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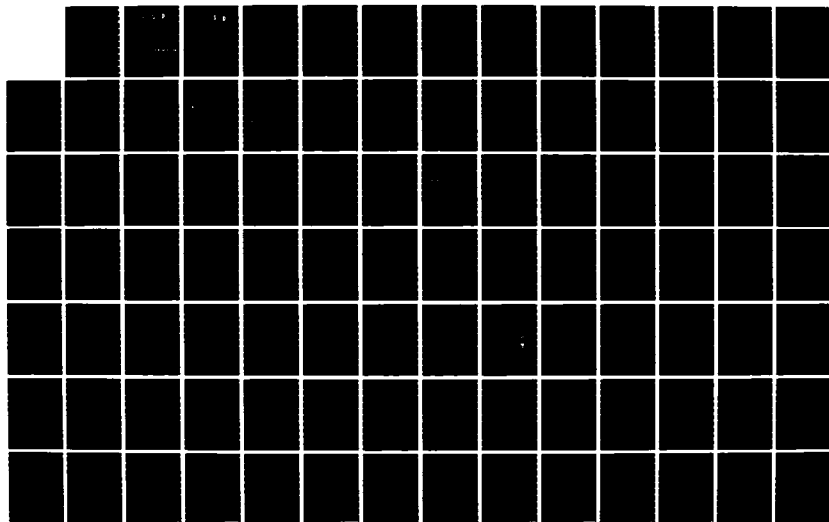
DESIGN CALCULATIONS OF THE HURRICANE MOORINGS AT NAVAL
STATION MAYPORT FL. (U) NAVAL FACILITIES ENGINEERING
COMMAND WASHINGTON DC CHESAPEAKE. C A HUBLER DEC 84
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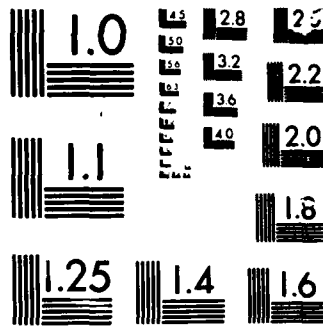
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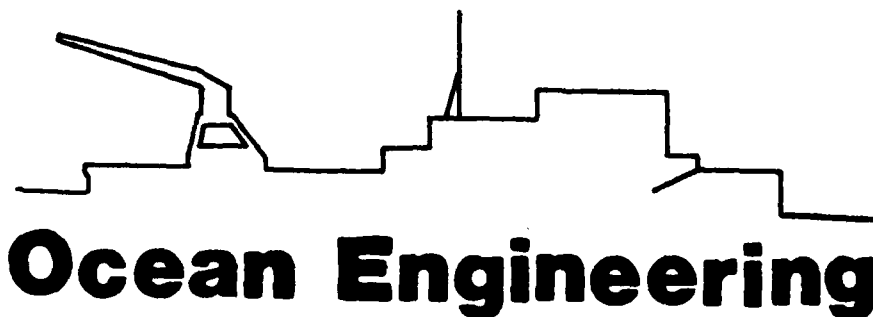
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DESIGN CALCULATIONS OF THE
HURRICANE MOORINGS AT
NAVAL STATION, MAYPORT, FLORIDA
FPO-1-84 (46)
December 1984



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

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December 1984

by

C. Allan Hubler

APPROVED BY:

Shun C. Ling
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Director

Engineering Analyses Division

OCEAN ENGINEERING & CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
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Summary

These design calculations are for specialized fleet moorings which will be installed for the Naval Station (NAVSTA) Mayport, Florida. It was requested that Chesapeake Division, Naval Facilities Engineering Command, Ocean Engineering and Construction Project Office, design and install the moorings for the NAVSTA. These fleet moorings are in a specialized category because they will be used to moor vessels during a hurricane. There will be three moorings that will accommodate 22 crafts ranging in size from LCM to YON that are assigned to the NAVSTA, (see pages B-2, B-3, and B-4).

The location of the moorings is on the east bank of the St. John River, west of Blount Island, (see page B-6). Bathymetry of the anchorage area and soil conditions at the anchor location has to be confirmed by a site survey. The vessels at moor under certain environmental conditions will swing into the channel. Informal discussions with federal and state agencies implied that there would be no denial for installation, however this needs to be formalized by submitting applications for construction to the appropriate agencies.

Because the moorings are a survival type, the 100-year extreme event will be used for the design criteria. Therefore, highest, fastest mile design wind will be 80 miles per hour. The current will be 1.5 knots, (see pages A-3 and A-5). These environmental events generated a maximum static hawser load of 32 kips (see page C-36) and a maximum dynamic hawser load of 55 kips, (see page D-4).

The final design is a free-swing riser type mooring. Each mooring will have four ground legs consisting of 2 inch chain so that each opposing leg can be proof loaded and verified to the design load. The anchors will be Navy stockless with stabilizers and with the flukes fixed open to 50 degrees. There is a 10 kips sinker connected to the ground ring. The mooring systems will be cathodically protected with zinc anodes.

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Calcs ck'd by: <u>M. S. S. S.</u>	date: <u>30 Nov 84</u>	

I Environmental Design Criteria

1. Design Wind

The design winds for this hurricane mooring were derived from raw wind data from the old Jacksonville Airport which has about 30 yrs of data. The airport is within 5 miles of the mooring site so this wind data is valid to use in establishing the design wind. Because the moorings are survival type the 100 yr return event will be used. The National Climatic Data Center (NCDC) did an extreme event analysis for tropical and non-tropical storms in 8 compass directions. The weibull distribution was used for the analysis. The fastest mile wind speeds are given below in mph. The highest wind speeds from any population are used as the design winds.

	Mixed Distribution	Non-Tropical Dist.	Tropical Dist.	Design Wind
N	70	62	80	80
NE	59	56	61	61
E	72	50	79	79
SE		51		51
S		56		56
SW		56		56
W		48		48
NW		48		48

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Because the crafts using the moorings are of light tonnage, the mooring response to the wind will be around the 30 second wind duration time. NCDC gave the fastest mile wind speed which has a varying duration equal to the time it takes for the wind to travel one mile. Therefore all NCDC wind speeds had to be converted to 30 second duration wind speeds. Below is an example of the conversion for an 80 mph wind.

Duration of 80 mph fastest mile wind

$$\frac{3600 \text{ sec/hr}}{80 \text{ mi/hr}} = 45 \text{ sec/mi.}$$

Use figure 1.1 to set up proportions using the gust ratio for the 30 and 45 second duration.

$$(\text{Fastest mile speed}) \times \left(\frac{30 \text{ sec. Gust Ratio}}{45 \text{ sec. Gust Ratio}} \right) = 30 \text{ sec Wind Speed}$$

$$80 \text{ mph} \times \left(\frac{1.32}{1.27} \right) = 83 \text{ mph.}$$

Now convert mph to ft./sec by multiplying by 1.467

$$83 \text{ mph} \times 1.467 = 122 \text{ ft/sec}$$

page A-2 of _____

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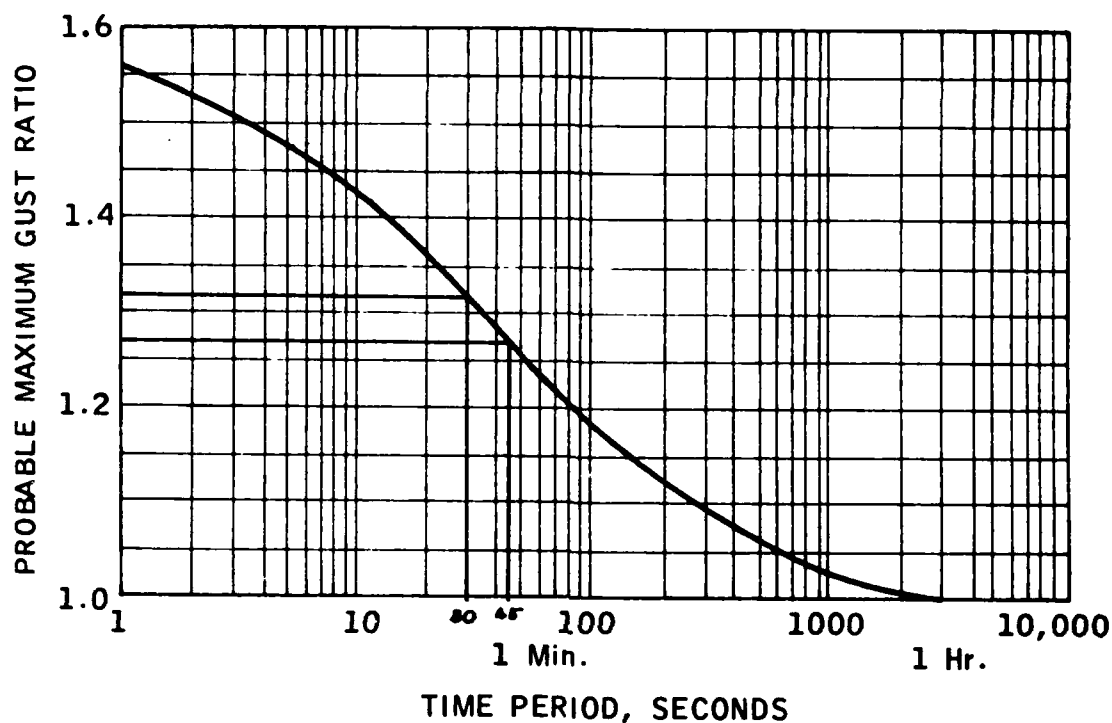
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Figure 1.1 - RATIO OF PROBABLE MAXIMUM AVERAGE (GUST) WIND VELOCITY FOR PERIOD TO ONE HOUR AVERAGE
From "Guidelines for Deepwater Port Single Point Mooring Design" NTIS AD/A-050-182

The Design wind speed and direction are given below:

N - 122 fps	S - 86.9 fps
NE - 89.5 fps	SW - 86.9 fps
E - 120 fps	W - 75.6 fps
SE - 79.6 fps	NW - 75.6 fps

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Design Current

The design currents for the moorings are controlled by the St. John's river tidal current. The current direction will be controlled by the river channel which is NNE by SW. The current speed for the moorings was derived from the St. John's inlet velocities. NAVFAC DM-26 states an inlet velocity of 3 knots and the 1984 NOAA Tidal table states that a maximum ebb velocity is 3.1 knots for Mayport inlet. These inlet velocities need to be translated to the mooring site. This was done by using the US Army Engineer Waterways Experiment Station hydraulic model investigation. This study titled "Mayport Mill Cove Model Study" (TR-HL-79-12) had a verification phase which included 2 days of real time velocities measurement taken close to the mooring site and at the inlet. Figure 1.2 shows stations 1 and 2 which were used to proportionate the inlet velocity to the mooring site. The analysis is shown below:

From WES Model Study

Station 1 - Max. recorded velocity - 4.5 fps

Station 2 - Max. recorded velocity - 2.2 fps

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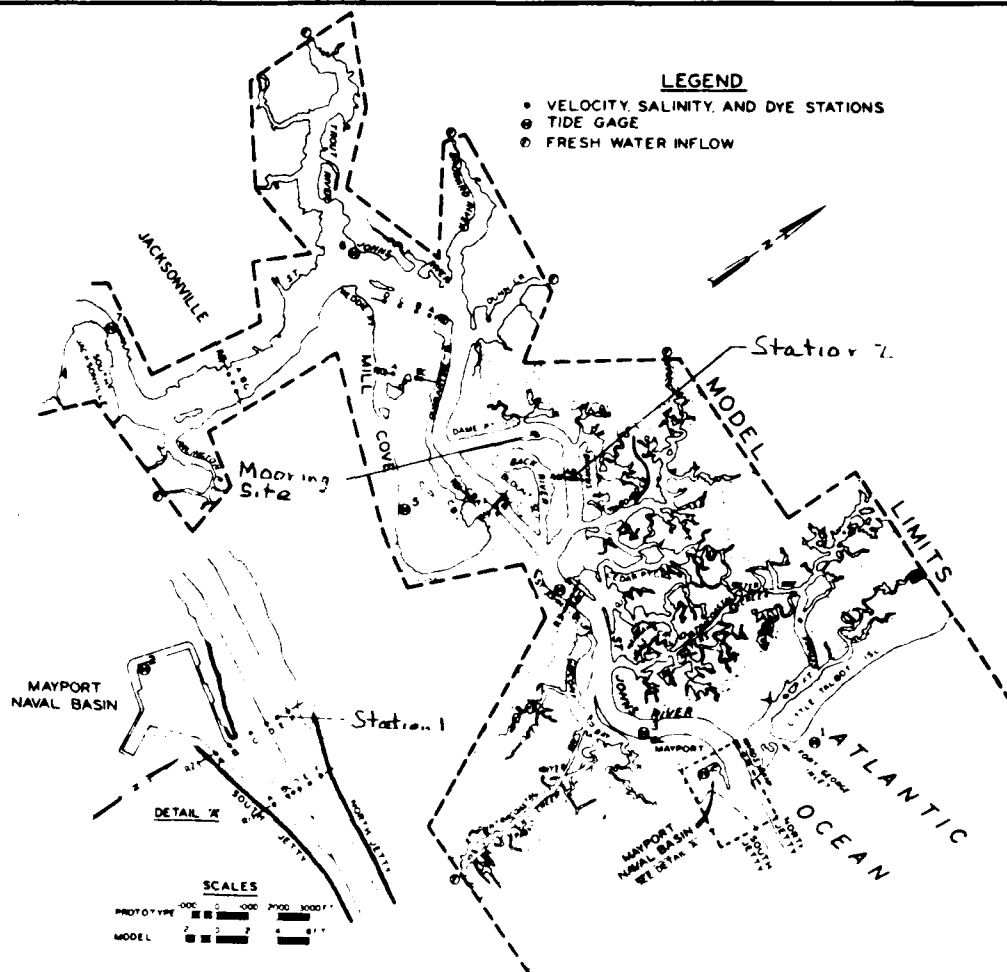
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MODEL LIMITS AND
PROTOTYPE STATION LOCATIONS

Fig 1.2 - Excerpt from Mayport-Mill Cove Model Study

$$\text{Design Current} = \text{Inlet current} \times \frac{\text{Current @ Station 1}}{\text{Current @ Station 2}}$$

$$= 3.1 \text{ knot} \times \frac{1.6 \text{ fps}}{1 \text{ knot}} \times \left(\frac{1.2}{4.5} \right)$$

$$= 2.5 \text{ ft/sec NNE and SSW}$$

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II Mooring Layout and Location

There will be three mooring to accommodate 22 vessels at the NAVSTA Mayport. Below is the list of vessels:

- | | | |
|------------|-------------|-------------|
| 1. YD-188 | 9. YON-259 | 17. YTB-3 |
| 2. YC-1444 | 10. YON-261 | 18. YTB-4 |
| 3. YD-204 | 11. YON-271 | 19. YTB-5 |
| 4. YON-88 | 12. YON-283 | 20. LCM-6-1 |
| 5. YC-360 | 13. YON-100 | 21. LCM-6-2 |
| 6. YC-1482 | 14. YON-258 | 22. YTL-30 |
| 7. YC-1884 | 15. YTB-1 | |
| 8. YC-1553 | 16. YTB-2 | |
- } These vessels will be lifted out of water and placed on the crane barges.

The moorings will be used by the vessels listed above and no others, and will be used only during a hurricane. The NAVSTA's Standard Operating Procedure for hurricane warning has a layout of which vessels used which moorings. These layouts are shown as Moorings A, B and C.

Figures 2.1, 2.2 and 2.3 show the barges rafted together. This will be done with wire rope and there will be sea cushion type fenders used between the vessels. The size required is 4 ft dia. x 7.4 ft long and 2 for each barge to barge face.

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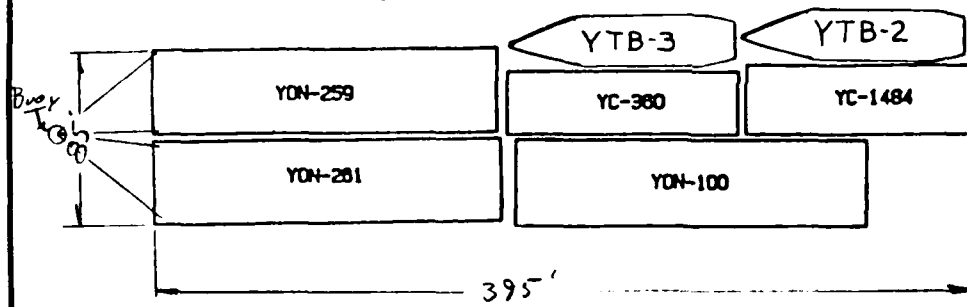
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Mooring E

Vessels	Length	Beam	Draft	▽	A _u Front	A _u Side	A _{wet}
1. YON 259	165	40	8	1445	610	2520	9,880
2. YON 261	165	40	3	1445	610	2520	9,880
3. YC 360	110	31	4	350	330	1090	4538
4. YON 100	165	35	8	1270	534	2520	8975
5. YC-1484	110	32	8	694	330	1090	5792
6. YTB-2	105	28	13	320	560	1790	
7. YTB-3	105	28	13	320	560	1790	

Layout - Figure 2.2



Total Displacement - 5844 long tons

Area front - 1220 ft² + 15% sheltering (barges)

Area Side - 2715 ft² + 11.7% sheltering (barges)

Wet Surface Area (barges) - 39,065 ft²

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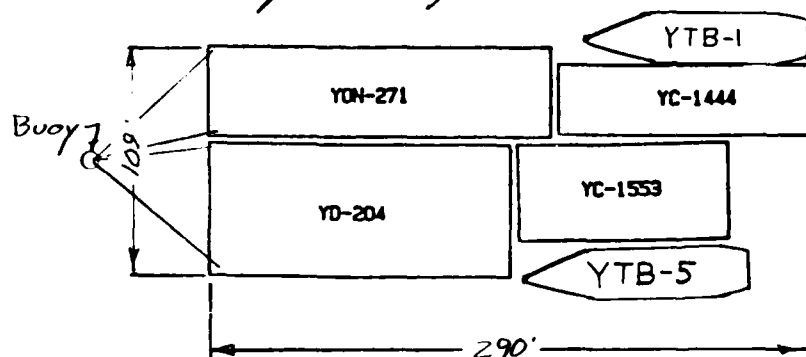
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Mooring C

Vessels	Length	Breadth	Draft	∇	Aw Front	Aw Side	Awet
1. YD-204	144	67	6	1064	500	1800	11,712
2. YON-271	165	40	8	1445	610	2520	9,880
3. YC-1444	120	33	8	755	450	1640	6408
4. YC-1553	110	46	4	210	630	1400	6544
5. YTB-5	105	28	13	320	560	1790	
6. YTB-1	105	28	13	320	560	1790	

Layout Figure 2.3



Total Displacement - 4114 long tons

Area Front $1410 \text{ ft}^2 + 15\% \text{ sheltering (buoys)}$
 Area Side $4160 \text{ ft}^2 + 15\% \text{ sheltering (buoys)}$

Wet Surface Area (buoys) = $34,544 \text{ ft}^2$

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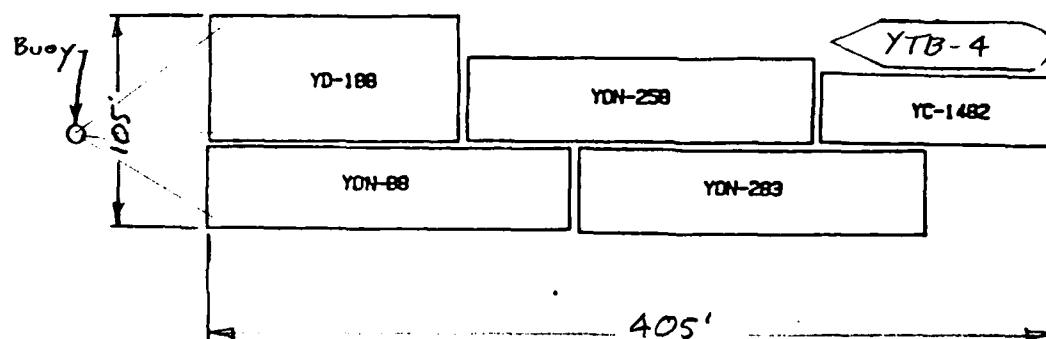
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Mooring - APAC

Mooring A

Vessels

	Length	Beam	D	V	A _{Front}	A _{Side}	A _{Net}
1. YD-188	120	60	8	637	800	1600	10,080
2. YON-88	174	40	8	1460	800	1600	10,384
3. YON-252	165	40	8	1445	610	2520	9,880
4. YON-283	166	40	9	1506	610	2520	10,348
5. YC-1482	110	32	8	694	330	1090	5,792
6. YTB-4	105	28	13	320	560	1790	

Layout - Figure 2.1



Total Displacement - 6062 long tons

Area Front - 1600 ft² + 15% sheltering (barges)Area Side - 5210 ft² + 15% sheltering (barges)Net Surface Area (barges) - 46,784 ft²

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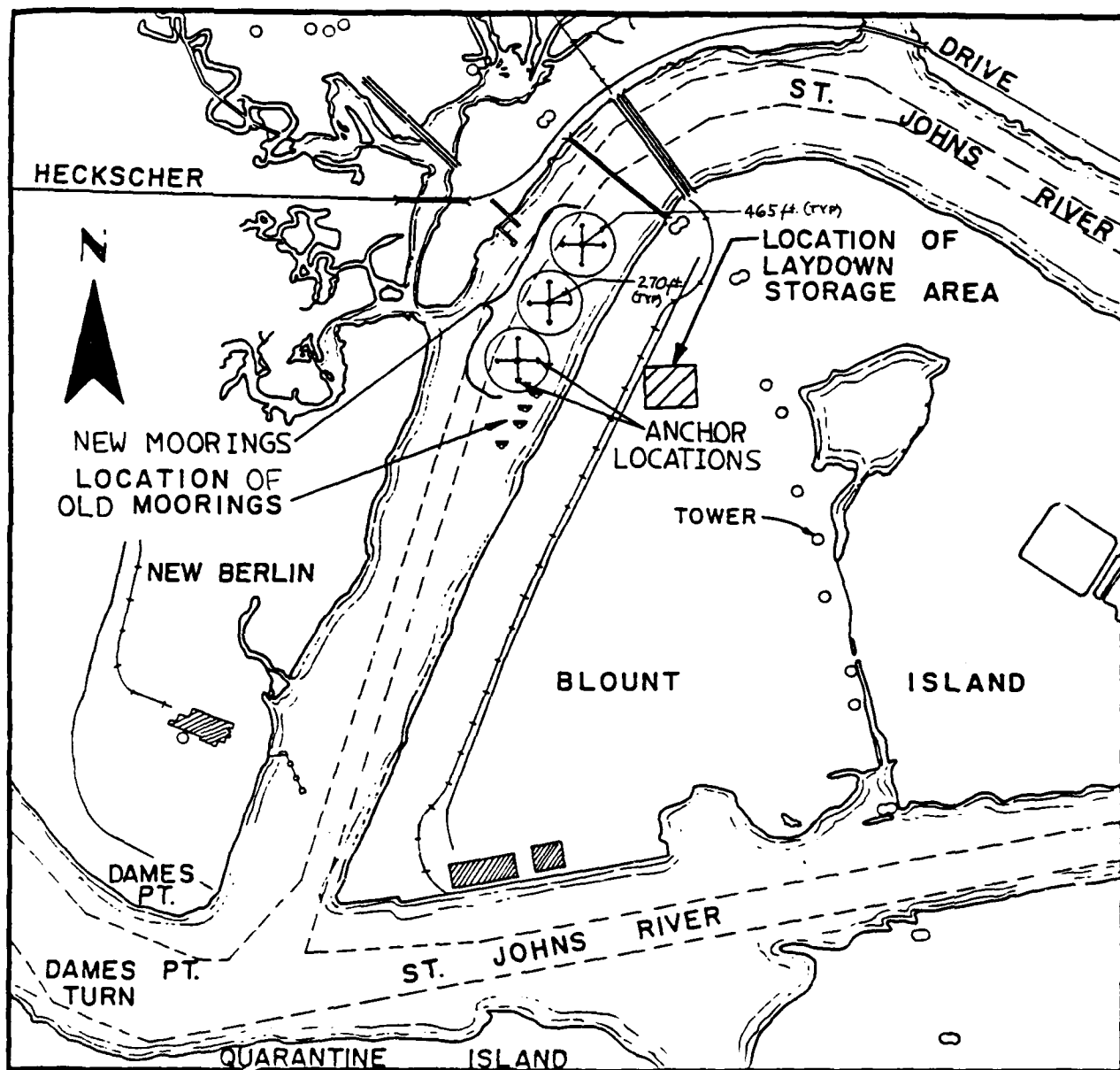
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**LOCATION MAP**

GRAPHIC SCALE IN FEET



Figure C.5

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The location of the moorings are on the West side of Blount Island as shown in the vicinity map below and the location map on the following page. The old mooring, which are being removed are bow/stern type. This type of mooring has large lateral forces for which large anchors had to be used to restrain this force. Unfortunately there is not enough soil for the anchor to hold. A free-swing type mooring will be designed for the barges and the vessel's watch circle and anchor location can be seen in figure 2.5.

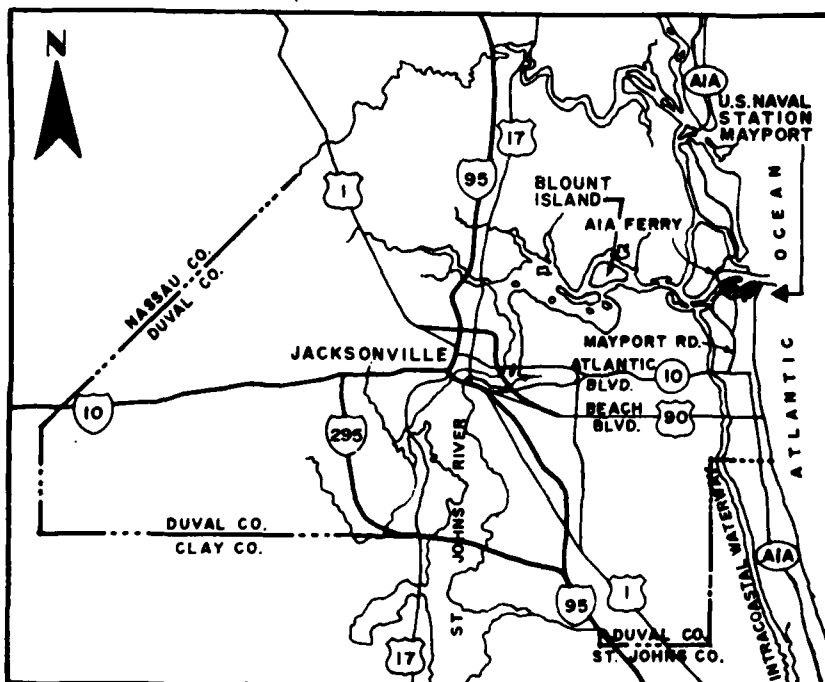


Figure 2.4

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III Static Environmental Loading

The present moorings had a bow/stern type configuration. In talking with the NAVSTA Public Works, Army Corps of Engineers, U.S. Coast Guard Jacksonville and the Jacksonville Port Authority, they all indicated that a free-swing type mooring with the vessel swing radius into channel will not cause any problems because the mooring will only be used during a hurricane.

The procedure for designing a free-swing mooring for static loading is given in NAVFAC DM-26.5-95% submittal. The procedure is simple but tedious and requires iterating the vessel's position until the moments acting on the vessels are zero. The flow diagram for the procedure is given on the next page. All figures, graphs and tables from this page on to page C-22 are taken from DM 26.5-95% submittal.

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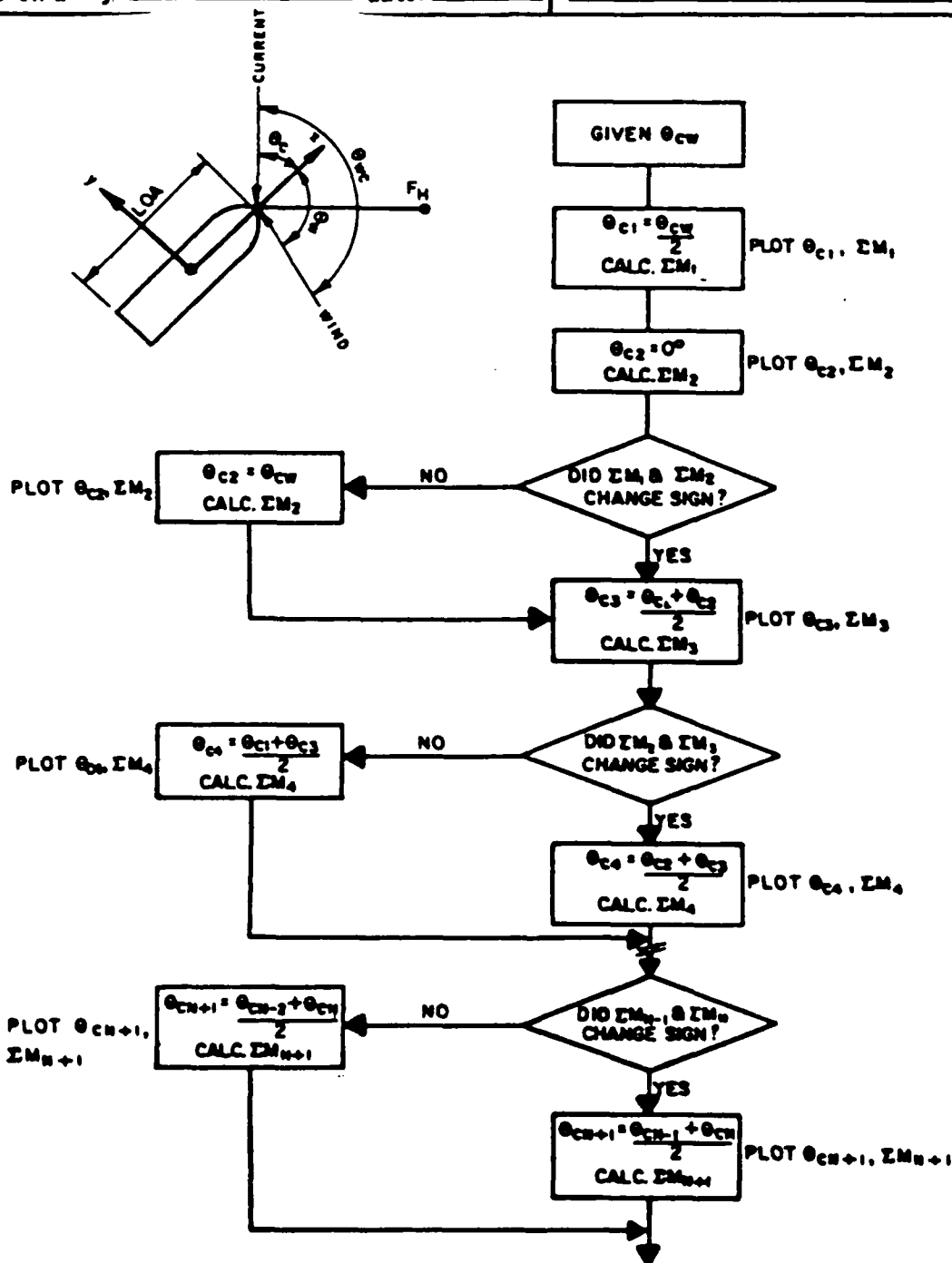
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Calculations for:



NOTE: CONTINUE PROCESS UNTIL DIFFERENCE BETWEEN θ_{cn+1} AND θ_{cn} IS SMALL OR UNTIL EQUILIBRIUM ANGLE CAN BE DETERMINED FROM GRAPH SHOWN IN FIGURE 66

Figure 3.1

page 2 of

CHESAPEAKE	DIVISION	PROJECT: _____
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The following are the calculations for environmental loads on Mooring A which will have the highest loads due to the size and number of vessels using the mooring. The 5 barges in this mooring will be grouped as one vessel. The length is the total length of the longest barges plus 5 ft. added between the barges for fender cushions. The same method is used to calculate the beam. The YTB will be calculated separately and then those forces will be added to the barge group.

The figure 3.2 on the next page shows the coordinate system and the nomenclature for the Wind and Current loads.

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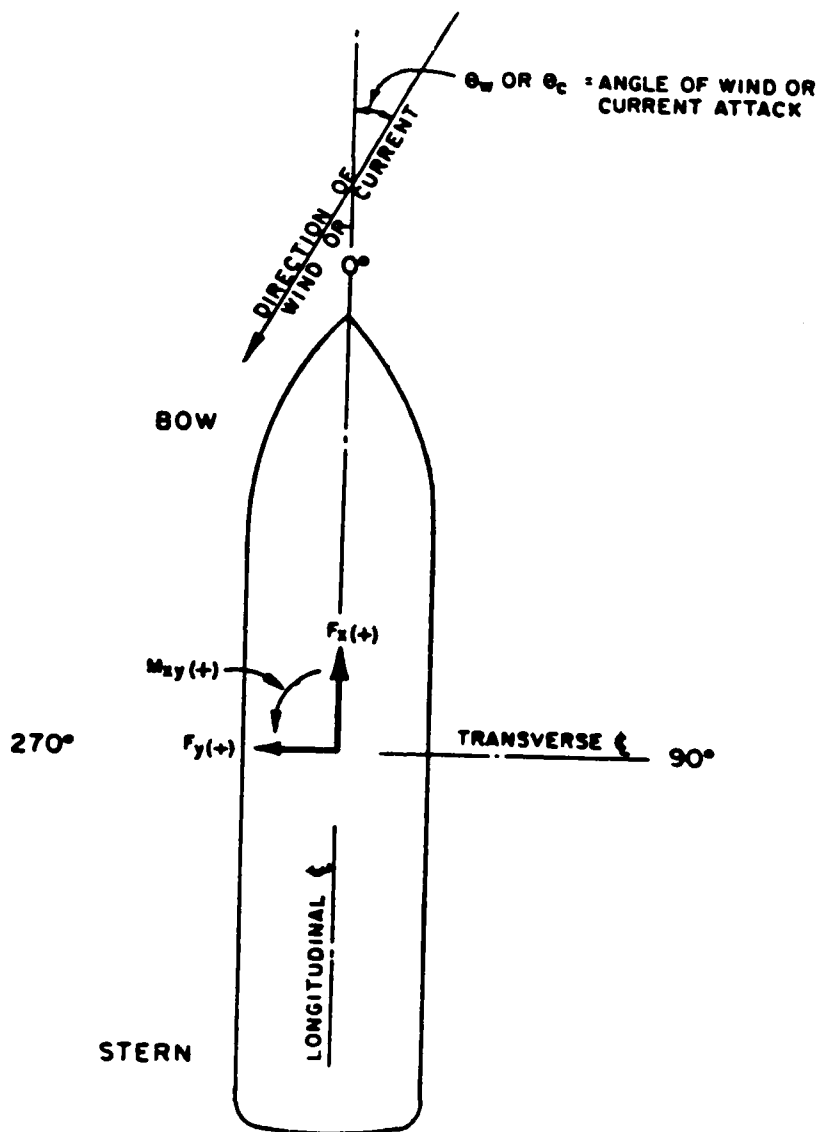
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180°
NOTE: DEGREES REFER TO θ_w OR θ_c

Figure 3.2

CHESAPEAKE**DIVISION****Naval Facilities Engineering Command****NDW****DISCIPLINE****PROJECT:** _____**Station:** _____**E S R:** _____**Contract:** _____**Calcs made by:** W. F. J. **date:** _____**Calcs ck'd by:** NMS **date:** _____**Calculations for:** _____

(a) Lateral wind load. Lateral wind load is determined using the following equation:

$$F_{yw} = \frac{1}{2} \rho_a V_w^2 A_y C_{yw} f_{yw}(\theta_w)$$

WHERE: F_{yw} = lateral wind load, in pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

V_w = wind velocity, in feet per second = *varies*

A_y = lateral projected area of ship, in square feet = *5210 ft²*

C_{yw} = lateral wind-force drag coefficient

$f_{yw}(\theta_w)$ = shape function for lateral load

θ_w = wind angle = *varies*

The lateral wind-force drag coefficient depends upon the hull and superstructure of the vessel:

$$C_{yw} = 0.92 \left[\left(\frac{V_S}{V_R} \right)^2 A_S + \left(\frac{V_H}{V_R} \right)^2 A_H \right] / A_y$$

WHERE: C_{yw} = lateral wind-force drag coefficient

V_S/V_R = average normalized wind velocity over superstructure

A_S = lateral projected area of superstructure only, in square feet = *1000 ft²*

V_S = wind velocity on superstructure

V_H/V_R = average normalized wind velocity over hull

A_H = lateral projected area of hull only, in square feet = *4210 ft²*

A_y = lateral projected area of ship, in square feet

V_R = reference wind velocity at 33.33 feet above sea level

V_H = wind velocity on hull

The values of V_S/V_R and V_H/V_R are determined using the following equations:

$$\frac{V_S}{V_R} = \left(\frac{h_S}{h_R} \right)^{1/7}$$

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NDW**DISCIPLINE****PROJECT:** _____**Station:** _____**E S R:** _____**Contract:** _____Calcs made by: 11/1/71

date: _____

Calcs ck'd by: NMS

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Calculations for: _____

$$\frac{V_H}{V_R} = \left(\frac{h_H}{h_R} \right)^{1/7}$$

WHERE: V_S/V_R = average normalized wind velocity over superstructure h_S = average height of superstructure, in feet = 45 ft. h_R = reference value of windspeed (33.33 feet) V_H/V_R = average normalized wind velocity over hull h_H = average height of hull, in feet = 4.5 ft.

$$\frac{V_H}{V_R} = \left(\frac{4.5}{33} \right)^{1/7} = .75, \quad \frac{V_S}{V_R} = \left(\frac{45}{33} \right)^{1/7} = 1.045$$

$$C_{yw} = .92 \left[1.045^2 (1000) + .75^2 (4210) \right] / 5210 = .611$$

The shape function for lateral load, $f_{yw}(\theta_w)$, is given as:

$$f_{yw}(\theta_w) = \frac{+ \left(\sin \theta_w - \frac{\sin 5\theta_w}{20} \right)}{1 - \frac{1}{20}}$$

WHERE: $f_{yw}(\theta_w)$ = shape function for lateral load θ_w = wind angle

$$F_{yw} = \frac{1}{2} (0.00237) V_w^2 (5210) (.611) \frac{\sin \theta_w - \frac{\sin 5\theta_w}{20}}{0.95}$$

$$3.772 V_w^2 \frac{\sin \theta_w - 0.05 \sin 5\theta_w}{0.95}$$

15% is added to account for the sheltering.

$$F_{yw} = \frac{4.338 V_w^2 (\sin \theta_w - 0.05 \sin 5\theta_w)}{0.95}$$

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(b) Longitudinal wind load. Longitudinal wind load is determined using the following equation:

$$F_{xw} = \frac{1}{2} \rho_a v_w^2 A_x C_{xw} f_{xw}(\theta_w)$$

WHERE: F_{xw} = longitudinal wind load, in pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

v_w = wind velocity, in feet per second

A_x = longitudinal projected area of ship, in square feet = 1600 ft²

C_{xw} = longitudinal wind-force drag coefficient

$f_{xw}(\theta_w)$ = shape function for longitudinal load

The longitudinal wind-force drag coefficient varies according to vessel type and characteristics. Additionally, a separate wind-force drag coefficient is provided for headwind (over the bow: $\theta_w = 0$ degrees) and tailwind (over the stern: $\theta_w = 180$ degrees) conditions. The headwind (bow) wind-force drag coefficient is designated C_{xwB} and the tailwind (stern) wind-force drag coefficient is designated C_{xwS} .

Because the barge group has the same shape over the bow or stern, $C_{xwB} = C_{xwS} = 0.7$

Longitudinal shape function, $f_{xw}(\theta_w)$, differs over the headwind and tailwind regions. The incident wind angle that produces no net longitudinal force, designated θ_{wz} for zero crossing, separates these two regions. The barge group has a $\theta_{wz} = 90^\circ$.

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Ships with distributed superstructures are characterized by a "humped" cosine wave. The shape function for longitudinal load is:

$$f_{xw}(\theta_w) = \frac{-\left(\sin \delta - \frac{\sin 5\delta}{10}\right)}{1 - \frac{1}{10}}$$

WHERE: $\delta_{(-)} = \left(\frac{90^\circ}{\theta_{wz}}\right) \theta_w + 90^\circ$ for $\theta_w < \theta_{wz}$

$$\delta_{(+)} = \left(\frac{90^\circ}{180^\circ - \theta_{wz}}\right) \theta_w + \left(180^\circ - \frac{90^\circ \theta_{wz}}{180^\circ - \theta_{wz}}\right) \text{ for } \theta_w > \theta_{wz}$$

As explained above, use $360^\circ - \theta_w$ for θ_w when $\theta_w > 180^\circ$.

$$\delta_{(-)} = \frac{90^\circ}{90^\circ} (\theta_w) + 90 = \theta_w + 90^\circ, \theta_w < \theta_{wz}$$

$$\begin{aligned} \delta_{(+)} &= \left(\frac{90^\circ}{180^\circ - 90^\circ}\right) \theta_w + \left(180^\circ - \frac{90^\circ (90^\circ)}{180^\circ - 90^\circ}\right) \\ &= \theta_w + 90^\circ \quad \theta_w > \theta_{wz} \end{aligned}$$

$$\begin{aligned} F_{xw} &= \frac{1}{2} (0.00237) V_w^2 1600 (.7) \frac{-\left(\sin \delta - \frac{\sin 5\delta}{10}\right)}{.9} \\ &= 1.327 V_w^2 \left(-\left(\frac{\sin \delta - .1 \sin 5\delta}{.9}\right)\right), \delta = \theta_w + 90^\circ \end{aligned}$$

15% is added to this force to account for sheltering.

$$F_{xw} = 1.526 V_w^2 \left(-\left(\frac{\sin \delta - 0.1 \sin 5\delta}{.9}\right)\right), \delta = \theta_w + 90^\circ$$

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(c) Wind yaw moment. Wind yaw moment is calculated using the following equation:

$$M_{xyw} = \frac{1}{2} \rho_a V_w^2 A_y L C_{xyw}(\theta_w)$$

WHERE: M_{xyw} = wind yaw moment, in foot-pounds

ρ_a = mass density of air = 0.00237 slugs per cubic foot at 68°F

V_w = wind velocity, in feet per second = Variable

A_y = lateral projected area of ship, in square feet = 5210 ft²

L = length of ship = 405'

$C_{xyw}(\theta_w)$ = normalized yaw-moment coefficient

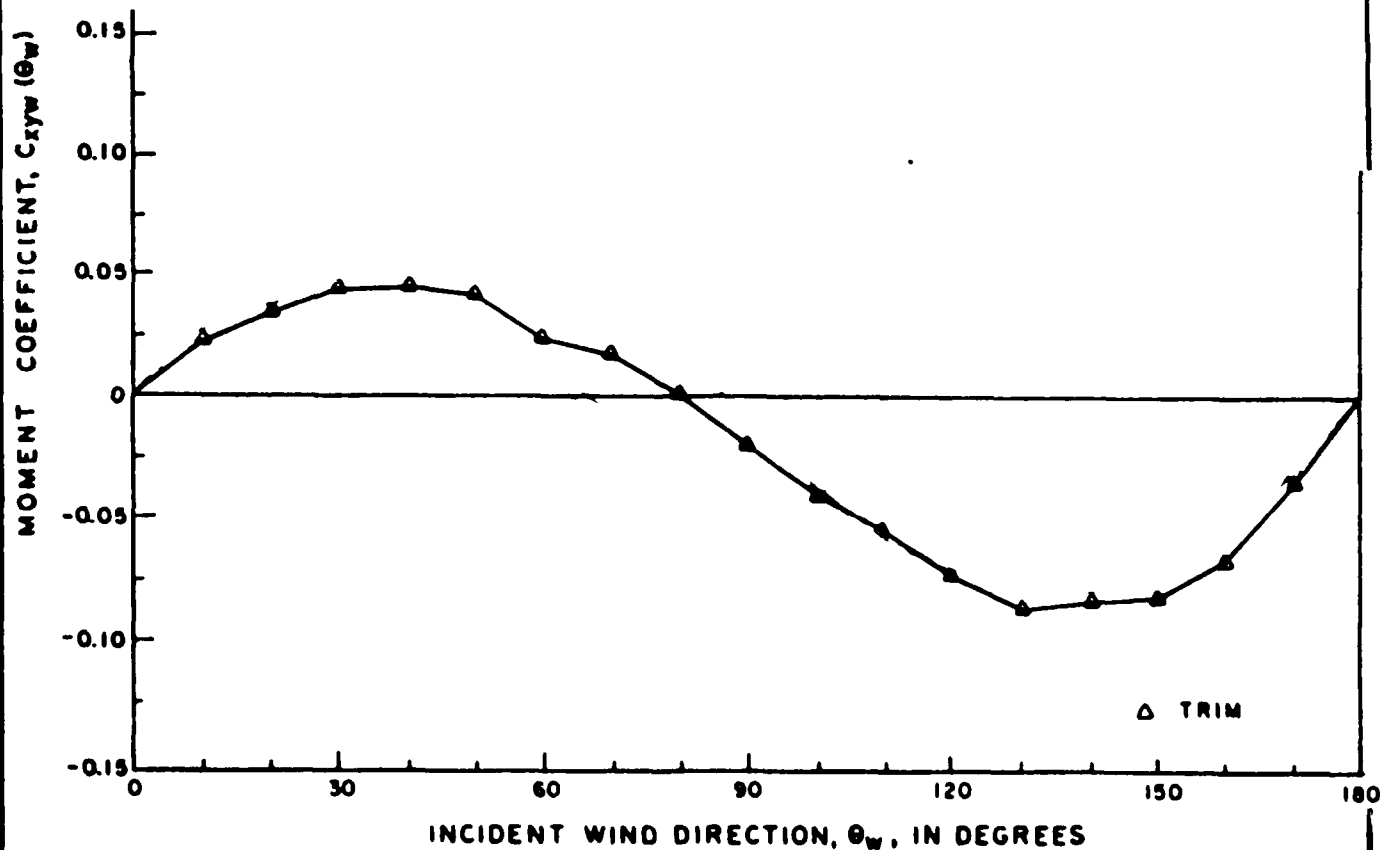


Figure 3.3

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$$M_{xw} = \frac{1}{2} (0.00237) V_w^2 5210 (405) C_{xw} (\theta_w)$$

$$= \underline{\underline{3500 V_w^2 C_{xw} (\theta_w)}}$$

b. Current Load.

(1) Lateral Current Load. Lateral current load is determined from the following equation:

$$F_{yc} = \frac{1}{2} \rho_w V_c^2 L_{wL} T C_{yc} \sin \theta_c$$

WHERE: F_{yc} = lateral current load, in pounds

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = current velocity, in feet per second = 3.5 ft/sec

L_{wL} = vessel waterline length, in feet = 405 ft.

T = vessel draft, in feet = 8 ft.

C_{yc} = lateral current-force drag coefficient

θ_c = current angle: 90 deg

The lateral current-force drag coefficient is given by:

$$C_{yc} = C_{yc|\infty} + (C_{yc|1} - C_{yc|\infty}) e^{-k \left(\frac{wd}{T} - 1 \right)}$$

WHERE: C_{yc} = lateral current-force drag coefficient

$C_{yc|\infty}$ = limiting value of lateral current-force drag coefficient for large values of $\frac{wd}{T}$

$C_{yc|1}$ = limiting value of lateral current-force drag coefficient for $\frac{wd}{T} = 1$

e = 2.7182818

k = coefficient

wd = water depth, in feet = 22 ft.

T = vessel draft, in feet: 8 ft.

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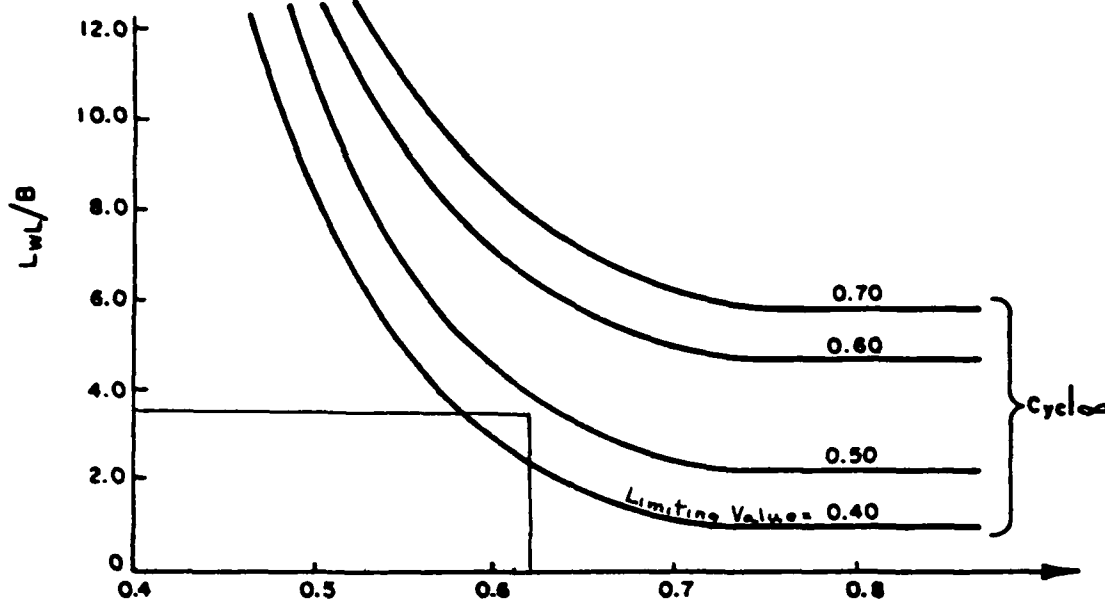
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Figure 3.4

BLOCK COEFFICIENT, ϕ

The block coefficient is defined as:

$$\phi = \frac{35 D}{L_{wl} B T}$$

WHERE: ϕ = vessel block coefficient

D = vessel displacement, in long tons: 6062 tons

 L_{wl} = vessel waterline length, in feet: 405 ft.

B = vessel beam, in feet: 34 ft.

T = vessel draft, in feet: 8 ft.

$$\phi = \frac{35(6062)}{405(105)8} = 0.624$$

$$L_{wl}/B = \frac{405}{105} = 3.86$$

$$C_{yc}/\infty = 0.46$$

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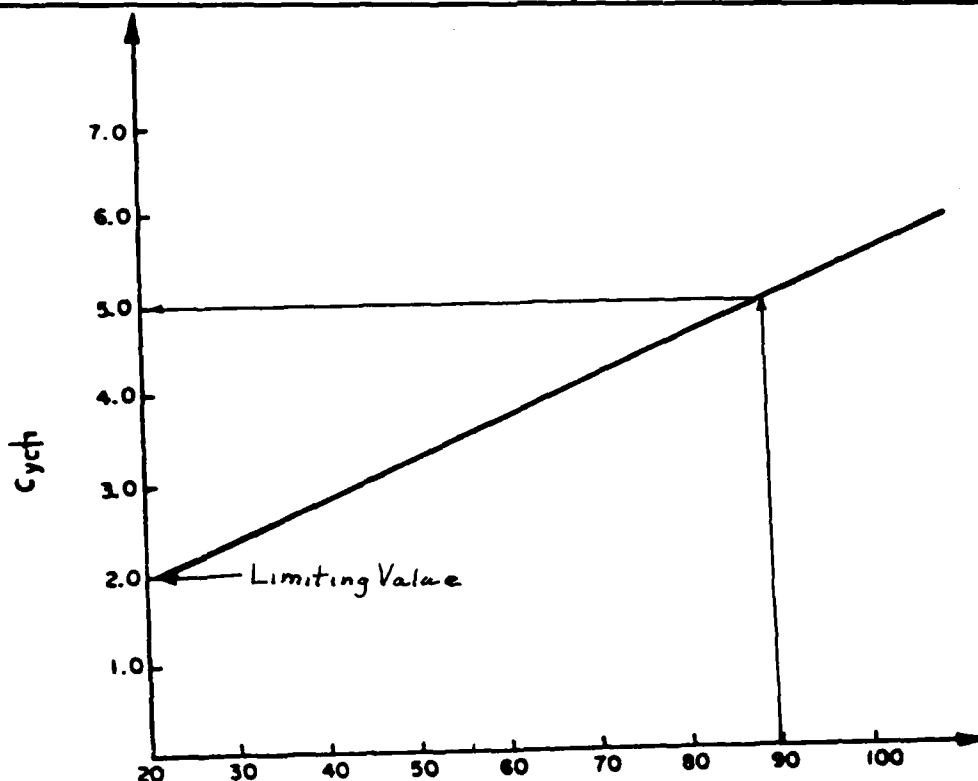
Calcs ck'd by: NAS date: _____

Figure 3.5

$$C_p L w L / \sqrt{T}$$

$$C_p = \frac{\phi}{C_m}$$

WHERE: C_p = prismatic coefficient of vessel ϕ = vessel block coefficient = 0.624
 C_m = midship section coefficient
 = $\frac{\text{immersed area of midship section}}{B T}$

B = vessel beam, in feet

T = vessel draft, in feet

$$\frac{C_p L w L}{\sqrt{T}} = \frac{0.624 (405)}{\sqrt{8}}$$

$$= 89$$

$$Cycl_1 = 5.$$

Because a barge has a square midship section
 the $C_m = 1$

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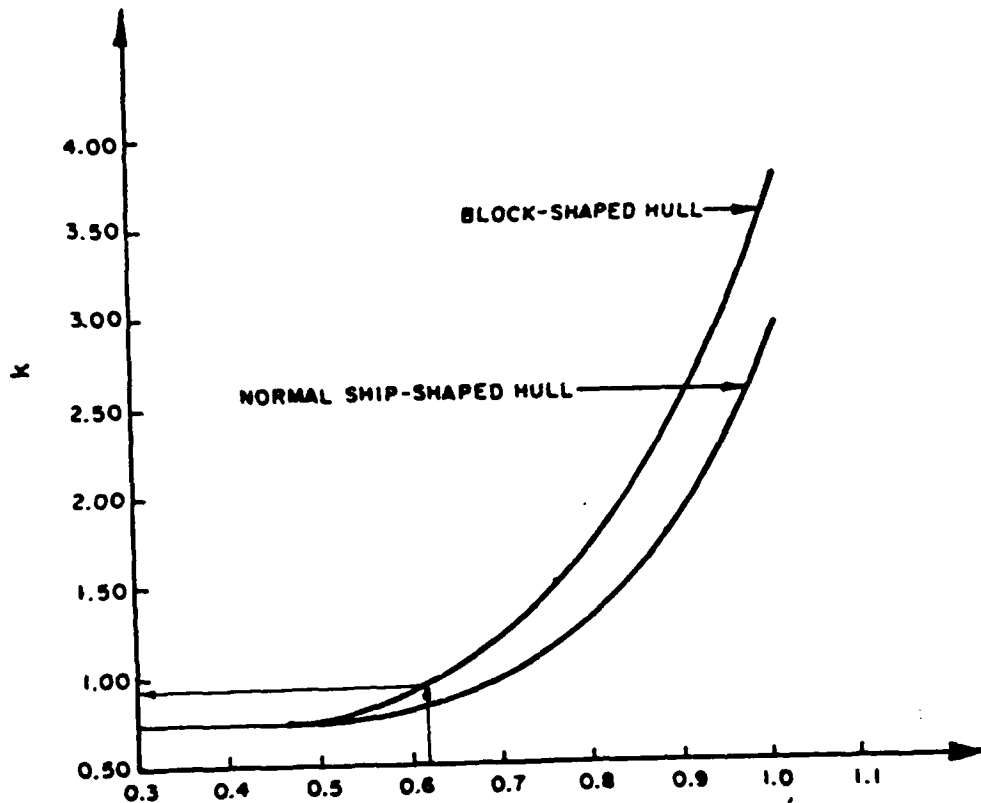
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Calcs ck'd by: NAS date: _____Figure 3.6 BLOCK COEFFICIENT, Φ

$$C_{yc} = 0.46 + (5 - 0.46) 2.7182818^{-0.9\left(\frac{2.2}{8} - 1\right)}$$

$$= 1.4$$

$$F_{yc} = \frac{1}{2}(2) V_c^2 (405) 8 (1.4) \sin \theta_c$$

$$= \underline{\underline{4536 V_c^2 \sin \theta_c}}$$

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(2) Longitudinal Current Load. Longitudinal current load procedures are taken from Cox (1982). Longitudinal current load is determined using the following equation:

$$F_{xc} = F_{x \text{ form}} + F_{x \text{ friction}} + F_{x \text{ prop}}$$

WHERE: F_{xc} = total longitudinal current load

$F_{x \text{ form}}$ = longitudinal current load due to form drag

$F_{x \text{ friction}}$ = longitudinal current load due to skin friction drag

$F_{x \text{ prop}}$ = longitudinal current load due to propeller drag = 0, for barges

Form drag is given by the following equation:

$$F_{x \text{ form}} = -\frac{1}{2} \rho_w V_c^2 B T C_{xcb} \cos \theta_c$$

WHERE: $F_{x \text{ form}}$ = longitudinal current load due to form drag

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = average current speed, in feet per second = 2.5 ft/sec.

B = vessel beam, in feet = 105 ft.

T = vessel draft, in feet = 8 ft.

C_{xcb} = longitudinal current form-drag coefficient = 0.1

θ_c = current angle

$$F_{x \text{ form}} = -\frac{1}{2} (2) V_c^2 105 (8) (0.1) \cos \theta_c$$

$$= -84 V_c^2 \cos \theta_c$$

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Friction drag is given by the following equation:

$$F_{x \text{ friction}} = -\frac{1}{2} \rho_w V_c^2 S C_{xca} \cos \theta_c$$

WHERE: $F_{x \text{ friction}}$ = longitudinal current load due to skin friction ρ_w = mass density of water = 2 slugs per cubic foot for sea water V_c = average current speed, in feet per second = 2.5 ft/sec S = wetted surface area, in square feet
= $(1.7 T L_{WL}) + (\frac{35 D}{T})$ T = vessel draft, in feet = 8 ft L_{WL} = waterline length of vessel, in feet = 400 ft D = displacement of ship, in long tons = 3062 tons C_{xca} = longitudinal skin-friction coefficient
= $0.075 / (\log R_n - 2)^2$ R_n = Reynolds number = $V_c L_{WL} \cos \theta_c / \nu$ ν = kinematic viscosity of water (1.4×10^{-5} square feet per second) θ_c = current angle

The formula above for wet surface area will not be used for the barge group. The actual wet surface area of the combined barges, 46,484 ft², will be used.

$$F_{x \text{ friction}} = -\frac{1}{2} (2) V_c^2 46,484 \frac{0.075}{(\log V_c 405 \cos \theta_c - 2)^2} \cos \theta_c$$

$$= -V_c^2 3486 / (\log V_c 2.893 \times 10^7 \cos \theta_c - 2)^2 \cos \theta_c$$

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$$F_{xc} = -V_c^2 C_{rc} \theta_c (34 + (\log V_c \frac{2486}{2.893 \times 10^7} \cos \theta_c - 2)^2)$$

(3) Current Yaw Moment. Procedures for determining current yaw moment are taken from Altmann (1971). Current yaw moment is determined using the following equation:

$$M_{xyc} = F_{yc} \left(\frac{e_c}{L_{WL}} \right) L_{WL}$$

WHERE: M_{xyc} = current yaw moment, in foot-pounds

F_{yc} = lateral current load, in pounds = $4536 V_c^2 \sin \theta_c$

$\left(\frac{e_c}{L_{WL}} \right)$ = ratio of eccentricity of lateral current load measured along the longitudinal axis of the vessel from amidships to vessel waterline length

e_c = eccentricity of F_{yc}

L_{WL} = vessel waterline length, in feet = 405 ft

The value of $\left(\frac{e_c}{L_{WL}} \right)$ is derived from the graph on the following page. The vessel curve that will be used is the small auxiliary floating dry dock (AFDL). This curve is used over the other curves because the AFDL has the same under-water hull shape as barges.

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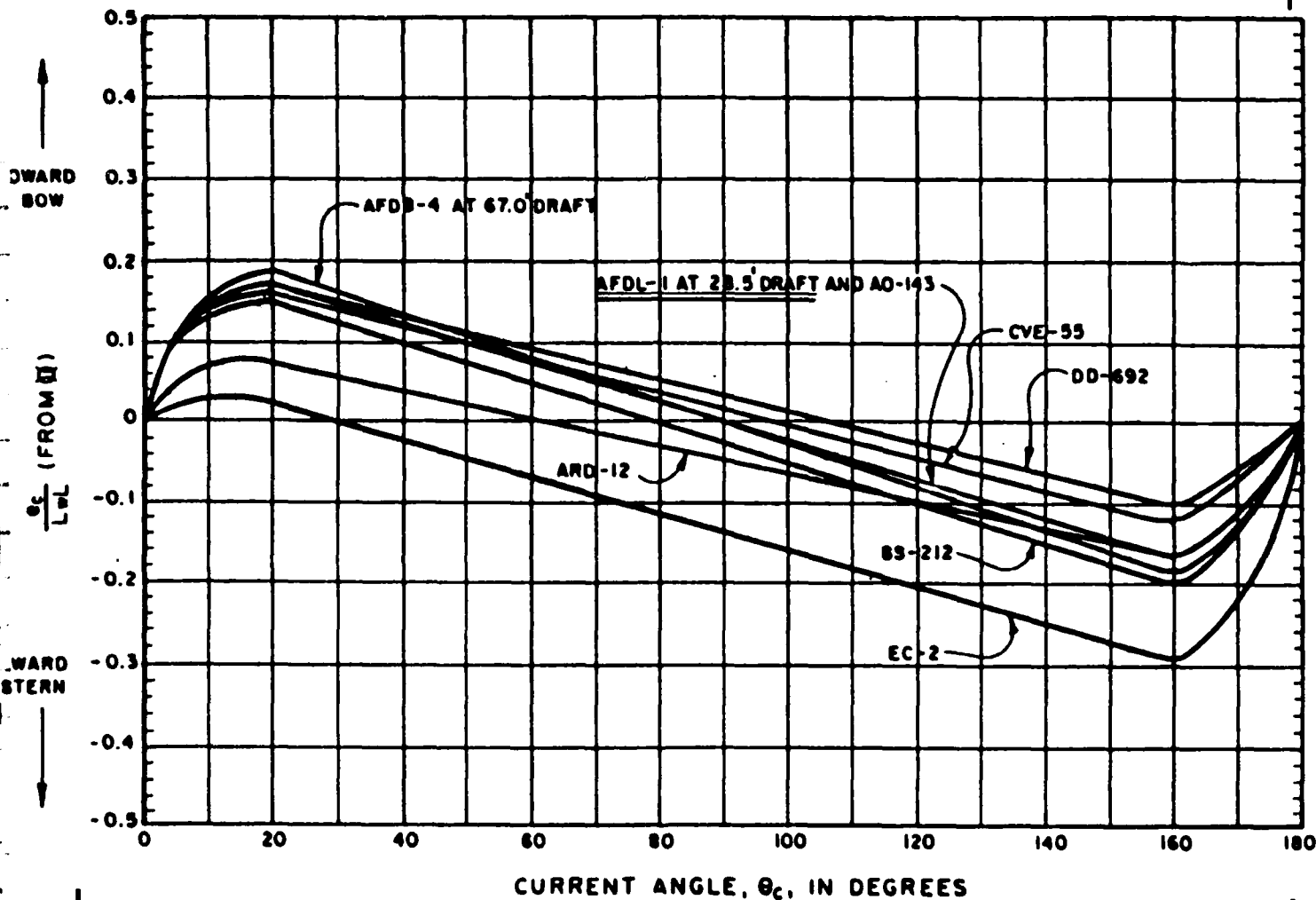
Calculations for: _____Calcs ck'd by: WJS date: _____

Figure 3.7

$$M_{xye} = 4536 V_c^2 \sin \theta_c \left(\frac{e_c}{L_{wl}} \right) 405$$

$$= \underline{\underline{1.837 \times 10^6 V_c^2 \sin \theta_c \left(\frac{e_c}{L_{wl}} \right)}}$$

These are all the formulas used to calculate the environmental loads on the barges.

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Environmental Static loads on the YTB

The same method used on the barges in the previous section will be used for the YTB. Therefore the details for this YTB calculation will be brief.

YTB - Length 105'
 Beam 28'
 Draft 13'
 Displacement 320 tons
 Area Side 1790 ft²
 Front 560 ft²

Wind loads

$$F_{yw} = \frac{1}{2} \rho_a V_w^2 A_f C_{yw} f_{yw}(\theta_w)$$

$$\frac{V_H}{V_R} = \left(\frac{3}{33.33} \right)^{1/2} = 0.709$$

$$\frac{V_s}{V_R} = \left(\frac{16}{33.33} \right)^{1/2} = 0.900$$

$$C_{yw} = .92 [(0.90)^2 (1160) + (0.709)^2 (630)] / 1790 = 0.6457$$

$$F_{yw} = \frac{1}{2} (0.00237) V_w^2 (1790) (0.6457) \left(\frac{\sin \theta_w - 0.05 \sin 50^\circ}{0.95} \right)$$

$$= \underline{\underline{1.370 V_w^2 \left(\frac{\sin \theta_w - 0.05 \sin 50^\circ}{0.95} \right)}}$$

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$$F_{xw} = \frac{1}{2} \rho A V_w^2 C_{xw} f_{xw}(\theta_w)$$

$$C_{xw} = .7$$

For ships with distinct superstructures such as YTB the longitudinal shape function is given below:

$$f_{xw}(\theta_w) = -\cos \phi$$

$\theta_{wz} = 80^\circ$ if the superstructure is forward of midships

$$\phi = \left(\frac{90}{\theta_{wz}} \right) \theta_w \quad \text{for } \theta_w < \theta_{wz}$$

$$= \frac{90}{80} \theta_w \quad \text{for } \theta_w < 80^\circ$$

$$\phi = \left(\frac{90}{120^\circ - \theta_{wz}} \right) (\theta_w - \theta_{wz}) + 40^\circ \quad \text{for } \theta_w > \theta_{wz}$$

$$= \left(\frac{90}{120^\circ - 80^\circ} \right) (\theta_w - 80^\circ) + 40^\circ \quad \text{for } \theta_w > 80^\circ$$

$$= .7 (\theta_w - 80^\circ) + 40^\circ$$

$$F_{xw} = \frac{1}{2} (0.00237) V_w^2 (560) (.7) (-\cos \phi)$$

$$= \underline{\underline{0.1645 V_w^2 (-\cos \phi)}}$$

The moments due to the YTB on the mooring group are small therefore they will not be considered when summing the moments to find the zero moment crossing.

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$$F_{yc} = \frac{1}{2} \rho V_c^2 L_{wl} T C_{p1} \sin \theta_c$$

$$C_{yc} = C_{yc|\infty} + (C_{yc|1} - C_{yc|\infty}) e^{-K(\frac{wd}{T} - 1)}$$

$$\frac{wd}{T} = \frac{22}{13} = 1.7$$

$$\phi = \frac{250}{L_{wl} BT} = \frac{25/320}{105(28)13} = .29$$

$$\frac{L_{wl}}{B} = \frac{105}{28} = 3.75$$

Use limiting value for $C_{yc|\infty} = 0.4$

$$C_p = \frac{\phi}{C_{in}} = \frac{.29}{.85} = .34$$

$C_{in} = 0.85$ from air tug shape

$$C_p L_{wl} / \sqrt{T} = .34(105) / \sqrt{13} = 9.9$$

Use limiting value for $C_{yc|1} = 2.0$

$$K = .75$$

$$C_{yc} = 0.4 + (2 - 0.4) 2.7182818^{-.75(1.7-1)}$$

$$= 1.346$$

$$F_{yc} = \frac{1}{2} (2) V_c^2 (105/13) (1.346) \sin \theta_c$$

$$= \underline{\underline{1837 V_c^2 \sin \theta_c}}$$

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$$F_{xc} = F_{xform} + F_{xfriction} + F_{xprop}$$

$$F_{xform} = -\frac{1}{2} \rho_w V_c^2 B T C_{xcb} \cos \theta_c$$

$$= -\frac{1}{2} (2) V_c^2 (28)(13)(.1) \cos \theta_c$$

$$= -36.4 V_c^2 \cos \theta_c$$

$$F_{xfriction} = \frac{1}{2} \rho_w V_c^2 S C_{xca} \cos \theta_c$$

$$S = 1.7 (T L_w) + \frac{350}{T}$$

$$= 1.7 (13) 105 + \frac{35 (320)}{13} = 3182$$

$$C_{xca} = \frac{0.075}{\left(\log V_c \frac{L_w \cos \theta_c}{1.4 \times 10^5} - 2 \right)^2}$$

$$F_{xfriction} = \frac{1}{2} (2) V_c^2 (3182) \frac{0.075}{\left(\log V_c \frac{L_w \cos \theta_c}{1.4 \times 10^5} - 2 \right)^2} \cos \theta_c$$

$$= -\frac{238.7 V_c^2 \cos \theta_c}{\left(\log V_c \frac{7.5 \times 10^6 \cos \theta_c}{-2} \right)^2}$$

Propeller drag is the form drag of the vessel's propeller with a locked shaft. Propeller drag is given by the following equation:

$$F_{xprop} = -\frac{1}{2} \rho_w V_c^2 A_p C_{prop} \cos \theta_c$$

WHERE: F_{xprop} = longitudinal current load due to propeller drag

ρ_w = mass density of water = 2 slugs per cubic foot for sea water

V_c = average current speed, in feet per second

A_p = propeller expanded (or developed) blade area, in square feet

C_{prop} = propeller-drag coefficient (assumed to be 1)

θ_c = current angle

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CHESAPEAKE**DIVISION****Naval Facilities Engineering Command****NDW****DISCIPLINE****PROJECT:** _____**Station:** _____**E S R:** _____ **Contract:** _____**Calcs made by:** WAS **date:** _____**Calculations for:** _____**Calcs ck'd by:** WAS **date:** _____ A_p is given by:

$$A_p = \frac{A_{Tpp}}{1.067 - 0.229 p/d} = \frac{A_{Tpp}}{0.838}$$

WHERE: A_p = propeller expanded (or developed) blade area, in square feet A_{Tpp} = total projected propeller area, in square feet p/d = propeller pitch to diameter ratio (assumed to be 1)

$$A_{Tpp} = \frac{L_{WL} B}{A_R}$$

WHERE: A_{Tpp} = total projected propeller area, in square feet L_{WL} = waterline length of vessel, in feet B = vessel beam, in feet A_R = area ratio, found in Table 1

TABLE 1
 A_R for Propeller Drag

Vessel Type	Area Ratio, A_R
Destroyer	100
Cruiser	160
Carrier	125
Cargo	240
Tanker	270
Submarine	125

YTB has a very small A_R and a YTM has
 $A_p = 27 \text{ ft}^2$ so a YTB's A_p will be larger
Use $A_R = 75$ for YTB

$$A_{Tpp} = \frac{105(28)}{75} = 39.2 \text{ ft}^2$$

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$$A_p = \frac{372}{1232} = 16.5 \text{ ft}^2$$

$$F_{xprop} = -\frac{1}{2} (2) V_c^2 (46.8)(1) \cos \theta_c$$

$$= -46.8 V_c^2 \cos \theta_c$$

$$F_{xc} = -V_c^2 \cos \theta_c (36.4 + (\log V_c (7.5 \times 10^6 \cos \theta_c - 2))^2 + 46.8)$$

$$= -V_c^2 \cos \theta_c [83.2 + (\log V_c (7.5 \times 10^6 \cos \theta_c - 2))^2]$$

Now all the formulas are complete for the vessels moored at Mooring A. Now an iterative process begins so that the mooring group position can be found when wind and current are acting on it.

The environment condition that will be tried is the wind coming out of the North at 122 ft/sec and the river flooding at 2.5 ft/sec. The current direction is from the NNE or 22.5°

Using the flow diagram on page 2

$$\theta_{c1} = \theta_{wc} / 2 = 22.5^\circ - 0^\circ / 2 = 22.5^\circ / 2 = 11.25^\circ$$

$$\theta_{w1} = \theta_{c1} - \theta_{wc} = 11.25^\circ - 22.5^\circ = -11.25^\circ$$

calculate F_{yw} for $\theta_{w1} = -11.25^\circ$

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$$F_{yw \text{ barge}} = 4.33 A V_w^2 \left(\sin \frac{\alpha_w - 0.05 \sin \alpha_w}{0.95} \right) \\ = -10,434 \text{ lbs}$$

$$F_{wy \text{ barge}} = 1.37 V_w^2 \left(\sin \frac{\alpha_w - 0.05 \sin \alpha_w}{0.95} \right) \\ = -3295 \text{ lbs}$$

$$F_{w \text{ tot}} = -13729 \text{ lbs}$$

$$F_{yc} \text{ for } \theta_c = 11.25^\circ$$

$$F_{yc \text{ barge}} = 4536 V_c^2 \sin \theta_c \\ = 5531 \text{ lbs}$$

$$F_{yc \text{ xrb}} = 1837 V_c^2 \sin \theta_c \\ = 2340 \text{ lbs}$$

$$F_{c \text{ tot}} = 7871 \text{ lbs}$$

$$F_{yt} = F_{yw} + F_{yc} = -5858 \text{ lbs}$$

$$M_{x \text{ yw}} \text{ for } \alpha_w = -11.25^\circ, C_{x \text{ yw}} = -0.02 \\ M_{x \text{ yw}} = 2500 V_w^2 C_{x \text{ yw}} (\rho_w) \\ = -744,200 \text{ ft-lbs}$$

$$M_{x \text{ yc}} \text{ for } \theta_c = 11.25^\circ, \left(\frac{e_c}{L_{wl}} \right) = 0.14 \\ M_{x \text{ yc}} = 1837 \times 10^6 V_c^2 \sin \theta_c (0.14) \\ = 313,600 \text{ Ft-lbs}$$

$$M_{x \text{ yt}} = M_{x \text{ yw}} + M_{x \text{ yc}} = -130600 \text{ ft lbs}$$

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$$\begin{aligned}\Sigma M_1 &= M_{xyr} + F_{yr} (\frac{1}{2}) L_{wl} = \\ &= -430600 - (-5858)(.5)(105) \\ &= 755,695 \text{ ft-lbs}\end{aligned}$$

2nd Try
 $\theta_{c2} = 0, \theta_{w2} = \theta_{c2} - \theta_{wc} = 0 - 22.5^\circ = -22.5^\circ$

$$\begin{aligned}F_{ywbg} &= 4.338 V_w^2 \left(\frac{\sin \theta_w - 0.05 \sin 5\theta_w}{0.95} \right) \\ &= -22,870 \text{ lbs}\end{aligned}$$

$$\begin{aligned}F_{wyrb} &= 1.37 V_w^2 \left(\frac{\sin \theta_w - 0.05 \sin 5\theta_w}{0.95} \right) \\ &= -7,220 \text{ lbs}\end{aligned}$$

$$F_{wtr} = -30,090 \text{ lbs}$$

$$F_{rc} \text{ for } \theta_{c2} = 0^\circ, = 0$$

$$F_{yr} = -30,090 \text{ lbs}$$

$$\begin{aligned}M_{xyw} \text{ for } \theta_w = -22.5^\circ, \quad C_{xyw} = -0.035 \\ M_{xyw} &= 2500 V_w^2 C_{xyw}(\theta_w) \\ &= -1,302,350 \text{ ft-lbs}\end{aligned}$$

$$M_{xrc} \text{ for } \theta_c = 0, = 0$$

$$M_{xyr} = -1,302,350 \text{ ft-lbs}$$

$$\begin{aligned}\Sigma M_2 &= M_{xyr} - F_{yr} (\frac{1}{2}) L_{wl} \\ &= -1,302,350 - (-30,090)(.5)(105) \\ &= 4,790,900 \text{ ft-lbs}\end{aligned}$$

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$\Sigma M_1 + \Sigma M_2$ did not change signs

$$\therefore \theta_{c2} = \theta_{c10} = 22.5^\circ$$

$$\theta_{w2} = \theta_{c2} - \theta_{wc} = 22.5^\circ - 22.5^\circ = 0^\circ$$

$$F_{yw} = 0$$

$$F_{yc \text{ barge}} = 4536 V_c^2 \sin \theta_c$$

$$= 10,350 \text{ lbs}$$

$$F_{c \text{ yte}} = 1237 V_c^2 \sin \theta_c$$

$$= 4390 \text{ lbs}$$

$$F_{c \text{ tot}} = 15240 \text{ lbs}$$

$$M_{xyw} \text{ for } \theta_{w2} = 0^\circ, 0$$

$$M_{xyc} \text{ for } \theta_{c2} = 22.5^\circ, \left(\frac{e_c}{1.1}\right) = 0.16$$

$$M_{xyc} = 1.837 \times 10^6 V_c^2 \sin \theta_c (0.16)$$

$$= 702,990 \text{ ft-lbs}$$

$$M_{xyT} = 702,990 \text{ ft-lbs}$$

$$\Sigma M_2 = M_{xyT} - F_{yT} \left(\frac{1}{2}\right) l_{w1}$$

$$= 702990 - (15240)(.5)(405)$$

$$= -2,383,110 \text{ ft-lb}$$

Third Try

$$\theta_{c3} = \frac{\theta_{c1} + \theta_{c2}}{2} = \frac{11.25^\circ + 22.5^\circ}{2} = 16.875^\circ$$

$$\theta_{w3} = \theta_{c3} - \theta_{wc} = 16.875^\circ - 22.5^\circ = -5.625^\circ$$

$$F_{c \text{ barge}} = 4,338 V_w^2 \left(\sin \theta_w - \frac{0.05 \sin 5 \theta_w}{0.95} \right)$$

$$= -5060 \text{ lbs}$$

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$$F_{1/10 \text{ yr}} = 137 V_w^2 \left(\frac{\sin \theta_w - 0.05 \sin 5 \theta_w}{0.75} \right)$$

$$= -1600 \text{ lbs}$$

$$F_{1/10 \text{ Tot}} = -6660 \text{ lbs}$$

$$M_{xyw} = 2500 V_w^2 \left(\frac{\sin \theta_w}{L_w} \right)$$

$$= 2500 V_w^2 (-0.01)$$

$$= -3,721,000 \text{ ft-lbs}$$

$$M_{xyc} = 1837 V_c^2 \sin \theta_c \left(\frac{L_c}{L_w} \right) = 0.158$$

$$M_{xyc} = 1837 \times 10^6 V_c^2 \sin \theta_c (0.158)$$

$$= 526,600$$

$$M_{xyr} = M_{xyw} + M_{xyc} = -3,194,400 \text{ ft-lbs}$$

$$F_{1/10 \text{ change}} = 4536 V_c^2 \sin \theta_c$$

$$= 8230 \text{ lbs}$$

$$F_{1/10 \text{ Tot}} = 1837 V_c^2 \sin \theta_c$$

$$= 3330 \text{ lbs}$$

$$F_{1/10} = -3330 \text{ lbs}$$

$$\Sigma M_3 = M_{xyr} - F_{1/10} \left(\frac{1}{2} \right) L_w$$

$$= -3,194,400 - (3330)(.5)(405)$$

$$= -2,520,000 \text{ ft-lb}$$

4th Try

$$\Sigma M_3 \text{ and } \Sigma M_2 \text{ did not change}$$

$$\therefore \theta_{c4} = \frac{\theta_{c1} + \theta_{c2}}{2} = \frac{11.25 + 16.875}{2} = 14.0625^\circ$$

$$\theta_{1/10} = \theta_{c1} - \theta_{c4} = 14.0625^\circ - 22.5^\circ = -8.4375^\circ$$

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$$F_{YUTR} = F_{YUBARGE} + F_{YUTR} = 5.7 \times 10^3 V_u^2 \left(\sin \theta_c \frac{0.05 \sin 5 \theta_w}{0.75} \right)$$

$$= -10,200 \text{ lbs}$$

$$F_{YCTR} = F_{YCTR} + F_{YCTR} = 6,373 V_c^2 \sin \theta_c$$

$$= 9,680 \text{ lb}$$

$$F_{YT} = -440 \text{ lbs}$$

$$M_{XYU} \text{ for } \theta_w = -51.375^\circ, C_{XYU} = -0.02$$

$$M_{XYU} = -744,200 \text{ ft-lbs}$$

$$M_{XYC} \text{ for } \theta_c = 14.0625^\circ, \frac{C}{T_{max}} = 0.153$$

$$M_{XYC} = 426,800 \text{ ft-lbs}$$

$$M_{XYT} = -317,400 \text{ ft-lbs}$$

$$\Sigma M_4 = M_{XYT} - F_{YT} (1/2)(101)$$

$$= -317,400 - (-440)(50.5)$$

$$= -228,300 \text{ ft-lbs}$$

The graph on the following page is a plot of the ΣM with reference to θ_c . The graphical solution shows $\theta_c \approx 13.5^\circ$

$$\therefore \theta_w = \theta_c - \theta_{wc} = 13.5 - 22.5 = -9^\circ$$

The loads will now be calculated using $\theta_w = -9^\circ$ and $\theta_c = 13.5^\circ$

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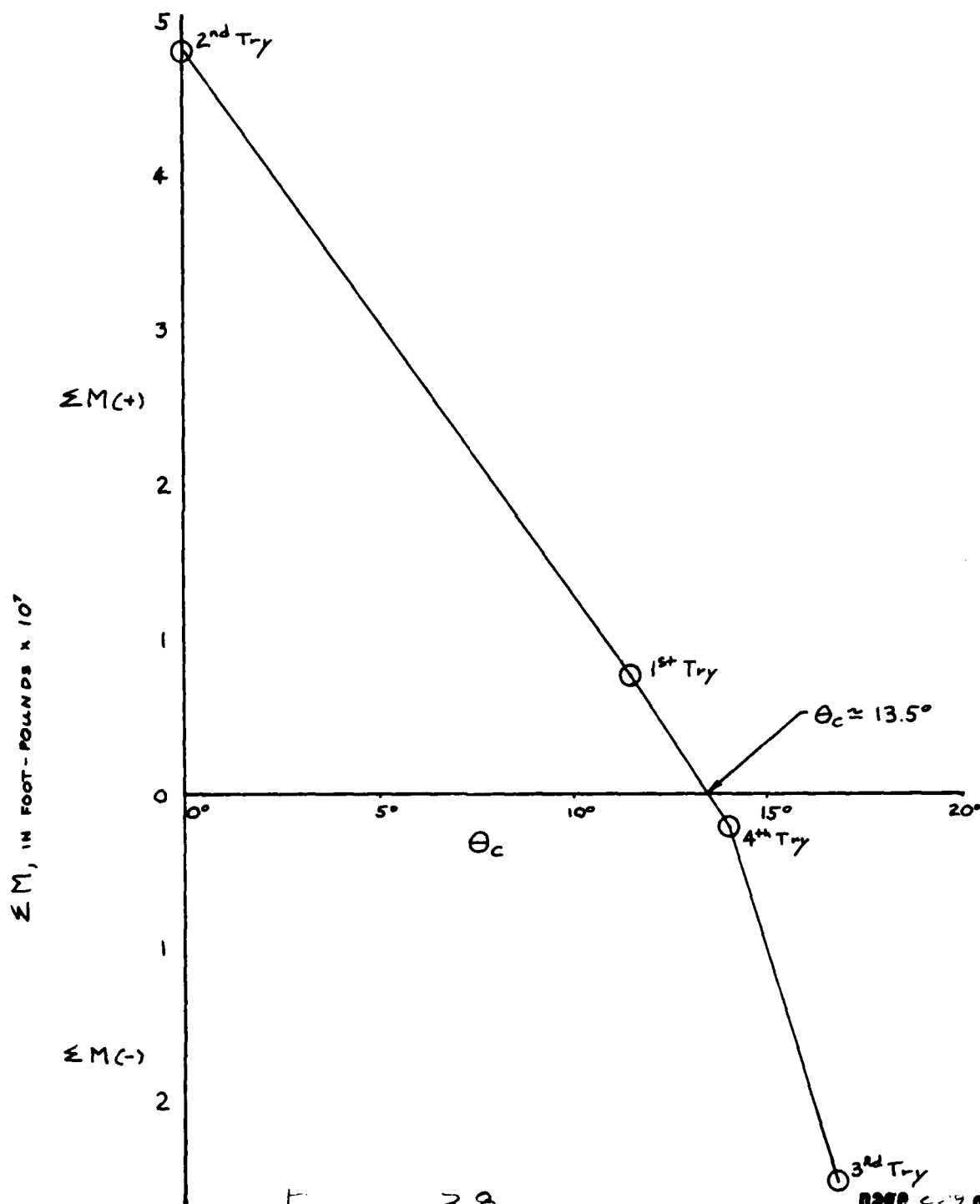


Figure 3.8

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$$F_{x10y10} = 4.338 (122)^2 \sin 9^\circ - \frac{2000 \sin 9^\circ}{0.9}$$

$$= -8230 \text{ lbs}$$

$$F_{x10y10} = 1.37 (122)^2 \sin 9^\circ - \frac{2000 \sin 9^\circ}{0.9}$$

$$= -2600 \text{ lbs}$$

$$F_{x10y10} = -10,830 \text{ lbs}$$

$$F_{x10y10} = 1.526 (22)^2 \left(- \left(\frac{2000 \sin 9^\circ - 0.1 \sin 9^\circ}{0.9} \right) \right)$$

$$= -23,140 \text{ lbs}$$

$$\gamma = -9^\circ + 90^\circ$$

$$F_{x10y10} = 0.4645 (122)^2 - \cos \left(\frac{90^\circ}{80^\circ} 9^\circ \right)$$

$$= -6800 \text{ lbs}$$

$$F_{x10y10} = 27,940 \text{ lbs}$$

$$F_{x10y10} = 4536 (2.5)^2 \sin 13.5^\circ$$

$$= 6600 \text{ lbs}$$

$$F_{x10y10} = 1837 (2.5)^2 \sin 13.5^\circ$$

$$= 2680 \text{ lbs}$$

$$F_{x10y10} = 9280 \text{ lbs}$$

$$F_{x10y10} = -2.5^2 \cos 13.5^\circ \left(84 + \frac{3986}{\log(2.5) 2.893 \times 10^7 \cos 13.5^\circ - 2} \right)$$

$$= -1130 \text{ lbs}$$

$$F_{x10y10} = -2.5^2 \cos 13.5^\circ \left[822 + \frac{2387}{\log(2.5) (2.5 \times 10^6) \cos 13.5^\circ - 2} \right]$$

$$= -550 \text{ lbs}$$

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$$F_{x \text{ total}} = 1633 \text{ lbs}$$

$$F_{yT} = -10,830 + 7280 = -1550 \text{ lbs}$$

$$F_{xT} = 29940 + 1,680 = 31,620 \text{ lbs}$$

$$\begin{aligned} \text{Answer load} &= \sqrt{F_{xT}^2 + F_{yT}^2} \\ &= \sqrt{1550^2 + 31620^2} \\ &= \boxed{31,660 \text{ lbs}} \end{aligned}$$

The answer load calculation takes about 4 hrs to go with someone that is experienced and this is only for one wind direction. There are 8 wind directions to do. The value of the answer is also limited in that it does not give a feel for the loads as the vessels move, hence a static answer. We in Ches Div developed some software to do this lengthy calculation on a computer. This hand calculation was done to validate the software. On the pages that follow, this software and the output from it will be explained.

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Software for solution of hawser loads
of a free-swinging mooring.

The software uses the same equations as shown in the previous hand calculation. The output is in the form of a graph which shows the moment and the hawser loads as the vessel is rotated 360° .

A single graph is for a given wind and current, velocity, and direction.

A computer run for a single graph takes about 15 minutes.

An example of the output for the problem which was done by hand is shown in the following page. The remainder of the graph outputs for the other loading conditions can be found in the appendix A.

This output is shown just to validate the software. The zero moment occurs when the vessel has a heading of 8° or $\theta_w = -8^\circ$ and $\theta_c = 14.5^\circ$. The corresponding hawser load is 31.7 kips. There is some rounding in the angle and the load but the answers show that the software is within less than 5% of the angle and within less than 0.1% of the hawser load thus validating the software.

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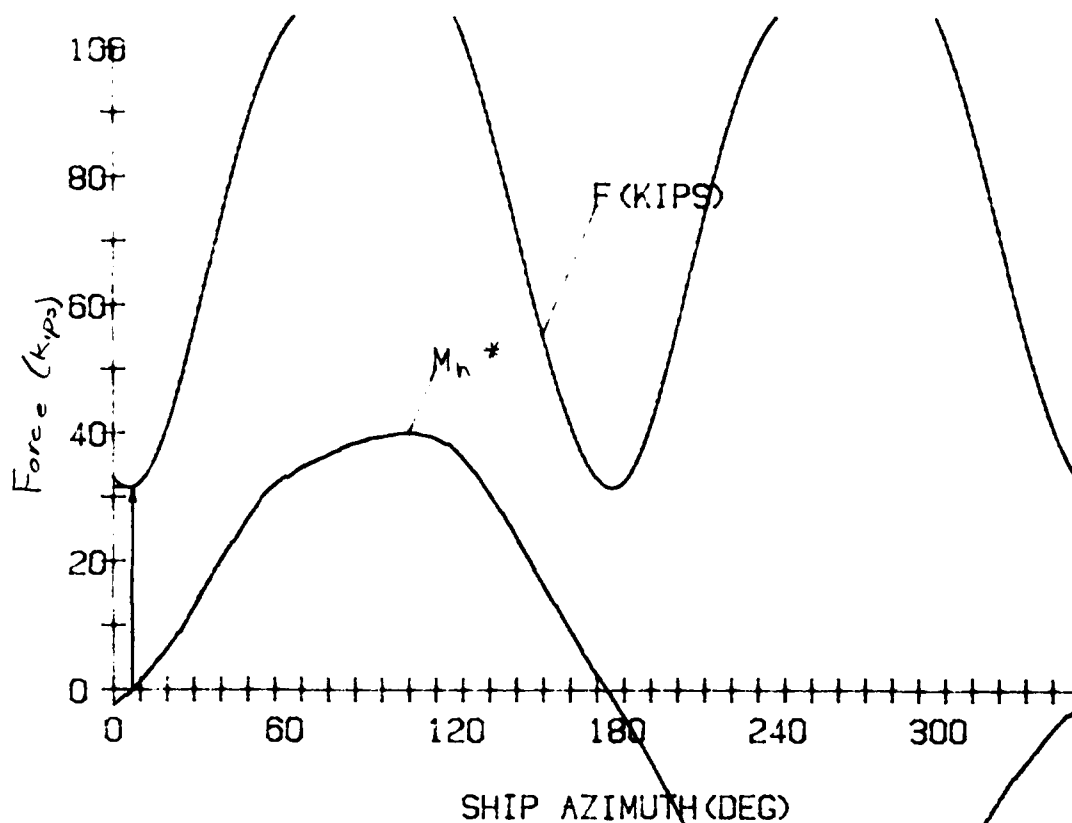
Calcs made by: _____ date: _____
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Calculations for: _____



WIND SPEED(FPS),A(DEG)=122.0 0.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

16.E+004	-7.E+005	42.E+004	-9.E+003	71.E+002	-3.E+004	-1.E+003	31.7
184	-1.E+004	-3.E+005	-5.E+005	47.E+002	-9.E+003	30.E+003	31.6

EM=008°

Hawser Load - 31.7 kips

Figure 3.9

* M_n is a normalized dimensionless moment which is used only to indicate zero moments.

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A quasi-dynamic solution will be performed using the graphical solution shown previously. When a vessel is in a mooring and the wind is up, the ship swings or flaps in her mooring. The figure 3.10 shows this. This deviation from true direction that the wind blows can be as much as $\pm 20^\circ$ from the direction of the wind. This amount of flapping is a function of many things such as length of hawser, speed of wind, speed of current, stiffness of the mooring system and others. A 20° deviation will be used for this analysis.

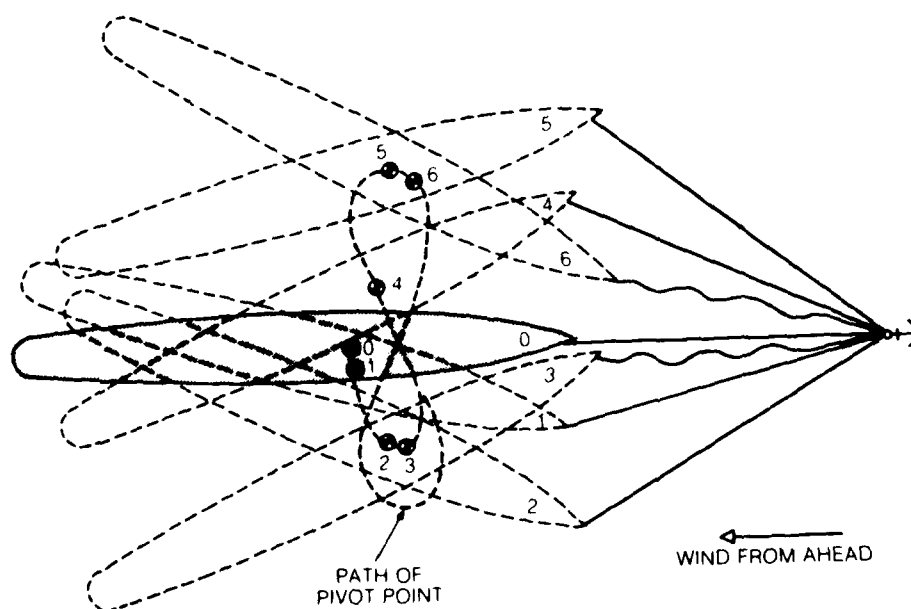


FIGURE 3.10 Manner in which a ship swings in the wind when at anchor.

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The additional loads due to the ship's plugging can be derived from the graphical output of the software. Twenty degrees are added to and subtracted from the zero moment crossing. From the graph below one can see that the $+20^\circ$ from zero moment increased the load to 54 kips.

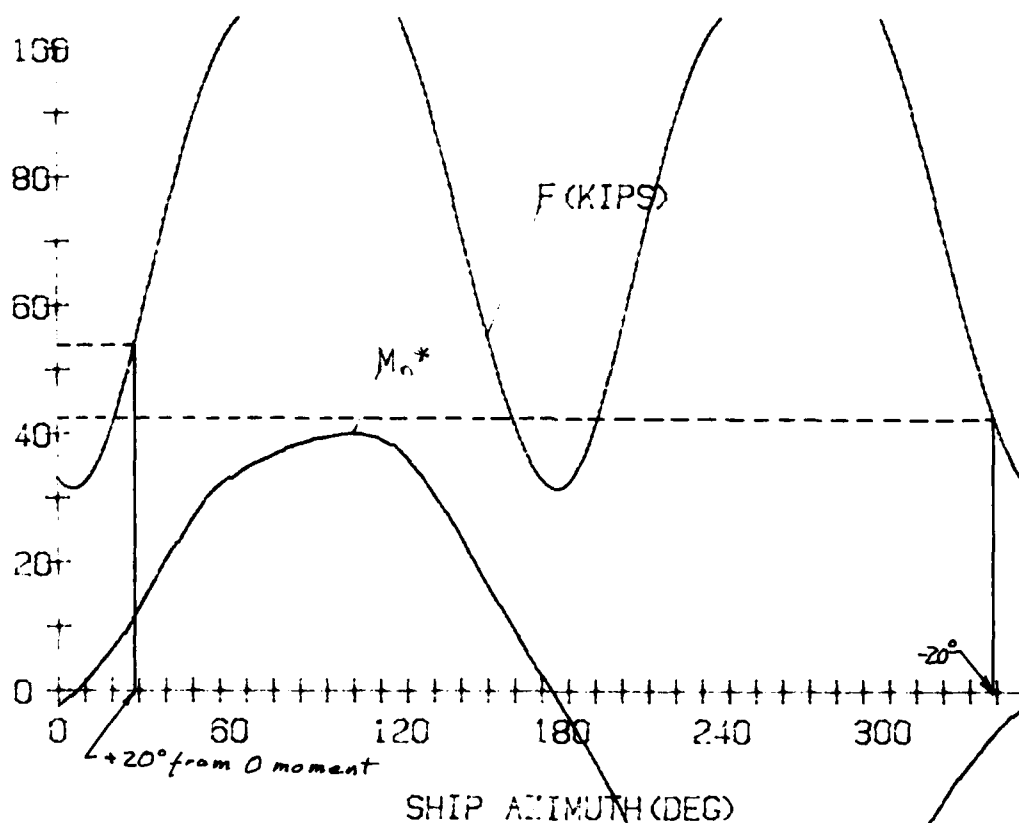


Figure 3.11

* M_n is a normalized dimensionless moment which is used only to indicate zero moment.

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All $\pm$ wind directions were run with either flooding or ebbing current. The static solution for zero moment crossings was obtained and then $\pm 20^\circ$ added to that zero moment crossing, thus obtaining a quasi-dynamic solution from the flagging. From this a polar plot was made of the tower loads of both the static and quasi-dynamic solutions, which is shown below.

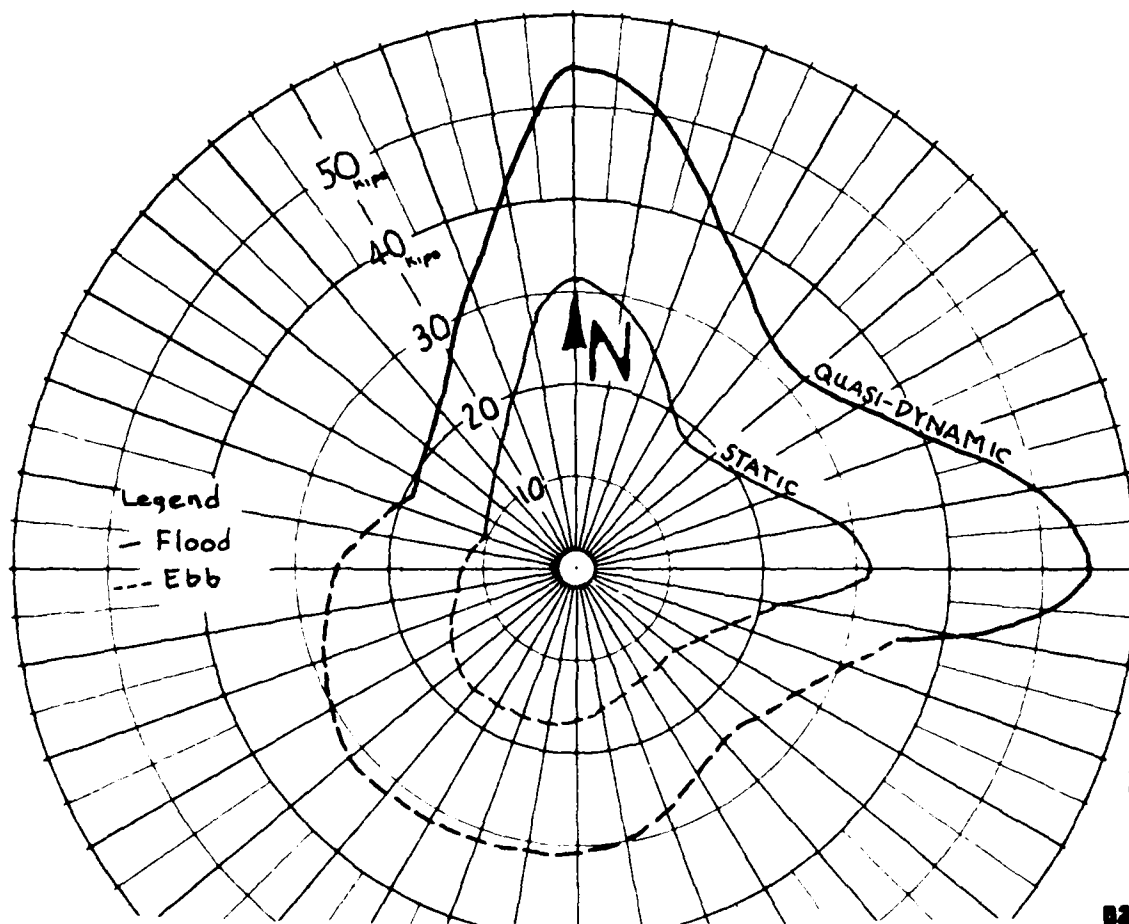


Figure 3.12

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The last figure showed a strong directional loading for the mooring. The highest loads were 51 kips for the North direction and 56 kips for the East direction. This directionality will have to be accounted for in the mooring orientation.

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IV Dynamic Environmental Loading

Wave Action Dynamics

The moorings are located in a river where there is a limited fetch for which waves can be generated. Significant wave heights were predicted using COE, Coastal Engineering Research Center, Coastal Engineering Technical Note -I-6, 3/81. A figure from that report is shown below.

Note: Waves in a water depth of 25 feet with wave periods less than 3.1 sec. are considered to be deepwater waves, i.e. $\frac{H}{L} > 2.56$.

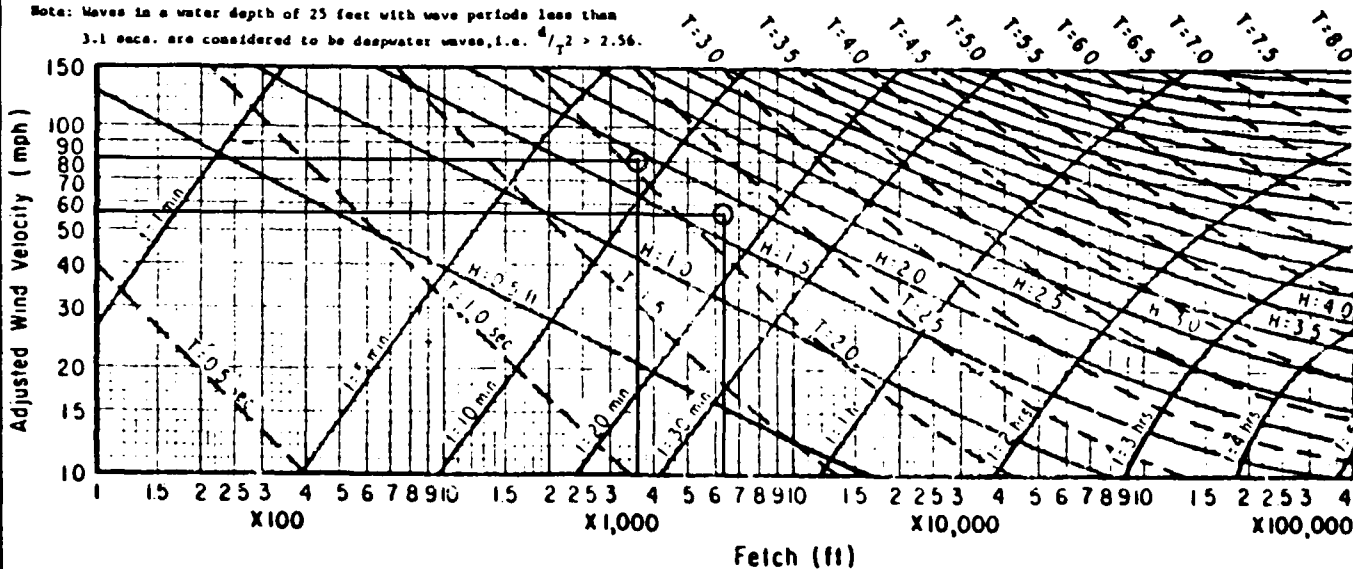


Figure 4.1 Forecasting Curves for Shallow-water Waves. Constant Depth = 25 Feet.

The results are that the North direction has 80 MPH wind but only 3600 ft. of fetch generate a 1.9 ft wave, and the Southwest has 6340 ft. of fetch but only 56 mph winds generate a 1.75 ft wave.

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These limited waves will not have a dynamic effect on the mooring.

Wind Action

This section is concerned with the dynamic effect that wind has on a mooring system. A one degree of freedom numerical model of mooring dynamics was created in-house by Mr. W. Seelig. This paper can be found in Appendix B. This dynamic analysis is another technique used to define the hawser loads. When compared with the other techniques, as shown on figure 4.3, the load response is reasonable.

An input to the model is a wind spectrum. This spectrum is used to create a model of the real time wind which is the forcing function on the mooring model. The spectrum used in the model was derived from the Journal of the Structural Division, Proceedings of the ASCE, June 1968 titled "Gust Response Factors" by J. Vellozzi and E. Cohen. The spectrum was also used by Exxon Research and Engineering Co. in a report titled "Guidelines for Deepwater Port Single Point Mooring Design."

A typical output can be seen in figure 4.2 on the following page. The remaining 7 graphs for the other directional loads can be seen in the Appendix C. From these graphical outputs a hawser load rose was created for the

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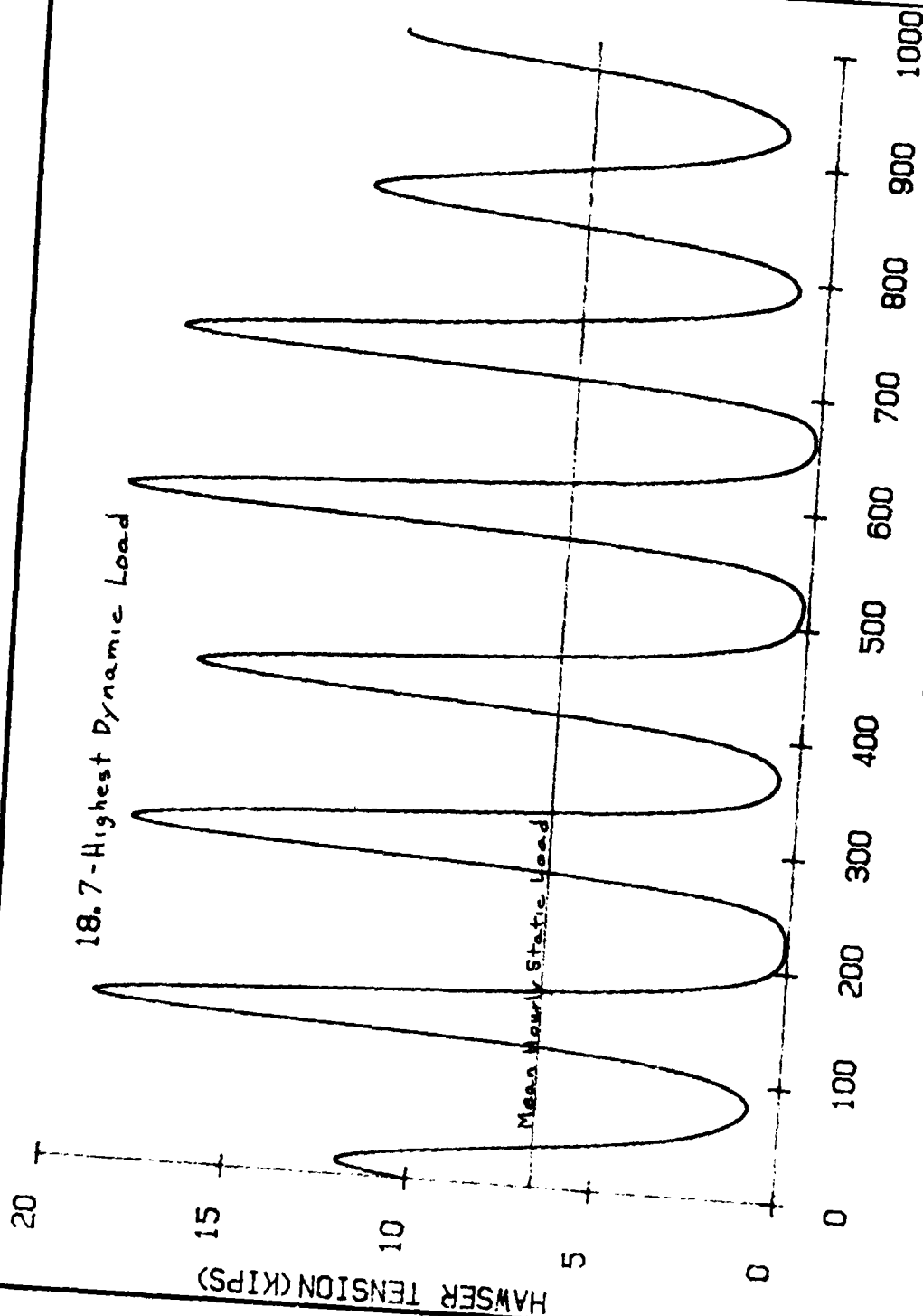
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18.7-Highest Dynamic Load



TIME (SEC)

Figure 4.2 Dynamic Hawser Loads for Wind at 180° Bearing with an Ebb Tide.

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dynamic response. It was plotted on the load nose created previously and can be seen below. The dynamic load was greater than the quasi-dynamic in one case only. This was the North direction and it only increased by 1 kip over the 54 kips of the quasi-dynamic solution.

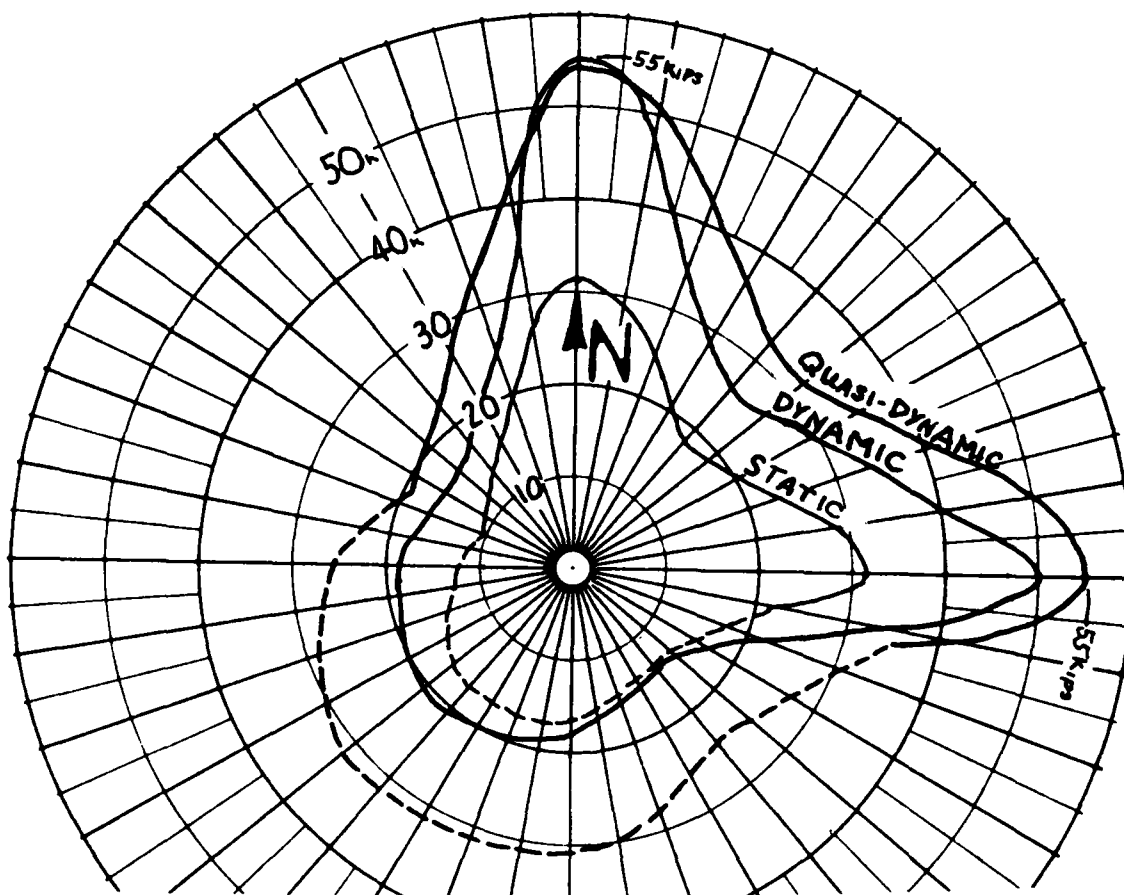


Figure 4.2

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The conclusions from the static and dynamic environmental loading of the moorings are that the maximum load will be 55 kips from the North and East and 30 kips from the South and West. Because these loads are relatively low, all moorings will be designed and built for a load of 55 kips from any direction.

The dynamics due the movement of the mooring group is considered to be minimal because the waves are small and the barges will be rafted together with wire rope. Therefore the dynamic loading due to the articulating vessel group was not considered in this analysis.

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V Mooring System Design

1. Anchor selection

1.1 Geotechnical Data

There are 2 sources of geotechnical data: Army Corps of Engineers, Jacksonville Port Authority and Law Engineering.

1.1.1 The US Army COE geotechnical information was derived from 20 ft. long vibro cores taken in 1977 in the river channel. The cores were adjacent to the mooring site. All cores indicated 20 ft of black organic silt.

1.1.2 The Jacksonville Port Authority has two sets of geotechnical data. One set is from the design effort of a fixed bridge and the other set is from the design of a new wharf. The mooring site is equal distance from both sets of data. The overview of the geotechnical is shown in figure 5.1.

5.1.3 Law Engineering investigated the mooring site with 3 borings. The results can be found in Appendix D.

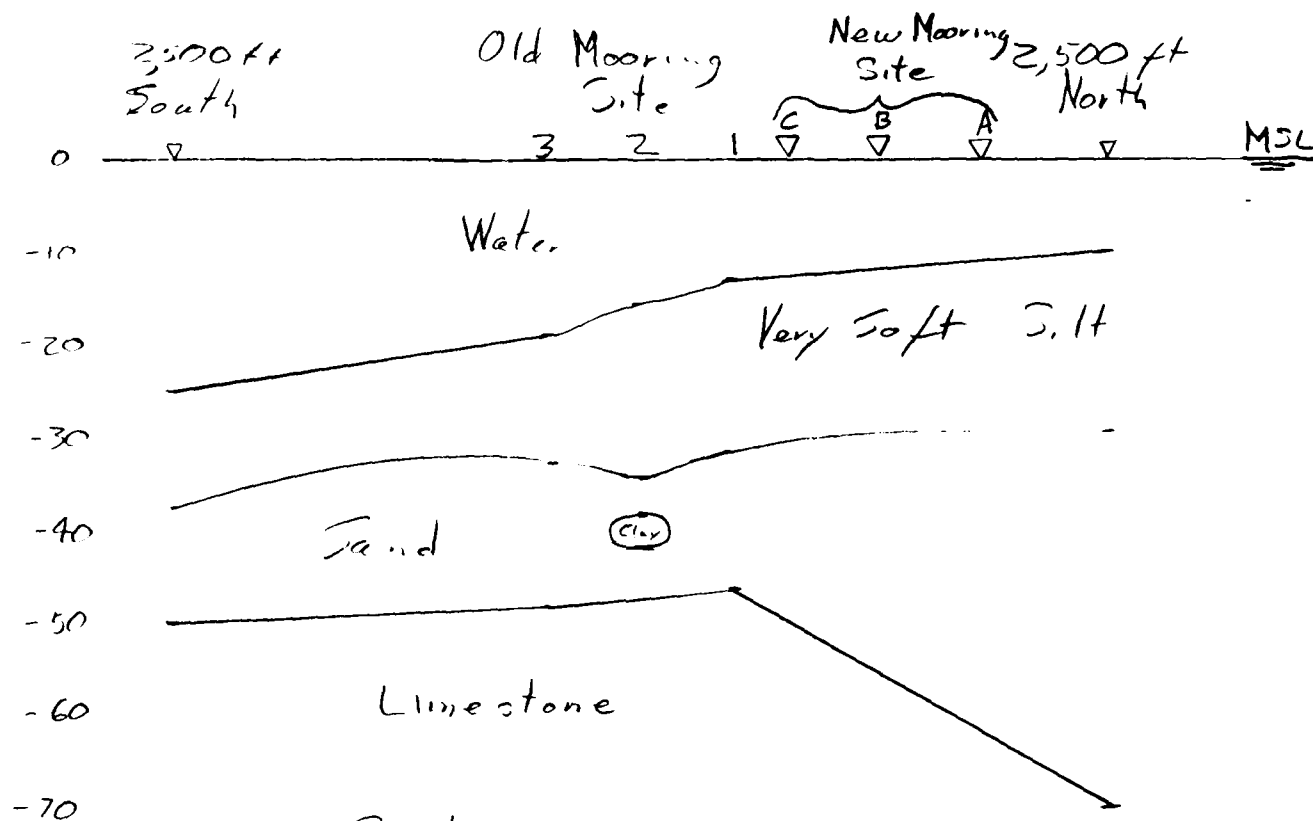
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Geotechnical Overview.



Sketch -
Figure 5.1

1.1.4 Conclusions

The sketch above shows a geotechnical cross-section. The very soft silt at all geotechnical investigation sites did not have shear strength analysis performed on them. There was a site on the South of the island that the moorings are adjacent to that did have shear strength values.

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The soils at this site shows a very soft silt, 31 ft. thick with sand underlying this which is the same strata as at the mooring site.

The shear strength in the top 16 ft increased from 220 PSF at the top to 650 PSF, 16 ft below the top. The soil shear strength increases with depth at 27 psf / ft.

According to NCEL Technical Note - N-1688 an increase

in soil strength of 10 psf / ft is sufficient for holding in mud.

Therefore a Navy stockless anchor with stabilizers will be used.

The next question is if there is sufficient thickness of mud to hold a stockless anchor. The NCEL Report titled "Design Guide for Drag Embedment Anchors", Technical Note N-1688, Jan. 1984 will be used to select the proper anchor.

Design load = 55 kips = H_D
Calculate the ultimate horizontal holding capacity, H_u .

$$H_u = FS \times H_D$$

$$= 1.5 \times 55$$

$$= 82.5 \text{ kips}$$

The factor of safety, FS, for stockless anchor is 1.5

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Select an anchor size using T_u as T_M from the figure below.

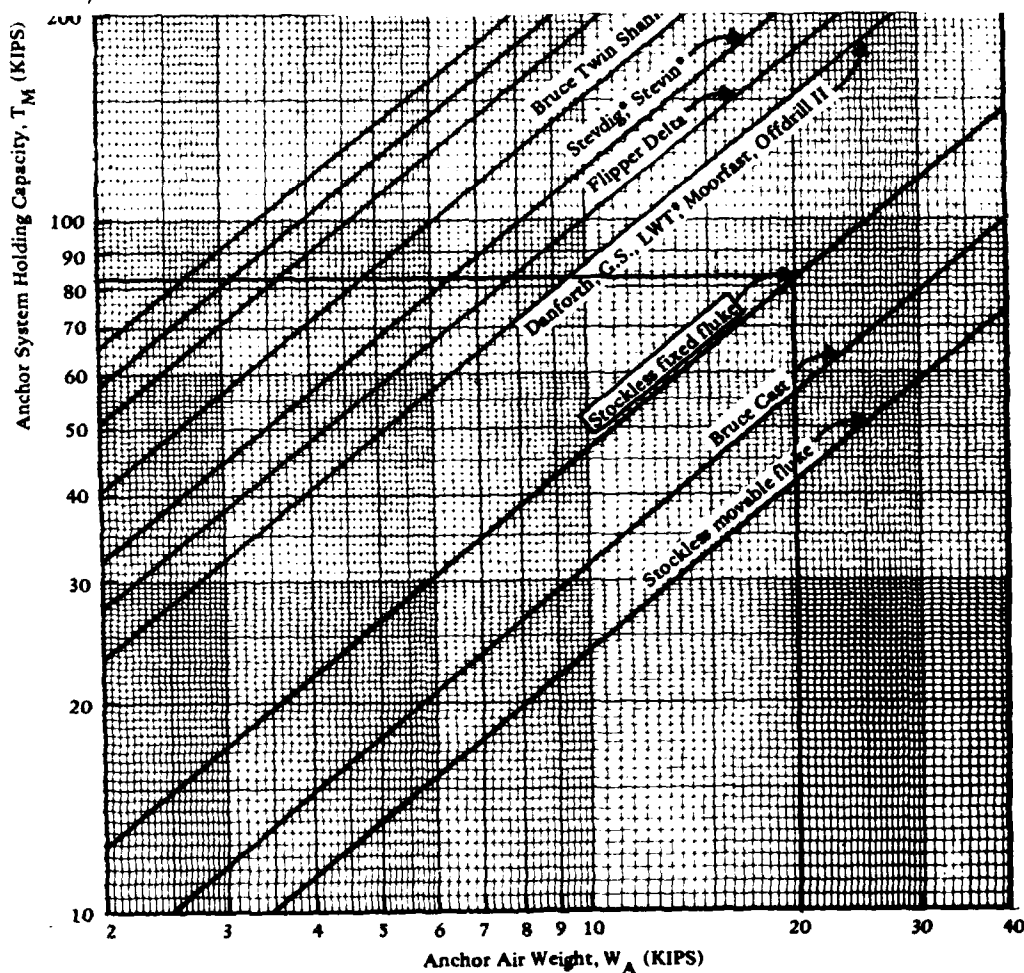


Figure 5.2 Holding capacity at mudline - mud (anchor-chain system).

The selected anchor is a 20 kip stockless with fixed flukes opened to 50°.

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Naval Facilities Engineering Command

NDW**DISCIPLINE**Calcs made by: 194011 date: _____Calcs ck'd by: NAS date: _____

PROJECT: _____

Station: _____

E S R: _____ Contract: _____

Calculations for: _____

Determine the soil thickness is required.
The normalized plate tip penetration
for a stockless in mud is 3. This multiplied
by the plate length of 6.8 ft gives
a required soil thickness of 20.4 ft.
The silt layer at the mooring site is
only about 18 ft. thick. After consulting with
NCEL and using a mathematical
model for predicting hold capacity, a
new soil thickness was calculated
to be 15 ft of 12 pcf/ft soil, which
has an ultimate holding capacity of
9,300 lbs. Therefore the 20 kip
stockless anchor is approved if
the soil depth and shear strength
if the anchor location meet the
above criteria. Because 20K anchors
are available only on the West Coast,
a 25 kip stockless anchor will be used.
For the 25K stockless to have a
holding capacity of 55 kips, 19 ft.
of silt must be present at all
anchor locations. Once again the
plates will be set open at 50°.

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

Chain Selection

T_u , Ultimate capacity = $1.15 \times \text{Factor of Safety} \times \text{Design Load, HD}$

$$T_u = 1.15 \times 3 \times 55k = 189.75k$$

1 3/4 in stud link Grade 2 has a breaking strength of 249 kip and would be sufficient but because of availability 2" grade 3 stud link chain will be used.

Determine tension at vessel

$$T_D = w(k+d)$$

w = chain weight per ft = 31.9

k = $H_D / w = 55000 / 31.9 = 1724$

d = water depth = 22' + 3' tide = 25

$$T_D = 55800 \text{ lbs}$$

$$\begin{aligned} T_U &= F_S \times T_D \\ &= 3 \times 55800 \\ &= 167,400 \text{ lbs} \end{aligned}$$

T_U for 2" Grade 3 Chain is 454,000 lbs

$\therefore$ Chain is ok to use

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

The chain length will be a standard class D mooring which has 2 1/2 shots for each ground leg plus the riser chain. There will also be a 10 kip water weight sinker attached to the ground ring.

Booy requirements with 2 ft. of freeboard.

Length of chain suspended in water is 25' which multiplied by unit weight of 31.9 equals about 800 lbs. The existing 9.5' by 7' booy at site will be adequate.

$$\text{Buoyancy} = \pi (4.75)^2 (5) 64 - 7700 (\text{booy wt.})$$

$$= 15 \text{ kips}$$

Cathodic Protection

$$\begin{aligned} \text{Surface area per shot} \\ &= 0.91 \text{ ft}^2 / \text{link} \times 135 \text{ links / shot} \times 50\% \text{ area} \\ &\quad \text{unpainted} \\ &= 61.4 \text{ ft}^2 \end{aligned}$$

Mil-spec zinc (Mil Spec A-18001) produces
 $\frac{350 \text{ Amps}}{\text{lb}}$

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

10 ^{ma}/ft need in sea water

What is the life for a 250 lb anode

$$\text{Life} = \frac{(250 \text{ lb}) \left(\frac{350 \text{ Amps} \cdot \text{hr}}{\text{lb}} \right)}{(8760 \text{ hr/yr}) (0.01 \frac{\text{Amp}}{\text{ft}^2}) 61.4 \text{ ft}^2} = \underline{16 \text{ yrs.}}$$

∴ A 250 lb zinc anode with continuity wire will be used

CHESAPEAKE		DIVISION	PROJECT: _____
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: <u>T. Smith</u>		date: _____	Calculations for: _____
Calcs ck'd by: <u>AMS</u>		date: _____	

Concluding Requirements

1. Adequate silt thickness of 19 ft. has to be determined at each anchor location.
2. The ground legs will be oriented North, South, East and West.
3. At the time of installation the anchors will be proof loaded to design load of 55 kips for a period of 15 minutes.

CHESAPEAKE**DIVISION**

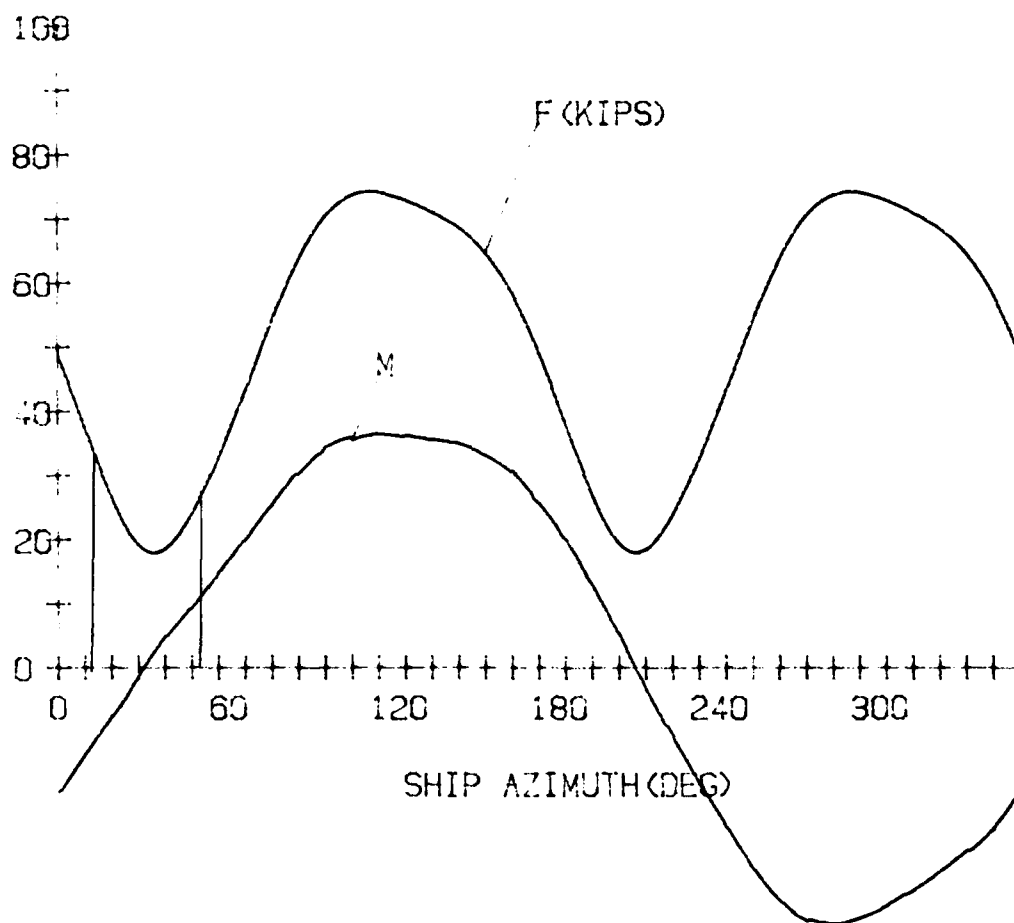
Naval Facilities Engineering Command

NDW**PROJECT:** _____**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____Calcs made by: MS date: _____**Calculations for:** _____Calcs ck'd by: MMS date: _____**VI Bill of Material for Que mooring**

Item	Description	Qty
1	25kip Stockless Anchor w/ stabilizer	4
2	Chain 2" Grade 3 1 shot	8
3	Chain 2" Grade 3 1/2 shot	5
4	10kip Inwater Weight Sinkers	1
5	Ground Ring 2" chain size	1
6	Swivel 2"	5
7	Detachable Link 2"	13
8	Anchor Joining Link 2"	10
9	Detachable Link 2 1/2" (for sinker)	1
10	Zinc Anodes 250 lbs	9
11	Hose Clamps	320
12	Continuity Wire 7/8" IWRC	1000'
13	Sea Cushion type fenders (4' x 7.4' long)	10
This list does not contain spare parts for mooring hardware.		

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**PROJECT:** _____**Station:** _____**DISCIPLINE****E S R:** _____ **Contract:** _____**Calcs made by:** _____ **date:** _____**Calculations for:** _____**Calcs ck'd by:** _____ **date:** _____

WIND SPEED(FPS),A(DEG)= 39.5 45.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5
39.5 21.5+004 48.5+004 29.5+004 79.5+002 -5.5+003 -1.5+004 -1.5+003 18.1
22.5 -1.5+004 54.2+004 -4.2+005 -5.5+003 86.5+002 16.5+003 17.5+002 17.8

DISCIPLINE

DIVISION

NDW

PROJECT: _____

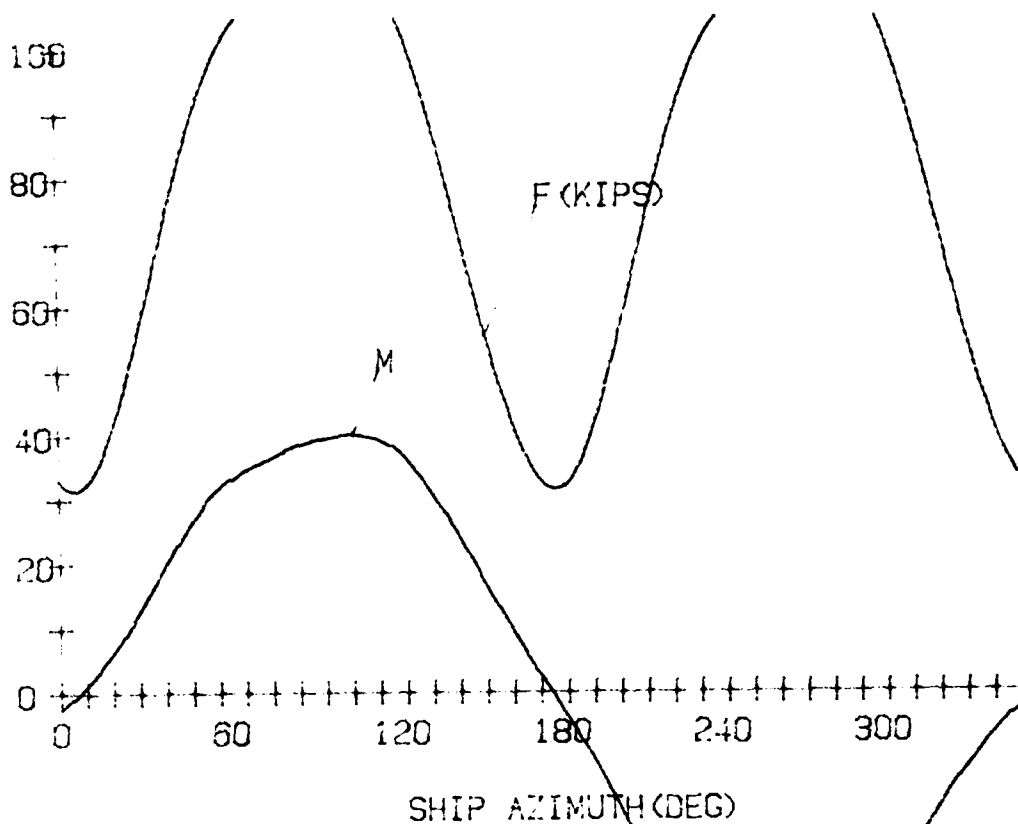
Station: _____

ESR: _____ **Contract:** _____

Calculations for: _____

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____



MINI) SPEED(FPS),H(DEG)=120.0 5.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

2003	13.0+004	13.0+005	42.8+004	42.8+003	71.2+002	33.5+004	11.5+003	31.7
2004	13.0+004	13.0+005	42.8+005	42.8+002	71.2+003	30.5+003	16.2+002	31.6

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____

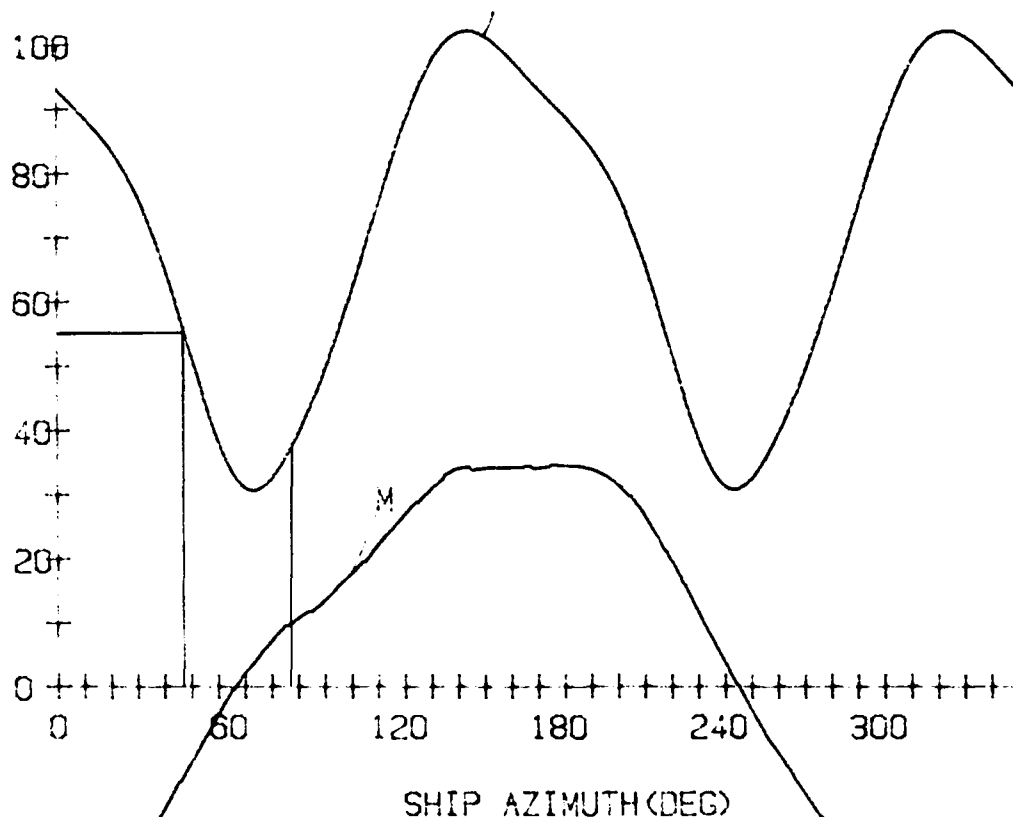
PROJECT: _____**Station:** _____**E S R:** _____ **Contract:** _____**Calculations for:** _____

Appendix A - Static Solutions for
Free-swing Moorings.

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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:** _____

WIND SPEED(FPS),A(DEG)=120.0 30.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

37 12.E+004 10.E+005 89.E+004 39.E+003 -2.E+004 -1.E+004 -1.E+003 32.4
255 -4.E+005 15.E+005 -7.E+005 -1.E+004 20.E+003 19.E+003 11.E+002 31.0

page 64 of _____

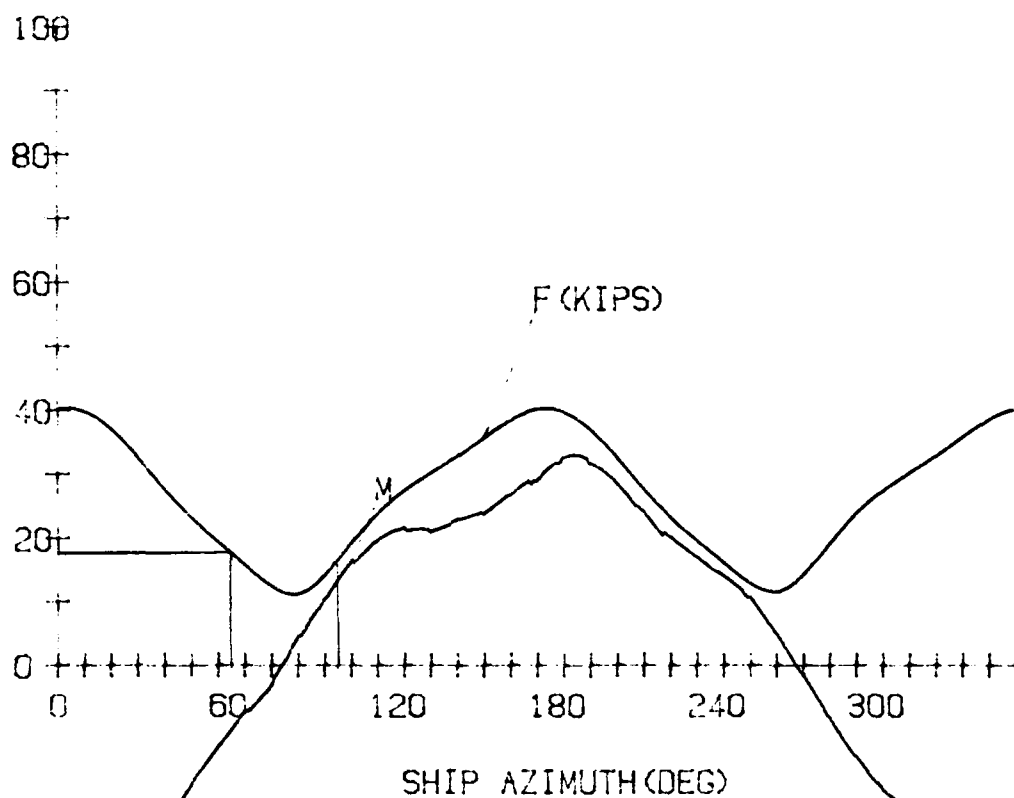
CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____

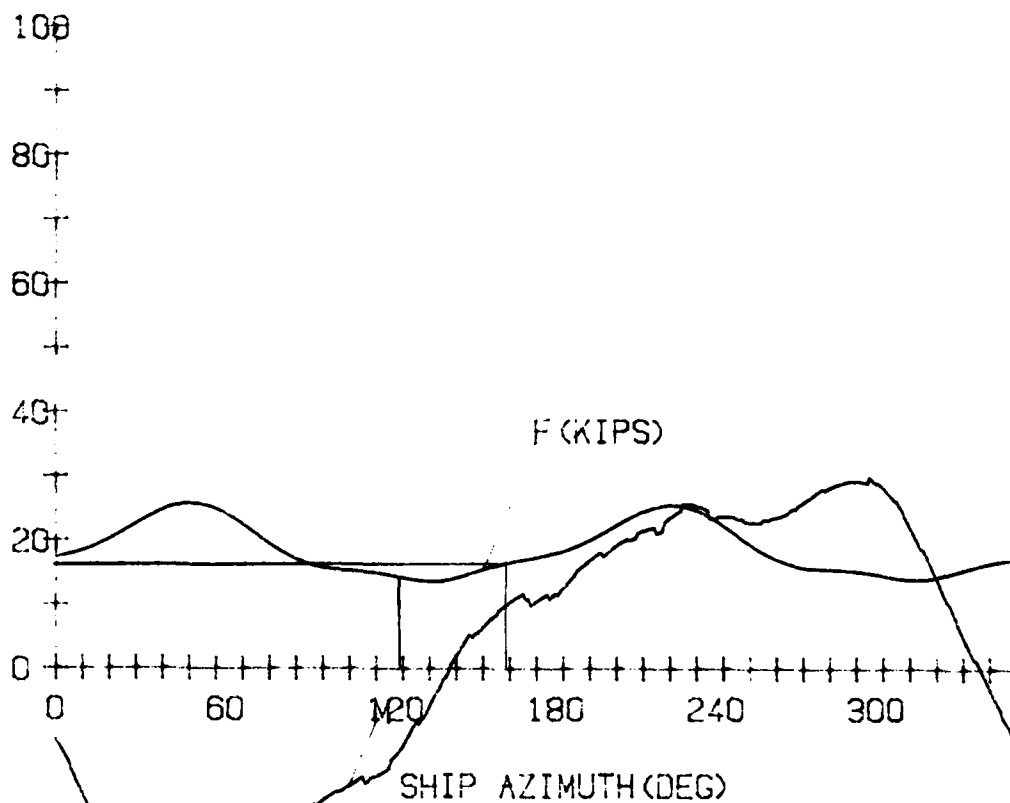
PROJECT: _____**Station:** _____**E S R:** _____ **Contract:** _____**Calculations for:** _____

WIND SPEED(FPS),A(DEG)= 79.6135.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

35	15.E+004	67.E+004	66.E+004	31.E+003	-2.E+004	-8.E+003	-8.E+002	11.3
178	-1.E+005	12.E+005	-3.E+005	-2.E+004	27.E+003	12.E+003	48.E+001	13.3

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**PROJECT:** _____**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____**Calcs made by:** _____**date:** _____**Calcs ck'd by:** _____**date:** _____**Calculations for:** _____

WIND SPEED(FPS),A(DEG)= 36.9180.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

148 81.E+003 88.E+004 -7.E+005 23.E+003 -2.E+004 -1.E+004 10.E+002 13.9
147 -2.E+004 74.E+004 36.E+004 -8.E+003 16.E+003 15.E+003 -1.E+003 16.2

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW

DISCIPLINE

Calcs made by: _____ date: _____

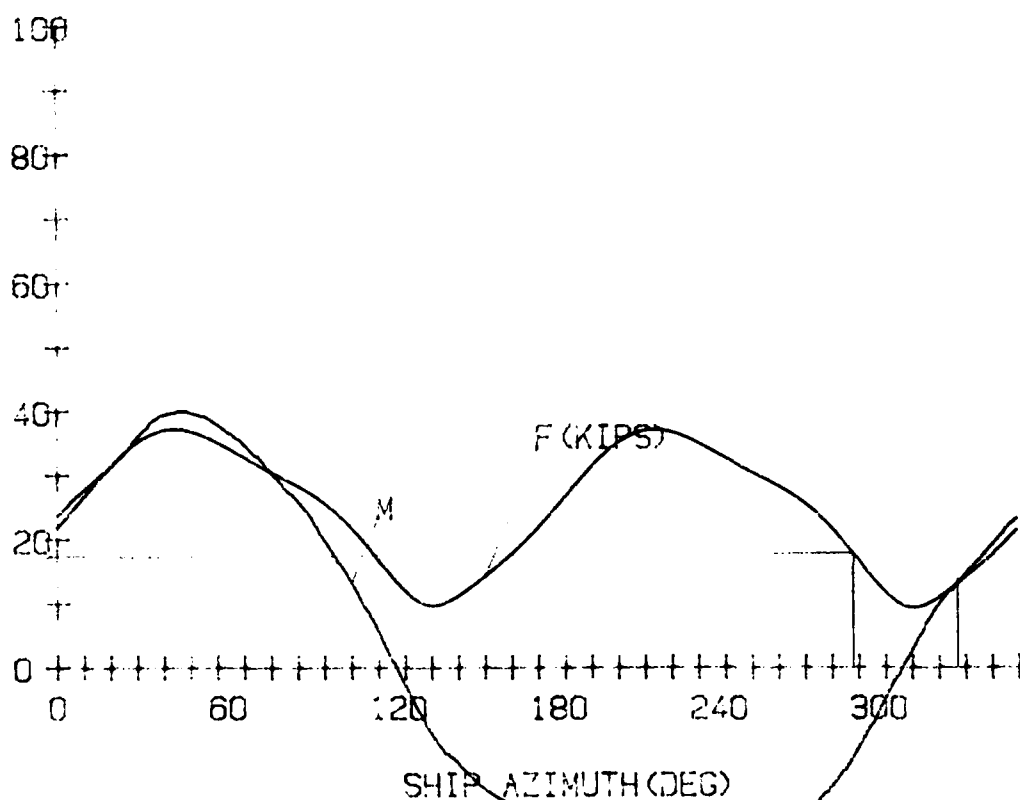
Calcs ck'd by: _____ date: _____

PROJECT: _____

Station: _____

E S R: _____ Contract: _____

Calculations for: _____



WIND SPEED(FPS),A(DEG)= 75.6270.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

127 -7.E+004 -1.E+006 -3.E+005 21.E+003 -2.E+004 11.E+003 48.E+001 13.2
217 14.E+004 -6.E+005 66.E+004 -2.E+004 26.E+003 -9.E+003 -7.E+002 9.6

page 6-2 of _____

CHESAPEAKE**DIVISION****PROJECT:** _____

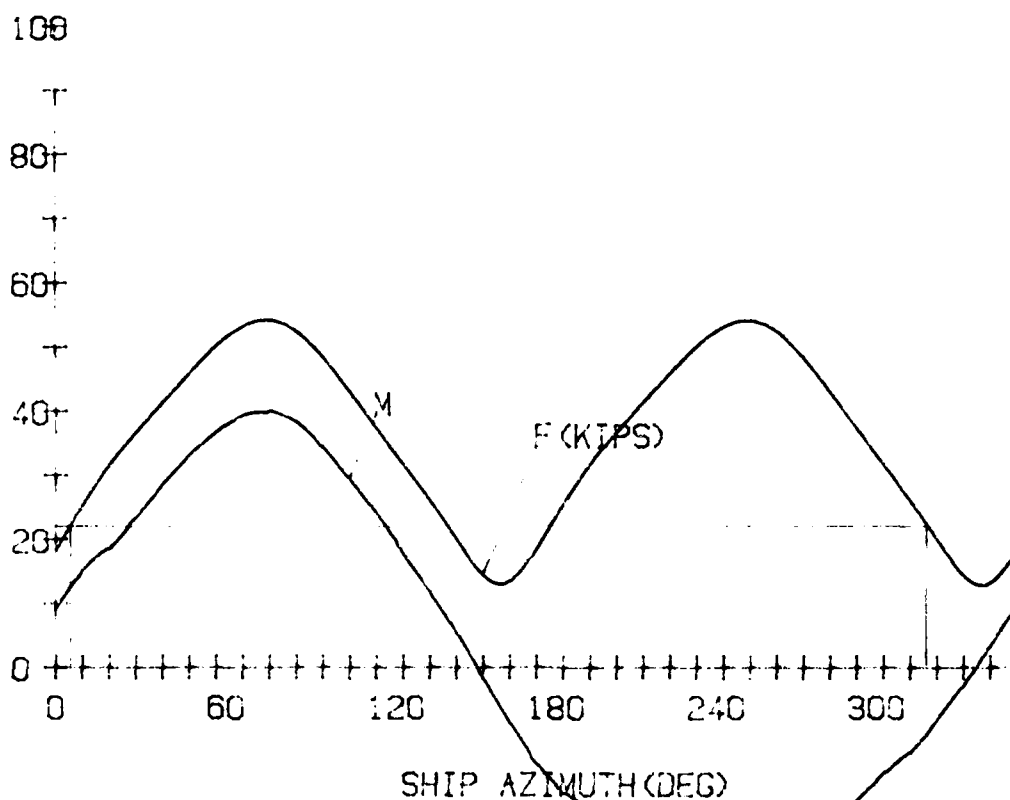
Naval Facilities Engineering Command

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

Calcs made by: _____ date: _____

Calculations for: _____

Calcs ck'd by: _____ date: _____



WIND SPEED(FPS),A(DEG)= 75.6315.0 CURRENT SPEED(FPS),A(DEG)= 2.5 22.5

136 -1.E+005 -6.E+005 -8.E+005 12.E+003 -2.E+004 12.E+003 13.E+002 15.3
445 50.E+003 -6.E+005 37.E+004 -1.E+004 17.E+003 -1.E+004 -1.E+003 12.9

page 6e of _____

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Naval Facilities Engineering Command

NDW

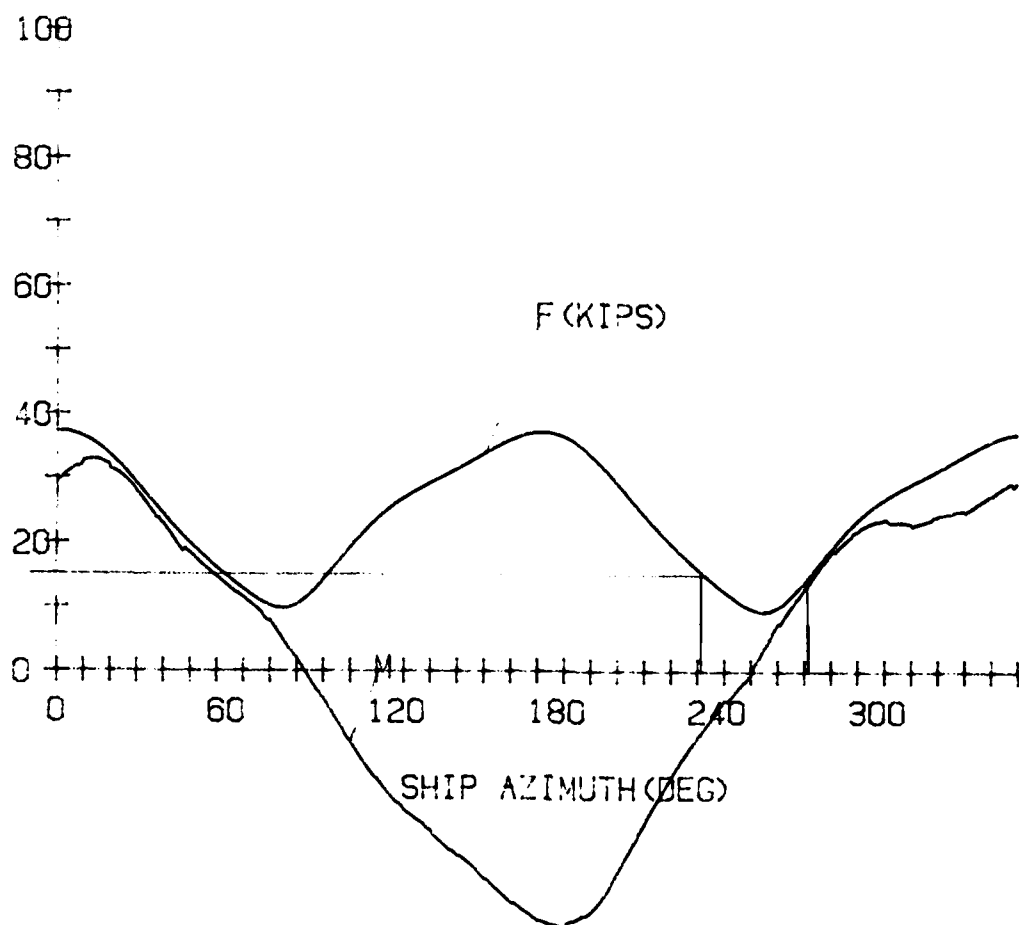
PROJECT: _____**Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____

Calcs made by: _____

date: _____

Calcs ck'd by: _____

date: _____

Calculations for: _____

WIND SPEED(FPS),A(DEG)= 75.63'5.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

93 -2.E+004 11.E+005 -5.E+005 -2.E+004 27.E+003 10.E+003 62.E+001 11.1
261 14.E+004 50.E+004 71.E+004 29.E+003 11.E+004 -7.E+003 -9.E+002 9.6

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Naval Facilities Engineering Command

DIVISION

NDW

DISCIPLINE

Calcs made by: _____ date: _____

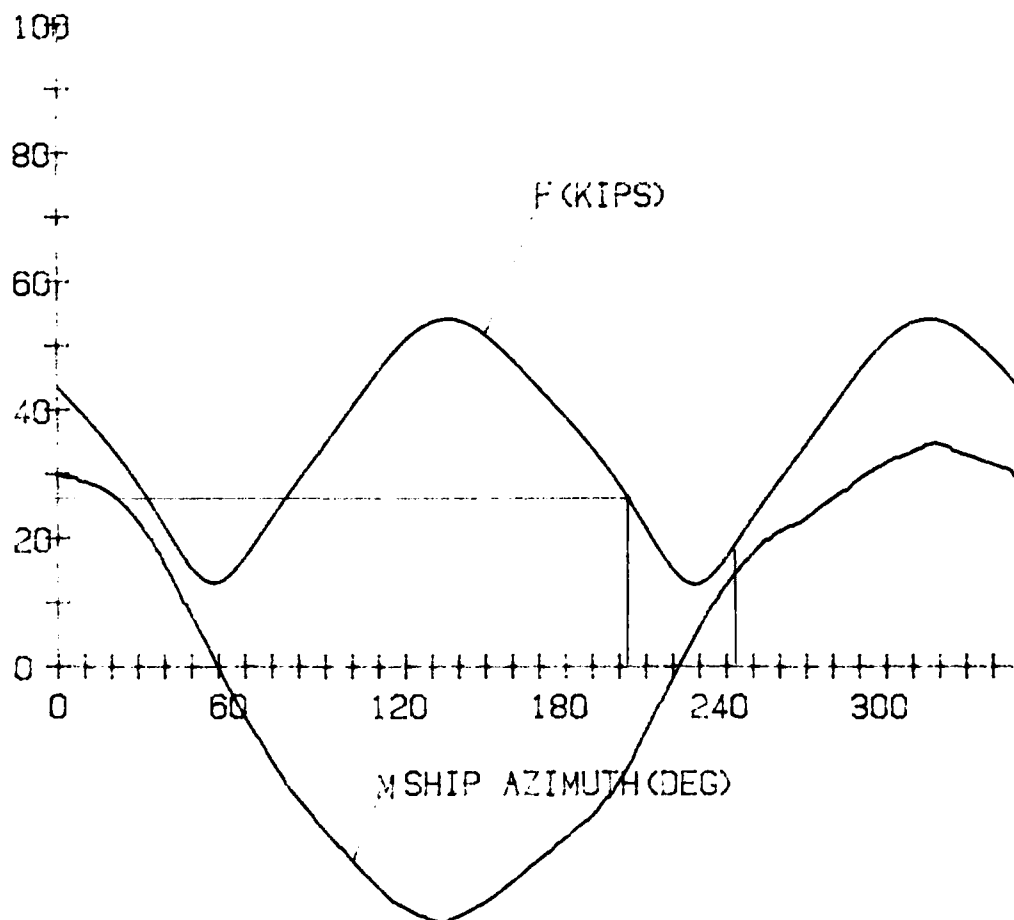
Calcs ck'd by: _____ date: _____

PROJECT: _____

Station: _____

E S R: _____ Contract: _____

Calculations for: _____



WIND SPEED(FPS),A(DEG)= 75.6270.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

50	-8.E+004	97.E+004	-8.E+005	-1.E+004	17.E+003	12.E+003	14.E+002	13.9
233	16.E+004	66.E+004	81.E+004	21.E+003	-1.E+004	-1.E+004	-1.E+003	13.8

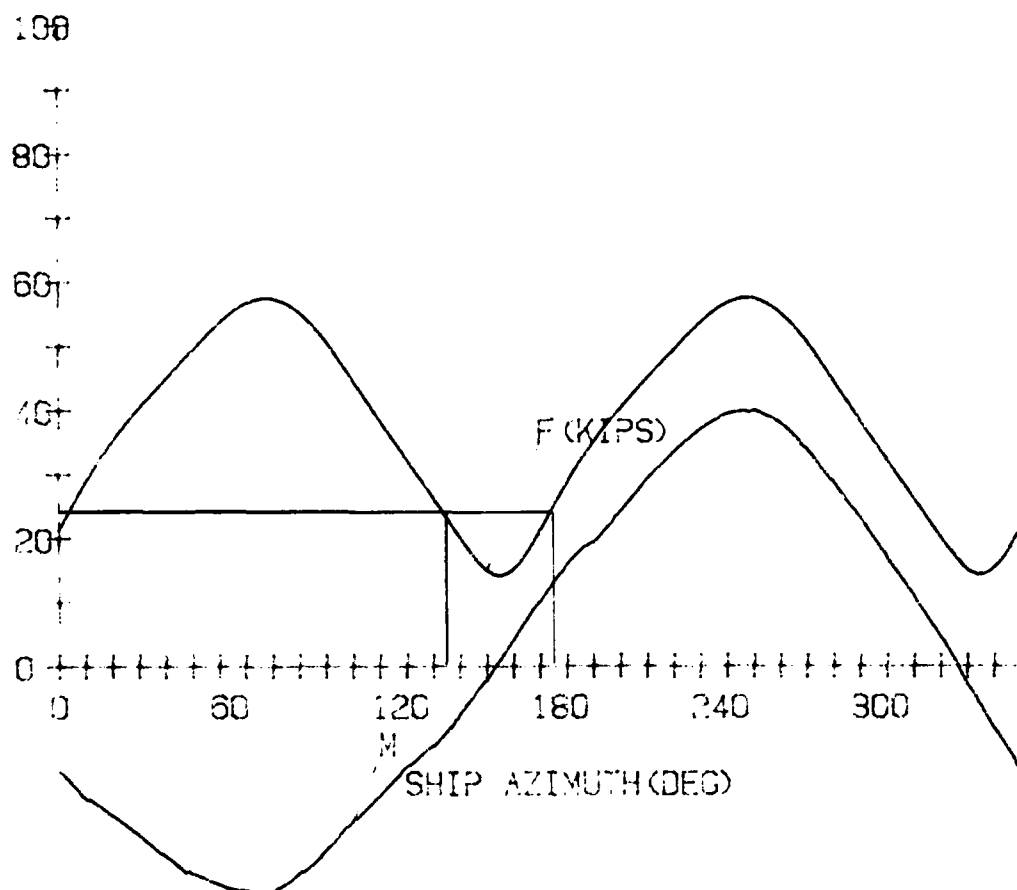
CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____

PROJECT: _____**Station:** _____**E S R:** _____ **Contract:** _____**Calculations for:** _____

WIND SPEED(FPS),A(DEG)= 79.6135.0 CURRENT SPEED(FPS),A(DEG)= 2.5 202.5

154 13.E+004 -7.E+005 58.E+004 -1.E+004 19.E+003 -1.E+004 -1.E+003 14.1
237 -1.E+005 -8.E+005 -9.E+005 12.E+003 -2.E+004 13.E+003 12.E+002 16.3

page 611 of _____

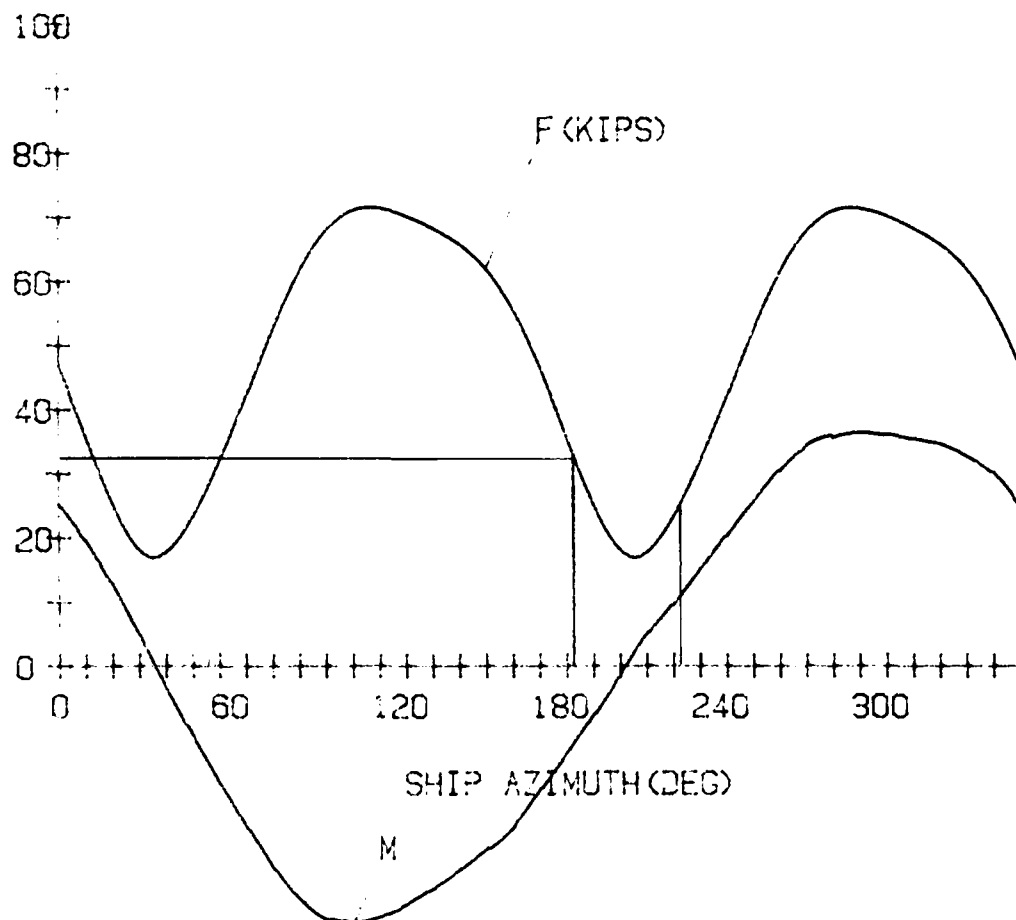
CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____

PROJECT: _____**Station:** _____**E S R:** _____ **Contract:** _____**Calculations for:** _____

WIND SPEED(FPS) .A(DEG) = 86.9225.0 CURRENT SPEED(FPS) .A(DEG) = 0.5 202.5

1.6 -1.E+005 51.E+004 -4.E+005 -5.E+007 56.E+002 15.E+003 17.E+002 16.9
112 28.E+003 47.E+004 26.E+004 82.E+002 -4.E+003 -1.E+004 -1.E+003 17.4

DISCIPLINE

NDW

PROJECT: _____

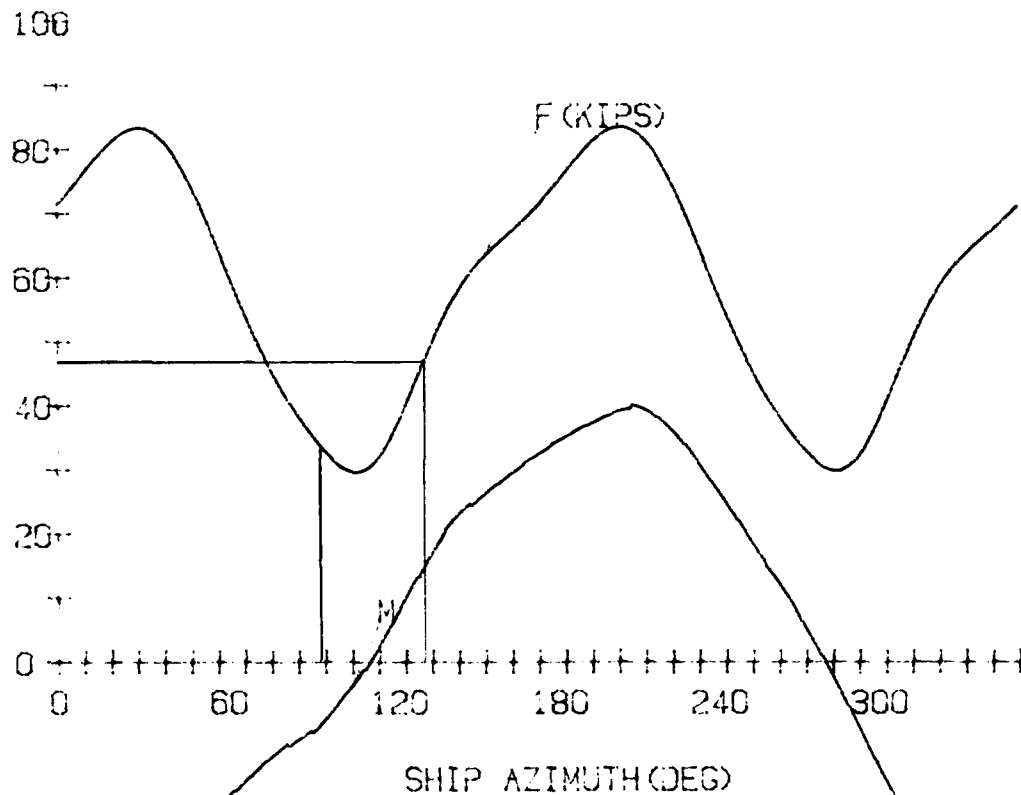
Station: _____

E S R: _____ **Contract:** _____

Calculations for: _____

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____



1.00 (DEED/APS). A(PEG)=120.0 30.0 CURRENT (EPI/NO/PS)=0.00 0.00 0.00

[illegible]

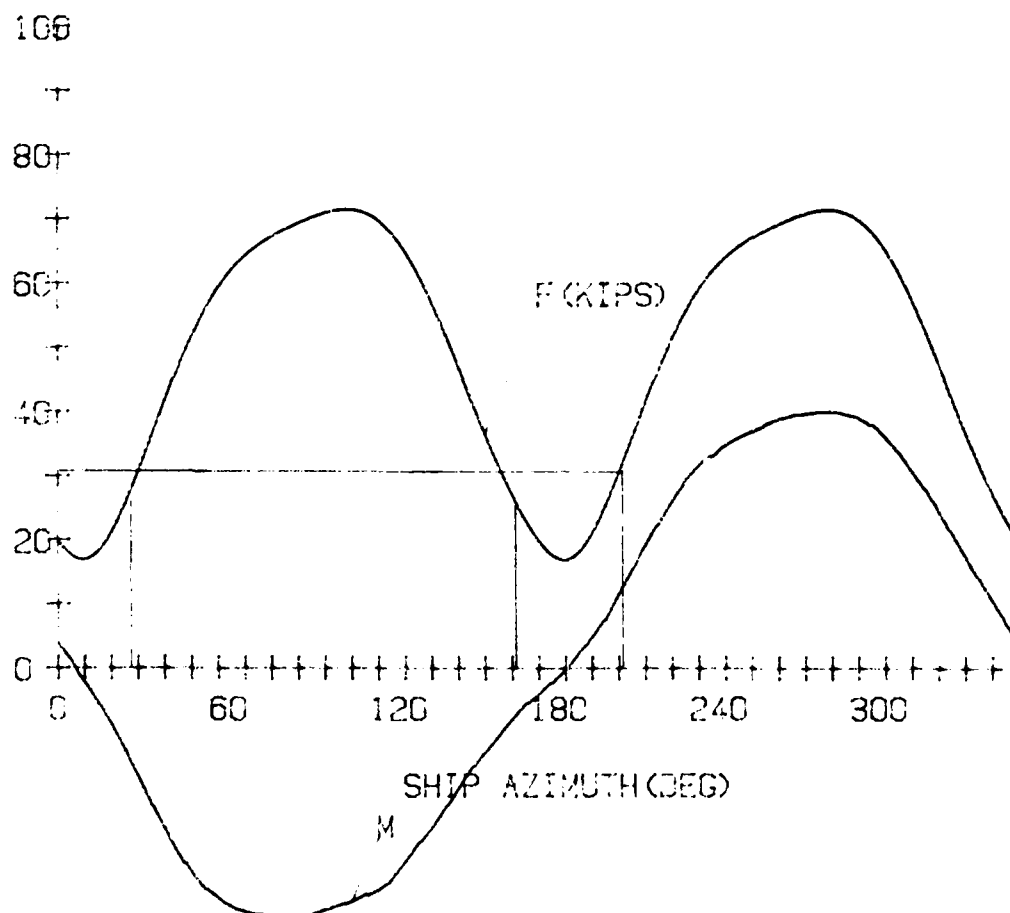
CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**

Calcs made by: _____ date: _____

Calcs ck'd by: _____ date: _____

PROJECT: _____**Station:** _____**E S R:** _____ **Contract:** _____**Calculations for:** _____WIND SPEED (FPS), θ (DEG) = 96.9/180.0 CURRENT SPEED (FPS), θ (DEG) = 2.5/202.5

-1.E+005	-4.E+005	-4.E+005	42.E+002	-7.E+003	15.E+003	17.E+002	17.2
13.E+004	-4.E+005	32.E+004	-6.E+003	57.E+002	-1.E+004	-1.E+003	17.0

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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: _____		_____	

Appendix B - Numerical Model of Mooring
Dynamics

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**Calcs made by: Seelig date: 9 DEC 82

Calcs ck'd by: _____ date: _____

PROJECT: Mooring Dynamics - Long Waves

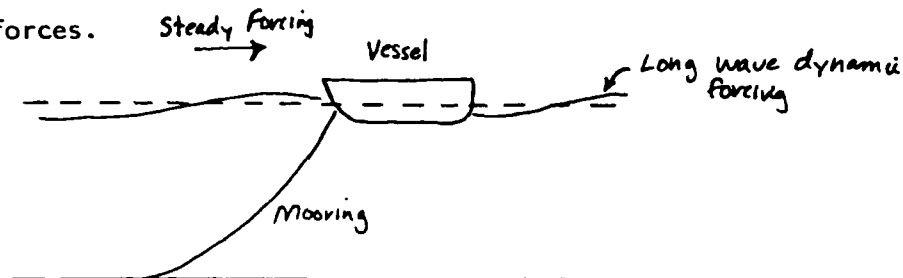
Station: _____

E S R: _____ Contract: _____

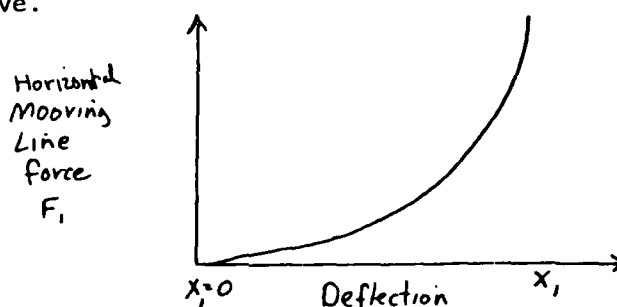
Calculations for: Problem Statement & Setup

Forces on mooring consist of two types, static and dynamic. Static forces can be determined from DM 26 or computer programs, such as STATMOR. The purpose of this analysis is to predict dynamic mooring line forces for the case of long waves.

In this simple analysis the system consists of a mooring, vessel, steady and dynamic forces.



Steady forces must first be determined and the entire mooring line system by statically analyzed with the CHESDIVNAVFACENGCOM catenary program to determine the load deflection curve.



In this analysis the load-deflection curve is represented by the the power formula:

$$F1 = K1 \cdot X1 + K2 \cdot X1^2 + \dots \quad (1)$$

where $X1$ is the deflection from the neutral position and $F1$ is the horizontal component of the mooring line force at the vessel. Here only the first two terms in Eq (1) have been used.

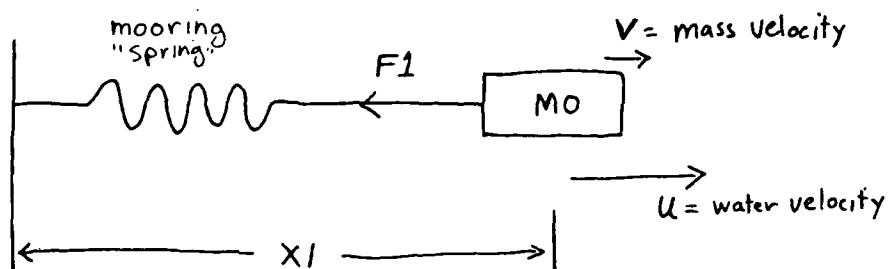
CHESAPEAKE**DIVISION****Naval Facilities Engineering Command****NDW****DISCIPLINE****PROJECT:** Mooring Dynamics**Station:** _____**E S R:** _____ **Contract:** _____**Calcs made by:** Seelig **date:** 9 DEC 82**Calcs ck'd by:** _____ **date:** _____**Calculations for:** _____

In this analysis the ship is represented by a mass, M_0 , that includes the ship mass, M , and the added mass of water around the ship. This total mass is given by:

$$M_0 = C_H M \quad (2)$$

where C_H is a mass coefficient determined from the curves on the following page (found in DM-25.1).

The analyzed system is then treated as a damped forced mass restrained by a non-linear spring:



V is the velocity of the vessel at any instant in time and A is the acceleration of the mass (only sway, surge, ^{or heave} motion are considered in this analysis).

U is the velocity of water at the vessel induced by long waves, such as harbor oscillations or surf beat. These long waves may be considered as "shallow water" waves, so:

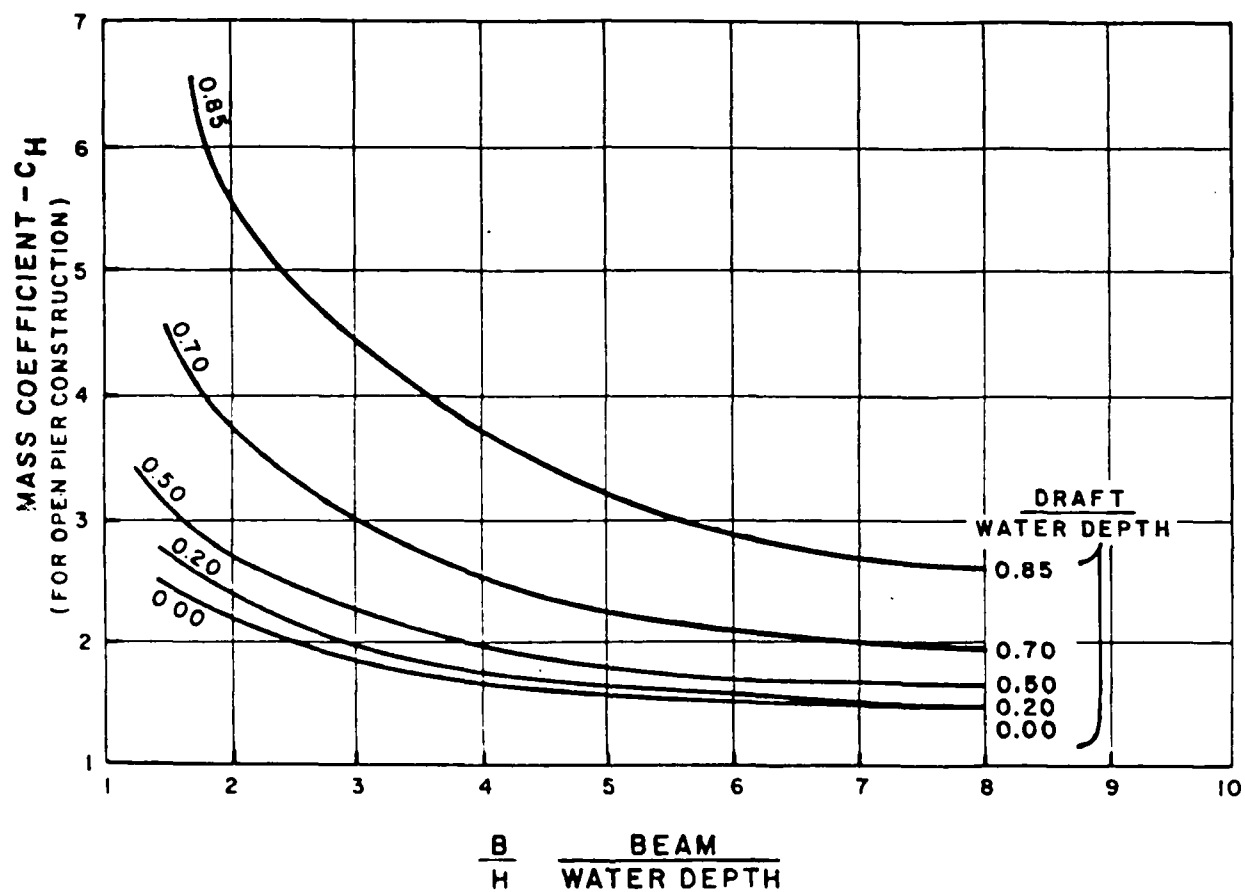
$$U = a \sqrt{\frac{g}{d}} \sin(2\pi t/T) \quad (3)$$

where a is the long wave amplitude, g is the acceleration due to gravity, d is water depth, t is time and T is period of the long wave (see the "Shore Protection Manual", US Army Corps of Engineers, CERC, 1977).

If V is the velocity of the vessel and U is the velocity of the water, then the relative water velocity is given by:

$$W = U - V$$

(4)
page 617 of _____



(after DM-25.1, Figure 47)

Recommended Ship Mass Coefficients
(added mass of water included)

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**PROJECT: Mooring Dynamics

Station: _____

E S R: _____ Contract: _____

Calcs made by: Seelig date: 9 Dec 82

Calcs ck'd by: _____ date: _____

Calculations for: _____

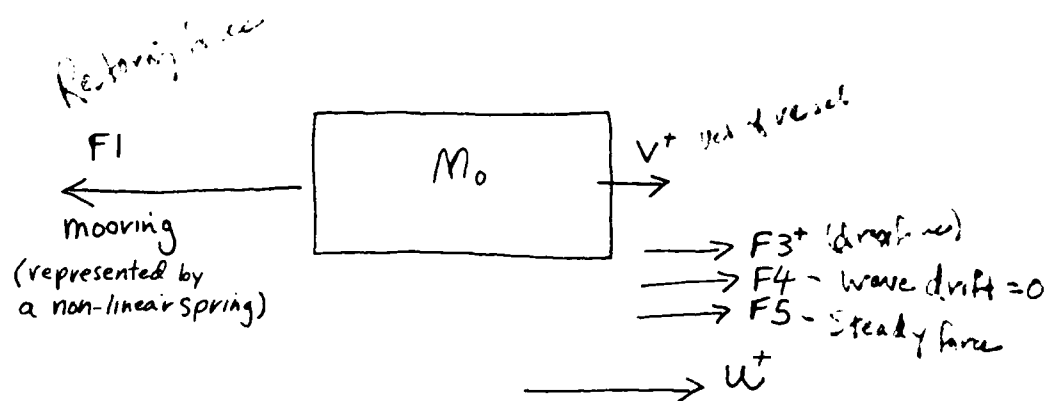
The drag force on the vessel due to relative water motion is taken as:

$$F_3 = \frac{\rho}{2} C_d A W |W| \quad (5)$$

where ρ is the fluid density, A is the projected area of the body in the direction of flow and C_d is a drag coefficient. Typical values of C_d for idealized shapes are given in the figure on the next page.

Steady forces are due to uniform wind and currents, F_5 , and a "wave drift force" due to the change of wind wave height around the ship. This wave drift force, F_4 , can be determined using the method of Remery et al. (1973, OTC Paper No. 1741).

A sketch of the modeled system with forces is shown below:



U = Current Velocity

$$W = U - V$$

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW**DISCIPLINE**Calcs made by: Seelig date: 9 Dec 82

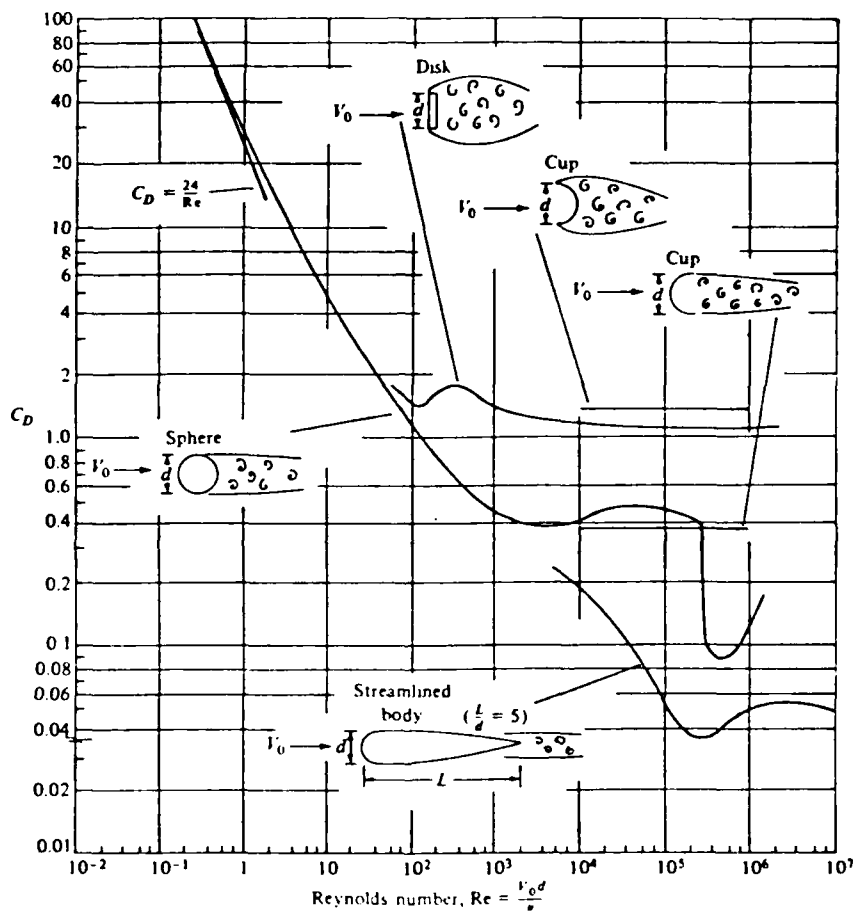
Calcs ck'd by: _____ date: _____

PROJECT: Mooring Dynamics

Station: _____

E S R: _____

Contract: _____

Calculations for: Drag Coefficients

Drag Coefficients for Idealized Shapes

(after Roberson and Crowe, Engineering Fluid Mechanics,
Houghton Mifflin Co., Boston, Mass., 1975)

CHESAPEAKE		DIVISION	PROJECT: <u>Mooring Dynamics</u>
Naval Facilities Engineering Command		NDW	Station: _____
DISCIPLINE			E S R: _____ Contract: _____
Calcs made by: <u>Seelig</u>		date: <u>9 Dec 82</u>	Calculations for: _____
Calcs ck'd by: _____		date: _____	

At any given instant in time the sum of forces acting on the body is:

$$F = F1 + F2 + F3 + F4 + F5 \quad (7)$$

where the location is $X1$ and ship velocity is V . To find the ship position at some very small time step into the future, Δt , the equation of motion is first used to find the ship acceleration:

$$A = \frac{F}{M0} \quad (8)$$

The change in distance, $\Delta X1$, is then found from the following finite-difference equation:

$$\Delta X1 = V \Delta t + A (\Delta t^2 / 2) \quad (9)$$

and new vessel location given by:

$$X1' = X1 + \Delta X1 \quad (10)$$

The above procedure is applied in very small time steps to determine the vessel position and horizontal forces in the mooring as a function of time. In this analysis, the forcing is assumed to be periodic^{E4(3)} to allow easy computation on a desk-top computer. This is assumed to be adequate for a first "quick look".

Probably the most difficult portion of the analysis is determining the vessel coefficients to be used as input. These can be obtained from DM26 or other sources of marine architecture. When in doubt, I recommend that several values of the coefficients over a reasonable range be tested to determine if the value significantly influences results.

CHESAPEAKE**DIVISION****PROJECT:** Mooring Dynamics**Naval Facilities Engineering Command****NDW****Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____**Calcs made by:** Seelig**date:** 22 Dec82**Calculations for:** Program Listing**Calcs ck'd by:** _____**date:** _____

```
10 PLOTTER 15 1
20 OPTION BASE 1
30 DEG
40 DIM T(200),X(200),F(200)
50 DISP "SHIP DISPL (TON)"
60 INPUT M0
70 DISP "MASS COEFF (CH)"
80 INPUT C
110 M0=C*2240/32300*M0
120 DISP "CROSS-SECT AREA (FT2)"
130 INPUT A9
140 DISP "DRAG COEFF"
150 INPUT C
160 DISP "STEADY FORCE (K)"
170 INPUT F5
180 DISP "MOORING K1="
190 INPUT K1
200 DISP "K2="
210 INPUT K2
220 DISP "TR (SEC)"
230 INPUT T2
240 F1=F2+1
250 DISP "MAX VELOCITY (FPS)="
260 INPUT V2
270 U=1/24*(C+A9+1000)
280 F=1
290 C1=0
300 C2=1000
310 T1=0
320 F4=0
330 F4=0
340 F6=F4+F5
350 X0=-F1+30*(C1+K2+K3+F6)/
360 2*(K2)
370 T9=0+F1
380 T8=T9+T4+1
390 C=C1+C2
400 C5=
410 N1=C+1000
420 F8=0
430 D6=-1000
440 D7=1000
450 T0=0
460 M=0
470 FOR I=1 TO 994
480 T0=T0+T2
490 U=A2*SIN(C+T0)
500 V=(N1-X0)/T2
```

page 622 of _____

CHESAPEAKE**DIVISION****PROJECT:** Mooring Dynamics**Naval Facilities Engineering Command****NDW****Station:** _____**DISCIPLINE****E S R:** _____**Contract:** _____**Calcs made by:** Seelig**date:** 22 Dec 82**Calculations for:** Program Listing**Calcs ck'd by:** _____**date:** _____

```
471 X0=X1
472 X2=ABS(X1)
473 S1=X2/X1
480 F1=-(C(X1*X2+X2*X2*X2)*S1)
490 W=U-V
510 F3=C(W*ABS(W))+C5
520 A=(F1+F3+F4+F5)/M0
530 X1=X0+W*T9+A*T8
542 T3=T3+T9
543 IF I<4 THEN GOTO 640
550 N=I MOD 10
560 IF N>0 THEN GOTO 640
562 IMAGE 4(000.00,1%)
570 M=M+1
580 TCM=T3
590 XCM=U
595 F1=-F1
600 IF F1<01 THEN NS=TCM)
601 IF F1<01 THEN O1=F1
602 IF F1<02 THEN O2=F1
610 FCM=F1
620 IF F1<F8 THEN F8=F1
640 IF X1>D6 THEN D6=X1
641 IF X1<D7 THEN D7=X1
642 NEXT I
643 D7= 5*(O1+O2)
648 PRINT USING #57 : O1,O2,D6,D
7
650 IMAGE "T=";000 : " F=";0000 :
D
653 IMAGE 4(0000,000)
660 CLEAR
670 PEN 1 @ GCLEAR
680 SCALE -100,TCM,-5.30
681 S3= 1*P2
684 XAXIS 0,53.0,TCM)
686 YAXIS 0,5,0,30
688 MOVE T(4),F(4)
692 FOR I=4 TO M
693 DRAW T(I),F(I)
694 NEXT I
695 MOVE 0,0
696 FOR I=1 TO M
697 IO=I MOD 2
698 IF IO=0 THEN MOVE T(I),X(I)
699 IF IO=0 THEN DRAW T(I),X(I)
700 NEXT I
704 MOVE 105,25
706 LABEL "25"
708 I3= 75*M
709 O1=O1+2
710 MOVE X5,O1
715 LABEL "F"
716 X0=X(I2)-2.5
717 MOVE T(I3),X0
719 LABEL "U"
722 X0=TCM*.4
725 MOVE X0,27
728 LABEL "F&U VS TIME"
740 END
```

page 623 of _____

CHESAPEAKE	DIVISION	PROJECT: <u>Mooring Dynamics</u>
Naval Facilities Engineering Command	NDW	Station: _____
DISCIPLINE		E S R: _____ Contract: _____
Calcs made by: <u>Seelig</u>	date: <u>22 Dec82</u>	Calculations for: <u>Example</u>
Calcs ck'd by: _____	date: _____	

Take the case of a large submarine and power barge attached to mooring 1-N in Sasebo Harbor, Japan.

GIVEN: The ship displacement is 7300 long tons.
The added mass coefficient is 2.6 (see the theory section).
The ship cross-section flow area is 700 square feet.
The drag coefficient is 0.1 (see the theory section).

FIND: The maximum force in the mooring at the buoy for a periodic reversing current with 2.6 fps maximum. The period of this wave is taken as 450 seconds. A light wind is assumed, which produces a 5 kip steady force on the vessel.

INPUT: The above information is input to the program in the following format:

```
SHIP DISPLACEMENT
7300
ADDED MASS COEFFICIENT
2.6
CROSS-SECTION FLOW AREA
700
DRAG COEFFICIENT
0.1
STEADY FORCE ON BUOY
5
PERIOD OF WAVE
450
MAX VELOCITY OF REVERSING
2.6
```

CHESAPEAKE**DIVISION**

Naval Facilities Engineering Command

NDW

DISCIPLINE**PROJECT:** Mooring Dynamics**Station:** _____**E S R:** _____ **Contract:** _____**Calcs made by:** Seelig **date:** 22 Dec 82**Calculations for:** Example**Calcs ck'd by:** _____ **date:** _____

OUTPUT: One line of printed output is available that includes:

maximum and minimum horizontal forces at the buoy (kips)

11.108

884

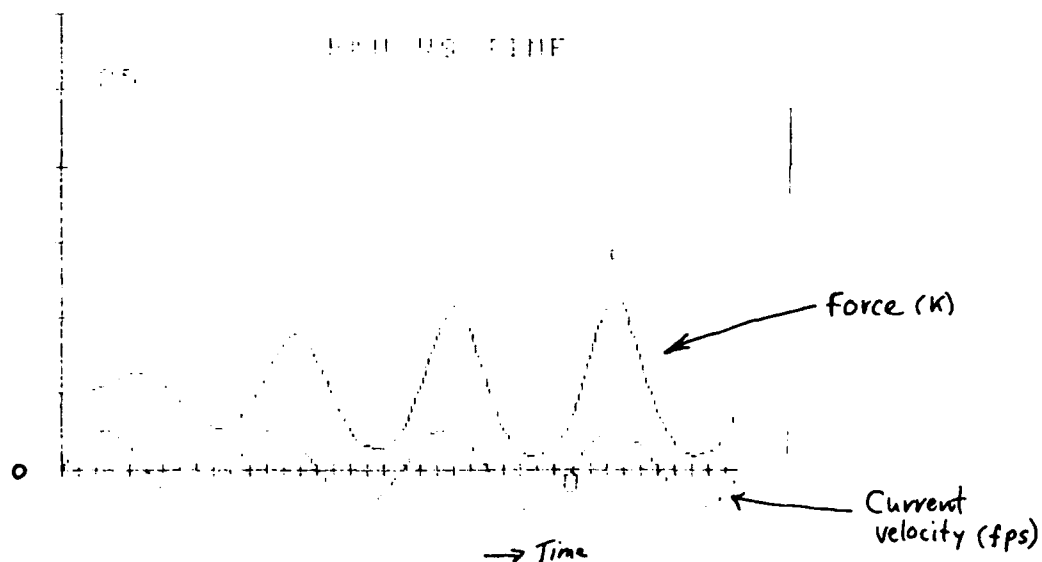
88.369

5.050

maximum and minimum excursion of the buoy (feet)

The watch circle is the extent of this excursion, which is 14 feet for this case.

A plotted time history of the forcing currents, U , (shown by the dashed line) and the resulting forces (F) are also produced (see below).

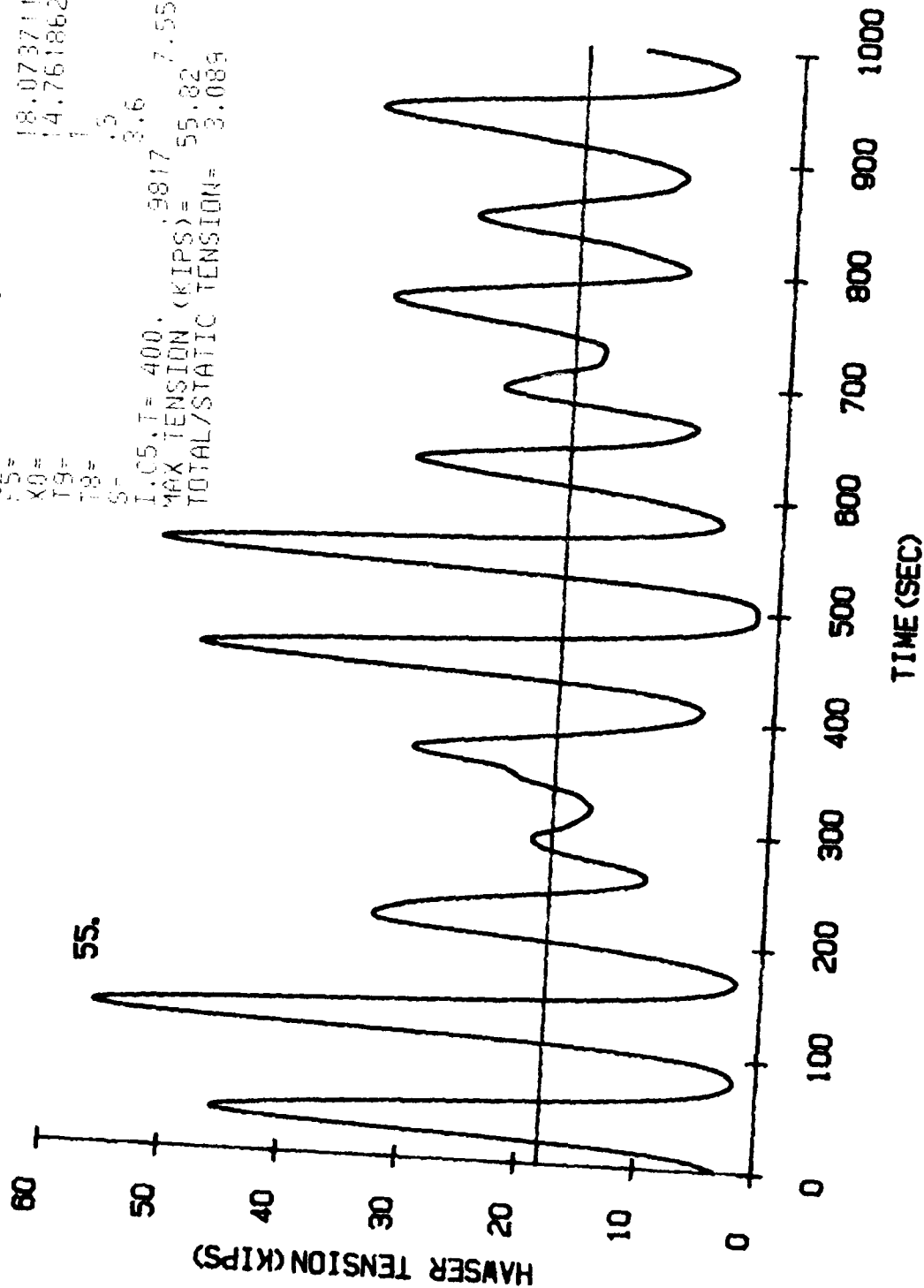


In this example the first wave is predicted to produce little force in the mooring because of inertia in the system. However, subsequent waves produce significant forces due to resonance in this case. More detailed analysis shows that the magnitude of the maximum current, wave period and magnitude of the steady forcing are all important in determining the amount of dynamic forcing and motion of the vessel.

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: _____	_____

Appendix C - Dynamic Solutions

STEADY CURRENT FORCE(K)= .989
WIND FORCE(K) DUE TO 30-SEC WIND= 0
R2= 0
IL(S)= 100.00
L5= 18.0737111754
X9= 14.7618622498
T9= 1
T8= .5
S= 3.6
I.05, T= 400, .9817 7.554
MAX TENSION (KIPS)= 55.82
TOTAL/STATIC TENSION= 3.089



0° Wind Azimuth

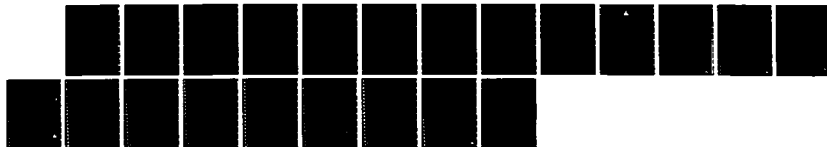
AD-A168 459

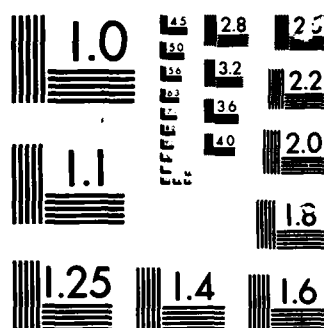
DESIGN CALCULATIONS OF THE HURRICANE MOORINGS AT NAVAL
STATION MAYPORT FL. (U) NAVAL FACILITIES ENGINEERING
COMMAND WASHINGTON DC CHESAPEAKE. C A HUBLER DEC 84
CHES/NAVFAF-FPO-1-84(46) F/G 13/10

2/2

UNCLASSIFIED

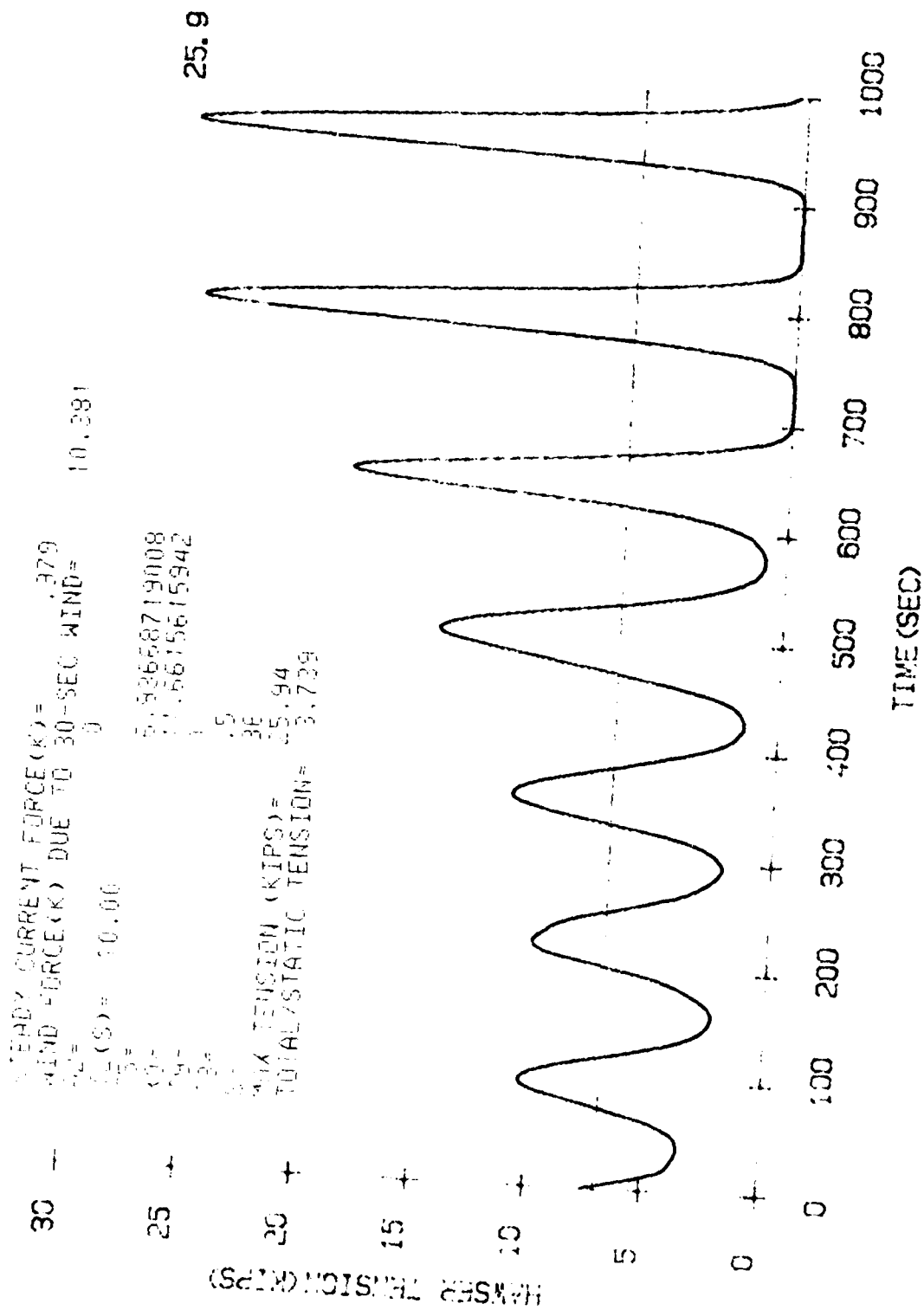
NL





MICROCOPY

CHART

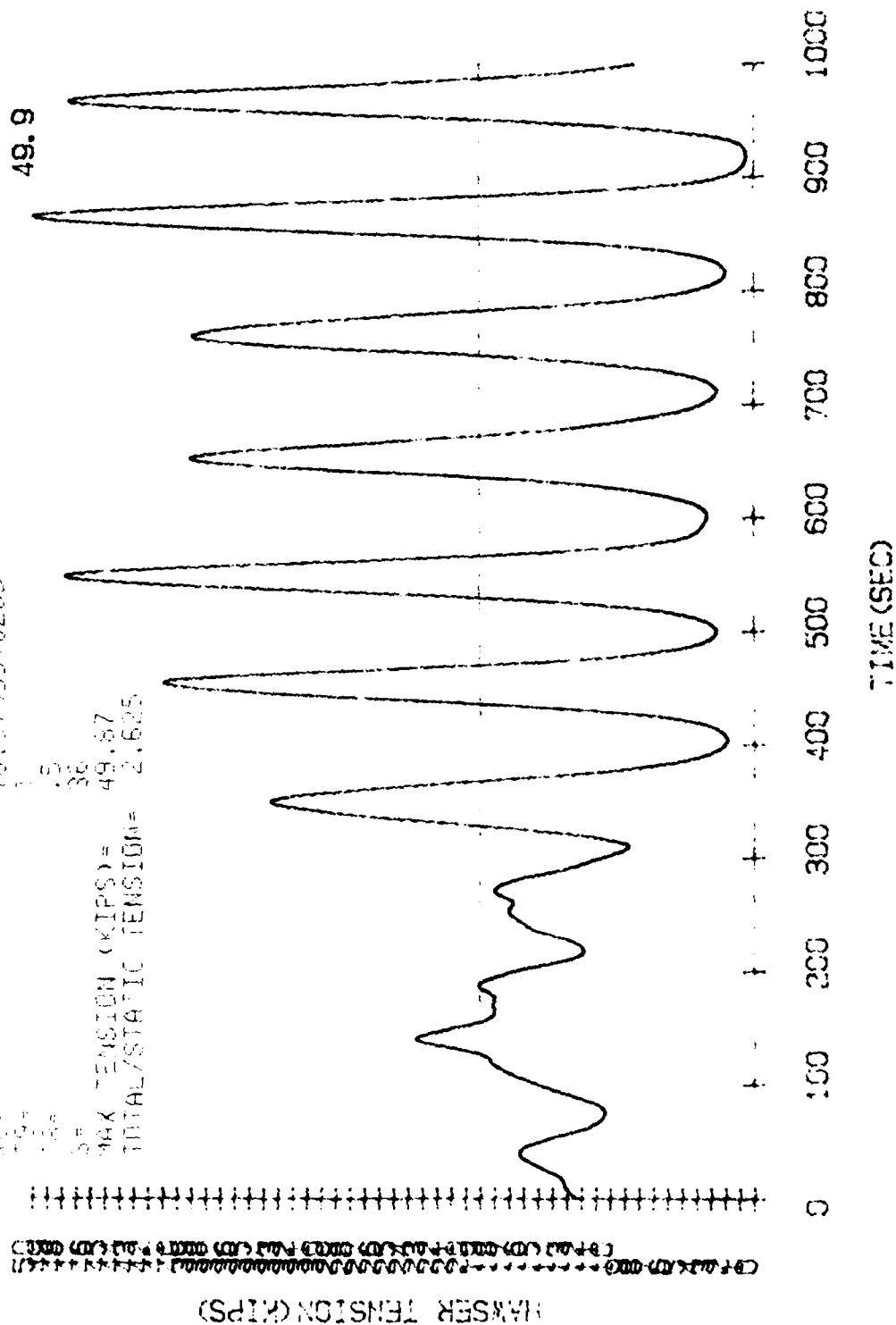


45° Wind Azimuth

```

TEMPY CURRENT FORCE(K) = .320
WIND FORCE(K) DUE TO 30-SEC WIND = 31.500
P1(0) = 0
P1(1) = 10.00
P1(2) = 10.9985123621
P1(3) = 19.3159510265
P1(4) = 1.5
P1(5) = 38.87
P1(6) = 49.87
P1(7) = 3.625
MAX TENSION (KIPS) =
INITIAL/STATIC TENSION =

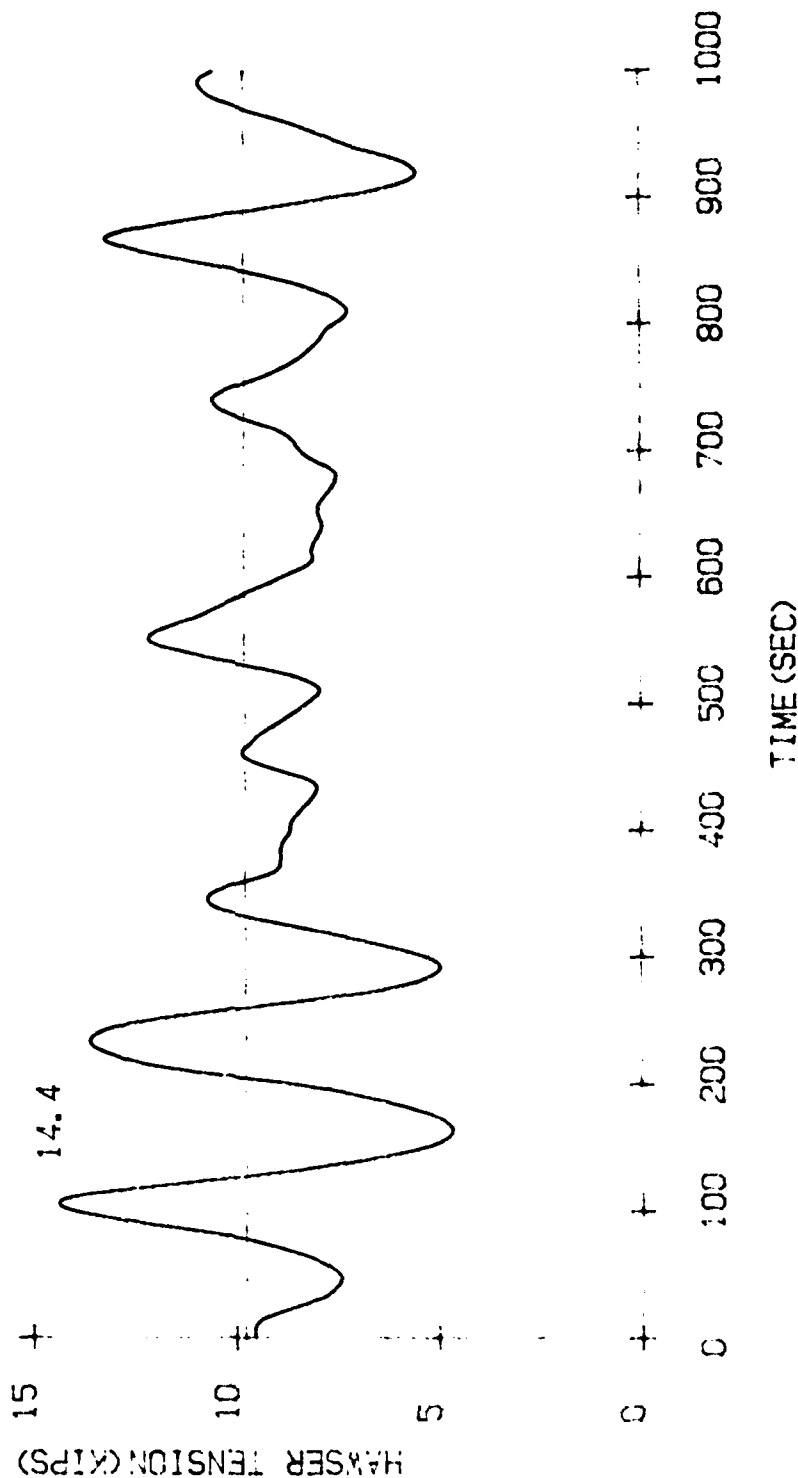
```



READY CURRENT FORCE(K)= 4.748
 WIND FORCE(K) DUE TO 30-SEC WIND= 8.744

WIND (K)= 100.00
 9.75620605993
 10.0701704686

WIND TENSION (KIPS)= 5
 3.6
 4.38
 TOTAL/STATIC TENSION= 1.475



135° Wind Azimuth

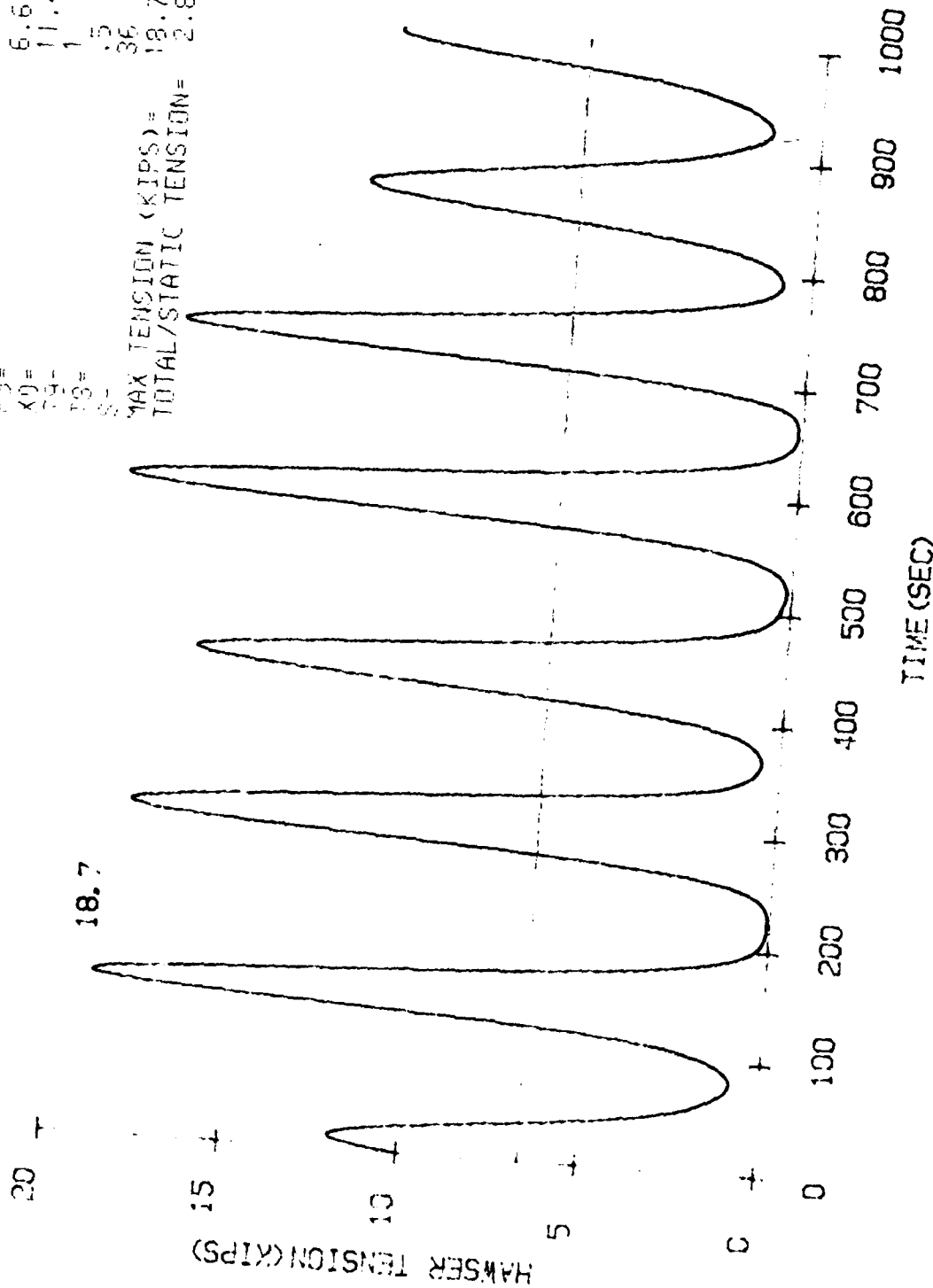
STEADY CURRENT FORCE (K) = .980
 WIND FORCE (K) DUE TO 30-SEC WIND = 0
 TL (S) = 10.00

9.900

15 = 6.60426679721
 X0 = 11.4722222146
 19 = 1
 13 = 15

MAX TENSION (KIPS) = 18.75
 TOTAL/STATIC TENSION = 2.839

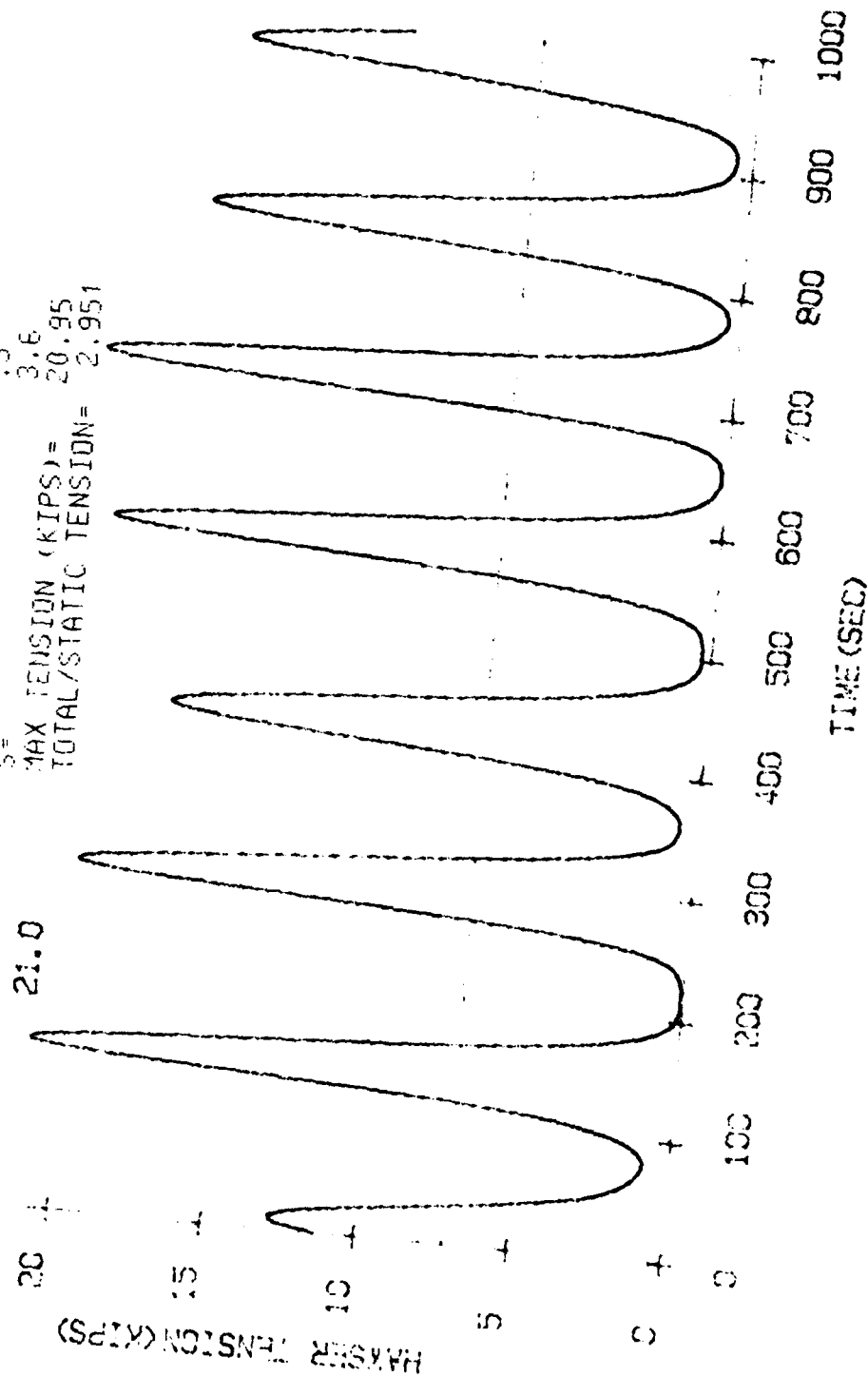
18.7



180° Wind Azimuth

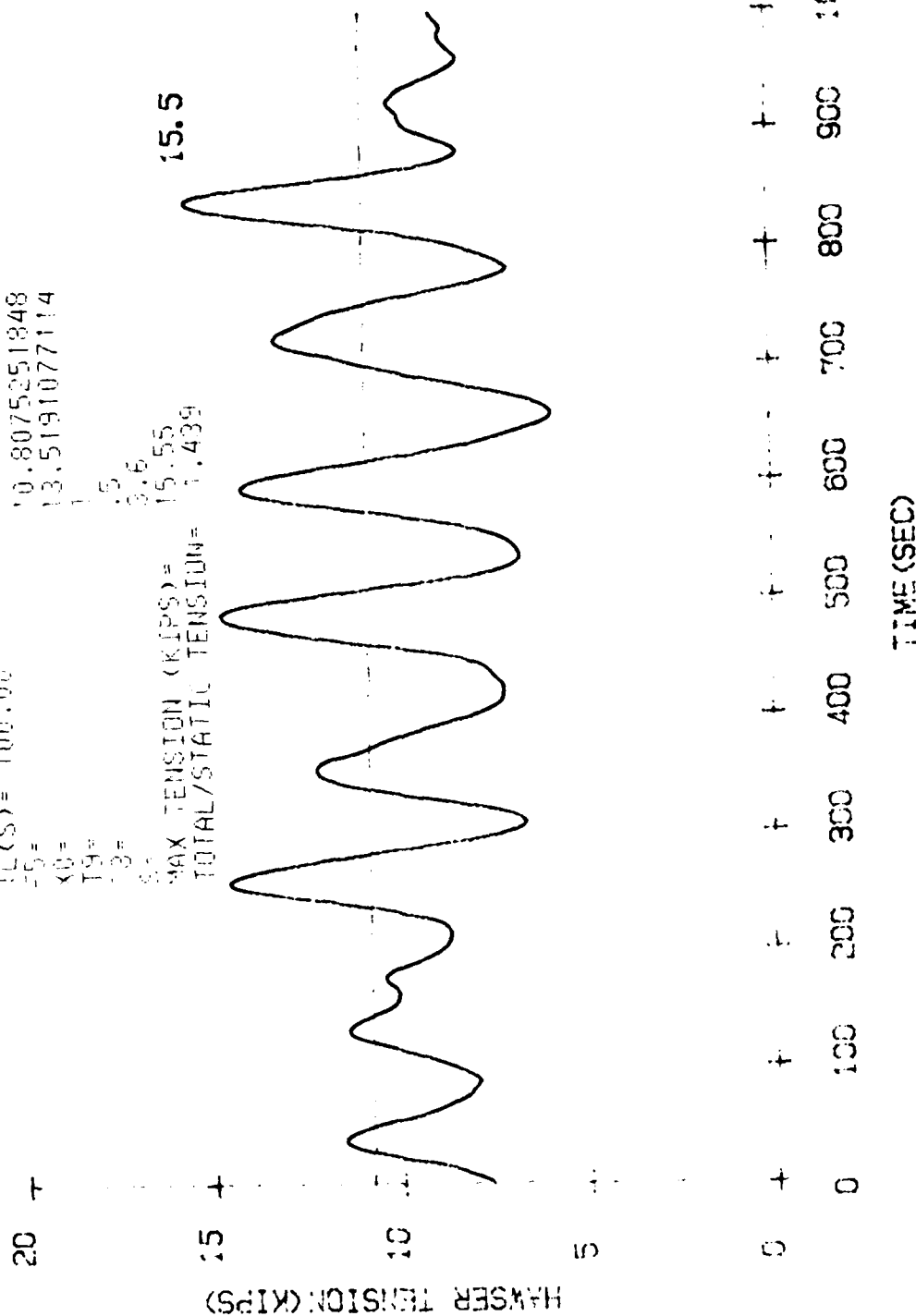
Page 631

STEADY CURRENT FORCE(K)= .968
WIND FORCE(K) DUE TO 30-SEC WIND= 10.685
A2= 0
TL(S)= 100.00
P5= 7.10028590277
X0= 11.7525276732
T9= 1
T8= .5
S= 3.6
MAX TENSION (KIPS)= 20.95
TOTAL/STATIC TENSION= 2.951

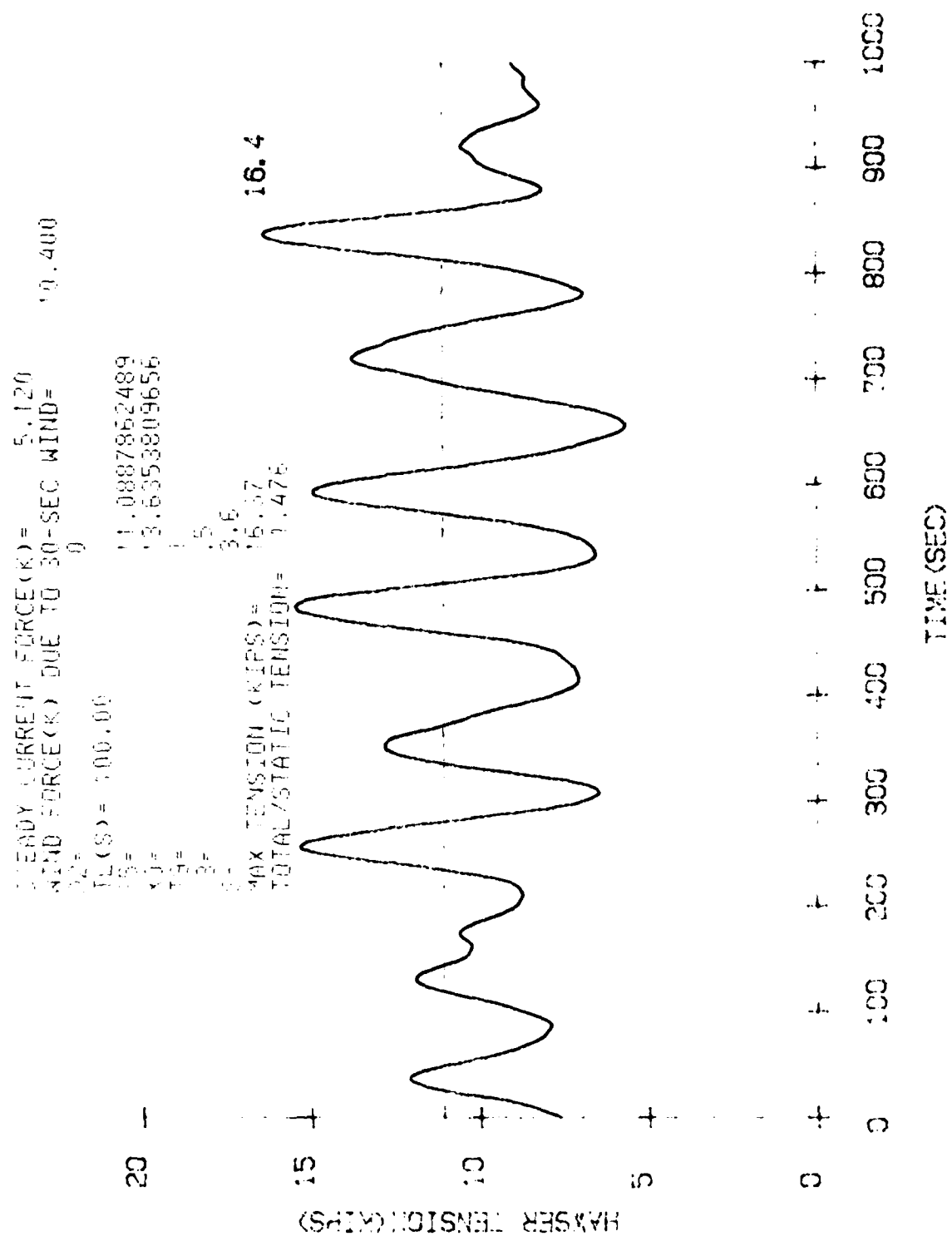


225° Wind Azimuth

STEADY CURRENT FORCE(K)= 5.310
WIND FORCE(K) DUE TO 30-SEC WIND= 9.579
A2= 0
TL(S)= 100.96
TS= 10.8075251848
X0= 13.5191077114
T9= 1
T3= 1.5
S= 3.6
MAX TENSION (KIPS)= 15.55
TOTAL/STATIC TENSION= 1.439



270° Wind Azimuth



315° Wind Azimuth

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: _____	

Appendix D - Law Engineering Testing Co Report



LAW ENGINEERING TESTING COMPANY
geotechnical, environmental & construction materials consultants
3901 CARMICHAEL AVENUE
P.O. BOX 5728 • JACKSONVILLE, FLORIDA 32207
(904) 396-5173

November 2, 1982

Frank Shumer, Architect
10695 Beach Boulevard
Jacksonville, Florida 32216

Attention: Mr. George G. Gooden

Subject: Report of Exploratory Borings
Mayport Hurricane Moorings at Blount Island
Jacksonville, Florida
LETCO Job No. J-4033

RECEIVED

NOV 2 1982

DLOUGHY & ASSOCIATES, INC.
CONSULTING ENGINEERS

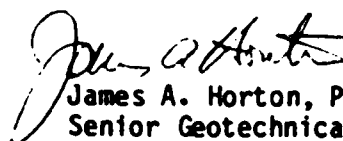
Gentlemen:

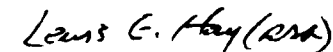
Law Engineering Testing Company has completed a series of exploratory borings for the subject project. This report briefly outlines our exploratory techniques and presents the data obtained.

We are pleased to be of service on this phase of your project. If you have any questions concerning this report or desire assistance in evaluating the data, please contact us.

Very truly yours,

LAW ENGINEERING TESTING COMPANY


James A. Horton, P.E.
Senior Geotechnical Engineer
Registered, Florida 23315


Lewis E. Hay
Engineering Geologist

Distribution: Frank Shumer, Architect (2)
Doughy & Associates (1)

JAH/LEH:/kk

FIELD EXPLORATION

As shown on the Site Location and Field Exploration Plan, the site of the borings is located in the old St. Johns River channel on the northwest side of Blount Island in north Jacksonville, Florida. For this exploration three soil test borings were made to the designated depth of 50 to 55 feet each below the existing water surface at the locations requested by your office. The attached Site Location and Field Exploration Plan also shows the locations of all the borings. The borings were located in the field by our drill crew using tape measurements from features such as the existing dolphins. The water surface elevations at the boring locations were established by measuring the level of water relative to the Blount Island Wharf at the time of drilling.

Soil Test Borings

The soil test borings were made in general accordance with ASTM D-1586, "Penetration Test and Split-Barrel Sampling of Soils." A three-inch I.D. casing was initially extended from slightly above the expected high water level to below river bottom. A rotary drilling process was subsequently used and bentonite drilling fluid was circulated in the bore holes to stabilize the sides and flush the cuttings. At regular intervals, the drilling tools were removed and soil samples were obtained with a standard 1.4 inch I.D., 2.0 inch O.D., split-tube sampler. The sampler was first seated six inches and then driven an additional foot with blows of a 140 pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot is designated the "Penetration Resistance."

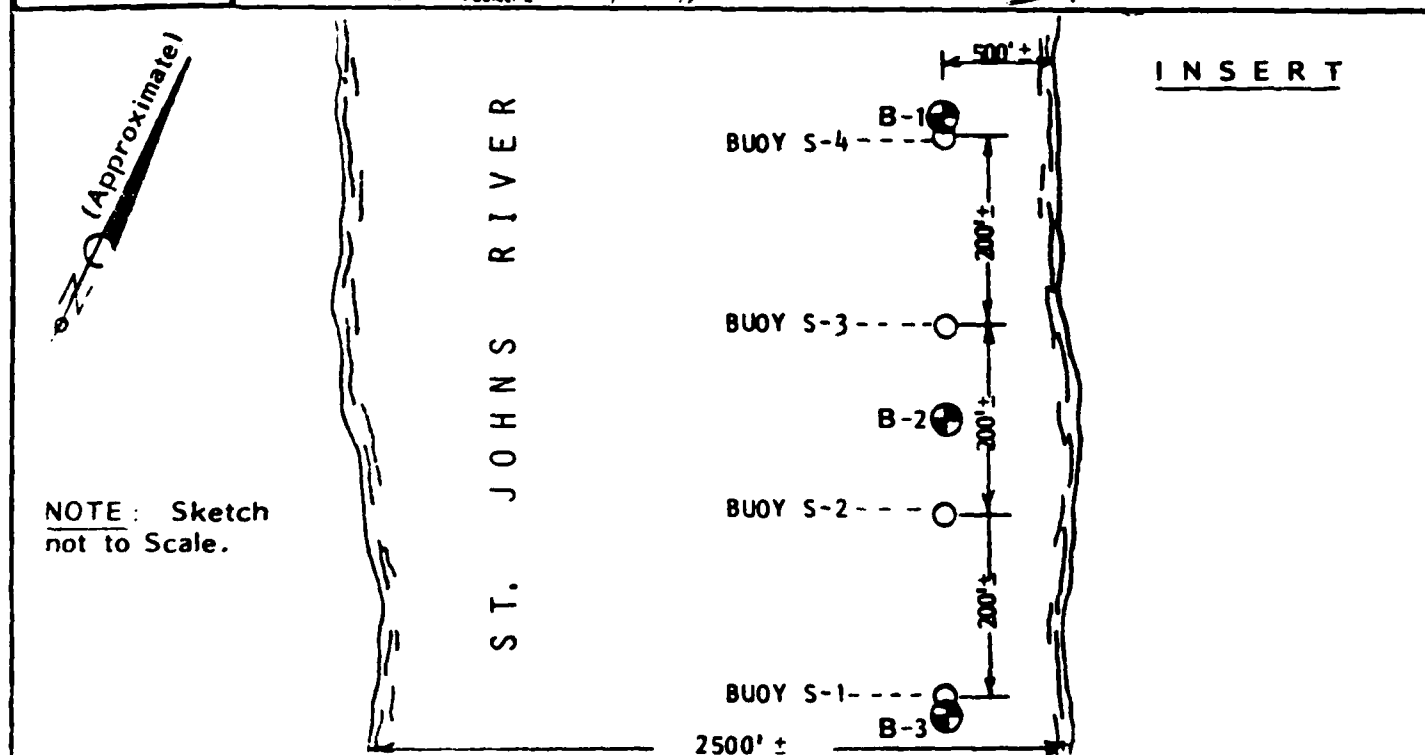
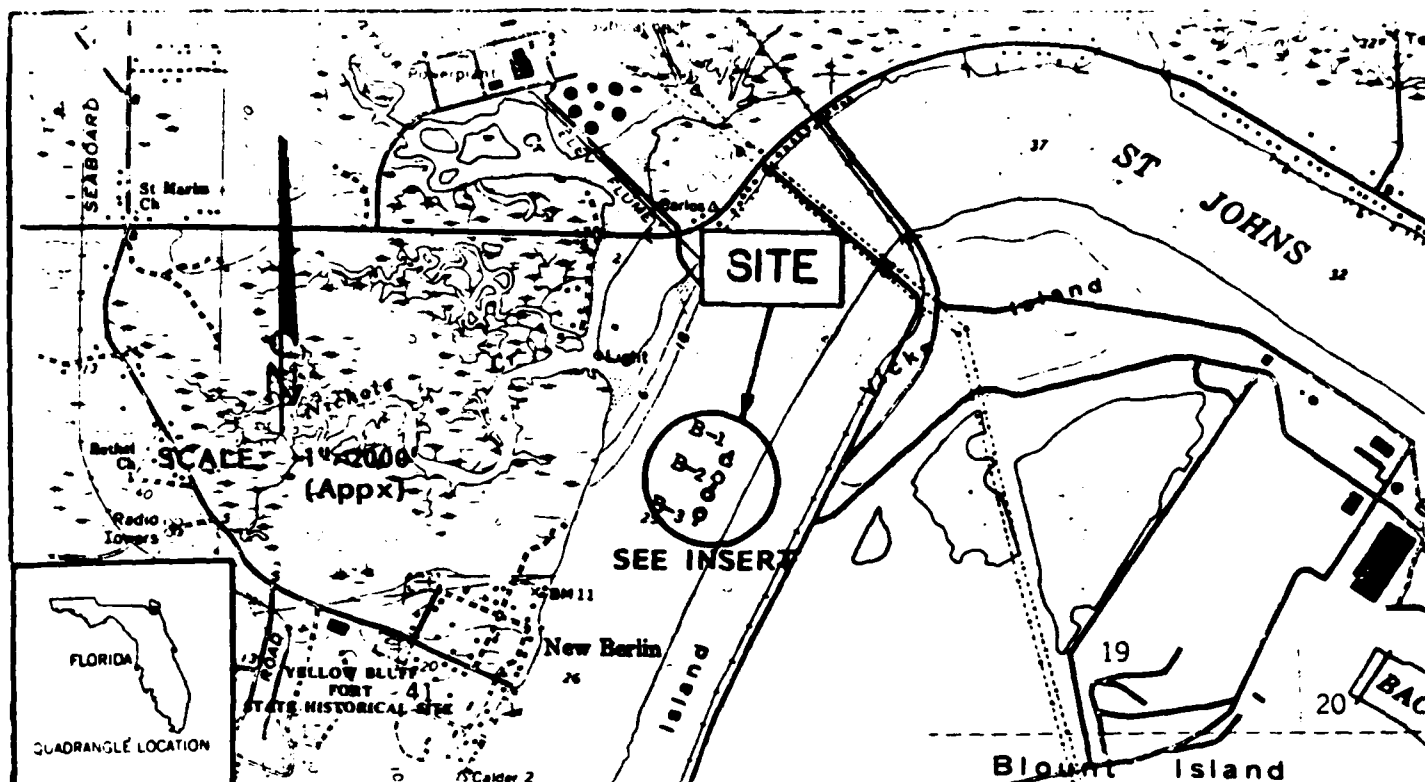
Representative portions of the soil samples, obtained from the sampler, were placed in glass jars and transported to our laboratory. The samples were then examined by an engineer in order to verify the field classifications.

For detailed information about the soil conditions encountered at each boring location, the attached Test Boring Records should be consulted. The horizontal stratification lines on these records indicate the approximate boundary between soil types and in some cases the transition may be gradual. It should be understood when reviewing these records that the soil conditions could vary between the boring locations.

ATTACHMENTS



Page 39



LEGEND

 Soil Test Boring Location

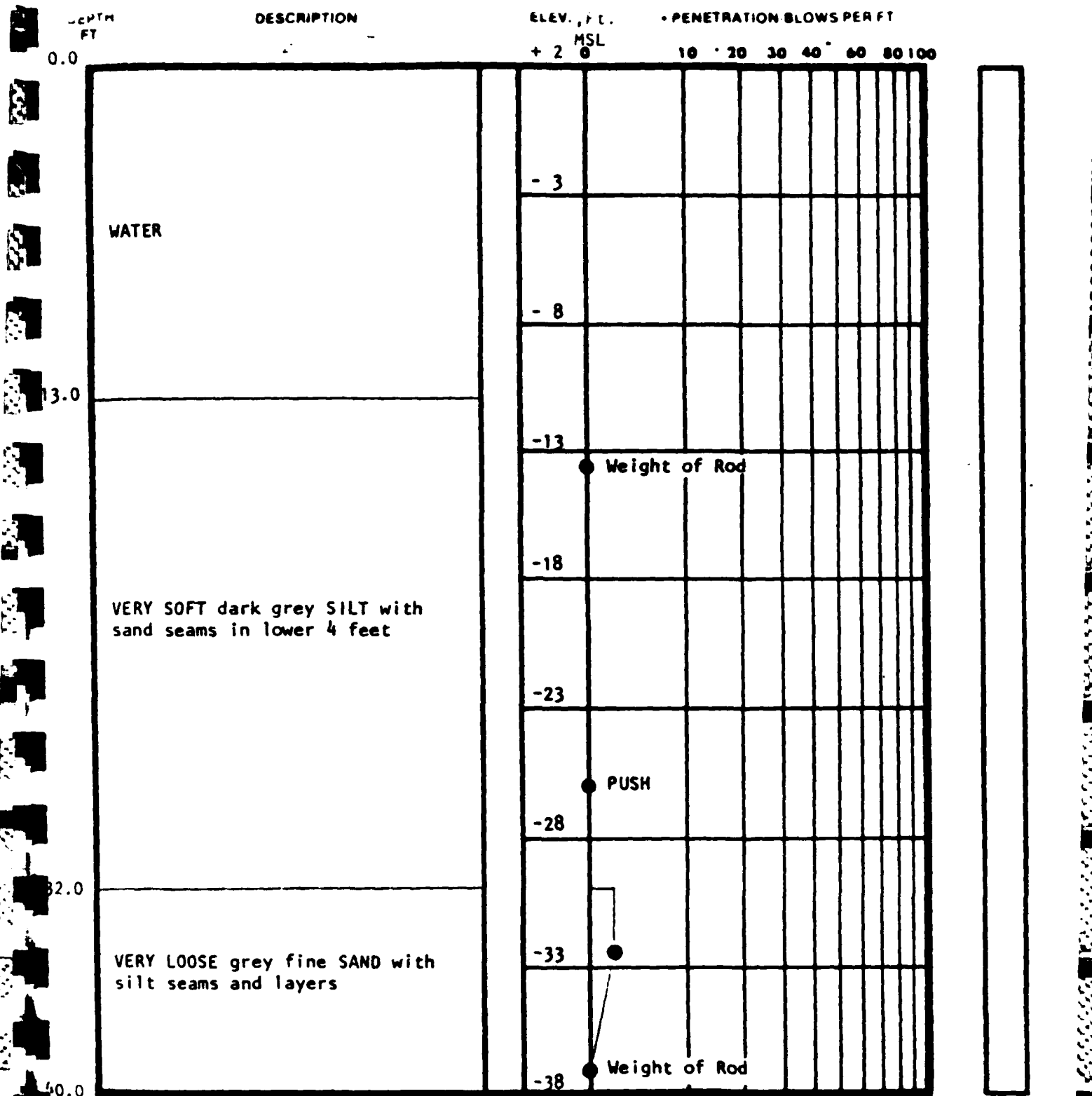
- References: 1) Eastport Quadrangle,
Florida; 1964, Rev. 1981
Topographic Map
U.S. Geological Survey
2) Location Map
Dlouhy & Associates, Inc.
Project No. 8020.0
Dated 5/07/80

**LAW ENGINEERING
TESTING COMPANY**
Jacksonville, Florida

SITE LOCATION & FIELD EXPLORATION PLAN

**Mayport Hurricane Moorings at Blount Island
Jacksonville, Florida**

DRAWN: DED	DATE: 10/27/82	SCALE: As Shown
CHECKED: JAH	JOB NO: J-4033	



PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113
PENETRATION IS THE NUMBER OF BLOWS OF 140 LB HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

BORING NO. B-1

DATE DRILLED 10/18/82

JOB NO. J-4033

UNDISTURBED SAMPLE

WATER TABLE, 24 HR

WATER TABLE AT TIME OF DRILLING

ROCK CORE RECOVERY

LOSS OF DRILLING WATER

LAW ENGINEERING TESTING CO.

Page 641

DEPTH
FT

DESCRIPTION

ELEV. ASL

PENETRATION BLOWS PER FT

-38 Weight of Rod 20 30 40 60 80 100

40.0

SOFT dark blue-grey slightly clayey SILT

42.0

SOFT brown slightly sandy SILT

46.5

Brown cemented to slightly cemented silty fine SAND with zones of brown slightly silty fine sand (Silty sandy LIMESTONE)

55.0

BORING TERMINATED

NOTE: Borehole cased to 35 feet.

-43

-48

-53

PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT.

UNDISTURBED SAMPLE

ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

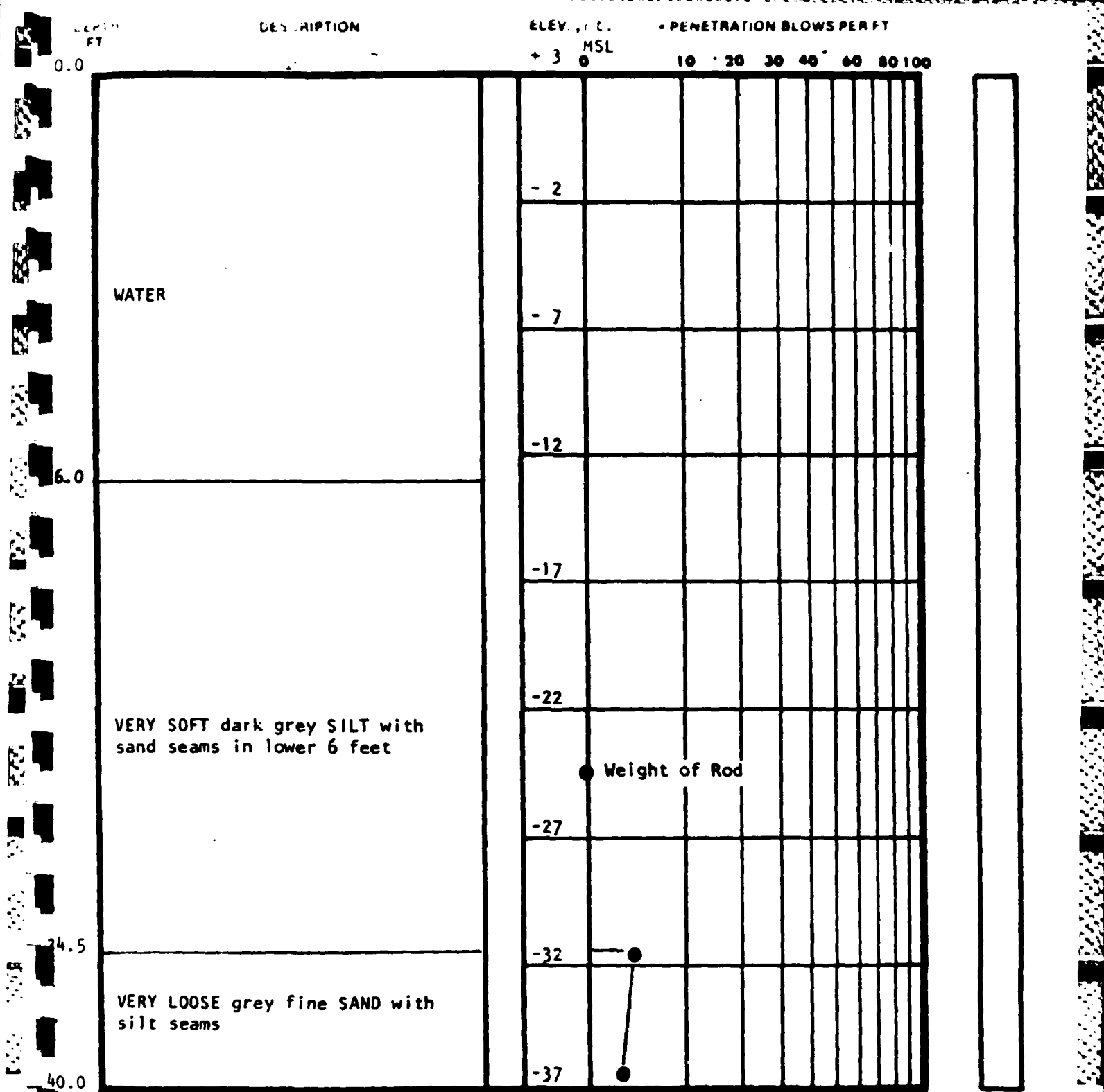
BORING NO. B-1

DATE DRILLED 10/18/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

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PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

UNDISTURBED SAMPLE

ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-2

DATE DRILLED 10/19/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

Page 643

DEPTH
FT

DESCRIPTION

ELEV., Ft.

• PENETRATION-BLOWS PER FT

-37 MSL

10 20 30 40 60 80 100

40.0

VERY LOOSE grey fine SAND with
silt seams

43.5

VERY SOFT blue-grey slightly clayey (1)

44.5

VERY SOFT to SOFT green-brown
slightly sandy slightly silty CLAY

47.5

Brown well cemented silty fine
SAND (Limestone)

50.0

BORING TERMINATED

-42

-47

100=2"

NOTE: Borehole cased to 35 feet.

(1) SILT with sand seams

PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D 1586
CORE DRILLING MEETS ASTM D 2113PENETRATION IS THE NUMBER OF BLOWS OF 140 LB HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT

UNDISTURBED SAMPLE

100% ROCK CORE RECOVERY

WATER TABLE 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-2

DATE DRILLED 10/19/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO

DEPTH
FT

DESCRIPTION

ELEV., F.T.
+ 2 MSL
0

PENETRATION-BLOWS PER FT

10 20 30 40 60 80 100

0.0

WATER

19.0

VERY SOFT grey SILT with sand
seams in lower 3 feet

32.5

VERY FIRM grey fine SAND with
some fine shell

37.0

38.0

VERY SOFT blue-green CLAY with
Brown cemented silty fine SAND
(Silty sandy LIMESTONE)

40.0

- 3

- 8

-13

-18

-23

-28

-33

-38

Weight of Rod

PUSH

(1)

(1) some sand seams

PAGE ONE OF TWO (1 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1 1/4 IN. I.D. SAMPLER 1 FT.

UNDISTURBED SAMPLE

% ROCK CORE RECOVERY

WATER TABLE, 24 HR.

WATER TABLE AT TIME OF DRILLING

LOSS OF DRILLING WATER

BORING NO. B-3

DATE DRILLED 10/13/82

JOB NO. J-4033

LAW ENGINEERING TESTING CO.

Page 645

FT

DESCRIPTION

ELEV. -38 MSL

PENETRATION BLOWS PER

10 20 30 40 60 100

40.0

Brown cemented silty fine SAND
(Silty sandy LIMESTONE)

42.5

LOOSE brown slightly silty fine
SAND with limestone fragments

46.0

Brown well cemented silty fine
SAND (Silty sandy LIMESTONE)

48.0

VERY FIRM grey fine SAND

49.0

Brown slightly cemented silty fine

50.0

BORING TERMINATED

(2)

-48

-43

NOTE: Borehole cased to 35 feet.

(2) SAND (Silty sandy LIMESTONE)

PAGE TWO OF TWO (2 of 2)

TEST BORING RECORD

BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

PENETRATION IS THE NUMBER OF BLOWS OF 140 LB. HAMMER
FALLING 30 IN. REQUIRED TO DRIVE 1 1/4 IN. I.D. SAMPLER 1 FT

BORING NO. B-3

DATE DRILLED 10/13/82

JOB NO. J-4033

UNDISTURBED SAMPLE



WATER TABLE, 24 HR.



WATER TABLE AT TIME OF DRILLING

ROCK CORE RECOVERY



LOSS OF DRILLING WATER

LAW ENGINEERING TESTING CO

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KEY TO SOIL CLASSIFICATION

Correlation of Penetration Resistances with Relative Density and Consistency

	NO. OF BLOWS, N	RELATIVE DENSITY
<u>SANDS AND GRAVELS</u>		
	0 - 4	Very Loose
	5 - 10	Loose
	11 - 20	Firm
	21 - 30	Very Firm
	31 - 50	Dense
	Over 50	Very Dense
	NO. OF BLOWS, N	CONSISTENCY
<u>SILTS AND CLAYS</u>		
	0 - 2	Very Soft
	3 - 4	Soft
	5 - 8	Firm
	9 - 15	Stiff
	16 - 30	Very Stiff
	31 - 50	Hard
	Over 50	Very Hard

Particle Size Identification (Unified Classification System)

Boulders -	Diameter exceeds 8 inches
Cobbles -	3 to 8 inches diameter
Gravel:	Coarse - 3/4 to 3 inches in diameter
	Fine - 4.76 mm to 3/4 inch diameter
Sand:	Coarse - 2.0 mm to 4.76 mm diameter
	Medium - 0.42 mm to 2.0 mm diameter
	Fine - 0.074 mm to 0.42 mm diameter
Silt and Clay:	Less than 0.07 mm (Particles cannot be seen with naked eye)

MODIFIERS

The modifiers provide our estimate of the amount of fines
(silt or clay size particles) in the soil sample.

APPROXIMATE FINES CONTENT	MODIFIERS
5% Fines 12%	Slightly silty or slightly clayey
12% Fines 30%	Silty or clayey
30% Fines 50%	Very silty or very clayey

END
DTIC

7-86