APPENDIX H

MOORING DESIGN PROCEDURE

Step 1 – Establish Criteria

A. Tidal range
B. MIL-HDBK 1026/4A criteria for wind, current, and wave
C. Vessel characteristics (to calculate wind and current loads) (see Appendix A)

Step 2 – Calculate Wind and Current Load on Single Vessel

A. Using DM26.4
B. Spot checked using MIL-HDBK 1026/4A

Step 3 – Calculate Wind and Current Load on MHP

A. Using DM26.4

Step 4 – Calculate Factors

A. Factors for nesting vessels
B. Factors for berthing configuration

Step 5 – Calculate MHP Mooring Load

A. Determine total mooring load due to wind and current

B. Select mooring fenders

Step 6 – Check EQ Condition

A. Determine mass
B. Calculate stiffness of fenders
C. Determine period of structure
D. Using San Diego seismic spectra, determine Δ of structure for 500-year EQ and 2,500-year EQ

Step 7 – Shaft Design

Step 8 – Pile Design

Step 9 – Pilecap Design

CRITERIA

Project: MHP Floating Pier PH 2
Designer: KAP

Tidal Range :

Norfolk, VA Ref: Deperming Pier and Dredging (Naval Station) *
Pier 2 Replacement, Norfolk **

	dwg	MLLW = 0.0 datum	MLLW = 0.0 datum	
ELW	-0.77 m	-0.97 m	-3.18 ft	*
MLLW	0.20 m	0.00 m	0.00 ft	*
MHHW	1.05 m	0.85 m	2.79 ft	*
EHW	2.77 m	2.57 m	8.43 ft	*
Pier 2 Replacement, Norfolk				
MLLW	168.00 mm	0.00 m	0.00 ft	**
Yard	3050.00 mm	2.88 m	9.45 ft	**
Sv. Deck	3015.00 mm	2.85 m	9.34 ft	**
Op. Deck	6700.00 mm	6.53 m	21.42 ft	**

Bremerton, WA Ref: Dry Dock #3 Repair (Bremerton Ship Yard)
** Pier D - FY2001 MCON Project P-341 Drawings
+++ NOAA/NOS Web Site (www.co-ops.nos.noaa.gov/benchmarks/9445958.html)

	dwg	MLLW = 0.0 datum	MLLW = 0.0 datum **	MLLW = 0.0 datum +++	
ELW	105.00 ft	-4.40 ft	-4.50 ft	-4.80 ft	(11/30/1936)
MLLW	109.40 ft	0.00 ft	0.00 ft	0.00 ft	
MHHW	120.20 ft	10.80 ft	11.70 ft	11.74 ft	
EHW	124.80 ft	15.40 ft	--- ft	15.10 ft	(12/15/1977)
Yard	127.00 ft	17.60 ft	--- ft	--- ft	

San Diego, CA Ref: * Navigation Chart (San Diego Bay)
** NOAA/NOS Web Site (www.co-ops.nos.noaa.gov/data_res.html)
*** Deperming Pier (Point Loma)
+++ NOAA/NOS Web Site (www.co-ops.nos.noaa.gov/benchmarks/9410170.html)

	dwg	MLLW = 0.0 datum		MLLW = 0.0 datum +++	
ELW	ft	est -2.00 ft	** (Data from Nov 1, 1995	-2.88 ft	(12/17/1973)
MLLW	ft	0.00 ft	*	0.00 ft	
MHHW	ft	5.90 ft	*	5.73 ft	
EHW	ft	est 8.00 ft	** (Data from Nov 1, 1995	8.35 ft	(01/27/1983)
Yard		12.00 ft	***	--- ft	

Mayport, FL Ref: * similar to San Diego
** NOAA/NOS Web Site (www.co-ops.nos.noaa.gov/data_res.html)
+++ NOAA/NOS Web Site (www.co-ops.nos.noaa.gov/benchmarks/8720220.html)
&&& NFESC SSR-6078-OCN (Mayport Hurricane Mooring)

	dwg	MLLW = 0.0 datum	MLLW = 0.0 datum +++	
ELW	ft	est -2.00 ft	-3.20 ft	(01/24/1940)
MLLW	ft	0.00 ft	0.00 ft	
MHHW	ft	--- ft	4.92 ft	
EHW	ft	est 7.00 ft	7.50 ft	(09/09/1964)
Yard		--- ft	12.67 ft (est)	&&&

harbors. Therefore, the facilities and ship's mooring hardware should accommodate the types of services shown in Table 6.

Table 6
Mooring Service Types

MOORING SERVICE TYPE	DESCRIPTION
TYPE I	This category covers moorings that are used in winds of less than 34 knots and currents less than 2 knots. Moorings include ammunition facilities, fueling facilities, deperming facilities, and ports of call. Use of these moorings is normally selected concomitant with forecasted weather.
TYPE II	This category covers moorings that for general purpose berthing by a vessel that **will leave** prior to an approaching tropical hurricane, typhoon, or flood.
TYPE III	This category covers moorings that are used for **up to 2 years** by a vessel that **will not leave** prior to an approaching tropical hurricane or typhoon. Moorings include fitting-out, repair, drydocking, and overhaul berthing facilities. Ships experience this service approximately every 5 years. Facilities providing this service are nearly always occupied.
TYPE IV	This category covers moorings that are used for **2 years or more** by a vessel that **will not leave** in case of a hurricane, typhoon, or flood. Moorings include inactive, drydock, ship museum, and training berthing facilities.

Vessles & MHP

MHP ONLY

Table 7
Facility Design Criteria for Mooring Service Types

MOORING SERVICE TYPE	WIND*	CURRENT**	WATER LEVEL	WAVES
TYPE I	Less than 34 knots	2 knots or less	mean lower low to mean higher high	P=1 or R=1 yr
TYPE II	P=0.02 (min.) R=50 yr (min.) V_w=64 knots (max.)	P=0.02 R=50 yr	extreme lower low to mean higher high	P=1 or R=1 yr
TYPE III	P=0.02 or R=50 yr	P=0.02 or R=50 yr	extreme lower low to high	P=0.02 or R=50 yr
TYPE IV	P=0.01 or R=100 yr	P=0.01 or R=100 yr	extreme water levels	P=0.01 or R=100 yr

*Use exposure D (American Society of Civil Engineers (ASCE) 7-95, Minimum Design Loads for Buildings and Other Structures; flat, unobstructed area exposed to wind flowing over open water for a distance of at least 1 mile or 1.61 km) for determining design wind speeds. Note that min. = minimum return interval or probability of exceedence used for design; max. = maximum wind speed used for design.

**To define the design water depth, use T/d = 0.9 for flat keeled ships; for ships with non-flat hulls, that have sonar domes or other projections, take the ship draft, T, as the mean depth of the keel and determine the water depth, d, by adding 0.61 meter (2 feet) to the maximum navigation draft of the ship.

Project: MHP PH II
Job No: A01047
Designer: KAP
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[Design_notes.xls]Design notes

Design Parameter:

	Design Site	Optional Site		
	San Diego	Bermerton	Norfolk	Mayport
Max Wind	**52 knots**	**78 knots**	**96 knots**	**113 knots**
[reference]	DM26.6	DM26.6	DM26.6	DM26.6
Max Current	**0.7 knots**	**0.5 knots**	**0.8 knots**	**3.0 knots**
[reference]	DM26.6	Pier D Repl	DM26.6	DM26.6

Note: DM26.6 wind information is based on 30seconds duration, 33ft above the sealevel.
(Not Maximum Sustained Wind Load)
DM26.6 Current information was recorded at the water surface.

Mooring Service Type:

Type II: Berthed Ship (upto 64knots wind) and MHP
Type IV: MHP only

For Design Site [San Diego]

Loads:

	Mooring Type II	Mooring Type IV
Wind Load	52 knots	52 knots
Current	0.7 knots	0.7 knots

Water Level:

Ref: * Navigation Chart (San Diego Bay)
** NOAA/NOS Web Site
*** Deparming Pier (Point Loma)

	EL (ft)	
EHW	8.0	** (Data from Nov1/95 to Oct/00)
MHHW	5.9	*
MLLW	0.0	*
ELW	-2.0	**
Mud Line	-40.0	***

Since shollower water gives higher current load,
USE Water Depth = Mud Line - ELW = **38.0** ft
USE **37.0** ft

For Optional Site [Bermerton, Norfolk & Mayport]

	Mooring Type II	Mooring Type IV **
Wind Load	64 knots	113 knots
Current	1 knots *	3 knots

Note: * Since I don't have a appropriate current value for 50YR Return, I am going to approximate and use 1.0 knots. This would give at least an idea for loading condition at Bermerton, Norfolk and maybe Mayport.

** : Mooring Type IV will be checked using the Mayport value. The result would be conservative, since we are using the max 30sec wind. Sustained Wind value should be smaller than the maximum wind load from DM 26.6.

Water Level: Ref: *#3 Repair (Bermerton Shipyard)

	EL (ft)		
	Bermerton *	Norfolk	Maypport
EHW	15.4	8.43	-
MHHW	11.7	2.79	-
MLLW	0.0	0	-
ELW	-4.5	-3.18	-
Mud Line	-45.0	-31 to -51	-

Since shollower water gives higher current load,
USE Water Depth = Mud Line - ELW = **27.8** ft
[Norfolk information: abs(-31-(-3.18))]

USE **27** ft

WIND AND CURRENT ON SINGLE VESSEL

WIND AND CURRENT LOAD ON SINGLE VESSEL

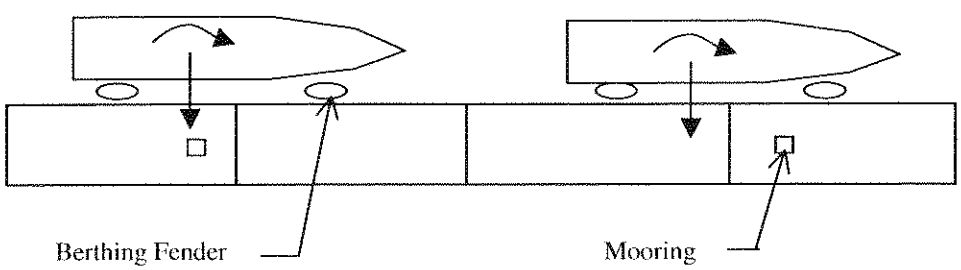
Refernce: DM 26.4

Calculation based on DM 26.4 were spot checked using Navy's Math CAD wind and current Program. (Author W. Seeling, Based on MIL-HDBK 1026.4A)

We also hand calculated the factor for nesting vessels. We determined that we an use the value based on DM 26.4 (conservative value compare to MIL-HDBK 1026/4A) for Phase II report.

ASSUMPTION:

Yaw moment for wind and current on vessels was not calculated Yaw moment would effect the berthing fender and MHP locally. However, for mooring load (MHP Mooring), we are only concerned with the total Transverse Load.



TRANSVERSE WIND LOAD

Fyw = 1/2 ρa Vw^2 Ay Cyw Fyw (θ w)

ρa = mass density of air
Vw = wind speed
Ay = longitudinal projected area of the ship
Cyw = Trans wind force drag coef
fyw (θ w) = shape function for transv. Force
θ w = wind angle

$$Cyw = 0.92 \left[\left(\frac{Vs}{VR} \right)^2 AS + \left(\frac{VH}{VR} \right)^2 AH \right] / AY$$

MIL-HDBK 1026/4A
TYPICAL = 0.92
HULL DOMINATED SHIP = 0.82
EXTENSIVE SUPERSTRUCT = 1.02

$$fyw(\theta w) = \frac{\sin qw - \frac{\sin 5qw}{20}}{1 - \frac{1}{20}}$$

TRANSVERSE CURRENT LOAD

Fyw = 1/2 ρw Vc^2 Lwl T Cyc sin(θ c)

ρw = mass density of water
Vc = current velocity
Lwl = vessel waterline length
T = vessel draft
Cyc = Lateral current-force drag coef.

MIL-HDKB 1026/4A
little different from DM 26.4 (Simpler for 1026/4A)

θ c = current angle

LONGITUDINAL WIND LOAD

Fxw = 1/2 ρa Vw^2 Ay Cxw Fxw (θ w)

ρa = mass density of air
Vw = wind speed
Ax = transverse wind area of the ship
Cxw = long. wind force drag coef
fxw (θ w) = shape function for Long. Force
θ w = wind angle

Cxw = Taken From DM 26.4 - Varies depends on the type of vessels

MIL-HDBK 1026/4A Pretty much the same

LONGITUDINAL CURRENT LOAD

Fxc = Fx form + Fx friction + Fx prop

Fx forom = Long. Current Load due to form drag
Fx friction = Long. Current Load due to skin friction
Fx prop = Long. Current Load due to propeller drag

Fx form = -1/2 ρw Vc^2 B T Cxcb cos(θ c)
ρw = mass density of water
Vc = current velocity
B = Vessel beam width
T = vessel draft
Cscb = Long. Current form-drag coef = **0.1**
θ c = current angle

Fx friction = -1/2 ρw Vc^2 S Cxca cos(θ c)
S = wetted surface area = (1.7 T LwL) + (3.5 D/T)
D = displacement of ship
Cxca = Long. Skin friction Coef = 0.75 / (Log Rn - 2)^2

Fx prop = -1/2 ρw Vc^2 Ap Cprop cos(θ c)
Ap = propeller expanded blade area
Cprop = Propeller - drag coef = **1.0**

MIL-HDBK 1026/4a Same Equation for Long. Current

Project: MHP PH II
Job #: A01047
Designer: KAP
Date: 4/27/2001
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[optiona_REVI.xls]Long Wind

Determine the Transverse Wind Load and Current Load on Single Vessel

SITE: San Diego
CONDITION: Light Draft w/ ELW

WIND:

V =	60	mph =	88	ft/s
p =	0.00237	slugs		
qw =	90	degree		

CURRENT:

V =	1.2	ft/sec
p =	2	slugs
theta =	90	degree

Compare with Lateral Wind+Current from "San Diego Pier Replacement"

Vessel	Fyw lbs	Fyc lbs	Fyw+Fyc kips (note 1)	Ws kips (note 2)	Ws / Fyw+Fyc
FFG 7	132,321	7,605	140	193	1.38
DDG 51	172,345	16,733	189	193	1.02
CG47	251,532	34,863	286	252	0.88
DD963	231,229	23,844	255	252	0.99
LPD 17	493,039	30,859	524	405	0.77
LHD 1	685,428	69,039	754	674	0.89
LHA 1	820,445	62,596	883	674	0.76

Note:

1 Lateral Wind Load and Current Load Using DM26.4
2 Lateral Wind Load and Current Load from San Diego Pier Replacement #10 and #11

Number of Nested Ships	2		
Factor Wind =	1	(for above number of Nested Condition)	DM26.4-70
Factor Current =	1.7	(for above number of Nested Condition)	DM26.4-72

	Single			Nested		
Vessel	Fyw lbs	Fyc lbs	Fyw+Fyc kips	Fyw lbs	Fyc lbs	Fyw+Fyc kips
FFG 7	132,321	7,605	140	132,321	12,928	145
DDG 51	172,345	16,733	189	172,345	28,446	201
CG47	251,532	34,863	286	251,532	59,266	311
DD963	231,229	23,844	255			
LPD 17	493,039	30,859	524			
LHD 1	685,428	69,039	754			
LHA 1	820,445	62,596	883			

Project: MHP PH II
Job #: A01047
Designer: KAP
Date: 4/27/2001
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[optiona_REVI.xls]Summary_Transv

Determine Longitudinal Wind and Current on Single Vessel

SITE: San Diego
CONDITION: Light Draft W/ ELW

WIND:

V =	60	mph =	88.0	ft/s
p =	0.00237	slugs		
θw_head=	0	degree =	0.00	rad
θw_tail=	180	degree =	3.14	rad

CURRENT:

V =	1.2	ft/sec		
θc_head =	0	degree =	0.00	rad
θc_tail =	180	degree =	3.14	rad

HEADWIND:

Number of Nested Ships	2		
Factor Wind =	2	(for above number of Nested Condition)	DM26.4-72
Factor Current =	2	(for above number of Nested Condition)	DM26.4-76

note 1

	Single			Nested		
Vessel	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips
FFG 7	(16,380)	(455)	(16.8)	(32,761)	(911)	(33.7)
DDG 51	(28,907)	(701)	(29.6)	(57,813)	(1,402)	(59.2)
CG47	(35,973)	(607)	(36.6)	(71,945)	(1,214)	(73.2)
DD963	(28,264)	(738)	(29.0)			
LPD 17	(40,469)	(1,404)	(41.9)			
LHA 1	(36,707)	(1,670)	(38.4)			
LHD 1	(42,213)	(1,633)	(43.8)			

TAILWIND:

note 1

	Single			Nested		
Vessel	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips
FFG 7	18,720	455	19.2	37,441	911	38.4
DDG 51	33,036	701	33.7	66,072	1,402	67.5
CG47	41,112	607	41.7	82,223	1,214	83.4
DD963	32,302	738	33.0			
LPD 17	40,469	1,404	41.9			
LHA 1	36,707	1,670	38.4			
LHD 1	42,213	1,633	43.8			

Note:

1 Longitudinal Wind Load and Current Load Using DM26.4

ct:	MHP PH II
Job #:	A01047
Designer:	KAP
Date:	4/27/2001
File:	O:\2001\A01047\ENGR\Mooring Design\LOADS\[optiona_REVI.xls]Long Wind

Determine the Transverse Wind Load and Current Load on Single Vessel

SITE: Optional Site
CONDITION: Light Draft w/ ELW

WIND:

V =	74	mph =	109	ft/s
p =	0.00237	slugs		
qw =	90	degree		

CURRENT:

V =	1.35	ft/sec
p =	2	slugs
theta =	90	degree

Number of Nested Ships	2		
Factor Wind =	1	(for above number of Nested Condition)	DM26.4-70
Factor Current =	1.7	(for above number of Nested Condition)	DM26.4-72

note 1

Vessel	Single			Nested		
	Fyw lbs	Fyc lbs	Fyw+Fyc kips	Fyw lbs	Fyc lbs	Fyw+Fyc kips
FFG 7	201,274	14,331	216	201,274.2	24362.08	225636.33
DDG 51	262,156	30,590	293	262,155.7	52003.81	314159.48
CG47	382,608	57,376	440	382,607.9	97539.88	480147.74
DD963	351,724	39,046	391			
LPD 17	749,967	58,418	808			
LHD 1	1,042,611	115,862	1,158			
LHA 1	1,247,988	104,168	1,352			

Note:

1 Lateral Wind Load and Current Load Using DM26.4

Project: MHP PH II
Job #: A01047
Designer: KAP
Date: 4/27/2001
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[optiona_REVI.xls]Summary_Transv

Determine Longitudinal Wind and Current on Single Vessel

SITE: Optional Site
CONDITION: Light Draft W/ ELW - Single Vessel

WIND:

V =	74	mph =	108.5	ft/s
p =	0.00237	slugs		
θw_head=	0	degree =	0.00	rad
θw_tail=	180	degree =	3.14	rad

CURRENT:

V =	1.35	ft/sec		
θc_head =	0	degree =	0.00	rad
θc_tail =	180	degree =	3.14	rad

HEADWIND:

Number of Nested Ships	2		
Factor Wind =	2	(for above number of Nested Condition)	DM26.4-72
Factor Current =	2	(for above number of Nested Condition)	DM26.4-76

note 1

	Single			Nested		
Vessel	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips
FFG 7	(24,916)	(575)	(25.5)	(49,833)	(1,150)	(51.0)
DDG 51	(43,970)	(885)	(44.9)	(87,940)	(1,770)	(89.7)
CG47	(54,718)	(766)	(55.5)	(109,437)	(1,531)	(111.0)
DD963	(42,993)	(931)	(43.9)			
LPD 17	(61,558)	(1,772)	(63.3)			
LHA 1	(55,835)	(2,109)	(57.9)			
LHD 1	(64,210)	(2,061)	(66.3)			

TAILWIND:

note 1

	Single			Nested		
Vessel	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips	**Fxw lbs**	**Fxc lbs**	**Fxw+Fxc** kips
FFG 7	28,476	575	29.1	56,952	1150	58.1
DDG 51	50,252	885	51.1	100,503	1770	102.3
CG47	62,535	766	63.3	125,070	1531	126.6
DD963	49,135	931	50.1			
LPD 17	61,558	1,772	63.3			
LHA 1	55,835	2,109	57.9			
LHD 1	64,210	2,061	66.3			

Note:

1 Longitudinal Wind Load and Current Load Using DM26.4

COMPARISON W/ DM26.4 CALC & NAVY'S MATHCAD

CG 47 @ SAN DIEGO

	DM 26.4	NAVY'S PROG MIL-HDBK 1046/4A
Trans. Wind	251.5 k	240 k
Long Wind	36 k	41 k
Trans. Current	34.8 k	33 k
Long. Current	0.6 k	0.58 k

We spot checked our wind and current calculation based on DM 26.4 with Navy's Wind and current program (Based on MIL-HDBK 1026/4A).

The result shows that the forces are compoarable. Therefore we will use our wind and current Load values for the preliminary analysis.

CALCULATE VESSEL WIND LOADS

File: W-cg47_SD.MCD
Input by KAP
26 April 2001

$knot \equiv \frac{6080 \cdot ft}{3600 \cdot sec}$ $\quad kip \equiv 1000 \cdot lbf$

@ SAN DIEGO
CG-47
LIGHT

This is a Mathcad file used to calculate wind loading on a single ship using the methods of DOD Design Manual DM.

ENTER REQUIRED ENVIRONMENTAL INPUT DATA

$\rho_\alpha := 1.221 \cdot \frac{kg}{m^3}$ mass density of air

$h_R := 10 \cdot m$ reference wind height

$v_R := 60 \cdot mph$ $\quad v_R = 26.82\, m\, sec^{-1}$ Wind speed at reference height

ENTER REQUIRED VESSEL DATA FOR WIND FORCE CALCULATIONS

$Lwl := 530 \cdot ft$ $\quad Lwl = 161.54\, m$ Waterline length of ship (to calculate avg. height of the hull)

$A_S := 9745 \cdot ft^2$ $\quad A_S = 905.34\, m^2$ Longitudinal wind area of superstructure

$A_H := 17255 \cdot ft^2$ $\quad A_H = 1603.04\, m^2$ Longitudinal wind area of hull $\quad A_Y := A_S + A_H$

$A_Y = 27000\, ft^2$ $\quad A_Y = 2508.38\, m^2$ Longitudinal wind area of ship

$h_S := 83 \cdot ft$ $\quad h_S = 25.3\, m$ Average height of superstructure above waterline

$h_H := \frac{A_H}{Lwl}$ $\quad h_H = 9.92\, m$ Average height of hull above waterline

$A_X := 5600 \cdot ft^2$ $\quad A_X = 520.26\, m^2$ Transverse wind area of ship

$L := 567 \cdot ft$ $\quad L = 172.82\, m$ Overall length of vessel (for moment calculations)

$$vcp := 1.142 \cdot \frac{0.5 \cdot (h_H) \cdot (A_H) + \left[(h_S - h_H) \cdot 0.5 + h_H\right] \cdot A_S}{A_Y}$$

Vertical center of pressure for list moment

$vcp = 10.88\, m$

CALCULATE THE TRANSVERSE WIND FORCES

Determine the empirical coefficient

To calculate the lateral wind-force drag coefficient, first determine the appropriate empirical coefficient as described in Section 4.3.1 using Table 4.2. Table 4.2 is also included below.

$C := 1.02$ Empirical coefficient, from Table 4.2

SHIP	C	NOTES
Hull dominated	0.82	aircraft carriers, drydocks
Typical	0.92	ships with moderate superstructure
Extensive superstructure	1.02	destroyers, cruisers

Determine the transverse wind-force drag coefficient

$$C_{yw} := C \cdot \frac{\left[\left[\frac{0.5\cdot(h_S + h_H)}{h_R}\right]^{\frac{2}{7}} \cdot A_S + \left(\frac{0.5\cdot h_H}{h_R}\right)^{\frac{2}{7}} \cdot A_H\right]}{A_Y}$$

Equation (4-2)

$C_{yw} = 0.966$

Transverse wind-force drag coefficient

Develop the transverse wind shape function

$i := 0..12$ $\qquad \theta_{\omega_i} := i \cdot 15 \cdot deg$

this simply sets angle increments in ten degrees from 0 to 180.

$$f_{ywtheta_i} := \frac{\left(\sin(\theta_{\omega_i}) - \frac{\sin(5\cdot\theta_{\omega_i})}{20}\right)}{\left(1 - \frac{1}{20}\right)}$$

this is the shape function for the lateral load Eq (4-3)

Develop the transverse wind-force coefficients

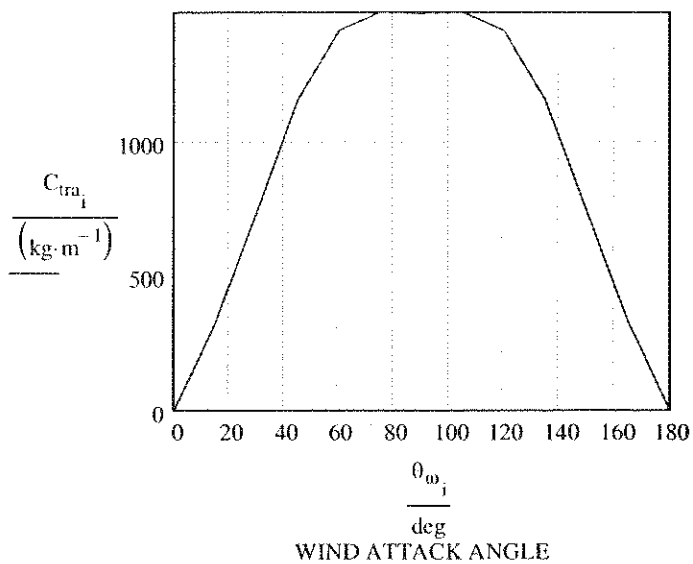
The transverse wind-force coefficient step is used if the user's analysis program calculates the wind forces in terms of the wind speed squared multiplied by a load coefficient (i.e.. Atkiins Quantitative Wave Analysis System, or AQWA, by W. S. Atkins).

$C_{tra_i} := 0.5 \cdot \rho_\alpha \cdot A_Y \cdot C_{yw} \cdot f_{ywtheta_i}$ $\qquad$ this is Eq (4-1), without wind speed terms

$WIRX_i := -vcp \cdot C_{tra_i}$ $\qquad$ Wind list moment factor

θ_{ω_i} / deg =	C_{tra_i} / $(kg \cdot m^{-1})$ =	$WIRX_i$ / kg =
0	0	0
15	327.93	-3567.79
30	739.89	-8049.97
45	1156.51	-12582.73
60	1416.43	-15410.63
75	1484.44	-16150.52
90	1479.79	-16099.94
105	1484.44	-16150.52
120	1416.43	-15410.63
135	1156.51	-12582.73
150	739.89	-8049.97
165	327.93	-3567.79
180	-0	0

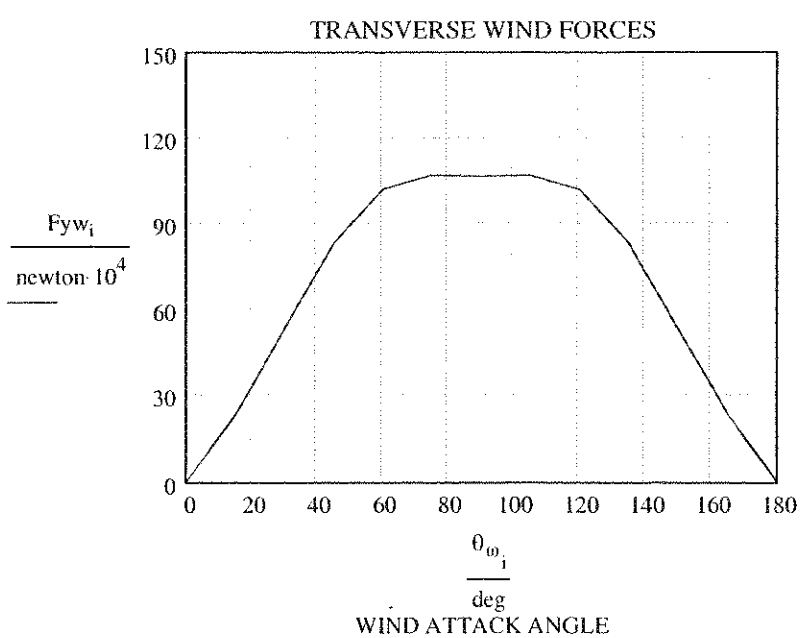
Graph of transverse wind force coefficients



Calculate the transverse wind forces

$Fyw_i := C_{tra_i} \cdot v_R^2$ Transverse wind force

θ_{ω_i} / deg =	Fyw_i / $newton \cdot 10^4$ =
0	0
15	23.59
30	53.23
45	83.2
60	101.9
75	106.8
90	106.46
105	106.8
120	101.9
135	83.2
150	53.23
165	23.59
180	-0



Maximum lateral wind force

$\max(Fyw) = 1.06797 \times 10^6$ newton

CALCULATE THE LONGITUDINAL WIND FORCES

Develop the longitudinal wind-force shape function

The longitudinal wind force shape will depend on whether the vessel analyzed is Case 1 or Case II and the wind angle that produces no net longitudinal wind force. Recommended values for this angle of no net longitudinal wind force is provided in Table 4.3. A copy is provided below.

LOCATION OF SUPERSTRUCTURE	θ_x
Just Forward of midships	100°
On midships	90°
Aft of midships (tankers)	80°
Warships	70°
Hull dominated	60°

$\theta_x := 70 \cdot deg$ Incident wind angle producing no net longitudinal force

Case One: Single Distinct Superstructure

$$\phi_i := if\left[\theta_{\omega_i} < \theta_x, \frac{90 \cdot deg}{\theta_x} \cdot \theta_{\omega_i}, \frac{90 \cdot deg}{(180 \cdot deg - \theta_x)} \cdot (\theta_{\omega_i} - \theta_x) + 90 \cdot deg\right]$$

Angle for shape function. Eq (4-5a&b)

$$f1_{xwtheta_i} := \cos(\phi_i)$$

Longitudinal shape function. This is DM Eq(4-5)

Case Two: Distributed Superstructure

$$\gamma_i := if\left[\theta_{\omega_i} < \theta_x, \frac{90 \cdot deg}{\theta_x} \cdot \theta_{\omega_i} + 90 \cdot deg, \frac{90 \cdot deg}{(180 \cdot deg - \theta_x)} \cdot \theta_{\omega_i} + \left[180 \cdot deg - \frac{(90 \cdot deg \cdot \theta_x)}{(180 \cdot deg - \theta_x)}\right]\right]$$

Angle for shape function. Eq(4-6a&b)

$$f2_{xwtheta_i} := \frac{\left(\sin(\gamma_i) - \frac{\sin(5 \cdot \gamma_i)}{10}\right)}{\left(1 - \frac{1}{10}\right)}$$

Longitudinal shape function. Eq(4-6)

Develop the longitudinal wind force coefficients

The longitudinal wind force coefficients will depend on whether the vessel analyzed is Case 1 or Case II and whether the loading is bow or stern loading. Longitudinal wind force drag coefficient for bow or wind loading are provided in Table 4.3. A copy is provided below.

VESSEL TYPE	C_{xwB}	C_{xwS}
Hull dominated (aircraft carriers, submarines, passenger liners)	0.40	0.40
Normal *	0.70	0.60
Center-Island Tankers *	0.80	0.60
Significant Superstructure (destroyers, cruisers)	0.70	0.80

*An adjustment of up to +0.10 to C_{xwB} and C_{xwS} should be made to account for significant cargo or cluttered decks.

$C_{xwB} := 0.7$ Drag force coefficient for bow wind loading

$C_{xwS} := 0.8$ Drag coefficient for stern wind loading

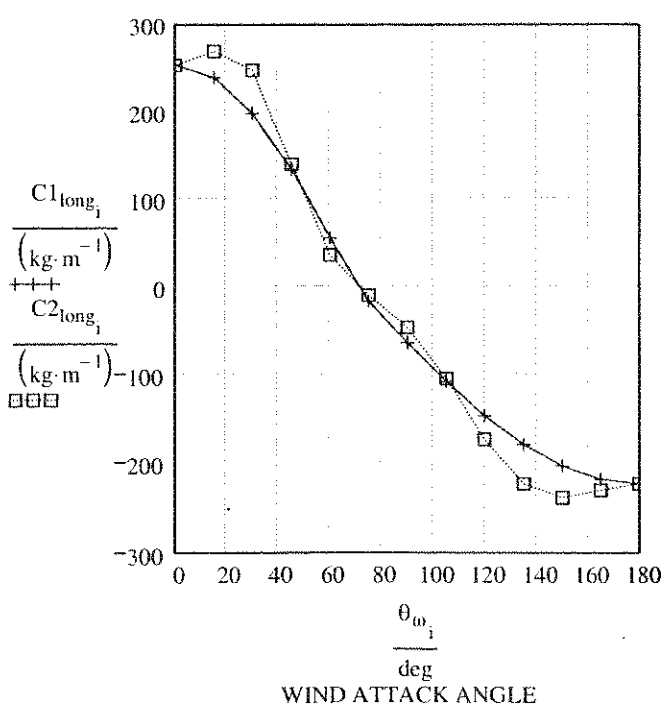
$$C1_{long_i} := 0.5 \cdot \rho_\alpha \cdot A_X \cdot \text{if}\left(\theta_{\omega_i} < \theta_x, C_{xwS}, C_{xwB}\right) \cdot f1_{xwtheta_i}$$

$$C2_{long_i} := 0.5 \cdot \rho_\alpha \cdot A_X \cdot \text{if}\left(\theta_{\omega_i} < \theta_x, C_{xwS}, C_{xwB}\right) \cdot f2_{xwtheta_i}$$

this is Eq(4-4), without wind speed terms. The negative sign is used to insure loads are consistent with the local coordinate system as shown in Figure 4.2.

$\frac{\theta_{\omega_i}}{deg} =$	$\frac{C1_{long_i}}{(kg \cdot m^{-1})} =$	$\frac{C2_{long_i}}{(kg \cdot m^{-1})} =$
0	254.09	254.09
15	239.83	269.64
30	198.66	248.26
45	135.19	140.88
60	56.54	37.39
75	-15.86	-8.99
90	-62.64	-45.15
105	-106.55	-103.59
120	-145.6	-172.04
135	-177.99	-222.4
150	-202.24	-238.07
165	-217.25	-229.55
180	-222.33	-222.33

Graph of longitudinal wind force coefficients



Calculate the longitudinal wind forces

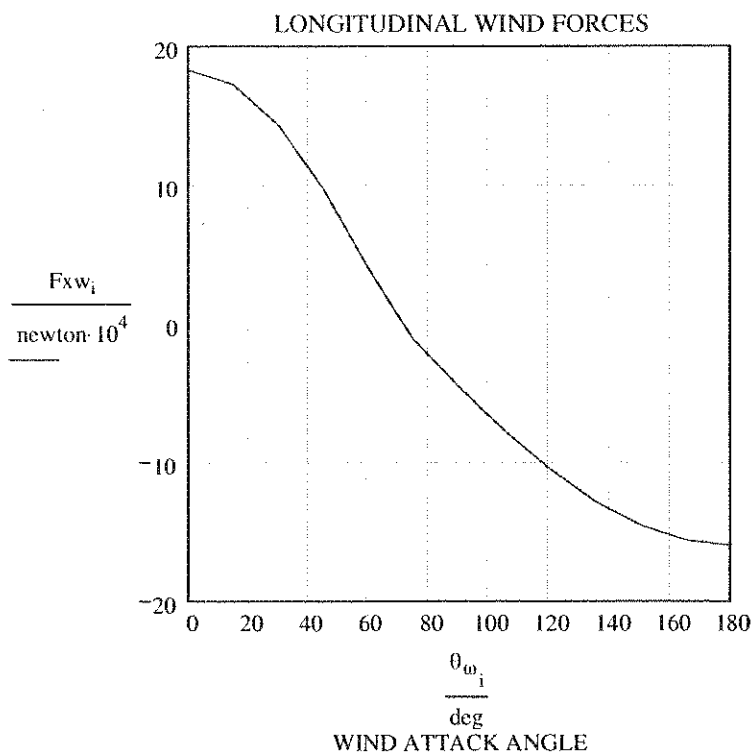
$Superstructure := 1$ Set superstructure "switch" to 1 for Case 1 and 2 for Case II.

For calculation of the longitudinal wind force, C1long is the shape function used if the user input term "Superstructure" in the input data block is set to 1. Otherwise the term C2long is used, a so-called "humped" distribution.

$$C_{long_i} := \text{if}\left(Superstructure = 1, C1_{long_i}, C2_{long_i}\right)$$

$$Fxw_i := C_{long_i} \cdot v_R^{\,2}$$ Longitudinal wind force

$\frac{\theta_{\omega_i}}{deg} =$	$\frac{Fxw_i}{newton \cdot 10^4} =$
0	18.28
15	17.25
30	14.29
45	9.73
60	4.07
75	-1.14
90	-4.51
105	-7.67
120	-10.47
135	-12.81
150	-14.55
165	-15.63
180	-16



Maximum longitudinal wind force

$$\max(Fxw) = 1.82805 \times 10^5 \text{ newton}$$

CALCULATE THE YAW WIND MOMENTS

Develop yaw wind normalized moment coefficient

The static wind yaw moment is defined as the product of the associated transverse wind force and its distance from the vessel's center of gravity. A plot of the yaw moment coefficients will produce a sinusoidal shaped curve that may have different positive and negative peaks. The zero moment angle or the point where the curve crosses the x-axis may be different than 90^0. Using Table 4.5, input the positive and negative peaks and the the zero moment angle for the type vessel analyzed A copy of Table 4.5 is provided below

SHIP TYPE	Zero Moment Angle (θ_z)	Negative Peak (a1)	Positive Peak (a2)	NOTES
Liner	80	0.075	0.14	
Carrier	90	0.068	0.072	
Tanker	95	0.077	0.07	Center island w/ cluttered deck
Tanker	100	0.085	0.04	Center island w/ trim deck
Cruiser	90	0.064	0.05	
Destroyer	68	0.02	0.12	
Others:	130	0.13	0.025	stern superstructure
	102	0.096	0.029	aft midships superstructure
	90	0.1	0.1	midships superstructure
	75	0.03	0.05	forward midships superstructure
	105	0.18	0.12	bow superstructure

EDIT USER INPUT TERMS

$a1 := 0.064$ This is the negative peak taken from Table 4.5, **must enter into equation as a positive value**

$a2 := 0.05$ This is the positive peak taken from Table 4.5,

$\theta z := 90 \cdot deg$ This is the zero moment angle taken from Table 4.5

$\theta 1 := 90 \cdot deg - \theta z$ **this is an angle used in the empirical equation below and should not be edited by the user**

$$\lambda := \frac{180 \cdot deg}{(180 \cdot deg - \theta z)} \qquad \text{Eq(4-8b)}$$

$$cxyw_i := if\left[\theta_{\omega_i} \le \theta z, -a1 \cdot \sin\left[\theta_{\omega_i} \cdot \frac{(180 \cdot deg)}{\theta z}\right], a2 \cdot \sin\left[\left(\theta_{\omega_i} - \theta z\right) \cdot \lambda\right]\right] \qquad \text{Eq(4-8)}$$

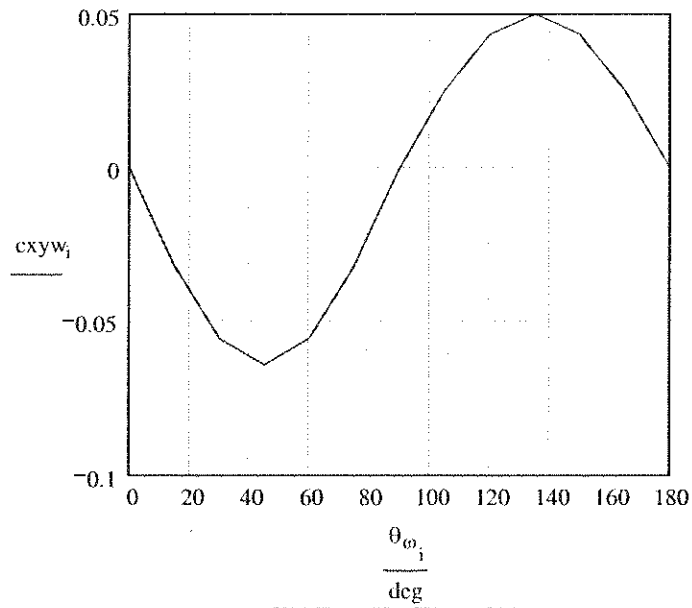
Calculate the yaw wind moment coefficients

$Cxyw_i := .5 \cdot \rho_\alpha \cdot A_Y \cdot L \cdot cxyw_i$

this is Eq(4-7) without the wind speed. The negative sign is to insure moments are consistent with the local coordinate system as shown in Figure 4.2

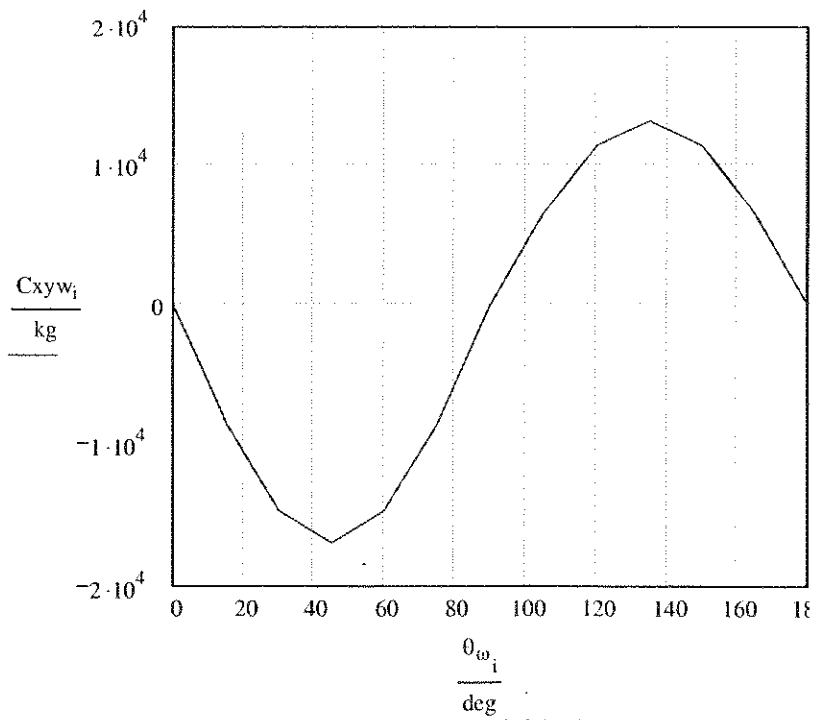
$\frac{\theta_{\omega_i}}{deg} =$	$cxyw_i =$
0	0
15	-0.03
30	-0.06
45	-0.06
60	-0.06
75	-0.03
90	0
105	0.03
120	0.04
135	0.05
150	0.04
165	0.03
180	0

Graph of normalized wind yaw moment coefficient



$\frac{\theta_{\omega_i}}{deg} =$	$\frac{Cxyw_i}{kg} =$
0	0
15	-8468.91
30	-14668.58
45	-16937.81
60	-14668.58
75	-8468.91
90	0
105	6616.33
120	11459.83
135	13232.67
150	11459.83
165	6616.33
180	-0

Graph of wind yaw moment coefficient

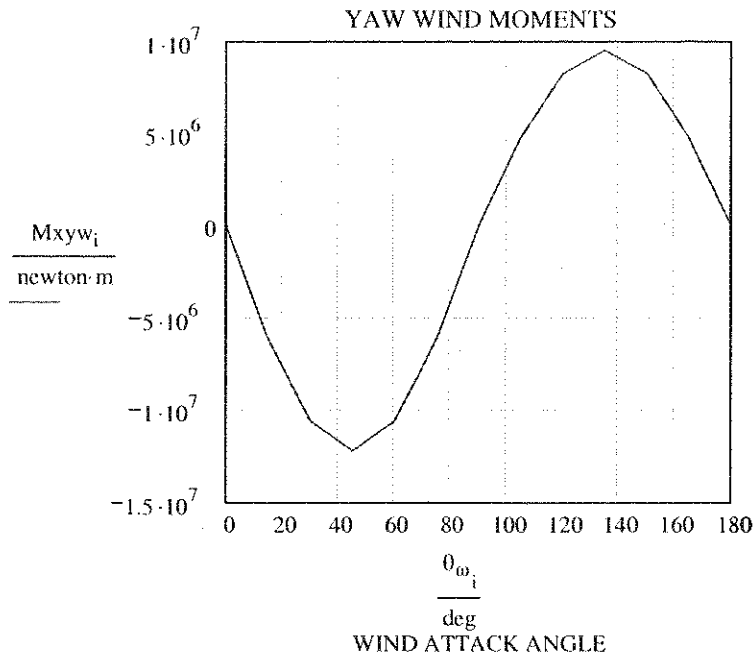


Calculate the yaw wind moments

$Mxyw_i := Cxyw_i \cdot v_R^2$

Yaw wind moment

$\frac{\theta_{\omega_i}}{deg} =$	$\frac{Mxyw_i}{ewton \cdot m \cdot 10^7} =$
0	0
15	0.61
30	1.06
45	1.22
60	1.06
75	0.61
90	0
105	0.48
120	0.82
135	0.95
150	0.82
165	0.48
180	0

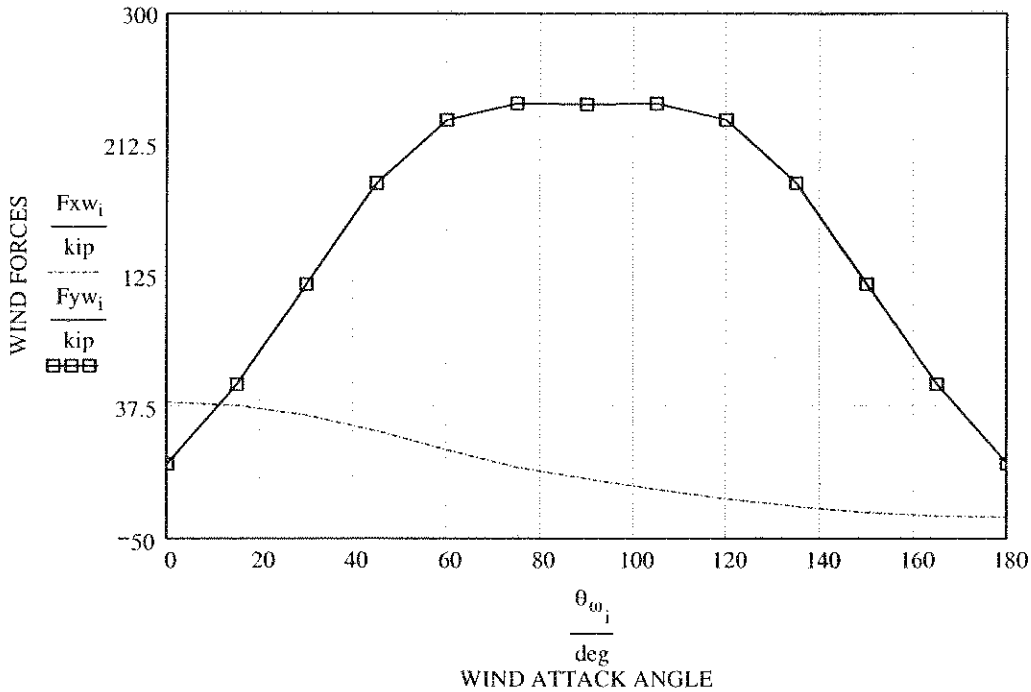


Maximum wind yaw moment

$\max(Mxyw) = 9.52013 \times 10^6 \, newton \cdot m$

Plot of wind forces and moments in US units

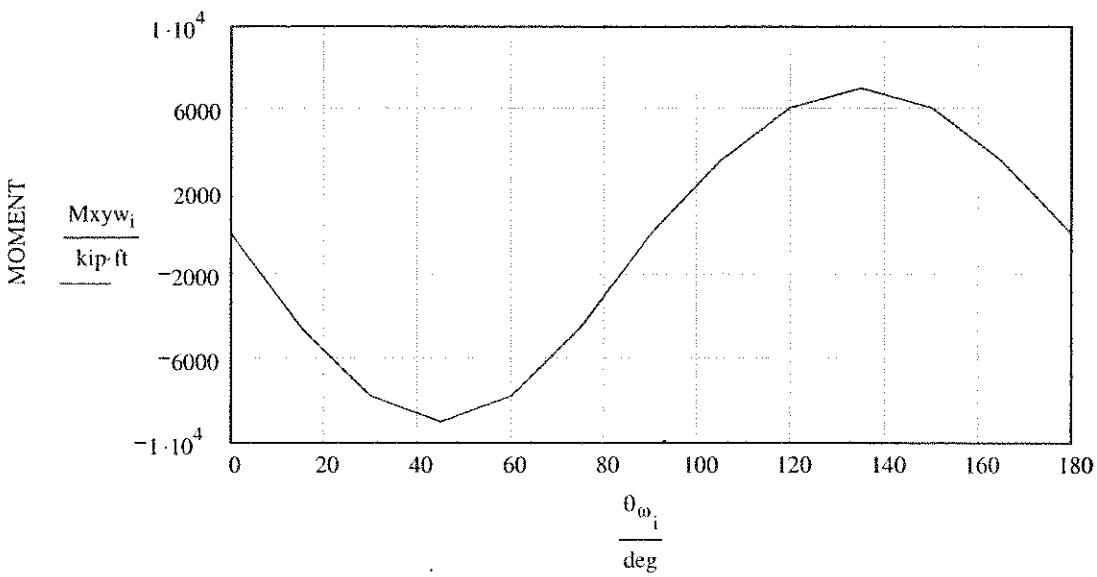
PLOT TRANSVERSE & LONGITUDINAL WIND FORCES



max(Fyw) = 240.09 kip

max(Fxw) = 41.1 kip

PLOT WIND YAW MOMENTS

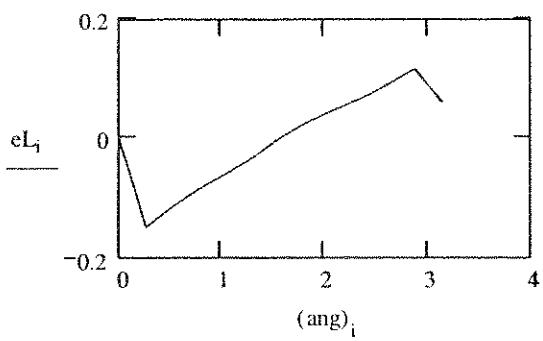


max(Mxyw) = 7021.68 kip·ft

$$eL_i := \frac{Mxyw_i}{(L \cdot Fyw_i)} \qquad facty_i := \frac{C_{tra_i}}{C_{tra_6}}$$

$$ang_i := i \cdot 15 \cdot deg$$

$\frac{\theta_{\omega_i}}{deg} =$	$eL_i =$	$facty_i =$
0	0	0
15	-0.15	0.22
30	-0.11	0.5
45	-0.08	0.78
60	-0.06	0.96
75	-0.03	1
90	0	1
105	0.03	1
120	0.05	0.96
135	0.07	0.78
150	0.09	0.5
165	0.12	0.22
180	0.06	0



WIND AND CURRENT ON MHP

WIND AND CURRENT LOAD ON MHP

Refernce: DM 26.4 - 54 to 60

MIL-HDBK 1026/4A does not have this section anymore.

1) WIND LOAD ON FLOATING DRYDOCKS

TRANSVERSE WIND LOAD

Fyw = 1/2 ρa Vw^2 Ay Cdw Fyw sin(θ w)

ρa = mass density of air
Vw = wind speed
Ay = Transv. Projected area of drydock
θ w = wind angle =USE 90 degrees
Cdw = wind-force drag coef
(Table 6 - Shows Cdw for floating Docks. Most values are 0.8 to 0.9. Therefore we will use 1.0 for our calculation.)

[Additional load due to Yaw Moment]

Myw = (Fyw) (ew)

$$ew = L\left(\frac{3.125}{100} - 0.0014\,(\theta w - 90\text{degree})\right)$$

= 0.03125 L = 40.6 ft (L = 1300 ft)

$$\Delta\, Fyw = \frac{Mxy\ w/\ L^*}{} = \frac{(40.6')\ (Fyw)}{650'} = 0.0625\ Fyw$$

L* = Length Btw mooring locations
= 1300 - (325' x 2) = SAY 650 ft

LET'S ADD 7 % TO Fyw

LONGITUDINAL WIND LOAD

Fxw = 1/2 ρa Vw^2 Ax Cbw cos(θ w)

Ax = Long. Projected area of Dock

NO Yaw Moment!!

2) CURRENT LOAD ON MHP

TRANSVERSE CURRENT LOAD

** Since we don't have specific equation for Floating Drydock, we will use EQ for Current on Vessels (DM26.4 60 to 68)

Assume

Cyc	1
Cm =	1
k =	Use block-shaped Hull Curve

** Let's Increase Fyc by 7 % to include Yaw moment Effect (same thought process as Wind load)

LONGITUDINAL CURRENT LOAD

** Since we don't have specific equation for Floating Drydock, we will use EQ for Current on Vessels (DM26.4 60 to 68)

- Floating Pier will not have propeller, Fx-Porp = 0

Project: MHP PH II
Job #: A01047
Designer: KAP
Date: 4/27/2001
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[pier_REV.xls]Summary

Determine the Longitudinal and Transverse Wind and Current Load on Pier

CONDITION: **Light Draft w/ ELW**

Pier Geometry:

h_light =	18	ft	Pier Height during light draft
B_pier	88	ft	Pier Width
L_pier	1300	ft	

Wind Load:

Site	Vw	
	mph	ft/s
Design II & IV	60	88.0
Optional II	74	108.5
Optional IV	130	190.7

Site	Vc	
	knots	ft/s
Design II & IV	0.7	1.2
Optional II	1.0	1.7
Optional IV	3.0	5.1

Longitudinal Wind on Pier

Site	Fyw lbs	Fyc lbs	HeadWind Fyw+Fyc kips
Design II & IV	(14,536)	(515)	(15.1)
Optional II	(22,111)	(1,012)	(23.1)
Optional IV	(68,238)	(8,161)	(76.4)

TailWind		
Fyw lbs	Fyc lbs	Fyw+Fyc kips
14,536	515	15.1
22,111	1,012	23.1
68,238	8,161	76.4

Transver Wind On Pier

Site	Fxw lbs	Fxc lbs	Fxw+Fxc kips
Design II & IV	229,766	19,450	249.2
Optional II	349,499	40,882	390.4
Optional IV	1,078,623	367,938	1,446.6

FACTORS – NESTING AND BERTHING

VERIFICATION II
COMPARISON BTW
1999 DM VS 1986 DM

Comparison between 1999 DM vs. 1986 DM

[1999 DM ——> MIL-HDBK 1026/4A]

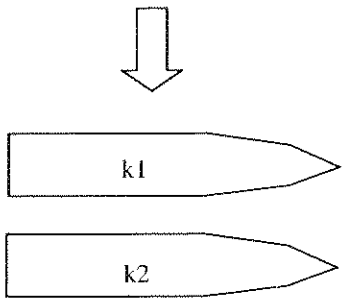
San Diego

v = 60 mph
c – 1.2 ft/s
water depth = 37 feet
For CG 47 (controlling ship – transverse wind)

	(Transverse)			
	Fy Wind	**Fy Current**	**Factor 2 Nested Ships Wind**	**Factor 2 Nested Ships Current**
'99 DM	240.336 lb	35,003 lb	0.94	1.3
'86 DM	251.532 lb	34,863 lb	1.0	1.7

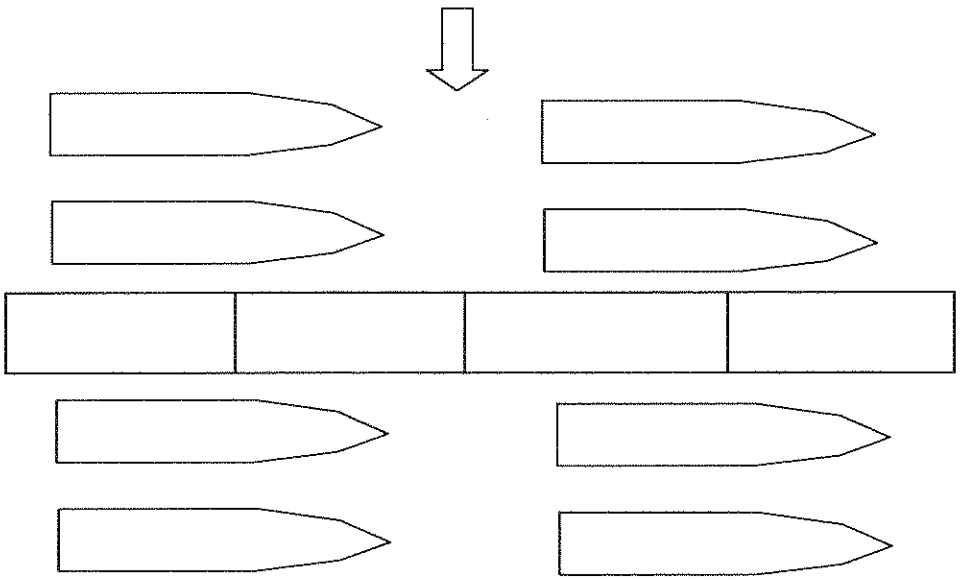
For our concept design purpose, loading (wind and current) calculated using 1986 DM are still valid.

Transv. Wind on Nested Vessels - [DM26.4-70]



[DM 26.4 70 CASE]

Factor for two nested vessels are more than the four nested vessels.



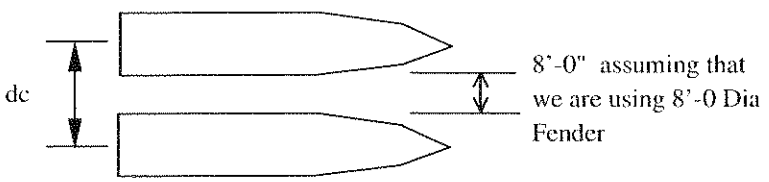
[OUR CASE]

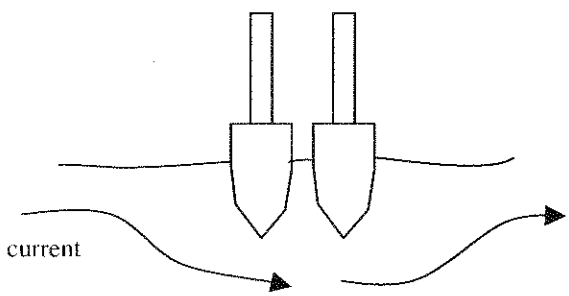
For Two Vessels Nested:

$$Fywg = Fyws\,[\,k1 \sin(\theta w) + k5\,(1 - \cos 4\theta w)] \qquad \theta w = 90 \text{ degree}$$
$$= 1.0\ Fyws \quad \text{(Same as Single Vessel)}$$

USE = 1.0 Fyws

Transv. Current on Nested Vessels - [DM26.4-72]





d cL = 45' (width of FFG-7) + 8' = 53'
B = 45' (for FFG-7)
d cL / B = 53' / 45' = 1.17

From Fig 30, DM 26.4 - 74

k6 @ θ = 90, k6 = **0.85**

From Fig 31, DM 26.4 - 75

1-2k7 = 1.0 k7 = **0**

First Vessels: Fyc 1 = 1/2 Fycs k6 (1-cos2(θc) = 0.85 Fycs

Second Vessels: Fyc 2 = (Fyc 1 @ 90) (sin(θc) - k7 (1-0.5cos2(θc)- 0.5cos6(θc))
= 0.85 Fycs

For 2 Vessels Nested = 2 (0.85 Fycs) = 1.7 Fycs

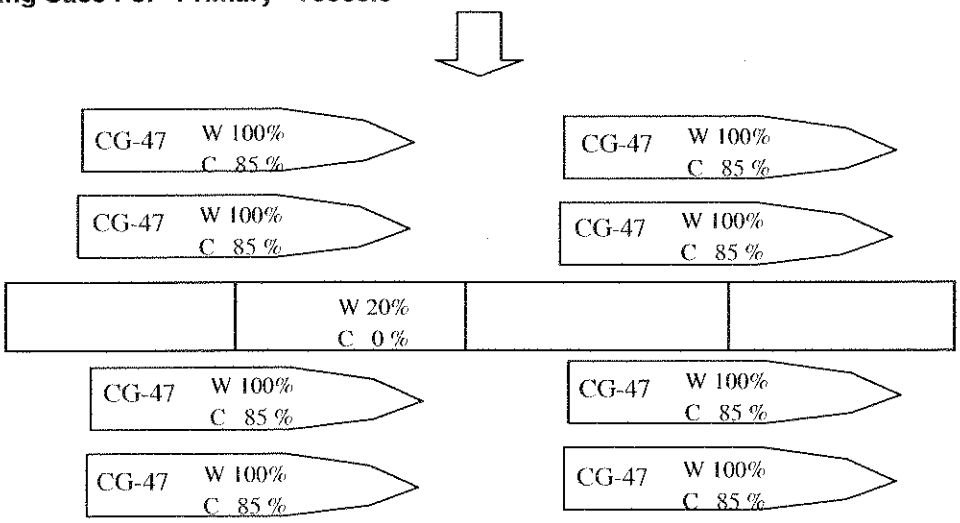
USE = 1.7 Fycs

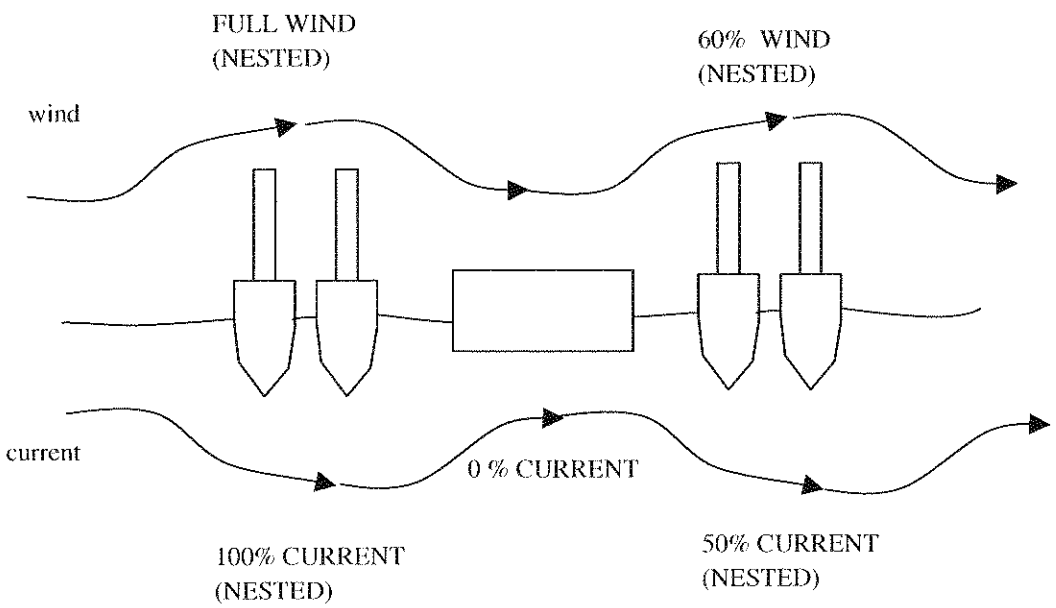
SUMMARY

BERTHING FACTOR FOR TRANSVERSE WIND AND CURRENT @ SAN DIEGO (DESIGN SITE)

@ San Diego: Vw = 60 mhp
Vc = 1.2 ft/sec

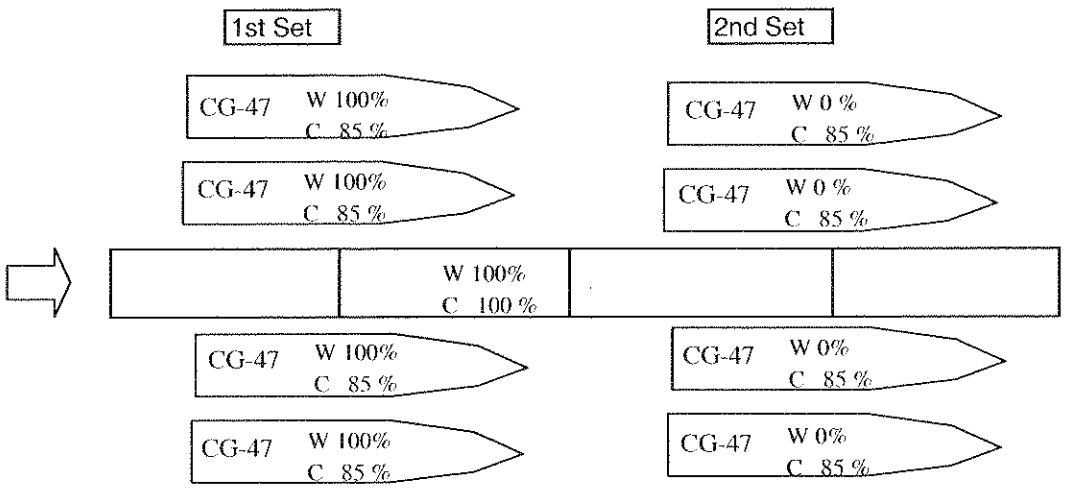
Controlling Case For "Primary" Vessels





BERTHING FACTOR FOR LONGITUDINAL WIND AND CURRENT @ SAN DIEGO (DESIGN SITE)

Controlling Case For "Primary" Vessels



* Tail wind value is little bit greater than Head wind. Therefore USE TAIL WIND

* Assumption is all primary vessels can be nested (after the meeting in May). Based on the calculation, Nested CG-47 would produce the largest force due to longitudinal wind and current

* Assumption - 1st set of CG-47 and 2nd sets of CG-47s would act as Nested

MOORING LOAD AND SELECTION OF FENDERS

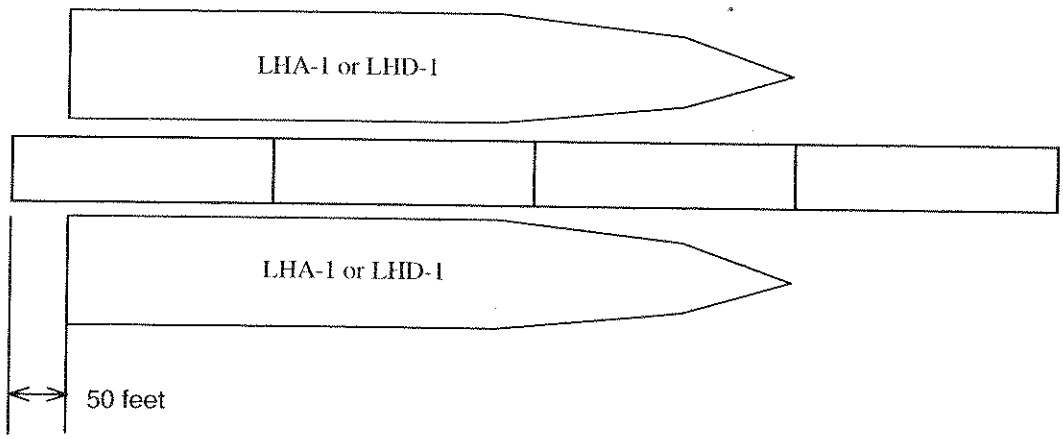
MOORING LOAD – DUE TO WIND AND CURRENT ON VESSELS AND PIER

Assumptions for Nesting Configuration and Location of Vessels

1. All primary vessels can be nested.

2. For optional vessels, only DD-963 can be nested.

3. When LHD or LHA are not berthed in the center of the MHP, the minimum distance from the end of the pier to beginning of vessel should be 50 feet.



4. Our mooring fender selections are based on assumptions that vessels are berthed symmetrically around transverse mooring reaction points.

** If we want to accommodate the possibility of "off center loading for LHA and LHDs," the fenders need to be reselected ——> increase the loading to pile cap and piles.

5. Berthing load does not control (berthing load from Phase I was used to check).

Project: MHP PH II
Job No: A01047
Designer: KAP
File Name: O:\2001\A010- File Name:

SUMMARY: Loads on MHP

Controlling Configuration:

[For Primary Ships]
Trans Wind & Current: 2 SETS OF NESTED CG-47 ON EACH SIDE
Long Wind & Current: 2 SETS OF NESTED CG-47 ON EACH SIDE

[For Optional Ships]
Trans Wind & Current: ONE LHA1 ON EACH SIDE
Long Wind & Current: 2 SETS OF NESTED DD963 ON EACH SIDE

SUMMARY of MOORING LOADS DUE TO WIND AND CURRENT

			TOTAL LOAD ON MHP (1)				Max. Load/shaft (2)		
			Service Load		Ult Load = 1.3 (Service Load)		Ult Load = 1.3 (Service Load)		
			Transv W+C kips	Long W+C kips	Transv W+C kips	Long W+C kips	Transv W+C kips	Long W+C kips	NOTE:
Design Site	Type II	Primary Vessels	1029	184	1337	239	669	239	[2 Mooring System]
		Optional Vessels	1499	149	1948	194	487	194	[4 Mooring System]
	Type IV	MHP only	249	15	324	20	162	20	[2 Mooring System]
Optional Site	Type II	Primary Vessels	1587	278	2063	362	805	362	[4 Mooring System]
		Optional Vessels	2293	226	2981	294	1162	294	[4 Mooring System]
	Type IV	MHP only	1447	76	1881	99	470	99	[4 Mooring System]

FENDER SELECTIONS : (These are not the only options.)
See Defenitions on the next page

			TRANSV	LONG	TOTAL LOAD ON MHP Transv W+C kips	TOTAL LOAD ON MHP Long W+C kips	Max. Load/shaft Transv W+C kips	Max. Load/shaft Long W+C kips	
Design Site	Type II	Primary Vessels	No1, Opt B MV1450x2000 A	No1, OptA MV1450x1000B	1392	244	696	244	
		Optional Vessels	No1, Opt C MV1450x1500A	No1, OptA MV1450x1000B	2088	244	522	244	
	Type IV	MHP only	No1, Opt B MV1450x2000 A	No1, OptA MV1450x1000B	1392	244	696	244	
Optional Site	Type II	Primary Vessels	No1, Opt C MV1450x1500A	No1, OptA MV1450x1500B	2088	366	522	366	(3)
		Optional Vessels	No2, Opt C MV1450x1500B	No1, OptA MV1450x1500B	2928	366	732	366	(3)
	Type IV	MHP only	No1, Opt C MV1450x1500A	No1, OptA MV1450x1500B	2088	366	522	366	

Note:
1) Assuming that Vessels would be berthed sysmetrically or in the center
2) When the vessles are berted closer to one Mooring only (for LHD and LHA and LPD) - See Calculation for the assumption of location
3) If vessels are allowed to berth closer to one Mooring, it needs to be updated to accommodate the value from table above.

DEFENITIONS:

Mooring System:

		Option A	Option B	Option C
		1 Mooring kips	2 mooring kips	4 mooring kips
MOORING No 1	2- (2)Trellex MV units per shaft	2R	4R	8R
MOORING No 2	2 - (4) Trellex MV units per Shaft	4R	8R	16R

Notation:

Mooring No 1: 2-Trellex per side of guided shaft

Mooring No 2: For Trans, 4 Trellex per side (Stacking 2-Trellex vertically)
For Long, 2 Trellex per side

OPTION A: Total Loads for 1 Mooring

OPTION B: Total Laods for 2 Moorings

OPTION C: Total Loads for 4 Moorings

Fenders:

			Mooring No 1			Mooring No 2		
			Option A	Option B	Option C	Option A	Option B	Option C
TRELLEX	Type	R, Reaction (kips)	1 Mooring kips	2 mooring kips	4 mooring kips	1 Mooring kips	2 mooring kips	4 mooring kips
MV 1450 x 1000	B	122	244	488	976	488	976	1952
MV 1450 x 1000	A	174	348	696	1392	696	1392	2784
MV 1450 x 1500	B	183	366	732	1464	732	1464	2928
MV 1450 x 1500	A	261	522	1044	2088	1044	2088	4176
MV 1450 x 2000	B	244	488	976	1952	976	1952	3904
MV 1450 x 2000	A	348	696	1392	2784	1392	2784	5568

Note:
*: For Mooring No 2, Design of pile cap and piles have to be changed.
** : MV1450 was selected to accommodate EQ displacement for BREMERTON and SAN DIEGO.
*** : MV1450x2000 B is the longest fender we can use for MV1450

BERGER/ABAM ENGINEERS INC.

Project MHP PH II

Sheet ____ of ____

Job Number A01047

Subject MHP Mooring Design

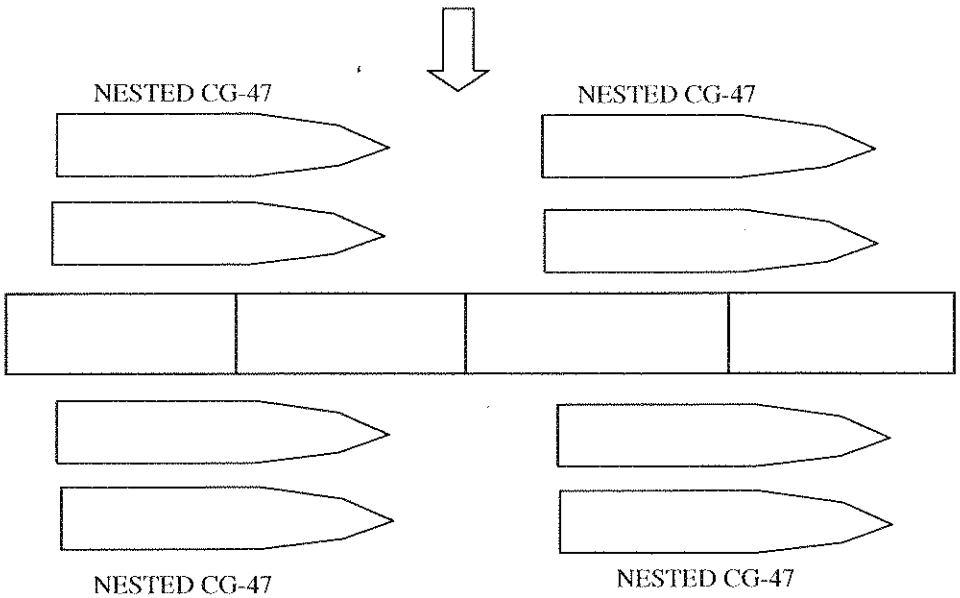
Designer KAP

Controlling "Wind and Current" Case

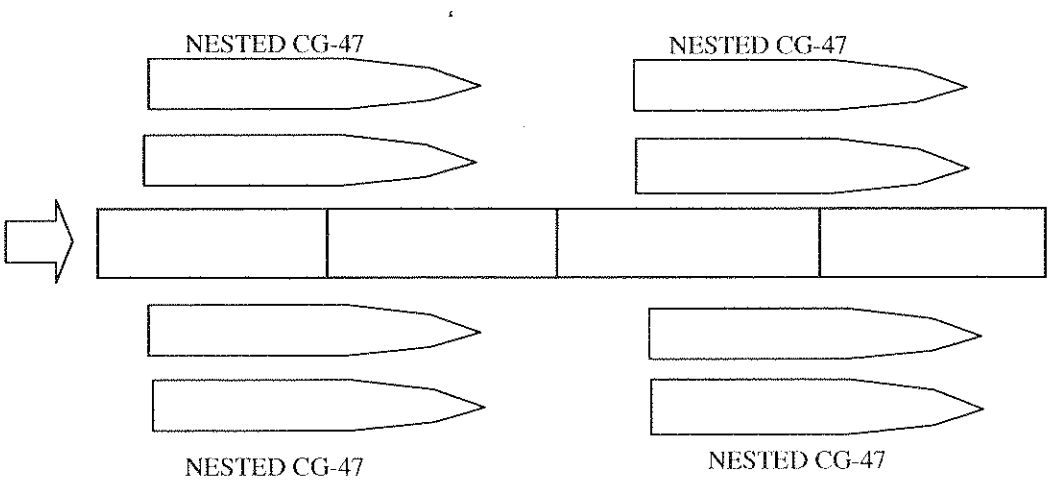
Date 5/2/01 updated

MOORING DESIGN FOR PRIMARY VESSELS

TRANSVERSE WIND AND CURRENT

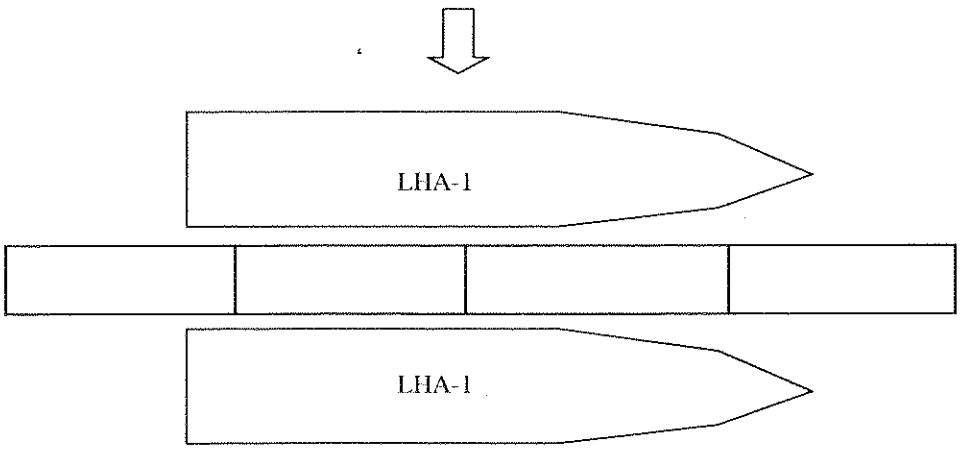


LONGITUDINAL WIND AND CURRENT



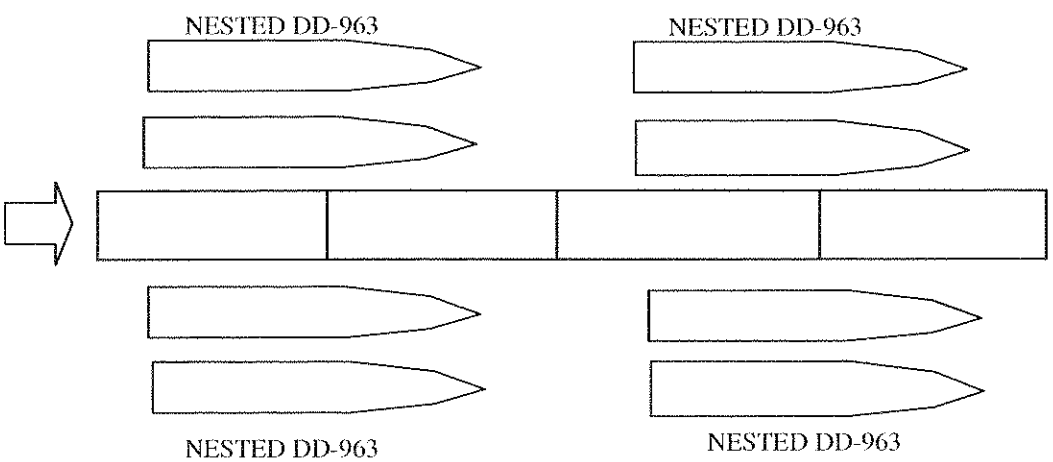
MOORING DESIGN FOR ALTERNATIVE VESSELS

TRANSVERSE WIND AND CURRENT



Note: When LHA-1 berthed off center, the loading on the mooring will be greater. However our assumption of the selection of fenders is symmetrical loading. If we want to accommodate the "off center loading" condition, the fenders need to be reselected to accommodate the additional load requirement.

LONGITUDINAL WIND AND CURRENT



Project: MHP PH II
Job No: A01047
Designer KAP
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[Design_notes.xls]OPTIONAL_LONG

TRANSVERSE Wind & Current

PRIMARY VESSELS

Wind and Current Distribution for Nested Condition:

	Wind 100% Current 85%		Wind 100% Current 85%
	W 0% C85%		Wind 0% Current 85%
PIER	Wind 20% Current 0%		
	W 60% C 42.5%		Wind 60% Current 42.5%
	W 0% C 42.5%		Wind 0% Current 42.5%

Note: 1) % shown is based on Single Vessel

Config 1

	FFG-7		FFG-7
	FFG-7		FFG-7
PIER			
	FFG-7		FFG-7
	FFG-7		FFG-7

Design Site:

	Fwy	Fcy	Factor W	Factor C
FFG 7	132.3	7.6	3.2	5.1
pier	229.8	19.4	0.2	0

Total = 508 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
FFG 7	201.3	0.6	3.2	5.1
pier	349.5	40.9	0.2	0

Total = 717 kips

Config 2

	DDG-51		DDG-51
	DDG-51		DDG-51
PIER			
	DDG-51		DDG-51
	DDG-51		DDG-51

Design Site:

	Fwy	Fcy	Factor W	Factor C
DDG 51	172.3	0.7	3.2	5.1
pier	229.8	19.4	0.2	0

Total = 601 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
DDG 51	262.2	30.6	3.2	5.1
pier	349.5	40.9	0.2	0

Total = 1065 kips

Config 3 CONTROLLING

	CG-47		CG-47
	CG-47		CG-47
PIER			
	CG-47		CG-47
	CG-47		CG-47

Design Site:

	Fwy	Fcy	Factor W	Factor C
CG 47	251.5	34.9	3.2	5.1
pier	229.8	19.4	0.2	0

Total = 1029 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
CG 47	382.6	57.4	3.2	5.1
pier	349.5	40.9	0.2	0

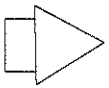
Total = 1587 kips

Project: MHP PH II
Job No: A01047
Designer KAP
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[Design_notes.xls]OPTIONAL_LONG

LONGITUDINAL WIND AND CURRENT

PRIMARY VESSELS

Wind and Current Distribution for Nested Condition:



	Wind 100% Current 85%		W 0% C85%
	W 100% C85%		W 0% C85%
PIER	Wind 100% Current 100%		
	W 100% C85%		W 0% C85%
	W 100% C85%		W 0% C85%

Note: 1) % shown is based on Single Vessel

Config 1

	FFG-7		FFG-7
	FFG-7		FFG-7
PIER			
	FFG-7		FFG-7
	FFG-7		FFG-7

Design Site:

	Fwy	Fcy	Factor W	Factor C
FFG 7	18.7	0.5	4	6.8
pier	14.5	0.5	1	1

Total = 93 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
FFG 7	28.5	0.6	4	6.8
pier	22.1	1.0	1	1

Total = 141 kips

Config 2

	DDG-51		DDG-51
	DDG-51		DDG-51
PIER			
	DDG-51		DDG-51
	DDG-51		DDG-51

Design Site:

	Fwy	Fcy	Factor W	Factor C
DDG 51	33.0	0.7	4	6.8
pier	14.5	0.5	1	1

Total = 152 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
DDG 51	50.3	0.6	4	6.8
pier	22.1	1.0	1	1

Total = 228 kips

Config 3 CONTROLLING

	CG-47		CG-47
	CG-47		CG-47
PIER			
	CG-47		CG-47
	CG-47		CG-47

Design Site:

	Fwy	Fcy	Factor W	Factor C
CG 47	41.1	0.6	4	6.8
pier	14.5	0.5	1	1

Total = 184 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
CG 47	62.5	0.8	4	6.8
pier	22.1	1.0	1	1

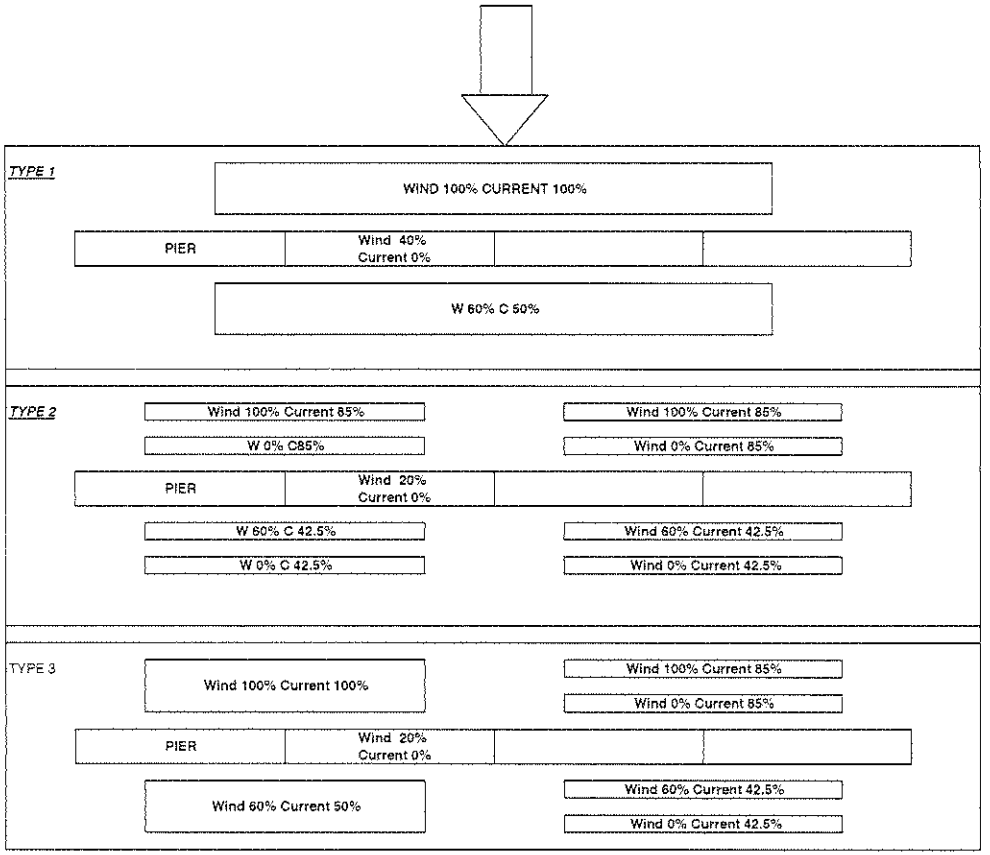
Total = 278 kips

Project: MHP PH II
Job No: A01047
Designer KAP
File: O:\2001\A01047\ENGR\Mooring Design\LOADS\[Design_notes.xls]PRIMARY_LONG

TRANSVERSE Wind & Current

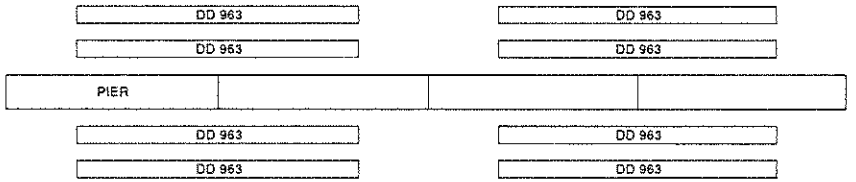
ALTERNATIVE VESSELS

Wind and Current Distribution for Nested Condition:



Note: 1) % shown is based on Single Vessel

Config 1



Design Site:

	Fwy	Fcy	Factor W	Factor C
DD 963	231.2	23.8	3.2	5.1
pier	229.8	19.4	0.2	0

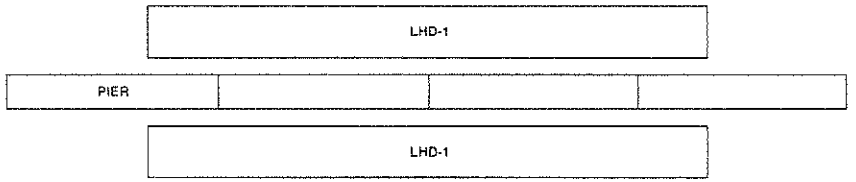
Total = 907 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
DD 963	351.7	0.9	3.2	5.1
pier	349.5	40.9	0.2	0

Total = 1200 kips

Config 2



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	685.4	34.9	1.6	1.5
pier	229.8	19.4	0.4	0

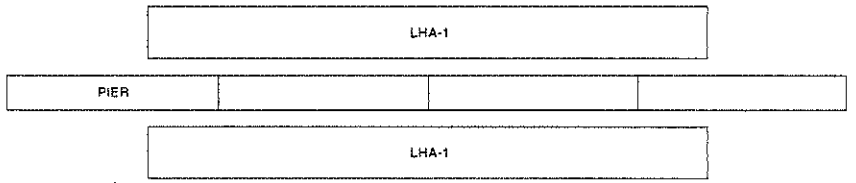
Total = 1241 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	1042.6	115.9	1.6	1.5
pier	349.5	40.9	0.4	0

Total = 1982 kips

Config 3 Controlling



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	820.4	62.6	1.6	1.5
pier	229.8	19.4	0.4	0

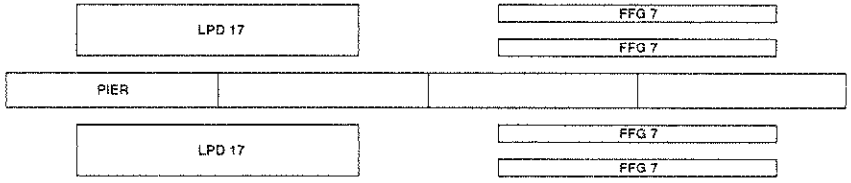
Total = 1499 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	1248.0	104.2	1.6	1.5
pier	349.5	40.9	0.4	0

Total = 2293 kips

Config 4



Design Site:

	Fwy	Fcy	Factor W	Factor C	
LPD 17	493.0	30.9	1.6	1.5	835.2
FFG 7	132.3	7.6	1.6	2.55	231.1
pier	229.8	19.4	0.2	0	

Total = 1112 kips

Dis Fact	Reaction	
0.75	646.6	R_a
0.54	465.6	R_b
	1112.2	

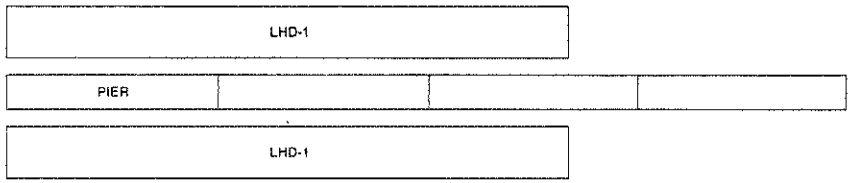
Optional Site:

	Fwy	Fcy	Factor W	Factor C
LPD 17	750.0	58.4	1.6	1.5
FFG 7	201.3	0.6	1.6	2.55
pier	349.5	40.9	0.2	0

Total = 1681 kips

Dis Fact	Reaction	
0.75	977.3	R_a
0.54	703.7	R_b
	1681.0	

Config 5



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	685.4	34.9	1.6	1.5
pier	229.8	19.4	0.4	0

Total = 1241 kips

Dis Fact	Reaction	
0.77	955.5	R_a
0.23	285.4	R_b
	1240.9	

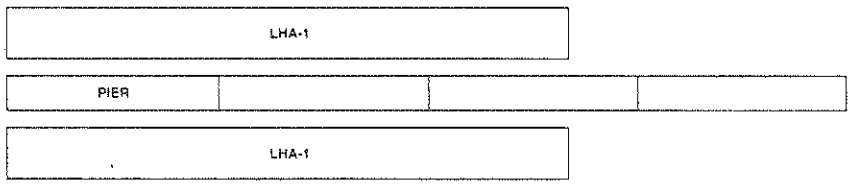
Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	1042.6	115.9	1.6	1.5
pier	349.5	40.9	0.4	0

Total = 1982 kips

Dis Fact	Reaction	
0.77	1526.6	R_a
0.23	455.8	R_b
	1981.8	

Config 6 Controlling



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	820.4	62.6	1.6	1.5
pier	229.8	19.4	0.4	0

Total = 1499 kips

Dis Fact	Reaction	
0.78	1168.8	R_a
0.22	329.7	R_b
	1498.5	

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	1248.0	104.2	1.6	1.5
pier	349.5	40.9	0.4	0

Total = 2293 kips

Dis Fact	Reaction	
0.78	1788.4	R_a
0.22	504.4	R_b
	2292.8	

Project: MHP PH II
Job No: A01047
Designer KAP
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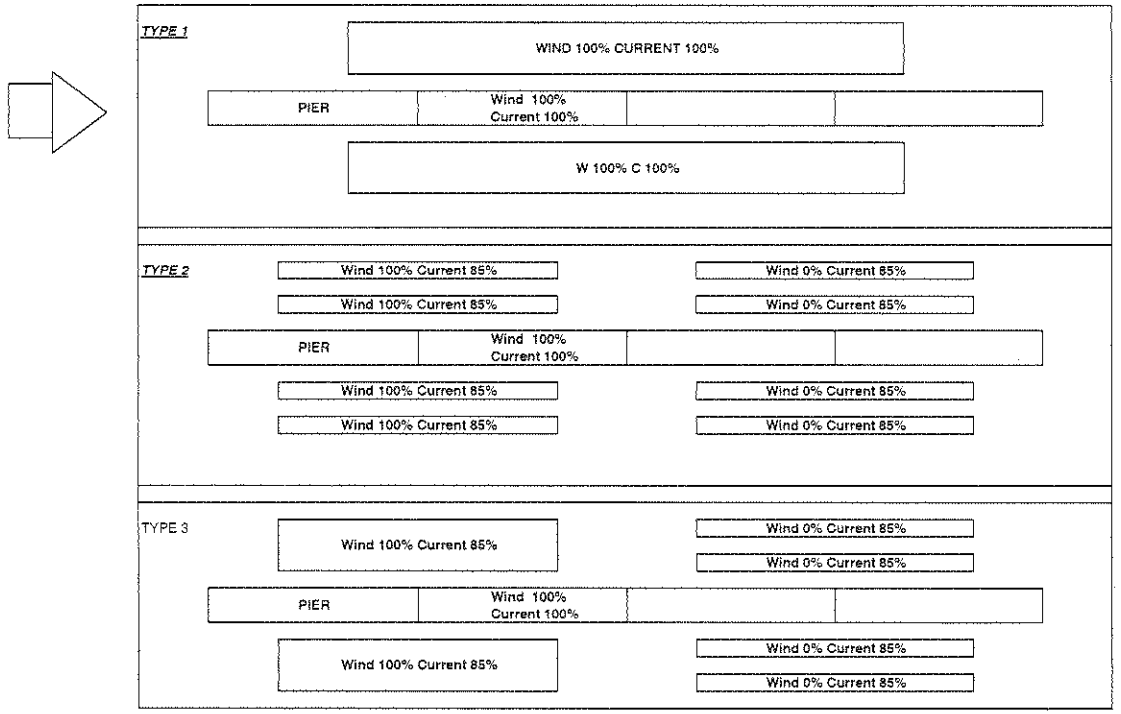
LONGITUDINAL Wind & Current

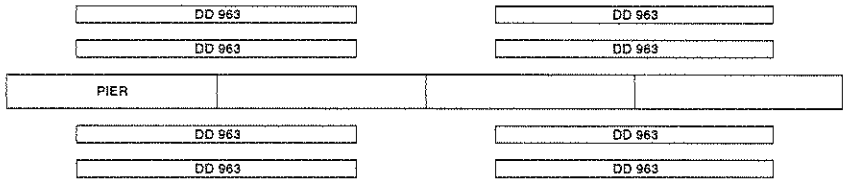
ALTERNATIVE VESSELS

Wind and Current Distribution for Nested Condition:



Note: 1) % shown is based on Single Vessel

Config 1 CONTROLLING



Design Site:

	Fwy	Fcy	Factor W	Factor C
DD 963	32.3	0.7	4	6.8
pier	14.5	0.5	1	1

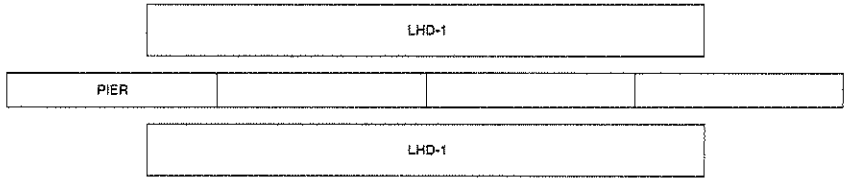
Total = 149 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
DD 963	49.1	0.9	4	6.8
pier	22.1	1.0	1	1

Total = 226 kips

Config 2



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	36.7	1.7	2	2
pier	14.5	0.5	1	1

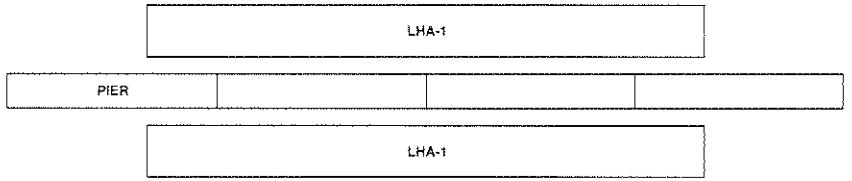
Total = 92 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHD 1	55.8	2.1	2	2
pier	22.1	1.0	1	1

Total = 139 kips

Config 3 Controlling



Design Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	42.2	1.6	2	2
pier	14.5	0.5	1	1

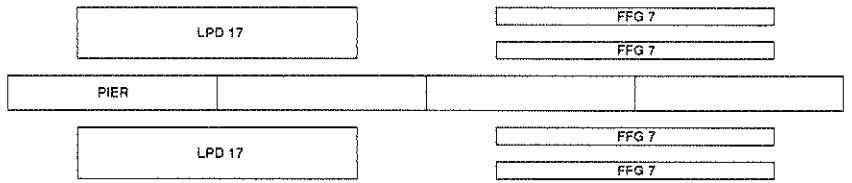
Total = 103 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LHA 1	64.2	2.1	2	2
pier	22.1	1.0	1	1

Total = 156 kips

Config 4



Design Site:

	Fwy	Fcy	Factor W	Factor C
LPD 17	40.5	1.4	2	1.7
FFG 7	18.7	0.5	0	3.4
pier	14.5	0.5	1	1

Total = 100 kips

Optional Site:

	Fwy	Fcy	Factor W	Factor C
LPD 17	51.6	1.8	2	1.7
FFG 7	28.5	0.6	0	3.4
pier	22.1	1.0	1	1

Total = 151 kips

MOORING EQ CHECK

MOORING LOAD AT SAN DIEGO – CHECKING EQ LOAD

Note: Fenders are selected due to wind and current. Now we'll check EQ.

Wind and Current Load at San Diego (Design Site)

(for primary vessels)

Type II	ULT wind + current $load_T$	=	1,337 kips	< $1{,}392^k$ ok
	ULT wind + current $load_L$	=	239 kips	< 244^k ok
Type IV (only MHP)	ULT wind + current $load_T$	=	324 kips	< $1{,}392^k$ ok
	ULT wind + current $load_L$	=	20 kips	< 244^k ok

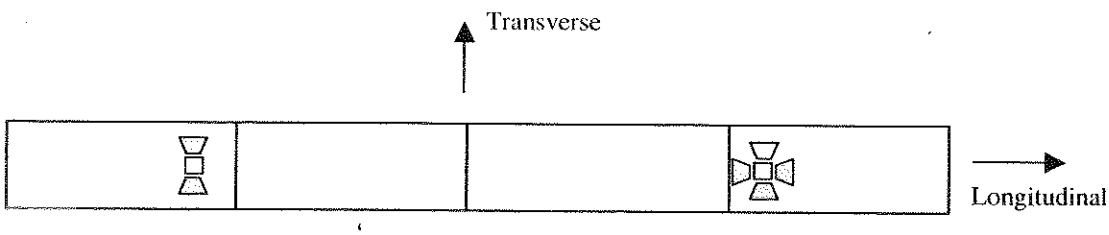
Fender Selected

Transv. 2 – (2) Trellex MV1450x2000A @ 348^k
on two moorings

Total R = $(348^k)(2)(2 \text{ moorings}) = 1{,}392^k$

Long 2 – (2) Trellex MV1450x1000B @ 122^k
on one mooring

Total R = $(122^k)(2) = 244^k$



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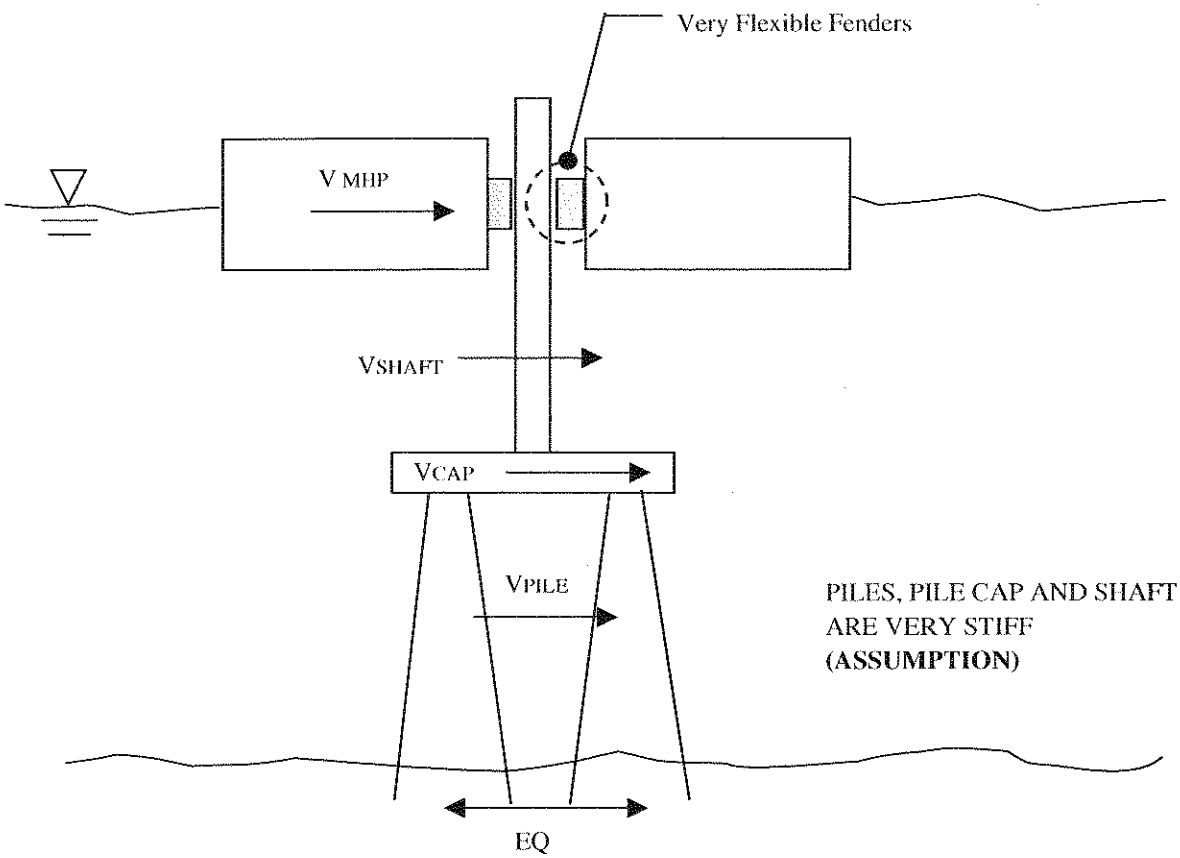
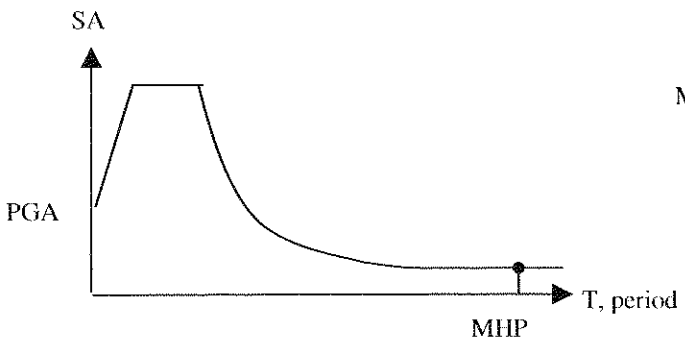
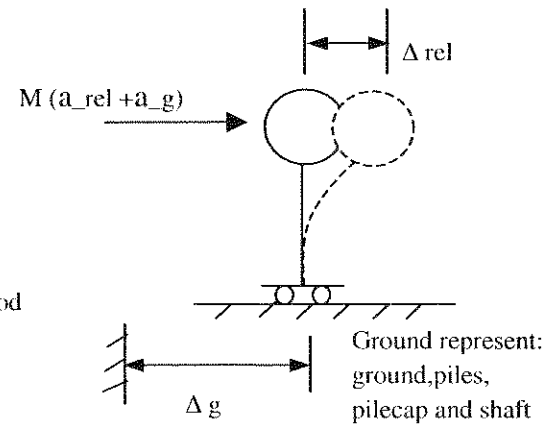
Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	EQ Concept	Date	5/3/01 updated



VMHP = SA MHP * W MHP : Very Small, because of the flexible fenders





V pile =
V cap = PGA*W pile
V shaft = cap
shaft

Assumption is that Piles, Cap, shat are very stiff that they will be moving with the ground.

$M (a_{rel} + a_g) + k \Delta rel = 0$

$M (a_{rel} + a_g) = -k \Delta rel$

$SA = k \Delta rel$

$SA = \omega^2 \Delta rel$

$\boxed{SA = \omega^2 SD}$

MOORING LOAD – EQ CONCEPT

In order to be an economical modular concept, we need to think how we can best accommodate the EQ load. The concusion was use very flexible springs (mooring fenders). This causes the period of structure to be large and will put the structure into the displacement base EQ rather than acceleration and velocity base EQ. This way we can minimize the EQ force that needs to be taken by the piles and pilecap. The idea is to make EQ force and wind and current force to be close.

However, the structure will have to be able to accommodate the displacement due to EQ. In other words, the fender that we choose needs to be able to reflect the appropriate EQ displacement.

EQ Calculation Outline

STEP 1 DETERMINE THE PERIOD

A) Mass Paticipation, M

Some of water will be added mass to the actual mass of pier. However it is difficult to determine exactly how much water mass would be added. Therefore, for this analylsils, Mass of Pier was used without any added mass. This should be give some what conservative value.

B) Determine Wt of oMHP Pier (W/ Light Draft = 10')

TRANSVERSE
For 2 Mooring System:

$$W = \frac{64 \text{ lb/cf}}{1000} (10') (88')(1300') (1/2) = \boxed{36{,}608} \text{ kips}$$

$$M = \frac{W}{g} \qquad g = 32.2 \text{ ft/sec}^2$$

$$M = 36{,}608 / 32.3 = \boxed{\mathbf{1{,}137}} \ \mathbf{k\ sec^2/ft}$$

For 4 Mooring System:

$$M = 1137 * 0.5 = \boxed{\mathbf{568}} \ \mathbf{k\ sec^2/ft}$$

LONG.
1 Mooring System:

$$M = 36608 * 2 / 32.3 = \boxed{\mathbf{2{,}274}} \ \mathbf{k\ sec^2/ft}$$

C) Calculate Stiffness of Fenders

Trellex MV1450: Δ 100 = 1450 mm x 0.575 = 834 mm = 33 in
Δ 50 = 1450 mm x 0.27 = 392 mm = 15.4 in

TRANSVERSE MV1450X2000 A R = 348 kips

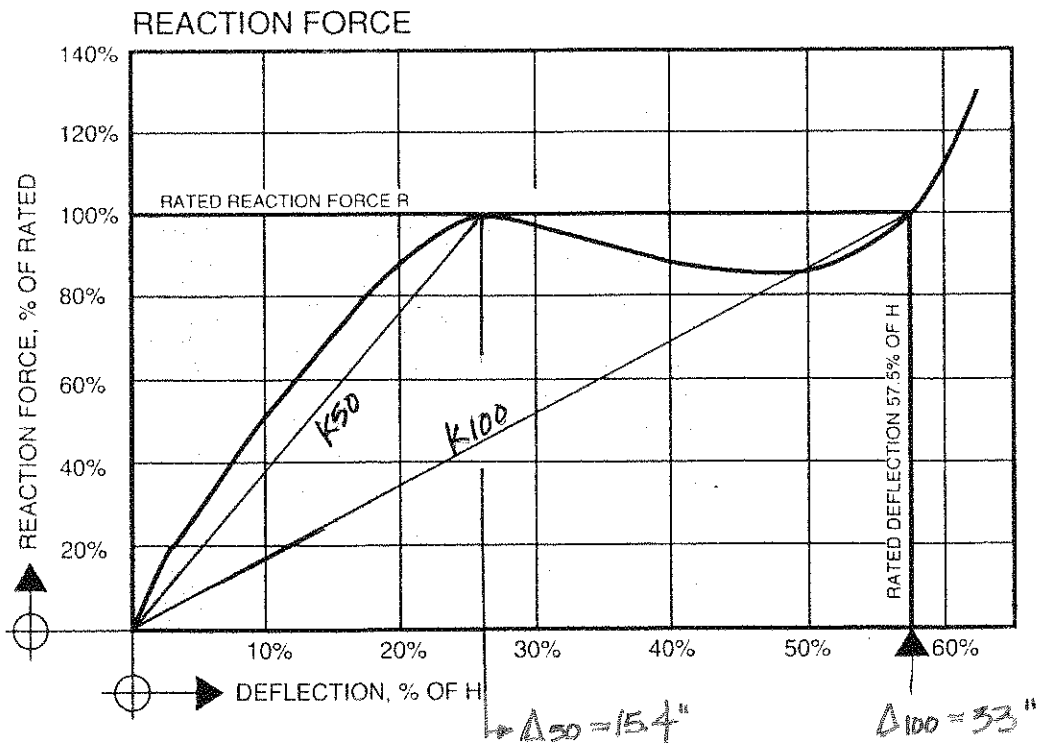
$$k\ 100 = \frac{F}{\Delta\ 100} = 348\ k / 33" = 10.33\ k/in \times 2\ sets = 21.1\ k/in = 253\ k/ft$$

$$k\ 50 = \frac{F}{\Delta\ 50} = 348\ k / 15.4" = 22.6\ k/in \times 2\ sets = 45.2\ k/in = 542\ k/ft$$

LONGITUDINAL MV1450X1000 B R = 122 kips

$$k\ 100 = \frac{F}{\Delta\ 100} = 122\ k / 33" = 3.7\ k/in \times 2\ sets = 7.4\ k/in = 89\ k/ft$$

$$k\ 50 = \frac{F}{\Delta\ 50} = 122\ k / 15.4" = 7.92\ k/in \times 2\ sets = 15.8\ k/in = 190\ k/ft$$



Detailed curves for all element sizes available on request.

D) Determine T

$$T = 2\pi\sqrt{\frac{M}{k}}$$

Transverse:

2 Mooring System:

$$T\ 100 = 2\pi\sqrt{\frac{1137}{253}} = 13.3 \text{ sec}$$

$$T\ 50 = 2\pi\sqrt{\frac{1137}{542}} = 9.1 \text{ sec}$$

4 Mooring System:

$$T\ 100 = 2\pi\sqrt{\frac{568}{253}} = 9.41 \text{ sec}$$

$$T\ 50 = 2\pi\sqrt{\frac{568}{542}} = 6.4 \text{ sec}$$ greater than 4 sec

Longitudinal:

1 Mooring System:

$$T\ 100 = 2\pi\sqrt{\frac{2274}{89}} = 32 \text{ sec}$$

$$T\ 50 = 2\pi\sqrt{\frac{2274}{190}} = 22 \text{ sec}$$

Per Lee Marsh, SD will be platau @ T = 4 sec.
Therefore Transverse and Longitudinal (1, 2, or 4 mooring systems), fender should deflect the same amount due to EQ.

$$SD = \frac{SA}{\omega^2}$$

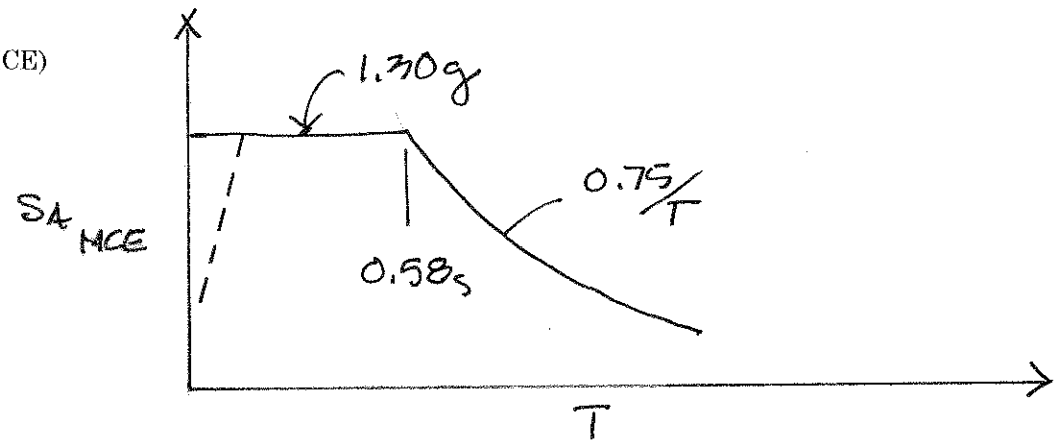
due to T = 4 sec

Location	MCE				500			
	Ss	Fa	Si	Fv	Ss	Fa	Si	Fv
Bremerton, WA	1.45 g	1.0	0.48	1.5	0.70g	1.24	0.23g	1.95
San Diego, CA (Coronado)	1.30g	1.0	0.50	1.5	0.70g	1.24	0.25g	1.90

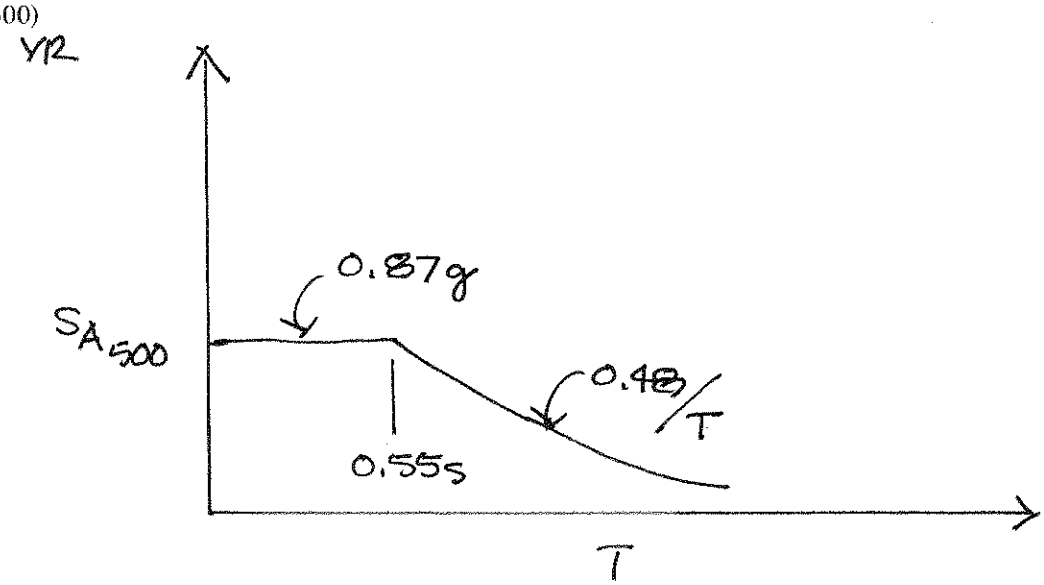
Assume Soil Type D

Use San Diego

(MCE)



(500)



STEP 2 DETERMINE SD (Spectral Displacement)

Per Lee Marsh (verbal, 12/14/00)

Spectral acceleration, SA = w^2 SD
Spectral displacement, SD = SA / w^2, plateauing at T = 4 sec

Use 500 yr Return EQ for design, 2500 yr to sensitivity of design to exceedance of criteria.

Per Lee Marsh (calcs 12/8/00), assume Coronado, soils Class D

For San Diego, $SA\ 500 = \frac{0.48}{T}$ and $SA\ 2500 = = \frac{0.75}{T}$

PWB calc's

FOR 500 YR EQ

$SA\ 500 = \frac{0.48}{T} = 0.12\ g \times 386\ in/sec^2 g = 46.4\ in/sec^2$

$w = 2\pi f = \frac{2\pi}{T} = 1.57\ rad/sec$ T = 4 sec

$SD\ 500 = \frac{SA\ 500}{w^2} = 18.8\ in$, constant for T >= 4 sec

FOR 2500 YR EQ

$SA\ 2500 = \frac{0.75}{T} = 0.188g \times 386\ in/sec^2 g = 18.8\ in/sec^2$

$w = 2\pi f = 2\pi = 1.57\ rad/sec$

$SD\ 2500 = \frac{SA\ 2500}{w^2} = 29.3\ in$, constant for T >= 4 sec

STEP 3: EQ REACTION TO FENDERS

Transverse and Longitudinal Δ eq500 = 20 in

Δ eq2500 = 30 in

What % deflection for MV1450?

SD 500 % Δ = (20in) / (1450 mm* 0.0394 in/mm) = 0.35 => 35 % ---> 95% R

SD 2500 % Δ = (30in) / (1450 mm* 0.0394 in/mm) = 0.525 => 53 % ---> 95% R

However, as you can see in the Trellex Fender curve, it has to go through 100% Reaction @ Δ = 15in.

Therefore we have to design the mooring for 100% of Fender Reaction.

T, R500&2500 = 348 kips x 2 = 696 kip/shaft
L, R500&2500 = 122 kips x 2 = 244 kip/shaft

STEP 4: Load Summary

Transverse: MV1450 x 2000 A (2 Mooring System)

Service Wind, T	515 k/shaft	Δ 17% = 10in
Ult. Wind, T	1.3*515k = 669k/shaft	Δ 25% = 15 in
Ult. EQ, T	696 kip/shsft	Δ eq500= 20 in
		Δ eq2500= 30 in

Longitudinal: MV 1450 x 1000 B (1 Mooring)

Service Wind, L	184 k/shaft	Δ 25% = 6.7 in
Ult. Wind, L	1.3*184 k = 239 k/shaft	Δ 25% = 10 in
Ult. EQ, L	244 kip/shaft	Δ eq500= 20in
		Δ eq2500= 30in

SHAFT DESIGN

Project: MHP PH 2
Designer: KAP
File: O:\2001\A01047\ENGR\Design Criteria\[shaftlength.xls]Sheet1
Date: 6/26/2001

Subject: Guided Shaft Length

Damaged Condition Draft = 17.25 feet
Light Draft = 11.25 feet
Loaded Draft = 14.25 feet

EL Service Deck 16.667 ft

ASSUMPTIONS:

A) Pile and Pile Cap is designed for MHHW (Use Design Arm Length).
The percentage of Maximum Wind event and EHW event coinciding is relatively low.
B) Shaft Length would not accommodate the special tide condition (such as storm surge and seismic seiche)
The special condition should be accommodated with the shaft extension.
C) Elevation is measured from MLLW.(MLLW = 0)

LOCATION	# ELW	* DAMAGED DRAFT (FT)	BOT MHP @ ELW Damaged	TOP of Pile cap Elevation (ft)	# EHW	16.667' - LIGHT DRAF (FT)	Service Deck @ EHW LIGHT	# MHHW	&& (note 1) MAX ARM L	&& (note 2) DEISGN ARM L	&& (note 3) SHAFT LENGTH
San Diego	-2.88	17.25	-20.13	-22.13	8.35	5.417	13.77	5.73	35.90	33.28	41.00
Bremerton	-4.80	17.25	-22.05	-24.05	15.40	5.417	20.82	11.74	44.87	41.21	50.00
Norfolk	-3.18	17.25	-20.43	-22.43	8.43	5.417	13.85	2.79	36.28	30.64	42.00
Mayport	-3.20	17.25	-20.45	-22.45	7.50	5.417	12.92	4.92	35.37	32.79	41.00

NOTE:

#	: Value is taken from tidalrange_REV.xls
*	: Damaged Draft - Conservative, since Damaged condition (3' extra draft - conservative) is added to loaded condition.
1	: Max Arm Length (ft) = Service Deck @ EHW LIGHT - BOT MHP @ ELW Damaged + 2' (CLR)
2	: Design Arm Length (ft) = Max Arm Length - (EHW - MHHW)
3	: Shaft Legnth (ft) = Max Arm Length + 5 feet
&&	: Seismic Seiche and Sotrm Surge are not included. (For these special conditions, Use shaft extension.)

BERGER/ABAM ENGINEERS INC.

Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	SHAFT DESIGN	Date	5/3/01 updated

SUMMARY LOAD TO SHAFT

	Mooring 2	Mooring 1	
Service Load			
W + C Transv	515 k	515 k	
W + C Long	0 k	184 k	
Ultimate Load			
1.3(W + C) T	669 k	669 k	
1.3(W + C) L	0 k	240 k	
			USE
EQ 500 T	696 k	696 k **	⇦
EQ 500 L	0 k	244 k **	
EQ 2500 T	696 k	696 k **	
EQ 2500 L	0 k	244 k **	

Note:

** Notice that wind load and EQ load are comparable
Fenders are selected based on the wind and current load. The EQ loads are based on the capacity of fenders. That is why EQ and Wind Loads are comparable.

BERGER/ABAM ENGINEERS INC.

Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	SHAFT DESIGN	Date	5/3/01 updated

SHAFT DEISGN @ SAN DIEGO (DESIGN SITE)

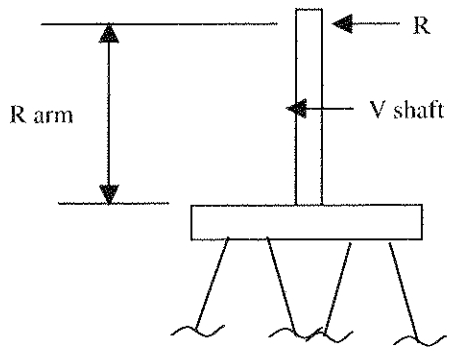
Assumption:

Top of Cap = EL -20 ft
Service Level = EL 12 ft

R arm = (12') - (-20') = 32'

Say R arm = 34 ft

V arm = Say 34' / 2 = **17 ft**



Recall Forces

R eq T = 696 kip./shaft
R eq L = 244 kip/shaft
V shaft = 15k (Base shear of shaft)

Determine Moment at Base

Mu,t = (696k)(34ft) + (15k)(17ft) = 23,919 k-ft
Mu,l = (244k)(34ft) + (15k)(17ft) = 8,551 k-ft

Therefore, Mu = **24,000.0 k-ft**

Per LRFD 3-5

$$Lp = \frac{300\ ry}{\sqrt{Fy}}$$

Let's use 7'-6" x 7'-6" x 1" shaft :

I = 470,039 in^4
A= 356 in^2
Z = 11,882 in^3

$$ry = \sqrt{\frac{I}{A}} = \sqrt{\frac{470039\ in^4}{356\ in\&2}} = 36\ in$$

$$Lp = \frac{(360)(36")}{\sqrt{50}} = 1527\ in = 127\ ft$$

Lb= 34 ft Lb< Lp ok

Mu = ϕ Mn = ϕ Zx Fy / 12

$$Zx\ ,\ req = \frac{(12)Mu}{Fy} = \frac{12(24{,}000\ k\text{-}ft)}{(0.9)\ (50)} = 6{,}400\ in^3 < Z = 11{,}882\ in^3\ ok$$

Even though 1" thick TS would work, we'll use 1.5" to allow some rusting.

LET'S USE 7'-6"x7'-6" x 1.5 " TS

PILE DESIGN

PILES AND PILE CAP DESIGN AT SAN DIEGO

Ref. AASHTO 16th Edition

(Design Procedure)

1. Pile Design

   A. Check soil bearing and uplift capacity will be adequate (service load)

   B. Check pile capacity (ULT load case)

2. Pilecap Design

   A. Cap capacity (ULT load)

(Load Combination)

Service — 125% stress increase

1.0 (1.0 DL + W)

Ultimate

1.3 (1.0 DL + 1.0 W)
1.3 (0.75 DL + 1.0W)
1.0 (DL + EQM) – per Div. 1A

PILE DESIGN AT SAN DIEGO

(Assumptions)

1. Soil bearing and uplift capacity

We don't have geotechnical information; therefore, we used a typical pile capacity with 18-inch octagonal pile (solid) ——> (tension 100T/compression 200T)

We prorate the soil capacity depending on the size of the pile

2. Use precast concrete pile

3. Pile group effect

With our pile arrangement, we do have pile group effect. However, since we don't have geotechnical information so far for this conceptual design stage, we are ignoring the effect.

However, we do need to account the group effect of pile for actual design.

4. FERRITTO Criteria

To comply with FERRITTO criteria, additional analysis will be done for the final design.

a. Service load – check R = 72 yr EQ
b. Vertical acceleration

For transverse and long combined mooring

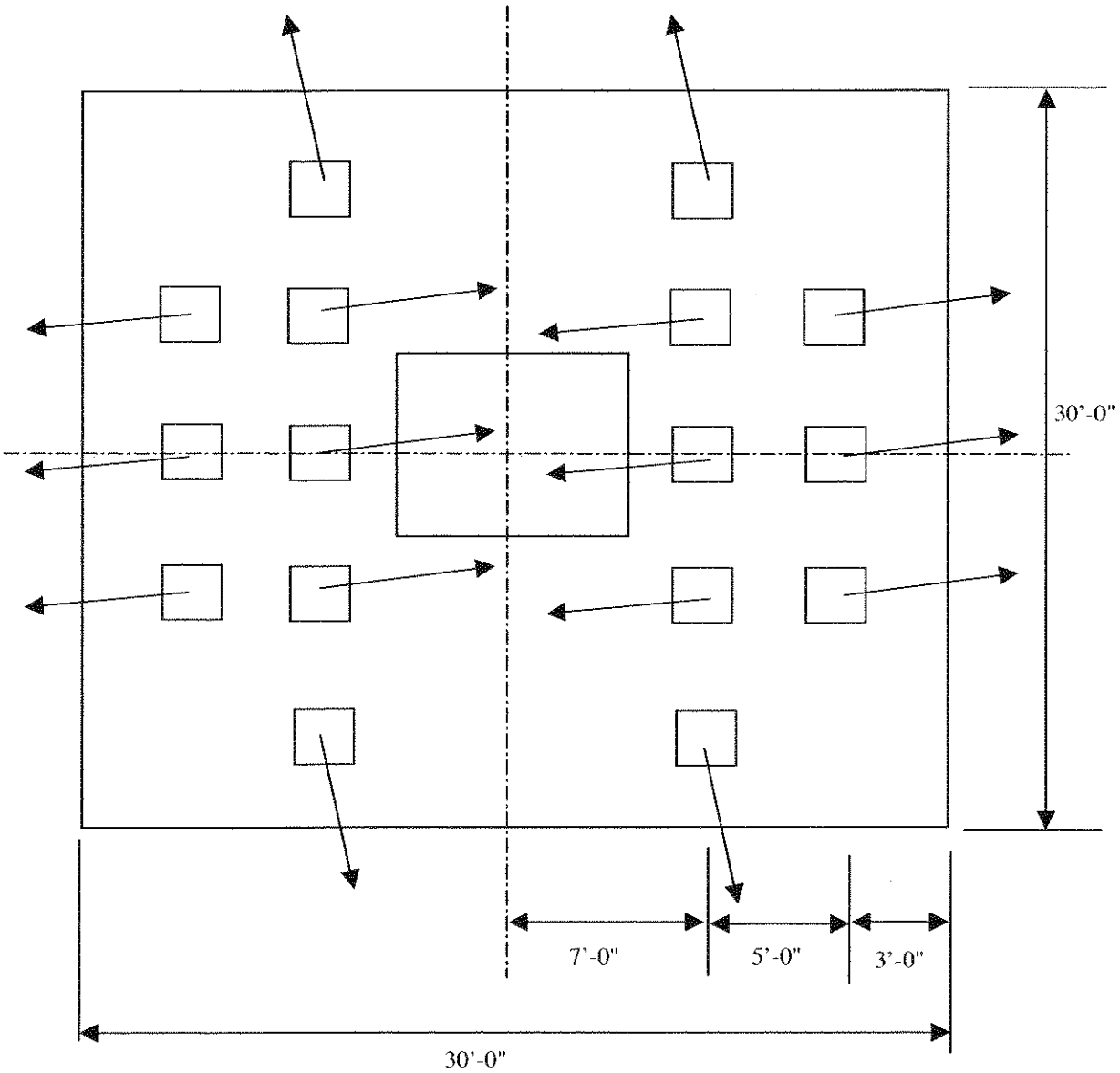
(Recall service load)

Type II	Transverse wind + current	=	$1{,}029^k/2$ moorings = 515^k/mooring
	Long wind + current	=	184^k/mooring
Type IV	Transverse wind + current	=	$249^k/2$ moorings = 125^k/mooring
	Long wind + current	=	15^k/mooring

BERGER/ABAM ENGINEERS INC.

Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	PILE ARRANGEMENT	Date	5/3/01 updated

PILE ARRANGMENT



(Not to Scale)

PILE CAP DEPTH = **USE 6'-6"**

Comment:
This arrangment is one of the pile arrangment that can be used.
When the arrangement was established, we were assuming that the shaft will be already installed prior to the pile driving.
V-arrangment of piles were chosen because of the constructability.

Since the shaft will be install later, the different pile arrangment may be more efficient. (Pile arrangement can be investigated more in the final design.)

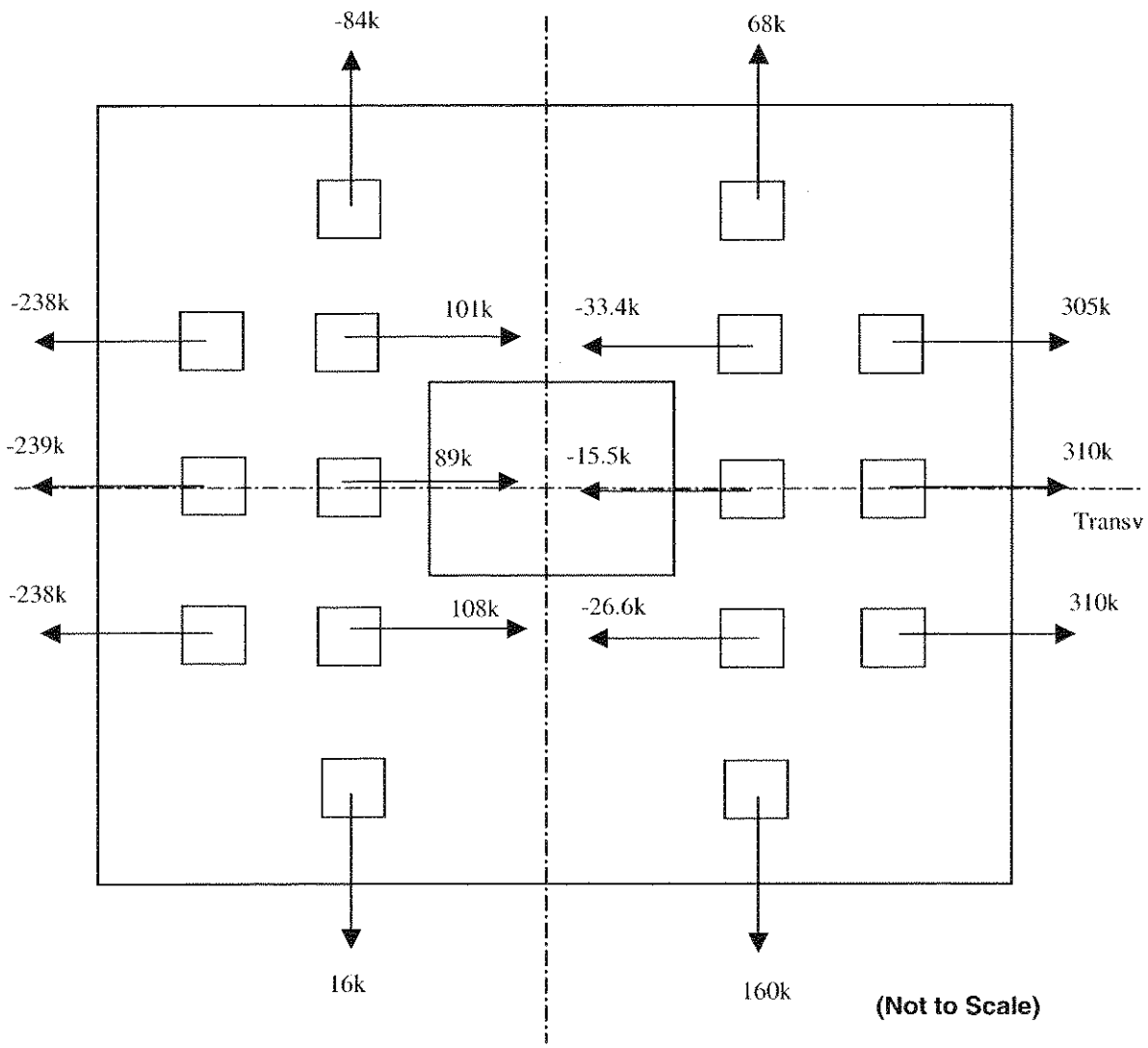
BERGER/ABAM ENGINEERS INC.

Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	PILE DESIGN - Result from RISA 3-D	Date	5/3/01 updated

SERVICE LOAD

24" Oct. PILES: 10ft above soil / 40ft embedded length (10-40)

DL+1.0 WT+0.3WL



(Not to Scale)

T allow =	**-266**	**kips**	ok
C allow =	**532**	**kips**	ok

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Project MHP PH II

Sheet ____ of ____

Job Number A01047

Subject MHP Mooring

Designer KAP

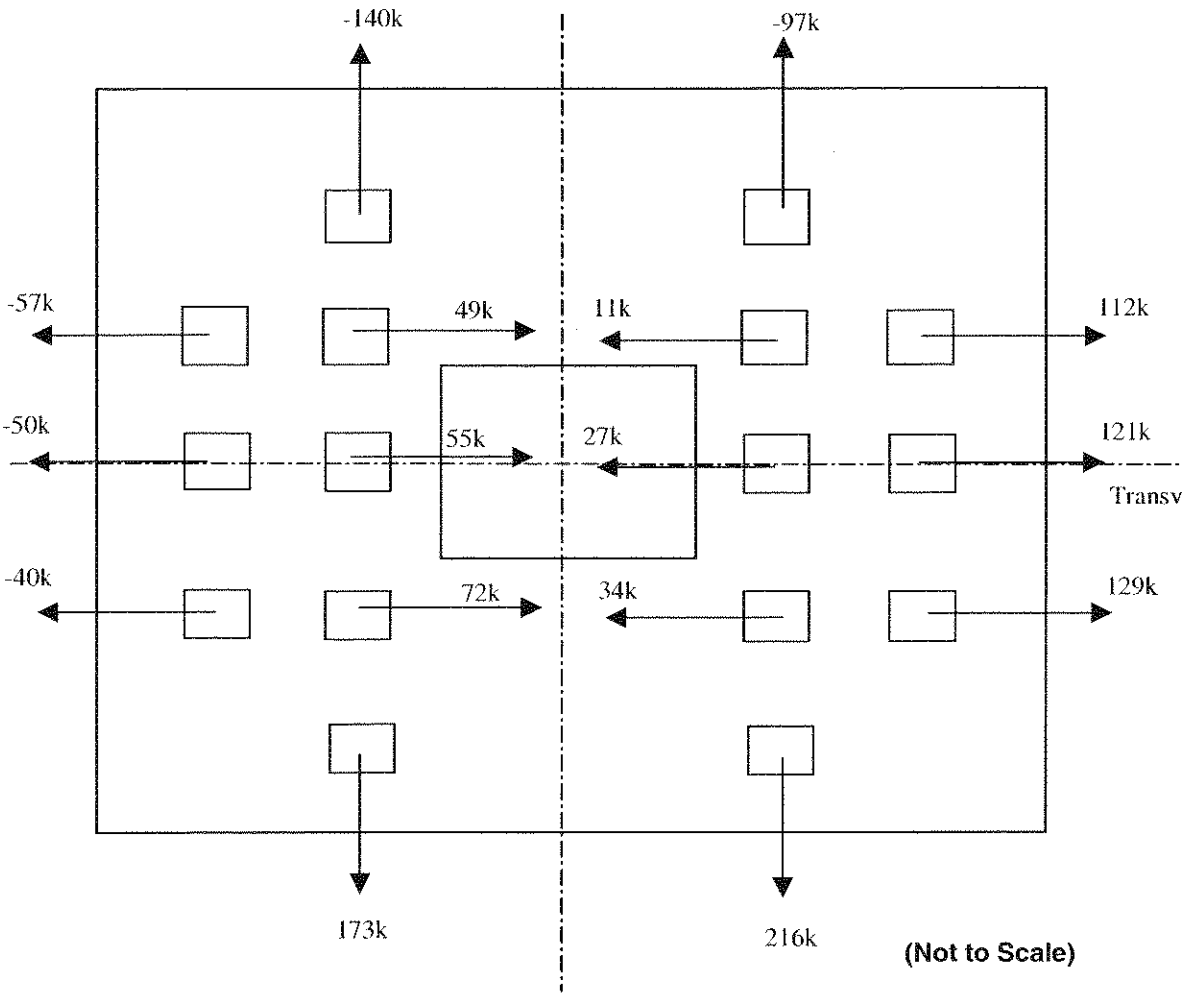
PILE DESIGN - Result from RISA 3-D

Date 5/3/01 updated

SERVICE LOAD

24" Oct. PILES: 10ft above soil / 40ft embedded length (10-40)

DL+0.3WT+1.0WL



(Not to Scale)

T allow =	**-266**	**kips**	ok
C allow =	**532**	**kips**	ok

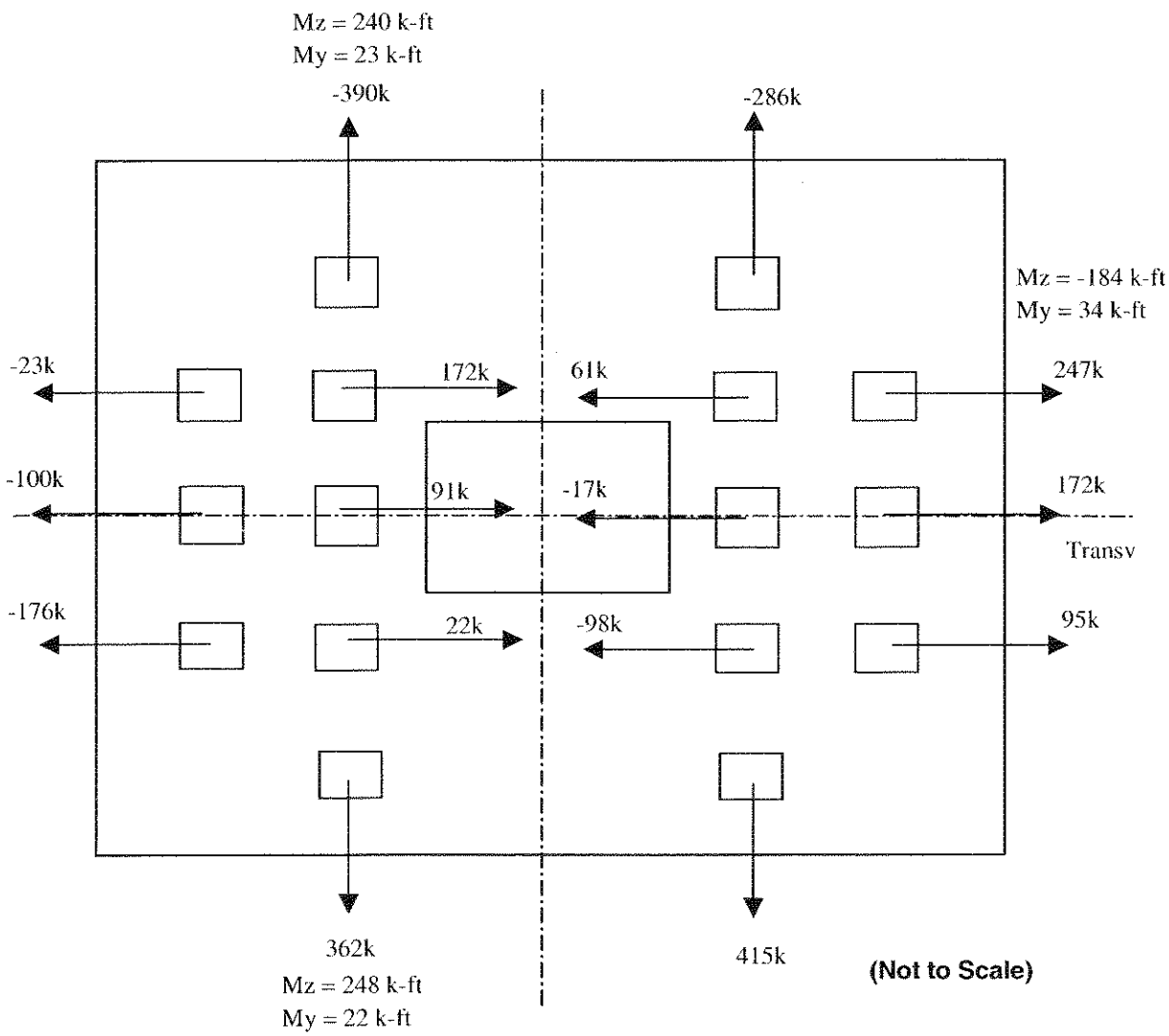
BERGER/ABAM ENGINEERS INC.

Project	MHP PH II	Sheet	of
		Job Number	A01047
Subject	MHP Mooring	Designer	KAP
	PILE DESIGN - Result from RISA 3-D	Date	5/3/01 updated

ULTIMATE LOADS

24" Oct. PILES: 10ft above soil / 40ft embedded length (10-40)

DL+0.3EQT+1.0EQL



24"OCT.- 22 Strands - Ref CTC Pile Capacity

T ult =	**-500**	**kip**	**@ M=240k-ft**	ok
C ult =	**1000**	**kips**	**@ M=250k-ft**	ok

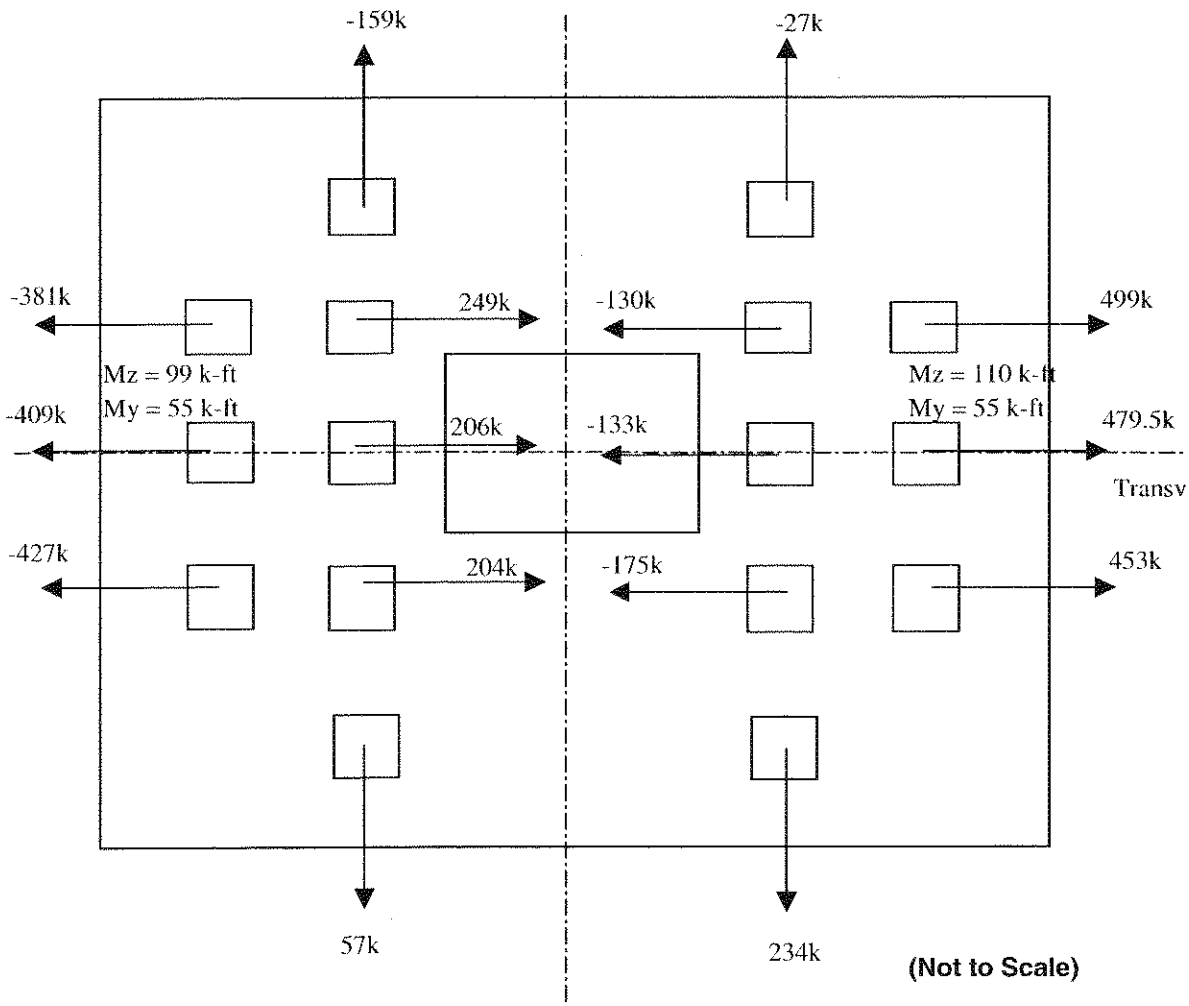
BERGER/ABAM ENGINEERS INC.

Project MHP PH II
Sheet ____ of ____
Job Number A01047
Subject MHP Mooring
Designer KAP
PILE DESIGN - Result from RISA 3-D
Date 5/3/01 updated

ULTIMATE LOADS

24" Oct. PILES: 10ft above soil / 40ft embedded length (10-40)

DL1.0EQT+0.3EQL



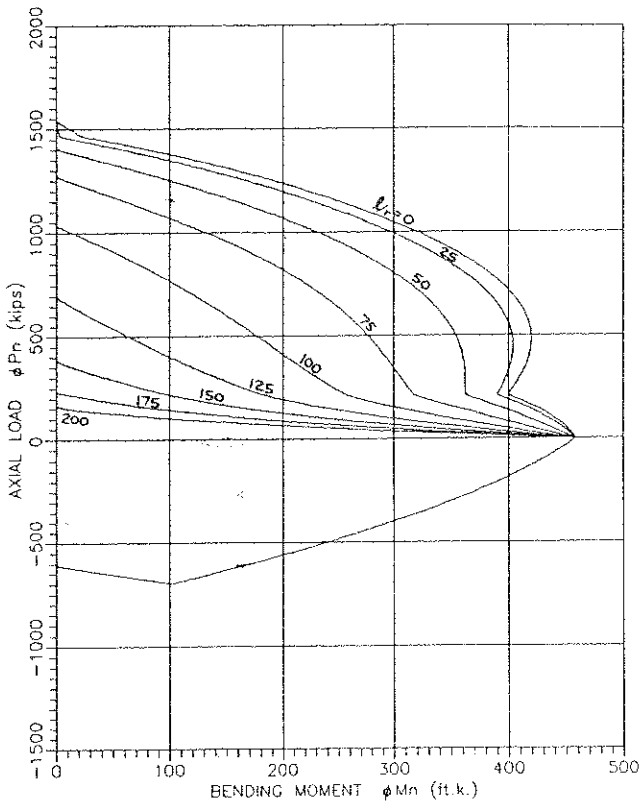
(Not to Scale)

24"OCT.- 22 Strands - Ref CTC Pile Capacity

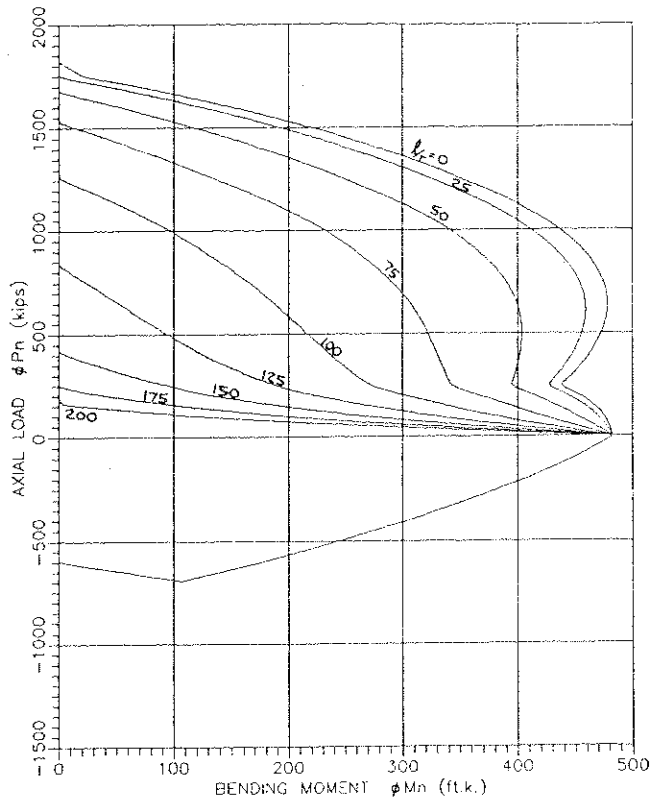
T ult =	**-650**	**kip**	**@ M=100k-ft**	ok
C ult =	**1200**	**kips**	**@ M=100k-ft**	ok

24" SOLID OCTAGONAL PILE, 22-STRANDS

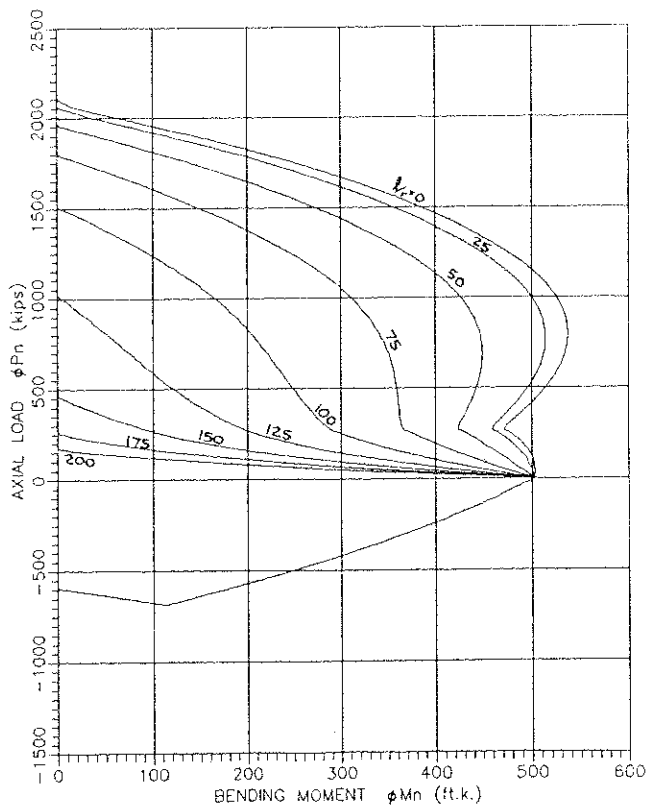
$f'_c = 6$ ksi



$f'_c = 7$ ksi



$f'_c = 8$ ksi



PILECAP DESIGN

Project: MHP PH II
Deisnger: KAP
Date: 5/4/2001
File: O:\2001\A01047\ENGR\Mooring Design\CAP\[DESIGN1.xls]CAPDIM

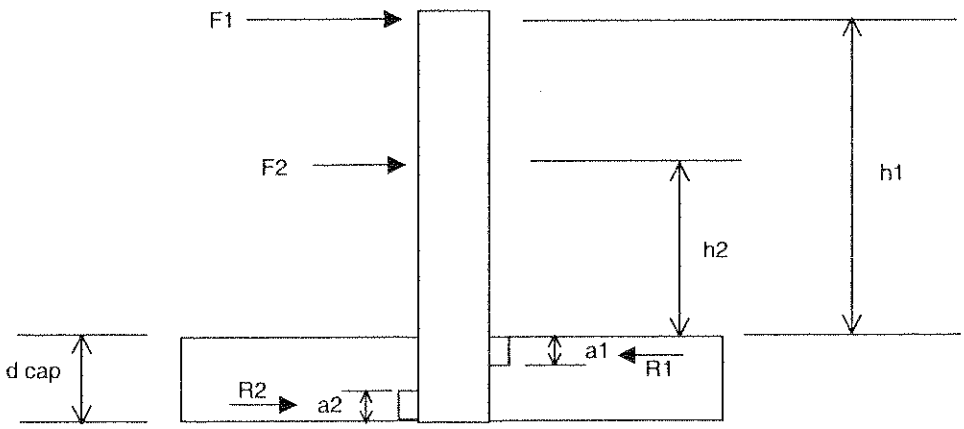
SUBJECT: PILE CAP DESIGN

INPUT:

F1 =	696	kips	: Loading 1 on the shaft
F2 =	15	kips	: Loading 2 on the shaft
h1 =	34	ft	: Point of Loading 1 from top of cap
h2 =	17	ft	: Point of Loading 2 from top of cap
d cap=	6.5	ft	: Depth of CAP
b =	90	in	: Width of Shaft
phi =	0.7		: Ref ACI 9.3.2.4 (Bearing on Concrete)
f'c =	4	ksi	: Conc. Compressive Strength
Assume:			
a1 =	33	in	: Assume depth of compression block at top of cap
a2 =	30	in	: Assume depth of compression block at bottom of cap

PILE CAP WT:

W =	30	ft
L =	30	ft
Conc dens=	0.15	kcf
WT =	877.5	kips



STEP 1: CALCULATE Moment Arm Between R1 and R2

d = d cap - (a1+a2)/ (2*12) = 3.875 ft

STEP 2: DETERMINE R1 and R2

Sum M @ R2 = 0

0 = F1 (h1+d cap - a2/(2*12)) + F2 (h2 + d cap - a2/(2*12)) - R1*d
R1 = (F1 (h1+d cap - a2/(2*12)) + F2 (h2 + d cap - a2/(2*12))/ d
R1 = 7135.9 kips

R 2 = R1- (F1+F2) = 6424.9 kips

STEP 3: DETERMINE a1 and a2

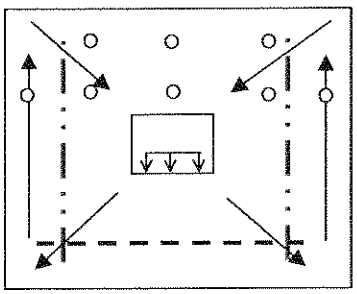
a = R / (phi * 0.85 * f'c * b)
a1 = 33.3 in
a2 = 30.0 in

Project: MHP PH II
Deisnger: KAP
Date: 5/4/2001
File: O:\2001\A01047\ENGR\Mooring Design\CAP\[DESIGN1.xls]CAPREINF

SUBJECT: PILE CAP REINFORCEMENT DESIGN

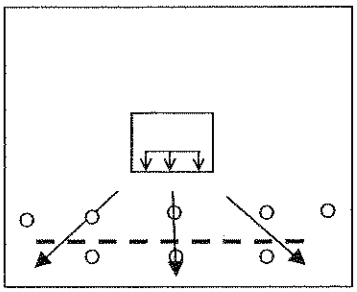
A condition

Force path to the back of piles



B Condition

Force Path to the front piles



Assumption:
Assume 1/2 of the force will taken by the back of piles and the other 1/2 of force will be taken by the front piles

[A condition]

INPUT:

phi =	0.9	ACI 9.3.2.2 Axial Tension
fy =	60	ksi

Recall: R1 = 7136 kips [Transverse Load]

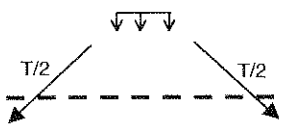
DETERMINE Reinforcement

T = phi * As * fy

RED REINF:

T = R1 / 2 =	3568	kips
As, req =	66	in^2 / both side
	33	in^2 / side

BLUE REINF:

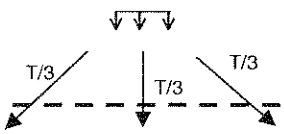


As, req = (T/2) / phi*fy = 33 in^2

[B condition]

DETERMINE Reinforcement

BLUE REINF:



As, reg = (T/3) / (phi*fy) = 22 in^2

Due to Transv. Lateral Load:

TOTAL RED As =	33	in^2 / SIDE
TOTAL BLUE As =	55	in^2 / SIDE

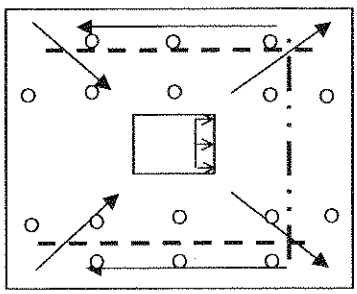
Due to Long. Lateral Load:

** Let's prorate the Reinfocement Amount by the Ratio of Transv Load and Long Load.

Transv EQ Load =	696 kips
Shaft EQ load =	15 kips
	711 kips

Ratio = 0.36

Long EQ Load =	244 kips
Shaft EQ load =	15 kips
	259 kips



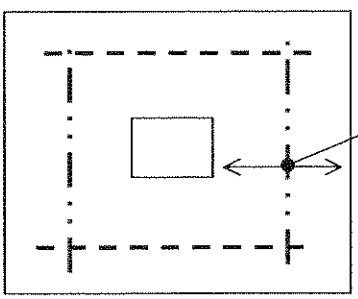
TOTAL RED As =	BLUE As (T) * Ratio =	20	in^2 / SIDE
TOTAL BLUE As =	RED As (T) * Ratio =	12	in^2 / SIDE

COMBINE THE REINFORCMENT FOR

1.0 EQT + 0.3 EQL	TOTAL RED =	39	in^2 / SIDE
	TOTAL BLUE =	59	in^2 / SIDE
0.3 EQT + 1.0 EQL	TOTAL RED =	20	in^2 / SIDE
	TOTAL BLUE =	29	in^2 / SIDE

REINFORCEMENT RQUIRED = 59 in^2 / SIDE

Equivalent of
59-#9 / side (spa 2.25")
47-#10 / side (spa 2.8")



2 Layers 24-#10 Top and Bot (5.4" spa)
(Each Side)