Deep Draft Submarine Camel/Fender Study

Prepared For:
Commander, Submarine Force U.S. Atlantic Fleet (COMSUBLANT)

Final Report

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Prepared By:
Anthony L. Farmer, P.E.
Daniel A. Musiker, E.I.T.

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Notice:

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EXECUTIVE SUMMARY

The Naval Facilities Engineering Command - Atlantic (NAVFAC - Atlantic) was tasked to study the feasibility of developing a deep draft camel suitable for use with all classes of submarines at all Navy installations. This camel would be considered “Universal.”

Sixteen Navy installations covering seven regions were surveyed by questionnaire and site visits to collect data about the deep draft camels and waterfront facilities used to berth submarines. This study discovered multiple differences between the installations surveyed, which include environmental conditions, waterfront facilities, submarines berthed, missions, and operations. These differences make each installation unique. It was also discovered there are numerous deep draft camels in the Navy’s inventory. The camels are constructed from various designs and materials. In all, seventeen types of camels were surveyed. The actual number of camel types is greater due to minor variations in construction and modifications to existing camels. The camels may be divided into seven general groups which include: Steel/Tube Frame, Barge, Fixed, Trident, Hydro-Pneumatic, Composite, and Miscellaneous. The performance, costs, and advantages and disadvantages were investigated to determine if an existing concept would meet the requirements for a Universal camel.

A review of the design and analysis criteria for camels and fender system was conducted along with preliminary berthing and mooring analyses. Key parameters influencing the design of camels include berthing and mooring loads, submarine geometry and characteristics, and pier fender systems. Parameters for the design of a Universal camel were also developed.

A Universal camel design would include all the requirements of all installations and submarines. Due to the wide range of differences between these

requirements, it is impractical to develop a single deep draft “Universal” camel for use by all classes of submarines at all Navy installations. However, a limited set of alternatives can be developed that meet the requirements of all classes of submarines while fulfilling a range of installation requirements, thus consolidating the number of camel types. The alternatives include using hydro-pneumatic fenders, barge type camels, fully composite camels, and steel/composite camels.

It is recommended to continue using the existing camels until it is no longer practical to maintain them. Once obsolete, or for new procurements, camels should be replaced by the most advantageous alternative. Hydro-Pneumatic fenders prove to be the most versatile and are recommended for most installations. Barge type camels are required at installations with high tidal ranges. The wider use of composite materials in fully composite camels or steel/composite camels shows promise at reducing lifecycle costs. These alternatives should be further developed and investigated. Further recommendations may be found in this report.

1.0 <u>INTRODUCTION</u>

1.1 *Purpose*

The Naval Facilities Engineering Command - Atlantic (NAVFAC - Atlantic), supported by the NAVFAC Engineering Innovation and Criteria Office (NAVFAC - EICO), was tasked to study to determine the feasibility of developing a deep draft camel suitable for use with all classes of submarines at all Navy installations.

1.2 *Definitions and Explanations*

A *camel* is a structure used to maintain standoff or separation between a ship and a waterfront facility. Camels are required when berthing and mooring submarines to prevent damage to the submarine hull, diving planes, screws, fairings, special skin treatments, and appurtenances. Submarines have most of their body below water, so typical camels used for surface ships do not have the draft to accommodate submarines. Thus, unique *deep draft camels* were developed to accommodate the low draft of submarines (Figure 1). Camels are considered part of a facility and fall under the jurisdiction of NAVFAC.

Some installations referred to camels as separators. Camels and separators are not the same. A separator is a structure used to provide standoff between nested ships while camels provide standoff between ships and waterfront facilities. However, some separators can be used as camels and vice versa. This study only addresses camels. Separators are considered ship entities and fall under jurisdiction of NAVSEA.

The term *fender* refers to elements designed to absorb energy from berthing or mooring as they deflect, deform, or compress. They are common components used on camels, however some fenders are large enough to be used as camels by themselves. A *fender system* is an energy absorption system installed on a pier, wharf, quay, or other waterfront facility and may consist of piles, fender elements, wales, and chocks.

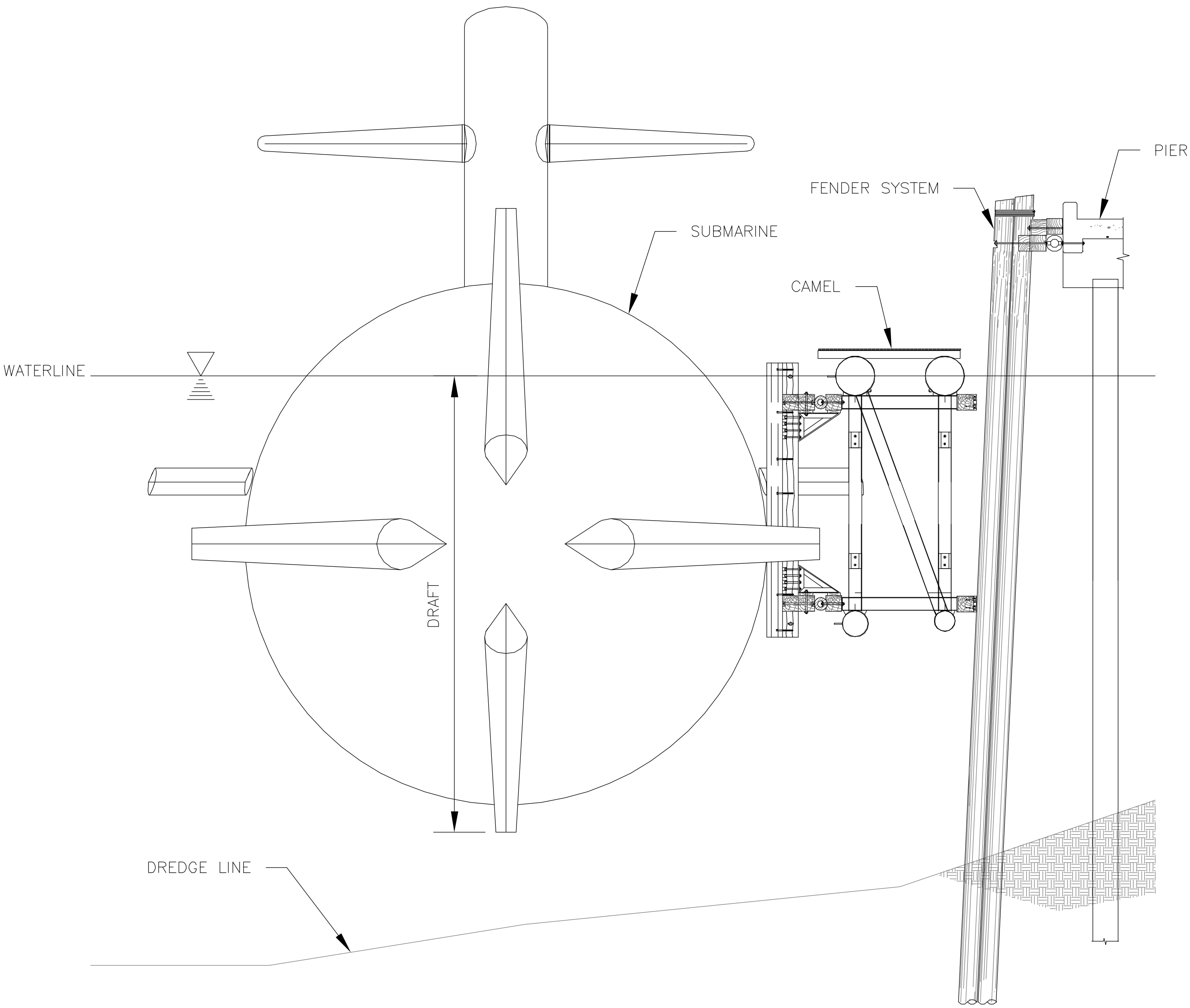


FIGURE 1 - TYPICAL DEEP DRAFT CAMEL CONFIGURATION

The term *waterfront facility* or generally *pier* means any pier, wharf, quay, or other waterfront structure used to berth vessels.

1.3 *Background*

The Navy has numerous camels of many different varieties in its inventory. Many camels were developed for use with specific classes of submarines the Navy has had over the years, while other camels were constructed from NAVFAC standard designs. Some Navy installations have developed their own types of camels to suit their specific needs. Private industry also developed its own versions of camels for use with submarines. All these factors have increased the number and types of camels in the inventory and very few have been removed from service.

The multitude of camels has lead to confusion and inefficiencies in their proper use. NAVFAC - EICO, who is responsible for waterfront related issues, has received numerous inquires about camels. From this, they realized there is very little standardization across the Navy with regard to camels and identified the need to survey the current camel inventory and determine the feasibility of developing a single type of camel that could be used for any class of submarine and at any Navy installation. This idea was presented to Commander, Submarine Force U.S. Atlantic Fleet (SUBLANT) who agreed to support the study.

A similar study was conducted in 1972 and is entitled, "*Investigative Report on Deep Draft Nuclear Submarine Mooring Camels*." This study determined submarine-to-pier clearance requirements, conducted installation surveys, developed design parameters for camels and fender systems, and lead to the design of the Trident Mooring Camel.

1.4 *Goal*

The goal of this study was to determine if one camel concept would emerge that is suitable for use with all classes of submarines at all Navy installations. This single concept would need to be:

- Inexpensive and easy to procure
- Efficient to operate and maintain
- Have favorable lifecycle costs
- Be suitable for use with any class of submarine
- Be adaptable to all Navy installations

By developing a single type of deep draft camel, several positive results would arise including:

- Achieve greater flexibility in berthing submarines by eliminating the need for submarine class specific camels
- Reduce the inventory of camels
- Allow support between Navy installations
- Provide tangible cost savings to the Navy by lowering lifecycle costs and improving operational efficiency

1.5 *Project Plan of Action*

The project plan of action included: gathering general information using a questionnaire, performing site visits, analyzing the data gathered, and summarizing the findings and recommendations in a report.

The questionnaire was developed to gather information on the types of camels, waterfront facilities and environmental data at each installation, the operations at the installations, and user recommendations. This information was used to compile a list of current camels in the Navy's inventory, to make comparisons between installations, and to help prepare for site visits.

Site visits were conducted to see the camels and facilities in operation, verify the data provided in the questionnaire was interpreted accurately, and to discuss the experiences with and advantages and disadvantages of various types of deep draft camels. Once the information gathering was complete, the data was analyzed and alternatives were developed. Finally, the findings of this study were then compiled and presented in this report.

2.0 INSTALLATION SURVEYS

Several Navy installations were surveyed, by questionnaire and site visit, to collect data about the deep draft camels and waterfront facilities used to berth submarines. The surveys included homeports, some visiting ports, and repair ports for submarines. Port operations personnel, Public Works personnel, NAVFAC personnel, and others provided input into the surveys. Questionnaires were sent to most installations listed in Table 1, but site visits were not conducted at every site. Reports summarizing each site visit were prepared and may be found in Appendix A. General information about the Navy installations surveyed is included in Table 1.

All the installations surveyed have deep draft camels and/or fenders and waterfront facilities available to berth submarines. Sometimes camels are loaned to installations that do not regularly berth submarines when a submarine is anticipated to make a port call. Camels are also borrowed from other installations when a requirement cannot be met by the camels the installation currently has.

2.1 *Installation Survey Discussion*

The main conclusion drawn from the results of the surveys is that every installation appears to be doing something different with regard to usage and operations of camels and submarine berthing facilities. This conclusion was not surprising because it was expected and the reason for this study. What is interesting to note is the reasons for the differences between installations. The key reasons are differing environmental conditions, pier and fender system designs, submarines berthed, missions and operations, and other factors.

2.1.1 Environmental Differences

The most notable difference between the Navy installations surveyed is their local environmental conditions and physical location.

Table 1 – NAVY INSTALLATION CHARACTERISTICS

Navy Installation	Location	Camels	Submarines Berthed	No. of Submarine Piers/Wharfs	Type of Pier	Tide (ft), avg	Wind Speed (mph)	Current (knots)
Mid-Atlantic						MHW-MLLW		
Naval Station Norfolk	Norfolk, VA	688 Standard Deep Draft Camel (tapered), Trident Modified 688 Camel	Los Angeles Class-h, Seawolf Class-v, Ohio Class-v, foreign submarines	1-dedicated 3-temporary	Concrete pile supported piers	3	110	2.3
Norfolk Naval Shipyard	Portsmouth, VA	688 Standard Deep Draft Camel (tapered), 688 Standard Deep Draft Camel (non-tapered), 35ft Trident Camel	Los Angeles Class-v, Seawolf Class-v, Ohio Class-v	4-temporay	Closed concrete pier	3	105	0.1
Southeast								
Naval Submarine Base Kings Bay	Kings Bay, GA	688 Standard Deep Draft Camel (tapered), Spudmoor/Spudlock Camel, Trident Mooring Camel	Ohio Class-h, Los Angeles Class-v_r, foreign submarines	1-dedicated 3-temporary	Concrete pile supported piers	7	125	1.4
Naval Ordnance Testing Unit (NOTU)	Port Canaveral, FL	688 Standard Deep Draft Camel (tapered), Trident Deep Draft Camel, Hydro-pneumatic Fender (3.3m x 10.6m)	Ohio Class-v, Los Angeles Class-v_r, foreign submarines	2- dedicated	Concrete pile supported piers	4	130	0.3
Naval Station Mayport	Jacksonville, FL	688 Standard Deep Draft Camel (tapered), Hydro-pneumatic Fender (4.5m x 9.0m)	Los Angeles Class-v_r	2-temporary	Concrete wharfs	5	125	8.4
Northeast								
Naval Submarine Base New London	Groton, CT	688 Standard Deep Draft Camel (tapered), Seawolf Camel, Trident Mooring Camel, Composite Camel	Los Angeles Class-h, Seawolf Class-h	8-dedicated	Concrete pile supported piers	3	120	2.0
Portsmouth Naval Shipyard	Kittery, ME	688 Standard Deep Draft Camel (tapered), 24 Foot Deep Draft Camel, 32 Foot Deep Draft Camel, Float Camel	Los Angeles Class-h/v	3-dedicated	Concrete pile supported pier, Concrete wharfs	9	100	6.8

h-homeport, v-visiting, v_r-visiting rarely, d-dedicated submarine pier/wharf, t-temporary submarine pier/wharf

Table 1 – NAVY INSTALLATION CHARACTERISTICS – Continued

Navy Installation	Location	Camels	Submarines Berthed	No. of Submarine Piers/Wharfs	Type of Pier	Tide (ft), avg	Wind Speed (mph)	Current (knots)
Northwest						MHW-MLLW		
Naval Station Bremerton/Puget Sound Naval Shipyard	Bremerton, WA *(now Naval Base Kitsap - Bremerton)*	Trident Deep Draft Barge Camel	Los Angeles Class-h/v, Ohio Class-h/v	8-temporary	Concrete pile supported piers	11	85	0.1
Naval Submarine Base Bangor	Bangor, WA *(now Naval Base Kitsap - Bangor)*	688 Standard Deep Draft Camel (tapered), Trident Deep Draft Barge Camel, Modified Trident Barge Camel, Trident Mooring Camel, Captured Camel, Hydro-pneumatic Fender (3.3m x 10.6m), USS Parche Camel, EHW Camel	Ohio Class-h, Los Angeles Class-v_r,	2-dedicated 3-temporary	Concrete pile supported piers	11	85	3.2
Southwest								
Naval Base Point Loma	San Diego, CA	Hydro-pneumatic Fender (3.3m x 10.6m)	Los Angeles Class-h, Ohio Class-v	2-dedicated	Concrete pile supported piers	6	85	14.2
Pacific								
Naval Station Pearl Harbor	Pearl Harbor, HI	688 Standard Deep Draft Camel (tapered), Hydro-pneumatic Fender (3.3m x 10.6m), Hydro-pneumatic Fender (4.5m x 9.0m)	Los Angeles Class-h, Ohio Class-v_r	13-dedicated 4-temporary	Concrete pile supported pier, Concrete wharfs	2	105	0.0
Naval Station Guam	Marians Islands	688 Standard Deep Draft Camel (tapered), Hydro-pneumatic Fender (3.3m x 10.6m)	Los Angeles Class-h	2-dedicated 2-temporary	Concrete wharfs	6	155	0.3
White Beach *(not surveyed)*	Okinawa, Japan	Hydro-pneumatic Fender	Los Angeles Class-v	no data	Concrete pile supported pier	no data	no data	no data
Naval Support Facility Diego Garcia *(not surveyed)*	British Indian Ocean Territory	Hydro-pneumatic Fender	Los Angeles Class-v, Ohio Class-v	2-temporary	Steel sheet pile wharf	no data	no data	no data

h-homeport, v-visiting, v_r-visiting rarely, d-dedicated submarine pier/wharf, t-temporary submarine pier/wharf

Table 1 – NAVY INSTALLATION CHARACTERISTICS - Continued

Navy Installation	Location	Camels	Submarines Berthed	No. of Submarine Piers/Wharfs	Type of Pier	Tide (ft), avg MHW-MLLW	Wind Speed (mph)	Current (knots)
Europe								
Naval Station Rota	Rota, Spain	688 Standard Deep Draft Camel (tapered)	Los Angeles Class-v, Ohio Class-v_r	1-temporary	Concrete wharfs	12	85	4.3
Naval Support Activity Souda Bay	Souda Bay, Crete, Greece	688 Standard Deep Draft Camel (tapered)	Los Angeles Class-v, Ohio Class-v	1-temporary	Concrete wharfs	1	80	no data
Naval Support Activity La Maddelena	La Maddelena, Sardinia, Italy	Hydro-pneumatic Fender (3.3m x 10.6m), Standard Separators	Los Angeles Class-v	Berth submarines against sub tender	AS 39	1	85	no data

h-homeport, v-visiting, v_r-visiting rarely, d-dedicated submarine pier/wharf, t-temporary submarine pier/wharf

Conditions such as wind, tide, current, dredge depth, geology, ship traffic, and harbor orientation influence the berthing and mooring loads of ships, and thus, the design and behavior of camels, fender systems, and waterfront facilities. Environmental data for each installation can be found in Table 1.

Maximum wind speeds vary from 85 mph to 155 mph at the installations surveyed. Mooring loads and sometimes berthing loads are influenced by wind pushing on the wind area of a submarine. Submarines are typically not berthed or moored during high or extreme winds. However, it is possible especially if a submarine is in a shipyard undergoing repairs and not able to get underway. For this reason, camels and waterfront facilities are designed for maximum wind conditions.

The tides at the Navy installations surveyed ranged from approximately one foot to 15 feet, however tides can be much higher during extreme conditions or storms. Tides influence camel geometry. Some installations with large tidal ranges use spud pile and barge type camels. Submarines are moored to Spud pile/Fixed camels, which are connected to spud piles allowing the two to ride the tide together, thus reducing line tending efforts. Barge camels are used to serve as platforms for double brow systems that are necessary for large tidal ranges.

Currents vary from near zero to over 3 knots at the installations surveyed. The current influences loading and design because a submarine or camel may be pushed into or pulled away from a waterfront facility.

The dredge depth of the installations surveyed varied from 35 feet to 50 feet and the topography of the dredge bottom varies. The dredge depth must be sufficient to accommodate the draft of submarines. The fender system and waterfront facility must be designed to fit the required depth. Because submarines have most of their body below water, camels and fender systems must also extend well below the waterline to accommodate submarines and provide adequate standoff from submerged obstructions and dredge topography.

The exposure of waterfront facilities influences the behavior and design of camels, fender systems, and waterfront facilities. In exposed areas where waves are frequently high, smaller camels tend to bounce around in relation to the more massive submarine they are used against. This action can cause damage to the camels, fender system, or submarine. Nearby ship traffic can cause a similar effect.

2.1.2 Pier and Fender System Differences

Major differences between the installations' waterfront facilities exist because there is no standard pier or fender system used throughout the Navy. Individual facilities are typically designed for function and site. Other factors influencing facility design include: facility use, design philosophy, facility age, local geologic conditions, and local availability of materials.

The waterfront facilities at the installations surveyed have been designed for various classes of ships. Every facility currently berthing submarines was not necessarily originally designed for submarine berthing. Facilities may have been designed for a single class of ship, several classes of ships, or general berthing in both single and nested configurations. Some facilities were designed for a specific class of submarine, but may not be able to accommodate other classes of submarines. For example, a pier designed for a Los Angeles class submarine may not be long enough or have a slip depth to accommodate an Ohio class submarine. Also, ship classes are replaced more frequently than piers. Therefore, some piers may have been designed for a class of ship that is no longer in service.

Waterfront facility construction and materials vary between and within the installations surveyed. Open and closed piers, open and closed wharfs, and quays were all noted. Various materials including concrete, steel, timber, and composite materials were used in the construction of the waterfront facilities and fender systems. A concrete pile supported pier/wharf with a concrete deck was the most typical type of waterfront facility construction noted.

Fender systems undergo repair and are replaced more often than piers due to their somewhat sacrificial nature. Fender systems are the first line of protection for a pier and are in direct contact with ships and camels, which tend to wear them. They may be constructed of concrete, steel, timber, or composite materials. The design and selection of materials is based upon the loads transmitted from ships, the dredge depth, local geologic features, and the local marine environment. Timber fender systems were the most common fender system noted (Figure 2). This is most likely due to the relatively low cost of materials, availability, ease of construction, and is a traditional carryover from older pier designs. Newer fender systems are tending toward concrete and composite materials because of lower lifecycle costs, increased durability, and environmental concerns.

Figure 2 – Timber Fender System

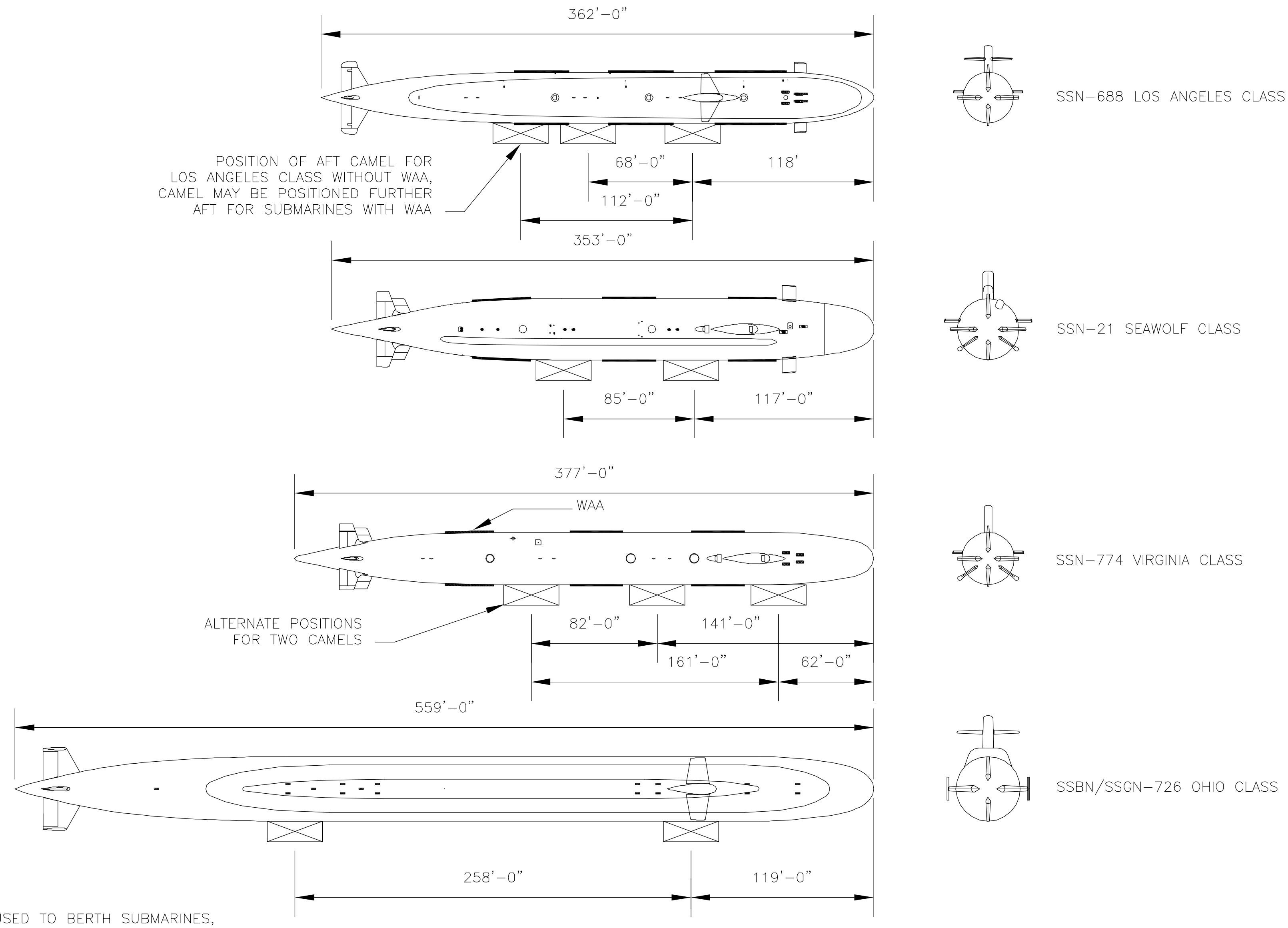
Waterfront facilities may have dedicated or temporary berths, which have an effect on the location of the camels and the design of the fender system. If the pier is dedicated, then specific locations may be established where the camels are set or they can be fixed to the pier. Temporary berths require the entire fender system, or a set of discrete locations, be designed for the submarine classes berthed.

2.1.3 Submarine, Mission, and Operations Differences

The installations surveyed support different submarines, missions, and operations. These factors influence the design of camels, fender systems, and waterfront facilities used to berth submarines.

There are four primary classes of submarines in the Navy (Figure 3). These classes can be divided into two groups, fast attack submarines and ballistic submarines. Each class has different characteristics including length, beam, displacement, and draft. Characteristics of the four classes of submarines considered in this study are shown in Table 2a. Further, some of the submarines are fitted with appurtenances such as a Wide Aperture Array (WAA). A WAA is a flank array installed on the sides of some of the Los Angeles class submarines and all of the Seawolf and Virginia class submarines for long range passive target location. Also, all submarines considered have a Special Hull Treatment (SHT) installed on the outer surface for improved silencing. Some Ohio class submarines are presently going through a SSGN conversion program to modify them from ballistic submarines to tactical submarines that support Land-Attack/Strike and Special Operations Forces missions.

Each installation operates differently based on their mission and the missions of the ships they support. Navy installations support multiple classes of ships and vessel types. They serve as homeports, visiting ports, and repair ports. For example, NS Norfolk and NS Pearl Harbor homeport surface ships and fast attack submarines, NSB New London and NSB Point Loma homeport fast attack submarines, NSB Kings Bay and NSB Bangor (now Naval Base Kitsap – Bangor) homeport ballistic submarines, and Norfolk NSY, Puget Sound NSY, and Pearl Harbor NSY repair surface ships, fast attack and ballistic submarines, while Portsmouth NSY only repairs fast attack submarines. The mission and operations of a Navy installation dictate the requirements of its infrastructure and waterfront facilities, thus driving the design of the waterfront and camels to meet this mission.



* TWO CAMELS USED TO BERTH SUBMARINES,
POSSIBLE ALTERNATE LOCATIONS SHOWN

FIGURE 3 - SUBMARINE CLASSES AND POSITIONING OF CAMELS

Table 2a - SUBMARINE CHARACTERISTICS

Submarine Class	Length (ft)	Beam (ft)	Fully Loaded Draft (ft)	Fully Loaded Displacement (Long-ton)	Depth to Extreme Beam (ft)	Maximum Allowable Hull Pressure (psi)
SSN 688 – Los Angeles Class	362	33	32.3	6082	10'-8"	27.2
SSN 21 – Seawolf Class	353	40	35.8	8060	12'-10"	27.0, 7.0 for WAA
SSN 774 – Virginia Class	377	34	30.5	7700	12'-5"	no data
SSBN 726 – Ohio Class	559	42	36.4	16600	14'-7"	30.3

Table 2b - SUBMARINE BERTHING ENERGY AND MOORING LOADS

Submarine Class	Berthing Velocity (ft/s) (moderate)	E_{ship} (kip-ft)	E_{fender} (kip-ft) (accidental berthing)	Mooring Load, Maximum Wind (kips)	Mooring Load Maximum Current (kips)
SSN 688 – Los Angeles Class	0.67	94.6	282.3	60	2131
SSN 21 – Seawolf Class	0.60	102.4	273.9	59	2292
SSN 774 – Virginia Class	0.61	101.2	265.5	50	1480
SSBN 726 – Ohio Class	0.48	135.0	265.6	155	5480

* Mooring Loads are based on results from FIXMOOR analysis where Wind = 120 mph, Current = 10.0 knots, and Tide = 12 ft

This leads to differences between the waterfront facilities at Navy installations. For example, a homeport for fast attack submarines does not necessarily meet the requirements for berthing a ballistic submarine. Further differences may arise if the mission of an installation has changed since the facility was constructed.

The operations of an installation influence its ability to service submarines and to operate and maintain camel and fender systems at the installation. One difference noted is crane operations. Some installations have access to cranes because they are used regularly in everyday operations. Shipyards, for example, are outfitted with a large number of high capacity cranes to perform their mission which also can be used to lift camels in and out of the water for positioning or maintenance. This gives shipyards an advantage over other installations that do not have cranes with adequate capacity and mobility. Mobile truck, YD, and portal cranes are used at other installations to perform this function (Figure 4).

Figure 4 – Portal Crane

Operations performed on waterfront facilities were noted as widely varying and significantly affects the efficiency of camel operations. The size of and activities performed on piers has an effect on deploying, removing, and positioning camels. Limited pier space restricts the use of cranes and amount of open space to set camels on shore. This can be seen at NS Mayport where there is very limited space along the waterfront for cranes to setup and to deploy and retrieve camels and to store them on shore near the waterfront. The camels must be stored far away from the waterfront due to the lack of space available. At NS Bremerton/Puget Sound NSY (now Naval Base Kitsap – Bremerton), there is very limited space to set brows on the pier because the portal crane rails run within three feet from the edge of the pier. This requires the brows to be placed on outrigger platforms off the face of the piers (Figure 5).

Figure 5 – Outrigger Platform

2.1.4 Other Differing Factors

Other factors that differ across installations include: inspection and maintenance programs; opinions and experiences with various types of camels and fender systems; and resources available. The depth and frequency of inspection and maintenance of camels and berthing facilities was noted as widely varying across the installations. This variance can be attributed to the available funding for inspection and maintenance, experience, knowledge of needed maintenance, and different opinions on inspection, maintenance, and repair needs. Further differences in the use of certain types of camels were based upon the user's opinions and experiences. Some installations believed one type of camel performs better than another, while other installations believe the opposite. This was based on both positive and negative experiences with various types of camels, lack of knowledge of other camels and fender systems available, and personal opinions. Also, resources play a role in the differences in camels and fender systems. Some installations have the support of in-house engineering coupled with the necessary materials, construction, and maintenance capabilities to support the development and maintenance of camels. Meanwhile, other installations must out-source all the work or seek assistance from other installations or departments.

2.2 *Deep Draft Camel/Fender Survey Discussion*

This study found there numerous deep draft camels currently in use by the Navy, which are referred to by a variety of names. Table 3 summarizes the camels surveyed and lists several of the names used and the typical nomenclature

Table 3 - DEEP DRAFT SUBMARINE CAMELS

Camel Type/Name	Drawing Title	Drawing No.	Year	Dimensions (LxWxH)	Design Submarine Class	Approx. Cost	Notes
Steel/Tube Frame						(set of 2 camels)	
688 Standard Deep Draft Camel (tapered)	Camel Submarine	749924-749925	1960	36'x(12'-5", 13'-7" taper width)x17'-4"	Los Angeles Class	$130,000-$180,000	Tapered, Old Design 60,000 lbs
688 Standard Deep Draft Camel (tapered)	Submarine Mooring Camel	1404664-1404666	1988	36'x(12'-5", 12'-2" taper width)x17'-4"	Los Angeles Class	$130,000-$180,000	Tapered, New Design 60,000 lbs
688 Standard Deep Draft Camel (non-tapered)	Submarine Mooring Camel	1404943-1404947	1995	36'x13'-5"x17'-4"	Los Angeles Class	$130,000-$180,000	Non-tapered 60,000 lbs
Deep Draft Camel	Deep Draft Camels	2098499-2098500	1986	36'x(12'-5", 13'-7" taper width)x17'-4"	Los Angeles Class	$130,000-$180,000	Modified tapered 1960 688 Camel, NSB New London, 60,000 lbs
Seawolf Camel	Attack Submarine Camel	1404667-1404670	1988	32'x11'-8"x20'-6" (10'-10" front taper)	Los Angeles Class, Seawolf Class	$200,000	Old Design 41,000 lbs
Seawolf Camel	Attack Submarine Camel	10400031-10400034	2002	32'x11'-8"x20'-6" (10'-10" front taper)	Los Angeles Class, Seawolf Class	$200,000	New Design 41,000 lbs
24 Foot Deep Draft Camel	32 Foot Deep Draft Camel	PS 29015, PS 28962 (1-3)	199X	24'x18'-5"x18'-3"	Los Angeles Class	$150,000	Portsmouth NSY approx 40,000 lbs
32 Foot Deep Draft Camel	32 Foot Deep Draft Camel	270.3-29015, PS 28962 (1-4)	2001	32'x18'-5"x18'-3"	Los Angeles Class	$150,000	Portsmouth NSY approx 40,000 lbs
Barge Camels							
Trident Deep Draft Barge Camel	Trident Deep Draft Camel	X72502 (1-4)	1989	60'x18'-10"x21'-10"	Ohio Class	$250,000	Barge camel designed by Puget Sound NSY, 93870 lbs
Modified Trident Barge Camel	Deep Draft Camels	6296882-6296888	1988	60'x18'-10"x21'-10"	Ohio Class	$326,000	Modified barge camels of NS Bremerton, NSB Bangor, 93870 lbs
Float Camels	Puget Sound Design Barge Camels	PED 8526	~1995	60'x18'-10"x21'-10"	Ohio Class	unknown	Modified barge camels of NS Bremerton, Portsmouth NSY 93870 lbs

* costs are based on a set of two camels/fenders and are based on best information provided by installations, see site visit reports for more information on costs

Table 3 - DEEP DRAFT SUBMARINE CAMELS - Continued

Camel Type/Name	**Drawing Title**	**Drawing No.**	**Year**	**Dimensions** (LxWxH)	**Design Submarine Class**	**Approx. Cost**	**Notes**
Fixed Camels						(set of 2 camels)	
Spudmoor/Spudlock Camel	Refit Wharf No.1	5122222-5122223, 5122276, 5122285-5122294	1984	30'x12'-6"x37'	Ohio Class	$800,000	NSB Kings Bay 298,000 lbs
Captured Camel	Camel	6046044-6046049	1978	50'x12'-5"x37'	Ohio Class	$800,000	NSB Bangor 462,740 lbs
Trident Camels							
Trident Mooring Camel	Mooring Camel Deep Draft Submarine	1403447-1403452, 1403455-1403057	1975/ 1980	30'x(15', 16'-8" taper width)x21'-8"	Los Angeles Class, Ohio Class	$250,000	Design from 1972 camel study, tapered, Supercede 749924-749925, NSB New London, NSB Kings Bay, 82,792 lbs
Trident Deep Draft Camel	Mooring Camel Trident Submarine	1403444-1403445, 1403458-1403461, 1403567-1403578	1976	23'x14'-9"x26'	Ohio Class	unknown	NOTU 83,061 lbs
35ft Trident Camel	SSBN Camel	600-02 (1/9)	2002	31'-6"x33'-1"x25'-4"	Ohio Class	$1,420,000	35' SSBN camel for Norfolk NSY, cost includes the design fee, construction, transport, and setup
Trident Modified Camel	SSBN-726 Camel Locations	S-1 – S-2	~1995	36'x13'-5"x17'-4"	Los Angeles Class, Ohio Class	$100,000	Modified 688 camel used for Ohio class submarines, 79,000 lbs, cost is for modifications only
Trident Modified 688 Camel	688 Camel Modifications for Trident Submarine	SK5432-04 - SK5433-04	2004	36'x13'-5"x17'-4"	Los Angeles Class, Seawolf Class, Ohio Class	$100,000	Modified 688 camel used for Trident and Seawolf class submarines, NS Norfolk/Norfolk NSY, 79,000 lbs cost is for modifications only

* costs are based on a set of two camels/fenders and are based on best information provided by installations, see site visit reports for more information on costs

Table 3 - DEEP DRAFT SUBMARINE CAMELS - Continued

Camel Type/Name	Drawing Title	Drawing No.	Year	Dimensions (LxWxH)	Design Submarine Class	Approx. Cost	Notes
Hydro-Pneumatic Fenders						(set of 2 camels)	
Hydro-pneumatic Fender (3.3m x 10.6m)	3.3m x 10.6m (10.8’ x 34.8’)	7916374-7916424, 7944790-7944842 (NS PH) 7812042-7812042 (Japan)	1994	3.3m x 10.6m (10.8’ x 34.8’)	Los Angeles Class, Seawolf Class, Ohio Class	$330,000	NOTU, NS Point Loma, NS Pearl Harbor, NS Mayport, Okinawa, Japan 22,000 lbs
Hydro-pneumatic Fender (4.5m x 9.0m)	4.5m x 9.0m (14.8’ x 29.5’)	none provided		4.5m x 9.0m (14.8’ x 29.5’)	Los Angeles Class, Seawolf Class, Ohio Class	unknown	NS Pearl Harbor, NS Mayport 26,000 lbs
Composite Camels							
Composite Camel/Fixed Fenders/ Universal Camel	Universal Camels	MR03-AD-01	2000	24’x8’x16’	Los Angeles Class, Seawolf Class	$400,000	NSB New London 37,779 lbs
Miscellaneous Camels							
USS Parche Camel	Sub Camel/Brow Platforms	S-5.8-S-5.12	1994	32’’x13’-2”x15’	Sturgeon Class	unknown	Camel design specifically for facility and submarine
EHW Camel	EHW Camel	5226323-5226519	1988	not recorded	Ohio Class	unknown	Camel design specifically for facility

* costs are based on a set of two camels/fenders and are based on best information provided by installations, see site visit reports for more information on costs

encountered. Some of the camels listed are similar and are either modified versions of or subsequent generations of the same design. Drawings have been obtained for the various camels and are on file at NAVFAC - Atlantic. Appendix B contains sketches of the camels surveyed.

2.2.1 Deep Draft Camel/Fender System Description

Deep draft camels act as separators between a submarine and a waterfront facility and are used to transfer load from a berthing or moored submarine to a pier or wharf structure through a fender system. They are constructed of several materials including: steel, timber, rubber, and composite materials. Camels typically consist of a frame with a flotation system and have a fendering system on the submarine (outboard) side and a rub system on the pier (inboard) side (Figure 6). Most camels are constructed of steel, but composite camels and hydro-pneumatic rubber fenders also exist.

The camel fendering system is designed to absorb energy from submarine berthing operations or movements during a moored condition. It usually is constructed of a timber or steel frame and is lined with rubber fender elements. Fender elements may also be found on the pier side of a camel or within the frame. The pier side of a camel typically has rub rails lined with fender elements or UHMWPE elements for energy absorption and smoothness.

Some of the older camel designs were tapered, in plan view, and originally designed to accommodate classes of submarines that are no longer in service. Modern submarines have a parallel mid-body, which does not fit the taper of the camels. These camels cannot be used effectively without modifications, unless the camels are positioned on the ends of the submarines were there is a taper (Figure 7). More recent camel designs are configured without a taper and some of the older designs have been updated to remove the taper.

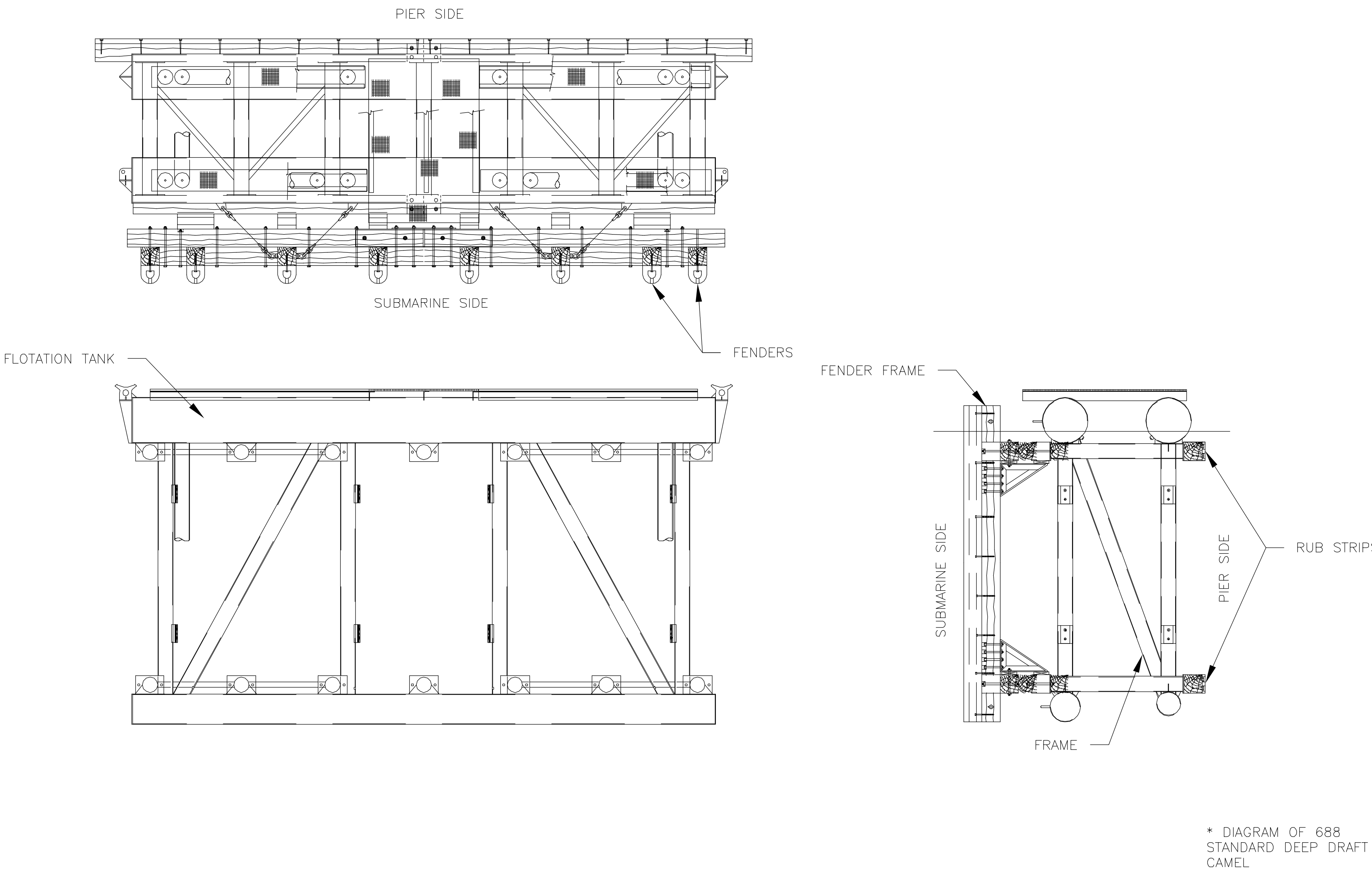


FIGURE 6 - TYPICAL STANDARD, 688 STANDARD DEEP DRAFT CAMEL (NON-TAPERED)

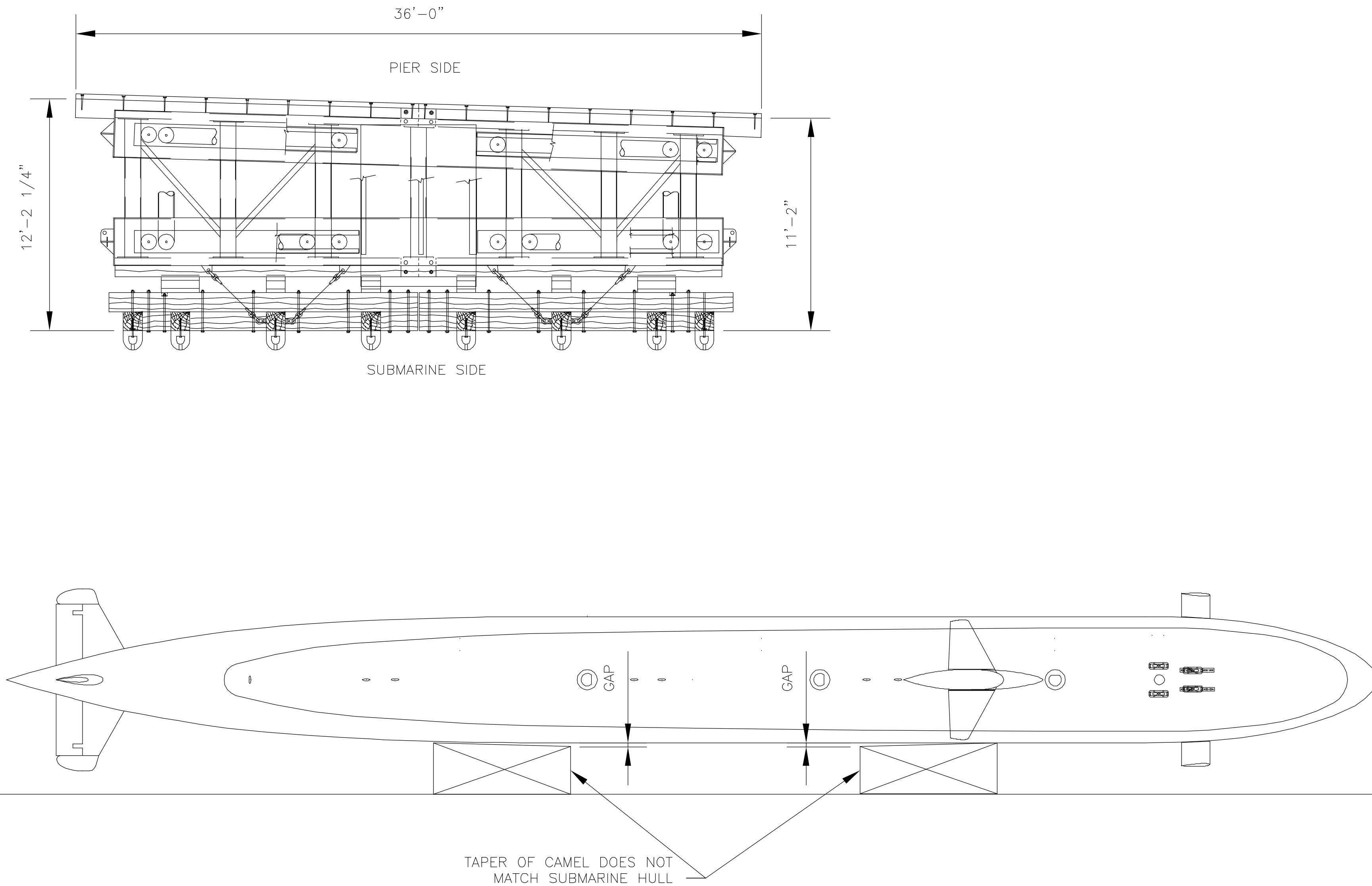


FIGURE 7 - TAPERED 688 STANDARD DEEP DRAFT CAMEL

A fender system on a waterfront facility acts to protect the facility from ships, camels, barges, and other craft moored to the waterfront facility. Fender systems typically consist of fender piles, fender elements, wales, and chocks. They are constructed of various materials including timber, steel, concrete, rubber, and composite materials. Fender systems are designed to be flexible to absorb the energy generated from the berthing and mooring of ships or loads transmitted by camels.

2.2.2 Deep Draft Camel/Fender Types

The camels surveyed may be divided into several categories. This report will divide the camels into seven groups based on their general construction and/or use. These groups are: Steel/Tube Frame, Barge, Fixed, Trident, Hydro-Pneumatic, Composite, and Miscellaneous. Table 3 shows the camels and categories.

2.2.2.1 ***Steel/Tube Frame Type Camels*** are constructed of a steel tube frame and steel tube flotation tanks with fenders on the submarine side and rub strips on the pier side.

688 Standard Deep Draft Camels:

The 688 Standard Deep Draft camels are a NAVFAC standard design and is the most common camel in use (Figure 8). There are tapered and non-tapered versions of this camel with the tapered version being the most common. These camels have a timber frame with rubber

Figure 8 – 688 Standard Deep Draft Camel

fenders on the submarine side for fendering and timber rub strips on the pier side. The design is the oldest noted that is still in use and has gone through several revisions. Some of the modifications to the original design have been made by installations to improve their performance and reduce maintenance.

Observations:

- 688 Standard Deep Draft Camels are versatile and have performed well when used and maintained properly.
- They are flexible in positioning along a typical fender system found at most Navy installations.
- Their weight makes them difficult to lift and position.
- These camels have problems with corrosion of the steel structure and components and deterioration of the timber face.
- They are very prone to listing if not properly maintained.
- Although opinions vary as to the amount and degree of maintenance required for these camels, extensive maintenance is required to keep them in good working order.

Submarine Berthing:

These camels were originally designed in the 1960's to berth submarine classes that are no longer in service. Modifications to the design have been done to accommodate the newer classes of submarines. They are currently used to berth Los Angeles class submarines, however they have been used to berth other classes of submarines. Typically, two camels are used to berth submarines. Two or four camels have been used to berth Ohio class submarines, though they do not have sufficient draft to be used efficiently with this class of submarine. Modifications have been made to these camels to lower their draft as seen in the Trident Type Camel section.

Seawolf Camels:

The Seawolf Camels are a NAVFAC standard design that is used at NSB New London (Figure 9). These camels are trapezoidal in plan view to accommodate the wide aperture array (WAA) on some submarines. Some modifications have been made to the original design to improve their performance.

Figure 9 – Seawolf Camel

Observations:

- They are versatile and have performed well at NSB New London.
- They are flexible in positioning along their existing fender system.
- These camels are new and very little maintenance has been required.
- Because these camels are constructed of steel, corrosion will potentially be a problem if not properly maintained.
- The design has been modified to increase the buoyancy so the camels will ride higher in the water.

Submarine Berthing:

These camels are used to berth Los Angeles, Seawolf, and Virginia class submarines. Two camels are used to berth these submarines.

24/32 Foot Deep Draft Camels:

Portsmouth NSY personnel designed the 24 and 32 Foot Deep Draft Camels and are only currently used at this installation. The designs of these two camels are basically the same. However, the 32 Foot Camel has longer rub strips and tubes on the pier side of the camel to better distribute the load to the fender system.

<u>Observations</u>:

- These camels are versatile and have performed well.
- They are flexible in positioning along their existing fender system.
- Regular maintenance is performed on these camels. Typical maintenance consists of pressure washing the camels to remove marine growth, painting, and performing minor maintenance.

<u>Submarine Berthing</u>:

These camels are used to berth Los Angeles class submarines. Two camels are used to berth these submarines.

2.2.2.2 ***Barge Type Camels*** consist of either a YC barge or some other barge like flotation tank with a steel frame connected to the underside. The steel frame has rubber fenders on both the submarine and pier sides (Figure 10).

Barge Camels:

The design was originally used at Puget Sound NSY, however it has been modified and adapted at other installations including NSB Bangor and Portsmouth NSY. These camels are used at installations where there is a significant tidal range, which makes the use of a single brow difficult, and/or have limited pier space.

Figure 10 – Barge Camel

Where a single brow cannot be used, a double-brow system is used. One brow goes from the pier to the camel and another goes from the camel to the submarine (Figure 11). The brow coming from the pier to the camel is secured to a platform that extends from the face of the pier (Figure 5).

This keeps the brow and other obstructions completely off of the main pier deck. This system could also be necessary if there is limited space on the pier, such as the presence of crane rails near the edge of the pier. Also, Barge Camels are advantageous because they serve as work platforms and an area to store equipment. The camels were originally designed with a tapered steel frame to accommodate the Sturgeon Class (SSN 637) submarine geometry. More recent procurements and overhauls eliminated or reduced the taper and extended the draft to adjust to current submarine geometry and draft.

Figure 11 – Double Brow System

<u>Observations</u>:

- They are versatile and have performed well.
- They are flexible in positioning along the existing fender system at the installations that currently use them.
- Their size and weight makes them difficult to lift in and out of the water and maneuvering them through the water is difficult and slow.
- These camels have typical maintenance requirements including cleaning, painting, and replacement of fenders and zinc anodes regularly. However, because their material is prone to corrosion and the large size and number of exposed members, more extensive maintenance and overhaul might be necessary.

<u>Submarine Berthing</u>:

These camels are typically used to berth Los Angeles and Ohio class submarines, however they are frequently used to berth other classes of submarines. Two camels are used to berth these submarines.

2.2.2.3 *Fixed/Spud Type Camels* are constructed of a steel flotation tank with a steel frame connected to the underside (Figure 12). The camels have rubber fenders on the submarine side and a locking arm system that connects to the steel tube (spud) piles. Because the camels are connected to spud piles they are fixed in the horizontal plane but move freely in the vertical plane, which compensates for tidal action.

Fixed/Spudmoor Camels:

There are two types of these camels, one is used at NSB Kings Bay and the other is used at NSB Bangor. Both were designed by Berger/ABAM Engineers Inc. about the same time and are very similar in design. The length and number of fenders are the primary differences between the two. These camels are used at dedicated Ohio class submarine berths. Their positions are fixed by the spud piles and are not adjustable.

Figure 12 – Spudmoor Camel

<u>Observations</u>:

- These camels are have performed very well.
- They can act as a platform similar to the barge type camels.
- The spud pile system allows the camels to remain in a fixed location at a dedicated submarine berth.
- Submarines can moor directly to these camels, thus tending the lines is not required.
- Cranes of adequate capacity and mobility are not typically available to remove the camels from the water; therefore these camels must be floated to a drydock for repair and maintenance. Scheduling

use of a drydock is difficult and can cause delays in performing inspections and other necessary maintenance.

- Maneuvering these camels through the water is very difficult because of the large amount of the structure is below the water.
- The camels often experience corrosion to the steel components.
- The locking arm system creates a nuisance when the camels are moved because divers are required to disengage the arms and the bolts are often corroded and must be cut off.

Submarine Berthing:

These camels are used to berth Ohio class submarines, but are also used to berth Los Angeles and other class submarines. Typically three or four of these camels are used to berth these submarines, but two can be used.

2.2.2.4 ***Trident Type Camels*** are camels specifically designed for Ohio class (Trident) submarines and are not specifically used at a dedicated locations like the Fixed/Spudmoor Type Camels. Other types of camels may be used to berth Ohio class submarines, but these were designed for this specific purpose. The construction may be from an original design or a modification to an existing design to allow a camel to be used with Ohio class submarines.

Trident Mooring Camels:

Trident Mooring Camels were designed as part of the camel study in 1972 (Figure 13). They are constructed of a steel plate frame and flotation tanks with rubber fenders on both sides of the camel. The design was intended to be a “Standard Camel” and was meant to replace the 688 Standard Deep Draft Camels. These camels are tapered in plan view.

Observations:

- There are very few of these camels in existence and they are rarely used.
- Most of these camels are in disrepair and some installations are scrapping them or not using them at all because they are high in maintenance, large and difficult to use, and other camels exist that better suit their needs.

Figure 13 – Trident Mooring Camel

Submarine Berthing:

At NSB Kings Bay, these camels are used to berth Los Angeles class, Ohio class, and foreign submarines occasionally. Two camels are used to berth these submarines. NSB New London does not use these camels for submarine berthing; they are used as work barges.

Trident Deep Draft Camels:

Trident Deep Draft Camels are very similar in design to the Trident Mooring Camels. They are constructed of a steel plate frame and flotation tanks with rubber fenders on both sides of the camel (Figure 14). These camels are not tapered. Naval Ordnance Testing Unit (NOTU) at Port Canaveral, FL uses this camel to berth Ohio class submarines and was found to be the only station currently using this

Figure 14 –Trident Deep Draft Camel

camel design.

Observations:

- These camels perform well, however they tend to move around during ship passing.
- They are flexible in positioning along existing fender systems.
- NOTU maintains their Trident camels on a regular basis. Typical maintenance includes replacing the zinc anodes, inspecting and replacing deteriorated steel connectors and timber, and inspecting lifting eyes.
- NOTU plans to replace the Trident and other camels with hydro-pneumatic fenders to reduce maintenance.
- A set of Trident camels was noted at NSB Bangor, but the design of the camels was not determined. They do not use these camels except occasionally as separators.

Submarine Berthing:

These camels are used to berth Ohio class submarines, but are sometimes used for Los Angeles class or visiting foreign submarines. Two camels are used to berth these submarines.

SSBN Camels:

Norfolk NSY had a set of SSBN Camels designed and constructed for their unique requirements. The existing dredge depth at NNSY is insufficient near the pier for berthing submarines and testing of some systems on the submarines. Therefore, camels were designed with a 35-foot standoff to set the submarine into a deeper part of the berth. They consist of a steel flotation tank supporting a steel frame, with rubber fenders and UHMWPE platens (Figure 15).

<u>Observations</u>:

Figure 15 – SSBN Camels

- The camels were designed around the Ohio class submarine and a modified fender system at NNSY.
- The existing timber fender system proved inadequate for berthing Ohio class submarines and was modified with concrete fender piles at specific locations.
- These camels are very large and difficult to lift and maneuver.
- They are very new and no maintenance has been performed on them to date.

<u>Submarine Berthing</u>:

These camels are used to berth Ohio class submarines, but are also used to berth Los Angeles and other class submarines. Two camels are used at dedicated locations to berth these submarines.

"Universal" Camel Concept:

Manufacturers and designers in the waterfront industry have proposed their version of a Universal camel. The concept is similar to the NNSY SSBN camel design. It would consist of a steel box flotation tank, with steel frame legs below, and rubber fenders and UHMWPE platens. The design is intended to be adjustable for different classes of submarines and can be reconfigured to different fender systems. Also, the camel is designed to breakdown to allow shipping by truck.

<u>Observations</u>:

- The camels are designed to be modular and may be shipped and shared between installations.

- The camels are not suitable for all classes of submarines unless they are reconfigured, which would be time consuming and labor intensive.
- They could be used for all classes of submarines, if configured for the worst case.
- The platens may pinch the SHT on the submarines.
- This camel would be subject to typical corrosion of steel components and marine growth.
- The concept provides only 8 feet deep (standoff) which may not be large enough to accommodate submarine hull projections.

Submarine Berthing:

This camel concept can be configured for each class of submarine. Two camels would be used to berth submarines.

Trident Modified 688 Deep Draft Camels:

Norfolk NSY and NS Norfolk use Trident Modified 688 Deep Draft Camels to berth Ohio and Seawolf class submarines (Figure 16). The Ohio (Trident) and Seawolf class submarines have deeper drafts and greater displacements than Los Angeles (688) class submarines (Table 2a). 688 Standard Deep Draft Camels do not have the draft or fendering to properly berth Ohio or Seawolf class submarines. Modifications have been made to these camels to accommodate these classes of submarines and include adding a ballast block of steel and concrete to the bottom to sink the camel and attaching a foam filled fender to the top of the camel to suspend it at the proper depth (Figure 17).

Figure 16 – Trident Modified 688 Standard Camel

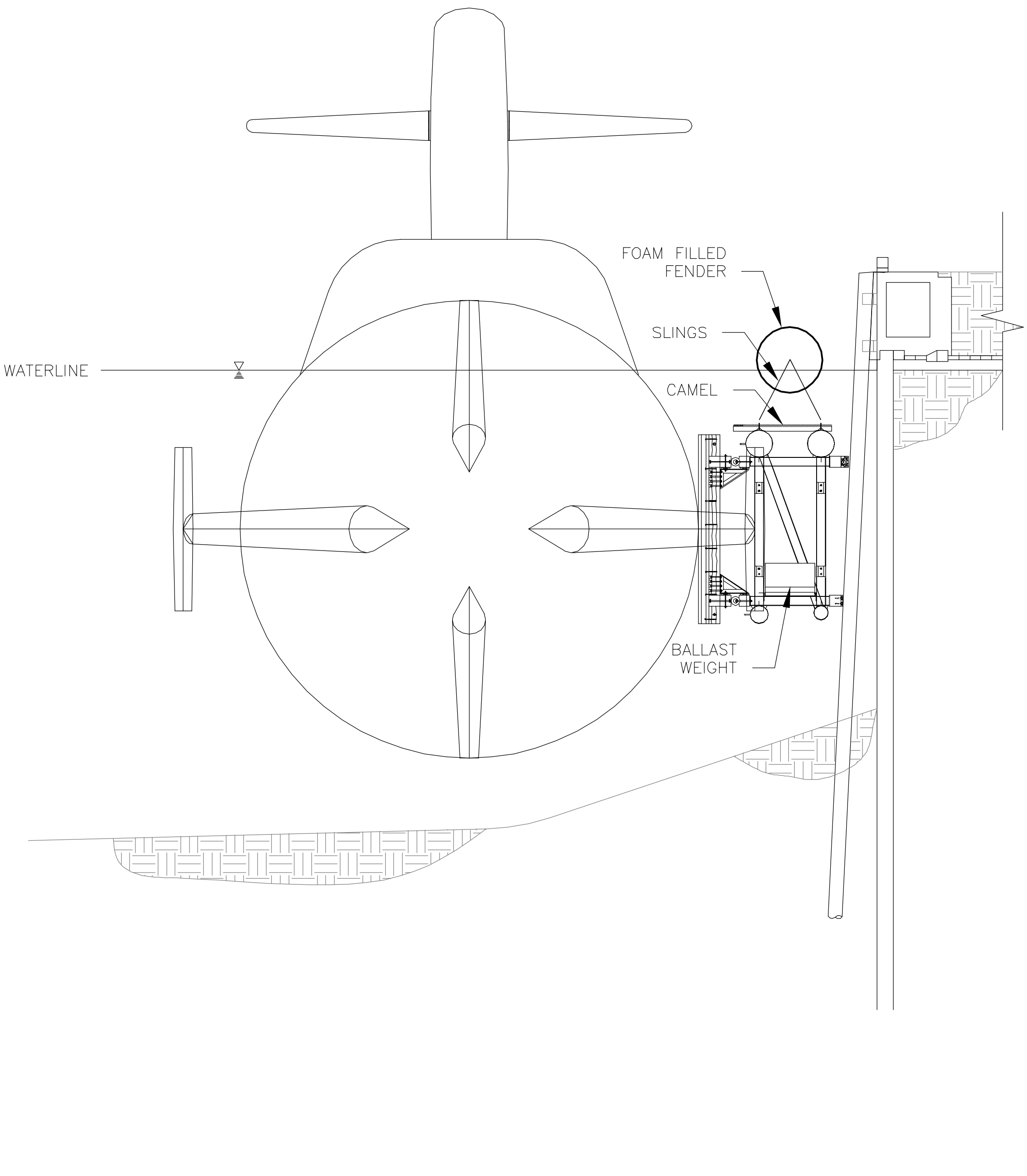


FIGURE 17 - TRIDENT MODIFIED 688 STANDARD CAMEL CONCEPT

The slings that attach the foam filled fender to the camel have a specified length to set the depth at which the camel sits. Several generations of these camels have been developed and the concept has been continuously improved. The current modifications are designed to be removable so that the camels can be converted back to use as 688 Standard Deep Draft Camels.

Observations:

- These camels were very labor intensive to deploy in their original design, however recent modifications have simplified this process.
- They have been used to berth Ohio and Seawolf class submarines during emergent port calls, but were not originally designed for this purpose.
- These camels required the same maintenance as the 688 Standard Deep Draft camels.
- Fender system modifications are necessary to properly use these camels.

Submarine Berthing:

In a modified state they may be used to berth Ohio and Seawolf class submarines. In an unmodified state they are used to berth Los Angeles class submarines. Two camels are used to berth these classes of submarines.

2.2.2.*5 Hydro-Pneumatic Fenders* are airtight rubber bladders that are partially filled with water. The fenders are then weighted on one end to make them float in a vertical position (Figure 18) and are moored to the waterfront facility against a backer system.

Hydro-Pneumatic Fenders:

Figure 18 – Hydro-Pneumatic Fender

The fenders are a proprietary product and are manufactured by several companies around the world. Two sizes of fenders are used to berth submarines, which are 3.3 m x 10.6 m (10.8 ft x 34.8 ft) and 4.5 m x 9.0 m (14.8 ft x 29.5 ft) in diameter and length respectively. The exact sizes of the fender vary slightly based on the manufacturer. A detailed analysis by the manufacturer is necessary to set the internal pressure of the fenders and the air-to-water ratio. This may be simplified if a single solution is developed. Some installations use these fenders extensively while some deploy them when submarines are visiting or a submarine visits a port that does not have camels to accommodate submarines. These fenders may also be used for nesting submarines and berthing against submarine tenders. Hydro-pneumatic fenders must meet the ISO 17357-2002 standard; however there are some fenders currently used that were procured before this standard was developed and implemented that do not meet this standard.

Observations:

- These fenders are easy to procure, transport, and maintain.
- Deploying these fenders is a multi-step process.
- Very little regular maintenance is performed or required. Typical maintenance includes removing the fenders for cleaning, inspection, and pressure adjustments.
- Several problems with the valves on the fenders have been noted.
- Chafing and cracking of the outer skin has been noted.
- UV deterioration of the outer skin is a problem.

- A regular inspection and maintenance program needs to be developed for hydro-pneumatic fenders. Distributors offer maintenance and inspection services.
- In 1997 a hydro-pneumatic fender failed at NS Point Loma. No damage occurred to the submarine or pier from the failure. The Naval Facilities Engineering Service Center (NFESC) conducted an investigation and produced a report entitled, "*Hydro-Pneumatic Submarine Fender Failure – Phase III Sub Base San Diego*." This investigation concluded the fender failed due to manufacturing defects in the fender's skin. However, there is still debate as to the actual cause of the failure.
- A failure of a hydro-pneumatic fender occurred at NS Mayport in January 2005. The failure was attributed to the inner bladder separating from the fender and blocking the drain, causing fender to explode and injuring workers when water was being evacuated from the fender during retrieval. This fender that failed was not manufactured in accordance with ISO 17357-2002. This failure lead to a Navy Safety Announcement, which instructed to discontinue using hydro-pneumatic fenders not manufactured in accordance with ISO 17357-2002.
- These fenders are usually used at dedicated locations where the fender system has been modified to serve as a backer system. The backer system usually consists of a group of concrete fender piles with a load-distributing frame in front, between the piles and fender (Figure 19). Several backer positions may be constructed to allow for adjustment of the positions of the fenders for the different classes of submarines (Figure 20). Appendix D contains a description and a sketch of a general backer system for hydro-pneumatic fenders. Alternatively, the backer system may be a frame system designed and installed on existing fender piles for use in a temporary berthing situation.

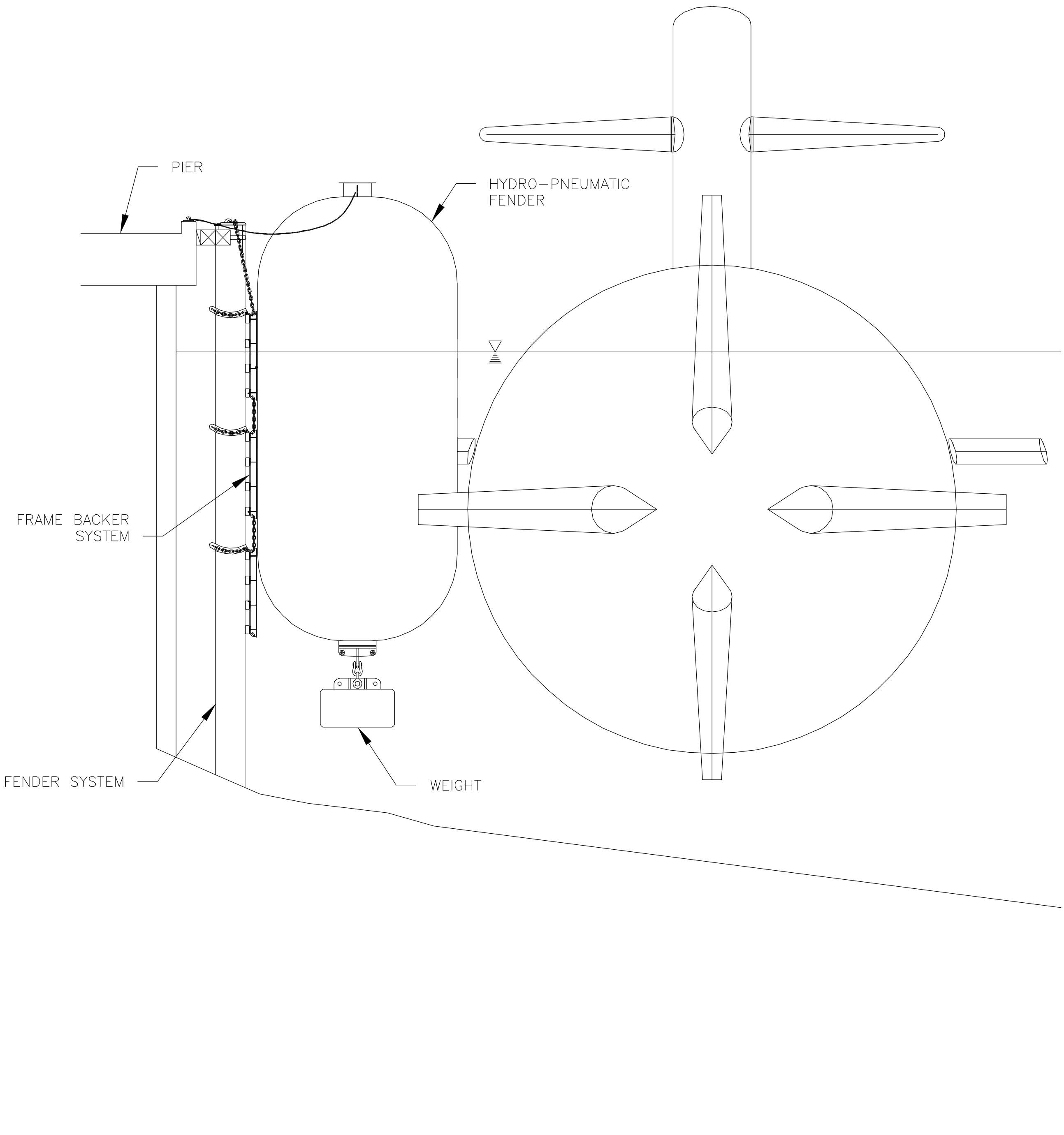


FIGURE 19 - HYDRO-PNEUMATIC FENDER ARRANGEMENT

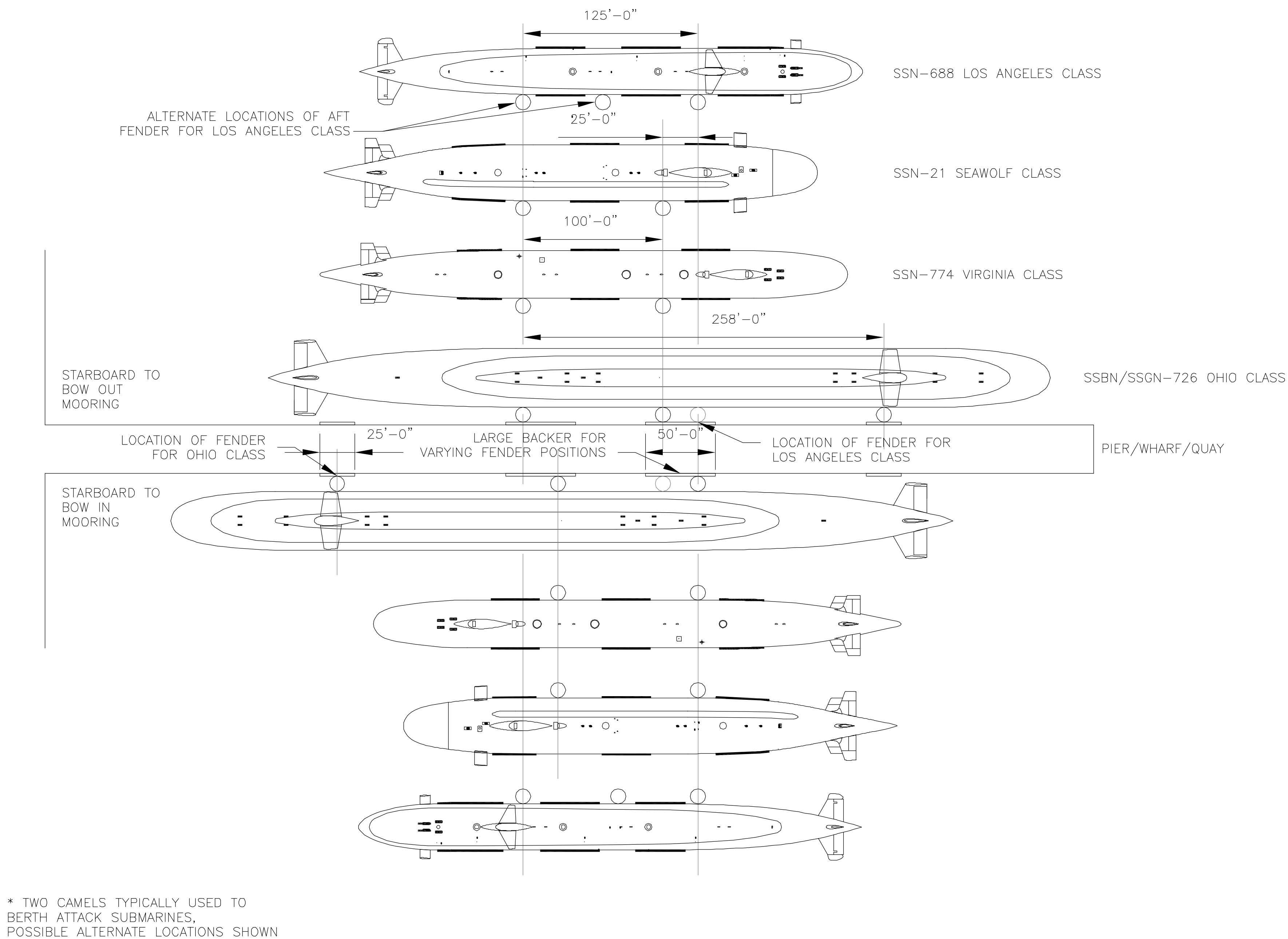


FIGURE 20 - CAMEL/FENDER LOCATIONS FOR DEDICATED POSTIONS

<u>Submarine Berthing</u>:

Los Angeles, Seawolf, and Ohio class submarines have been berthed against these fenders. These fenders could also be used for Virginia class submarines. Two fenders are used to berth Los Angeles and Seawolf class submarines and two, three, or four are used to berth Ohio class submarines based on the model of fender selected. They are also used as separators.

2.2.2.6 *Composite Type Camels* are constructed of composite materials and are also referred to as *Fixed Fender* or *Universal Camels*. There is only one set of these camels and they are used at NSB New London.

Composite Camels:

NFESC designed the camels as a prototype system that is low in maintenance and provides flexibility in positioning a submarine on the camels. They are D-shaped and constructed of composite materials, with a ballast system for stability, fenders on the submarine side, and a built-in backer board with UHMWPE rub strips on the pier side (Figure 21). The camels are moored to the waterfront facility against a pile backer system.

<u>Observations</u>:

- Low maintenance due to the corrosion resistant nature of the composite materials.
- Allow flexibility in berthing a submarine equipped with a WAA. The camels are positioned above the WAA, so they can contact the submarine at any point along its length (Figure 22).

Figure 21 – Composite Camel

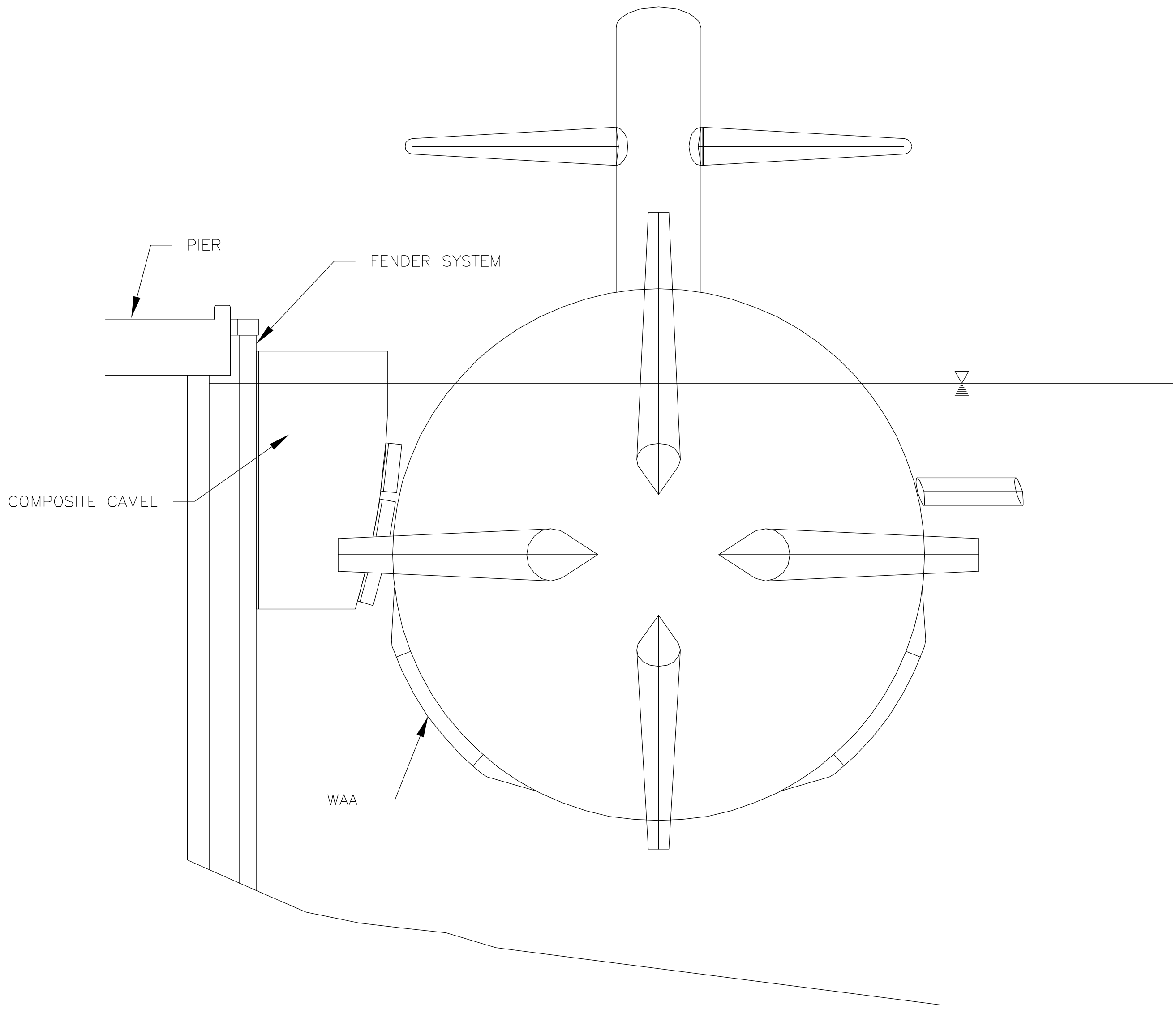


FIGURE 22 - COMPOSITE CAMEL DIAGRAM

- The camels require a specially designed and dedicated fender system that consists of a group of fender piles and a pile cap (Figure 23).
- This system requires a dedicated berth due to the special fendering required, which limits the mobility of the camels.
- No regular maintenance program has been established for these camels because they are new and because of the few number of parts that tend to deteriorate. It is planned to remove the camels and inspect them in the near future.
- Modifications to the design have been proposed for future versions of this camel including: adding gussets, add inspection holes, and designing for Ohio class submarines.

Figure 23 – Composite Camel Locations

Submarine Berthing:

Los Angeles, Seawolf, and Virginia class submarines are berthed using these camels. Two camels are used to berth these submarines.

2.2.2.7 *Miscellaneous Camels*

Several other camels are used by Navy installations. The Explosive Handling Wharfs (EHW) at NSB Kings Bay and NSB Bangor use camels that were designed for specific use with Ohio class submarines at these specific locations. An EHW is an enclosed over-water structure that covers a U-shaped slip to berth submarines during operations. The camels are of typical steel tube construction and are attached to the sub prior to it entering the facility.

The USS Parche (SSN 683), berthed at NSB Bangor, uses a unique mooring and camel system that is specially designed for this submarine and waterfront facility. This submarine will be decommissioned shortly and a MILCON project will modify the pier to berth the USS Parche's replacement the USS Jimmy Carter (SSN 23). The new camels used at this pier will be similar to the Fixed/Captured Camels used at NSB Bangor. It may be noted that the camels used for berthing the USS Parche are similar in design to the concept NS Norfolk is considering for its new piers. This camel consists of a steel frame fixed to the pier with large bore cylindrical fenders.

Because these other camels are designed for a specific use at these installations and because the facilities are not used for general berthing, these camels will not be considered in the study.

2.2.3 Typical Camel Findings

Below is a summary of typical camel use in berthing and mooring situations, typical camel maintenance and inspection, and typical pros and cons of the camels surveyed.

2.2.3.1 *Typical Camel Use*

The use of camels is relatively standard across the installations surveyed. Typically two deep draft camels are used to berth submarines. However, some installations use three or four when berthing Ohio class submarines. The camels are usually positioned at the parallel mid-body of the submarine (Figure 3). Their positions are generally determined by an engineering mooring analysis. In some instances, when a submarine is equipped with WAA, the positioning of the camels becomes very limited. The use of the camels is also dependent upon the experiences and opinions of the users.

2.2.3.2 *Typical Inspection and Maintenance*

Inspection and maintenance of camels varies greatly across the installations surveyed. Some installations performed inspection and maintenance regularly, while others do little or no inspection or maintenance. However, most installations have some sort of inspection and maintenance program that is typical.

When camels are inspected they are typically removed from the water, however topside and underwater inspections are also performed. Inspections include visual inspection of the camel, nondestructive testing of various members, and pressure testing of the flotation tanks.

The condition of the camels varies widely from very poor to very little deterioration to brand new. In any condition, the camels need to be maintained. Typical maintenance includes: cleaning off marine growth, painting, repairing corroded steel, replacing deteriorated or broken parts, including timber and rubber fenders, adjusting ballast and pressure, and replacing zinc cathodic protection anodes.

2.2.3.3 *Typical Problems*

There are advantages and disadvantages to any type of camel/fender system. These include performance, operations, maintenance, and personal opinions.

The size and weight of most of the camels surveyed are problematic. Most camels are constructed of steel and are stoutly designed to resist large berthing and mooring loads and the size is driven by the site specific geometric requirements. This makes the camels heavy and some installations do not have the capabilities to lift the camels in and out of the water. Also, because a submarine camel has most of its structure below water they are difficult to maneuver through the water.

The deployment and retrieval of camels is time consuming and labor intensive. This is primarily due to the weight and cumbersome nature of the camels and the time to setup cranes to lift camels. Some require divers to assist during deployment and retrieval operations.

Some camels tend to bounce and move around at berths in exposed areas where waves are frequently high or high currents push the camels around. This can cause damage to the camels, fender system, or submarine. Harbors with large ships passing near by cause a similar bouncing effect on camels as well as submarines.

The extensive maintenance required to keep up the camels is problematic. Most camels are made of steel, which corrodes in a saltwater environment if not maintained properly. The timber used in some camels is also susceptible to deterioration from rot and wood boring organisms. Deterioration of rubber elements due to wear and UV exposed has posed a problem. Composite and corrosion resistant materials are ideal for this environment.

The valves on hydro-pneumatic fenders have posed many problems. The valves have leaked and have required major overhaul or replacement. However, the problems have been limited to only certain manufactures.

Fixed/Spudmoor type camels with locking arms that connect them to spud piles creates a nuisance because divers are required to disengage the locking arms to perform maintenance and inspection and the bolts are often corroded and need to be cut off.

Fixed/Spudmoor type camels allow the submarines to moor directly to the camel, which decreases the need for tending mooring lines sine the camel and the submarine ride together with the tide. This is advantageous in areas with a large tidal range or dedicated submarine berths.

Several camels are either fixed to a facility or are dedicated to specific locations because they require a special fendering system. This situation limits the positioning of camels and thus berthing locations for submarines. Other camels are very flexible in positioning because they do not require a specific fendering system and can be placed anywhere along the fender system on a pier. Examples of these camels may be found in the Deep Draft Camel/Fender Survey Discussion section 2.2.

Some camels, particularly the 688 Standard Deep Draft camels, are unstable on land because the bottom is not level. In the case of the 688 Standard Deep Draft camels, the bottom tubes are not the same diameter and the timber face extends below the bottom tubes. This requires special cribbing to be setup to make the camel sit upright (Figure 24). Sometimes these camels are laid down to perform maintenance or transport, which is cumbersome, complicated, and time consuming.

Several species of marine organisms attach themselves to camels and removal of marine growth is a typical maintenance issue (Figure 25). It must be removed to allow for proper inspection of the camels and to reduce weight.

Figure 24 – Camel Cribbing

Figure 25 – Marine Growth on Camel

3.0 CAMEL DESIGN/ANALYSIS CRITERIA

A review of the design and analysis criteria for camels and fender systems was conducted along with a preliminary berthing and mooring analysis.

3.1 *Submarine Characteristics*

The design of camels is based on the submarine berthing and mooring against them. General information on the submarines included in this study may be found in Table 2a. The classes of submarines considered in this study are:

Los Angeles (SSN 688) Class
Ohio Class (SSBN 726, Trident) Class
Seawolf (SSN 21) Class
Virginia (SSN 774) Class

Figure 3 shows the relative sizes of the submarines. Submarine characteristics such as length, beam, draft, displacement, wind area, and arrangement of mooring cleats are considered in the design and analysis of a mooring configuration and fender system.

3.2 *General Camel Design Parameters*

Many of the parameters used in the design of waterfront facilities are used in the design of deep draft camels. Key parameters influencing the design of a camel include berthing and mooring loads, geometry, pier and fender systems, allowable hull pressure, and special requirements.

3.2.1 Loads

Berthing and mooring loads are derived from environmental conditions, ship characteristics, and waterfront facility characteristics. NAVFAC uses MIL-HDBK 1025/1, “Piers and Wharves,” and MIL-HDBK 1026/4 “Mooring Design” to determine the berthing energy and mooring loads respectively. Berthing and mooring analysis software such as FIXMOOR or BeAN can aid this process.

3.2.2 Geometry and Positioning

The geometry and characteristics of the submarine control the design, geometry, and positioning of camels. The depth of a camel is dependent upon the draft of the submarine moored against it. Camels must be deep enough so that the extreme beam of the submarine lies in the center of the camel fendering to distribute loads equally and provide a range of movement between the camel and submarine. Figure 26 shows the location of the extreme beam for the four classes of submarines considered in this study. A range of approximately four feet exists between the depths to the extreme beams for the different submarines. A Universal camel must cover the full range of extreme beam depths. Some of the camels currently in use have limited depth and cannot accommodate some classes of submarines.

The position of camels is also dependent on the class of submarine. Camels are typically placed on the parallel mid-body of the submarines, usually around the quarter points. Also, a mooring analysis is conducted to show where camels may be placed based on the capacity of the waterfront facility. However, some submarines are equipped with a WAA that is not designed to take berthing and mooring loads and a camel cannot be placed against this area. Camels must be placed between the WAA's or beyond them. Figure 3 shows the typical placement of camels on the submarine classes with and without WAA's. The Composite Camel used at NSB New London does not have this problem, because it is designed to contact the submarine above the extreme beam as not to interfere with the WAA (Figure 23). Also, the width of camels on the submarine side is restricted by the WAA (Figure 3). The Seawolf Camel at NSB New London is an example where the fender face is tapered in to fit between the WAA's.

The width of a camel is governed by the geometry of a submarine and its projections (i.e. bow and stern planes, WAA's), the geometry of the waterfront facility and other structures, and the minimum clearance required. Camels must

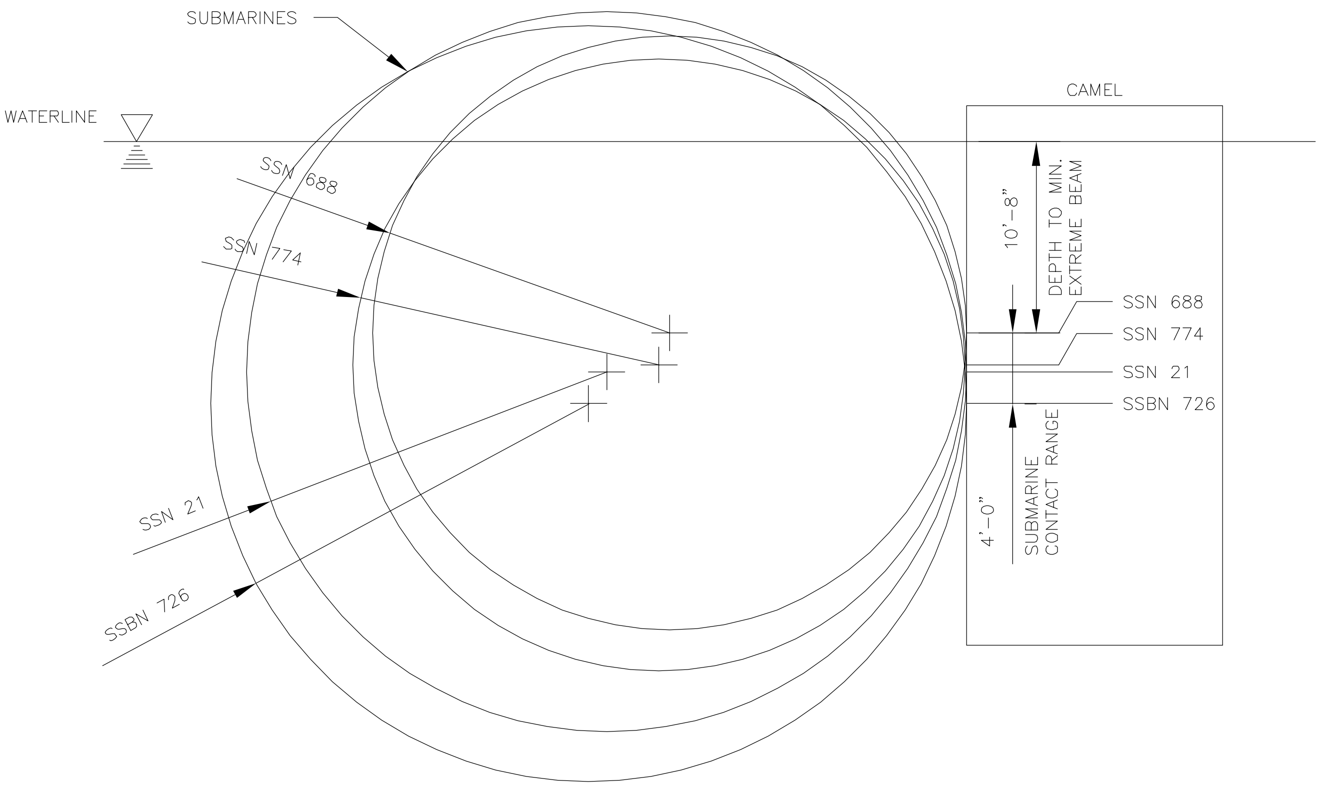


FIGURE 26 - SUBMARINE DEPTH TO EXTREME BEAM

provide standoff to protect the submarine from coming in contact with waterfront facilities and other structures. The geometry of submarine projections can be determined from submarine models and data. The minimum clearance is based on varying factors and requirements. Several references address the minimum clearances required, however there is no published standard identifying a minimum clearance. It is generally accepted that a minimum clearance of 5 feet be maintained between a submarine and its projections and waterfront facilities and other structures when a camel and its associated fendering is fully compressed. NAVSEA has requirements for a submarine to be moored at least 12 feet from a waterfront facility to provide clearance to perform maintenance on a submarine, see reference SSN 688 (I) Retractable Bow Plane (RBP) Cofferdam System Installation Procedure. This requires a camel to be at least 7 feet wide if a clearance of 5 feet is acceptable. There are similar clearance requirements for submarines with arrays. NAVSEA and other commands and activities must provide input on there standoff requirements.

3.2.3 Pier and Fender System

The capacity of waterfront facilities and fender system is a factor in the design of camels. Camels must be designed to distribute berthing and mooring loads to a fender system and waterfront facility without overloading these elements.

Camels may be designed around the fender system, which tends to increase the size in order to engage more elements of the fender system. Camels may also be designed to absorb as much energy as possible to limit the loads distributed to the fender system and pier. In some instances, the fender system must be modified to accept different camels or camel positions because the original design might not be adequate to accommodate other types of camels or submarines. An example would be modifying a berth to accept a hydro-pneumatic fender. Modifying berths for different classes of submarines leads to dedicated camel locations.

3.2.4 Hull Pressure

A major controlling factor in camel design camels is the allowable hull pressure of a submarine. The fender size, type, and quantity must be selected as not to exceed the maximum allowable hull pressure of a submarine. Because the hull of a submarine is round and the fender face of a camel is typically flat, the submarine contacts the camel over a relatively small area causing a pressure concentration. Larger fender elements, such as large diameter cylindrical fenders or hydro-pneumatic fenders, are soft and experience greater deformation causing them to conform to the contour of a submarine's hull and thus distributing the contact pressure over a larger area.

3.2.5 Special Requirements

The fender elements in contact with the submarine must be designed to prevent damage to the surface of the submarine. Submarines are outfitted with Special Hull Treatments (SHT). SHT tiles have very low shear strengths and are susceptible to cutting. Therefore, the fender material between the vessel and the camel must be selected as to not damage the submarine surface.

3.3 *Berthing Energy*

MIL-HDBK 1025/1 was used to determine the berthing energy for each class of submarine listed in Table 2b. Characteristics of submarines and waterfront facilities both play a role in the determination of berthing energy. In order to develop a Universal camel that is suitable for all classes of submarines and could be used at all Navy installations, some conservative assumptions were made based on the "worst case" conditions. See Appendix C for berthing energy development data.

The berthing energy from MIL-HDBK 1025/1 assumes a single berthing velocity. The velocity could be varied to determine its effects on the berthing energy, however in this study only the worst case berthing velocity was used, which occurs at a moderately exposed harbor (Table 2b). Different analysis procedures and programs, such as AQWA and BeAN, may be used to develop berthing energies by varying berthing velocity, wind speed, and current.

Berthing loads are determined by applying the berthing energy to a specific fender or system of fenders on a camel and then determining the reaction produced. This load is used to design or analyze a waterfront facility or fender system. Because of the wide range of fender elements used on the camels surveyed, a detailed analysis of each camel and fender was not conducted. The Fender Energy/Reaction section discusses the properties of the fenders and provides a relative comparison of the fenders used on camels.

3.4 *Mooring Loads*

Wind, current, and other environmental conditions induce loads on ships, which are then transmitted to the mooring lines and camels and then to the waterfront facility. A mooring analysis is required to model their effects and is typically conducted when the waterfront facility is designed, however an analysis may be conducted at any time to determine if a new mooring arrangement, camel/fender, ship position, or different ship may be used at a waterfront facility.

The effects of wind and current on a submarine in a moored condition can be evaluated by using MIL-HDBK 1026/4 and FIXMOOR. This procedure determines the environmental loads on the ship and the mooring line loads and the reactions produced by camels. The mooring line loads are used to verify the capacity of the mooring lines and pier fittings (bollards, cleats, bitts). The camel reaction is used in the design of the camel and fender system. This reaction is compared to the berthing loads to see which controls. Typically, berthing loads control due to the small sail area of submarines. However, in extreme current loads this may not be the case. All conditions must be investigated.

A preliminary mooring analysis was conducted for each class of submarine. The results may be found in Table 2b. The ‘worst case’ conditions were used in the analyses and include the highest wind and current conditions noted. The results are conservative and may not be practical for every installation. However, they are useful for comparison purposes and for designing camels for the worst case loading condition.

3.5 *Fender Energy/Reaction*

Fender systems for use with submarines are designed differently than those for surface ships. Surface ships have most of their structure above the waterline and camels and fenders are positioned around the waterline, which causes their reactions to be transmitted almost directly into a pier. Conversely, submarines have most of their structure below the waterline and camels and fenders are positioned below the waterline to mate up with a submarine (Figure 1). This causes a camel or fender to engage the fender system below the waterline and it must be designed to handle this condition and transmit their reactions back to the waterfront facility. A fender system may be designed to absorb a portion of the energy or as a hard point that causes to camel's fenders to absorb all the energy.

Camels have fendering on them to absorb energy from a ship and transmit this energy in the form of a reaction to a waterfront facility. The fendering is designed around the energy they are required to absorb from a ship and the allowable reaction they may produce. The allowable hull pressure also controls the design (size, type, and quantity) of fenders. Fenders have different characteristics based on their size, shape, and material properties. Fender manufacturers develop energy (E) vs. deflection, reaction (R) vs. deflection curves, and other data to aid designers in selecting an appropriate fender. The R/E (reaction-to-energy) ratio of a fender is the relative relationship of reaction produced by a deflected fender to the energy used to deflect the fender. For a given deflection and energy, the higher the R/E ratio the higher the reaction produced. Conversely, for a given reaction and deflection, the lower the R/E ratio the more energy is absorbed.

An analysis is required to properly select fendering for a camel based on the required energy absorption, maximum allowable reaction, and allowable hull pressure. The maximum reaction may be adjusted based on how the camel utilizes the fender system on a waterfront facility. Large camels/fenders distribute the loads over a large portion of fender system, while small camels/fenders focus loads and may require modifications to existing fender systems in the form of discrete locations.

A preliminary analysis of the different types of fender elements found on the camels surveyed was conducted and is shown in Table 4. The values are based on data published in manufacturer's catalogs and are for the fenders compressed to 50% of their depth and the values are per unit length. The data published in the catalogs is based on tests performed on fenders using a flat plate, however the hull of a submarine is curved. Therefore, a more detailed analysis of the energy absorbed and the reaction produced is necessary to obtain a more accurate answer. However, the values are valid to make a relative comparison.

As Table 4 shows, the R/E ratios vary between the fenders. It is optimal to use the low R/E ratio, so the fender absorbs as much energy as possible and transmits the lowest reaction to the fender system and waterfront facility. The 'D' and Wing Type fenders have the highest R/E ratios. These elements are used primarily on the 688 Standard Deep Draft camels, which is the most common camel. Therefore, these camels absorb little energy and transmit large loads to the fender system and waterfront facility. Furthermore, because the fenders are relatively stiff, the allowable hull pressure may be reached with very little deflection of the fenders. This requires a large number of fenders to distribute the loads and pressure. The remaining fenders listed have R/E ratios about the same with the hydro-pneumatic fenders having the lowest values. These fenders are large and deform more allowing for greater energy absorption. Hydro-pneumatic and large cylindrical fenders have the added benefit of deflecting large amounts and conforming to a ship hull, thus distributing the load across a larger area and reducing the pressure.

Table 4 – FENDER REACTION-TO-ENERGY COMPARISONS

Fender Element	Camel Outfitted	Number Used on Camel	Reaction (per fender)	Energy (per fender)	R/E (per fender)
			kips/ft	kip-ft/ft	kip/kip-ft
12" 'D' Fender	688 Standard Deep Draft Camel	8	52	6.8	7.7
8" Wing Fender	688 Standard Deep Draft Camel	8	65	5.9	11
Arch Fender	Seawolf Camel	2	15	10	1.5
Arch Fender	24 & 2 Foot Deep Draft Camels	3	108	86.9	1.2
500 mm Arch Fender	Spudmoor Camel	3	82.3	50.2	1.6
MV 500B	SSBN Camel	8	84	63	1.3
Cylindrical Fender (1050x600)	USS Parche/NS Norfolk Concept	2	33.4	26.3	1.3
Hydro-pneumatic Fender* (3.3m x 10.6m)	3.3m x 10.6m Hydro-pneumatic Fender	1	477	682	.70
Hydro-pneumatic Fender* (4.5m x 9.0m)	4.5m x 9.0m Hydro-pneumatic Fender	1	2250	2000	1.1

Reaction and Energy values are based on one fender compressed 50% of its depth
* Values for hydro-pneumatic fenders is based on a Los Angeles class submarines and are not per length

3.6 *Universal Camel Design Criteria*

A new deep draft camel suitable for all classes of submarines should be designed for the following parameters:

- Have midpoint of submarine side fendering 12’-8” below waterline and allow for a 4’-0” range of depth of extreme beam (Figure 26).
- Maintain minimum submarine projection-to-pier clearance of 5’-0” when camel/fender is compressed to 50%. Restrictions given by other commands and activities also need to be considered.
- Have fendering capable of absorbing the worst case accidental berthing energy, approximately 282 kip-ft (Table 2b).
- Limit reaction to waterfront facility and fender system by utilizing fenders with low R/E ratio, at or below 1.0 [(k/ft)/(k-ft/ft)].

Analysis of existing fender systems and waterfront facilities is necessary to determine if modifications are necessary.

4.0 CAMEL/FENDER ALTERNATIVES

A Universal camel design would include all the requirements of all submarines and Navy installations. Due to the wide range of differences in submarine requirements, environmental conditions, waterfront facilities, installation requirements, and resources available it is difficult to develop a single "Universal" deep draft camel that may be used by all classes of submarines at all Navy installations that would be practical. However, it is possible to develop a set of alternative camel concepts that would meet a range of requirements for submarines and installations.

It is possible to develop a single camel solution, which may be used by all classes of submarines, by designing a camel around the worst case loads for the submarines, as discussed in the Camel Design/Analysis section. However, for certain installations this may not be practical since some submarines may never visit certain waterfront facilities due to their physical limitations such as dredge depth or pier length.

Developing a single camel solution that is applicable to all Navy installations is more complicated and not practical due to the great amount of differences between installations. All the installations have unique requirements, which warrant differences in camels, fender systems, and waterfront facilities. However, categorizing the requirements into a few groups would make it possible to develop a set of camel standards that could be implemented at several installations.

4.1 *Optimal Camel Parameters*

A set of camels that would meet all the requirements of all classes of submarines and Navy installations would meet the criteria in the Universal Camel Design Criteria section and have as the following characteristics:

- Easy to procure
- Low initial cost

- Does not deteriorate
- Easy to maintain
- Low maintenance cost
- Light and easy to lift
- Easy to deploy
- Flexible in positioning along submarines and waterfront facilities
- Able to berth all classes of submarines
- Adaptable to existing fender systems with no modifications required
- Easy to maneuver through the water
- Stable in varying environmental conditions (does not bounce around)
- Can moor submarine to camel to limit line tending
- Distributes load evenly on submarine and waterfront facility

Several of these parameters are contradictory to one another. For instance, a camel cannot be too light else it has the potential to bounce around. A balance between these parameters must be established to best suit as many installations as possible. Therefore, a set of alternatives has been developed to best fit a set of parameters applicable to a range of installations.

4.1.1 Camel Lifecycle Costs

Lifecycle costs have been developed for each alternative and may be found in Table 5. The costs of constructing and maintaining camels can vary greatly between installations due to the local contracting community, availability of in-house forces to accomplish work, and extent of maintenance and repairs performed. The costs given are an estimate or average range of what might be typically expected.

The present value lifecycle costs are based on a 30-year camel life with an annual interest rate of 3.5%. The maintenance costs and periods are based on a 3% escalation rate. All costs have been projected back to present day values for comparison purposes.

Table 5 – CAMEL ALTERNATIVE LIFECYCLE COSTS

Camel/Fender	**Initial Cost**	**Fender System Modification Cost**	**Maintenance Interval**	**Maintenance Cost**	**Total Life Cycle Cost (Present Value)**
Hydro-pneumatic Fender	$340,000	$150,000	2 years	$5,000	$555,000
Barge Camel	$350,000	$0-$100,000	5 years	$250,000	$1,380,000
Composite Camel	$400,000	$100,000	5 years	$5,000	$523,000
Steel/Composite Camel	$200,000	$0-$100,000	5 years	$100,000	$765,000

*Costs are based on a set of two camels/fenders

4.2 *Hydro-Pneumatic Fender Alternative*

4.2.1 Concept

Hydro-Pneumatic fenders consist of an airtight rubber bladder that is partially filled with water. The fender is then weighted on one end to make it float in a vertical position (Figures 18, 19) and moored to a waterfront facility against a backer system. A more detailed description of this fender may be found in the Deep Draft Camel/Fender Survey Discussion section.

4.2.2 Preliminary Structural Analysis

A preliminary analysis of the energy and reaction for this fender is given in Table 4. Hydro-Pneumatic fenders have a relatively low R/E ratio, so they absorb more energy and transmit a relatively low reaction. These fenders are relatively soft and deform, thus allowing them to conform to the shape of a submarine hull and distribute load more evenly.

4.2.3 Lifecycle Costs

Lifecycle costs for this alternative have been developed from general data obtained during this study and are contained in Table 5.

4.2.4 Advantages and Disadvantages

Advantages of hydro-pneumatic fenders include:

- Low lifecycle costs
- Little maintenance required
- Low maintenance costs
- Few parts that can corrode or deteriorate
- Can be left in water for long periods of time
- Light weight
- Easy to transport and share resources if necessary
- Can be used with Los Angels, Seawolf, Virginia, and Ohio class submarines
- Low R/E ratio

- Provides a uniform pressure distribution on the submarines and backer system
- Contact with submarine hull is soft and does not abrade SHT on submarine's hull
- Can be used as separators

Disadvantages of hydro-pneumatic fenders include:

- Relatively high initial cost
- Time consuming to set up and deploy, but typically are not constantly deployed and removed.
- Require a special fender and backer system. This leads to dedicated positions (Figure 20, Appendix D). However, a series of positions could be constructed to allow flexibility with berthing several classes of submarines as seen at NS Point Loma and NS Pearl Harbor. Backer system may be designed to work with existing fender system as is done at NSB Bangor.
- Some sizes of fenders might not meet standoff requirements. Larger fenders could be used to attain standoff or additional standoff may be achieved by offsetting backer system from pier similar to what is seen at NS Point Loma.
- History of valve problems, with some manufactures
- Chaffing and cracking of outer skin reported
- UV deterioration can cause problems
- Light weight could cause it to move around when mooring lines become slack at high tides
- Lack of structural redundancy from a frame as seen on a typical camel. Additional fenders may be required.
- Fenders could be overcompressed and release pressure and thus lose rigidity
- Fenders are proprietary products
- Require regular monitoring of the air pressure

4.2.5 Recommendations

Hydro-Pneumatic fenders are the most advantageous type of camel/fender for use with submarines because they are versatile, simple, low in maintenance, and transportable, though they require a dedicated fender system. These fenders are best used at installations that are not subject to high tidal fluctuations, have limited topside space on waterfront facilities, and can integrate backer systems into existing fender systems or can utilize a portable backer system.

Figure 20 shows locations where fenders and backer systems are required for the different classes of submarines. Appendix D contains a description and a sketch of a general backer system for hydro-pneumatic fenders. These fenders are an off-the-self type of item that can be easily procured. The manufacturer performs all the design and fabrication. Installations have used a NAVSEA contract with marine equipment and maintenance companies to procure these fenders. Fenders must meet ISO 17357-2002 standard. One recommendation to improve the performance of hydro-pneumatic fenders is to redesign the valve system to perform consistently without requiring major overhaul or replacement. Adding depth marks to the side of the fenders would assist with tracking fender draft.

4.3 *Barge Camel Alternative*

4.3.1 Concept

This camel consists of a barge or barge like flotation tank with a steel frame connected to the underside. The frame may have rubber fenders on one or both sides and rub strips or a locking arm system on the pier side (Figures 10, 12). A more detailed description of this fender may be found in the Deep Draft Camel/Fender Survey Discussion section.

4.3.2 Preliminary Structural Analysis

A preliminary analysis of the energy and reaction for this camel is given in Table 4. Barge Type camels typically use arch type fenders, which have a relatively low R/E ratio. These camels are large and are capable of distributing reactions over a wide area across a fender system.

4.3.3 Lifecycle Costs

Lifecycle costs for this alternative have been developed from general data obtained during this study and are contained in Table 5.

4.3.4 Advantages and Disadvantages

Advantages of Barge Type Camels include:

- Flexibility in classes of submarines berthed
- Accommodates a double brow system
- Serves as a work platform
- Submarines can moor directly to camels, if designed as such
- Flexible in positioning along existing fender systems

Disadvantages of Barge Type Camels include:

- Relatively expensive initial cost
- Very heavy and difficult to lift
- Difficult to maneuver through water
- A special fender system may be required, which may include a spud pile system
- Camels may be limited to use at dedicated locations
- Large structure with numerous members require extensive maintenance
- Large laydown area is required to perform maintenance
- Locking arm system, if equipped, susceptible to corrosion
- Divers required to disengage locking arms, if equipped

4.3.5 Recommendations

Barge Type camels are suitable for installations were tidal fluctuations are high and a double brow system is necessary. These camels are versatile for most existing fender systems due to their large size and their ability to distribute loads. This type of camel also provides a work platform for installations where pier side space is limited. They are flexible and may be used with all submarine classes. Existing camels meet parts of this concept, but a single camel that incorporates all of these concepts should be developed to improve the present designs. The drawback of this type of camels is that they are large and heavy which makes them difficult to lift, maneuver, and maintain.

4.4 *Composite Camel Alternative*

4.4.1 Concept

The camels are constructed of a composite material in a D-shape with a ballast system for vertical stability. The camels have fenders on the submarine side, and a built-in backer board with UHMWPE rub strips on the pier side (Figures 21, 22, 23). A more detailed description of this fender may be found in the Deep Draft Camel/Fender Survey Discussion section.

4.4.2 Preliminary Structural Analysis

A preliminary analysis of the energy and reaction for this camel is given in Table 4. Composite camels use arch type fenders, which have a relatively low R/E ratio. These camels have a large built-in backer system designed to distribute reactions over a wide area. A specially designed fender system is required to support this camel.

4.4.3 Lifecycle Costs

Lifecycle costs for this alternative have been developed from general data obtained during this study and are contained in Table 5.

4.4.4 Advantages and Disadvantages

Advantages of Composite Camels include:

- Low lifecycle costs
- Little maintenance necessary
- Few parts that can corrode or deteriorate
- Do not interfere with WAA
- Flexible in positioning submarines on camels
- Modular in design
- Camels may be transported easily
- Can be used as a separator

Disadvantages of Composite Camels include:

- Relatively high initial cost (prototype), production costs may be less
- New concept and testing is ongoing
- Lifting and setting these camels on shore is difficult because they do not sit upright and must be laid down.
- Current camels are only designed for Los Angels and Seawolf class submarines, but plans are to develop a concept for Ohio class submarines. This concept could be expanded to include all classes of submarines.
- A specially designed and dedicated fender system is required and limits the positioning of camels and submarines at different locations on the pier
- Camels have a tendency to “pop up” when a submarine is berth hard against them

4.4.5 Recommendations

Composite camels have great potential in that they are very low maintenance and may be positioned at any location along a submarine since they are designed not to interfere with a submarine’s WAA. These camels are ideal for installations with dedicated submarine berths or can allow for modifications to submarine berths because they require a special fender system. Further investigation should be conducted on this concept and improvements should be made based on the lessons learned from the prototype. A design that is applicable for all classes of submarines should be developed. The wide use of composite materials in camels should be maximized because corrosion and deterioration resistant.

4.5 *Steel/Composite Design Alternative*

4.5.1 Concept

From this study, it was seen that there is no one “best” steel tubular frame camel. Versions of these camels have been in service for many years and have performed well, but they are high in maintenance, are constructed of materials that deteriorate readily, and are typically only designed for a limited number of submarine classes. Since this concept has proven very useful, it is feasible to develop an alternative steel tubular frame camel to cover a broader range of requirements not met by the current camels and that incorporates materials and technology that would improve its performance.

A new steel tubular frame concept would use a combination of several of the most advantageous aspects of the camels surveyed in order to develop a camel that is simple, inexpensive to construct and operate, easy to procure and maintain, easy to use, and meets a variety of installation and submarine requirements. The concept would consist of a steel tubular frame with a flotation tank system or built into a waterfront facility. Composite materials would be incorporated into this concept along with round steel members, which better resist deterioration and will reduce the number of edges that tend to corrode easily. The fenders on this camel should have a low R/E ratio for optimal energy absorption and be positioned vertically to allow for a wide range of drafts. Existing fender systems will have to be analyzed for compatibility with this camel and modified, if necessary, to accommodate this camel.

4.5.2 Preliminary Structural Analysis

Based on the fenders surveyed, a large cylindrical or arch type fender would provide the best energy absorption and reaction characteristics and should be used in this concept. Values for these fenders are given in Table 4. These fenders have a relatively low R/E ratio. The camels may be designed around a fender system or a specially designed fender system may be used in conjunction with this camel.

4.5.3 Lifecycle Costs

Lifecycle costs for this alternative have been developed from general data obtained during this study and are contained in Table 5.

4.5.4 Possible Advantages and Disadvantages

Advantages of steel/composite camel concept include:

- Relatively low initial cost

- Camel designed for Los Angels, Seawolf, Virginia, and Ohio class submarines
- Simple concept with few parts
- Uses composite materials that do not deteriorate as readily
- Uses rounded steel shapes to reduce deterioration along edges
- Incorporates low R/E ratio fenders

Disadvantages of steel/composite camel concept include:

- Camels may be required to be used in a dedicated location
- Steel can corrode and will require regular maintenance
- This camel is only a concept and detailed investigations has not been conducted

4.5.5 Recommendations

A Steel/Composite Camel concept should be developed to incorporate the most advantageous aspects of camels noted during this survey into a single camel design. The general design concept would be similar to hydro-pneumatic fenders and the camel concept NS Norfolk is considering. These concepts consist of a frame and backer system, either floating or attached to a facility, with a large fender element that is positioned vertically. This configuration appears to provide to be the most optimal from the findings of this study. This is only a concept and further concept development and design and analysis is necessary.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Due to the wide range of differences between waterfront facilities, submarines, and unique requirements of Navy installations, no single “Universal” deep draft camel solution can be developed that may be used for all classes of submarines at all Navy installations that is practical. The most optimal solution would be to develop a unique camel for every installation to meets its exact requirements. However, this would not meet the need to standardize the camels the Navy currently uses. Therefore, a compromise solution is to use and/or develop a limited set of alternative deep draft camels that would meet the requirements of a set of installations with similar conditions and requirements and that can work with all classes of submarines.

It is recommended that Navy installations continue to use their present camels until the camels become obsolete and need to be replaced or they become cost prohibitive to maintain. When camels are replaced, or new procurements are planned, it is recommended that one of the alternatives described in this study, that best suits the installation’s requirements, be used.

Hydro-Pneumatic fenders prove to be the most versatile and advantageous alternative because they are low in maintenance, easy to procure, and easily transportable between installations. However, the initial cost is relatively high, they can be complicated to deploy, and require a special backer and fender system. It is recommended to use hydro-pneumatic fenders for most installations that are not subject to high tidal fluctuations, have limited space on top of waterfront facilities, and can allow for modified fender systems at discrete locations or can have a portable backer system designed. Hydro-Pneumatic fenders must meet ISO 17357-2002 standards.

Barge Type camels prove to be the best alternative at installations with high tidal fluctuations and limited space. They are very versatile with respect to the submarine classes that can be berthed against them and the fender systems they can go against. However, the initial cost is relatively high, they are heavy and difficult to maneuver, and can be expensive to maintain. It is recommended to use barge camels at installations that are subject to high tidal fluctuations and/or have limited space on waterfront facilities. Further, a Standard Barge Type camel design should be developed.

The use of composite materials in camel construction is promising because they do not deteriorate as readily as more common materials. The design of the Composite camel is advantageous, as it does not interfere with the WAA on submarines. Incorporating the most advantageous aspects of the camels surveyed also shows promise. Further investigation into the composite camel and a hybrid Steel/Composite camel should be conducted.

Regular inspection and maintenance needs to be performed on camels to insure their functionality and to reduce overhaul costs. If the cost to overhaul a camel becomes near or greater than the cost of a new camel, then the camel should be replaced.

Tapered camels should be phased out as soon as possible because they are no longer compatible with current classes of submarines. All 688 Standard Deep Draft Camels should be phased out of service due to the limited use of the tapered version, high maintenance costs, age of most of these camels, and poor fendering properties.

Timber should no longer be used on deep draft camels. Timber components are a hold over from earlier camel designs. Timber, even when treated, deteriorates in a marine environment from decomposition and wood boring organisms. Also, the use of treated lumber is becoming limited due to environmental concerns. Composite materials should be used as a substitute for timber. They are becoming more readily available. There is a higher initial cost to purchase these products, but this cost is offset by the lifecycle cost savings of maintaining and replacing timber elements.

Timber used in fender systems should also be limited. Environmental concerns and the lack of strength and durability of timber make other materials such as concrete, steel, and composite materials more advantageous to use.

Round steel shapes or tubes should be used for steel components because this shape does not present edges that tend to corrode easily. Galvanizing the steel components of a camel will help to protect them from corrosion. Steel should be protected from corrosion and marine growth by using zinc anodes and anti-foulant paint, respectively.

6.0 ACKNOWLEDGEMENTS

We would like to thank Leon Hutchinson of Commander, Submarine Force U.S. Atlantic Fleet (COMSUBLANT) for supporting this project.

We would also like to thank everyone we contacted and visited during the course of this study. The information they provided was very useful and was the heart of this study. Their cooperation and responsiveness should be commended. They played a critical role in making this study a success.

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MIL-HDBK 1026/4 Mooring Design, NAVFAC 1999.

Appendix A – SITE VISIT REPORTS

NSB Kings Bay, GA

NS Mayport, FL

Naval Ordnance Testing Unit (NOTU), Cape Canaveral, FL

NS Bremerton/Puget Sound NSY, WA (now Naval Base Kitsap – Bremerton)

NSB Bangor, WA (now Naval Base Kitsap – Bangor)

NS Point Loma, CA

NS Pearl Harbor, HI

NS Rota, Spain

Portsmouth NSY, ME

NSB New London, CT

NS Norfolk, VA

SITE VISIT REPORT
NAVAL SUBMARINE BASE KINGS BAY, GA
02 February 2004
Prepared on 10 February 2004

Visitors:

Frank Cole, NAVFAC Engineering Innovation & Criteria Office (EICO)
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:

CWO4 John Martin, Port Operations, (912) 573-2550, john.w.martin6@navy.mil
CWO3 Don Smith, Drydock Officer, (919) 266-2512, cwo3_smith@trfkb.navy.mil
Ed Gamwell, TRF Facilities, (912) 573-9262, ed_gamwell@trfkb.navy.mil
John Garner, EHW Crane Foreman, (912) 573-4569, spk34@swflant.navy.mil
Bob Thomas, EHW Foreman, (912) 573-8772, spk3413@swflant.navy.mil

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Layberth, Site IV	SSN 688, 21, 774, ARDM, surface ships	Trident Camel[1] 688/Deep Draft Camel[2]	NAVFAC 1403444-61[1] NAVFAC 1404664-66[2]	Steel H-piles, Steel wale, Timber Chocks, Rubber fender blocks
MSF Wharf	All	None	None	Fiberglass Composite Fender Piles
Trident Refit Wharves	SSBN/SSGN 726, SSN 688	Spudlock/Spudmoor[3]	NAVFAC 5140206-208[3]	Concrete-filled steel tube piles, Timber chocks, Fender blocks
EHW	SSBN/SSGN 726	Special **	NAVFAC 5226323-519	Concrete-filled steel tube piles

1- Trident Camel (1 set-steel plate frame with bumpers and fenders, designed by J.J. Henry Inc.)
2- 688 Deep Draft Camel (2 sets-tapered - steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)
3- TRF wharf spudlock/spudmoor camel (4 sets - steel tube frame with pipe clamps on spud piles and fenders, designed by ABAM / HNTB for Kings Bay)
Special ** - Facility specific camel
MSF = Magnetic Silencing Facility
EHW = Explosive Handling Wharf

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Trident Camel	unknown	$600,000	5-years	$30,000	
688/Deep Draft Camel	unknown	$200,000	5-years	$100,000	
TRF Wharf Spudlock	1978	$800,000	5-years	$260,000	

* costs based on a set of two camels, procurement costs are in year constructed and maintenance costs are from most recent service

Current Situation:
NSB Kings Bay has one set (2 camels) of Trident Camels. These camels are kept in the water at the layberth pier. They are rarely used for Ohio class (Trident) submarines. Instead, they are used for other classes of visiting subs, sometimes from foreign countries. On occasion, the camels are also used for surface ships. The camels sometimes get caught on the steel wale along the pier fender piles, causing them to ride in the wrong position and possibly causing local buckling and distortion of the wale and vertical steel H-pile. Overhaul on these camels is often performed on the layberth pier or in the dry dock.

There are two sets (four camels) of tapered standard 688/Deep Draft Camels. One set is kept in the water at the lay berth. The other set is presently being overhauled. One 688/Deep Draft Camel was completely overhauled last year and is being kept in a storage yard. The corresponding camel from the set was in the same storage yard awaiting an overhaul. The 688/Deep Draft Camels have experienced typical rusting of steel parts and excessive pitting of the steel tube structure. Some of the timber and most of the fenders were in good repair and salvageable. These camels also get caught on the steel wale along the pier fender piles, causing them to ride in the wrong position and possibly causing local buckling and distortion of the steel fender system. They are used for berthing Los Angeles (688) class submarines at the layberth.

There are six sets (12 camels) of TRF Spudlock/Spudmoor Camels used at the Trident Refit Facility (TRF) to berth Ohio and Los Angeles class submarines. These camels are kept in the water along the trident refit wharf. Four camels are used at each of the three berths. Cranes of adequate capacity and mobility are not available to remove the spudlock camels from the water. Therefore, these camels must be floated to the dry dock for repair and maintenance. Scheduling use of the dry dock is difficult and can cause delays in performing inspections and other necessary maintenance. The camels are built with a locking arm system that fixes the camels in the horizontal plane to the steel tube (spud) piles. The camels move freely in the vertical plane to compensate for tidal action. The system is advantageous because the camels perform well and can remain in a fixed location because the wharf is dedicated to submarine service. The submarines moor directly to the camels, thus tending the lines is not required. The system creates a nuisance because divers are required to disengage the locking arm system to float the camels to dry dock and the bolts are often corroded and need to be cut off.

Future Plans:
The station does not anticipate any changes in the use and maintenance of current camel types.

Miscellaneous:

The site visit at this base included a tour of the EHW, Explosive Handling Wharf. The EHW is an enclosed over-water structure that covers a U-shaped slip for a couple of days to a couple of weeks during operations. The camels were designed for specific use with Ohio class submarines at this specific location. The camels are attached to the sub prior to it entering the facility. Because the camels are specifically designed for use in this facility and because the facility is not used for general berthing, these camels will not be considered in the study.

SITE VISIT REPORT
NAVAL STATION MAYPORT, FL
03 February 2004
Prepared on 11 February 2004

Visitors:
Frank Cole, NAVFAC Engineering Innovation & Criteria Office (EICO)
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Rodney Jones, Harbor Ops Repair Officer, (904) 270-5385, rjones@nsmayport.spear.navy.mil
CDR Rex Tullos, Harbor Ops Officer, (904) 270-5250, rtullos@nsmayport.spear.navy.mil
Bob Reeder, Deputy Harbor Ops, (904) 270-5266, rreeder@nsmayport.spear.navy.mil
Mike McVann, PWC Engineering, (904) 270-5207 x137, mmcvann@nsmayport.spear.navy.mil

Camel and Fender Information:

Pier /Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Wharf B3	SSN 688, SSBN 726, surface ships	Hydro-pneumatic Fender[1] 688/Deep Draft Camel[2]	None[1] NAVFAC 1404664-66[2]	Steel sheet pile, concrete cap @ MLW
Wharf C2	SSN 688, SSBN 726, CV, surface ships	Hydro-pneumatic Fender[1] 688/Deep Draft Camel[2]	None[1] NAVFAC 1404664-66[2]	Steel sheet pile, concrete cap @ MLW

1- Hydro-pneumatic Fender (3 fenders-10'x33' hydro-pneumatic fender, manufactured by Seaward International Inc.)
2- 688/Deep Draft Camel (1 set-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Hydro-pneumatic	unknown	transferred from NSB Kings Bay	as needed	$5,000	$10,000 to deploy
688/Deep Draft Camel	unknown	procured from NS Roosevelt Roads	none established	none established	none established

* costs based on a set of two camels, procurement costs are in year constructed and maintenance costs are from most recent service

Current Situation:
There are no submarines homeported at NS Mayport. Submarines visit approximately 2 to 3 times a year. Wharf structures comprise most of the waterfront and are constructed of steel sheet pile with a concrete pile cap. There are no fender piles on the wharves. The ships use foam filled fenders, mounted to wharf, to berth surface ships and CVN camels to berth aircraft carriers. The submarine camels are used a wharves B3 and C2 and ride directly on the wharf structure.

There are three hydro-pneumatic fenders at NS Mayport, which were given to the station by NSB Kings Bay about 10 years ago. The hydro-pneumatic fenders are kept in a storage yard one half mile from the waterfront because there is limited storage space at the waterfront. The deployment of the fenders is time consuming and costly. It takes approximately two full days to deploy the fenders and costs approximately $10,000 for the required crane and trailer service and 4-5 person crew. Deployment is difficult because cranes of adequate capacity are not readily available and because of limited space to operate at the waterfront. The fenders are also not very maneuverable in water. Overhaul on these fenders is rarely/never performed because of undefined maintenance requirements. Previous maintenance problems include replacement of an air relief valve and damage to the inner air jacket. The outer lining of one of the fenders was damaged during a storm when it was on loan to NAS Pensacola.

There is one set (two camels) of tapered 688/Deep Draft camels at NS Mayport, which were brought from Naval Station Roosevelt Roads, Puerto Rico within the past 6 months. Prior to arrival, the camels were completely overhauled. The camels were recently placed in the water. Since these camels have not had much use, no substantial maintenance cost information was provided. LANTDIV will coordinate with NS Mayport about a suggested operation and maintenance procedure and associated costs. Drawings will be provided that most likely match this type of camel.

<u>Future Plans:</u>
Because of the limited number of submarines that visit, the naval station does not anticipate any major changes in the use of the current camel types. NS Mayport will like to develop a regular maintenance schedule and operating procedure for the current camel types.

<u>Miscellaneous</u>
The site visit at this base included a meeting with Mike McVann with Mayport PWC Engineering. Mr. McVann provided information about the wharf construction and referred to the underwater inspection report performed in August 2002 by Naval Facilities Engineering Service Center. The wharves are not a flat surface from top to bottom. There is a concrete lip at the interface between the pile cap and the sheet pile. It must be noted that the hydro-pneumatic fenders may ride on this edge and the pier rub rails of the 688/deep draft camels may get caught on the lip. Also, the taper of the 688/deep draft camels does not match mostly parallel mid-body of the current submarines

SITE VISIT REPORT
NAVAL ORDANANCE TESTING UNIT (NOTU)
CAPE CANAVERAL AIR FORCE STATION, FL
04 February 2004
Prepared on 11 February 2004

Visitors:
Frank Cole, NAVFAC Engineering Innovation & Criteria Office (EICO)
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Carlos Alvarado, Facility Engineering, (321) 853-1223, spp122@spp.navy.mil
CWO4 Dennis Siler, Port Services Officer, (321) 853-1242, spp42@spp.navy.mil

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Poseidon Wharf	SSN 688, 21, 774, SSBN 726, surface ships	688/Deep Draft Camel[1]	NAVFAC 1404664-66[1]	Timber piles, Timber wale, Rubber fender blocks, Timber chocks
Trident Wharf	SSN 688, 21, 774, SSBN 726, FFG, DDG, DD, CG	688/Deep Draft Camel[1] Trident Camel[2] Hydro-pneumatic Fender[3]	NAVFAC 1404664-66[1] NAVFAC 1403444-45, 58-61, 3576-78[2] None[3]	Steel H-piles, Steel wale, Rubber fender blocks, Timber chocks

1- 688 Deep Draft Camel (3 sets-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)
2- Trident Camel (2 sets-steel plate frame with bumpers and fenders, designed by J.J. Henry Inc.)
3- Hydro-pneumatic Fender, (1 fender-3.3mx10.6m hydro-pneumatic fender, manufactured by Yokohoma Rubber Co., procurement for March 2004)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
688/Deep Draft Camel	1991	$182,000	1-year	$20,000, $95,000 overhaul	none established
Trident Camel	1978	$167,000	1-year	$20,000	none established
Trident Camel	1987	$250,000	1-year	$20,000	none established
Hydro-pneumatic	2004	$167,400 for fender, $150,000 for wharf modifications	To be established, per manufacturer	unknown	none established

* costs based on a set of two camels, except there is only one hydro-pneumatic, procurement costs are in year constructed and maintenance costs are from most recent service

Current Situation:
NOTU has two sets (four camels) of Trident Camels. The camels are stored in the water at the trident wharf. They are used to berth Ohio (Trident) class submarines at the Trident wharf. They are removed, inspected, and maintained annually. The annual maintenance consists of replacing the zinc anodes, inspecting and replacing deteriorated steel connectors and timber, and inspecting lifting eyes. The floatation tanks are pressure tested and NDT is performed every five years. Marine growth is not removed during inspection because it is thought to provide corrosion protection. Most submarines are berthed at the Trident wharf using these camels.

There are three sets (six camels) of tapered 688/Deep Draft Camels. One set is kept in the water at the Poseidon wharf. One set is presently being overhauled. The third set is stored on the shore and is planning to be overhauled in FY05. The 688/Deep Draft Camels have experienced typical rusting of steel parts, excessive pitting of the steel tube structure, and deteriorated timber. Marine growth is not removed during annual inspection and maintenance because it is thought to provide corrosion protection. However, the marine growth is removed when the camels are overhauled. These camels are only used at the Poseidon wharf for Los Angeles (688) class submarine berthing for a few hours.

One 3.3m x 10.6m hydro-pneumatic fender is on order and scheduled for delivery in March 2004. Fender modifications at the Trident wharf are in analysis and design stage to accommodate the new camel type. Additional hydro-pneumatic fenders will be procured when funds are available. The hydro-pneumatic fender and fender system modifications are being designed for a Los Angeles (688) class submarine. The costs of the modification is approximately $150,000. Projects to procure additional hydro-pneumatic fenders and to modify the Trident wharf fender system to berth an Ohio class submarine are currently being planned.

Future Plans:
NOTU is in the process of modifying its berths to accommodate the use of hydro-pneumatic fenders and is currently in the process of procuring these fenders. This modification is primarily due to positive experiences with the use of hydro-pneumatic fenders at other naval installations.

Miscellaneous
While on-site, we meet with representatives from the Yokohoma Rubber Co. and discussed hydro-pneumatic fenders. We were briefed on the hydro-pneumatic fenders available and the one presently being procured. We also met with Sandra Rice of Gee & Jenson / CH2MHILL and Kim McDonald of Cape Design Engineering and discussed the modifications to the fender system on the Trident wharf in order to accommodate hydro-pneumatic fenders for a Los Angeles class submarine.

SITE VISIT REPORT
PUGET SOUND NAVAL SHIPYARD
NAVAL STATION BREMERTON, WA
(Naval Base Kitsap – Bremerton)
15 March 2004
Prepared on 25 March 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Bill Johnson, Regional Harbormaster, (360) 476-1138, william.h.johnson@navy.mil
Darryl Stuart, Regional Service Craft Boat Custodian, (360) 476-9663, darryl.stuart@navy.mil
Bob Stroup, PSNSY Piermaster, (360) 476-3532, stroupr@psns.navy.mil

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Piers 3-7, B, C	SSN 688, SSBN 726, AOE, CV, CVN, DD, DDG, FFG	Trident Deep Draft Barge Camel[1]	PSNS #X72502[1]	Timber piles, wales and chocks, Rubber fender blocks
Pier D	SSN 688, SSBN 726, AOE, CV, CVN, DD, DDG, FFG	Trident Deep Draft Barge Camel[1]	PSNS #X72502[1]	Concrete piles with UHMWPE rub strips

1- Trident Deep Draft Barge Camel (2 sets-tapered, 4 sets non-tapered, steel W-shape and angle frame with fenders, designed by Production Engineering Division, Code 380 PSNS)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Trident Deep Draft Barge Camel	1960-1990	$250,000	8-years	$400,000	$2,000

* costs based on a set of two camels, procurement costs are based on 1980 construction cost and maintenance costs are from most recent service

Current Situation:
The Puget Sound Naval Shipyard and Naval Station Bremerton (NS Bremerton), now Naval Base Kitsap – Bremerton, are co-located and share six sets (12 camels) of Trident Deep Draft Barge camels. The camels consist of either a 15'x60' or 15'x56' YC barge with a steel frame connected to the underside of the barge. The steel frames have rubber fenders on both the submarine and pier sides. The station typically berths Los Angeles and Ohio class submarines for repairs, overhauls, and scrapping. Other older classes of submarines are berthed at the station in preparation for scrapping. Several Ohio class submarines are in port and are being overhauled for the SSBN to SSGN conversion.

The Naval Station and Shipyard piers have a typical timber fender pile system throughout, except Pier D has concrete fender piles. The barge camels are chained to the fender piles and ride directly against them. Also, there is a log camel attached to the fender system to keep floating debris out. Submarines are moored to both the pier and camel with the spring lines running to the camel.

A double-brow system is used between the pier and the submarine. One brow goes from the pier to the camel and another goes from the camel to the submarine. This system is necessary because portal crane tracks run three feet from each pier edge, which does not allow sufficient distance to accommodate typical brow movements. Also, the tidal range is approximately 15 feet, which makes the use of a single brow difficult.   The brow coming from the pier to the barge camel is secured to a platform that extends from the face of the pier. This keeps the brow and other obstructions completely off of the main pier deck. The barge camel provides a work platform and an area to store equipment. Typical equipment includes weld boxes, electrical converters, and utility cable supports.

The camels were originally designed with a tapered steel frame to accommodate the Sturgeon Class (SSN 637) submarine geometry. More recent procurements and overhauls (~1980, ~1990) eliminated the taper and extended the draft to adjust to current submarine geometry and draft, however two tapered sets are still in use. The barge camels are used with all classes of submarines. Two barge camels are used to berth all classes of submarines. When not in use, the camels are kept in the water. The barge camels may be used at any berth and are moved as necessary. Towing and maneuvering the camels through the water is difficult and slow because the camels are so large.

A contractor typically performs the maintenance on the camels at an offsite location. The camels are removed from the water and overhauled about every eight years. Divers inspect the camels about every four years and do minor maintenance. This typically costs $5,000. Station personnel state that the camels are virtually maintenance free and only require typical cleaning, rubber, and replacement of the zinc anodes, and inspection and testing. Adequate crane capacity is available to remove the camels from the water. The need for repairs does not cause any operational problems since multiple camels are available.

Future Plans:

The region plans to maintain the status quo for use and maintenance of current camel types. This is primarily driven by the large tidal changes, pier layout and space constraints at the facility. The station prefers the current system because of dual purpose the camels serve, setting the submarine off the pier at an adequate distance as well as providing a brow and work platform to support the submarine overhaul and keep the pier free from obstructions. The station dislikes the size and weight of the camels, which makes them difficult to maneuver and position.

Miscellaneous:

Local environmental constraints have other small impacts on general berthing. Fender piles are restricted to replacement during certain periods of the year due to fish spawning. Large log camels are chained along each pier and between camels to keep debris from floating under the pier and getting trapped. The presence of a log camel creates a gap in the camel-to-fender interaction and may cause some rotation in the camel during use.

NS Bremerton uses NSB Bangor personnel and berthing systems to berth submarines at an off station location. The berthing system used consists of hydro-pneumatic fender with a portable backer board known as a flyaway kit.

SITE VISIT REPORT
NAVAL SUBMARINE BASE BANGOR, WA
(Naval Base Kitsap – Bangor)
16 March 2004
Prepared on 25 March 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Brian Farr, Docking Office, (360)315-1862, brian.farr@imfb.navy.mil
Jerry Hackett, Public Works Engineer, (360) 396-5057, gerald.hackett@navy.mil
Norm Clare, Facilities Dept., (360) 315-1677, norman.clare@navy.mil (did not meet)

Camel and Fender Information:

Pier /Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Delta Refit Pier	SSBN 726, SSN 688	Refit Pier Captured Camel[1]	NAVFAC 6046044-49[1]	Concrete filled steel tube piles, steel wales
Marginal Wharf	SSN 688, surface ships	Deep Draft Barge Camel[2] Hydro-pneumatic Fender[3] 688 Standard Deep Draft Camel[4] Trident Camel[5]	NAVFAC 6296882-88[2] None[3] NAVFAC 1404664-66[4] NAVFAC 1403444-61, 1403576-78[5]	Concrete filled steel tube piles mixed with Timber piles, Rubber fender blocks
Service Pier	SSN 683	Special **	None	Timber & steel piles

1- Refit Pier Captured Camel (5 camels - steel tube frame with pipe clamps on spud piles and fenders, designed by ABAM / HNTB for NSB Bangor)
2- Trident Deep Draft Barge Camel - (2 sets, steel W-shape and angle frame with fenders, designed by PSNS and modified by Jesse Eng. and NSB Bangor)
3- Hydro-pneumatic Fender (6 fenders-11'x33' hydro-pneumatic fender, manufactured by Yokohama Rubber Company)
4- 688 Standard Deep Draft Camel (1 set-tapered, 1 set non-tapered - steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM, non-tapered standard design modified)
5- Trident Camel (1 set-steel plate frame with bumpers and fenders, designed by J.J. Henry Inc.)
Special ** - Facility specific camel, will be replaced with entire facility in future MCON project to support SSN 23 (Jimmy Carter), new camels will be similar to captured camels on Delta Refit Pier

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Refit Pier Captured Camel	1980	$400,000	5 years	$65,000	Mission Funds**
Trident Deep Draft Barge Camel	1982/1985	$163,000/$90,000	5 years	$25,000	Mission Funds**
Hydro-pneumatic	1985-88	$250,000	1 year	$5,000	Mission Funds**
688 Standard Deep Draft Camel	1984	Unknown	None established	N/A	Mission Funds**
Trident Camel	1980	Unknown	None established	N/A	Mission Funds**

* Costs based on a set of two camels except the captured camel and hydro-pneumatic is single, procurement cost in year constructed, and maintenance cost from most recent service
** Operation Costs are provided through mission funds

Current Situation:
Naval Submarine Base Bangor (NSB Bangor), now Naval Base Kitsap – Bangor, has a variety of submarine camels. The camel predominantly used is the Captured camel. This camel is very similar to the Spudlock/Spudmoor camels used at NSB Kings Bay. NSB Bangor has five Captured camels, which are used at the Delta Refit Pier and are kept in the water along the pier. This pier has 2 submarine berths, which use either 2 or 3 Captured camels. The camels are built with a locking arm system that fixes the camels in the horizontal plane to steel tube (spud) piles. The camels move freely in the vertical plane to compensate for tidal action. The system is advantageous because the camels perform well and can remain in a fixed location because the wharf is dedicated to submarine service. The submarines moor directly to the camels, thus tending the lines is not required. Cranes of adequate capacity and mobility are not available to remove the camels from the water. Therefore, these camels must be floated to the drydock for repair and maintenance. Maneuvering these camels through the water is very difficult because of the large amount of the structure is below the water. Scheduling use of the drydock is difficult and can cause delays in performing inspections and other necessary maintenance.

There are 2 sets (4 camels) of Barge camels kept in the water at the Marginal Wharf. These camels are similar to the Barge camels at NS Bremerton. These camels have a 15’x60’ float platform with a steel frame connected to the underside of the barge. The steel frames have rubber fenders on both the submarine and pier sides. The first set of camels included an all rubber fender face and was built by a contractor based on the NS Bremerton design. The second set included a timber and rubber fender face and was built by in-house personnel based on a modified in-house design. A double-brow system is used to span between the pier and the submarine. This system is useful because a single brow can not accommodate the large tidal changes. The barge is also useful because it provides a staging area for equipment and material. Overhaul on these camels is similar to the Captured camels, also performed in dry dock. Since the camels are so large, towing and maneuvering them through the water is difficult and slow.

There are six - 11’x33’ hydro-pneumatic fenders that are not used for general submarine berthing at NSB Bangor. They are used for submarine berthing at sites that do not regularly berth submarines or do not have an adequate fender system. They are also are used for breasting out other submarines and ships, such as submarine tenders. The fenders are part of a system known as a “fly-away” kit, which also includes backer-board that is developed specifically for the deployment site. Four of these fenders are used when berthing Ohio class submarines. Some of the hydro-pneumatic fenders are kept slightly inflated on the marginal wharf while others were left floating in the water. One fender had valve problems and was left deflated on the pier. This fender also has significant cracks in the outer rubber surface including around the valve. Another fender previously had valve problems and needed replacement. The fenders are pulled out of the water, if not already, and cleaned and inspected annually. This form of deep draft submarine camel is easy to transport and setup, but requires the use of a backer system.

There are two sets (4 camels) of the typical 688 Standard Deep Draft camels. Two are tapered and two are non-tapered. There have been some modifications made to these camels, but they are basically the same as the standard design. They are stored out of the water, to prevent further deterioration, at the Marginal Wharf. They were brought to the base in 1984 from an unknown installation. The camels are rarely, if ever used, and therefore no regular maintenance is performed except for recently being blasted and cleaned. NSB Bangor is looking at replacing the timber with composite plastic materials. The 688 Standard Deep Draft camels are not very useful because they cannot be used for submarine classes other than the Los Angeles class, they require a lot of maintenance, they do not work well with the existing fender system, and they are not large enough to adjust with the changing tide.

There is one set (two camels) of Trident camels. The camels are stored in the water at the Marginal Wharf. They are occasionally used as separators. The camels were constructed as part of the drydock construction project. They were intended to provide mooring for an Ohio class submarine on the East side of the drydock as a wet berth. However, it is believed that the camels but have never used for this purpose. The camels are not maintained.

<u>Future Plans</u>

The station does not anticipate any changes in the use and maintenance of their current camel types, except for a MILCON project to refurbish the Service Pier. The camels used at this pier will be similar to the Captured camels.

<u>Miscellaneous</u>

The site visit at this base did not include touring the Magnetic Silencing Facility or the Explosive Handling Wharf, since similar structures were observed at a previous site visit to NSB Kings Bay, GA. The Service Pier was inspected briefly because USS Parche (SSN 683) is berthed at this pier. The mooring and camels used at its berth are specially designed for this unique submarine. This submarine will be decommissioned shortly and a MILCON project will modify the pier to berth the USS Jimmy Carter (SSN 23). The camels used at this pier will be similar to the Captured camels. Therefore, the current camels used at this service pier were not considered in this study.

SITE VISIT REPORT
NAVAL STATION POINT LOMA
NAVAL STATION SAN DIEGO, CA
18 March 2004
Prepared on 31 March 2004

Visitors:

Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:

Soliman Labrador, SWDIV Project Manager, (619) 556-9898, soliman.labrador@navy.mil
BMC Darrell Morgan, Dock Master, (619) 553-8141, darrell.morgan@navy.mil
Paul Miller, Port Operations Contractor, (619) 553-8141, spp42@spp.navy.mil
William McAndrew, Crane Division Supervisor, (619) 556-8582, william.mcandrew@navy.mil

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
November Pier, 5003	SSN 688	Hydro-pneumatic Fender[1]	None[1]	Concrete fender piles, Steel plate/beam backer board
Mike Pier, 5000	SSN 688, SSBN 726	Hydro-pneumatic Fender[1]	None[1]	Concrete fender piles, Steel plate/beam backer board
Sierra Pier, 5002	AFDM, AOE, Oiler	N/A (Foam Filled Fenders)	N/A	N/A

1- Hydro-pneumatic Fender, (11 fenders-11'x33' hydro-pneumatic fenders, manufactured by Seaward, PROMAR-YRC, installed under pier fender system modification project NAVFAC Dwg # 8110793-8110819)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Hydro-pneumatic	1997	Unknown**	Annual-minimal	$2,000	OM&N***

* Costs based on a single hydro-pneumatic fender, procurement cost in year procured, maintenance cost from most recent service
** Procurement costs unknown because fenders were procured under pier fender system modification project, but is estimated to be $500,000 per fender and backer system
*** Operation Costs are provided through operational funding

Current Situation:

Naval Station Point Loma (NS Point Loma) has 11 - 11'x33' Hydro-pneumatic fenders, which it solely uses to berth Los Angeles class submarines and visiting Ohio class submarines. The fenders are from a variety of manufactures including Seaward and PROMAR-YRC. The fender systems at the November and Mike piers where modified with a MILCON project in 1997 to accept the fenders at dedicated locations to accommodate submarines. Two hydro-pneumatic fenders are used for Los Angeles class submarines and three fenders are used to berth Ohio class submarines.

The fender system consists of eight 24-inch square prestressed concrete piles with a UHMWPE rub strip on the ship side and a steel support frame connecting the tops of the piles together and to the pier. The hydro-pneumatic fenders are breasted off the fender piles with a steel backer-board hung from the fender piles. The hydro-pneumatic fenders are stored in the water at the dedicated locations. Sierra Pier does not berth submarines.

The site visit included a meeting with William McAndrew of Public Works to review maintenance procedures for the hydro-pneumatic fenders. He indicated that no regular maintenance is conducted on the fenders, but have required some maintenance over the years. They are removed, cleaned, inspected, and the pressure is adjusted on an as-needed basis. Public Works is called out about once a year to fill some fenders with air because they have shown signs of sinking. It was also indicated that they have had to remove two fenders to clean, rework, and reinstall them. It was identified that a regular inspection and maintenance program should be established. A concern about the condition of the ballast weight, chain, and shackle was indicated. The area experiences wave action and high tides and current, which may lead to significant wear and deterioration to these components and the fender itself. Since no regular maintenance is performed, the condition of the fenders and components is unknown. Typical maintenance should include removal of marine growth, inspection and repair of the ballast weight, chains, shackle and the valve system as needed. The pier fender system and backer should also be inspected and maintained.

Port Operations and Public Works like this camel/fender system and have no problems or dislikes with the hydro-pneumatic fenders concerning their use or maintenance. Concern was expressed that the future submarine modifications that could extend the submarine's dive planes may require a greater standoff than what is provided with the current camels in use. It was observed that some of the protective covers on the chains, which connect the fender to pier, have slipped down and are starting to abrade the rubber surface of the hydro-pneumatic fenders.

<u>Future Plans</u>

Since the fender systems for the 2 piers were recently replaced to utilize hydro-pneumatic fenders for all submarine berths, the station plans to continue using the hydro-pneumatic fenders. Port Operations is interested in a lease program for hydro-pneumatic fenders where the manufacturer or a contractor provides maintenance and support. Alternatives are currently being analyzed to berth multiple Ohio class submarines at Mike pier using the current fender configuration.

<u>Miscellaneous</u>

In 1997 a hydro-pneumatic fender, manufactured by Seaward, failed on Pier 5003. No damage occurred to the submarine berthed using the fender or to the pier. The Naval Facilities Engineering Service Center (NFESC) conducted an investigation. This investigation concluded the fender failed due to manufacturing defects in the fender's skin. However, there is still debate as to the actual cause of the failure.

SITE VISIT REPORT
NAVAL STATION PEARL HARBOR, HI
22 March 2004
Prepared on 31 March 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
DMC Rodney Williams, Dock Master, (808) 473-2500, williarl@pearlharbor.navy.mil
Mel Tsutahara, PACDIV Structural, (808) 472-1271, melvyn.tsutahara@navy.mil
Aaron Kam, PACDIV Structural Engineer, (808) 472-1278, aaron.kam@navy.mil
Joanne Higuchi, Regional Engineer Office, (808) 473-3612, joanne.higuchi@navy.mil

Camel and Fender Information:

Pier /Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
S-1A, S-1B Wharf	SSN 688	Hydro-pneumatic Fender[1]	None[1]	Concrete fender piles, Plastic wales, chocks, blocks, Steel beam backer boards
S-8, S-9 Pier	SSN 688	Hydro-pneumatic Fender[1]	NAVFAC 7616371-7916424 (pier fender system modifications)	Concrete fender piles, Plastic chocks, blocks, Steel beam backer boards
S-10, S-11 S-12, S-13 Wharfs	SSN 688	Hydro-pneumatic Fender[1]	NAVFAC 7944790-7944842 (pier fender system modifications)	Concrete fender piles, Plastic wales, chocks, blocks, Steel beam backer boards
S-20, S-21 Wharfs	SSN 688	688 Standard Deep Draft Camel[2]	NAVFAC 1404664-66[2]	Timber fender piles, wales and chocks
Y-2 Wharf	SSN 688	Hydro-pneumatic Fender[1]	None[1]	Concrete fender piles, Timber wales, chocks, blocks, Steel beam backer boards
Y-3A, Y-3B Wharfs	SSN 688	Hydro-pneumatic Fender[1]	None[1]	Concrete fender piles, Timber wales, chocks, blocks, Steel beam backer boards
F-12, F-13 Wharfs	SSN 688 SSBN 726	688 Standard Deep Draft Camel[2]	NAVFAC 1404664-66[2]	Timber fender piles, wales and chocks

1- Hydro-pneumatic Fender, (22 fenders-11'x33' and 6 fenders- 14'x30' hydro-pneumatic fenders, manufactured by Seaward, PROMAR-YRC, and Yokohoma)
2- 688 Standard Deep Draft Camel (12 sets-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Hydro-pneumatic	1995-2004	$118,000	Not established	$5,000	OM&N**
688 Standard Deep Draft Camel	Unknown	Unknown	3-4 Years	$126,000	OM&N**

* Costs based on a set of two camels, except the hydro-pneumatic is based on one fender, procurement costs are in year procured, maintenance costs are from most recent service
** Operation Costs are provided through operational funding

Current Situation:

Naval Station Pearl Harbor (NS Pearl Harbor) uses two types of camels at its multiple submarine berths. The station has 28 Hydro-pneumatic fenders of various sizes and 12 sets (24 camels) of tapered 688 Standard Deep Draft camels. The camels/fenders are stored in the water at various locations around the station, however some of the 688 Standard Deep Draft camels are presently on shore for maintenance and overhaul. The station is homeport for several Los Angeles class submarines and Ohio class submarines visit occasionally. NS Pearl Harbor has been designated a homeport for Virginia class submarines, however none have been stationed there yet. Two camels or hydro-pneumatic fenders are used to berth Los Angeles class submarines and four camels or hydro-pneumatic fenders are used to berth Ohio class submarines. Ohio class submarines are berthed for short periods of time at berths F-12 or F-13 and are berthed overnight at berths B-7 or B-16. The fender system for Berth B-7 consists of timber fender piles where 688 Standard Deep Draft camels are used and Berth B-16 consists of concrete fender piles at dedicated locations where Hydro-pneumatic fenders are used.

There are several sizes of hydro-pneumatic fenders used at NS Pearl Harbor and include 11'x33', and 14.8'x30'. The fenders are also from a variety of manufacturers including Seaward, PROMAR-YRC, and Yokohoma. The fenders have been procured in several manners, but the most recent procurement method was through a NAVSEA contract with Fender Care. Relatively little maintenance is performed on the hydro-pneumatic fenders. However, there have been problems with the valves leaking on several of the fenders causing them to sink, particularly those manufactured by Seaward. There were several fenders in a storage area that were deflated and/or sunk because of loss of air. Marine growth on the fenders is another problem. At one time, Seward had a contract to visit the station and inspect and maintain the camels on a quarterly basis. The fenders are difficult and cumbersome to deploy. A tugboat is used to move the fenders around in the water. NS Pearl Harbor really like the hydro-pneumatic fenders they currently use because of they are low in maintenance and work well at this location.

The 688 Standard Deep Draft Camels are used at Berths S-20, S-21, F-12, and F-13 because these berths have not been modified to accept hydro-pneumatic fenders. The fender systems at these locations consist of timber fender piles. The camels have experienced typical corrosion of steel parts and structural members and deterioration of timber elements. Some of the camels have had the timber elements replaced with reinforced composite members. These camels have a tendency to break the old deteriorated timber fender piles they are put against. No regular maintenance is performed on the camels. They are repaired on an as needed basis. A contractor is used to perform overhaul and maintenance on these camels. There is limited crane capacity at the station and a YD crane must be used to lift the camels. They are extremely heavy and are difficult to lift and haul.

Future Plans

The station plans to procure more hydro-pneumatic fenders in the next few years and to modify Berths S-20, S-21, F-12, and F-13 to accommodate the fenders. The goal is to have every berth modified to use the hydro-pneumatic fenders and have hydro-pneumatic fenders for every berth. The hydro-pneumatic fenders will be used as much as possible and the station plans to phase out the use of 688 Standard Deep Draft camels.

Miscellaneous

It was observed that the hydro-pneumatic fenders were riding much higher in the water than what was typically observed. The fender should ideally be positioned where the center of the submarine lines up with the center of the fender. If the fender is too high then the fender might not be providing enough cushioning effect to the submarine and may pop up when pushed against or the counter weight may contact the submarine or pier.

When an Ohio class submarine is berthed using 688 Standard Deep Draft camels, the camels are not modified in any manner. The 688 Standard Deep Draft camels are designed for use with Los Angeles and earlier class attack submarines. The Ohio class submarine has a deep draft and a much greater displacement than attack submarines. The Seawolf class submarine also has a draft similar to the Ohio class. The 688 Standard Deep Draft camels do not have the draft or fendering to properly berth Ohio and Seawolf class submarines.

SITE VISIT REPORT
NAVAL STATION ROTA, SPAIN
10 March 2004
Prepared on 8 June 2004

Visitors:

Rick Kahler, NAVFAC, Atlantic Division, Supervisory Structural Engineer

Points of Contact:

Chief Williams Barnes, Port Operations, (314) 757-2811 DSN, BarnesW@navsta.rota.navy.mil
CPO Lockett, Port Operations

Camel and Fender Information:

Pier /Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Pier I	SSN 688, SSBN 726	688 Standard Deep Draft Camel[1]	NAVFAC 1404664-66[2]	Closed concrete quay wall

1- 688 Standard Deep Draft Camel (1 set-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
688 Standard Deep Draft Camel	Unknown	Unknown	3-4 Years	$207,000	OM&N**

* Costs based on a set of two camels, procurement costs are in year procured, maintenance costs are from most recent service
** Operation Costs are provided through operational funding

Current Situation:

Naval Station Rota, Spain (NS Rota) has one set (2 camels) of the tapered type of 688 Standard Deep Draft camels for the berthing submarines. It is not known how or when these camels were procured. They are constructed of a steel tube frame and floatation tanks with fenders on the submarine side and timber rub strips on the pier side. There is only one berth (1200 ft) on the inboard end pf Pier I at NS Rota for all U.S. ships to use. Pier I is a closed concrete quay wall that is integral with the breakwater of the harbor. Foam filled fenders are used as the primary fender system on Pier I to berth surface ships and the 688 Standard Deep Draft are used for submarine berthing and are breasted directly against the quay wall. The camels may be placed anywhere along the berth, but typically positioned where services are convenient. Los Angeles class submarines visit the station about once a month and stay for 3 to 10 days.

The camels are stored out of the water and are presently located on a YD crane. The camels are susceptible to damage due to weather events and swells if they are stored in the water because the large tidal range (8’-10’) requires long mooring lines which become slack at high tide. Also, due to the limited berth space, leaving the camels in the water at the berth impractical. The camels are deployed 72 hours prior to the arrival of a submarine.

The camels have experienced typical corrosion of steel parts and structural members and deterioration of timber elements. Regular maintenance and painting is performed on the camels about every 18 months. The camels were completely overhauled in 1994 for $207,000 and the timber fenders were replaced in 2003 for approximately $80,000. There is limited crane capacity at the station presently because the portal crane is under repair. A YD crane is temporarily in port to support lifting operations. In the past, a 200-ton mobile crane or two smaller mobile cranes and a low boy have been used to lift and haul the camels around the station. The camels are extremely heavy, difficult to lift, and it is time consuming and expensive to lift and haul around.

In 2000 a Ohio class submarine visited NS Rota. Two 11'x33' hydro-pneumatic fenders were loaned to NS Rota by NSA La Maddalena to berth the submarine. It is believed that SUBLANT owns these fenders and uses them for submarine berthing throughout the Mediterranean region. The berthing of the Ohio class submarine occurred before the current personnel were at the station, so no first hand knowledge of the use of the hydro-pneumatics is known.

Future Plans

A security fence is planned to be constructed around the waterfront at NS Rota. This fence will limit the onshore mobility of the camels and will require them to be stored on the pier further limiting usable pier space.

Miscellaneous

SITE VISIT REPORT
PORTSMOUTH NAVAL SHIPYARD
11 May 2004
Prepared on 24 May 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Dan Granahan, Public Works, (207) 438-4590, granahandw@mail.ports.navy.mil
Roger Raymond, Code 270.3, (207) 438-3172, raymondrc@mail.ports.navy.mil
Ted Knowles, Port Operations, (207) 438-1100, knowlesct@mail.ports.navy.mil

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Berth 6B	SSN 688, Coast Guard	Float Camels[1] 688 Standard Deep Draft Camels[2]	PED 8526[1] NAVFAC 749924-749925[2]	Sloped steel H-pile with concrete panel quay wall
Berth 6C	SSN 688, Coast Guard	Float Camels[1] 688 Standard Deep Draft Camels[2]	PED 8526[1] NAVFAC 749924-749925[2]	Sloped steel sheet pile quay wall
Berth 11B	SSN 688, SSBN 726	24ft Deep Draft Camel[3]	PS 29015, 28962[3]	Timber piles, wales and chocks, Rubber fender blocks
Berth 11C	SSN 688, SSBN 726	32ft Deep Draft Camel[4]	270.3-29015, PS 28962[4]	Timber piles, wales and chocks, Rubber fender blocks
Berth 13B	SSN 688	24ft Deep Draft Camel[3]	PS 29015, 28962[3]	Timber piles, wales and chocks, Rubber fender blocks

1- Puget Sound Design/Float Camel (1 set-tapered, steel W-shape and angle frame with fenders, design adapted from Puget Sound Naval Shipyard Barge Camel design, modified by Facilities Branch – Waterfront Support, Code 270.3, Portsmouth Naval Shipyard)
2- 688 Standard Deep Draft Camel (2 sets-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)
3- 24 Foot Deep Draft Camel (2 sets- steel pipe frame with fenders and timber rub strips, designed by Code 270.3, Portsmouth Naval Shipyard)
4- 32 Foot Deep Draft Camel (1 set- steel pipe frame with fenders and timber rub strips, designed by Code 270.3, Portsmouth Naval Shipyard)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Float Camels	Unknown	Unknown	Unknown	Unknown	OM&N**
688 Standard Deep Draft Camels	Unknown	Unknown	None, no longer used	N/A	N/A
24ft Deep Draft Camel	1998	$150,000	5-years	$10,000	OM&N**
32ft Deep Draft Camel	2001	$150,000	5-years	$10,000	OM&N**

* Costs based on a set of 2 camels, procurement cost in year constructed, and maintenance cost from most recent service
** Operation Costs are provided through operational funds

Current Situation:
Portsmouth Naval Shipyard (Portsmouth NSY) uses four types of camels to berth submarines. The station has 1 set (2 camels) of Float camels, 2 sets (4 camels) of tapered 688 Standard Deep Draft camels, 2 sets (4 camels) of 24 Foot Deep Draft camels, and 1 set (2 camels) of 32 Foot Deep Draft camels. The camels/fenders are stored in the water at various locations around the station, except the 688 Standard Deep Draft camels are presently on shore. One set of camels is used to berth submarines. The shipyard typically only sees Los Angeles class submarines, but when an Ohio class submarine visited previously, a set of 24 Foot Deep Draft camels were used at Berth 11 to berth the submarine.

The Float camels are an adaptation of the Puget Sound Naval Shipyard - Trident Deep Draft Barge camel design. The design consists of a flotation barge with a steel frame connected to the underside of the barge. The steel frame has rubber fenders on both the submarine and pier sides. Portsmouth NSY personnel modified the design where the steel frame hangs from the barge, which makes the frame removable for maintenance. A double brow system, similar to that used at NS Bremerton/ Puget Sound NSY, is used with this camel to access the submarines because of the significant tidal fluctuation and current in this area. These camels are primarily used at Berth 13, but are used at Berth 6 when needed. Submarines are moored directly to the pier and not the camels. The Float camel has its advantages by acting as a work platform and allowing services to be run to camel. The steel frame is tapered, because it is based on the old Puget Sound NSY design, but the timbers on the back have been built out to take out some of the taper. These camels are large and difficult maneuver through the water.

The 688 Standard Deep Draft camels are not presently used and are being phased out. When they were in use, they were placed at any pier. They are old, deteriorated, and difficult to maintain. The camels are tapered and were original designed for a class of submarine that is no longer in service. Modern submarines have a parallel mid-portion of the hull, which does not fit the taper of the camels unless the camels are put on the ends of the submarines were there is a taper. This is recognized by shipyard personnel and is one reason why the camels no longer used. The camels have experienced typical corrosion of steel parts and structural members and deterioration of timber elements. There have been some modifications to the original design, which include the use of arch fenders, additional rub rails, and additional angle braces. No regular maintenance is performed on the camels any longer.

The 24 Foot and 32 Foot Deep Draft camels are basically the same. They were designed by Portsmouth NSY personnel and consist of a steel tube frame and floatation tanks with arch fenders on the submarine side and timber rub strips on the pier side. The 24 Foot Deep Draft camels have 24 ft long flotation tanks and lower tubes while the 32 Foot Deep Draft camels have a 24 ft long flotation tank and lower tube on the submarine side and a 32 ft long flotation and lower tube on the pier side. The 24 Foot Deep Draft camels originally had a 32 ft timber on the pier side to distribute mooring loads to more fenders piles, but this timber would get caught in the fender system and they were cut back to 24 ft. The newer design has the pier side tubes 32 ft long with a 32 ft timber to distribute the mooring loads. These camels are easy to maneuver through the water. Regular maintenance is performed on these camels on a five-year basis, depending on the budget in any given year, and consists on blasting marine growth off, painting, and performing minor maintenance. The brows used with these camels have been redesigned to include steps and a cantilevered access platform to accommodate the high tidal fluctuations. The shipyard really likes the 24 Foot and 32 Foot Deep Draft camels.

Future Plans

Portsmouth Naval Shipyard plans to phase out the 688 Standard Deep Draft camels and continue to use the 24 and 32 Foot Deep Draft camels. There currently is no plan to procure additional camels.

Miscellaneous

Berths 6B and 6C are also used by a Coast Guard ship that is homeported at Portsmouth NSY. These berths have been modified with foam filled fenders and UHMWPE rub strips attached to the quay wall to accept the ship. The foam filled fenders are removable if the berth is needed for a submarine. Berth 6C sees the highest current of the submarine berths a Portsmouth NSY due to its geographic location along the Piscataqua River.

SITE VISIT REPORT
NAVAL SUBMARINE BASE NEW LONDON
12 May 2004
Prepared on 1 June 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Stephen Meagher, Public Works, (860) 694-4912, stephen.meagher@navy.mil
Chief Nixon, Port Operations, (860) 694-1437, gary.nixon@navy.mil
Chief Richardson, Port Operations, dwayne.richardson@navy.mil
Preston Tonepahhote, Port Operations, (860) 694-3756, preston.tonepahhote@ navy.mil

Camel and Fender Information:

Pier/Berth	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Pier 8	SSN 688, SSN 21	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber wales and vertical chocks facing, steel wales, steel blocks, column fenders
Pier 10	SSN 688, SSN 21 (South)	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber wales and vertical chocks facing, steel wales, steel blocks, column fenders and steel blocking
Pier 12	SSN 688	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber wales and vertical chocks facing, steel wales, steel blocks, column fenders
Pier 15/S	SSN 688, SSN 21, SSN 774	Fixed Fenders/ Universal Camels[3]	None[3]	Concrete filled composite piles, composite/concrete pile cap, round fenders, cabled back
Pier 17/S	SSN 688, SSN 21	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber and HDPE facing, timber chocks, steel wale, arch fenders, chained back
Pier 31/N	SSN 688	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Timber piles, wales, chocks, blocks, bottom wale
Pier 32	SSN 688	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber chocks and wales facing, steel wales, steel blocks, arch fenders
Pier 33	SSN 688	Seawolf Camels[1] 688 Standard Deep Draft Camels[2]	NAVFAC 1404667-1404670[1] NAVFAC 1404664 - 1404666[2]	Steel H-pile with timber chocks and wales facing, steel wales, steel blocks, arch fenders

1- Seawolf/Attack Sub Camel (8 sets- steel tube frame with fenders and UHMWPE rub strips, designed by LANTNAVFACENGCOM)
2- 688 Standard Deep Draft Camel (14 sets-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)
3- Fixed Fender/Universal Camels (1 set- composite D-shaped camel with fenders and built-in backer with UHMWPE rub strips, designed by NFESC)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
Seawolf Camels	1996-2002	$200,000	Non-established	$10,000**	Unknown***
688 Standard Deep Draft Camels	Unknown	Unknown	As needed	$80,000	Unknown***
Fixed Fenders/ Universal Camels	2000	$490,000	Non-established	N/A	Unknown***

* Costs based on a set of 2 camels, procurement cost in year constructed, and maintenance cost from most recent service
** Materials only, labor is provided by station personnel
*** Operation Costs are provided through operational funds

Current Situation:

Naval Submarine Base New London (NSB New London) uses three types of camels to berth submarines. The submarine base has 8 sets (16 camels) of Seawolf/Attack Submarine camels, 14 sets (28 camels) of tapered 688 Standard Deep Draft camels, and 1 set (2 camels) of Fixed Fender/Universal camels. The camels are stored in the water at various locations around the station, however, several of the 688 Standard Deep Draft camels are presently on shore to be repaired and several have sunk due to deterioration. Ohio class submarines have not been stationed at or visited NSB New London because they are too large for the pier facilities. NSB New London uses sets of two camels are used to berth submarines at its piers. The submarine base typically only sees Los Angeles class and Seawolf class submarines. Typically only one submarine is berthed at a pier, because a single submarine tends to take over the entire pier with its equipment and services due to the narrowness of the piers. It was indicated that there is adequate crane service to perform lifting operations.

The Seawolf or SSN 21 class (Attack Submarine per NAVFAC drawings) camels are constructed of a steel tube frame and floatation tanks with arch fenders on the submarine side and steel and UHMWPE rub strips on the pier side. The camels are trapezoidal shaped, in plan view, with the small end on the submarine side. This was done to minimize the width of the camel on the submarine side as not to interfere with a submarine’s wide aperture array (WAA) and give more flexibility in positioning the submarine. These camels are very versatile because they can be used at any of the piers at the submarine base and they can berth both Los Angeles and Seawolf class submarines. The camels are new and have not experienced a lot of deterioration. Only minor maintenance has been performed on these camels, which include general inspection and replacing zinc anodes. The first camels procured were built with the flotation tanks constructed of spiral tubing, which was not the specified tubing. These camels have approximately 12 inches of freeboard. Later camels that used the specified tubing only had approximately 3 inches freeboard. The access grating on the top of some of the camel was removed to give them a freeboard of approximately 6 inches. The camels are easy to move around in the water due to their small size.

NSB New London has several sets of 688 Standard Deep Draft camels. However, these camels are very old, severely deteriorated, and difficult to maintain. The camels are tapered and were original designed for a class of submarine that is no longer in service. Modern submarines have a more parallel hull, which does not fit the taper of the camels, except and the ends of the submarine. The camels have experienced severe corrosion of steel parts and structural members and deterioration of timber elements. Several of the camels have sunk and are being disposed of after they sink. Some of the camels have had flotation bladders installed in their flotation tanks due to a large amount of holes that developed in the tanks. There have been some modifications to the original design, which include adding a tapering assembly around the upper rub rail to prevent it getting caught on the lower wale on the fender system and adding a seat/stiffener system to the bottom tubes on the camels to distribute the load when the camels are on shore. In-house personnel perform regular maintenance on the camels as a means of training. Typical maintenance includes repairing corroded steel parts, installing bladders, if necessary, replacing timbers, replacing zinc anodes, blasting off marine growth, and painting. Submarine base personnel indicated it takes about three months to refurbish a camel and about 5 are done a year. The submarine base does not like these camels because they can only be used for Los Angeles class submarines, they are severely deteriorated, and are difficult to maintain.

The Fixed Fender or Universal camels were designed by the Naval Facilities Engineering Service Center (NFESC) as a prototype system that is low in maintenance and provides flexibility in positioning a submarine equipped with a WAA as the camel is positioned above the array and does not interfere with it. The D-shaped camels are constructed of a composite material with a ballast system to keep them upright, fenders on the submarine side, and built-in backer board with UHMWPE rub strips on the pier side. The camels must be used with a specially designed and dedicated fender pile system that consists of concrete filled composite piles and a composite/concrete pile cap. This system limits the positioning of a submarine on the pier and limits the mobility of the camels, as they are dedicated to a specific berth. Los Angeles, Seawolf, and Virginia class submarines are berthed using these camels. The submarine base has never had to perform maintenance on these camels. There is no regular maintenance program established for these camels because they are new and because of the few number of parts that tend to deteriorate. It is planned to remove the camels and inspect them in the near future. Modifications to the design have been proposed for future versions of this camel.

Future Plans

NSB New London is presently going through a recapitalization program that is demolishing, replacing, and upgrading several of its piers. A fendering project is about to start to add a new fender system on Pier 17 North berth that will make this berth usable for general submarine berthing.

The submarine base anticipates continuing to use the 688 Standard Deep Draft and Seawolf camels. No camel procurements are planned at this time. It is planned to use Seawolf camels when the Virginia class submarine is berthed at NSB New London.

Miscellaneous

Two sets of Trident camels were observed at NSB New London. These camels were procured from another naval station and have never been used as camels only as floats. Some of the Trident camels are being scrapped. Submarine base personnel indicated that they would not like the hydro-pneumatic fender design because it would require a new backer system and the current camels offer very flexible positioning of the camels.

Miller Marine visited the site last year and gave a presentation on their concept for a universal camel. It consists of a steel frame with fenders and other composite materials suspended from a floatation barge that may be reconfigured and dissembled easily. The submarine base personnel thought this concept was interesting and provided feedback on the design. Miller Marine is using this input to modify their universal camel concept.

It was indicated that craneless brows are being installed on the piers, which is going to limit the flexibility in positioning submarines.

SITE VISIT REPORT
NAVAL STATION NORFOLK
30 June 2004
Prepared on 12 July 2004

Visitors:
Anthony Farmer, NAVFAC, Atlantic Division, Structural Engineer
Dan Musiker, NAVFAC, Atlantic Division, Structural Engineer

Points of Contact:
Sandra Hawkinson, Port Operations, (757) 444-0889, shawkinson@nsn.cmar.navy.mil
Skip Gronbach, Wharf Builders, (757) 444-1264, gronbachaf@pwcnorva.navy.mil
I.W. Harris, Port Operations, (757) 444-7716, iharris@nsn.cmar.navy.mil
Paul Payne, Port Operations, (757) 444-7716, ppayne@nsn.cmar.navy.mil
Capt. Al Dykes, Harbor Pilot, (757) 444-3178, adykes@nsn.cmar.navy.mil
Chief Zuellig, Pier Ops, NSSC, (757) 485-6915, jeffrey.zuellig@navy.mil
Chief Wasson, NSSC, (757) 445-0078, jerry.wasson@navy.mil
SC Randall, Harbormaster

Camel and Fender Information:

Pier/Wharf	Sub/Ship Class	Camel Type	Camel Drawing	Fender/Backing
Pier 3	SSN 688, SSN 21	688 Standard Deep Draft Camels[1]	NAVFAC 1404664-1404666[1]	Timber pile clusters, wales and chocks
Pier 4	SSN 688	688 Standard Deep Draft Camels[1]	NAVFAC 1404664-1404666[1]	Timber pile, wales and chocks
Pier 12	SSN 688, SSBN 726	688 Standard Deep Draft Camels[1]	NAVFAC 1404664-1404666[1]	Timber pile, wales and chocks
Pier 14	SSN 688, SSBN 726	Trident Modified 688 Deep Draft Camels[2]	SK5432-04 - SK5433-04	Timber pile, wales and chocks

1- 688 Standard Deep Draft Camel (10 sets-tapered, steel pipe frame with timber bumpers and fenders, designed by LANTNAVFACENGCOM)
2 - Trident Modified 688 Deep Draft Camel (1 set-tapered, steel pipe frame with timber bumpers and fenders, steel/concrete ballast block and slinged foam filled fender, designed by PWC Norfolk, LANTNAVFACENGCOM)

Costs:

Camel	Year Constructed	Procurement Cost	Maintenance Interval	Maintenance Cost	Operation Costs
688 Standard Deep Draft Camels	Various Years	$170,000	2 – 4 years	$100,000	$5,000
Trident Modified 688 Deep Draft Camel	mid-1990's	$100,000 modification cost	2 – 4 years	$100,000	$5,000

* Costs based on a set of 2 camels, procurement cost in year constructed, and maintenance cost from most recent service
** Operation Costs are provided through operational funds

Current Situation:
Naval Station Norfolk (NS Norfolk) uses two types of camels to berth submarines. The station has 11 sets (22 camels) of tapered 688 Standard Deep Draft camels with one set modified to be used with Ohio class (Trident) submarines. The camels are primarily stored in the water at Pier 3, except when the camels are being overhauled on shore. The modified set of camels is typically stored on shore. Two sets are stored at Norfolk Naval Shipyard and one set is stored and used at Naval Weapons Station Yorktown. One set of camels is used to berth submarines. NS Norfolk is the homeport for several Los Angeles class submarines, but Ohio, Seawolf, and Virginia class submarines visit the naval station. Pier 3 is the dedicated submarine pier at NS Norfolk. However, submarines could be berthed at any of the piers. Ohio class submarines are typically berthed at Piers 12 or 14.

The tapered 688 Standard Deep Draft camels are constructed of a steel tube frame and floatation tanks with a timber frame and fenders on the submarine side and timber rub strips on the pier side. Some minor modifications have been made to the design to improve the camel's performance and reduce maintenance. Modifications include: adding two additional sets of chains to hold the timber frame on, adding steel saddles to the upright timbers on the camel face, using wing type fenders instead of the 'D' shape fenders, and using 12x12 timber chocks instead of 8x8's. The camels have experienced typical corrosion of steel parts and structural members and deterioration of timber elements. It has been considered to replace the timber elements with reinforced composite members due to the arsenic content of the treated timber and to reduce the maintenance and replacement need. NS Norfolk is positioned at the confluence of the Elizabeth and James Rivers and the waterfront is pretty exposed on the West side. The camels are frequently damaged and bounce around a lot during heavy weather and when ships pass. The camels are maintained regularly about every two to four years. The naval station Wharf Builders handles the overhaul and maintenance work for the camels. YD cranes are used at NS Norfolk and are frequently utilized in camel lifting operations. The camels are readily moved and positioned in the water.

The Ohio class (Trident) submarine has a deeper draft and a much greater displacement than Los Angeles (688) class submarines. The 688 Standard Deep Draft camels do not have the draft or fendering to properly berth Ohio class submarines. To accommodate the Ohio class submarine, Trident Modified 688 Deep Draft camels have been developed. The camel consists of taking a Standard 688 Deep Draft camel and adding a ballast block of steel and concrete to the bottom to sink the camel and adding a foam filled fender to the top of the camel to keep if from sinking too far. The slings that attach the foam filled fender to the camel have a specified length to set the depth at which the camel sits. Two of these camels are used to berth an Ohio class submarine and they berth directly against the timber pile fender system. These camels were being set on Pier 12 when the site visit was conducted.

Future Plans
Naval Station Norfolk really likes the camels they currently have. They consider them easy to maintain, though their maintenance is intensive. However, NS Norfolk plans phase out the use of camels as its piers are replaced. The new piers will be designed around the submarine and the fender system constructed to act as a camel. This system will basically consist steel frame mounted to the pier with large bore cylindrical fenders attached to the frame. The pier support piles will be offset to allow clearance for the dive planes and deck will be bumped out at the locations of the fenders as necessary.

Miscellaneous
The 688 Standard Deep Draft camels are tapered, in plan view, and were original designed for a class of submarine that is no longer in service. Modern submarines have a parallel mid-portion of the hull, which does not fit the taper of the camels unless the camels are put on the ends of the submarines were there is a taper. The design was updated in 1995 to remove the taper (NAVFAC 1404943-1404947).

Appendix B – DEEP DRAFT CAMEL DRAWINGS

688 Standard Deep Draft Camel, Non-tapered

688 Standard Deep Draft Camel, Tapered

Seawolf Camel

24 & 32 Foot Deep Draft Camel

Barge Camel

Spudmoor/Spudlock Camel

Captured Camel

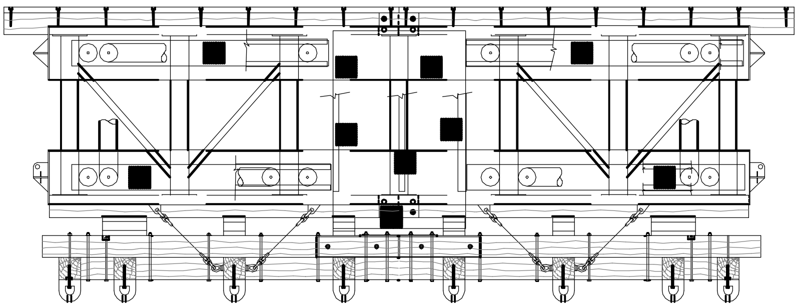
Trident Camel

SSBN Camel/35-Foot Trident Camel

Trident Modified 688 Camel

Hydro-Pneumatic Fender

Composite Camel



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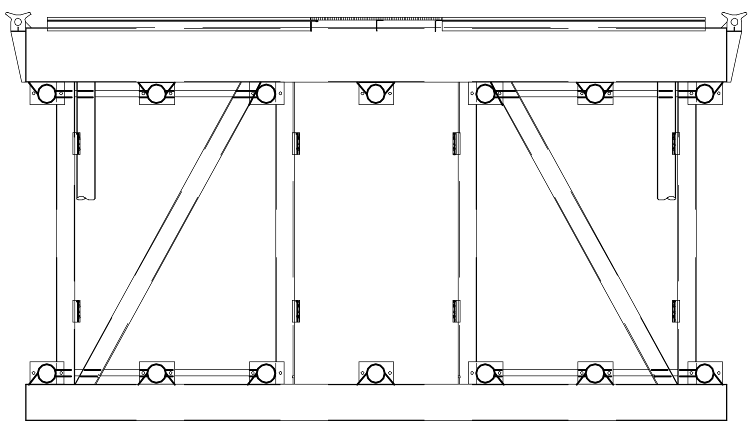

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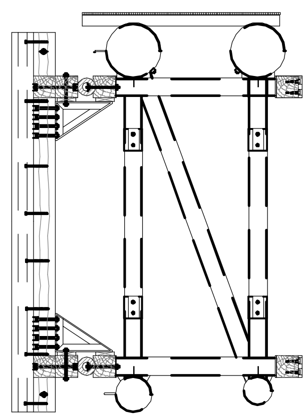
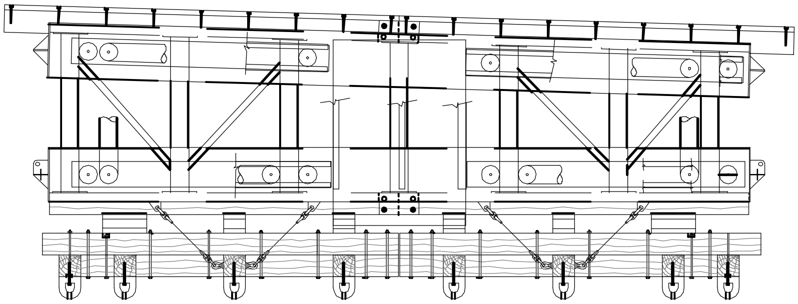


SIDE VIEW

688 DEEP DRAFT, NON-TAPERED CAMEL



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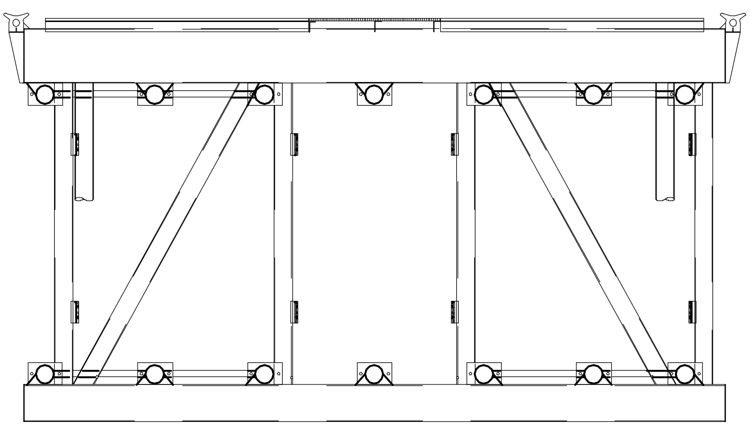

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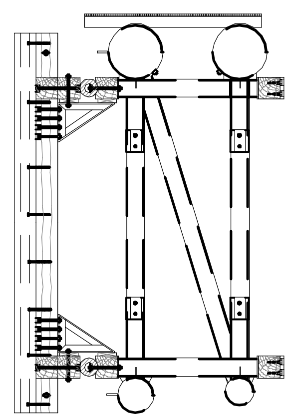
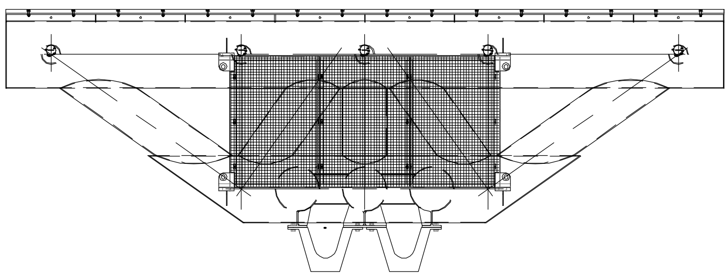


SIDE VIEW

688 DEEP DRAFT, TAPERED CAMEL



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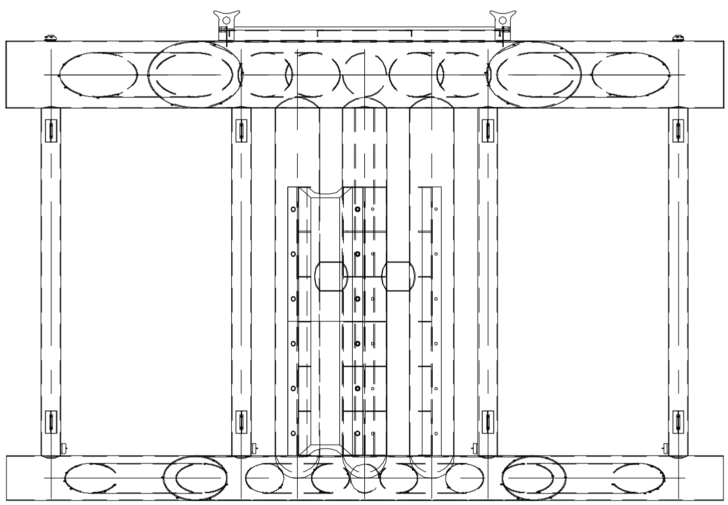

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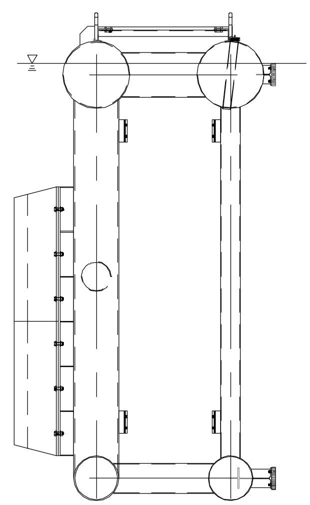
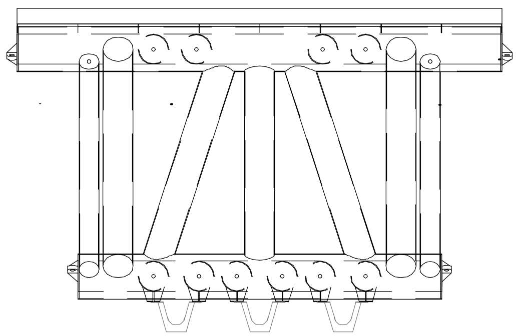
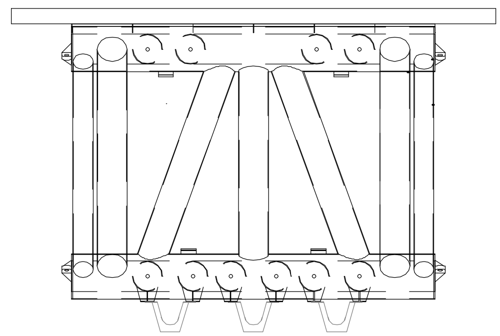


SIDE VIEW

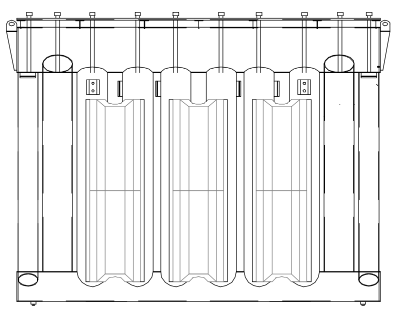
SEAWOLF CAMEL



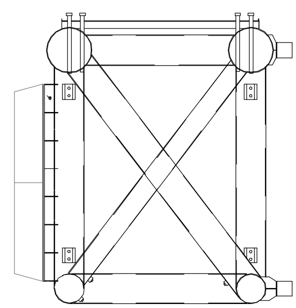
32 FOOT DEEP DRAFT CAMEL
PLAN VIEW



24 FOOT DEEP DRAFT CAMEL
PLAN VIEW

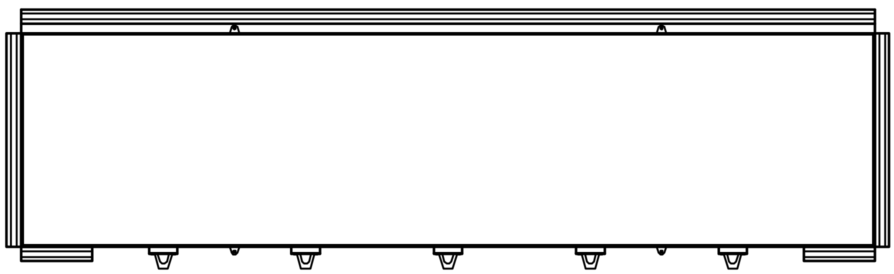


32 FOOT DEEP DRAFT CAMEL
ELEVATION VIEW



32 FOOT DEEP DRAFT CAMEL
SIDE VIEW

24 FOOT & 32 FOOT DEEP DRAFT CAMEL



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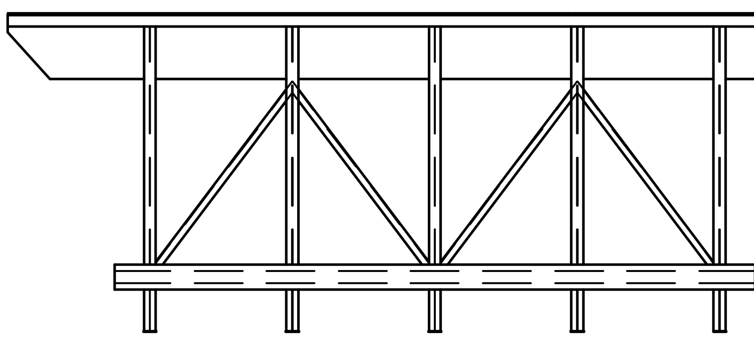

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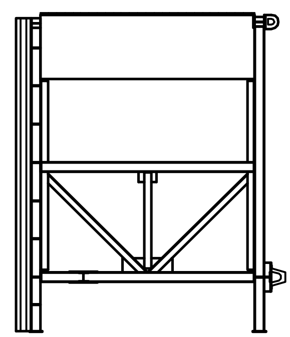
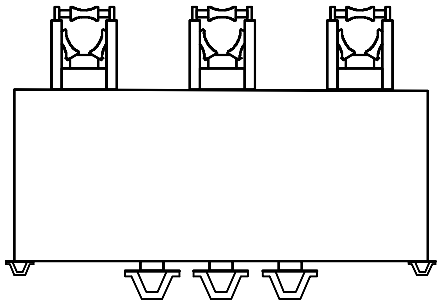


SIDE VIEW

BARGE CAMEL



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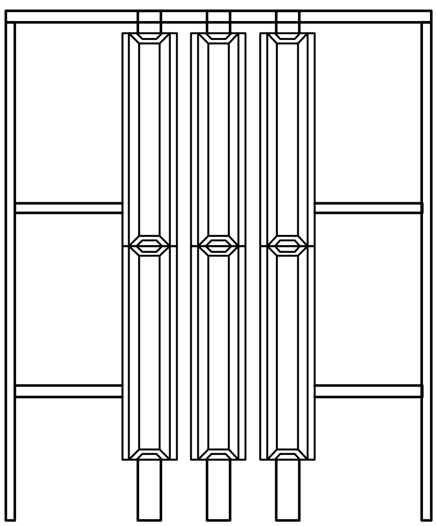

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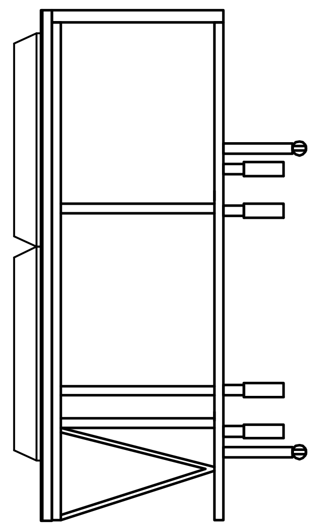
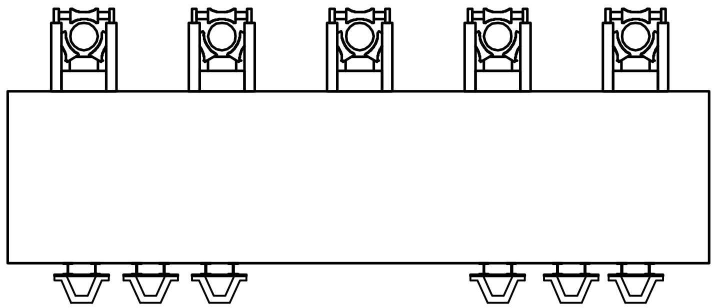


SIDE VIEW

SPUDMOOR / SPUDLOCK CAMEL



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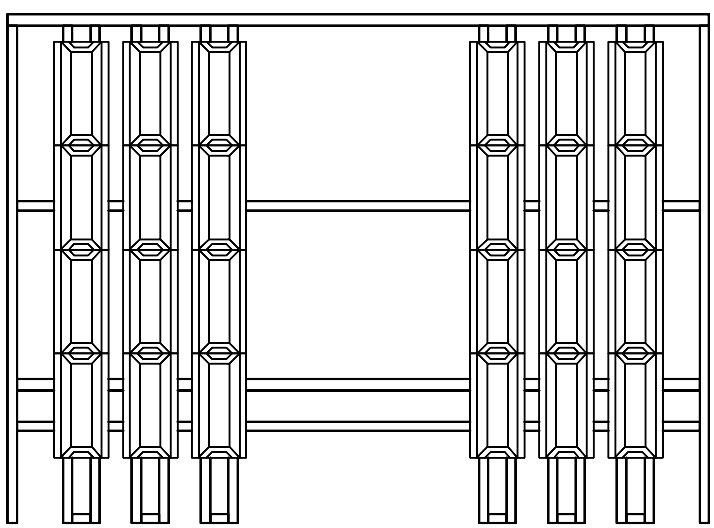

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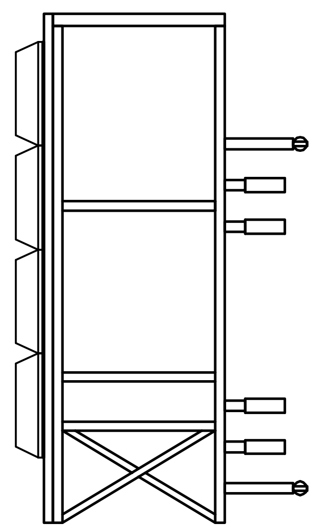
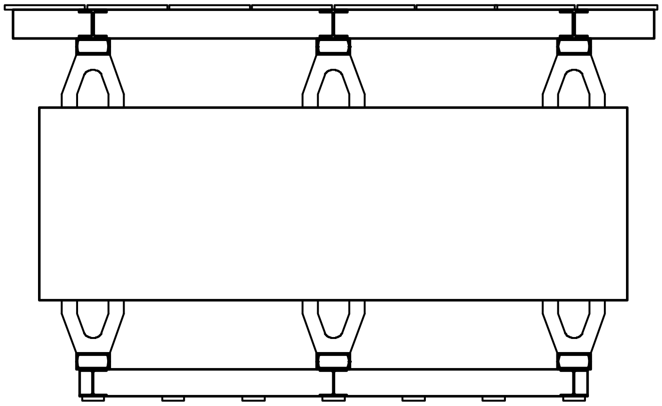


SIDE VIEW

CAPTURED CAMEL



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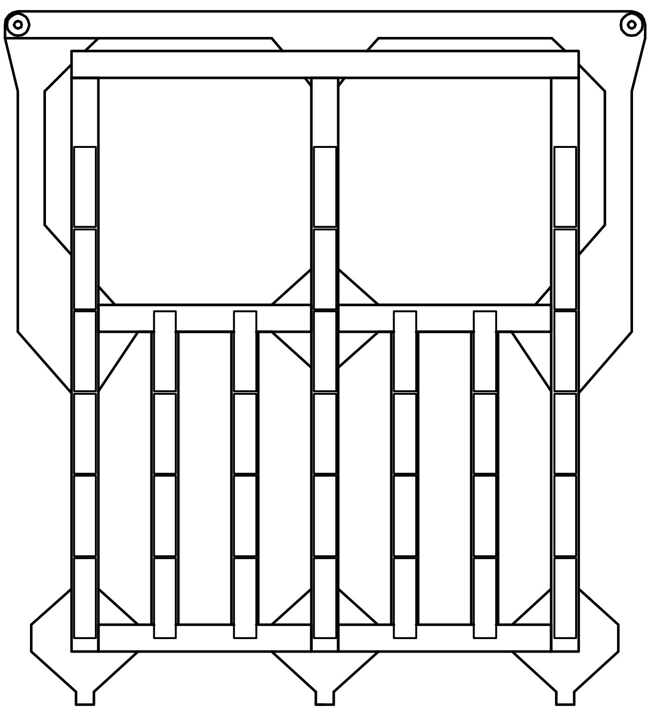

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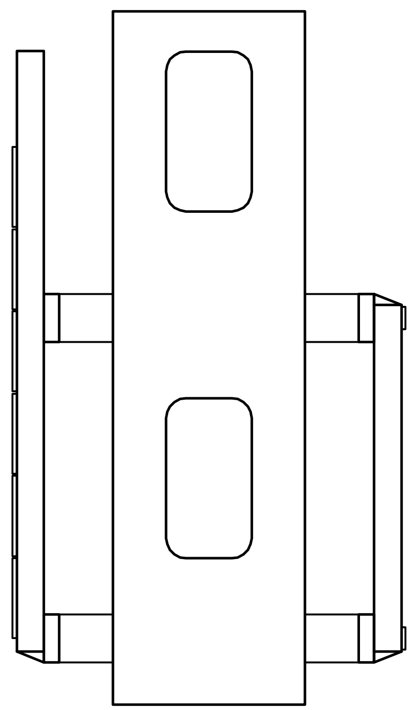
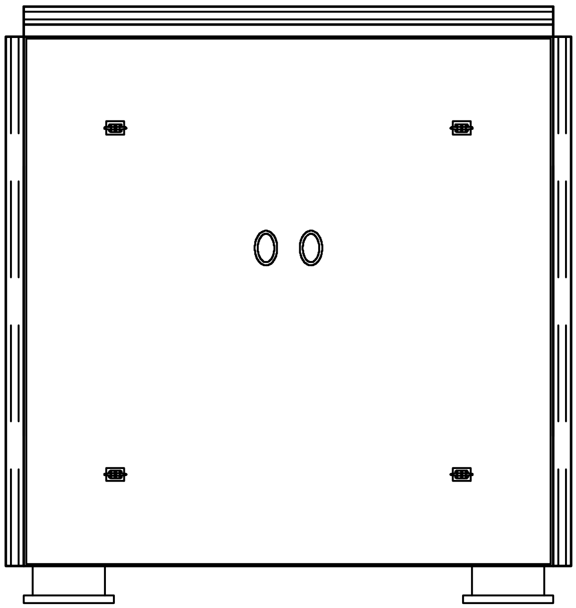


SIDE VIEW

TRIDENT CAMEL



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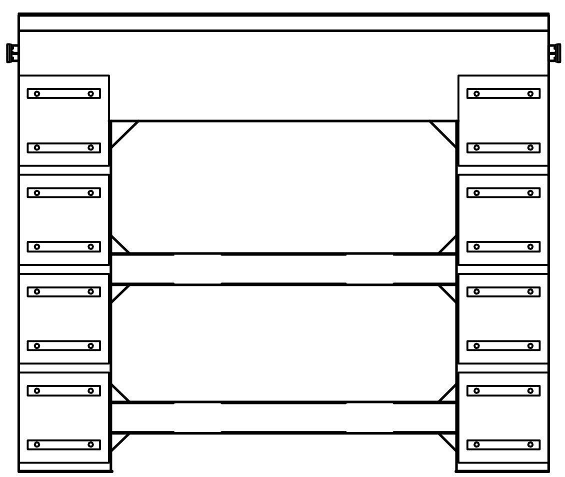

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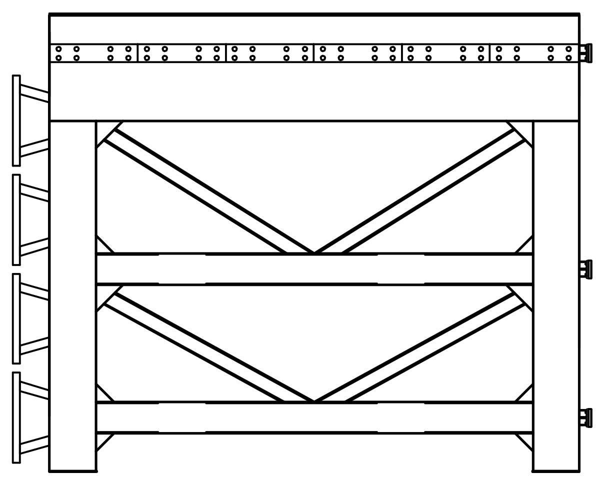
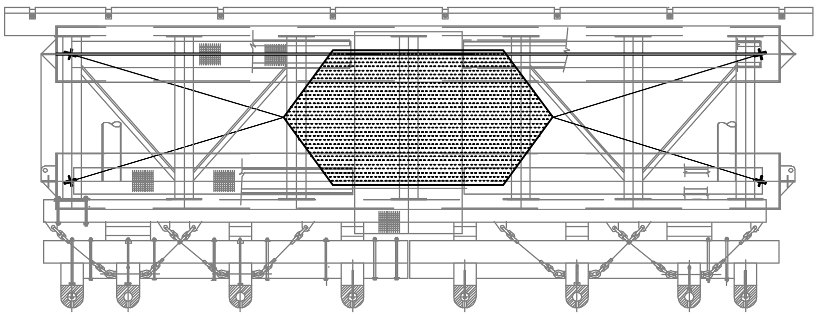


SIDE VIEW

35 FOOT TRIDENT CAMEL



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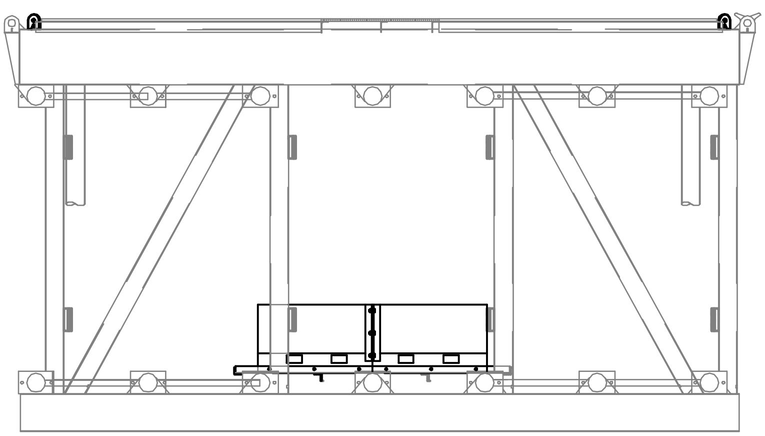
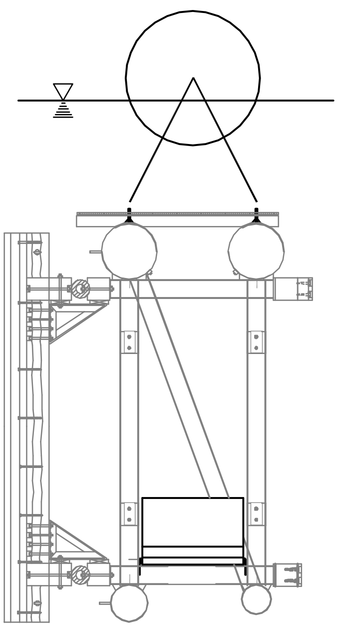
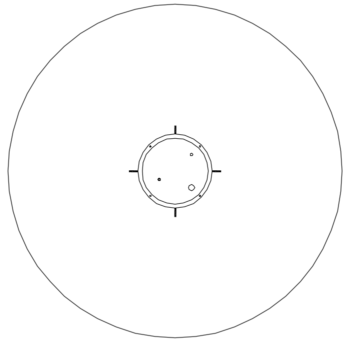


ELEVATION VIEW



SIDE VIEW

TRIDENT MODIFIED CAMEL



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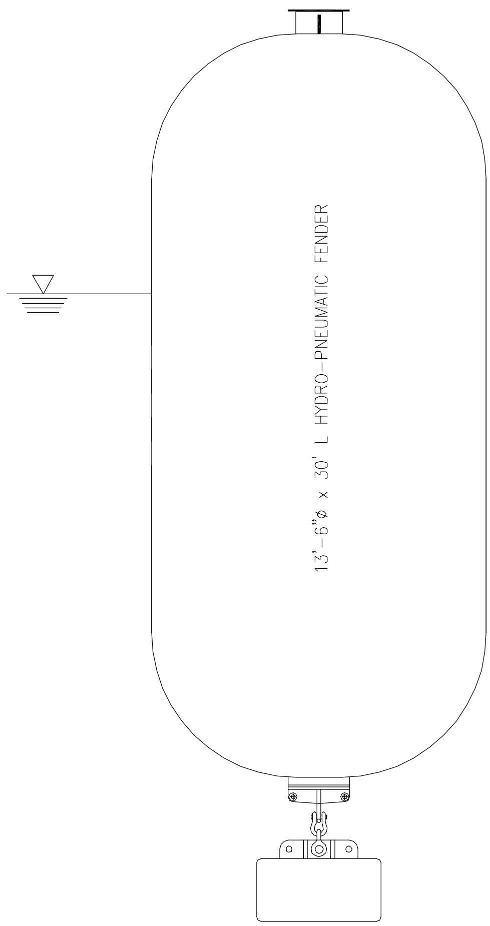
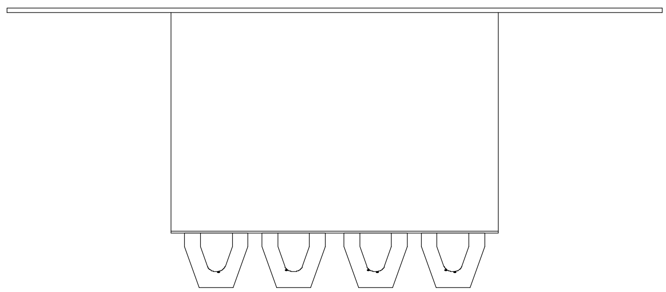


ELEVATION VIEW

HYDRO-PNEUMATIC FENDER



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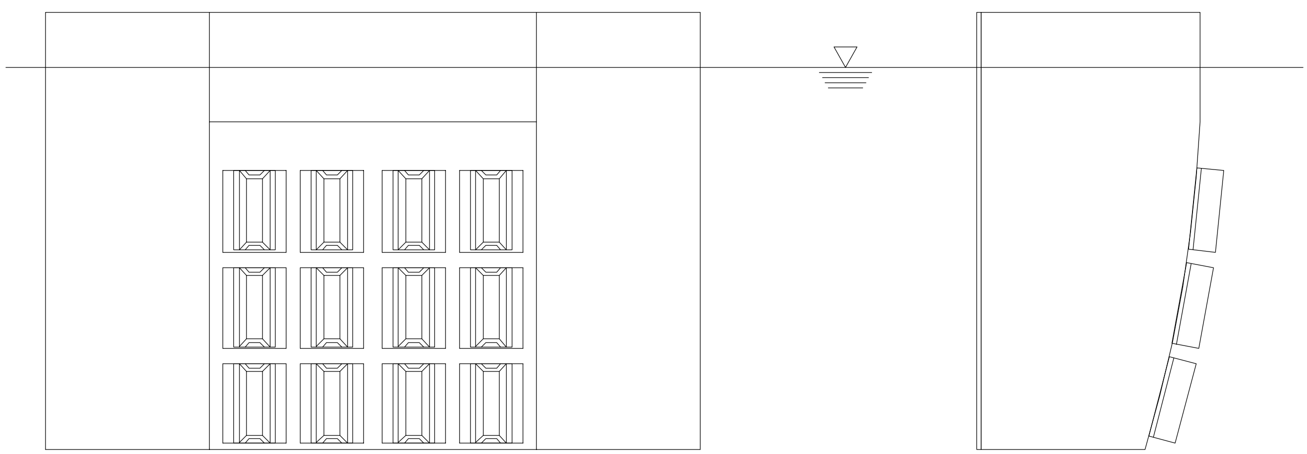

ELEVATION VIEW

SIDE VIEW

COMPOSITE CAMEL

Appendix C – BERTHING ENERGY CALCULATIONS

NAVFAC
Naval Facilities Engineering Command
ATLANTIC DIVISION

Title:	Deep Draft Camel/Fender Study
Job Order:	3J0880
Designer:	ALF
Date:	1-Sep-04 Page: 1

BERTHING LOAD

Design Criteria: MIL-HDBK-1025/1

SHIP DESIGNATION:		**SSN 688**	**SSN 21**	**SSN 774**	**SSBN 726**	
CLASS:		Los Angeles	Seawolf	Virginia	Ohio	(units)
Length of Ship @ Full Load (L)	L=	362	353	377	559	ft
Beam (B)	B=	33	40	34	42	ft
Draft @ Full Load (D)	D=	32.3	35.8	30.5	36.4	ft
Displacement @ Full Load	d=	6082	8060	7700	16600	long tons
	d=	6812	9027	8624	18592	tons
Berthing Velocity						
(Fig. 44, sheltered-to-moderate, 5.2.4)						
(moderate calculated)	***V=***	***0.67***	***0.60***	***0.61***	***0.48***	ft/sec
Berthing Coefficents						
Eccentricity Coefficient						
= k ^ 2/(a ^ 2 + k ^ 2) where:						
k = Radius of Longitudinal Gyration of the ship, assumed k = 0.24L						
a = Distance between ship center of gravity and point of contact with berth, projected onto the longitudinal axis fo the ship L						
	k=	86.9	84.7	90.5	134.2	ft
(from CAD dwg)	a=	6	29.5	34.25	97.3	
	C_e=	0.995	0.892	0.875	0.656	
	(Use Ce=1.0 for typical ship, values typically between 0.4 and 0.7)					
(conservative)	C_e=	1.0	1.0	1.0	1.0	
Geometric Coefficient						
0.85 for convex curvature						
0.95 for impact beyond 1/4 points of ship						
1.25 for concave curvature						
1.00 for straight side (parrallel midbidy)						
(conservative)	C_g=	1.00	1.00	1.00	1.00	
Deformation Coefficient						
0.9 for nonresiliant fender system						
1.0 for resiliant fender system						
1.0 for stiff submarine hull						
(conservative)	C_d=	1.00	1.00	1.00	1.00	
Configuration Coefficient						
0.8 for solid berths						
1.0 assuming open berths						
(conservative)	C_c=	1.00	1.00	1.00	1.00	
Berthing Coefficient						
$C_b=C_eC_gC_dC_c$						
	C_b=	1.00	0.89	0.87	0.66	
Effective Mass Coefficient						
$C_m=1+2(D/B)$ $1.5<C_m2.0$ (calculated)	C_m=	2.96	2.79	2.79	2.73	
(conservative)	C_m=	2.00	2.00	2.00	2.00	
Berthing Energy of Ship						
$E_{Ship}=0.5(W/g)V^2$	E_{Ship}=	94.6	102.4	101.2	135.0	k-ft
Energy Absorbed by Fender System						
$E_{Fender}=C_bC_mE_{Ship}$	E_{Fender}=	188.2	182.6	177.0	177.1	k-ft
Energy Absorbed by Fender System						
Accidental Factor=1.5 Efender (5.1.5.4)	E_{Fender}=	**282.3**	**273.9**	**265.5**	**265.6**	k-ft

Appendix D – GENERAL HYDRO-PNEUMATIC FENDER BACKER CONFIGURATION

D. General Hydro-pneumatic Fender Backer Configuration

D.1 *Description*

A complete description of hydro-pneumatic fenders may be found in section 2.2 Deep Draft Camel/Fender Survey Discussion of the body of this report. A hydro-pneumatic fender requires a backer system to distribute berthing and mooring loads to a waterfront facility (Figure 19). The backer system can consist of the flat face of a sheet pile wall or a panel backer system used in conjunction with a pile fender system. Most waterfront facilities used by the Navy are outfitted with a pile fender system, thus a panel backer system will be discussed here. Figure D-1 shows the general configuration of a hydro-pneumatic fender and backer system that has been developed through the use of several existing designs. The reference information for these designs may be found in section D.4.

The panel backer system generally consists of fender piles, backer panels, connection hardware, and pier connection hardware. A backer position is approximately 25 feet wide. A typical layout of backer locations along a waterfront facility may be seen in Figure 20. This configuration would accommodate all classes of submarines currently used by the Navy. Some potions are 50 feet wide giving the option to berth a submarine bow in or bow out.

Due to environmental, waterfront facility, and installation differences, the exact size and configuration of a panel backer system for hydro-pneumatic fenders will have to be developed on a per location basis. Presented here is the general configuration of what a typical panel backer system would look like.

D.2 *Backer System Components*

D.2.1 Fender Piles

Typically, 6 to 8, 24-inch square precast prestressed concrete fender piles are used to distribute loads to a waterfront facility and the harbor bottom (Figure D-

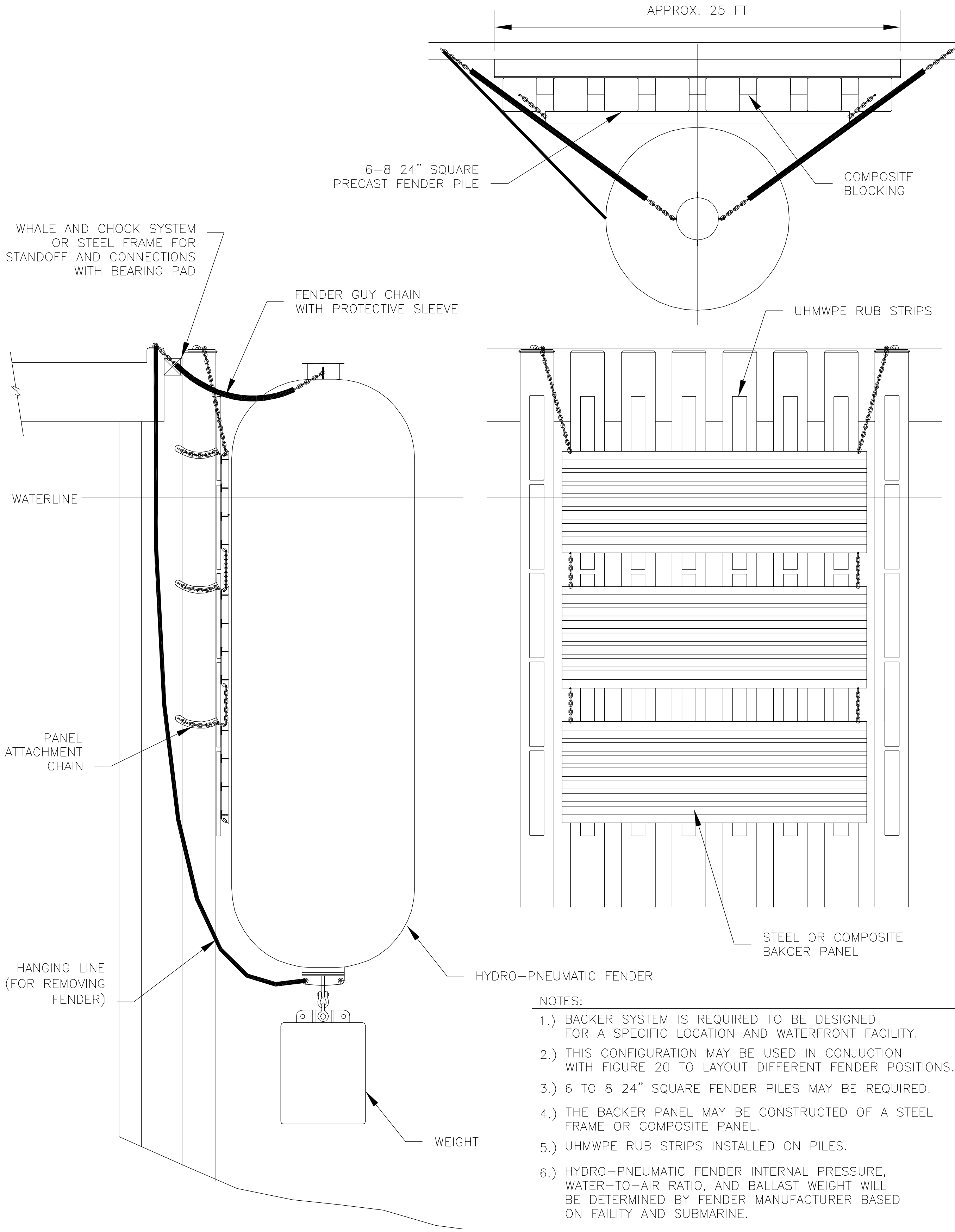

FIGURE D-1 - GENERAL HYDRO-PNEUMATIC FENDER BACKER CONFIGURATION

1). The piles are incorporated into the fender system along a waterfront facility. They are typically about 65 feet long and spaced 3 feet on center. UHMWPE rub strips are installed on either the pile face or on the backer panels to prevent abrasion. Bearing pads are placed between the piles and the pier connection components for energy absorption and protection. The exact size, layout, pile length, and spacing must be designed for each waterfront facility.

D.2.2 Backer Panels

Backer panels are placed in front of the fender piles to distribute loads from the hydro-pneumatic fender (Figure D-1). The panels may consist of a steel frame or composite panels. There can be one frame or several smaller frames connected together to form a backer panel. A steel frame typically consists of steel beams, W or T shapes, connected to plates spanning along the face of the fender piles to form a panel. The steel is galvanized to prevent corrosion. Some composite manufacturers indicate they can produce a composite backer panel. This system would be advantageous because it would not corrode. The backer panels are suspended by chains in front of the fender piles and chains are wrapped around the fender piles to hold the panels in place. The exact design will need to be determined based on the loads to distribute and the geometry of the backer system.

D.2.3 Connection Hardware

There are several pieces of hardware necessary to connect the hydro-pneumatic fender to the backer system (Figure D-1). The fender and backer panel may be connected to the fender piles or waterfront facility depending on how it is configured. Fender guy chains are necessary to keep the fender in place. These chains have a rubber sleeve on them to protect the fender from the chains rubbing against them. A line connected to the bottom of the fender is required during fender deployment and retrieval. Leaving a hanging line in place connected to the bottom of the fender and to the backer system would make the deployment and retrieval easier. Other miscellaneous components include shackles, connection plates, and anchors.

D.2.4 Pier Connection Hardware

Connecting the backer system to the waterfront facility may be accomplished by several methods. A typical wale, chock, block system may be used. These components may be timber or composite materials. In some instances a steel frame may be advantageous. This could provide extra standoff if required or may serve as a small work platform. This system could also be setup as a guide for installing and connecting the fender piles. NS Point Loma uses a unique steel frame system.

D.3 *Cost*

The cost of installing a set of two backer systems 25 foot wide is estimated to be approximately $150,000. This cost may be adjusted due to inflation and area cost factors.

D.4 *Reference Drawings*

- REPLACE METAL FENDER SYSTEMS AT NAVY PIER – 1146
  WHITE BEACH, OKINAWA, JAPAN
  NAVFAC DRAWING NO. 7812042

- PIER 5003 FENDER INSTALLATION
  NAVAL SUBMARINE BASE SAN DIEGO, CALIFORNIA
  NAVFAC DRAWING NO. 8051112 – 8051130, 8049353

- REPLACE FENDER PILES PIER 5000 (R28-93)
  NAVAL SUBMARINE BASE SAN DIEGO, CALIFORNIA
  NAVFAC DRAWING NO. 8110792 – 8110820

- FY06 MCON PROJECT P-097 BERTHING PIER
  NAVAL SUBMARINE BASE PEARL HARBOR, HAWAII
  NAVFAC DRAWING NO. 7916330 – 7916485

- SPECIAL PROJECT R8-93 REPAIR FENDER PILES, WHARF S-10
  NAVAL SUBMARINE BASE PEARL HARBOR, HAWAII
  NAVFAC DRAWING NO. 7925851 – 7925864

- SPECIAL PROJECT R8-93 REPAIR FENDER PILES, WHARF S-10
  NAVAL SUBMARINE BASE PEARL HARBOR, HAWAII
  NAVFAC DRAWING NO. 7944737 - 7944879