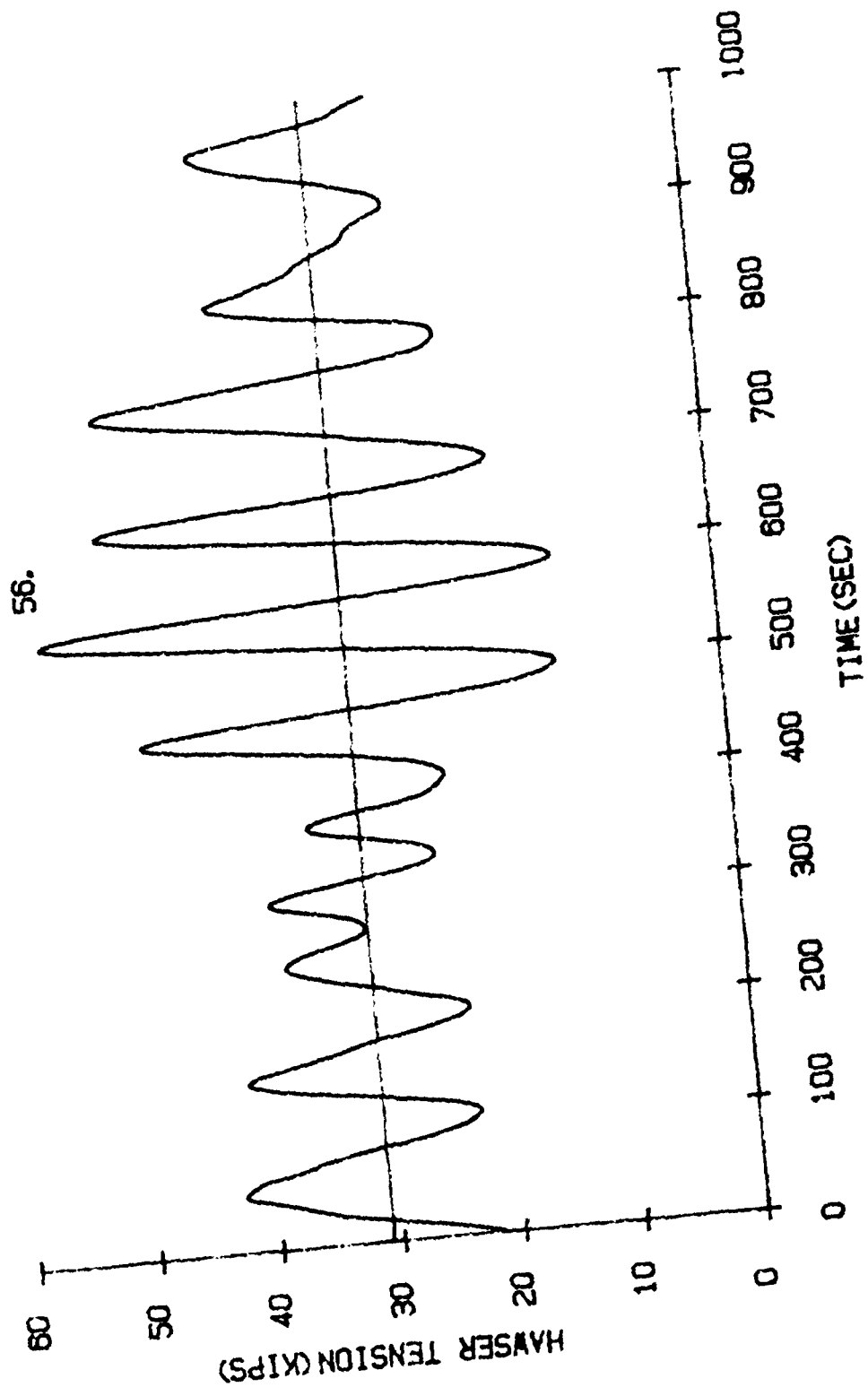
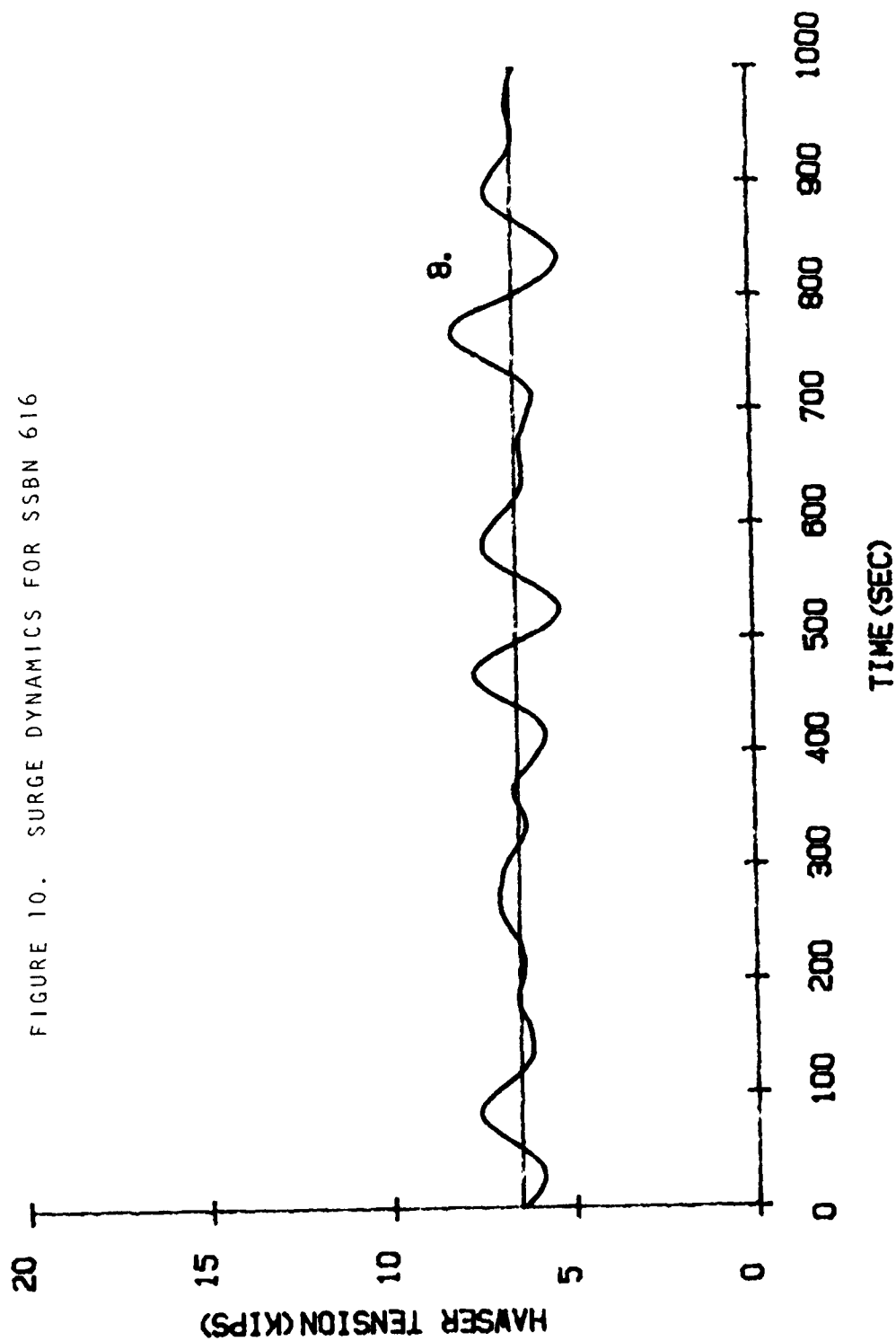


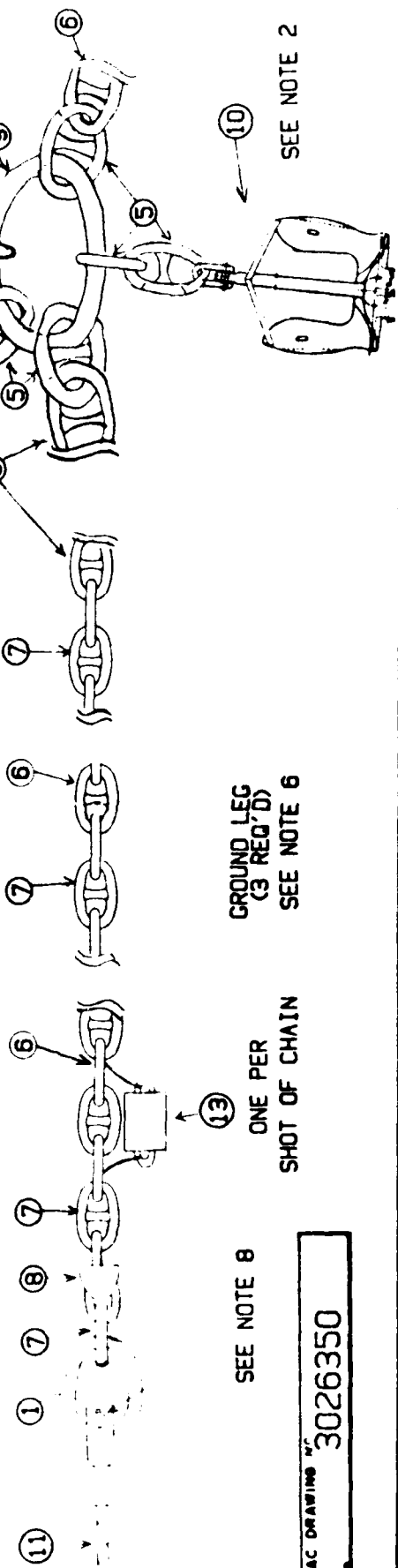
FIGURE 9. HAWSER TENSION UNDER SURGE DYNAMICS (DD 963)

30-second wind speed - 50 Knots
steady current speed - 2.0 Knots



PARTS LIST				MATERIAL	
QTY	DESCRIPTION	UNIT	REMARKS	QTY	REMARKS
1	1/2 INCH THICK PLATE	1		STEEL	
2	1/2 INCH THICK PLATE	1		STEEL	
3	1/2 INCH THICK PLATE	1		STEEL	
4	1/2 INCH THICK PLATE	1		STEEL	
5	1/2 INCH THICK PLATE	1		STEEL	
6	1/2 INCH THICK PLATE	1		STEEL	
7	1/2 INCH THICK PLATE	1		STEEL	
8	1/2 INCH THICK PLATE	1		STEEL	
9	1/2 INCH THICK PLATE	1		STEEL	
10	1/2 INCH THICK PLATE	1		STEEL	
11	1/2 INCH THICK PLATE	1		STEEL	
12	1/2 INCH THICK PLATE	1		STEEL	
13	1/2 INCH THICK PLATE	1		STEEL	
14	1/2 INCH THICK PLATE	1		STEEL	
15	1/2 INCH THICK PLATE	1		STEEL	
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23	1/2 INCH THICK PLATE	1		STEEL	
24	1/2 INCH THICK PLATE	1		STEEL	
25	1/2 INCH THICK PLATE	1		STEEL	
26	1/2 INCH THICK PLATE	1		STEEL	
27	1/2 INCH THICK PLATE	1		STEEL	
28	1/2 INCH THICK PLATE	1		STEEL	
29	1/2 INCH THICK PLATE	1		STEEL	
30	1/2 INCH THICK PLATE	1		STEEL	
31	1/2 INCH THICK PLATE	1		STEEL	
32	1/2 INCH THICK PLATE	1		STEEL	
33	1/2 INCH THICK PLATE	1		STEEL	
34	1/2 INCH THICK PLATE	1		STEEL	
35	1/2 INCH THICK PLATE	1		STEEL	
36	1/2 INCH THICK PLATE	1		STEEL	
37	1/2 INCH THICK PLATE	1		STEEL	
38	1/2 INCH THICK PLATE	1		STEEL	
39	1/2 INCH THICK PLATE	1		STEEL	
40	1/2 INCH THICK PLATE	1		STEEL	
41	1/2 INCH THICK PLATE	1		STEEL	
42	1/2 INCH THICK PLATE	1		STEEL	
43	1/2 INCH THICK PLATE	1		STEEL	
44	1/2 INCH THICK PLATE	1		STEEL	
45	1/2 INCH THICK PLATE	1		STEEL	
46	1/2 INCH THICK PLATE	1		STEEL	
47	1/2 INCH THICK PLATE	1		STEEL	
48	1/2 INCH THICK PLATE	1		STEEL	
49	1/2 INCH THICK PLATE	1		STEEL	
50	1/2 INCH THICK PLATE	1		STEEL	
51	1/2 INCH THICK PLATE	1		STEEL	
52	1/2 INCH THICK PLATE	1		STEEL	
53	1/2 INCH THICK PLATE	1		STEEL	
54	1/2 INCH THICK PLATE	1		STEEL	
55	1/2 INCH THICK PLATE	1		STEEL	
56	1/2 INCH THICK PLATE	1		STEEL	
57	1/2 INCH THICK PLATE	1		STEEL	
58	1/2 INCH THICK PLATE	1		STEEL	
59	1/2 INCH THICK PLATE	1		STEEL	
60	1/2 INCH THICK PLATE	1		STEEL	
61	1/2 INCH THICK PLATE	1		STEEL	
62	1/2 INCH THICK PLATE	1		STEEL	
63	1/2 INCH THICK PLATE	1		STEEL	
64	1/2 INCH THICK PLATE	1		STEEL	
65	1/2 INCH THICK PLATE	1		STEEL	
66	1/2 INCH THICK PLATE	1		STEEL	
67	1/2 INCH THICK PLATE	1		STEEL	
68	1/2 INCH THICK PLATE	1		STEEL	
69	1/2 INCH THICK PLATE	1		STEEL	
70	1/2 INCH THICK PLATE	1		STEEL	
71	1/2 INCH THICK PLATE	1		STEEL	
72	1/2 INCH THICK PLATE	1		STEEL	
73	1/2 INCH THICK PLATE	1		STEEL	
74	1/2 INCH THICK PLATE	1		STEEL	
75	1/2 INCH THICK PLATE	1		STEEL	
76	1/2 INCH THICK PLATE	1		STEEL	
77	1/2 INCH THICK PLATE	1		STEEL	
78	1/2 INCH THICK PLATE	1		STEEL	
79	1/2 INCH THICK PLATE	1		STEEL	
80	1/2 INCH THICK PLATE	1		STEEL	
81	1/2 INCH THICK PLATE	1		STEEL	
82	1/2 INCH THICK PLATE	1		STEEL	
83	1/2 INCH THICK PLATE	1		STEEL	
84	1/2 INCH THICK PLATE	1		STEEL	
85	1/2 INCH THICK PLATE	1		STEEL	
86	1/2 INCH THICK PLATE	1		STEEL	
87	1/2 INCH THICK PLATE	1		STEEL	
88	1/2 INCH THICK PLATE	1		STEEL	
89	1/2 INCH THICK PLATE	1		STEEL	
90	1/2 INCH THICK PLATE	1		STEEL	
91	1/2 INCH THICK PLATE	1		STEEL	
92	1/2 INCH THICK PLATE	1		STEEL	
93	1/2 INCH THICK PLATE	1		STEEL	
94	1/2 INCH THICK PLATE	1		STEEL	
95	1/2 INCH THICK PLATE	1		STEEL	
96	1/2 INCH THICK PLATE	1		STEEL	
97	1/2 INCH THICK PLATE	1		STEEL	
98	1/2 INCH THICK PLATE	1		STEEL	
99	1/2 INCH THICK PLATE	1		STEEL	
100	1/2 INCH THICK PLATE	1		STEEL	

Figure 11. MOORING DESIGN



SEE NOTE 8

GROUND LEG
(3 REQ'D)
SEE NOTE 6

ONE PER
SHOT OF CHAIN

3026350

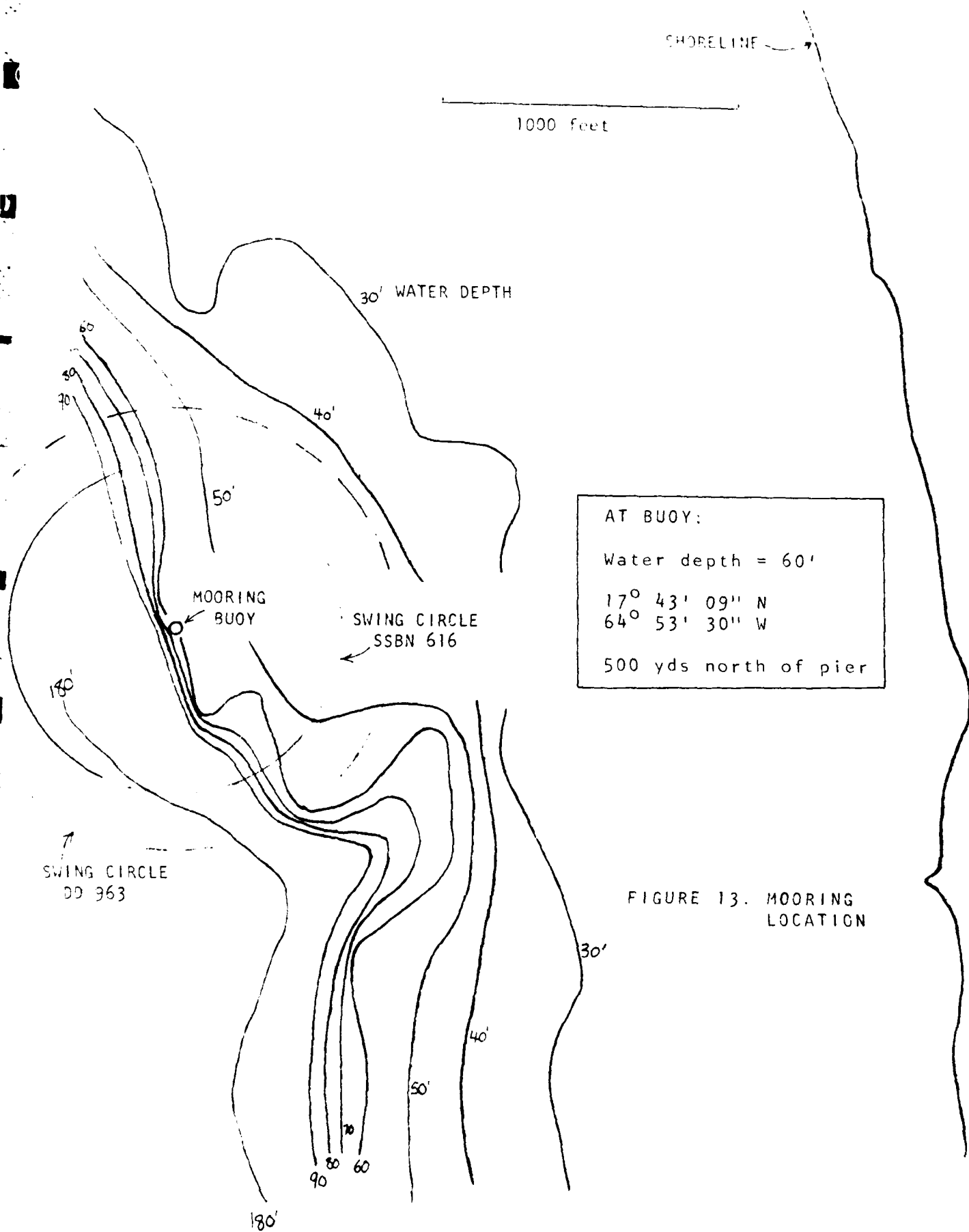


FIGURE 13. MOORING LOCATION

CHESAPEAKE**DIVISION****PROJECT:** St. Charles A. O. ring

Naval Facilities Engineering Command

NDW**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____Calcs made by: W. Seeladate: 12/14/84Calculations for: Ships in Mooring

Calcs ck'd by: _____

date: _____

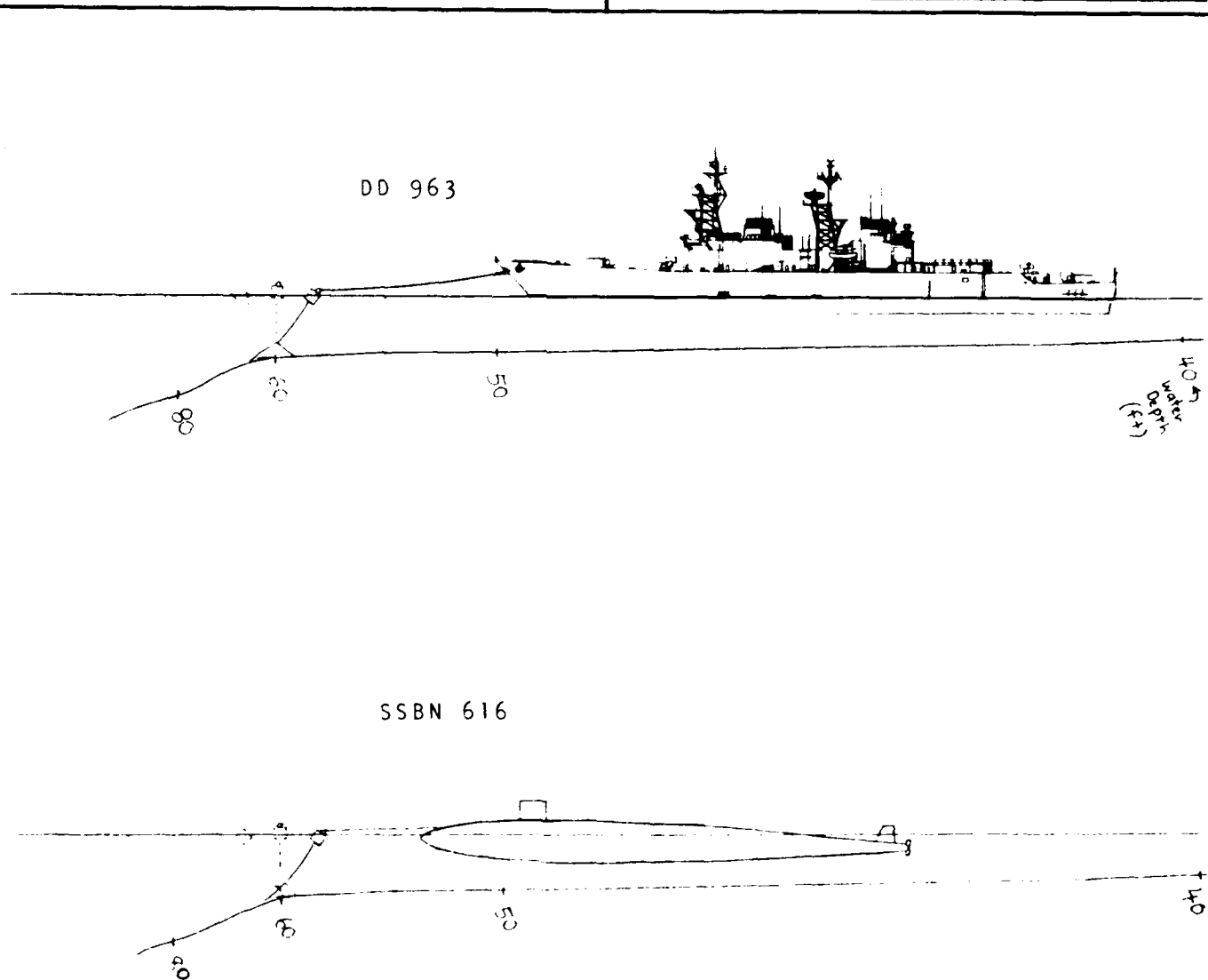


FIGURE 14. PROFILE VIEW OF TYPICAL SHIPS IN THE MOORING

APPENDIX A. FORCE CALCULATIONS FOR SSBN 616

DM - 26.5 "Fleet Moorings" is used in this appendix to calculate forces and moments due to wind and currents on a "Lafayette" Class submarine. Here force and moment calculations are made only in dimensionless form. A computer program is then used to make detailed calculations and to determine the corresponding mooring forces. The approach taken in this appendix is to directly quote and use equations in the DM. DM 26.5 (95%) can be referenced for a detailed description of equations and variables.

CHESAPEAKE	DIVISION	PROJECT: <u>SSBN 616</u>
Naval Facilities Engineering Command	NDW	Station: _____
DISCIPLINE		E S R: _____ Contract: _____
Calcs made by: <u>W. Coalg</u>	date: <u>12/15/84</u>	Calculations for: <u>SSBN-616</u>
Calcs ck'd by: <u>^</u>	date: _____	<u>Lafayette</u>

"Lafayette" SSBN 616

$L = 421'$
 $B = 33'$
 $T = 25.2'$ (32' Max navigational) $1/2$ SDRF
 $Disp = 6920$ LT. "
 $A_{side} = 4870$ ft² "
 $A_{end} = 430$ ft² "

Lateral Wind Load

$$\begin{aligned}
 E_{\text{S-11}} \quad F_{yw} &= \frac{1}{2} (1.00237) V_w^2 (0.75) f_{yw}(\theta) \times 4870 \\
 &= 4.33 V_w^2 f_{yw}(\theta)
 \end{aligned}$$

^{See Trident}
 $\uparrow$ Eq (S-15)

Longitudinal Wind Load

$$\begin{aligned}
 E_{\text{S-16}} \quad F_{xw} &= \frac{1}{2} (1.00237) V_w^2 (430) 0.4 f_{xw}(\theta) \\
 &= 0.20 V_w^2 f_{xw}(\theta)
 \end{aligned}$$

$\uparrow$ Eq (S-15)

CHESAPEAKE		DIVISION	PROJECT: _____
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE		E S R: _____	Contract: _____
Calcs made by: _____	date: _____	Calculations for: <u>Lairdette</u>	
Calcs ck'd by: <u>TC</u>	date: _____		

Wind Yaw Moment

$$\begin{aligned}
 \text{Eq (5-29)} \quad M_{xyw} &= \frac{1}{2} (1.00237) V_w^2 (4270) (421) C_{xyw}(\theta) \\
 &= 2430 V_w^2 C_{xyw}(\theta)
 \end{aligned}$$

↑ Fig 52

Lateral Current Load

$$\text{Let } wd = 75'$$

$$(5-37) \quad \phi = 35(6920) / 421 \times 33 \times 25.2 = 0.69$$

$$\text{Let } C_m \approx 1.0$$

$$\text{Then } C_p = \phi / C_m = 0.69$$

$$L/B = 421 / 33 = 12.76$$

$$C_p L / \sqrt{T} = 0.69 (421) / \sqrt{25.2} = 57.9$$

$$\text{From Fig 58} \quad k = 1.2$$

$$\text{" Fig 57} \quad C_{yc1} = 3.6$$

$$\text{" Fig 56} \quad C_{yc60} = 0.7$$

$$(5-36) \quad C_{yc} = 0.7 + (3.6 - 0.7) e^{-1.2 \left(\frac{75}{25.2} - 1 \right)} = 0.97$$

$$\begin{aligned}
 (5-35) \quad F_{yc} &= \frac{1}{2} (2) V_c^2 (421) (25.2) 0.97 \sin \theta \\
 &= 10291 V_c^2 \sin \theta
 \end{aligned}$$

CHESAPEAKE	DIVISION	PROJECT: _____
Naval Facilities Engineering Command	NDW	Station: _____
DISCIPLINE		E S R: _____ Contract: _____
Calcs made by: _____ date: _____		Calculations for: "Catawba"
Calcs ck'd by: <u>A</u> date: _____		

Longitudinal Current Load

$$(S-41) F_{xform} = \frac{1}{2}(2) V_c^2 (33)(25.2) 0.1 \cos \theta_c$$

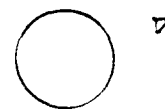
$$= 83.2 V_c^2 \cos \theta_c$$

$$(S-44) R_n = V_c (421) / |\cos \theta_c| / .000014$$

$$C_{xca} = 0.075 / (\log R_n - 2)^2$$

$$S \approx \frac{2}{3} \pi D L = 0.66 (3.14) 33 \times 421$$

$$= 28792.$$



$$(S-42) F_{xfri} = \frac{1}{2}(2) V_c^2 28792 (C_{xca}) \cos \theta_c$$

From Table 13 (Pg 113)

$$A_R = 125$$

$$(S-48) A_{TTP} = 421 (33) / 125 = 111.1$$

$$(S-47) A_p = A_{TTP} / .838 = 132.6$$

$$(S-46) F_{xprop} = \frac{1}{2}(2) V_c^2 (132.6) \cos \theta_c$$

APPENDIX B. FORCE CALCULATIONS FOR DD 963

DM - 26.5 "Fleet Moorings" (95%) is used in this appendix to calculate forces and moments due to wind and currents on a "Spruance" Class destroyer. Here force and moment calculations are made only in dimensionless form. A computer program is then used to make detailed calculations and to determine the corresponding mooring forces. The approach taken in this appendix is to directly quote and use equations in the DM. DM 26.5 can be referenced for a detailed description of equations and variables.

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE****PROJECT:** _____**Station:** _____**E S R:** _____**Contract:** _____

Calcs made by: _____

date: _____

Calcs ck'd by: _____

date: _____

Calculations for: _____

FORCE

Use DMI - 26.5 (75%)

"SPRUANCE" CLASS DESTROYER DD963

Scale 1" = 100'

$$L_{wl} = 529'$$

$$B = 55'$$

$$T = 18.8' \text{ (1/3 Stowage) } [30.0 \text{ Max Nav}]$$

$$\text{Disp} = 6450 \text{ L.T. "}$$

$$A_s = 25,250 \text{ ft}^2$$

$$A_e = 4,350 \text{ ft}^2$$

Lateral WIND LOAD

$$(5-12) \quad C_{yw} = 0.92 \left[\left(\frac{21}{33} \right)^{2/3} \times 1.6 + \left(\frac{55}{33} \right)^{2/3} \times 1.4 \right] = 0.93$$

$$F_{yw} = \frac{1}{2} (0.00237) V_w^2 25,250 (0.93) f_{yw}(\theta)$$

$$= 27.8 V_w^2 f_{yw}(\theta) *$$

*Note: coefficient value of 30.2 used.
This is conservative by 7.6%.

page ____ of ____

CHESAPEAKE		DIVISION	PROJECT: _____
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: _____ date: _____		Calculations for: _____	
Calcs ck'd by: <u>AM</u> date: _____			

Longitudinal Wind Load

$$F_{xw} = \frac{1}{2} (.00237) V_w^2 (4,350) (0.7) f_{xw}(\theta)$$

$$= 3.608 V_w^2 f_{xw}(\theta)$$

WIND YAW: MOMENT (5-29) $M_{xyw} = \frac{1}{2} (.00237) V_w^2 (29250) 529 C_{xyw}$

Lateral Current Load $= 15,828 V_w^2 C_{xyw}(\theta)$

Let $d = 75'$

$$\phi = 35 (6450) / 529 \times 55 \times 18.8 = 0.41$$

$$L_{WL}/B = 529/55 = 9.6$$

from Fig 56 Use $C_{y1\infty} = 0.4$ (Limiting value)

$$C_p \approx \phi / 1.0$$

$$C_p L_{WL} / \sqrt{T} = 0.41 + 529 / \sqrt{18.8} = 50.$$

from Fig 57 $C_{y1_2} \approx 3.2$

from Fig 58 $K \approx 0.7$

$$(5-36) \quad C_{yc} = 0.4 + (3.2 - 0.4) e^{-0.7 \left(\frac{75}{18.8} - 1 \right)}$$

$$= 0.745$$

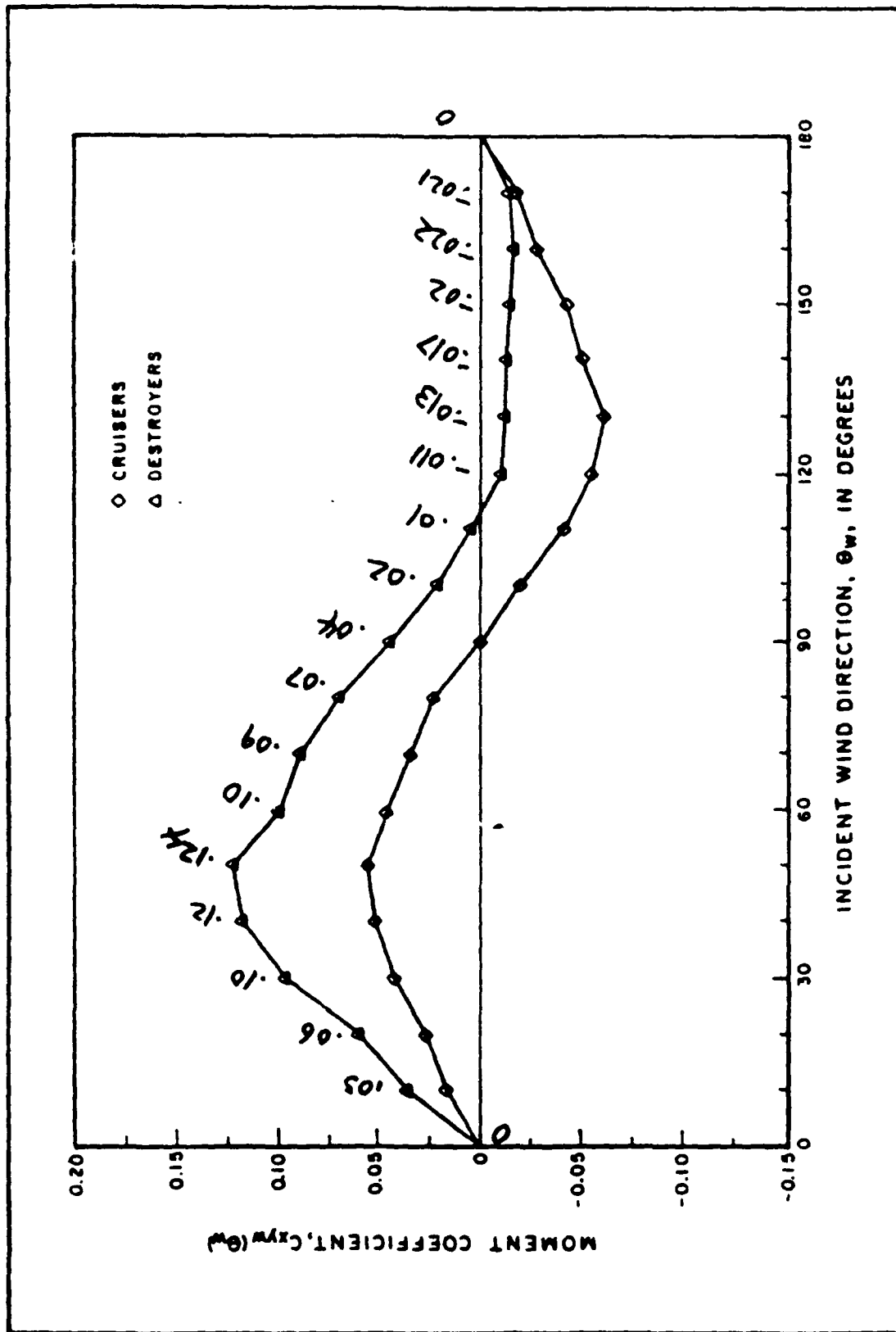


FIGURE 55
 Recommendedyaw Moment Coefficient for Typical Naval Warships

CHESAPEAKE

DIVISION

PROJECT: _____

Naval Facilities Engineering Command

NDW

Station: _____

DISCIPLINE

E S R: _____

Contract: _____

Calcs made by: _____ date: _____

Calculations for: _____

Calcs ck'd by: _____ date: _____

$$(S-35) F_{yr} = \frac{1}{2} (2) V_c^2 (529) (18.8) (0.742) \sin \theta_c$$

$$= 7409. V_c^2 \sin \theta_c$$

Longitudinal Current Load

$$(S-41) F_{x\text{form}} = -\frac{1}{2} (2) V_c^2 (55) (18.8) (1) \cos \theta_c$$

$$= -1034 V_c^2 \cos \theta_c$$

$$(S-45) R_e = V_c (529) \cos \theta_c / 0.000014$$

$$(S-42) F_{x\text{res}} = -\frac{1}{2} (2) V_c^2 S (x_{ca} \cos \theta_c$$

$$(S-43) S = 1.7 (18.8) 529 + 35 \times 6450 / 18.8 = 28915$$

$$(S-48) A_{Tep} = (529) (55) / 100 = 290.95$$

$$(S-47) A_p = 290.95 / 0.838 = 347$$

$$(S-46) F_{x\text{prop}} = -\frac{1}{2} (2) V_c^2 (347) (1.6) \cos \theta_c$$

CHESAPEAKE		DIVISION	PROJECT: _____
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: _____		date: _____	Calculations for: _____
Calcs ck'd by: <u>SA</u>		date: _____	

Current Yaw moment

$$(S-49) \quad M_{xyc} = F_{yc} \left(\frac{e_c}{L_{WL}} \right) 529$$

APPENDIX C. BUOY SURVIVABILITY

This appendix addresses the ability of the buoy to survive various events.

CHESAPEAKE		DIVISION	PROJECT: <u>St. Croix Mooring</u>
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: <u>W. Seelig</u>		date: <u>12/13/84</u>	Calculations for: <u>Buoy Survivability</u>
Calcs ck'd by: <u>AA</u>		date: _____	

What can go wrong with the mooring when a ship is not moored?

Accidents

Little damage to the mooring or a vessel is expected if a vessel accidentally runs into the mooring. The buoy is "soft" and riser chain covered with a protective tube. Therefore a ship or small boat will bounce off the buoy. Submariners should avoid getting propellers too close to the riser. Submarine propelled design is unknown by the author. However, problems are possible if the propeller gets too close to the riser.

Vandalism/Sabotage

Any determined group of individuals could seriously damage the mooring with high explosives or high temperature torches. Any mooring would have similar vulnerability. A large amount of reserve buoyancy is provided, so if even a large portion (say 25%) of the buoy were removed, the buoy would still support the riser. If a section were removed on one side, then the buoy would list and would be more difficult to moor to the buoy.

CHESAPEAKE

DIVISION

PROJECT: St. Croix Mooring

Naval Facilities Engineering Command

NDW

Station: _____

DISCIPLINE

E S R: _____

Contract: _____

Calcs made by: W. Seelig date: 12/13/84Calculations for: Buoy SurvivabilityCalcs ck'd by: /// date: _____Extreme Environmental Forces

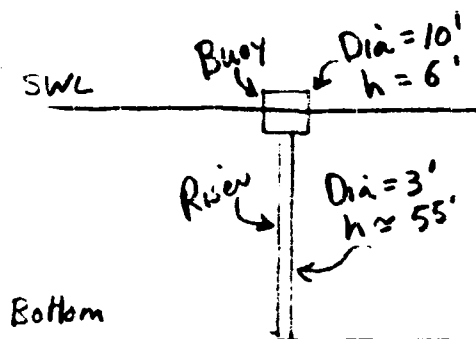
What happens if the largest wave possible hits the mooring?

Soln:

$$H_{max} = 0.78d$$

$$= 0.78(55) = 42.9'$$

$$T \approx 13 \text{ Sec}$$



The dynamic interaction between mooring and wave will be complex and beyond the scope of this report. As an extreme upper limit assuming the the buoy/riser is a fixed pile.

Riser

Shore Protection Manual^{*} Eq (7-36) (SPM)
(1977)

$$F_d = C_D \frac{1}{2} \rho g D H^2 K_{DM}$$

From SPM Fig. 7-47

$$K_{DM} = 0.4$$

page 2 of _____

* US Army Corps of Engineers, CERC, 1977.

CHESAPEAKE

DIVISION

PROJECT: St. Croix Mooring

Naval Facilities Engineering Command

NDW

Station: _____

DISCIPLINE

E S R: _____ Contract: _____

Calcs made by: W. Seelig date: 12/13/84Calculations for: Buoy SurvivabilityCalcs ck'd by: TA date: _____

From SPM Fig 7-62

$$C_D = 0.7$$

$$\therefore F_d = 0.7 \left(\frac{1}{2}\right) (2) (32.2) (3) (42.9)^2 (0.4) \\ = 48,900 \text{ lbs}$$

Buoy

SPM Eq (7-25)

$$F_D = \int_{h_1}^{h_2} f_d dz \approx h \bar{f}_D$$

SPM Eq (7-18)

$$f_D = C_D \frac{1}{2} \rho D u |u|$$

$$\therefore F_D = h C_D \frac{1}{2} \rho D u |u|$$

SPM Eq (2-13)

$$u = \frac{H}{2} \frac{g T}{L} \frac{\cosh(2\pi(z+d)/L)}{\cosh(2\pi d/L)} \cos\left(\frac{2\pi x}{L} - \frac{2\pi t}{T}\right)$$

page 3 of _____

CHESAPEAKE

DIVISION

PROJECT: St. Croix Mooring

Naval Facilities Engineering Command

NDW

Station: _____

DISCIPLINE

E S R: _____ Contract: _____

Calcs made by: W. Seelig date: 12/13/84Calculations for: Buoy SurvivabilityCalcs ck'd by: HA date: _____

at Surface

$$U_{max} = \frac{H g T}{2 L} (1.0) (1.0)$$

from SPM

$$\frac{d}{L_0} = \frac{d}{5.12(T)^2} = \frac{55}{5.12(13)^2} = 0.06$$

from SPM, Volume III

$$\frac{d}{L} = 0.104$$

$$\therefore L = \frac{d}{\left(\frac{d}{L}\right)} = \frac{55}{0.104} = 528.8 \text{ feet}$$

$$\therefore U_{max} = \frac{42.9 (32.2) (13)}{2 (528.8)} = 16.97 \text{ fps}$$

$$\begin{aligned} \therefore F_0 &= 6 (0.7) \frac{1}{2} (2) (10.0) (16.97)^2 \\ &= 12,095 \text{ lbs} \end{aligned}$$

CHESAPEAKE		DIVISION		PROJECT: <u>St. Croix Mooring</u>	
Naval Facilities Engineering Command		NDW		Station: _____	
DISCIPLINE				E S R: _____ Contract: _____	
Calcs made by: <u>W. Seelig</u>		date: <u>12/13/84</u>		Calculations for: <u>Buoy Survivability</u>	
Calcs ck'd by: _____		date: _____			

For a totally Stiff structure the maximum drag force would be:

$$F = F_{rise} + F_{buoy} = 48,900. + 12,095 \\ \approx 61 \text{ Kips}$$

Since the mooring buoy will surely move some under wave action, it is believed the actual wave force will be much less than 61 kips. For a Class "A" mooring good to 100 kips working load the mooring will survive any anticipated wave action.

Submergence of the buoy is not anticipated to cause any problems because the buoy is "soft" and can flex under pressure.

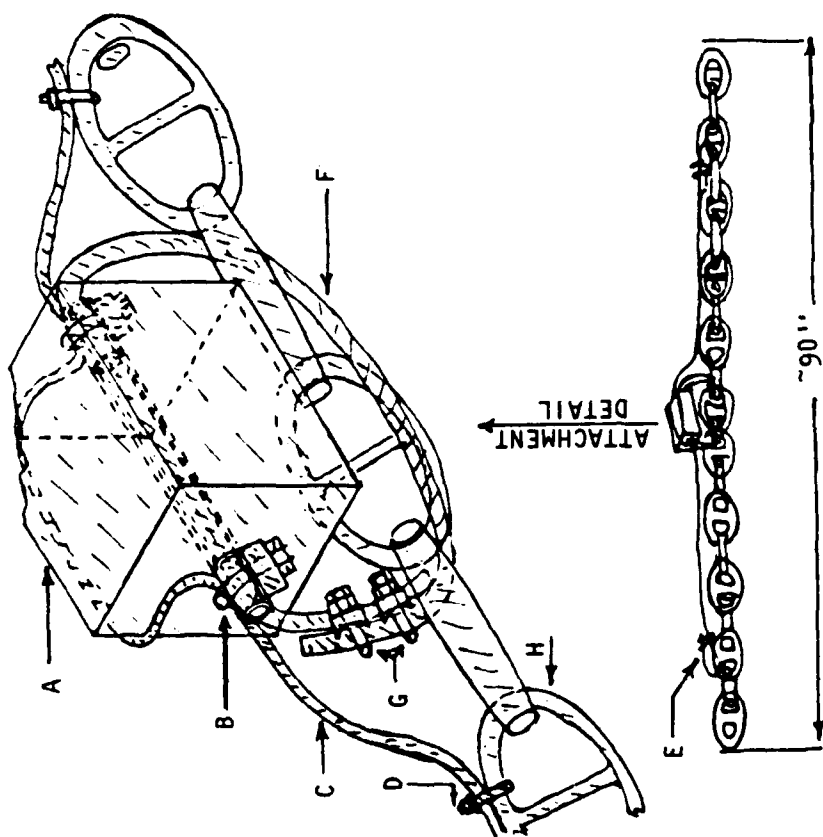
APPENDIX D. CATHODIC PROTECTION FOR CHAIN

The chain cathodic protection design developed for use at Diego Garcia is also specified for this mooring design.

TAB A TO APPENDIX V TO ANNEX B
SACRIFICIAL ZINC ANODE ATTACHMENT DETAIL

- A 250 lb. zinc anode. 1-anode per shot needed.
MIL-A-18001 zinc 1" sch. 40 pipe core nominal dimensions 9" x 9" x 12" zinc.
- B 1 1/4" wire rope clips. Two required per anode.
- C 1/2" preformed IWRC improved plow steel wire rope. 110 feet needed per shot.
- D 2 1/2" pipe clamps/U-bolts. One required every five links.
- E 1/2" wire rope clips. Four required per shot.
- F 3/4" preformed IWRC improved plow steel wire rope. 8' required per anode.
- G 3/4" wire rope clips. Two required per anode.
- H Stud link chain, 1 3/4" to 2 3/4" wire diameter.

See detailed materials list - next page.



From "Diego Garcia Fleet Moorings Installation",
Project Execution Plan, OPOORDER 6-80,
FPO-1, CHESNAVFACENGCOM, 1 Nov 1980.

END

Dtic

7-86