UNIFIED FACILITIES CRITERIA (UFC)

GRAVING DRY DOCKS

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GRAVING DRY DOCKS

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location

This UFC supersedes UFC 4-213-10 Change 1, dated September 2012

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD-3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-213-10, *Graving Dry Docks*

Superseding: UFC 4-213-10, *Design: Graving Dry Docks*, 1 September 2012, with Change 1

Description: This revised UFC serves as a specific guidance for planners, designers, contractors and maintenance technicians involved in the planning, designing, construction and maintenance of graving dry docks. The document is organized into chapters that address the various phases beneficial to the personnel involved in working with a dry dock. The document provides a unified approach to the formatting and content of Unified Facilities Criteria**.**

Reasons for Document:

- This UFC provides revised information that adheres to the format and content of the criteria documents.

- Revisions capture current changes in shipyard requirements and anticipated requirements of the Shipyard Industrial Optimization Program (SIOP). Revisions include: dry dock dimensions for new submarine classes, dry dock production needs, changes in flood elevation, fire safety standards, etc.

Impact:

- This revision does not have any cost impacts.

Unification Issues:

- This revision does not have any unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of UFC 4-213-10 is to provide a uniform guidance for the planning, design, construction, renovation and maintenance of graving dry docks. This document has undergone many iterations over the decades. Much of the specific recommendations have been lifted from existing facility designs that have proven valuable.

Any dry dock construction or other work must be performed in concert with the NAVSEA Dry Dock Certification program, namely the requirements of MIL-STD-1625 and Naval Ship's Technical Manual (NSTM), Chapter 997, must be met.

1-2 APPLICABILITY.

UFC 4-213-10 applies to all facility planners, designers, contractors, and maintenance technicians involved in the planning, design, construction, and maintenance of Graving Dry Docks. It is assumed that the general vicinity, such as specific shipyard, has been selected, that the size of ship to be accommodated has been determined, and that the dry dock function, shipbuilding or repair has been decided. Consideration must be given to strategic site selection to meet present or future naval requirements, ease of defense, and general accessibility to and from the sea.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-3.1 Anti-Terrorism and Security.

In some locations, consideration should be given to protective construction for the upper part of the pumpwell and the service tunnels. For waterfront security criteria, refer to UFC 4-025-01, *Waterfront Security Design*.

1-4 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-5 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-6 REFERENCES.

APPENDIX C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 SHIPYARD LAYOUT

2-1 SHOP FACILITIES.

Locate a dry dock near yard supporting industrial shops, or vice versa, from which material requiring fabrication or manufacture may be obtained.

2-2 LAYDOWN SPACE.

Provide ample space on both sides of a dry dock. If there are no restrictions, furnish a strip at least 250 ft (76.2 m) wide on each side of the dry dock coping and at the head end.

2-3 POWER AND UTILITIES.

Proximity to sources of power and utilities is desirable but seldom a determining factor. Electricity, fresh water, saltwater fire protection, compressed air, steam, oxygen, acetylene, and sewers are usually required as described in CHAPTER 8.

2-4 CRANE AND CRANE TRACKS.

Captive cranes should not be used if it can be avoided. Trackage should be interconnected for portal crane utilization elsewhere in the same yard.

2-5 SHIP APPROACHES.

Maneuvering a ship into a dry dock necessitates careful attention to the shape of the approach body of water, locations of ship channels, prevailing winds, currents, and relationship to other waterfront structures.

2-5.1 Turning Basins.

A ship must parallel the long axis of a dry dock before it enters; therefore, provide a turning basin of appropriate width, length, and depth of water outboard of a dry dock entrance. The length and depth of a dry dock are indicative of the maximum ship to be accommodated. The turning basin should have a width outboard of the dry dock at least two times the dock length and properly shaped for turning. The depth of water in the turning basin should be no less than that at the entrance sill of the dry dock. Where piers or other structures extend into a waterway and flank the approach to a dry dock entrance, the turning basin should be large enough to allow a ship to be turned before coming abreast of such flanking structures. A dry dock must not be located where flanking structures are too close to the path of a ship entering or leaving the dry dock. Leave room for tugs to operate beside a ship until it is clear of the dry dock entrance. The distance between such structures and the side of the ship path should not be less than 150 ft (45.7 m).

2-5.2 Dry Dock Orientation Effect.

In some cases, through necessity or choice, a dry dock may be oriented with the axis at an acute angle to the general shoreline.

This orientation is advantageous where, like a river, there is a current parallel to the shoreline, in which case the slanted position precludes the necessity of having a ship abreast of the current flow when entering or leaving the dry dock. Turning basin layouts are modified by such positioning, but the guidance for clearance of structures flanking the entrance must be observed.

2-6 FITTING OUT/REPAIR PIERS.

Fitting out or repair piers should be provided adjacent to dry docks.

2-6.1 Existing Piers.

In planning dry docks for existing shipyards, it may be that existing piers can serve this purpose for ships to be built or overhauled in the dock. The locations of such piers might influence positioning new dry docks reasonably near the piers, but the importance of this is not great since it involves only a single transfer of the ship after undocking.

2-6.2 New Piers.

When fitting out/repair pier capacity does not exist, new piers or wharves must be included in the project as essential support for dry docks. Refer to UFC 4-152-01, *Piers and Wharves*, for pier and wharf design.

2-7 SILTING AND SCOURING.

Ascertain the stability of the access waterway with regard to silting or scouring. A prospective site should be reconsidered if the possibilities of silting or scouring indicate excessive future dredging maintenance. Study historical characteristics of the waterway and possible effects on current flow due to planned new work or anticipated future structures.

2-8 TOPOGRAPHY, HYDROLOGY, AND METEOROLOGY.

2-8.1 Site Conditions.

Prior to the design of a dry dock, certain minimum information is required about conditions at the proposed site. Dry dock construction methods used are usually closely related to site conditions and to the type and shape of a dry dock.

2-8.2 Yard Grades.

The coping of a new dry dock must be compatible with general grades in a yard, or at least the grades in the vicinity of the dry dock and supporting facilities serviced by dry dock cranes. Also, the elevation of the top of a dry dock must provide a certain minimum freeboard dependent on the highest anticipated tides, waves, and storm surge with consideration for sea level change.

2-8.3 Tide Range.

Ascertain the tidal range. Use this information as a basis to determine the final height of a dry dock, and also the height and strength of cofferdams or other temporary structures possibly involved in the dry dock construction. For predictions, which may be peculiar to the specific site, refer to records and predictions of *National Oceanic and Atmospheric Administration (NOAA)*, and to the local historical records.

2-8.4 Storm Potentialities.

Ascertain potentialities of a site. These data have a bearing on the determination of the freeboard height of a dry dock, and on the design of temporary construction work. Design for at least 1-percent annual exceedance probability storm event (100-year return period). In some areas, 0.2-percent annual exceedance probability storms (500-year-return period) and tides should be considered.

2-8.4.1 Wind Effects.

Include a study of prevailing winds and their velocities, fetch of water involved, and the length and height of waves. When these data are combined with tide records, they indicate the expected probable high-water conditions. The wind effects may influence the design of fenders or moorings contiguous to a dry dock. Refer to NOAA wind records for areas of the United States and possessions.

2-8.5 Water and Air Temperatures.

Approach body of water temperature ranges are important in designing heating and ventilating systems, coolers, cathodic protection systems, and any systems utilizing the water. Air temperature data are required for similar reasons. Obtain water and air temperature in the vicinity from NOAA and the local historical records.

2-8.6 Water Chemical Content.

The chemical content of water is subject to pollution when a dry dock is located on a river. When water is supplied by wells or well points from soil layers permeated by other than seawater, the chemical content is not known. The corrosiveness of the water must be determined for design of pipes, coolers, any equipment utilizing the water, pumping equipment, and dry dock pressure relief systems. Refer to UFC 3-230-01, *Water Storage and Distribution.*

2-9 FOUNDATION CONDITIONS.

2-9.1 Features.

Dry docks generally have diverse and varied types of foundation designs, which encompass the whole gamut of soil and foundation engineering. Designs are found in the complete range of such engineering, from the simplest spread footing to a complex elastic mat. Consequently, site specific soil investigations must be especially thorough and complete in the determination of a great variety of soil properties.

2-9.2 Borings.

Examine all available records of borings in the vicinity of a proposed site. The scope of previous borings will help determine the program extent for additional borings. For soil investigation procedures, refer to UFC 3-220-01, *Geotechnical Engineering*.

2-9.2.1 Depths of Borings.

Overall or mean soil pressures under dry docks are not great; therefore, for areas under the main body of a dock, borings need not be as deep as for other structures where load concentrations are severe. Where a dry dock is likely to be the relieved type, the depths of borings should be sufficient to allow proper analyses of percolation problems. Where piles, either the bearing or hold-down types, might be used, boring depths should adequately indicate the soils to be penetrated.

2-9.2.2 Usage.

Borings determine soil properties and ground water levels for establishing tip elevations for piles supporting special structures. Borings can also be used for conducting permeability and pumping tests, if necessary. Refer to UFC 3-220-01 for criteria for pumping and permeability field tests and laboratory permeability tests.

2-9.3 Pile Driving Records.

Consult previous pile driving records for applicable information. Supplement these records, if necessary, by new test pile data, especially in areas where appurtenant foundation structures may be used for track supports, capstan foundations, and similar facilities. Pile driving information and equipment is discussed in UFC 3-220-01.

2-9.4 Laboratory Tests and Soil Analyses.

Laboratory tests applicable to soils are generally necessary. For application and interpretation of such tests refer to UFC 3-220-01.

2-9.5 Bearing Capacities of Soils.

Make tests for bearing capacity appropriate to the types of applied loading in accordance with provisions of UFC 3-220-01. For designs of dry dock cross-sections, especially those with thin floors, the soil modulus of subgrade reaction under a floor is important.

2-9.6 Foundation Materials.

Many types of foundation materials may be encountered in a site, and almost all may be utilized for supporting a dry dock. This material variability, however, results in a number of structural types from which a selection must be made. For selection of structural types affected by foundation conditions, refer to CHAPTER 4. Seismicity of the area should be considered.

2-9.6.1 Soils.

Types of soil which may be encountered, and upon which dry docks may be founded, include soft and hard rock, hardpans and shales, sand and/or gravel, soft and hard clay, marl, soft and hard mud, and certain types of coral. Extremely cavernous coral, through which water flows in quantities that precludes even grouting, cannot be used as a site support.

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CHAPTER 3 DETERMINATION OF GRAVING DOCK DIMENSIONS

3-1 MINIMUM DIMENSIONS.

This chapter presents design criteria on graving dock dimensions with particular reference to minimum inside length, width, depth, and configuration. The minimum inside dimensions of a graving dock depends on the classes of ships to be accommodated. However, the exact configuration of the inside of the walls and the resulting shape of the inside cross section will represent a compromise between several conflicting factors, the dominating one being the structural type that is finally selected. For designation of dry dock features, see Figure 3-1.

It is important to remember that all areas of the dry dock must be accessible for inspection. This includes all tunnels, chambers and ballast tanks. Inspection is performed by humans on a regular basis. Therefore, making tunnels tall enough to walk through and openings that allow for ladders is important for the design.

3-2 REPAIR AND SHIPBUILDING DRY DOCKS.

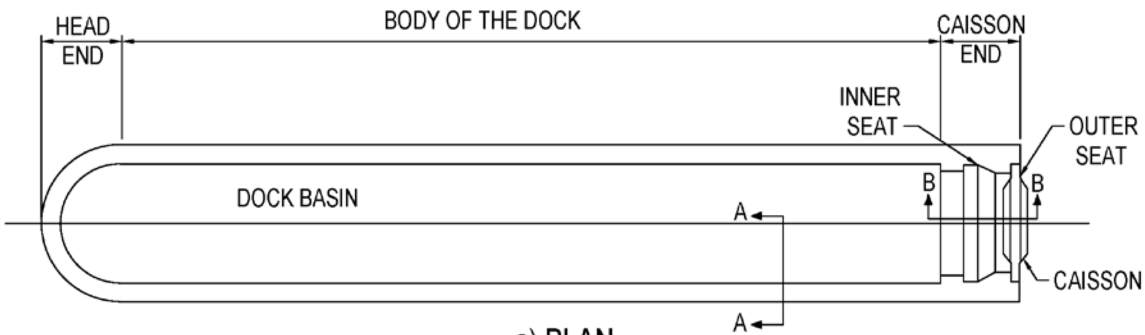
This type of double function dry dock is the only type constructed in naval shipyards. Ships needing routine maintenance and repair, or those coming into dry dock in a damaged condition, require a deeper dock than ships under construction that are generally removed to a fitting-out pier for completion. A damaged ship may have a severe list and/or trim requiring additional dry dock depth.

3-2.1 Basic Dimensions.

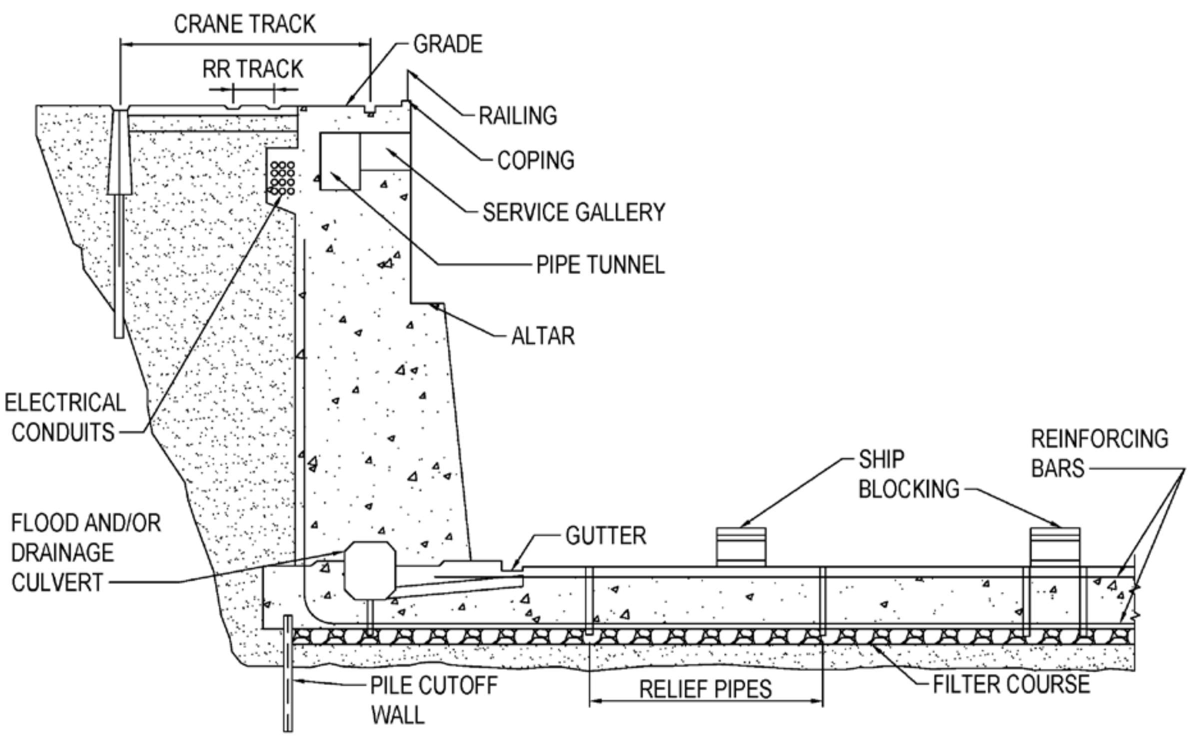
Lay out dry dock plans according to the applicable type of ship as shown in Table 3-1. The values listed in Table 3-1 are recommended for new dry dock layout and may not be applicable for existing dry docks. Guidance for minimum dimensional allowances to ease ship positioning and provide industrial space for shipbuilding or repair work are:

- Normal keel block height: 6 ft (1.8 m). Other size blocks are available and acceptable. Minimum recommended height of blocking is 4 ft (1.2 m). Consider taller blocking ships with sonar domes.
- Ships keel clearance over blocks: 2 ft (0.6 m). NSTM CH 997 requires 1 ft (0.31 m) clearance from hull or appendage during docking evolution.
- Ship to head end clearance: 10 ft (3.0 m)
- Ship to caisson end clearance: 40 ft (12.2 m)
- Ship to wall clearance, each side: 15 ft (4.6 m)

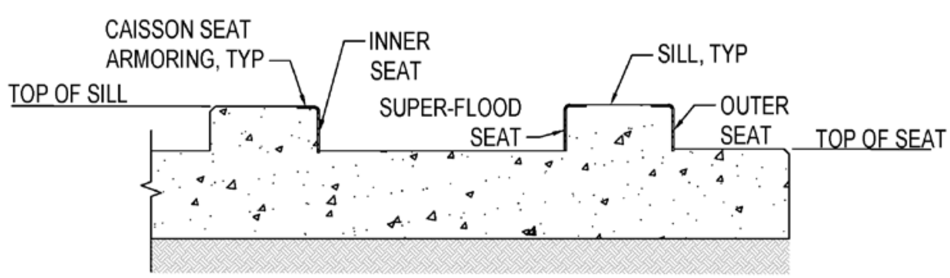
Figure 3-1 Designation of Dry Dock Features



a) PLAN



b) SECTION A-A



c) SECTION B-B

Table 3-1 Basic Dry Dock Dimensions [a]

Ship Type [b]	Width, Clear Inside Body ft (m)	Length, at coping from Head to Outer Caisson Seat ft (m)	Depth, from MHW to Dry Dock Floor ft (m)
SSN Submarine	90 (27.4)	630 (192.0) [c]	43 (13.1)
SSBN or SSGN	130 (39.6)	800 (243.8) [c, d]	48 (14.6)
Destroyer or Frigate	90 (27.4)	650 (198.1)	42 (12.8) [e]
Cruiser	115 (35.1)	800 (243.8)	38 (11.6)
Auxiliary	130 (39.6)	850 (259.1)	45 (13.7)
Carrier	Floor 210 (64.1) Coping 190 (58.0)	1,250 (381.0)	55 (16.8) [f]

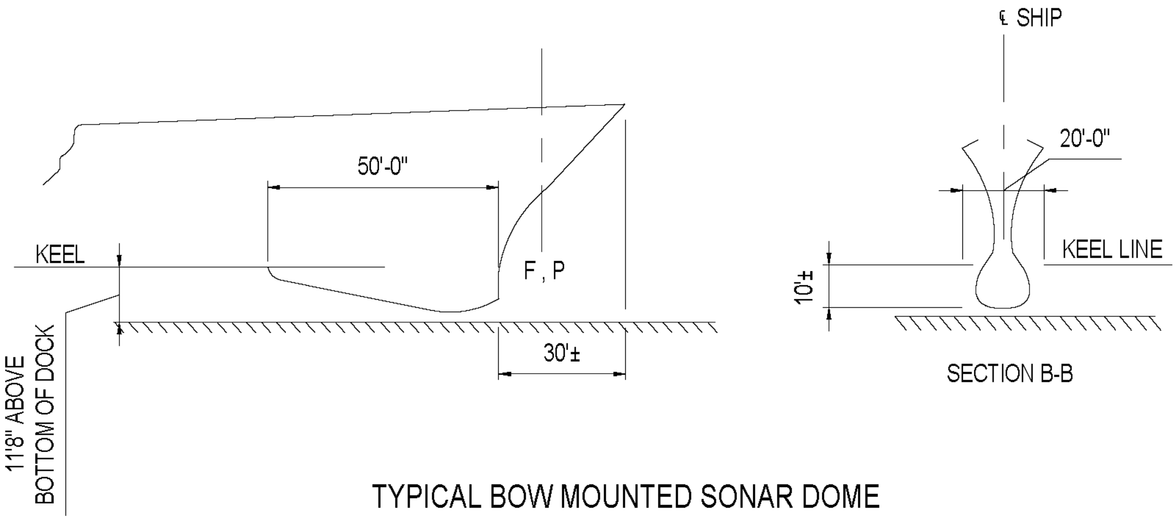
Note:

- a Dimensions listed are basic planning guidance. Ship class, site-specific conditions, and anticipated industrial work to be performed will dictate final design dimensions.
- b Refer to the following website for ship characteristics: https://www.nvr.navy.mil/SHIPS.html
- c Allowance for shaft and dome removal included.
- d Minimum floor work area. Does not include Caisson End shown in Figure 3-1 (a).
- e Allowance for sonar domes below keel line included.
- f Damaged condition.

3-2.2 Allowance for Sonar Domes.

Sonar domes are ordinarily located on the fore part of the ship keel. For a new dock to accommodate vessels so equipped, use the height of blocking required for removing domes with a sonar dolly. Sonar equipment is of various configurations and no set rules can be given (see Figure 3-2). Specific criteria must be outlined in project requirements. Sonar dome pits have been installed in some dry docks to reduce the required height of blocks.

Figure 3-2 Sonar Dome



3-2.3 Caisson Seats.

Provide an inner and an outer caisson seat at the entrance to graving docks. The outer seat is required to permit repairs to be made on the inner seat. For seat dimensions, refer to CHAPTER 9. A double-faced seat is required if a super-flooding feature is installed. For new construction, the inclusion of the superflood seat is negligible design and construction cost, therefore always provide an inner, outer and superflood caisson seats.

3-3 DRY DOCKS FOR SHIPBUILDING ONLY.

These dry docks, although sometimes built under the auspices of the Navy, are generally built in private shipyards and usually for a particular class or classes of ships. This type of dry dock is usually semi-permanent for economic reasons. The overall design, layout, pumping systems and utilities will be similar to repair dry docks. However main dewatering pump capacity can be reduced considerably as dewatering is only necessary prior to start of construction and not for docking existing ships.

Other considerations may be made to reduce cost if the life span of the dry dock will be 20 years or less. Determination of the dock lifespan and compromises weighed should be carefully considered. Experience has shown that docks built as semi-permanent have now been reclassified, and the associated life-extension project costs and risk have been considerable.

3-3.1 Height of Floor.

The draft at the time of undocking is predicated on the degree of vessel completion to be attained in the dry dock before removal to fitting-out pier. The weight and displacement will determine the elevation of the floor below mean high water.

3-3.2 Width.

Shipbuilding docks may be made narrower than repair dry docks for the same class of ships. Provide sufficient clearance to accommodate the required construction equipment between the hull and walls.

3-4 INSIDE CONFIGURATION.

3-4.1 Head End Shape.

The head end of the dry dock may be square, semicircular, trapezoidal, or ship shape as shown in Figure 3-3. One shape may best fit the pattern of adjacent structures. Additionally, there are other advantages and disadvantages which are directly associated with the construction and operation of the dry dock itself. A tabulation of these for each shape of head end is shown in Table 3-2, and is to be used as follows:

3-4.1.1 Square.

Use the square end for multiple docking, or for docks that are likely to have future extensions.

3-4.1.2 Semicircle.

Use the semicircular end for medium sized docks that cannot readily be lengthened at the head end.

3-4.1.3 Trapezoid.

Use the trapezoidal shape for small docks that are not likely to be lengthened at the head end.

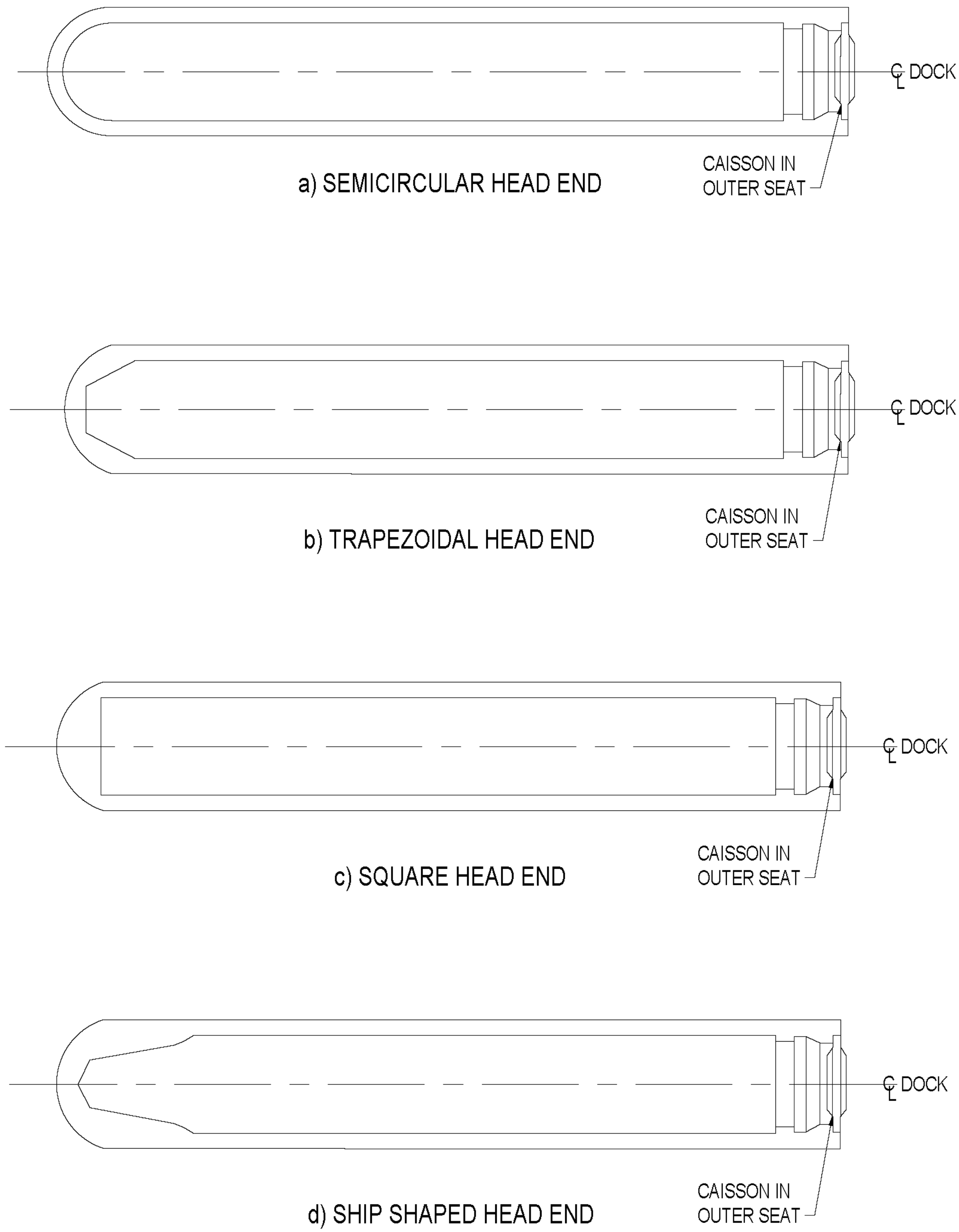
3-4.1.4 Ship Shaped.

Ship shaped dry docks are not versatile and are obsolete.

Table 3-2 Design Considerations for Various Head End Shapes

Design Considerations	Square	Semicircle	Trapezoid
Economy of formwork	Poor	Fair	Best
Economy of concrete	Poor	Best	Good
Simplicity of crane tracks	Poor	Best	Good
Simplicity of installation of service facilities	Best	Poor	Good
Fit into yard	Poor	Good	Good
Adaptability for future extensions	Best	Poor	Fair
Providing access to dock floor:			
for Carriers	Best	Fair	Poor
for Other Ships	Good	Good	Good
Suitability for multiple docking	Best	Fair	Poor

Figure 3-3 Head End Shapes



3-4.2 Entrance End.

At the entrance end of a dock, the walls may be vertical or sloped outward. Refer to CHAPTER 9 for caisson dimensioning and details of the seats.

3-4.2.1 Clearances.

Ship clearances are not as large at the entrance as in the body of the dock where working space is necessary. For docks having vertical walls, allow 5 ft (1.5 m) minimum clearance from the ship hull on each side.

3-4.2.2 Roadway.

Where an entrance caisson is to be used as a roadway for vehicular traffic, the dock coping in the way of the caisson must be designed and detailed to suit.

3-4.3 Cross Section.

The most important influence of the inside as well as the outside shape of a dry dock cross section is the structural type (and construction methods) adopted. For relation of shape to these factors, refer to CHAPTER 4.

3-4.3.1 Floor and Wall Coping Elevation.

Design the coping of the dry dock wall high enough so that it will not be overtopped by severe waves which could possibly occur at extreme high water (storm surge) level, or at the grade of the surrounding yard, whichever is higher. See Section 3-5. Establish floor elevation per Section 3-2; Floors should provide drainage to prevent standing water via crown, slope or trenches.

3-4.3.2 Service Tunnels and Galleries.

In order to bring utilities and services from the shipyard to the docked ship it is convenient to have either service tunnels, galleries or both along the top of the dry dock wall. Attention should be paid to the location of these wall features and the anticipated water level in a flooded dock. Flooding service tunnels and galleries is not desired.

3-4.3.2.1 Service Tunnels.

Service tunnels are located in and near the top of walls. The tunnel is utilized to route large size salt and fresh water piping from the yard to the dry dock. Smaller piping such as for compressed gases, electrical and data cabling can also be run in these tunnels. The tunnel must be designed for intermittent human occupancy. Openings from the service tunnel to galleries allow service to pass through. Service tunnels and galleries should be designed and constructed such that they are always kept dry. Sump pumps, isolation valves and tunnel drains should be installed if necessary. Tunnels should be wide enough to accommodate all the required piping plus clearance for people to walk and to effect repairs. The height should provide 6.5 ft (2 m) headroom even where pipe crossovers exist. Refer to Section 3-4.3.5 entitled “Crane Rails” for the relation of shape and location of tunnels to crane tracks.

3-4.3.2.2 Galleries.

Galleries can be set into the wall or cantilevered out from the wall surface. Their design should consider ship clearances during docking evolutions. The purpose of the gallery is to allow that final length of hose connection from the services in the tunnel to the ship. Gallery size should use the same parameters as service tunnels.

3-4.3.3 Steps or Altars.

The number of setbacks or altar platforms in the inboard faces of the dock walls should be kept to a minimum. Modern reinforced concrete design practically eliminates the necessity of any altars.

For full hydrostatic dry docks, gravity walls, a single step back may be made, part way up on the inboard face, to reduce concrete thickness in the upper part of the wall and to improve the stability of the wall.

3-4.3.4 Flooding and Drainage Tunnels.

Flooding and drainage tunnels are usually provided in the walls of dry docks. In order to create the most favorable stress conditions- See CHAPTER 6 and CHAPTER 7 for design considerations for these systems. Any tunnel should be designed for periodic human inspection but made as small as is compatible with hydraulic requirements. Large tunnels should never be less than 6 ft (1.8 m) high. Except for pure gravity walls, drainage tunnels present structural problems and result in increased cost.

3-4.3.5 Crane Rails.

Place one crane rail on top of the wall as close to the centerline of the dry dock as possible and compatible with other wall and tunnel design considerations. Never place the inboard rail nearer than 5 ft (1.5 m) to the edge of the coping. Rails should be set with the top flush with the concrete surface. The companion rail is generally located off the wall structure and supported independently. For additional criteria regarding location of crane rails, refer to CHAPTER 8.

3-5 FLOOD ELEVATION AND SEA LEVEL CHANGE.

A design flood elevation (DFE) must be determined in order to set the coping elevation, protect a dry dock and supporting infrastructure from flooding, and calculate the buoyancy factor of safety (FS). DFE is based on expected flood levels, additional water levels from extreme events, and future sea levels. Integrating shipyard and supporting infrastructure at new and retrofitting existing dry docks is both cost and time prohibitive. Therefore, a risk-based, adaptive approach is recommended in order to design for future extreme water events. Unless other guidance superseding this UFC is released, the following methodology is recommended.

1) First, calculate a design flood elevation using each of the three methods described below.
2) Second, rank the three elevations from lowest to highest. Begin a design that meets all structural requirements for the lowest elevation and formulate strategies to adapt to the higher elevations.
3) Finally, perform an analysis of alternatives (AOA) for future adaptive mitigations. This can be done by assigning relative cost and risk values to each of the three elevations relative to buoyancy FS, over-toping the dock, and the shipyard flood mitigation plans.

3-5.1 Flood Elevation Determination Methods.

3-5.1.1 UFC 3-201-01 Method.

This method follows UFC 3-201-01 using Table 2-1 for ASCE Flood Design Class 4. The coping is set to the minimum Design Flood Elevation (DFE) using the Base Flood Elevation (BFE). The BFE is the elevation of flooding, including wave height, having a 1% chance of being equal or exceeded in any given year.

Equation 3-1 Computation of Flooding Rate

$$DFE = BFE + 3\ ft\ (0.91\ m)$$

3-5.1.2 Extreme Event Method.

Compute the Extreme Flood Elevation (EFE) by using the FEMA value for elevation of flooding, including wave height, having a 0.2% chance of being equal or exceeded in any given year + 1 foot to coping.

Equation 3-2 Computation of Flooding Rate

$$EFE = FEMA\ 0.2\% + 1\ ft\ (0.31\ m)$$

3-5.1.3 Sea Level Change Approach.

Sea Level Change (SLC) affects the future storm surge and extreme tides. Global and local SLC shall be considered on any new construction or major dry dock renovation project. The science of SLC and application to design is an area under rapid development. All SLC values shall use the projections for at least the year 2100. Compute the extreme sea level elevations (ELSE) by:

Equation 3-3 Computation of Flooding Rate

$$ESLE = Local\ SLC + MHHW\ + Extreme\ Water\ Level$$

Where:

Local SLC = Global Scenario + Site Specific Adjustments

3-5.2 Minimum Values for New Construction.

The coping elevation shall be at or above the ELSE when using the medium global scenario and compared to the high and highest scenario for purposes of the AoA. Buoyancy FS shall be satisfied at ELSE for at least the high global scenario. If the FS is below 1.0, iterate on the design by adding mass or additional hold down elements. Check and report the FS for the highest global scenario.

3-5.3 Adaptive Strategies for Existing Docks.

For existing docks, the prediction and analysis should follow the same methodology minimum values. The mitigation for buoyancy is limited to adding hold down elements via tension piles through the floor to engage the rock or earth below the dry dock. Mitigating the potential for high water events that over-top the dry dock coping and caisson weather deck include permanent or semi-permanent floodwalls, adding a weir to the caisson, and raising the elevation of the immediate surrounding area. For any approach, the increased hydrostatic loads and resilience must be analyzed.

3-5.4 Shipyard Area Planning.

Recognizing that the dry dock does not stand alone and its mission requires the resources of the entire shipyard. Mitigating strategies for flooding the surrounding shipyard can only be addressed at the installation level. Dry Dock construction projects shall consult the area development plan and the Shipyard Infrastructure Optimization Planning (SIOP) office PMS 555 in order to maximize the dock’s operational days per year.

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CHAPTER 4 STRUCTURAL TYPES OF DRY DOCKS

4-1 DESIGN AND CONSTRUCTION.

This section deals with the influence of foundation requirements on shape and the reasoning leading up to specific type selection.

4-1.1 Basis of Type Designation.

Type designations are determined by the structural requirements necessary to neutralize the pressure of the water that surrounds it.

4-1.1.1 Hydraulic Pressure.

Hydraulic pressure can be resisted by the employment of sufficient weight and strength to resist the full pressure potential or can be diminished by absorbing the flow so as to lower the hydraulic gradient under the dry dock. The degree to which the water pressure is relieved determines the type terminology: (1) full hydrostatic; (2) fully relieved; and (3) partially relieved.

4-1.1.2 Piles.

Each of the three types of dry docks may be built with or without piles. For the full hydrostatic type, piles may be used to engage soil beneath the dry dock to contribute to the hold-down weight. For the fully and partially relieved types, piles may be used to improve the elastic modulus of the foundation or to reinforce the soil at locations of excessive soil pressure; for example, beneath the toes of walls or under ship blocking.

4-1.2 Methods of Construction.

Since a dry dock is constructed on the shore or extending into water, there is always the problem of excluding water from the construction site. To define completely the structural type of a dry dock, it is generally necessary to state its method of construction.

4-1.2.1 Water Exclusion.

On sites where water exclusion is feasible, a cofferdam, should be used. Since it must be deeper and wider than the finished dry dock, a cofferdam often presents technical and engineering problems more difficult than for the structural design of a dry dock itself. The structural type and shape of the dry dock may be influenced by the method used to solve the cofferdam problem. On sites where water exclusion is not feasible, a dry dock must be constructed by underwater methods, in which case the method used also influences the structural type and shape.

4-2 TYPES DICTATED BY FOUNDATION CONDITIONS.

4-2.1 Full Hydrostatic.

A dry dock is classed as full hydrostatic unless there is a relief drainage system that lowers the natural hydraulic head on the walls or floor. No material, even rock, can be considered impervious in the sense that it will prevent or decrease the hydraulic pressure on the structure. The full buoyancy of the dry dock must be resisted by one or more of the following factors: (1) weight of concrete; (2) weight of soil below the dock engaged by hold-down devices; or, (3) weight of earth resting on a ledge formed by the projection of the floor slab beyond the sidewalls or friction of the earth on the sidewalls.

4-2.1.1 Selection of Type.

Theoretically, a full hydrostatic dry dock can be built under almost any site or foundation condition. However, for large and deep docks, where the pressure on the floor and sidewalls is great, and especially where it is not feasible to secure a satisfactory hold-down system to the material beneath the dock, economic considerations may force the choice of another type.

4-2.1.1.1 Dry.

A full hydrostatic type of dock does not require relief pumping and, therefore, has the least cost of power and maintenance. If possible and where all other local conditions are suitable, it should be constructed in the dry.

4-2.1.1.2 Wet.

All dry docks constructed in the wet are of the full hydrostatic type because conditions preclude installing reliable relief systems underwater. Docks of this type can be constructed with or without pile hold-downs. See (a.) of Figure 4-1 for the cross section of a full hydrostatic dock constructed in the dry and (b.) of Figure 4-1 for a dock constructed by tremie methods.

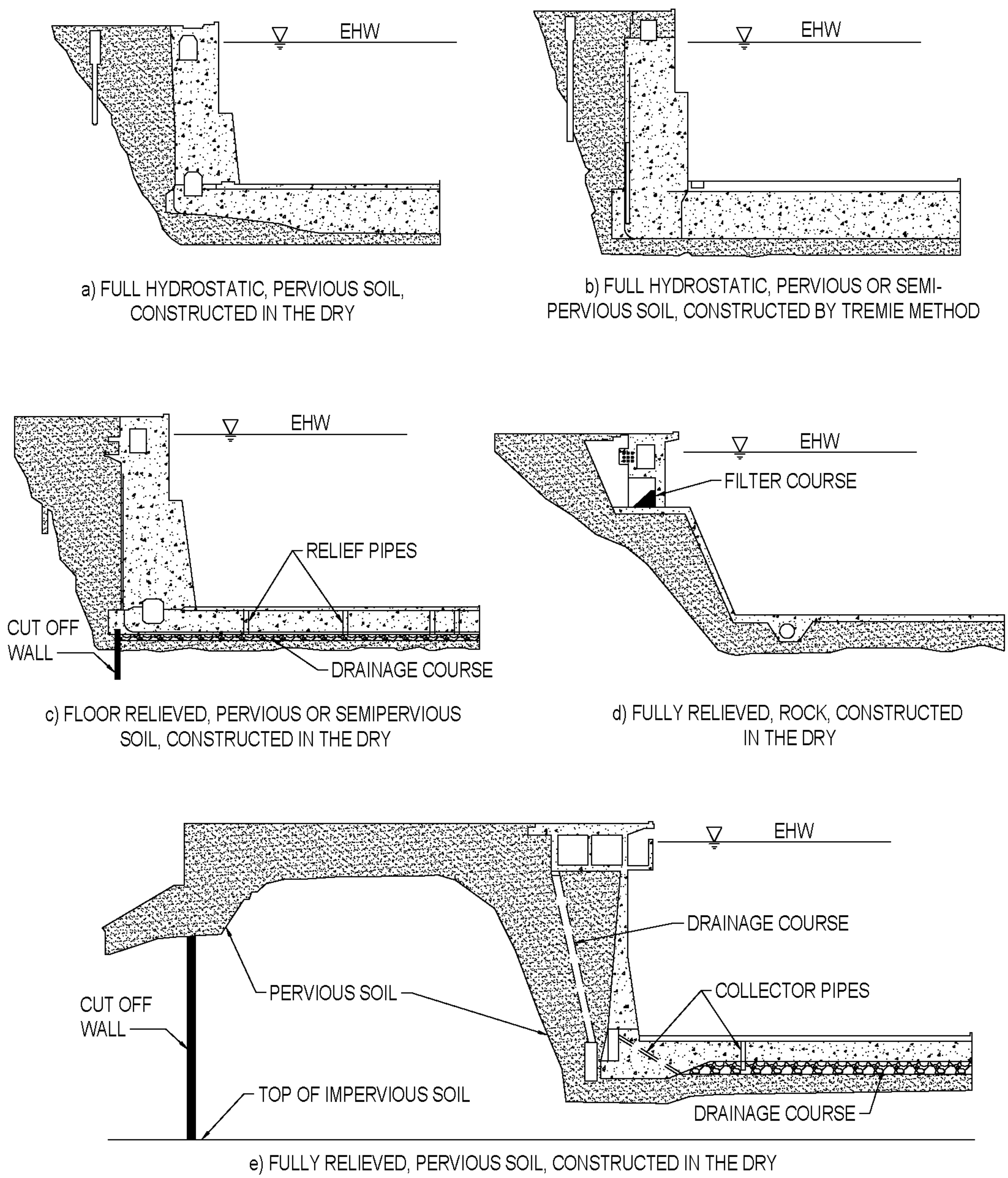
4-2.2 Fully Relieved.

A fully relieved dry dock requires a drainage system to eliminate or reduce the pressure on the floor and walls so that these elements may be of minimum size. Lower original cost will be offset to some degree by higher pumping costs throughout the life of the structure. The pressure relief type may be built for all types of foundation conditions if the flow of water is naturally cut off by not too pervious soil, or by natural or manmade means. The exception is for dry docks constructed in the wet.

4-2.2.1 Dry Dock in Rock.

For this type, it is necessary to line the rock excavation with concrete and provide weep holes through the floor and sidewall concrete lining. For an example of this type, see (d.) of Figure 4-1.

Figure 4-1 Graving Dock Sections by Structural Type and Construction Method



4-2.2.2 Dry Dock in Impervious Soil.

Where the soil is impervious, or nearly so, and the volume of seepage water to be handled is small, provide for this water to be drawn off through drainage courses placed under the floor and against the walls. This drainage course may or may not be supplemented by a pipe system to carry the seepage water into the dry dock chamber for disposal by pumping. The volume of seepage water that must be pumped during the life of a dry dock will depend on the degree of perviousness of the soil.

4-2.2.3 Dry Dock in Pervious Soil.

For a fully relieved dry dock to be built in pervious surrounding soil, provide a suitable cutoff outside the dry dock to stop the greater part of the general flow.

4-2.2.3.1 Sheet Pile Cutoff.

A dry dock may have an immediate surrounding of granular material underlain by an impervious stratum. A sheet pile cutoff, perhaps originally a part of the construction cofferdam and located at a distance from the dry dock, when driven to the impervious layer, can provide the necessary obstruction for cutting off the large volume of seepage flow which would otherwise reach the dry dock. For an example of this type, see (e.) of Figure 4-1.

4-2.2.3.2 Granular Material Filter.

Granular materials generally found at these dry dock sites must be excluded from the relief system flow. This requires the use of carefully designed filter courses and a system of drainage pipes adjacent to the walls and under the floor. The amount of pumping for this type will depend on the efficiency of the cutoff and the permeability of the soil.

4-2.3 Partially Relieved.

A partially relieved dry dock has relief provided for the floor only. Its use reduces the amount of floor concrete and minimizes difficulty in construction of the cofferdam. Provide the following:

4-2.3.1 Cutoff Wall.

Generally, a cutoff wall to surround the floor area only.

4-2.3.2 Filter Course.

A filter course under the floor. A system of collector pipes in the filter course may be used to carry the seepage water into the dry dock collecting tunnel.

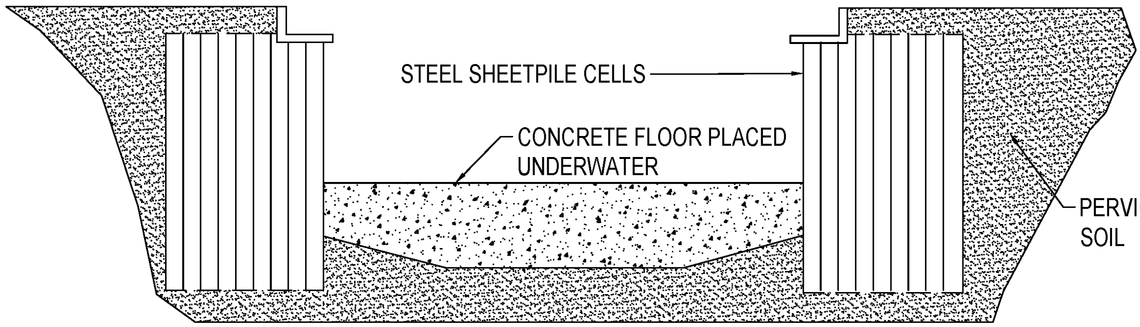
4-2.3.3 Alternate.

As an alternative to a collector system, provide holes through the floor for the seepage water to flow into the dry dock chamber then through trenches and scuppers to the collecting tunnel. See (c.) of Figure 4-1.

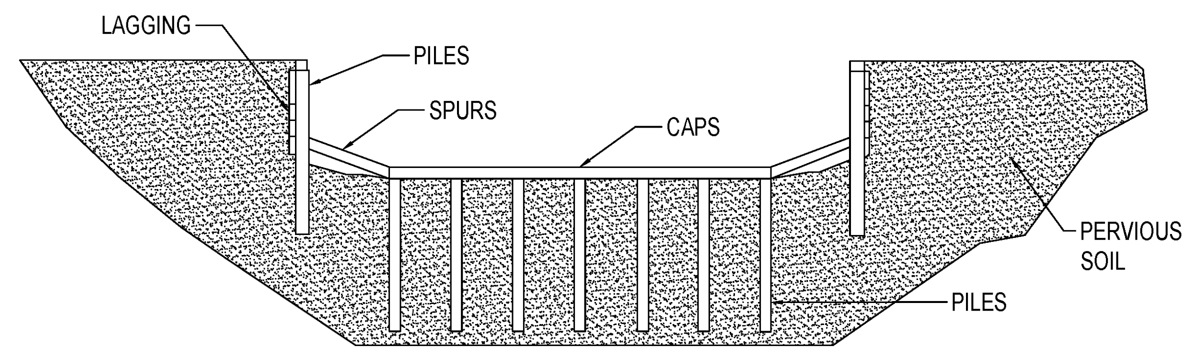
4-2.4 Miscellaneous Types.

For dry docks of temporary or semi-permanent nature, a great variety of types may be used. These types are so much different in general character from the conventional naval dry dock that classification in accordance with the method of solving the water pressure problem is not entirely definitive. These dry docks are generally for shipbuilding or for building other types of floating structures and take a great variety of shapes and forms (see Figure 4-2). For these dry docks, provide the simplest drainage systems. Either the floor or walls, or both, may not be watertight, and the water may seep through them into the dock chamber and run off the floor into trenches or pump sumps for disposal by pumping.

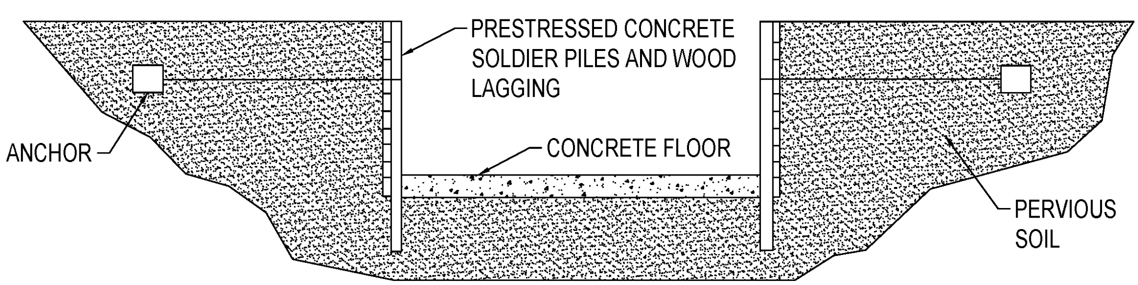
Figure 4-2 Miscellaneous Types of Dry Docks



a) SEMI-PERMANENT SHIPBUILDING DRY DOCK



b) TEMPORARY, ALL TIMBER DRY DOCK, CONSTRUCTED
IN OPEN CUT FOR BUILDING FLOATING STRUCTURES



c) TEMPORARY DRY DOCK, CONSTRUCTED IN OPEN CUT
FOR BUILDING TUNNEL SECTIONS

CHAPTER 5 STRUCTURAL DESIGN

5-1 SCOPE.

This section presents criteria on structural design of dry docks, with particular reference to dead loads, hydrostatic pressure, earth pressure, live loads, special conditions of loading, materials and design stresses, and methods of analysis.

5-1.1 Design Life.

Half the graving dry docks in the Navy's inventory are over 100 years old. It is incumbent on the design agent and end user to consider both the current mission and the future environment.

5-2 DEAD LOADS.

Dead loads are of special significance because the deadweight of the structure, including all mobilized earth weight plus friction and tension piles, must be greater than the maximum buoyancy.

5-2.1 Weight of Concrete Structure.

For design purposes, compute the weight of reinforced concrete structures on the basis of 150 lb/ft^3 (23.56 kN/m^3) weight in air. For plain or mildly reinforced concrete, assume it to be 145 lb/ft^3 (22.78 kN/m^3), unless higher value is justified by testing.

5-2.2 Weight of Earth.

In computing the total resistance to uplift, include the weight of earth engaged by any extension of the slab beyond the outside of the wall. Earth below the dry dock floor, when engaged by hold-down piles or other devices, is included in the computation of the total weight.

5-2.2.1 Weight of Earth on Floor Slab Projections.

5-2.2.1.1 Specific Weights.

Unless special, lightweight soils are encountered, use 60 lb/ft^3 (9.42 kN/m^3) for submerged soils and 100 lb/ft^3 (15.71 kN/m^3) for soils above water levels. The use of alternate values estimated based on geotechnical testing, is permitted.

5-2.2.1.2 Computation of Volume.

To compute volume with a dock empty and with mean high water, use the soil weight above the slab projection between a vertical plane at the outer edge of the projection and the back of the wall. With a dock empty and extreme high water, add the weight of earth wedge between the vertical plane and an intersecting plane sloping 15 degrees outward from the vertical plane.

5-2.2.2 Weight of Earth Engaged by Floor Slab Hold-downs.

5-2.2.2.1 Specific Weights.

This earth is always submerged. For ordinary soils, use 60 lb/ft^3 (9.5 kN/m^3). Since this weight is usually very important, determine the correct weight by geotechnical testing if there is any indication that the soil may be of a greater or lesser weight.

5-2.2.2.2 Computation of Total Weight.

The hold-down capacity of individual piles may be computed by methods given in UFC 3-220-01. The total hold-down capacity is not necessarily the sum of the individual capacities of a pile group.

- Weight: In computing the weight of this block, assume its plan dimensions to extend beyond the outer rows of piles by one-half the typical pile spacing.
- Depth: For the depth of block, assume the block bottom is above the pile tips by a distance of one-half the typical pile spacing. Where spacings are different in each direction, use the larger of the spacings.

5-3 HYDROSTATIC PRESSURE.

5-3.1 Weight of Water.

In computing pressures, use 64 lb/ft^3 (10.05 kN/m^3) for seawater and 62.4 lb/ft^3 (9.80 kN/m^3) for fresh water. For brackish water, the specific weight should be adjusted based on the water salinity content.

5-3.2 Buoyancy Computations.

Minimum factor of safety (FS) for buoyancy is 1.0 under all conditions and at all stages of the dry dock's life. This includes construction and through the end of the dry dock's expected operational life. Make all buoyancy computations for four water levels, as follows:

5-3.2.1 Extreme High Water (EHW).

To check safety against uplift with the maximum (15-degree) earth wedge mobilized. A FS shall be no less than 1.1 for this condition.

5-3.2.2 Mean High Water (MHW).

To check safety against uplift with the minimum earth block and friction mobilized. Refer to Section 5-2 entitled "Dead Loads" and Section 5-4 entitled "Earth Pressure".

5-3.2.3 Extreme Low Water (ELW).

With a ship in dock to determine maximum downward load on foundation soil or piles.

5-3.2.4 Flood Elevation.

Current and future flood elevations must be considered. After determining the design flood elevation (DFE), see Section 3-5, check the dry dock stability at this extreme event. For dry docks with a safety wall or flooding barrier the water above the yard grade may provide additional mass to counter act this increased buoyant force.

5-4 EARTH PRESSURE.

5-4.1 Variations.

Acting against a dock structure, the resultant outside earth pressure will vary considerably according to pressure and weight conditions inside the dock. Resultant earth pressures will be different when a dock is full of water, when a dock is dry but contains a vessel, and when a dock is empty. See UFC 3-220-01 for determination of earth pressures.

5-4.2 Water or Ship in Dock.

Active pressure is to be used because the rotation of the wall with respect to the floor is negligible. Do not use surcharge for computing pressure on dry dock walls except where railroad rails on ballast are near the wall.

5-4.3 Dock Empty.

Assume partial passive pressure to be operative where there is structural continuity at the juncture between sidewalls and floor because, with the dock empty, sidewalls of full hydrostatic docks tend to rotate outward against the backfill. The amount of passive resistance must be determined by assuming a uniform increase in resistance to occur throughout the sidewall height, starting from zero value at the top to an ascertained maximum bottom value. The rate of increase is based on the condition that the total internal work of the bending stresses throughout the dock cross section has a minimum value.

5-4.3.1 Inconsistency in Partial Passive Pressure Assumption.

The earth pressure at floor level should be no greater than active pressure, because the horizontal displacement of sidewalls is zero at about floor level, which is the approximate center of rotation for the sidewalls. Nevertheless, the method of approximating the total passive resistance for the condition of dock empty, as described previously, has proved satisfactory for existing structures so designed.

5-4.3.2 Upward Pressure.

5-4.3.2.1 Full Hydrostatic Dock.

The distribution of upward pressure beneath a dock designed to resist full hydrostatic pressure is known when the dock is empty, because the dock weight is nearly equal to total buoyancy.

5-4.3.2.2 Relieved Floors.

For relieved floors, earth pressures are not uniform because they are dependent on slab deflections induced by concentrated ship loads and moments at the wall bases. For the solution of elastic foundation problems and associated soil pressures, refer to any of the industry accepted foundation analysis books.

5-4.3.2.3 Friction on Sides.

In addition to the dock deadweight, friction piles, and earth weight over projections, the frictional resistance between backfill and sidewalls also is effective in preventing uplift.

- <u>Mean High Water (MHW):</u> To determine the frictional resistance for an empty dock at mean high water, the lateral force acting against the sidewalls (that is, the force corresponding to the active pressure of submerged earth) is multiplied by the coefficient of friction for the earth material on the sidewall material.
- <u>Extreme High Water (EHW):</u> Stability against uplift at extreme high water is computed using a deadweight of the earth wedges as described in Section 5-2 entitled “Dead Loads”, instead of frictional resistance.

5-5 LIVE LOADS.

For design purposes, conditions comprising live loads are:

- Shiploads applied to dock floors through blocking.
- Wheel loads from crane wheels, railroad tracks, and trucks applied to local beam and slab supports.
- Local static and moving loads on roofs and floors or pumpwells.
- Railroad track loadings, as a surcharge of earth pressure, from tracks carried on ties and ballast adjacent to sidewalls of docks and walls of pumpwells.
- An impact allowance of 15-percent is made for moving loads for structural members forming the primary support for the moving loads.

5-5.1 Shiploads.

Determine shiploads on the floor for the specific class ship. Shiploads on the floor must be determined in accordance with the guidance provided in MIL-STD-1625, and NSTM Chapter 997.

5-5.1.1 Thin Floors.

For thin floors, investigate the effect of these extra heavy loads, and reinforce the floor locally as necessary.

5-5.1.2 Positioning.

Base the blocking arrangement for design of the floor on any likely positioning of ships in the dock. Larger ships may be docked only on the centerline of the graving dock. For docks wide enough to permit multiple docking of ships abreast, or long enough to permit various placement fore and aft, apply the load pattern for such smaller ships multiple docked in odd positions to the floor as well as the load pattern of larger ships docked on the centerline.

5-5.2 Wheel Loads.

The typical wheel loadings for a 40 ST (36.3 t) locomotive crane, 25 ST (22.6 t), 35 ST (31.7 t), and 50 ST (45.4 t) portal cranes are given in UFC 4-152-01.

5-5.2.1 Full Hydrostatic Graving Docks.

Crane wheel loads do not normally influence the design of the main wall of graving docks designed to resist full hydrostatic pressure, because of the extensive longitudinal distribution of the wheel loads by the walls. Wheel loads from cranes operating around full hydrostatic graving docks, therefore, usually are significant only in the design of local beam supports under rails crossing the overhead of service tunnels, pumpwells, and other auxiliary structures.

5-5.2.2 Relieved and Partially Relieved Graving Docks.

For relieved and partially relieved graving docks, crane wheel load may influence the design of main dock walls as well as the design of local beam supports.

5-5.2.3 Mobile Crane Loads.

Mobile cranes are to some extent replacing locomotive cranes. Use truck crane wheel loads as given in UFC 4-152-01 or the crane manufacturers wheel load specifications (covering many of the larger ~ 220 ST (199.6 t) mobile cranes used by PWDs/Shipyards/Private Contractors) for beams, slabs, and the overhead structure of the pumpwell, where crane track loading does not govern.

5-5.3 Loads on Pumpwell Overhead and Floors.

Pumpwell overhead should be designed for a uniform load of 600 lb/ft^2 (28.8 kN/m^2) and for truck crane wheel loading when it is at ground level. The critical load for floors supporting main pumps usually corresponds to the maximum upward pressure. Use a uniform load of 300 lb/ft^2 (14.4 kN/m^2) for floors not subject to upward hydrostatic pressure; also these floors are to sustain loads from operating machinery placed thereon either in a permanent operating position or in a temporary overhaul position. Include vibrations induced by reciprocating and rotating equipment in the design.

5-5.4 Anti-Terrorism, Bomb and Blast Resistance and Security.

Dry docks are not usually designed to resist bombing or blast effects because of the massive size of the structure involved. In some locations, consideration should be given to protective construction for the upper part of the pumpwell and the service tunnels. For waterfront security and anti-terrorism/force protection criteria, refer to UFC 4-025-01, *Waterfront Security Design*.

5-6 EARTHQUAKE LOADS.

Seismic analysis of the dry dock must be performed in accordance with MIL-STD-1625. Seismic forces should be considered as an “extreme” load and are to be combined with the additional forces that are present during regular operations, with appropriate load factors in accordance with UFC 4-152-01. Site specific geotechnical studies must address seismic and soil-structure interaction based on the hazard levels addressed in MIL-STD-1625, consider Chapter 4 of ASCE 61.

5-7 SPECIAL CONDITIONS OF LOADING.

5-7.1 Full Hydrostatic Dry Docks.

Although there are many special loading conditions to be considered in the design of a graving dock (for example, nonsymmetrical loads, wave action on exposed walls, earthquake, and unusual water differentials), the design of full hydrostatic pressure docks generally is concerned with four especially critical conditions.

- **Case I**. Dock under construction.
- **Case II**. Dock empty. Maximum hydrostatic uplift.
- **Case III**. Maximum ship load. Minimum hydrostatic uplift.
- **Case IV**. Dock full of water. Include superflooding, if applicable.

5-7.2 Partially and Fully Relieved Dry Docks.

Critical conditions for partially and fully relieved designs are similar to those for full hydrostatic dry docks, except for appropriate allowance for decreased upward and lateral water pressures in accordance with the degree of lowering of hydraulic gradients.

5-7.3 Dry Docks Built by Underwater Methods.

When completed, these dry docks are always of the full hydrostatic type. In some cases, however, this method of construction involves loadings not encountered with construction in the dry. These cases occur when walls are built entirely in the dry in cofferdams set on slabs previously constructed underwater. Under these conditions, when wall cofferdams are dewatered, the partially completed structure does not have the benefits of wall and finish floor slab weight to overcome the buoyancy of the cofferdams, or the full sidewall thrust to overcome the tension in the slab. For examples of two such conditions, see Figure 5-1.

These dry docks are frequently associated with the use of hold-down piles, necessary if the weight of the floor slab is insufficient to overcome the total buoyancy including that of the empty cofferdam or cofferdams. Note in (a.) of Figure 5-1 there is a tendency to develop tension in the slab bottom without benefit of axial compression from a sidewall thrust. In (b.) of Figure 5-1, there is a tendency to develop tension in the slab top with a side thrust that is much smaller than will be developed against the walls of the completed dock.

5-8 MATERIALS AND DESIGN.

This section contains special provisions applying to concrete for dry dock walls, floors, and general cross section.

5-8.1 Concrete.

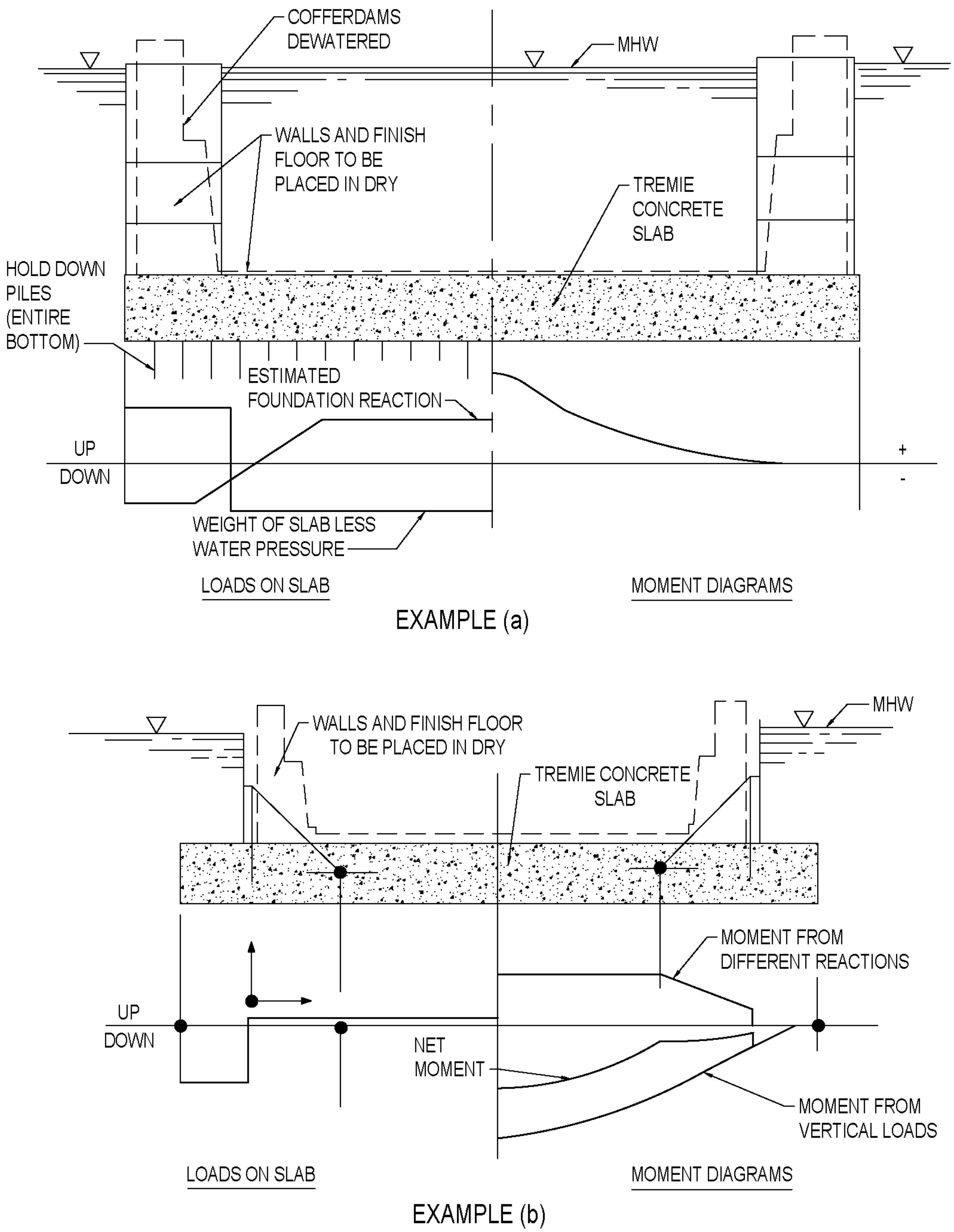
5-8.1.1 Classes of Concrete.

Recommend using concrete as specified in UFGS 03 31 29 or UFGS 03 31 30 *Marine Concrete* as appropriate. Use minimum 3,500 psi (24.12 MPa) estimated 28 days compressive strength cast-in-place concrete for the main body of the dock. Classes of greater strength may be used in accordance with structural requirements. Do not specify mortar intrusion concrete (see APPENDIX B, Glossary) for permanent dry docks.

5-8.1.2 Admixtures.

Admixtures may be used to produce air entrainment, higher strength, greater durability and better workability, up to maximum percentages detailed in the project specifications.

Figure 5-1 Dry Docks with Slabs Constructed Underwater, Walls and Finish Floor Constructed in Dry



5-8.1.3 Mass Concrete.

The designer must follow the guidance in UFGS 03 31 29, UFGS 03 31 30, ACI 207.1R, ACI 207.2R, and ACI 207.4R to prevent undesirable cracking in mass concrete used to construct the dry dock. A thermal study must be conducted as a part of the design effort when mass concrete will be used in construction of the dry dock. The designer must specify the methods of crack control to be used including mix design, pour size and sequencing, and temperature control during placement and curing. Consideration must be given to the following during design to minimize cracking:

- Maximizing aggregate size.
- Limiting monolith widths to 50 ft (15.5 m).
- Increasing temperature and shrinkage reinforcement above the minimum requirements of ACI 318 up #9 (#29) bars at 12 in. (305 mm) in each face.
- Requiring the contractor to conduct a mass concrete simulation test (mock up) prior to construction to validate the adequacy of crack control measures.
- Mass concrete temperature control plans.

5-8.2 Reinforcing Steel.

5-8.2.1 Cover.

Minimum concrete protection for reinforcement is as follows:

- 6 in. (152 mm) where face of concrete will be in contact with soil, and surfaces subject to cavitation or abrasion erosion.
- 3 in. (76 mm) for formed or finished surfaces not in contact with soil.
- 2 in. (51 mm) over bearing pile butts.
- At piles intended as tension piles and having a considerable length of embedment in the concrete, place the reinforcement as in the first bullet above.

5-8.2.2 Reinforcing Bars.

Reinforcement should have a minimum yield strength of 60,000 psi (413.7 MPa), and conform to either of ASTM A706/A706M, *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement* or ASTM A615/A615M*, Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement*, Grade 60. High strength or special large size reinforcement should conform to Grade 75 or Grade 80. Consider use of galvanized, coated or corrosion resistant reinforcement such as fusion bonded or purple bar coating. To control cracking, the maximum center-to-center spacing should not exceed 12 in.

5-8.3 Foundations.

Evaluate safe soil bearing capacity by methods set forth in UFC 3-220-01. Where the safe capacity of the soil is exceeded, provide structural support. Types of structural supports applicable to the foundation of dry dock proper and to supplemental structures are: timber piles, concrete piles, steel H-piles, pipe piles with open or closed ends, and caissons. For pile capacities, analytical treatment, information on range of capacities for various types of piles, and capacity of caissons, refer to UFC 3-220-01.

5-8.4 Cellular Cofferdam Wall.

The dock wall consisting of cellular sheet pile structure should be designed based on USACE EM 1110-2-2503 *Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures.*

5-8.5 Design.

5-8.5.1 Reinforced Concrete.

5-8.5.1.1 Load and Strength Reduction Factors.

In design of reinforced concrete structures, proportion members for adequate strength in accordance with provisions of the latest edition of ACI 318, *Building Code Requirements for Reinforced Concrete*, using load factors and strength reduction factors (Φ) specified.

5-8.5.1.2 Service Load Stresses.

Alternatively, non-prestressed reinforced concrete members may be designed using service loads and permissible service load stresses in accordance with provisions of ACI 318-99, Appendix A, Alternate Design Method.

5-8.5.1.3 Buoyant Condition Increases.

For a buoyant condition of a continuous U cross section, which might be produced in a relieved or partially relieved dock resulting from failure of the pressure relief system, or for construction stages, the ordinary working design criteria may be increased 50 percent.

5-8.5.2 Steel and Other Materials.

For appurtenant structures of concrete, steel, wood, and other structural materials, design must be in accordance with UFC 1-200-01.

5-8.5.2.1 Allowance for Corrosion of Steel Structures.

Steel structures must be designed with a corrosion allowance such that allowable stresses will not be exceeded when corrosion has reduced structural component cross sectional areas by the amount of the corrosion allowance. Corrosion allowances should be tailored to suit the environment of each steel structure. All pressure or flooding boundaries must be considered. This includes such examples as the caisson hull, watertight hatches and sluice gate thimble plates.

5-9 METHODS OF ANALYSIS.

5-9.1 Full Hydrostatic.

For analysis of four basic conditions of loading, refer to *American Civil Engineering Practice, Volume II*.

5-9.2 Fully or Partially Relieved.

Where these dry docks have relatively thin floors, concentrated ship blocking loads and wall reaction produce deflections resulting in variations in foundation pressures and requiring methods of elastic foundation analysis. The problem is to be treated as two-dimensional. The elastic foundation method may be used to assist in estimating foundation pressures for the special loading conditions discussed in Section 5-6 entitled “Special Conditions of Loading”.

5-9.3 Seismic Analysis.

Simple method of analysis such as Seismic Coefficient Method and Equivalent Lateral Method should be implemented in the initial stage of analysis and later progressing to increasing complexity by implementing linear elastic response spectrum, time-history modal-analysis and non-linear time history-direct integration procedure, if necessary. Refer to EM 1110-2-6053, Earthquake Design and Evaluation of Concrete Hydraulic Structures for general approach for the seismic analysis.

5-9.4 Computer Analysis.

The dock structure may be analyzed using structural finite element analysis (FEA) and/ or soil-structure interaction (SSI) analysis codes, depending on the complexity of the structure and loading. The analysis may initially be performed on two-dimensional (2D) sections and later progressing to three dimensional (3D) analysis, if necessary.

5-10 SAFETY CONSIDERATIONS.

5-10.1 Basic Safety Standards.

For general safety standards see OSHA Part 1915, *Occupational Safety and Health Standards for Shipyard Employment*, and Part 1910.29 *Fall protection systems and falling object protection-criteria and practices*. Local shipyard safety instructions or other current U.S. Navy safety requirements may take precedence. Consult representatives from the local safety office and the appropriate subject matter experts before finalizing the design of safety features.

5-10.2 Safety Features Peculiar to Dry Docks.

Observe the safety features described in the sections below.

5-10.2.1 Coping Railing.

It is necessary for coping railings to be removable to avoid fouling lines when docking and undocking ships. The removal and replacement must be accomplished with as little hazard as possible because of the seriousness of the accident should a person fall into an empty dock. Chain rail with removable stanchions were used in the past, but maintaining adequate chain tension is a common problem. Solid metal pipe or fiberglass railing, provided in 6 to 10 ft (1.8 to 3 m) sections for ease of removal/reinstallation, is preferred. The design and locations of the top rail, mid rail, and toeboard must meet fall protection requirements. Refer to the shipyard safety office or current U.S. Navy safety guidelines for specific requirements.

5-10.2.2 Stairways.

Use open mesh treads on all framed stairways. Use non-slip treads for concrete stairways. At the top of steep, infrequently used stairways provide a guard. Closing chains may be used however; self-closing gates are preferred because they do not rely upon personnel to reattach the chains after each use. Open stairways must have top rail and mid-rail. If the top rail is used to guard an opening then the top of the rail as measured from the stair nosing is between 36 in. and 38 in. (914 mm and 965 mm).

5-10.2.3 Toeboards.

Provide toeboards in accordance with fall protection requirements at all rails where falling object protection is required. At the coping edge, a curb may serve as a toeboard.

5-10.2.4 Obstructions to Mooring Lines.

Keep the top of coping clear between the edge of the coping and the line of capstans and bollards.

5-10.2.5 Stepdowns in Tunnels and Culverts.

Avoid unprotected stepdowns in all unlighted tunnels and culverts. Use guardrails, or an arrangement of rails and gratings, to protect personnel while still retaining the water carrying capabilities of the tunnel or culvert.

5-10.2.6 Spillways.

Provide replaceable corrosion resistant (type 316 Stainless Steel or Composite) ladder rungs or guardrails, depending on steepness, up flooding and discharge spillways, to aid in access for inspection of sluice gates and stoplogs.

5-10.2.7 Dock Floor Irregularities.

Graving dock floors should present an unbroken surface. Cover drainage conduits with gratings that do not protrude above the floor level. Run service pipes near the sidewalls and bridge them at stairways. Floor finish should be sufficiently rough to prevent slipping, but not so rough as to injure blocks.

5-10.2.8 Painting.

Paint obstructions with a striped pattern composed on contrasting colors as outlined in UFC 3-190-06.

- Service pipes are customarily painted according to established color codes, but those below headroom or otherwise forming obstructions should be painted with contrasting colors in stripes.
- Channel pedestrian traffic through safety zones by marking the borders of pedestrian passageways with traffic zone paint.

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CHAPTER 6 FLOODING

6-1 DESIGN FACTORS.

This chapter contains criteria and information on flooding of dry docks, particularly methods of flooding and the design of hydraulic structures.

6-1.1 Requirements.

Flooding of dry docks is done entirely by gravity; superflooding feature installations require a pumping system to raise the water inside basin to water levels to higher elevations than the tide range allows. Design and arrange all flooding systems to operate with a minimum of disturbance to ship blocking, no intake of silt or floating objects, a minimum of required special gate control, and no vacuum or cavitation effects in the water channels. Gates and gate operating mechanisms must be reliable and durable.

6-1.2 Flooding Periods.

The average time for flooding Navy Dry Docks of the five types may be used as a design guide. Flood times are for empty docks. Actual flood time will depend on many factors. New docks or renovations shall set flooding time requirements based upon operational, environmental and functional needs of the shipyard. The times for flooding the docks should be, for the main classifications:

- SSN Submarine and destroyer docks, 90 minutes.
- Cruiser docks, 135 minutes.
- Carrier and Auxiliary docks, 135 minutes.

6-2 FLOODING METHODS.

There are three general methods used for flooding graving dock basins.

1. From flooding intakes on one or both sides of the entrance through culverts built into the lower parts of sidewalls and connected to floor openings spaced along the dock length at the floor.
2. From flooding intakes on one or both sides of the entrance through culverts passing transversely under the floor near the entrance with openings leading upward into the floor.
3. Through ducts or tubes in the caisson or entrance closure gate. This is referred to as a flood through caisson.

6-2.1 Common Intake Features.

Except under special conditions, place one intake opening on each side of an entrance. For very large docks requiring large culverts, two openings on each side may be used to reduce sluice gate sizes. Opening edges should be rounded to reduce eddying and contraction of the stream.

6-2.1.1 Opening Elevations.

No standardization can be established for opening elevations since these depend on tidal ranges, stem rises of gate valves, and proximity and character of entrance approach bottoms. In general, depths below mean low water, where opening soffits are placed, should not be less than opening heights. When an entrance approach bottom is near the invert or openings, protect the bottom area in front of and adjacent to the openings from erosion by heavy rip-rap or other means.

6-2.1.2 Trash Racks.

Place trash racks over openings to prevent intake of solid matter. Trash racks must be removable for maintenance and replacement.

6-2.1.3 Stoplogs.

Between trash racks and sluice gates, provide vertical slots in culvert sides to accommodate stoplogs furnished to shut off the water for sluice gate maintenance with double valve protection.

6-2.1.4 Sluice Gates.

Control graving dock flooding with sluice gates. Provide two sluice gates per flooding opening or a sluice gate plus a stoplog to assure “double valve protection” against inadvertent flooding as required by MIL-STD-1625.

6-2.1.4.1 Minimum Design.

When under heavy hydrostatic pressures occurring during high tide levels with wave action, design must be adequate to prevent operating and maintenance troubles caused by distortion, warping, and excessive friction.

6-2.1.4.2 Maximum Design.

Design maximum sluice gate sizes to allow flooding a dock within the specified time.

6-2.1.4.3 Design for Two-Way Pressure.

When sluice gates are subjected to two-way pressure, they must be specifically designed for such service.

6-2.1.4.4 Specific Requirements.

- Minimum design life of 30 years.
- Maximum leakage of 0.05 gpm/ft (0.6 lpm/m) of the seal perimeter at the design seating and unseating head.
- Limit the largest dimension to 96 in. (2.44 m).
- Provide local mechanical gate position indicators at gate stands, and remote electrically operated indicators at pumpwell control boards.
- Design structural supports for gate lifting mechanisms to carry a load two times the manufacturer rated lifting force (Factor of Safety = 2.0).
- Sluice gates used in dock flooding, dewatering, or drainage systems must be oriented such that the greatest pressure they will experience will seat the gate leaf against the gate frame. Sluice gates that will experience pressure from both sides (dock flooding gates for superflooding docks, gates in interconnecting tunnels between dry docks, etc.) must be specifically designed to accommodate expected unseating heads.
- Suitable corrosion resistant thimbles should be embedded in concrete for attachment of sluice gate frames.
- For all wedges and seating surfaces where sliding occurs, the use of a metal sliding against a metal of the same alloy composition may create galling problems. Use metals of different alloy composition or the same metals with different hardness and anchor these seating surfaces with dovetail grooves. For specific wearing problems, consult a metallurgist.

6-2.1.5 Draft Boards and Dock Marks.

Draft Boards or water level indicators must be placed on dry dock walls near the entrance on each side and on dry dock walls near the head end on each side. The indicators must be clearly visible from the opposite side at the top of a dry dock. Mark gauges with numerals 6 in. (152 mm) high, 3 in. (76.2 mm) clear space above and below and with the bottoms of numerals corresponding to multiples of 1 ft (305 mm) of draft.

The gauges may be cast as recesses in wall concrete and painted, colored tile cemented into a wall, noncorrosive metal anchored into the wall or plastic composite also anchored to the wall. The zero level may be referenced to the dock floor elevation, sill height or the top of the standard docking blocks used. Refer to NSTM Chapter 997, and MIL-STD-1625 for additional requirements.

Dock marks are longitudinal markings along the dock length. They are helpful in referencing utility locations, work orders for maintenance requests and progress during dock evolutions. They should be placed along the upper wall or top-level coping facing inward so that they are visible from the opposite sides of the dock and from the floor when the dock is empty. Zero should be the inner caisson seat face. Maximum increments must not exceed 100 ft (31 m) center to center.

6-2.1.6 Vents.

Vents must be provided behind each gate, leading from water duct soffits to the free atmosphere on the coping where the vent openings must be covered by grating. A vent must be located at the highest point of a soffit before it curves down into the flooding culverts proper.

6-2.2 Flooding Culverts.

One of the two following types of culverts may be used to conduct flooding water from entrance works into a dry dock chamber.

6-2.2.1 Sidewall Type.

Sidewall culverts are located in the lower parts of sidewalls, connected to the sea through the entrance works. Floor openings and one or two large sidewall openings are connected to them.

6-2.2.1.1 Advantages.

This arrangement achieves filling without dangerous currents. A flooding culvert often serves in part as a drainage and/or dewatering culvert. The use of floor openings for filling provides a blanket of water to cushion the force of water from the outlets and also flushes the floor drains.

6-2.2.1.2 Flooding Design.

In a flooding culvert, maximum velocity occurs during early flooding stages and is gradually reduced by loss of head resulting from the rising water level inside a dock. The flooding time is greatly affected by the flow rate at reduced heads when a dock is nearly full. Therefore, large culverts and openings are desirable. It is important to reduce friction, eddy currents, and turbulence, by making interior surfaces of culverts smooth and all changes of direction by means of gradual curves.

6-2.2.1.3 Tunnels.

This system is efficient if hydraulic requirements do not result in tunnels of such size as to produce complex and high stress concentrations in the walls. This is especially true of thin walls with stressed reinforcing steel and less true in gravity walls. Even for the latter case, formwork is expensive. Long stretches of tunnel increase cleaning and maintenance work. From experience long stretches of tunnels that wrap around the dock floor or deliver water to the head end of dock are unnecessary. For existing docks, these tunnels should be filled, after checking for structural concerns, during renovations of the dock.

6-2.2.2 Transverse Floor Type.

Transverse floor culverts comprise a number of openings, spaced across a dock floor above a wide culvert located parallel to, and from 10 to 18 ft (3.1 to 5.6 m) inboard of, the inner caisson seat; the inboard distance depending on the dock size. The culvert ends rise in the sidewalls and terminate in the entrance works.

6-2.2.2.1 Flooding Factor.

In operation, the method of flooding through openings of transverse culverts necessitates partial opening of the sluice gates for a sufficient time to attain adequate water depth on the floor, so the flow velocity toward the head end will not dislodge or damage the blocking.

6-2.2.2.2 Cost Factor.

A properly designed system of this type will comply with specified flooding times at lesser cost than the system of flooding through sidewall culverts.

6-2.3 Flood Through Caisson.

Dry docks can be flooded through ducts or tubes in an entrance closure caisson or gate. This method for flooding the dry dock can be used exclusively, or it can be used in combination with flooding intakes in the dock walls. This is the preferred method because it provides greater redundancy and is more cost effective than the other two methods for both initial construction costs and O&M costs. Conversion of existing docks from using culverts to caisson flood through tubes is recommended when repair of flooding sources is studied.

For this method of dry dock flooding, multiple round tubes or ducts penetrate the caisson shell plating through the caisson ballast tank. Tube diameter is normally 30 in. (762 mm) and should not be larger than 36 in. (914.4 mm). The number of flooding tubes is dictated by the desired flooding time and hydraulic characteristics. However, utilize at least two flooding tubes for redundancy if the dock is to be flooded exclusively through the caisson. Each flooding tube must meet the requirements of double valve protection per MIL-STD-1625. This can be accomplished by having two valves installed in series or with one valve and flanges on the exterior of the caisson for steel blanks. Additional requirements are contained in CHAPTER 9.

6-2.4 Super-flooding.

Super-flooding is a system to raise the inside water levels to higher elevation than that of the normal tides. A super-flooding system has been used in several graving dry docks with inadequate water depth to enable them to dry dock sonar equipped ships and ships of newer deep draft design. Ideally a dry dock would be designed without the need for such a system. However, increased ship docking capability may be obtained by installing a super-flooding system that lifts ships by flotation. The operation consists of off-center vessel entry into the dock chamber, placing entrance caisson in seat, pumping water into the dock chamber thus raising the ship, breasting the ship over preset keel blocks, and then dewatering the dock chamber.

It also requires that the dry dock have an inboard faced caisson seat or securing devices for the entrance closure to resist the outward hydrostatic pressures caused by the raised interior water level. Super-flooding is most cost effectively accomplished by installing the super flooding pumps in the caisson. At least two super flooding pumps should be used. The system should be piped to allow suction to be taken from the outside face of the caisson and discharged into the dry dock. Super-flooding can also be accomplished by using the main dewatering pumps thorough a specifically designed arrangement of sluice gate and dewatering valves. This design requires that the main dewatering pumps take suction from the flooding source and discharging into the dock.

6-3 HYDRAULIC DESIGN.

6-3.1 Overall Factors.

In hydraulic design of flooding systems, consider the factors of waterheads, required flooding times, optimum configuration of culverts, permissible flow velocities, and limiting sizes of sluice gates.

6-3.1.1 Heads.

Hydrostatic head causing flow varies from a maximum when a dock chamber is empty, to zero when a dock chamber is full. Mean high water (MHW) or mean higher high water (MHHW) is used as the reference elevation for determining maximum head.

6-3.1.2 Required Flooding Time.

Refer to Section 6-1 entitled “Design Factors”.

6-3.1.3 Flow Velocities.

The maximum desired flooding flow velocity should be 25 ft/s (7.6 m/s). This velocity may not conform to an available head that could produce higher velocities. In such cases, either provide built-in head losses in the system or reduce the intake area by sluice gate throttling.

6-3.2 Evaluation of Flooding Time.

The many factors affecting flow in flooding systems make it practically impossible to compute accurately the time required for the flooding. Such factors include:

- Variations in Hydrostatic Head. These conditions exist because of water rise in the dock, and the difference in actual tidal conditions from those assumed in the design.
- Transitions in culvert cross sections in many cases are necessarily abrupt; for example, at dock floor openings.

- Changes in elevation and direction of the main culvert alignment.
- Head losses in trash racks and gratings.
- Roughness condition of culvert walls.
- Entrance and discharge head losses.
- Size of ship in dock.

6-3.3 Computation of Flooding Time.

Because of the difficulty in combining the various factors influencing flow, the entire system is treated as an entity with a single overall flooding coefficient applied in the basic formulas as in Equation 6-1.

Equation 6-1 Computation of Flooding Rate

$$Q = aC_f\sqrt{2gh}$$

Where:

Q = *flooding rate, ft^3/s (m^3/s)*

C_f = *overall flooding coefficient (dimensionless)*

a = *cross section area of main culvert, ft^2 (m^2)*

g = *acceleration of gravity, ft/s^2 (m/s^2)*

h = *difference in elevation between water in dry dock and outside water, ft (m)*

To determine the relationship between a varying head, as the water rises in the dry dock, and an interval of elapsed time, take the expression in Equation 6-2.

Equation 6-2 Computation of Flooding Velocity

$$\frac{Q}{A} = -\frac{dh}{dt}$$

Where:

A = *average plan area of the water pond in a dry dock, ft^2 (m^2)*

t = *interval of elapsed time, sec*

Then substituting the value of Q from Equation 6-1,

Equation 6-3 Time Rate of Change

$$dt = \frac{-Adh}{a \cdot C_f\sqrt{2 \cdot g \cdot h}}$$

Or for definite time intervals (integrating Equation 6-3 between limits h_2 and h_1)

Equation 6-4 Time rate of change for definite interval

$$t_2 - t_1 = \frac{2 \cdot A \cdot \left(\sqrt{h_1} - \sqrt{h_2}\right)}{a \cdot C_f \sqrt{2 \cdot g}}$$

The total time T, for the dock to reach the outside water level ($h_2 = 0$) with an initial difference h_1:

Equation 6-5 Total flooding time

$$T = \frac{2 \cdot A \sqrt{h_1}}{a \cdot C_f \sqrt{2 \cdot g}}$$

The value of C_f may be obtained from tests on dry docks or other structures such as ship locks with comparable flooding systems. For proposed flooding systems of unusual character, or for dry docks of unprecedented size, model tests should be considered.

CHAPTER 7 DEWATERING

7-1 DEWATERING SYSTEMS.

This section deals with criteria, data, and information on dewatering, with particular attention to basic components, basic requirements, and pumping systems.

7-1.1 Main Dewatering System.

This system is used to remove water from the dry dock basin during docking operations. Large grating covered culverts in the dry dock floor adjacent to the main pump suction chamber are normally used to facilitate flow into this system.

7-1.2 Drainage System.

A drainage system collects the last few inches (centimeters) of water blanketing the graving dock floor, as well as rainwater, flushing water. The floor should be sloped or crowned so that water will make its way to longitudinal floor trenches that lead to culvert adjacent to the main pump suction chamber. The trenches should be covered by securely anchored strong gratings.

7-1.3 Environmental Systems.

Environmental requirements in most locations now require that potentially contaminated water be treated prior to discharge. If potentially contaminated and uncontaminated waters are allowed to mix, the mixture must be handled as contaminated water. For this reason, it is usually necessary to segregate potentially contaminated water sources in the dry dock from uncontaminated sources that can be pumped directly into the harbor. Potentially contaminated sources can include water that contacts the dry dock floor where industrial activities are occurring. Uncontaminated sources include water pumped from the dry dock during docking/undocking operations, water that leaks past the caisson seat, ship’s cooling water, and water that leaks through dock walls or enters the dock through pressure relief pipes. Segregation is typically done by designating a location just beyond the sill beyond which all water is handled by the environmental discharge systems, and any water between this location and the caisson is discharged by the drainage system.

Design environmental systems so that system failure does not result in flooding of the dry dock floor. Environmental systems should overflow into the normal floor drainage system before the water reaches dry dock floor level.

Environmental system requirements vary by location and can be subjective. For this reason it is critical that environmental system planning and design be closely coordinated with the regulatory authorities to ensure compliance with environmental requirements.

7-2 DEWATERING SYSTEM COMPONENTS.

7-2.1 Floor Trenches.

The floor trench should be narrow and short grating covered leading to the pump suction chamber, collector channel, a wide, deep, grating covered open culvert leading to the pump suction chamber, handles the greater portion of water pumped out of the flooded graving dock by the main dewatering system.

7-2.2 Sand Sumps.

Abrasive materials harmful to pumps and pump fittings are continuously washed off a graving dock floor in sufficient quantities to justify the installation of a settling basin. Provide settling basins to retain most of these harmful suspended particles. Locate these basins in an accessible part of the collector channel to permit easy removal of collected sediment and sand. Other methods of containing this material may be used as an alternate, such as floor barriers around the ship.

7-2.3 Suction Chamber.

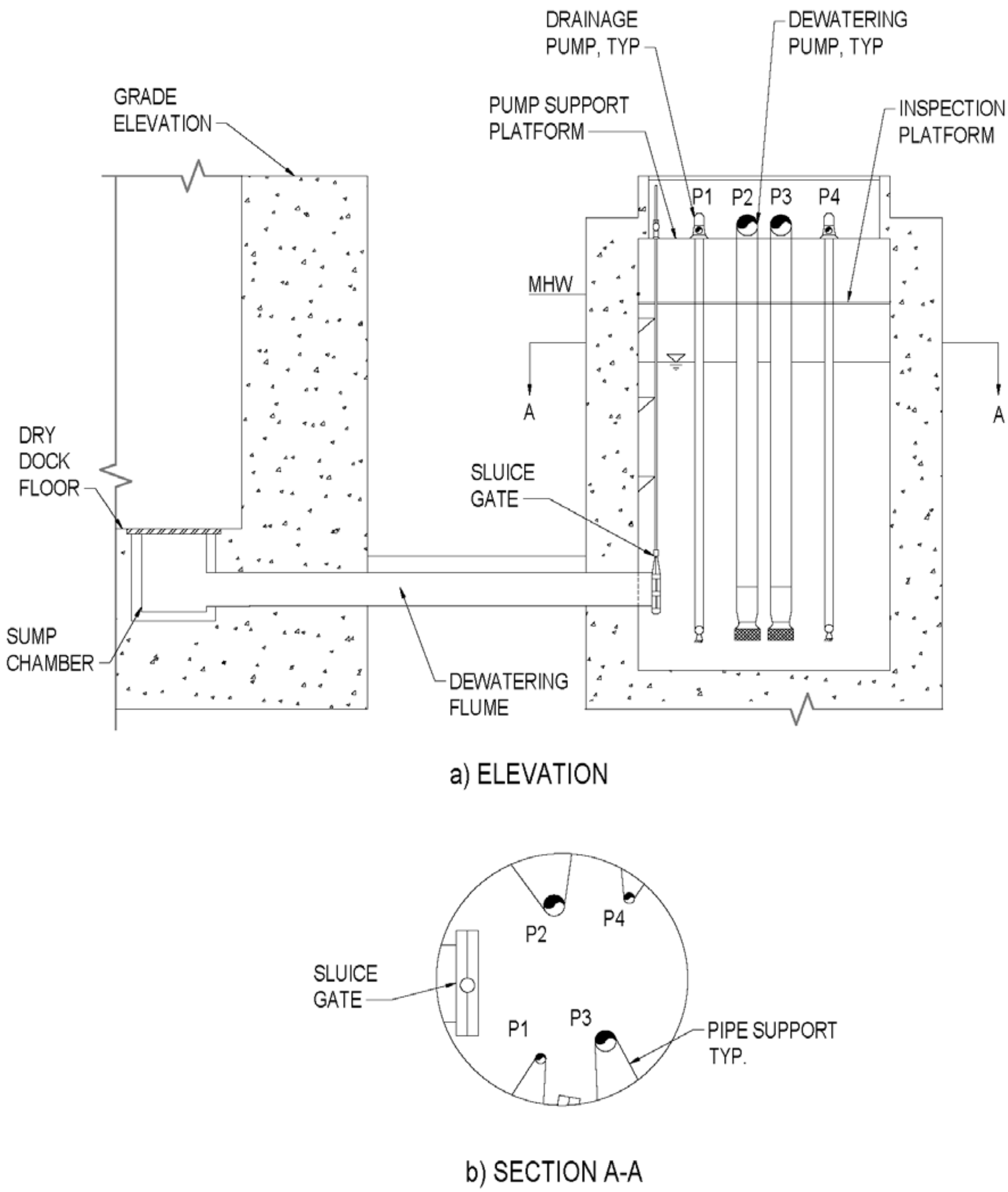
Provide a suction chamber (large enclosed space) for the suction bells of the dewatering pumps next to or in dock sidewalls, preferably near the dock entrance. Specific design requirements are:

- Locate the chamber floor below the graving dock floor approximately 10 ft (3.1 m); shape it to conform to flow lines of water entering pump suction bells, if necessary.
- Provide access to the main suction chamber from the dock floor culvert.

7-2.4 Pumpwell or Pumphouse.

Provide a pumpwell or pumphouses of reinforced concrete for housing the pumps, motors, valves, gates, controls, and other equipment. Pump suction chambers constitute the lower part of a pumpwell. A design, known as a wetwell (see Figure 7-1), can significantly reduce the amount of mechanical equipment and flooding risk compared to traditional Navy dry dock pumpwells. This design combines the suction chamber and pumpwell areas with an open, flooded center that equalizes with the dock. Wetwells also make use of more commercial off the shelf equipment vice custom manufacturing. Contact the NAVFAC EXWC Dry Dock SME for more information.

Figure 7-1 Elevation View of Wetwell Operations Level



7-2.4.1 Pumps and Motors.

Several functional types of pumps with motors may be housed in a pumpwell; main dewatering units predominate. Other pump and motor units are:

- Drainage pumps.
- Sump pumps.
- Sewage pumps.
- Salt water pumps (fire protection and flushing).
- Vacuum pumps (if required for priming).

7-2.4.2 Valves and Gates.

Include the following valves and sluice gates in a pumping plant:

- Gate valves in discharge line from each main pump.
- Check valves in discharge line from each main pump.
- Miscellaneous valves and sluice gates for operation of the drainage system.
- As an alternative, dewatering systems may discharge above sea level or be looped above sea level (with a suitable siphon breaker). In this case discharge gate valves and check valves are not required. The system must be designed to prevent back-flooding into the dry dock with outside water levels up to the caisson overtopping level if the valves will be omitted.

7-2.4.3 Double Valve Protection.

Dry docks must be protected from sources of potential flooding through normal flooding and dewatering sources. Therefore, dewatering and drainage systems must have two valves or a valve and a stoplog. In situation where an adjacent dock shares a pumphouse or suction chamber, each dock must be isolated. Combinations of valves and sluice gates may be used.

7-2.4.4 Amenities within Pumphouse.

Depending on the occupancy category and expected duration of docking evolutions, the pumphouse may require facilities to be provided for the staff. This may include one or more toilets, lockers, kitchenettes, even offices and tool rooms. With modern remote operations, communication equipment and more efficient equipment, the trend has been to reduce the size of pumphouses and suction chambers. Therefore, less space will be necessary for staff to continually occupy these areas.

7-2.4.5 Heating and Ventilating.

Refer to UFC 3-410-01 for heating and ventilating criteria for pumping stations.

7-2.5 Pump Discharge Tunnel.

Design the pump discharge tunnel in the form of a variable section header, or header tunnel, connecting the various pump discharge lines to carry water into the discharge tunnel outer portions. The tunnel should be designed for occasional human inspection.

7-2.5.1 Auxiliaries.

Install gate valves and check valves in all pump discharge lines, except in unusual cases where discharge is above high water.

7-2.5.2 Discharge Stoplog.

Provide a stoplog or hinged stoplog in the discharge tunnel to allow inspection and maintenance of discharge valves.

7-2.6 Gratings.

Gratings must have small openings to prevent small tools and other objects from going through the pumps. During work around a docked vessel, some dock floor drainage grates may be temporarily removed. As an added precaution to prevent damage to the pumps, it may be advisable to place a grating over pump suction boots or bells.

7-2.7 Salt Water Intake Screen.

Where salt water is to be pumped for fire protection or other purposes, provide a screen at the intake to catch solids of sizes that would interfere with pump operation. If large quantities of salt water are to be handled, moving mechanical screens may be required. Refer to UFC 3-230-01 for screen design.

7-2.8 High Water Sensing Systems.

Provide two independent water level sensing systems. The primary sensing system, which must operate from station power, must be designed to activate both the pumps and the alarm. A backup or secondary sensing system must have an independent power source and operate the alarm only. Both systems must announce locally and at a central location that is continuously manned. Refer to MIL-STD-1625 for additional system performance requirements.

7-3 BASIC REQUIREMENTS OF DESIGN FACTORS.

Three basic design factors enter into the design of a pumping system: (1) desired pumping time, (2) initial cost of pumps, motors, pumpwell structure, and appurtenances, and (3) power supply. Also consider the relatively small percent of time that pumps are in operation.

7-3.1 Pumping Time.

The average time for dewatering Navy Dry Docks of the five types may be used as a design guide. Pumping times are for empty docks. Actual dewatering time may depend on many factors. New docks or renovations shall set dewatering time requirements based upon operational, environmental and functional needs of the shipyard.

- Submarine docks, 135 minutes.
- Destroyer docks, 150 minutes.
- Cruiser and Auxiliary docks, 165 minutes.
- Carrier docks, 240 minutes.

7-3.2 Initial Cost of Installation.

For comparative studies, obtain the cost of various sizes of pumps, motors, controls, and other mechanical accessories from manufacturers. The cost of pumpwell and discharge structures increases with the sizes of pumps. This is especially true with regard to pumpwell foundations that are usually the deepest part of the entire dry dock foundation and lead to special construction problems.

7-3.3 Power Considerations.

Dewatering pumps of all naval dry docks should be driven by electric motors. These main pumping units require a considerable amount of electrical energy for brief periods of time and at infrequent intervals. If electrical current is purchased for this purpose, it involves a large demand or service charge. If current is furnished by the station, this results in a relatively heavy station demand, necessitating installation of additional power capacity for generating equipment.

7-3.3.1 Power Demands.

Keep the maximum power requirements as low as practicable, consistent with the required capacity. Keep power demands as constant as possible through the whole pumping head range. Although the initial cost of high-speed standard motors is relatively low, their operating characteristics are not suitable for driving dewatering pump units. Therefore, the design of the motor driven, direct connected pumping unit for dry docks involves an adjustment and compromise of the conditions of: varying hydraulic head, minimum range of required power, lower unit speeds, and relatively good efficiency. These conditions often necessitate a sacrifice in efficiency. High efficiency, however, is not of prime importance in equipment that is operated so small a percentage of the time.

7-4 PUMPING SYSTEMS.

7-4.1 Components.

The main dewatering system of a dry dock usually includes:

- The suction inlet located within the dock chamber
- The suction passage and/or culvert
- Pump suction chamber
- Pump suction bells
- Pumps
- Discharge check and gate valves
- Discharge culvert including backwash trash rack
- Hinged stop gate, sliding stoplog, or discharge sluice gate.

Where pumping plants may be designed to remove water from more than one dock, additional suction sluice gates are required to permit independent pumping of the docks. The pumphouse only has the operations level and the wet sump below the floor elevation. The discharge from the pumphouse should be as close to or above the tide level to reduce flood risk through the dewatering system. See Figure 7-1 for elevation view of pumphouse operations level.

7-4.2 Elevation of Discharge.

The most desirable operational pumping arrangement is a system in which the discharge invert is directly overboard above the level of the caisson weather deck, and in which no discharge check and gate valves, trash racks, or stop gates are required. Operation is simplified as there is no large power driven valves with electrical controls to be operated and maintained.

7-4.2.1 Design.

The design outlined above allows elimination of a large portion of the pump room substructure, with an accompanying reduction in pumping plant initial cost. The additional elevation required in delivering water overboard above the level of the caisson weather deck increases the total static pumping head. This increase, however, may be more than offset by reduction in friction owing to elimination of the pump check and discharge valves. The designer should consider the installation of a loop in the discharge piping to carry the water above the level of the caisson weather deck and then back down to discharge below sea level. The loop should have a siphon breaker installed at the top of the loop. The looped system may prove to be more efficient than one discharging at a higher level.

7-4.3 Pumping Head.

The pumping head of the main dewatering pumps is the sum of the maximum hydrostatic head and hydraulic system losses. See Figure 7-2. Maximum hydraulic system losses exist when maximum flow occurs, which is the time of minimum static head.

7-4.4 Pump Suction.

With reference to design and satisfactory functioning, the most critical portion of a hydraulic system is the suction portion extending from dock chamber to dewatering pump suction bell. This portion consists of the suction inlet, suction pit below the inlet, and conduits leading from the pit to individual pumps or to a pump suction chamber common to all pumps, and the pump suction bells. If the conduits are separate for each pump suction, sluice gates may be installed in each conduit to permit working on a pump without impairing the use of other pumps.

7-4.4.1 Periphery of Pit Opening.

In dewatering a dry dock, one or more of the main pumps may be shut down as the water level approaches the dock floor, in order to prevent loss of pump suction. As the water level continues to recede it generally becomes necessary to throttle the discharge of the last operating pump. This condition occurs when the pump capacity exceeds the quantity of water flow reaching the pump suction from the dock chamber through the pump suction pit and conduits. The elevation of the pumps with reference to the dock floor does not contribute to this condition. To delay the time of shutdown and throttling, design the dock floor suction inlet to have as large a perimeter as practicable.

7-4.4.2 Area of Pit Opening.

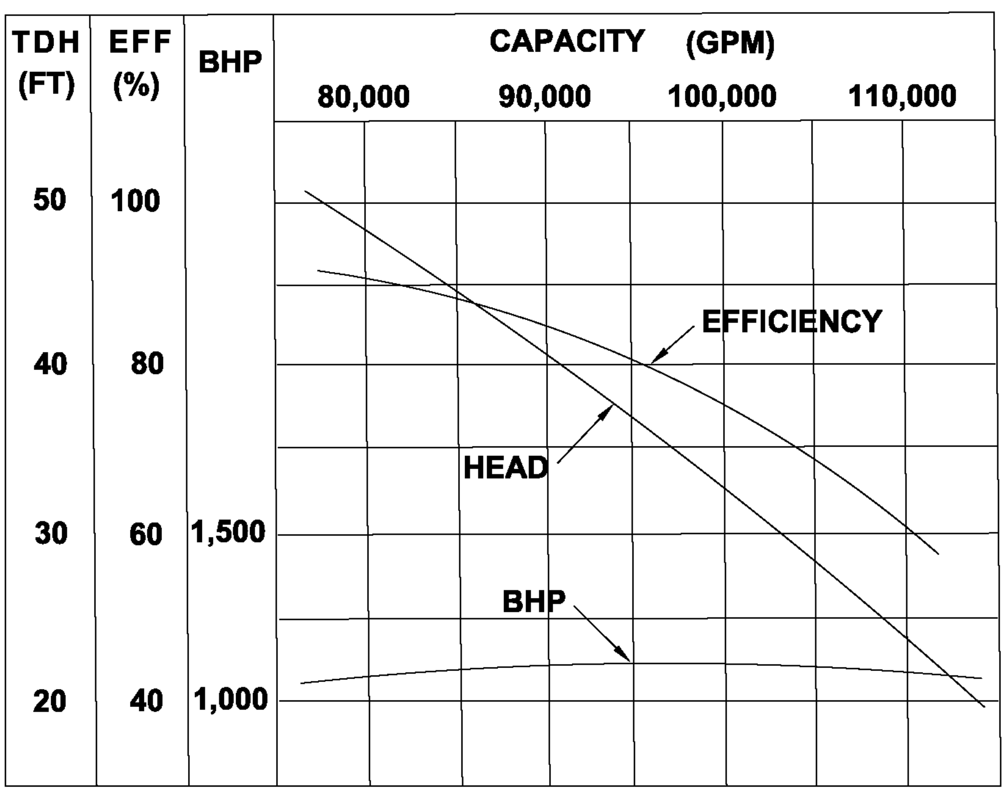
The suction pit opening (free area) should be of sufficient size to result in a flow velocity in the range of 3.5 to 4.5 ft/s (1.1 to 1.4 m/s). Base the flow on the pumping rate when the water level is 2 ft (0.6 m) above the dock floor and discharging against mean high tide. The suction condition may be greatly improved by providing openings on the opposite side of the dock chamber connected by conduits under the dock floor.

7-4.4.3 Use of Sidewall Culverts.

Where a sidewall culvert drainage system is used to facilitate removal of low-level water from the dock floor, it should drain to and terminate in the main dewatering pump suction chamber.

Figure 7-2 Characteristic Curves for 54 in. Mixed Flow Pump

TIME	TOTAL DYNAMIC HEAD (FEET)			CAPACITY (GALLONS)	NET STATIC HEAD (FEET)
	DISCH	SUCTION	NET		
12:10	116.5	92.5	24.0	109,000	0.8
12:33	113.8	87.5	26.0	105,000	5.5
1:06	109.6	76.8	32.8	100,000	13.1
1:37	106.8	72.0	34.5	95,000	20.3
2:08	104.6	64.3	40.3	90,000	26.7
2:40	102.7	58.0	44.7	85,000	33.3
3:06	101.4	53.0	48.4	80,000	38.3



7-4.4.4 Shape of Pump Suction Works.

Design the configuration of a pump suction pit and the conduit leading to the pump suction chamber, or suction bell, so that the flow will have a constant or uniformly accelerated velocity. The surface of the passages should be smooth and of such shape as not to produce eddies. There should be no sharp turns or abrupt changes in a conduit section. It may be necessary to install stream guide vanes in the suction chamber to effect good distribution and flow to the pump suction bells.

7-4.4.5 Arrangement of Suction Bells.

7-4.4.5.1 Design for Velocity.

Where several pump suction bells draw from a common chamber, the flow in the region of the bellmouth should be free from high velocities and changes in direction that tend to cause vortices.

In addition:

- The velocity of approach should be in the range of 2 to 3 ft/s (0.6 to 0.9 m/s).
- The designed bellmouth velocity should be in the range of 4 to 5 ft/s (1.2 to 1.5 m/s).
- The water depth below the bellmouth should be approximately one-half the bellmouth diameter.
- Laterally there should be no obstruction to flow within one diameter of the centerline of the bell.

7-4.4.5.2 Design for Vortex Action.

The system design should give such hydraulic characteristics as will preclude vortex action at the suction inlet and at the suction bell.

7-4.5 Pump Discharge.

The design of the pump discharge line is less critical than that of the suction line. The discharge conduit surfaces should be smooth, and sharp angles that tend to produce eddy currents must be avoided. The conduit should be such that the streams from individual pumps converge in as near a parallel direction as practicable. Changes in conduit sectional areas should be gradual and should not produce fluctuating velocities.

7-4.5.1 Allowable Velocities in Discharge Works.

At discharge of individual pumps, use 20 ft/s (6.1 m/s) maximum. In cross section of combining discharge culvert, use 14 ft/s (4.3 m/s) maximum.

7-4.5.2 Head Losses.

Head loss computations exclude losses through the pumping unit. These are included in the manufacturer rating. Total loss should not exceed 10 to 12 ft. (3.1 to 3.7 m). Suction loss should be not more than 2 to 3 percent of total loss.

7-4.5.3 Valves.

Where the discharge terminations are submerged, both gate and check valves are required. Where the discharge is above water, only a low resistance discharge flap valve is required. Gate valves should be the outside stem and yoke type suitable for throttling operation, and should be motor driven with push-button control. Check valves should be the low resistance, horizontal, nonslam, or dashpot control type. Check valves must be designed to shut automatically upon a power outage.

7-4.6 Pump Capacity.

Base the capacity of the main dewatering pumps on the desired dewatering time, volume to be removed, type of graving dock construction, and characteristics of the hydraulic system. As the water level in the dock recedes, the pump discharge volume falls off accordingly. The unit pump rating in gallons per minute should be taken as the average discharge volume. This average is based on the pump discharge when the hydrostatic suction head ranges from that of mean high water down to the head existing when the water level in the dock is 2 ft (0.6 m) above the dock floor.

7-4.7 Pump Efficiency.

Rate dewatering pumps in accordance with average overall efficiency instead of efficiency at a fixed capacity rating. Average overall efficiency is based on the range of head stated above, and is defined as the ratio of the total work done to the total power input to the motor. The total work is determined by multiplying the amount of water pumped in each interval between water level readings, by the average head in the same interval.

7-4.8 Pumps.

In the design and operation of pumping units, provision must be made for certain relationships between the suction lift and/or head, discharge head, capacity, and speed. This design factor is necessary to obtain rated capacity and efficiency, and to avoid outage and high maintenance from vibration and cavitation.

7-4.8.1 Main Dewatering Pumps.

At least two main dewatering pumps are required to meet the dewatering time requirement and to have redundancy. Limit the size to 54 in. (1.4 m).

7-4.8.1.1 Classes of Pumps.

The three general classes of pumps suitable for moving large volumes of water at relatively low heads are as follows:

- Axial flow. For static head pumping up to 25 ft (7.8 m), axial flow units (propeller) may be the most desirable.
- Mixed flow. Mixed flow units give good results on heads up to approximately 75 ft. (23.3 m).
- Centrifugal. Centrifugal pumps are more suitable for the higher heads.

7-4.8.1.2 Design Problems.

Dry dock dewatering presents unusual water pumping problems because of the extreme variations in both suction and discharge heads. See Figure 7-2 for typical operating characteristics of a 54 in. (1.4 m) mixed flow impeller pump operating under graving dock hydraulic conditions.

7-4.8.2 Drainage Pumps.

Provide drainage pumps to remove seepage, precipitation, caisson and valve leakage, and wash water, and to clear the dewatering pump suction chamber and drainage system. Because of sandblasting operations, the drainage pumps (and sump pumps discussed below) must be capable of handling a certain amount of sand and sandblasting products in suspension without excessive wear on casings of impellers. Also, ready access should be provided to pump suction chambers through manholes or other openings located so as to facilitate easy cleanout of these chambers.

7-4.8.2.1 Pump Capacity.

Estimate the total capacity required for relieved docks from an evaluation of the foundation permeability. For gravity docks, where only two units are required, the capacity of each unit should be:

- Submarine or destroyer docks: 2,500 gpm (568 m^3/h).
- Cruiser docks: 5,000 gpm (1,135 m^3/h).
- Carrier and Auxiliary docks: 7,500 gpm (1,703 m^3/h).

7-4.8.2.2 Types.

Drainage pumps should be vertical shaft, direct connected, motor driven; they may be of the wet or dry pit type:

- Wet pit pumps may be similar to main dewatering pumps of the axial discharge type.

- Dry pit pumps may be a mixed flow or centrifugal unit.
- Axial discharge pumps are the least expensive in that no suction piping and only a relatively small amount of discharge piping is required.

7-4.8.2.3 Head and Motor.

The required pumping head of drainage pumps is higher than that for the main dewatering pumps and is not so variable. Motors are generally located on the dewatering pump motor drive floor.

7-4.8.2.4 Environmental Requirements.

Local regulatory authorities may have specific requirements for drainage pumping discharges. Refer to local regulations.

7-4.8.3 Sump Pumps.

Sump pumps, vertical drive wet pit (submerged) centrifugal type, should have a capacity of 75 gpm (~280 l/min) each, and should be installed in duplicate.

7-4.9 Pump Drives.

Use vertical motors directly connected by line shafts to pump impellers. Main dewatering pumps generally are of the dry pit type. Install the motors and electrical switchgear on a floor only sufficiently below the top of the dock to allow for equipment and operating headroom. Place drainage pump motors and the drive mechanism for control of the main valves on the motor drive room floor. Drainage pump motors may be at a lower elevation to shorten the shafts, as long as they are above the possibility of being flooded due to a flooding pumpwell, or are submersible.

7-4.9.1 Speed.

Speeds of dewatering pump motors are dictated by the specific speed of the pump impellers; generally, low speed motors are required.

7-4.10 Driving Shaft.

The entire weight of revolving parts of the vertical pumping unit should be carried by a thrust bearing in the base of the motor at the top of the shaft. Specific requirements include the following:

7-4.10.1 Thrust Bearings.

Use self-aligning thrust bearings.

7-4.10.2 Guide Bearings.

Guide bearings must be of sufficient strength and adequate design to prevent vibration for lateral deflection of the vertical shaft. Use self-aligning and adjustable; the bearing surfaces may be of bronze or babbitt.

7-4.10.3 Lubrication.

Provide adequate lubrication. Generally, use water for this purpose where the bearings are submerged in the pump discharge stream. Provide clean, cold, fresh water of ample volume and pressure.

7-4.11 Elevation of Pumps.

Determine pump elevation by the vertical position of the dewatering pump impeller centerline. For vertical type centrifugal or mixed flow dewatering pumps, refer to the centerline of the pump discharge. For vertical mixed flow main pumps, the pump elevations must be about 3 ft (0.9 m) below the dry dock floor.

7-4.12 Priming.

All graving dock pumps not set at an elevation at which the impeller is submerged at all times must be equipped for priming. Priming consists of flooding the pump suction piping and the pump casing surrounding the impeller by removing air by means of a vacuum pump.

7-4.13 Heating and Ventilating.

Provide heating and ventilation in the pump room, as required to prevent damage by moisture condensation and freezing, and for the comfort of the operating personnel.

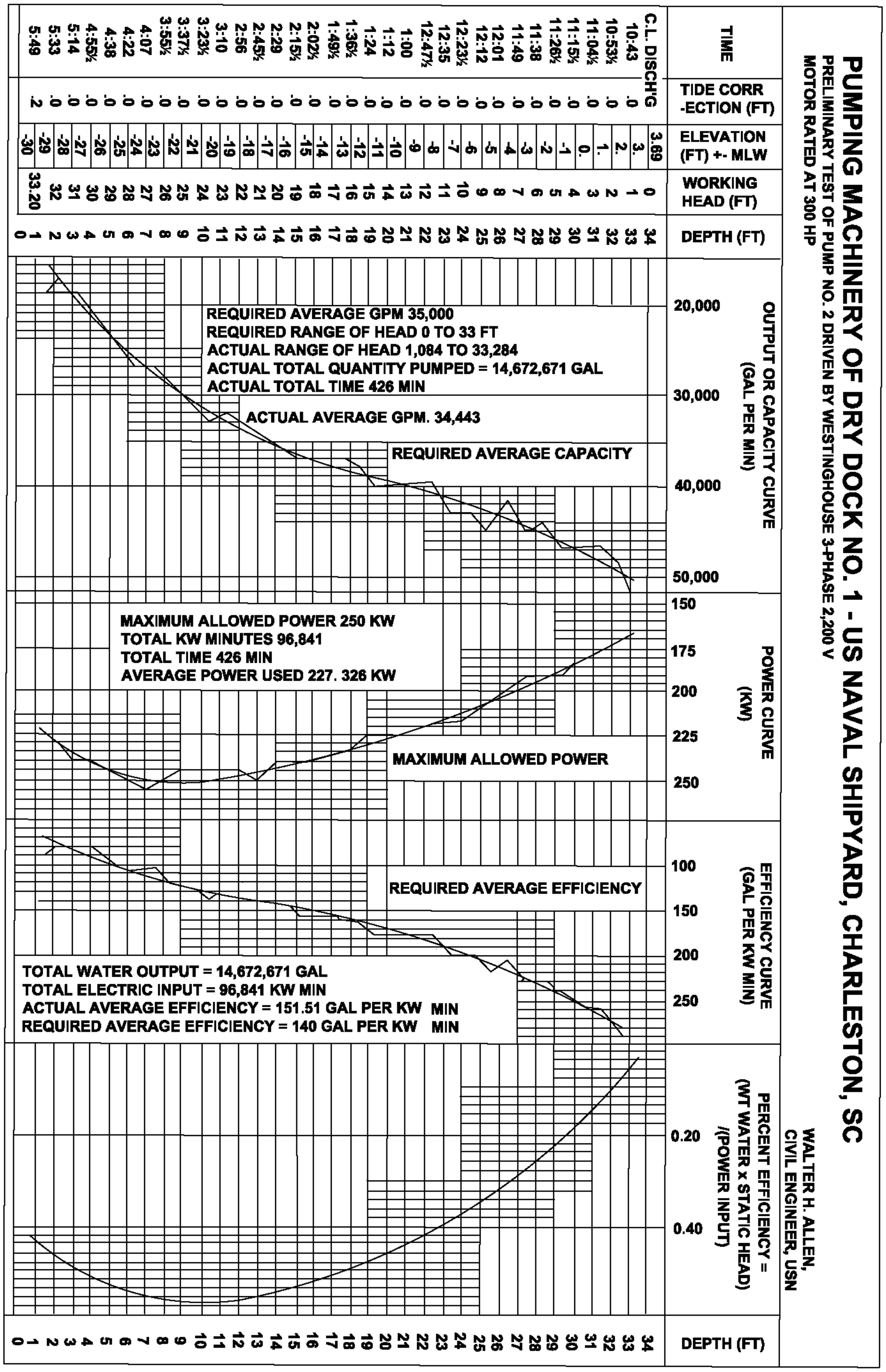
7-5 FIELD TESTING OF DEWATERING SYSTEM.

In order to check the operating characteristics with design requirements, it is necessary to field test the dewatering pumps, including the hydraulic system as installed. These tests cover pump capacity, power consumption, and evaluation of efficiency. For the results of an actual field test, see Figure 7-3.

7-5.1 Determination of Capacity.

Prepare a volumetric curve on which the volume of water in the graving dock, in cubic feet, is plotted against elevations referred to the datum plane, or to some other fixed elevation such as the graving dock floor or coping. When appreciable leakage occurs, a leakage curve is prepared by recording the rate at which water in the dock rises at various elevations.

Figure 7-3 Curves from Field Tests



7-5.1.1 Curve Construction.

During pumping tests, the water elevations in the dock are usually taken at intervals of 10 minutes. To the amounts of water pumped, as determined from these observations, add the appropriate amount of leakage taken from the leakage curves. The average capacity is the total amount of water pumped, divided by the pumping time. Take water level readings in the dock with great accuracy, preferably at two or more points simultaneously, and average. Use specially constructed gauges for obtaining accurate readings, unaffected by waves. To eliminate inaccuracies in observations, plot all readings to large scale, draw a smooth curve, and make any necessary corrections.

7-5.2 Power Input.

Take readings, simultaneously with those for capacity, of the power input to motors, as determined by calibrated wattmeters placed in the circuit as near as practicable to the main switchboard panels. In computing results, make corrections for ratio, scale, and phase-angle error. Determine frequency from speeds taken on a synchronous motor feeding from the same source of supply as the pump motors. Read pump speeds with a speed counter and stop watch directly from the motor shaft.

7-5.3 Determination of Head.

Efficiency requirements may be based on total dynamic head as determined by calibrated gauges in the suction and discharge of each pump, but variable results are obtained by this method. Tests based on static heads between the levels of the water in the dock and the sea are more reliable than gauge tests, and give a more practical indication of the performance of the plant as a whole. The objection to this method is that a pump manufacturer, in order to furnish guarantees of efficiency, must estimate all friction losses in the system.

7-5.4 Tide Effect.

Generally, tests to determine capacity and efficiency are so timed that the end of the test will occur when the elevation of the tide is at approximately mean high water or mean higher high water. Although it is necessary that the pumps be capable of dewatering docks at any tide stage, the average condition of the tide for graving dock pumping is probably nearer half tide than high water. At locations where tide range is considerable, it may be more reasonable to base capacity and efficiency requirements and tests on half tide conditions.

CHAPTER 8 FITTINGS, BLOCKING, SHIP SERVICES

8-1 FITTINGS.

Major fittings, and fittings peculiar to graving docks, are covered in this section; other fittings are merely mentioned. All fittings must be made of corrosion resistant materials and installed in a way that will minimize maintenance. Ferrous metal fittings must be zinc coated; small fittings may be cadmium plated.

8-1.1 Capstans.

Capstans are used at graving docks for pulling vessels into the dock chamber, and entrance caissons into seat or stowed position.

8-1.1.1 Location.

Locate one capstan on the centerline of the dock at the head end; one at each side of the caisson seats at the entrance end; and others on the sides of the graving dock, spaced not more than 300 ft (93 m) apart. Set capstans shoreward of the outermost crane rail of the track nearest to the centerline of the dock.

8-1.1.2 Requirements.

Typical capstan designs use the reversing gypsy-head type consisting of a barrel mounted on a vertical shaft and driven by an electric motor through reduction gearing. For electric control typically 460 volts nominal, three-phase 60 Hertz current, a magnetic reversing controller, including transformer and relay cabinet, push-button station having flexible cord, with a variable frequency drive (VFD) to provide infinite speed control with accurate current and thermal overload control. Arrange the completed equipment to operate with a minimum of noise and vibration.

Horizontal drum, winch type capstans are also acceptable. It is important to solicit and receive input from the shipyard rigging shop when deciding on capstan requirements.

Arrange all parts subject to wear so that they may be accessible for inspection, lubrication, and cleaning. Secure all fastenings that are likely to become loosened by vibration by locknuts or other suitable devices. Use material commonly used for the service required and marine environment. The entire capstan unit should be designed and furnished by the same fabricator. Templates should be furnished for setting anchor rods.

8-1.1.3 Capacity and Speed.

Capstans must be capable of pulling up to 30,000 lbs (13,500 kg) at a line speed of 30 fpm (0.15 m/s) and up to 15,000 lbs (6,750 kg) at 60 fpm (0.30 m/s) with slack speed of 90 fpm (0.46 m/s). Design capstans to also be used as bollards with a line pull of 100,000 lbs (45,000 kg) applied at the center of the barrel and directed upward at an angle of 30 degrees with the horizontal. Any required variations in the above indicated line pulls and speeds will be specified in project requirements.

8-1.1.4 Capstan Pits.

Typically, capstan driving mechanisms and foundations are located below coping elevation in pits generally consisting of concrete chambers founded on heavily reinforced concrete slabs firmly anchored and supported by batter and vertical piles. To avoid interference with lines, expose only the capstan barrel and the watertight cover of the capstan pit. See Figure 8-1.

- Secure machinery with anchor bolts embedded in chamber foundations. Provide watertight manholes for limited ready access to machinery, and an overall pit cover made in sections to permit removal of machinery.
- Provide capstan pits with drainage systems large enough to drain off normal precipitation as well as possible heavy leakage.
- Capstan pits, subject to humidity that might interfere with electric motor operation, may require portable blowers to dry out the pit before operation. For drawing of capstan and pit for dry dock application, refer to American Civil Engineering Practice, Volume II.

When replacing or renovating capstans consider removable or portable capstan units. These units would consist of a palletized self-contained capstan or winch, motor, controller. The capstan unit would be brought in via crane lift or fork truck only for the evolution, then removed and stored off site during the ship availability. In this design the capstan unit would not have a pit but a pad at the coping elevation and secured to permanently installed anchors in the coping concrete similar in design to aircraft runup pads.

8-1.1.5 Controls.

Install electric power capstan controls in machinery pits. Provide topside controls and locate them so that they allow the operator an unobstructed view, clear of lines and working parties. Topside controls should be portable so they may be stowed when not in use. Install controls in watertight enclosures.

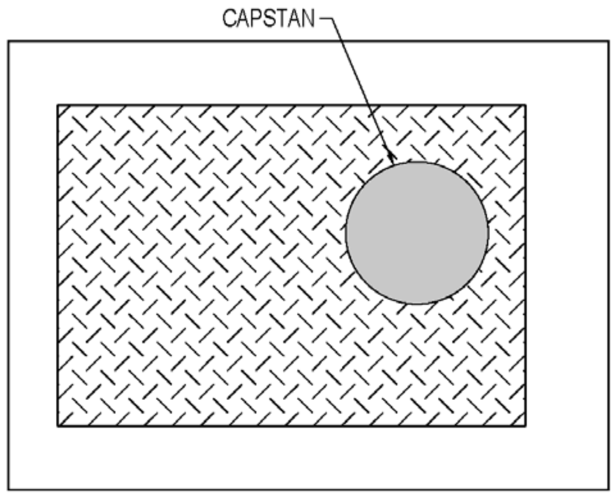
8-1.2 Bollards.

Bollards are iron or steel castings, upright (concrete filled) secured to foundations by steel bolts. Refer to UFC 4-152-01 and UFC 4-159-03 for description of bollards.

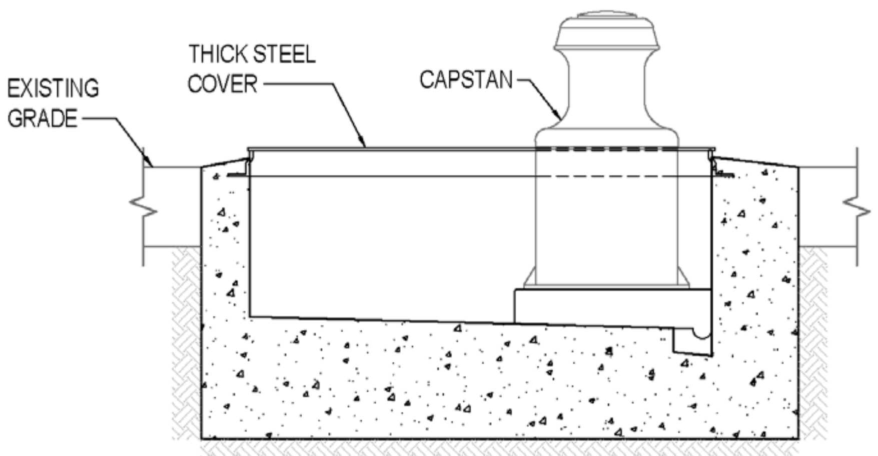
8-1.2.1 Location.

Set bollards in line with the capstans at approximately 50 ft (15.5 m) on centers between capstans.

Figure 8-1 Capstan Pits



a) PLAN



b) SECTION

8-1.2.2 Pull.

At a minimum, provide large bollard with horn per Table 6-11 of UFC 4-159-03 (nominal load 35 ST (31.8 t)).

8-1.2.3 Shape.

Bollards must include at least one horn and be shaped so that lines will not slip, jam, or ride off the top.

8-1.2.4 Foundations.

A bollard foundation may be a concrete substructure adequately supported by piles arranged to resist large overturning moments. Construction economy may be affected by tying bollard foundations to outer crane rail or dry dock foundations. Refer to UFC 4-159-03 for description of bollards.

8-1.3 Cleats.

Install 20 ST (18.1 t) cleats spaced at about 60 ft (18.6 m) centers on the coping for securing mooring lines. Refer to UFC 4-152-01 and UFC 4-159-03 for description of cleats. Consider aligning cleats on both sides of the dock at the coping level.

8-1.4 Stairways.

Stairways in the dry dock may be cast as part of the wall concrete or may be constructed of structural steel with open mesh treads bolted to the walls. Stairways can be damaged by falling objects, fouled lines, and swinging crane loads. Semi-permanent prefabricated stairways bolted to walls facilitate repair and allow for relocation. Stairs must comply with NFPA 101, dimensional criteria for new stairs.

The number and location of stairways must meet the following parameters:

- One stairway from coping to dry dock floor on each side of the dock at the head end.
- One stairway from coping to dry dock floor on each side of the dock at the caisson end.
- Spacing between stairways along each side of the dock must not exceed 300 ft (91 m).
- Pumpwells must have at least two stairway exits from pump room floor.

Alternatively, a life safety analysis or evacuation plan developed by a qualified fire protection engineer in consultation with the DFPE, both as defined in UFC 3-600-01, *Fire Protection Engineering for Facilities*, may be performed to optimize the number and location of pumpwell and dry dock floor stairways. The analysis must account for the actual work performed in pumpwell and on the dry dock floor with a ship in dock, and the number of individuals accessing the dock during typical shifts. Obstructions such as docking blocks, fork trucks, scaffolding, CONEX boxes and other equipment will impact evacuation. The pumpwell analysis must account for the mechanical equipment in the pumpwell that would impede movement. The life safety analysis must include those impacts when evaluating evacuation routes. In all cases, at least two stairways from the coping to the dock floor must be provided, with one located at the caisson end and one at the head end.

8-1.5 Ladders.

Provide ladders only where the available space is insufficient for stairways, or where traffic is too light to warrant stairway construction. Place ladders in pumpwells as leads to access hatches and large manholes. Refer to 29 CFR 1910.23 for ladder requirements. Also consult local safety regulations as to the maximum allowed ladder length without fall protection.

8-1.5.1 Steel Shapes.

Fabricate ladders of steel shapes. Plug weld rungs into rails. Install ladders so that the distance from the center of the rungs to the finished wall surface will not be less than 7 in. (178 mm). Secure ladders to the adjacent construction with heavy clip angles, welded to the rails and secured to masonry, concrete, or stud framing with not less than two 3/4 in. (19 mm) diameter bolts. Intermediate clip angles must be provided not over 5 ft (1.6 m) on centers. Provide brackets as required for securing of ladders welded or bolted to structural steel and built into the masonry or concrete. In no case should ends of ladders rest upon finished roof or floor. Ladders and supports must be galvanized after fabrication unless a corrosion resistant material is used. Bar steel rungs are installed 12 in. (305 mm) apart, vertically below manholes, and at other locations where frequent access is not generally necessary.

8-1.5.2 Stainless Steel.

Low carbon stainless steel (UNS S31600/ S31603) rungs and ladders should be considered for alternating wet-dry, high corrosion areas.

8-1.6 Safety Railing.

Provide railing (guard rail system) around fixed installations (such as machinery), around open shafts, along dock walls at altars or setbacks, and along the top edge of retaining walls in accordance with 29 CFR 1910.29. Removable solid railing sections may be installed where access is required around permanent openings and installations. Incorporate fall protection requirements where removable railings are installed. Install fall protection tie off points in areas that require inspection when railings are removed (fall protection may not be required during docking/ undocking).

8-1.6.1 On Coping.

Provide a removable railing with toeboards unless the coping wall serves as a fall protection barrier. Chain railing was used in the past but maintaining adequate chain tension was a common problem. Solid metal pipe or fiberglass railing, provided in 8 to 12 ft (2.5 to 3.7 m) sections for ease of removal/reinstallation, is preferred. Solid railing sections should fit securely into sleeves fastened to the coping and are open on the bottom to prevent debris accumulation.

8-1.6.2 On Stairways.

Provide rigid pipe rails of two parallel pipes approximately 2 in. (51 mm) diameter and running between fixed pipe stanchions on all stairways. These may be a removable type, if necessary. The top rail is not less than 36 in. (914 mm) and not more than 38 in. (965 mm) as measured from the leading edge of the stair tread to the top surface of the rail, the midrail is midway between the leading edge of the stair tread, and the top rail.

8-1.7 Marking Plates.

Provide plates in dock structures marked with their exact stationing in the dock to facilitate setting of keel and side blocking.

8-1.7.1 Composition and Marking.

Marking plates should be bronze or stainless steel metal plates approximately 8 in. (203 mm) long by 4 in. (102 mm) wide set flush with end anchored into the embedding concrete. Each plate must be marked appropriately with centerlines, and with respective distances to the graving dock centerline and abutment. Figures should be 2 in. (51 mm) high and permanent.

8-1.7.2 Location.

Marking plates must be laid out accurately. Set marking plates at the following points:

- One on each coping at the dry dock entrance.
- In both copings at approximately 50 ft (15.5 m) intervals from the dry dock entrance toward head end.
- One near the coping edge on the graving dock centerline, at the head end.
- One several feet back from the coping edge on the dock centerline, at the head end.
- One in the dock floor, several feet to one side of the dock centerline, sufficient to clear keel blocks, and at approximately 50 ft (15.5 m) intervals from the dry dock entrance coordinated with b) above.

8-1.8 Fenders and Chafing Strips.

To protect masonry structures at a dock entrance, or a caisson berth, provide fenders and/or chafing strips as required. Use fenders as necessary to protect equipment (such as stairways, ladders, floodlights, and service outlets) from being fouled by a vessel entering or leaving a dock. Generally, treated timbers anchored by bolts are used as chafing strips, but suitable, rotatable, pneumatic and rubber fenders may also be used. Refer to UFC 4-152-01 for design of fenders, and UFGS 35 59 13.14 20 for polymeric piles.

8-2 SHIP BLOCKING.

Responsibilities for design and material specification of ship blocking rests with the Naval Sea Systems Command (NAVSEA). The information herein is basic guidance; Consult NAVSEA for criteria beyond the planning stage.

8-2.1 Ship Supports.

Provide means to keep a docked vessel far enough above the floor to permit work on its keel, giving allowance for removal or installation of sonar domes, rudders, propellers, and similar parts. Blocking arrangements are laid out in the dock in accordance with the docking plan for each individual vessel.

8-2.2 Dog and Side Shores.

Long overhangs of vessels are frequently supported by shores. Shores are wedged against the ship bottom and/or its sides, either against dock wall altars or against the dock floor.

8-2.3 Keel Blocks.

Keel blocks are placed under the longitudinal centerline keel of the vessel. The exact location of the blocks depends on a vessel’s docking plan. All keel block are interchangeable; therefore, each is designed for the maximum ship load likely to be imposed upon it at any location. Compression is the primary stress, but provision must be made to resist uplift, overturning, and horizontal movements induced by eccentric loads, earthquakes, or accidental impacts. Reinforced concrete stresses are not critical in design; grade of concrete and amount of reinforcement steel are selected to resist rough handling and temperature variations. Standard composite keel blocks (see Figure 8-2) were historically rated at 25 LT/sf (274 t/m^2), based on an allowable stress for wet timber in compression perpendicular to the grain taken at 250 psi (1.7 MPa) for soft caps. This allowed a reasonable safety factor. For the standard 6 ft (1.9 m) center-to-center keel block spacing, that rating represented a 37.5 LT/ft (125 t/m) ship load. Now, the safe allowable timber compressive stress for distributed loading, taken as the fiber stress at the proportional limit of Douglas Fir, is 370 psi (2.6 MPa). This assumes a uniform pressure over the entire 42 by 48 in. (1,067 by 1,219 mm) top of a docking block, resulting in a total load of about 330 LT (335.2 t). Most ships have narrower skegs and the allowable block loading is decreased accordingly. For allowable block loadings for this condition, refer to NSTM Chapter 997, Docking Instructions and Routine Work in dry dock.

8-2.4 Bilge or Side Blocks.

Bilge or side blocks are composite or timber, built up, shaped, and located according to dimensions indicated in the table of offsets of docking plan of the vessel. These are designed for 250 psi (1.72 MPa) load applied uniformly over the effective bearing area in contact with the hull of the ship. Batten each block adequately for stability, and the resultant load reaction should fall within the middle one-third of the base dimension of the block on the dock floor.

8-2.5 Type of Construction.

Build composite blocks with wood top and bottom layers, and concrete sandwiched in between. Use sufficient concrete to make the blocks non-buoyant. Secure the wood layers to the concrete with steel bolts embedded in the concrete. U-bolts embedded in the sides of the concrete may be provided for lifting, or pipe holes may be provided through the blocks to insert pipes for lifting by forklift or crane rigging. All hardware (except dogs) should be zinc coated or cadmium plated. For a typical block, see Figure 8-2. For heavy loads, these blocks may be used double as indicated in Figure 8-2.

8-3 SUPPORTING FACILITIES.

8-3.1 Industrial Shop Facilities.

Shipbuilding graving docks and graving docks used for extensive repair, alteration, and the rebuilding of vessels must be supported by industrial shop facilities capable of manufacturing or otherwise supplying, installing, and testing the large number of items required.

8-3.2 Transportation Facilities.

A graving dock must be serviced by the following transportation facilities.

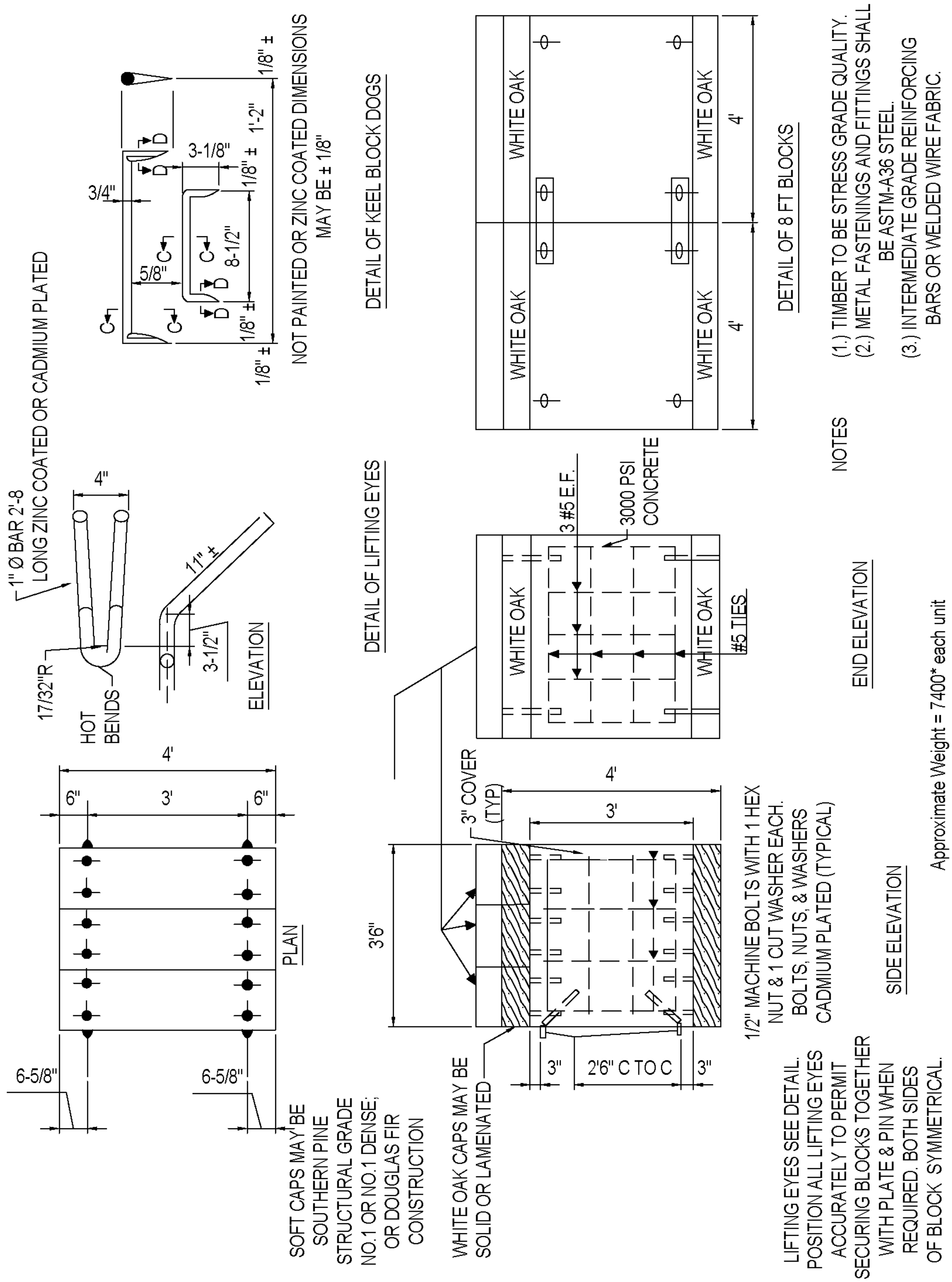
8-3.2.1 Paved Road Network.

This network provides access to the entire dock area and should be capable of carrying trailer trucks, flatbed trucks, mobile track cranes, truck cranes, and other heavy traffic.

8-3.2.2 Parking Facilities.

Provide parking as space permits clear of the graving dock operating areas.

Figure 8-2 Ship Blocks



8-3.2.3 Standard Gauge Railroad Track.

Where material for the graving dock operations are delivered to the yard by rail, a standard gauge track may be provided on either side of the dock. At the dock, locate this track between the portal crane rails nearest to the dock. This standard gauge track may also be used for the operation of locomotive cranes. At some yards, materials may be handled by heavy truck cranes instead of locomotive cranes, and railroad tracks may not be required. Use UFC 4-152-01 for track support design.

8-3.2.4 Portal Crane Track.

8-3.2.4.1 Location.

To minimize the required reach of dry dock cranes over a graving dock, locate crane rails as close to the edge of the coping as possible, but not nearer than about 5 ft (1.6 m). Because they must withstand high weight concentrations and shock loads, crane rails, unless supported directly on the dock walls, are usually supported by concrete beams on closely spaced piles, or by continuous spread footings generally tied in at intervals with the graving dock sidewalls. There are some locations where trackage may be supported by ties and ballast. Portal cranes may be designed to operate on either a two-rail track or a four-rail track. Space tracks far enough apart to allow passage of railroad and truck traffic between outer rails of pairs of rails.

8-3.2.4.2 Interchangeability.

To obtain maximum operational efficiency and economy, portal cranes should be interchangeable among the various yard facilities they might serve. As far as possible, incorporate the following features into a yard crane track layout:

- All portal crane tracks should have the same gauge as other yard crane tracks.
- When track consists of two pairs of rails, lay each pair at standard railroad gauge.
- Interconnect the various crane tracks.
- Provide spur track turnouts for repairing cranes.
- Provide a sufficient number of switches and passing tracks to permit individual cranes and other rolling stock to travel without interrupting the operation of other cranes.
- Refer to NAVFAC 11230.1 for track inspection, certification, and alignment procedure.

8-3.3 Weight and Materials Handling Equipment.

Small capacity locomotive or motor truck cranes are assigned to graving dock activities to supplement portal cranes. The locomotive cranes operate on the standard gauge railroad track.

8-3.3.1 Portal Cranes.

These cranes are constructed on portal frame bases that travel on wide gauge (20 to 30 ft (6.2 to 9.3 m)) tracks. Capacities and reach should be as specified for each individual project.

8-3.3.1.1 Clearances.

Clearances must be such as to permit complete rotation (360 degrees) without interference with the ship in dry dock, buildings, or other structures. Cranes and track layout must be carefully studied to ensure adequate clearances in the way of overhanging deck structures of aircraft carriers. For carrier docks, provide two sets of tracks on each side of the dock, one of conventional arrangement with rail near the edge of the coping, and one outboard at a distance sufficient for the crane to clear the flight deck of the carrier.

8-3.3.1.2 Power Drive.

Portal cranes may be powered by self-contained diesel electric drive or all electric.

8-3.4 Personnel Facilities.

Provide facilities such as lavatories, showers, and lunchrooms near the graving dock.

8-3.4.1 Lavatories.

Provide lavatories fairly close to the graving dock. They should contain toilets, urinals, washbowls, showers, first aid equipment, and perhaps equipment lockers. They should be large enough to accommodate the normal complement of the yard crew working in or around the graving dock, and the crew of any docked vessels. When the sanitary facilities of a docked vessel are being worked on, they are very often unavailable for use; therefore, separate dockside facilities are often reserved for use by the vessels officers and crewmembers on duty.

8-3.4.2 Lunchrooms.

Provide an appropriate type lunchroom near the graving dock.

8-3.4.3 Quarters for Ship’s Crew.

When extensive repairs or alterations are performed on a vessel in active service, work is often carried on around the clock. The accompanying noise and construction activities may prohibit habitation on the vessel. Under these conditions, provide quarters ashore, or berthing barges for the use of the officers and crew of the ship.

8-3.5 Storage Facilities.

Provide storage space to house the infrequently used dock gear, such as hawsers, cables, rafts, floats, fenders, portable communication equipment, and portable floodlights.

8-4 MECHANICAL SERVICES.

Ships in graving docks are unable to fill their own requirements for mechanical services essential for work, habitation, comfort, and protection. These services, and those required for repairs and cleaning associated with the docking operations, must be supplied from dockside facilities. Such services include steam, compressed air, water, Wheeler system, oxygen, acetylene, and sewage disposal. Utility requirements for specific ship classes is provided in UFC 4-150-02.

8-4.1 Pipe Galleries and Tunnels.

Carry service pipes, in tunnels, utilidors, or in galleries at the top of the dock sides. The open type gallery is desirable and should be used unless prohibited by some compelling reason or when steel is attached to the wall.

8-4.1.1 Design.

Design the gallery to be approximately 7 ft (2.2 m) high, and recessed 4 ft (1.2 m) or more into the dock wall. Provide a wall on the dock side approximately (2-1/2 ft (0.8 m) high, topped by a low railing for safety of personnel in the gallery (3-1/2 ft (1.1m) fall protection barriers).

8-4.1.2 Service Line Location.

Mount service lines on the walls and ceiling of this galleries and pipe tunnels.

8-4.1.3 Advantages.

Open type galleries have the following desirable features:

- Safer to work in than on an altar
- Better lighting
- Ample working space
- Ample room for addition of services
- Accessibility to all outlets along the dock.

8-4.1.4 Outlets.

Locate service outlets in accordance with criteria in UFC 4-150-02.

8-4.1.5 Looped Pipelines.

Sectionalize and valve all liquid, steam, and gas lines to provide service with a minimum of interruption of work should a break occur along any line.

8-4.2 Fresh Water.

For industrial use, and with an abundant supply, it may be used to fill fire protection, flushing and cooling requirements. In cold climates, waterlines must be protected from freezing. Provide meters to record water consumption. All fresh water outlets must have a backflow preventive device, and be painted as specified in UFC 4-150-02, for services on piers.

8-4.2.1 Potable Water.

Provide one 2-1/2 in. (63.5 mm) valved outlet at each service gallery, and size the mains to adequately provide the required quantity of distilled or potable water at a residual pressure of 40 to 80 psi (276 to 551 kPa) at any outlet. The quantity of water required by dry docks is contained in UFC 4-150-02.

8-4.2.2 Flushing and Cooling.

Flushing/cooling systems are to be part of the fire protection systems where high pressure fire protection systems are provided, including the following:

- If a graving dock is provided with fire hydrants only outside the dock, as fire protection, install the flushing/cooling systems separately.
- Provide one 2-1/2 in. (63.5 mm) valved outlet in each service gallery.
- Supply the quantity of water required for flushing and cooling to the most remote flushing/cooling outlets at not less than 40 psi (276 kPa) residual pressure. Connect systems either to station pumps or to separate graving dock pumps having a minimum discharge pressure of 150 psi (1034 kPa). The required quantities for combined flushing, cooling and fire protection are contained in contained in UFC 4-150-02.

8-4.3 Salt or Non-potable Water Supply.

When fresh water is not abundant, use salt or non-potable water system for flushing, cooling and fire protection.

Provide salt or non-potable water service to the dry dock to meet cooling, flushing, auxiliary seawater and fire protection requirements. Flow rates and pressures are governed by other documents. Refer to UFC 4-150-02, MIL-STD-1625 and NAVSEA 8010.

8-4.3.1 Station System Connection.

Where a graving dock fire protection system is connected to station fire protection and flushing/cooling systems, make connection through a valved check valve and a valved pressure reducing valve in a bypass permitting the station system to supply flushing/cooling water to the dock system. This arrangement also permits the graving dock fire protection pumps to augment the station system in emergencies.

8-4.3.1.1 Alternative Arrangement.

If this arrangement is not possible, install flushing/cooling pumps with minimum discharge pressures of 150 psi (1034 kPa) at most remote outlet. Arrange graving dock fire pumps in parallel operation for flushing and cooling, and arrange series operation for standby fire protection.

8-4.3.1.2 Fire Pumps.

Redundancy must be provided such that the required flow rate and pressure can still be provided after the loss of any single fire pump and/or the loss of the normal system power supply. Standby diesel fire pumps are normally provided to meet this requirement. Fire pump installations must conform to the provisions of NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*.

8-4.3.2 Type of Piping.

All piping for graving dock fire protection systems must be cement lined AWWA ductile iron pipe, class to suit required fire pressures, with lugged and rodded joints and fittings (except the pipes in pumpwells and service galleries should be flanged). Any joint of equal strength may be used, subject to the approval of the cognizant Service.

8-4.3.3 Pipe Sizes.

Where station systems are connected to dry dock systems, pipe sizes from station pumphouse to docks should be generous enough to provide pressures for dry dock flushing and cooling requirements.

8-4.4 Wastewater Collection.

Segregation of sanitary sewage, industrial wastewater and hydrostatic leakage water is required. Dry dock and ship sewage will be collected and discharged into the station sewerage system. Hydrostatic leakage not mixed with industrial waste is not polluted, therefore can be pumped into receiving waters, except at locations where local environmental regulations forbid it. Refer to local regulations.

8-4.4.1 Sanitary Sewer System.

All sewage and hotel wastes from ships in dry dock must be collected and transported to a treatment plant. Preferably, locate a sewer main on each side of the dock. Discharge of all sewage to a main on only one side of the graving dock should be considered if local circumstances dictate. Provide receiving manifolds located along the coping of the graving dock and connect to the main sewer through laterals. Transport sewage from the ship to the manifold receiving connection by way of a hose. Design the sewer system to meet peak flow rates from the largest ship class for which the dry dock is designed. These are contained in UFC 4-150-02. For additional design criteria refer to UFC 3-240-01, *Wastewater Collection and Treatment*.

8-4.4.1.1 Receiving Hose Connections.

Space the receiving hose connections approximately 300 ft (93 m) centers. The spacing may be varied to suit docking conditions in a specific dry dock. Locate the hose connections between the edge (coping) of the graving dock and the crane track to eliminate any interference with the operation of the cranes. Make each connection 4 in. (102 mm) diameter and install an in-line check valve to prevent backflow.

8-4.4.1.2 Laterals.

Laterals between the receiving hose connections and the main sewer must have a diameter of 4 in. (102 mm). Where possible, the laterals should be located in the dry dock service and pipe galleries to minimize installation costs and to facilitate maintenance. Pitch laterals to drain to the main sewer. Consider local conditions for the optimum location of the laterals.

8-4.4.1.3 Main Sewers.

Size main sewers to receive ship discharges plus any other flow entering into the collection system. Main sewers should be located in the pipe galleries or beyond the structural concrete of the graving dock. Consider local conditions for the optimum location of the main sewers. Main sewers should be gravity sewers and slope toward the inboard end of the dock and connect to the station sewer system or to a pump lift station. Use a force main where it is impracticable to install a gravity sewer. Locate sewer cleanouts in the main sewers at a maximum spacing of 300 ft (93 m).

8-4.4.1.4 Ship-to-Dock Transfer System.

Ships outfitted with CHT systems discharge sewage under pressure on the lowest weather deck. Ships not outfitted with CHT systems will discharge through existing outlets in the hull. For ships not outfitted with CHT systems, a temporary system for collecting sewage from multiple outlets must be installed.

- <u>Auxiliary Pumping:</u> Gravity dry dock sewer systems may require auxiliary pumping when the ship’s discharge point is below the level of the top of dry dock wall. The facilities required for auxiliary pumping include hose, portable wet well, and pump. Use a 4 in. (102 mm) sewage hose to transfer sewage from the ship or portable pumping unit to the dry dock sewer system. Refer to Figure 8-3.

- Collection System and Components: The temporary collection system for ships not outfitted with CHT system, and the auxiliary pumping system components, are collateral equipment to be furnished by the shipyard.

8-4.4.2 Industrial Wastewater Collection.

Collect and treat industrial wastewater, including runoff and hydrostatic leakage that come in contact with industrial waste, such as sand blasting grit and organotin paint chips, as necessary, prior to discharge. Refer to UFC 3-240-01.

8-4.5 Steam.

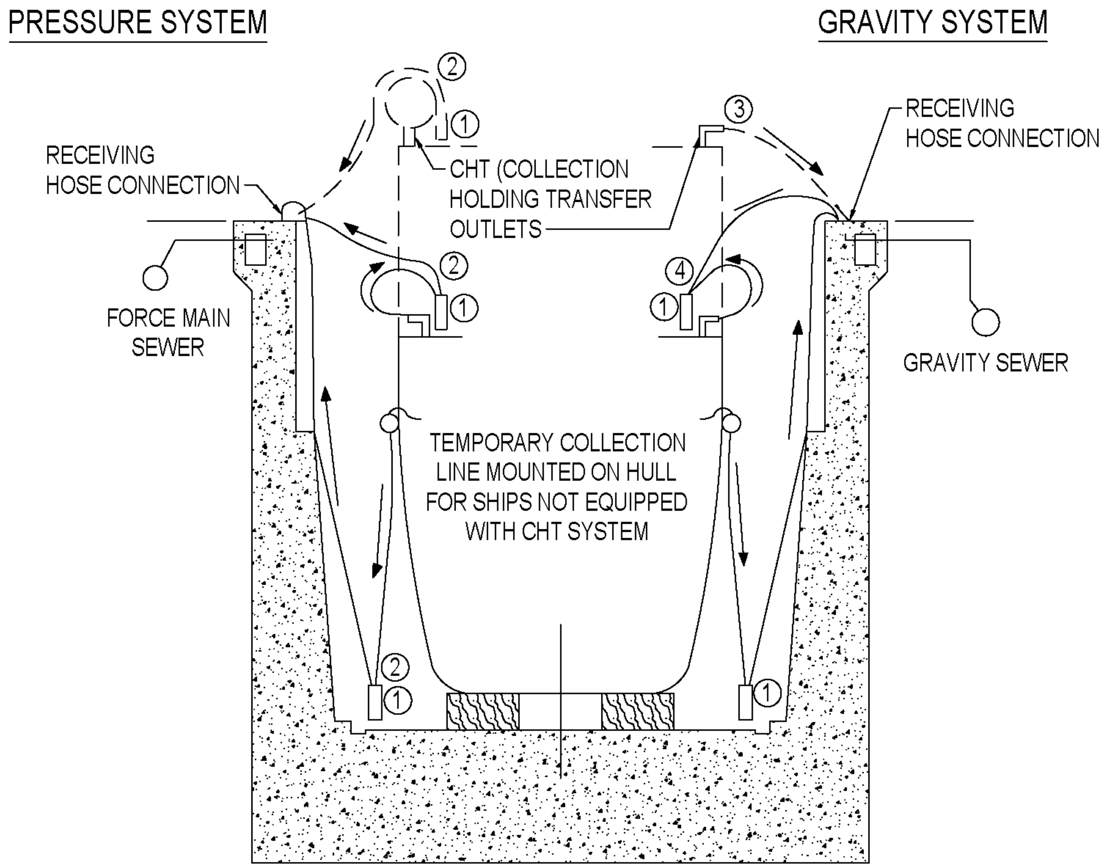
Steam may be required in a graving dock for heating, cleaning equipment and tanks, and ship use. In northern latitudes, provision must be made for heating those areas in which personnel must remain for lengthy periods, such as pump rooms, motor rooms, caissons, toilets, and shower rooms. Use steam for deicing and for keeping necessarily exposed fresh waterlines from freezing. Freezing may sometimes be prevented by running a parallel steam line.

8-4.5.1 Quantity.

Exact quantities of steam to be furnished to the ship are difficult to determine. Changes in ship designs, variations in ships of the same class, and differences in repair operations make close estimation of steam demand loads purely academic. On the other hand, providing sufficient steam to take care of the total maximum demand load that could occur under the worst conditions would result in a grossly over-designed and expensive system. UFC 4-150-02 gives the design steam demand for various ships.

Use engineering judgment to determine actual working values depending on the concurrency or nonconcurrency of other steam loads for the dry dock complex, frequency of docking of maximum ship, and effect of multiple docking. High-pressure steam for test operations is usually provided from portable generators. Consider planning for temporary portable steam generators that would utilize shipyard local power and potable water as supply.

Figure 8-3 Schematic of Conditions for Portable Sewage Pumping Systems in Graving Docks



1. INDICATES PORTABLE WET WITH SUBMERSIBLE PUMP
2. PUMPING MAY BE REQUIRED FOR ENTRY INTO PRESSURIZED SYSTEM
3. NO PUMPING REQUIRED WHEN CHT DISCHARGE IS ABOVE RECEIVING CONNECTION
4. PUMPING MAY BE REQUIRED WHEN CHT DISCHARGE IS BELOW CONNECTION

NOTE: THE TEMPORARY COLLECTION SYSTEM, HOSE, PUMP AND WET WELL ARE COLLATERAL EQUIPMENT TO BE FURNISHED BY THE SHIPYARD

8-4.5.2 Steam Mains.

If steam service is required, provide graving docks with steam mains on at least one side of the dock. Size the pipe supplying the mains to provide a carrying capacity equivalent to that of the two dock mains. For example, a 6 in. (152.4 mm) mains. Base the determination of equal carrying capacities on a table of equalization of pipes. Refer to UFC 3-430-09. The number and location of steam branch outlets vary from three to six per side, depending on the size of dry dock. Provide a suitable flanged valve provided with a blind flange for each branch outlet. Size mains and branch outlets for steam service, unless specifically directed otherwise, in accordance with the following:

8-4.5.2.1 Submarine and Destroyer Docks.

For both single and double width docks, use 4 in. (102 mm) main and 2-1/2 in. (63.5 mm) outlets.

8-4.5.2.2 Cruiser, Auxiliary, and Carrier Docks.

Size mains according to quantity of steam carried and the permissible pressure drop. Outlets should be 2-1/2 in. (63.5 mm). Provide carrier docks with an additional 4 in. (102 mm) outlet, located at the center group of service outlets on each side of the dock, for feeding ships with 4 in. (102 mm) steam shore connections.

8-4.5.2.3 Piping.

Steam piping must be in accordance with the provisions of UFC 3-430-09 concerning steam distribution systems. Condensate return piping usually is not required, but should be provided when recovery of the condensate is economically desirable or when dictated by special project requirements.

8-4.5.3 Insulation.

Steam lines must be thoroughly insulated from source to outlets.

8-4.6 Compressed Air.

Compressed air is required in a graving dock for tools and sandblasting.

8-4.6.1 Quantity.

Determination of required quantities is dependent on the operations to be performed and ranges from 3,500 to 8,000 ft^3/min (1.7 to 3.8 m^3/s) for small and large docks, respectively.

8-4.6.2 Mains.

All classes of graving docks should have mains on both sides of dock.

8-4.6.3 Outlets.

Base number and location of outlets on service air requirements for hull maintenance. Provide a suitable flanged valve provided with a blind flange for each branch outlet. Do not use plug valves

8-4.6.4 Size of Main and Outlets.

Size of mains and outlets as shown in Table 8-1 must be as follows:

Table 8-1 Size of Main and Outlet

Dock	Main inch (mm)	Outlet inch (mm)
Submarine and Destroyer	4 (102)	2.5 (63.5)
Cruiser	6 (152)	2.5 (63.5)
Auxiliary	6 (152)	2.5 (63.5)
Carrier	6 (152)	3 (76.2)

8-4.6.5 Piping and Fittings.

Piping and fittings must conform to the requirements of UFC 3-430-09.

8-4.6.6 Air Pressure.

Air pressure at branch outlets should be 100 psi (689 kPa) unless otherwise specified in project criteria. High-pressure air for testing 3,000 to 4,500 psi (2067 to 3101 kPa) should be described in project requirements and may be portable equipment.

8-4.7 Oxygen and Acetylene.

Oxygen and acetylene are required for cutting metals, brazing, heating, and welding operations. Graving docks are, for the most part, not equipped with a central oxygen and acetylene distribution system, and consequently are supplied from individual portable tanks (bottles or cylinders). The provision of a central distribution system should be considered in a new dock construction and in existing docks where large quantities of these gases are required. If distribution systems are planned, use the criteria below.

8-4.7.1 Location of Piping.

Never run mains for these gases in a pipe tunnel or an enclosed or partly enclosed service gallery, because of the extreme hazard involved. Locate both mains and outlets above extreme high water to prevent contact with oil floating on the water surface during flooding of the dock. Mains are best located in a special open slot formed as an integral part of the coping curb, or placed on the wall of the dock below the coping elevation, and protected from damage by a heavy fender member.

Place service outlets under open protective hoods above the coping level or on the inner faces of the coping line. Temporary connections to the dock floor may be made after each dewatering if distribution to the floor level is required.

8-4.7.2 Oxygen.

For oxygen piping, use standard weight, black steel, seamless tubing with beveled ends for welding. Pipe should be factory washed.

8-4.7.2.1 Sizes.

Provide these ranges of sizes, unless required otherwise:

- main from supply to side of dock, 2 to 3 in. (50.8 to 76.2 mm)
- distribution piping around the dock, 1-3/4 to 2-1/2 in. (44.5 to 63.5 mm)
- extensions to outlets 3/4 to 1 in. (19.1 to 25.4 mm).

It is standard practice to reduce the pipe size serving the more remote outlets in accordance with the reduction in volume of gas to be delivered.

8-4.7.2.2 Valves.

Use globe type shutoff valves, 400 psi (2,756 kPa), cold, non-shock gas working pressure. Prefabricate valve assemblies in the shop to minimize the possibility of leakage after fabrication.

8-4.7.2.3 Joints.

Use tinned threaded joints, made up with litharge and glycerin.

8-4.7.2.4 Testing.

Before outlets are attached, subject each section of line to a pressure air test at least 1.5 times the working pressure.

8-4.7.2.5 Identification.

Paint oxygen piping green and mark outlet valves “FOR OXYGEN.”

8-4.7.3 Acetylene.

For acetylene piping, use standard weight, black steel with beveled ends for welding.

8-4.7.3.1 Sizes.

Generally, provide these ranges of sizes:

- main from supply to side of deck, 1-1/2 to 2-1/2 in. (38 to 63.5 mm)
- distribution piping around the dock, 1 to 2 in. (25.4 to 51 mm)
- extensions to outlets, 3/4 to 1 in. (19 to 25.4 mm).

8-4.7.3.2 Valves.

Use forged or cast steel of the lubricated plug type cutoff valves.

8-4.7.3.3 Testing.

After fabrication, but before attaching outlet equipment, pressure test each section of line to at least 1.5 times the working pressure.

8-4.7.3.4 Identification.

Paint acetylene piping yellow and mark the outlet valves “FOR ACETYLENE.”

8-4.7.4 Supply.

If not supplied in portable tanks, the required supply of oxygen and acetylene may come from an existing yard system or be produced by stationary generators.

8-4.7.4.1 Alternate System.

If an existing system is not available, the choice between installation of stationary generators or banks of tanks will depend on the volume of gases required, estimated on both daily and weekly consumption rate. Where an appreciable volume of gas is required per week, it may be produced by stationary generators more economically than if supplied by tanks.

8-4.7.4.2 Building Design.

Buildings housing either tanks or generators should be of light steel construction and located at least 50 ft (15.5 m) from any adjacent structure or operation.

8-5 ELECTRICAL SERVICES.

8-5.1 Electrical Conduits.

Keep electrical circuits separate from service piping. They may be placed in concrete encased ducts behind the dock wall or, for large dry docks, in a separate tunnel shoreward from the pipe tunnel or gallery. Secondary electric power distribution lines are sometimes placed in supplementary utility tunnels, separate from immediate dry dock outlet system.

8-5.1.1 Support.

Wherever electric cables in underground installations are mounted on wall racks, support the cables away from the wall to allow leakage water to pass by.

8-5.2 Substations.

One or more electrical substations are required per UFC 4-150-02 to provide for conversion and distribution of electricity at the required voltages and capacities for ship services, and for operation of dock supporting facilities. Use mobile or portable transformer units to supply occasional high demand loads, and for testing nuclear vessels. Provide suitable protected primary feeder terminations at appropriate locations for portable design guidance.

Two feeders should be run to the pumphouse, in the event that the main feeder goes down. They should be fed from two separate power sources.

Install a back-up stand-by diesel power generator near each pumphouse to run at least the drainage pumps and alarms in the event all electrical power is lost. Consider sea level change and EHW for elevation of substations and generators.

8-5.2.1 Design.

A single substation may be incorporated into the pumpwell machinery room or, for a large dry dock, one may be required on each side of the dry dock, and not necessarily in the pumpwell machinery room.

8-5.2.2 Power Service Outlets.

Power must be conducted from the substation to dockside capstans, lights, and other necessary outlets, through cables in ducts run from manhole to manhole. The outlets should be weathertight and above mean high water. Make provisions for draining this secondary underground electric distribution system. Refer to UFC 4-150-02 criteria for outlets for ship services and portable equipment, and recommended design of electrical distribution systems.

8-5.3 Power Uses.

Electric power is required for the following:

- Pumps (see paragraphs 8-5.7.1, and 8-5.7.2)
- Sluice gates and valves (see paragraph 8-5.7.3)
- Capstans and winches (see paragraph 8-1.1.2)
- Lighting (dry dock, laydown area and pumphouse) (see paragraphs 8-5.7.8, 8-5.8.2.1, and 8-5.8.4)
- Ship services (see paragraph 8-5.8.1)

- Permanent Loads and Industrial Power (see paragraph 8-5.8.2)
- Telephones (see paragraph 8-5.7.9)
- Alarm systems (see paragraphs 7-2.8, 8-5.2, 8-5.8.3, 9-3.5.3, and 9-3.5.4)
- Control systems (see paragraphs 8-5.7.6, 8-5.7.7, 9-3.5.1, and 9-3.5.2)
- Welding machines (see paragraph 8-5.8.2.2)
- Battery charging (for some submarine requirements, see UFC 4-150-02.
- Heating, ventilating fans and air conditioning (see paragraph 7-4.13)
- Caisson (see paragraph 9-3.5.2)
- Elevators (as required by operations).

8-5.4 Methods of Installation.

Install outlets for servicing the vessels in the galleries on the sides of the dock, with other services. Carefully place outlets to facilitate connecting ships to the shore cables. All outlets, if subject to flooding, must be the watertight receptacle type. Provide a grounding system with connections in each service gallery.

8-5.5 Power Requirements.

Estimation of total power requirement calls for a careful analysis of the occurrence of simultaneous power uses listed in Section 8-5.3 entitled “Power Uses”.

8-5.5.1 Individual Requirements.

Correlate individual requirements by preparing a schedule of probability of usage. For assistance in formulating a schedule, refer to UFC 4-150-02 that shows ship service power and welding requirements for the various classes of vessels. These values are only indicative of range, and may be influenced by special requirements peculiar to any given installation. Meet the direct current welding requirement with portable converters rather than a fixed direct current bus system.

8-5.5.2 Special Requirements.

The project scope will specify any special power requirements. The total requirements for the electrically supplied supporting facilities must be estimated from the final design capacity of various installations.

8-5.6 Pumping Plant.

All electrical equipment in pumping plants must be a type suitable for installation in damp, humid atmospheres. Provide electrical heaters in large motors and switchgear to minimize condensation. The power distribution equipment should be a coordinated assembly of switchgear. Assemble the controls for all pumps, gates and valves, and the valve position indicators in a suitable panel or benchboard unit.

8-5.7 Power Demand Range.

The following tabulation presents probable range of electrical power demand for pumping the several classes of graving docks and is shown in Table 8-2. These figures may be used for preliminary purposes of study and/or design but are only indicative of the ranges to be expected.

Table 8-2 Range of Power Demand for Graving Docks

Class of Dock	Range of Power demand hp (kW)
Submarine	1,005 to 1,675 (750 to 1,250)
Destroyer or Frigate	1,273 to 1,742 (950 to 1,300)
Cruiser	1,742 to 4,020 (1,300 to 3,000)
Carrier & Auxiliary	4,690 to 6,700 (3,500 to 5,000)

8-5.7.1 Main Pump Motors.

Main pump motors should generally be of the wound rotor induction type, with starting resistance steps provided in the secondary windings, except where variable pitch impeller type pumps are used. In this latter case, use synchronous motors with reduced voltage starting where required. In general, operate these motors on a minimum of 2,400 volts, and at greater voltage where economically sound. Use drip-proof construction, and provide space heaters to heat the windings to approximately 5 °F (3 °C) above the ambient room temperature whenever the motor is disconnected from its voltage supply.

8-5.7.2 Drainage Pump Motors.

Drainage pump motors should be of the squirrel cage induction type, operated at 480 volts and at higher voltage where economically sound. Provide reduced voltage starting when required by design conditions. Provide drip proof construction and space heaters for the windings of the pump motors.

8-5.7.3 Other Motors.

Provide sump pumps, sluice gates, gate valves, sewage pumps, and ventilation fans operating at 460 volts. Motors should be drip proof or totally enclosed.

8-5.7.4 Switchgear.

Install high voltage protection and distribution equipment in a steel-enclosed, dead front assembly of switchgear. Carefully coordinate interrupting ratings of the gear with the systems to which connection is to be made. Construction should be drip proof, and space heaters should be provided to maintain the compartments of the switchgear approximately 5 °F (3 °C) above the ambient room temperature when the pumping plant is not in use.

8-5.7.5 Grounding.

Provide grounding systems for all electrical equipment frames, enclosures, and conduit systems.

8-5.7.6 Control Voltage.

Control voltage for all electrical equipment should be either 115 or 230 volts.

8-5.7.7 Control Panel.

Assemble pushbuttons and indicating lights for all pumps, gates, and valves (in addition to the synchronous position indicator for each valve and the dry dock water level indicator) on a steel control panel or benchboard type structure. Provide motor control on or adjacent to the starting equipment for each motor.

8-5.7.8 Lighting.

Provide vaporproof LED fixtures. Provide receptacle outlets at strategic locations for use during repair and inspection.

8-5.7.9 Telephone.

Provide telephone outlets at or near the control panels. Consider systems to support data, cybersecurity, and cell phone signal in pumpwell.

8-5.7.10 Installation.

All electrical installation should be in accordance with the requirements of NFPA 70, National Electrical Code. Use rigid steel type conduit. Plastic coated rigid steel conduit should be used where the conduit is exposed and subjected to flooding. Galvanized, rigid steel conduit should be used where the conduit is exposed but not subjected to flooding. Concrete encased conduit should be Schedule 40 PVC. Use cables in accordance with the latest revisions of the Uniform Facilities Guide Specifications (UFGS) Division 26, *Electrical*.

8-5.8 Dock Services.

Services are required as described in the sections below, as specified.

8-5.8.1 Ship Services (Hotel).

Power for ship services is supplied to provide the living requirements of the ship's crew, and includes loads such as lighting, cooking, pumps, fans, and other equipment. Current characteristics of the system must be the same as that of the ship supplied. Power is taken to the ship with portable cables, and connected to its electrical system through a connection box at one or more ship service outlets, which are located as indicated for each ship class in UFC 4-150-02.

8-5.8.2 Permanent Loads and Industrial Power.

Other electrical equipment such as dock lighting, receptacles, weight handling equipment ,and industrial power should be supplied from dedicated 480Y/277 Volt transformers.

8-5.8.2.1 Temporary Lighting and Power.

Design temporary lighting and power systems to supply 120-volt, 1-phase power for portable tools, lights, blowers, and other equipment used aboard the ship for repair.

8-5.8.2.2 Welding.

Provide welding service by both single- and multi-operator welding sets. The multi-operator sets are generally placed on shore, and single operator sets are placed on board ship or, if space permits, on shore. Large size welding sets are motor driven. The small sizes are either motor generator or static types. All types should be 480-volt operated. The base welding power should provide 75 percent of the total demand, and the single operator placed either aboard ship or on shore should supply 25 percent of the total demand.

8-5.8.2.3 Welding Power.

Provide power for welding equipment should from the Industrial power Cam-lok receptacles.

8-5.8.2.4 Electric Lines.

On small docks, electric lines are placed in ducts encased in concrete on the land side of the walls. For large docks, where the electrical requirements are great, place lines in a separate concrete electrical tunnel on the land side.

8-5.8.3 Fire Alarm Service.

For fire alarm system design and installation, refer to UFC 3-600-01.

8-5.8.4 Lighting.

All lights in the dry dock should be centrally controlled and the lighting intensity on the work surface should be not less than 10 foot-candles (107.6 lux).

8-5.8.4.1 Temporary Lighting.

Consider the minimum lighting requirements in 29 CFR 1915.82(a)(2) and supplementation lighting requirements in 29 CFR 1915.82(a)(4) for minimum foot candle lighting levels.

8-5.8.4.2 Night Lighting.

Provide adequate lighting on the walls of the dry dock for night work and, for daylight work, in high sidewall dry docks where daylight lighting is often impaired.

8-5.8.4.3 Types.

These lights may be of the submersible or non-submersible type. If the latter, they must be kept above the dock flooding level. If of the former type, they may be placed at a lower level, and sometimes at two levels for deeper docks.

8-5.8.4.4 Location.

Place lights on mounts to permit training and elevating, and locate at suitable intervals horizontally. They must be placed in niches or protected by cages.

8-5.8.4.5 Floodlighting.

Fabrication and material storage areas around the dock generally are lighted by banks of floodlights mounted on portable or fixed towers, or on sides of buildings. The lighting intensity for these areas should be about 10 foot-candles (107.6 lux). Portable towers should be connected to Industrial power receptacles.

8-5.8.4.6 Emergency Lighting.

Provide emergency lighting in accordance with in 29 CFR 1915.82(c)(1) and 1915.82(c)(2).

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CHAPTER 9 ENTRANCE CLOSURES

9-1 SELECTION.

This chapter contains basic data for criteria to design and construct entrance closures, including various types of gates and caissons. Advantages and disadvantages of each type are discussed.

9-1.1 Requirements.

Basic requirements in the choice of entrance closure are reasonable initial costs, ease and rapidity of control, low maintenance, and feasibility of traffic movements across the top.

9-1.2 Types.

A review of available types reveals why floating caissons have been adopted as standard for Navy dry docks. Other types may be suitable for smaller, temporary, nonmilitary dry docks.

9-1.2.1 Miter Gates.

Miter gates were probably the first satisfactory mechanical gates. Each closure consists of a pair of gate leaves, hinged at the dock walls, swinging horizontally so when closed the free ends meet in fitted contact. Gates are moved by means of a hawser to a nearby power capstan. The sides and bottoms bear against seats in the dry dock walls and floor. This type of gate is suitable for timber construction and steel; however, they are now no longer commonly used.

9-1.2.2 Hinged Gates.

A flap gate is a rigid, one-piece gate hinged at its bottom, and swinging downward and outward. It is a compartmented structure with means for varying its buoyancy for raising and lowering. Although this type of gate does not impose such severe loads on the hinges as the miter gates, it has similar disadvantages except those of recesses. Means must be provided to support a gate when down in open position.

9-1.2.2.1 Foster Hinged Gate.

This type of gate was a commercial device developed by C. J. Foster, Inc. It was a structure that could be folded, and that did not require transverse girders between the sidewalls of the dock. It was designed for unlimited widths and depths to suit dock conditions. Reaction due to water pressure on the gate was distributed to the floor slab of the dock. Massive abutments were not required to support the ends of the gate.

9-1.2.3 Set-in-Place Gates.

Set-in-place gates are in various forms and may be built in one piece or multiple sections. They are of beam and plate construction, with reactions carried to the walls by girders and to the floor by beams. Since their placement and removal must be done by weight handling equipment, the sizes of cranes required for naval dry dock closures makes this type of closure unpractical.

9-1.2.4 Sliding and Rolling Caissons.

These types are built-in box shapes, mounted on hardwood sliding surfaces or metal rollers that move them into or out of place. They may be equipped with air chambers for buoyancy which reduce the work of moving. They have some advantages of a floating caisson but require expensive recesses in dock walls for stowage. Cleaning and maintenance of the roller or slide paths are difficult.

9-1.2.5 Floating Caissons.

Floating caissons are watertight structures with flooding and dewatering systems for operation. For design of hull, floating stability, and all operational purposes, they are symmetrical both transversely and longitudinally. See Figure 9-1 and Figure 9-2 for typical design and hull elements of a floating caisson with flood through capability.

9-1.2.5.1 Advantages.

- The cost is reasonable, since practically all of the hull elements function structurally.
- A caisson may be handled easily and is seaworthy for towing to other sites (to another dry dock for repair) or from its construction site to point of use.
- It may be used at more than one seat in the same dry dock or other dry docks.
- Its symmetrical form allows reversibility with either side toward the dock chamber, permitting maintenance and repair on exposed side.

9-1.2.5.2 Disadvantages.

- The time for closing and opening the dock entrance is slower than for other types of closures.
- Because of shore service connections (electric and sometimes air), it is not operative too far from the caisson seat.

Figure 9-1 3D Perspective View of Caisson

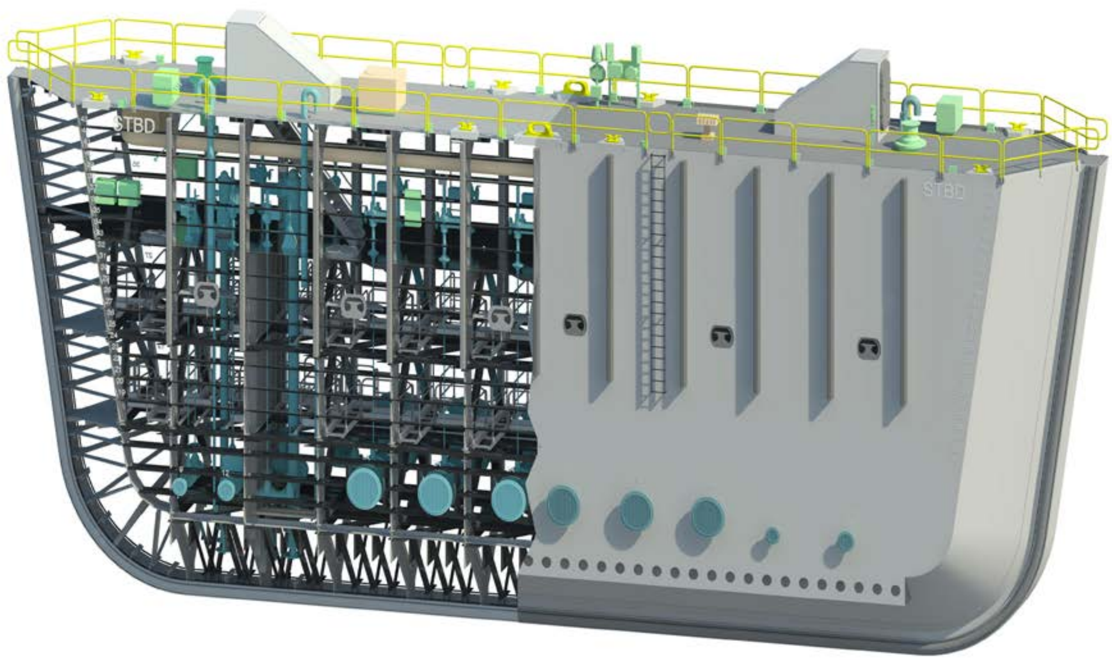
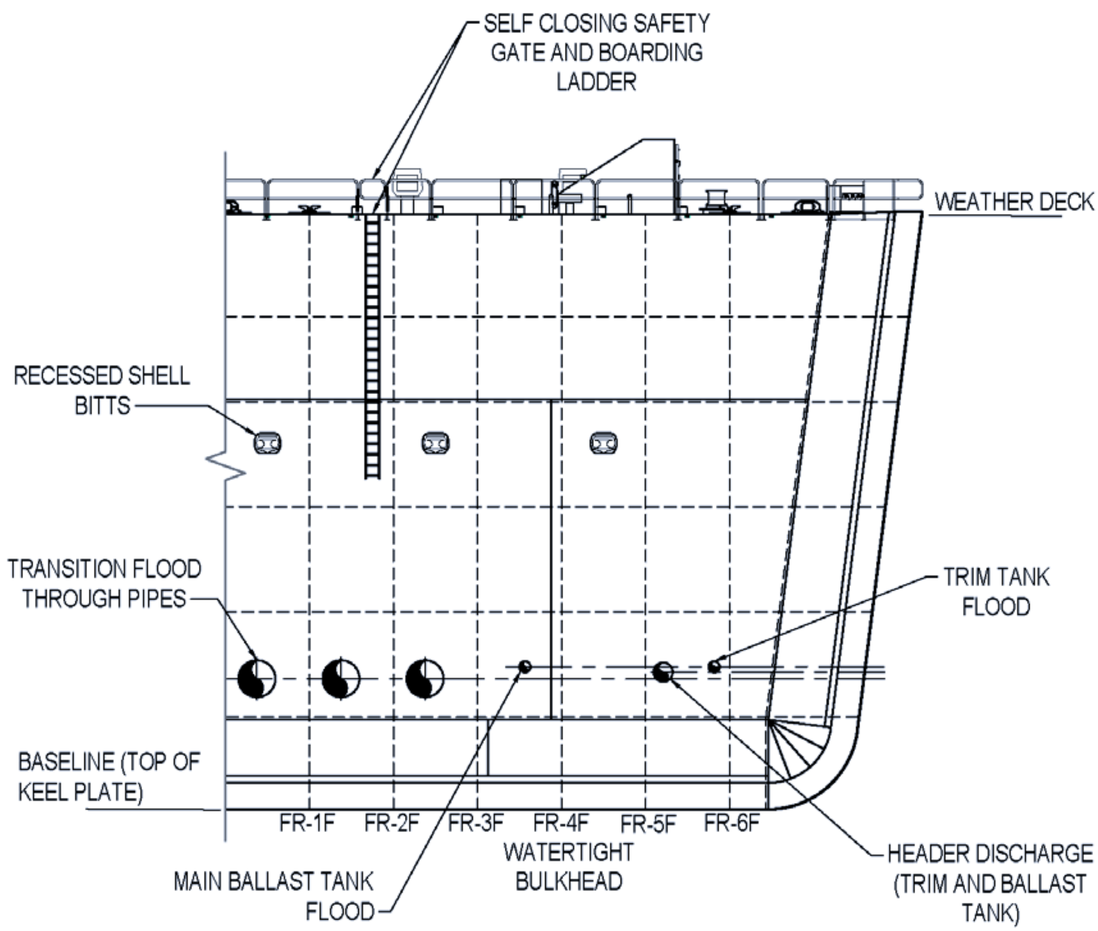


Figure 9-2 Hull Elements



9-2 DESIGN OF FLOATING CAISSONS.

9-2.1 Application.

The following paragraphs describe types of floating caissons, their operation, and materials of construction.

9-2.2 Requirements.

Caissons must allow reasonably rapid opening and closing of the dock entrance at any tide stage, be stable transversely and longitudinally at any draft, have strength and other characteristics to resist water pressure, and provide watertight seal when seated.

9-2.3 Types.

Floating caissons are usually one of the four types described below.

9-2.3.1 Ship Type Caisson.

This type has a faired shape similar to the lines of a ship. The required curvatures for frames and plates make the construction uneconomical, and it is now outmoded.

9-2.3.2 Hydrometer Type.

This type has a narrow width over as much of the height as possible between its waterline at extreme light draft when afloat and its waterline at mean high water when seated. This reduces the amount of adjusted water ballast during lowering and raising for seating and unseating operations.

9-2.3.3 Box Type.

This type is constructed in the shape of a box, with vertical or sloped ends to suit the seat shape. The girder ends project from the box to bear against the seats built in the dock side walls.

9-2.3.4 Rectangular Type.

This type is similar to the box type. It has simplified internal and external welded construction. All body girders and breasthooks are completely enclosed by the plating. All modern designs have been of this type.

9-2.4 Ballast Control.

The draft of caissons is adjusted for seating, unseating, and towing by flooding or pumping out water ballast. (Refer to Section 9-2.7 entitled “Machinery” for ballast control).

9-2.5 Operation.

Operation is functional as applied to the design objectives. Detailed operational instructions must be supplied for each installation but are, in general, as described in the two sections below: “Opening the Entrance” and “Closing the Entrance”.

9-2.5.1 Opening the Entrance.

To open the entrance, the procedure is as follows:

- In preparation for lifting the caisson from its seat, the water level inside the graving dock must be raised to the water level outboard the caisson, by flooding the dock basin.
- Caisson dewatering pumps are started; then with the discharge valves open and sufficient water ballast removed, the caisson floats off the seat. Pumping is continued until desired draft is obtained. The caisson in operation is very rarely pumped up to light draft.
- After the discharge valves are closed and secured, and the machinery is shut down, the caisson is warped out of the graving dock entrance channel limits by capstans and/or tugs. The caisson weather deck is fitted with chocks, bitts, and cleats for line attachment.

9-2.5.2 Closing the Entrance.

To close the entrance, the opening operation is reversed, except that ballast tanks are filled by opening flooding valves to let in water. During submergence, the caisson must be positioned correctly with respect to seats, and must have negligible list or trim.

9-2.6 Materials of Construction.

Modern caissons are built of welded steel.

9-2.7 Machinery.

The main machinery of a floating caisson consists of dewatering pumps and flooding, dewatering, and equalizing valves to control the water ballast. Design the ballast control system so that complete control of trim may be maintained during submerging and raising operations. The pumps are driven by electric motors powered through cables attached to shore connections located near the caisson seat at coping. Compressed air, when used, is also obtained from shore connections, through air hose.

9-2.7.1 Auxiliary Machinery.

Auxiliary machinery may include electric fans, motorized dry dock flooding valves, and an air compressor. When a dry dock is flooded through the caisson, two valves in each flooding tube are required for double valve protection.

9-3 DESIGN OF RECTANGULAR TYPE FLOATING CAISSONS.

9-3.1 Shape.

Since construction of caissons is not sufficiently repetitive, definitive drawings have not been prepared.

9-3.1.1 Elevation.

In elevation, the shape of a caisson must conform to the shape of the seats in the dry dock walls, which have been dimensioned to provide the required ship clearances.

9-3.1.2 Height.

The elevation of the caisson weather deck is normally the same as the dry dock coping. However, the elevation of the weather deck need not be any higher than required to prevent overtopping at the maximum possible outside water level (storm surge or extreme high water (EHW) level with consideration for sea level change). If there is a significant difference between the level of the dry dock coping and the maximum possible outside water level, then consider a lower weather deck elevation.

9-3.1.3 Cross Section.

For a typical caisson cross section, see Figure 9-3. Determine beam by strength and stability requirements. Slope the bottom and sides from the stems and keel at an angle of approximately 45 degrees, to meet the beam width. Slope the sides slightly inward at the top but maintain requirements for roadway and deck layout.

9-3.1.4 Plan.

Make the structure symmetrical about both axes. See Figure 9-4.

9-3.1.5 Stability Afloat.

Caisson stability afloat must meet the requirements of the current edition of The ABS Rules for Building and Classing Steel Vessels Under 90 Meters. The stability analysis will consider all ballasting conditions (tanks empty, partially full, full), towing loads, windage loads, mooring loads, live loads on weather deck and machinery deck (safety deck), and free surface effects.

9-3.2 Tanks.

Ballast is used to control the caisson draft and stability.

Figure 9-3 Cross Section and Typical Framing Arrangement of Welded Caisson

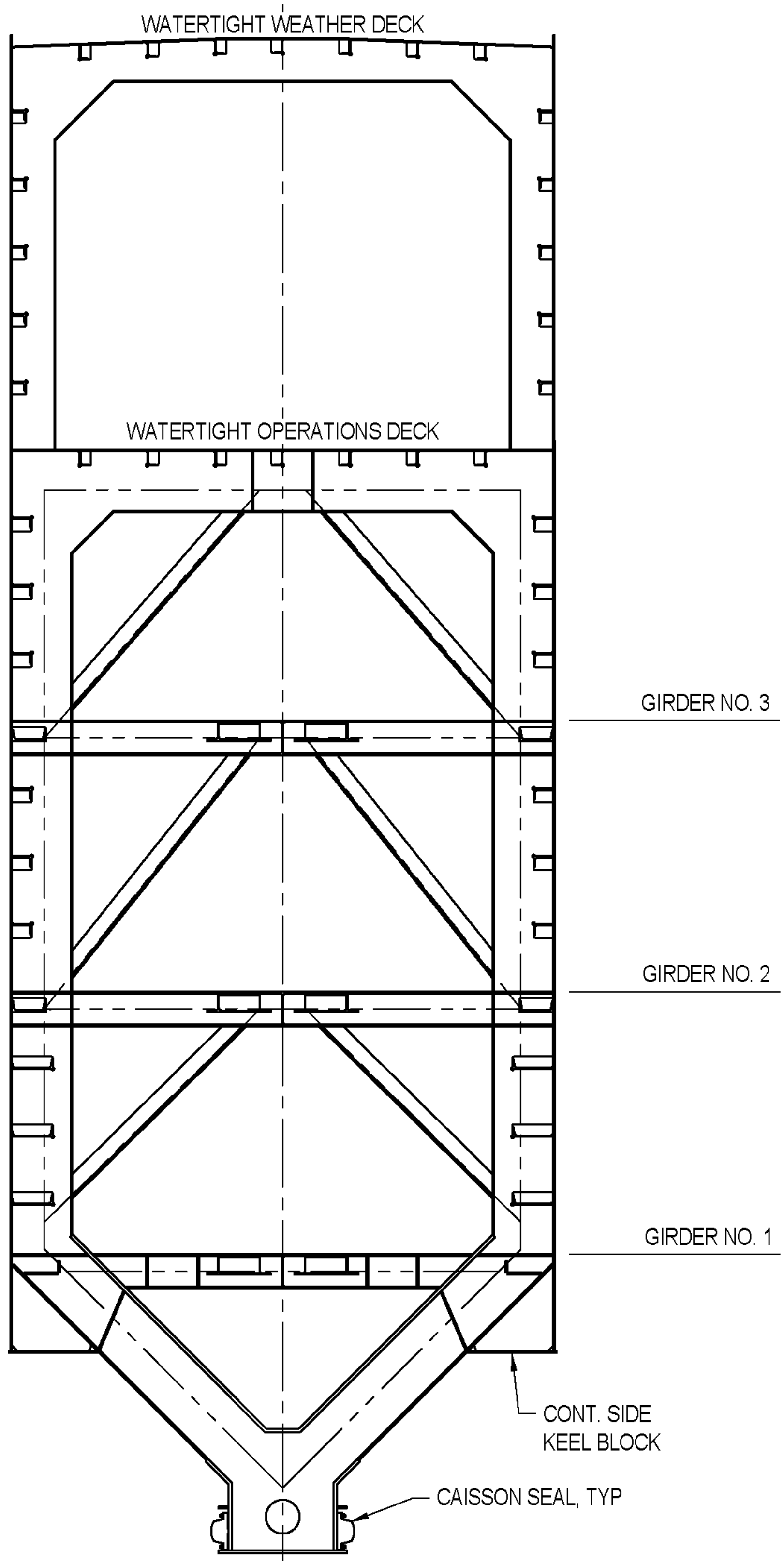
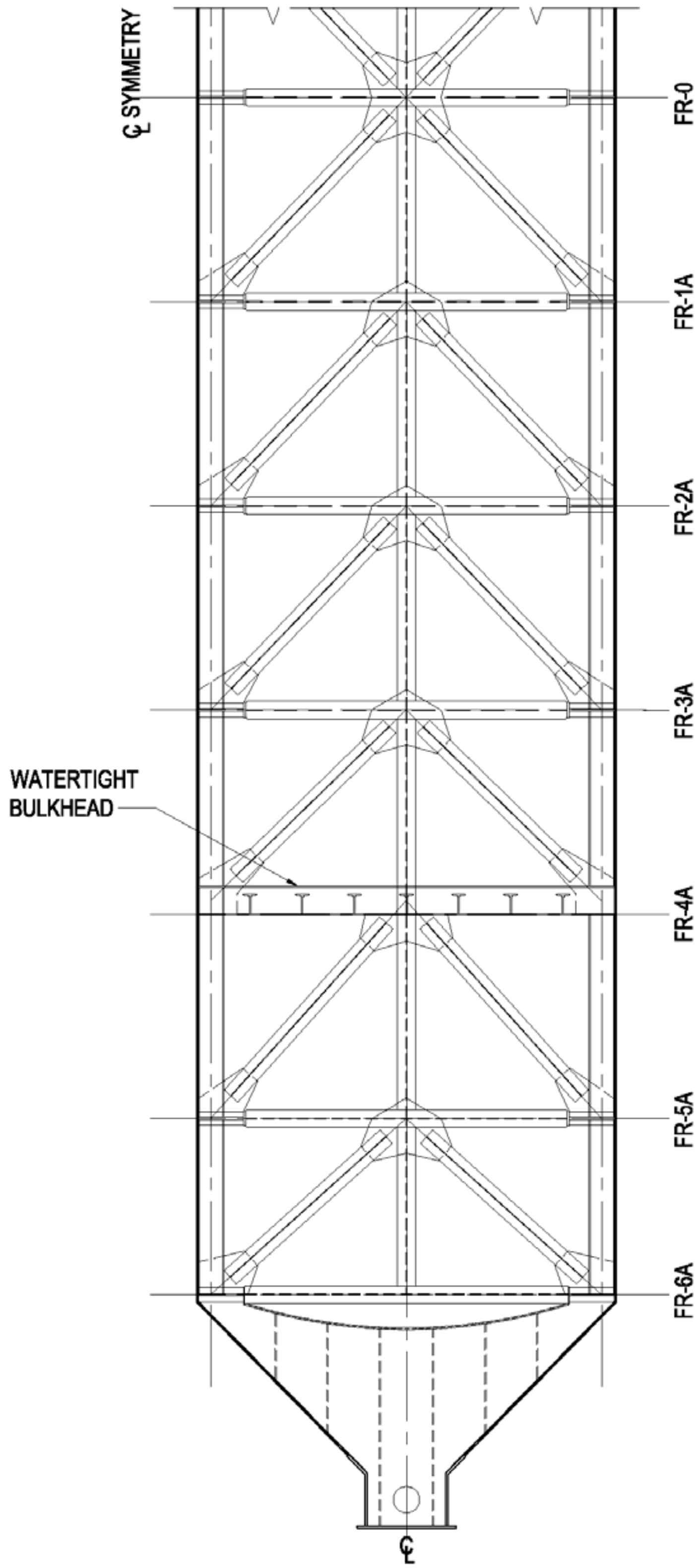


Figure 9-4 Typical Horizontal Girder for Welded Caisson



9-3.2.1 Fixed Ballast.

Fixed ballast is required to insure stability under all operating conditions. Fixed ballast at the bottom of a caisson is concrete. Quantity of fixed ballast is determined by the minimum draft and stability requirements. The minimum draft of a floating caisson must be such that it can be raised from the sill or seated at mean lower low water.

9-3.2.2 Water Ballast.

The maximum draft of a caisson normally occurs while the caisson is being seated at extreme high water. As a general rule, caissons are designed to allow for seating at mean high water, and the machinery deck (safety deck) is located, and dip pipes proportioned, to suit this condition.

If the dock can be superflooded, adequate water ballast must be provided so the total weight of the caisson (light weight plus water ballast) exceeds the amount of water displaced with the water level outside the dock at mean high water and the water level inside the dock at the maximum superflood level.

If the dry dock is located in an area where there is a significant possibility that the water level will rise above the overtopping level (coping or floodwall level) and flood the dock during destructive weather, then the caisson should be designed such that when floating and fully ballasted it has a freeboard of between 1 ft (0.31 m) and 2 ft (0.62 m) below the weather deck level. This will allow the caisson to be safely removed from its seat when the water level approaches the top of the caisson.

9-3.2.3 Ballast Tank Design.

9-3.2.3.1 Tank Layout.

Ballast tanks should be configured so the caisson can be trimmed, if necessary, by adjusting water ballast. This is normally accomplished by either using a single main ballast tank with trim tanks on either end of the caisson, or by using two ballast tanks with a watertight bulkhead on the caisson's centerline.

9-3.2.3.2 Tank Sizing.

It is desirable to be able to dewater ballast and trim tanks one at a time with the caisson in its seat and the dock dry to facilitate inspections and maintenance. If tanks are to be dewatered individually for inspections and maintenance, then they must be sized such that the caisson's weight (light weight plus water ballast) always exceeds the caisson's buoyant force, and there must never be an unseating moment on one end of the caisson. This calculation is done with the outside water level at MHW to allow tank inspection and maintenance under all normal operating conditions.

9-3.2.3.3 Machinery Deck (Safety Deck) Location.

The locations of machinery decks (safety decks) depend on necessary water ballast, adaptability to framing arrangements, and required headroom for machinery. There are advantages to raising the machinery deck (safety deck) higher over the end trim tanks than over the center tanks of the caisson because it allows use of shorter pump shafts and valve stems. Locate machinery decks (safety decks) at elevations higher than those indicated by computations.

9-3.2.3.4 Dip Pipes.

Provide dip pipes in each water ballast compartment to limit ballast water to design level and to keep water from wetting the underside of the machinery deck (safety deck). Dip pipes serve as vents until ballast water reaches the pipe ends. Once the dip pipes are immersed, the air remaining in the ballast tank is compressed until it limits the water level in the tank to the maximum design level. This provides a safety feature if there is a failure in the ballast tank's flooding or dewatering systems. These pipes are installed extra long, and cut off to the elevation determined by submergence tests. Steel dip pipes corrode quickly since their interiors are inaccessible and protective coatings can't be maintained. For this reason, dip pipes should be constructed from type 316L stainless steel.

9-3.3 Watertight Integrity.

The caisson hull structure must be watertight below the weather deck level. Main ballast and trim tank vent/dip pipes, caisson power supply, etc. must penetrate the weather deck and not the side shell plating. Windows and/or portlights must not be installed in the side shell plating.

Provisions to ensure the watertight integrity of the weather deck must be provided including watertight hatches for personnel access to the machinery deck (safety deck) level and trim tanks (if applicable). Weather deck penetrations for utilities, tank vents, machinery level ventilation, etc. must be watertight to at least 6" above the level of the weather deck.

Provisions to ensure the watertight integrity of machinery spaces must be provided. Watertight hatches must be provided in the machinery deck (safety deck) and bulkheads (if applicable) for access to the main ballast tank and trim tanks. All machinery deck (safety deck) penetrations including pump and valve shafts, lubrication lines, electrical wiring, etc. must be watertight.

The caisson must be designed to ensure that it will remain afloat in a satisfactory condition of equilibrium with the uncontrolled flooding of any one compartment (main ballast or trim tank) except the machinery space.

9-3.4 Analysis and Design.

Analyze and design caissons for all applicable loading conditions such as dead and live loads, hydrostatic pressure, and seismic. Refer to Figure 9-5 and Figure 9-6 for some example loading scenarios. Structural steel design may be in accordance with either AISC Steel Construction Manual or ABS Rules for Building and Classing Steel Vessels Under 90 Meters.

9-3.4.1 Approximate Analysis.

To resist external water pressure when a caisson is seated and the dock is empty, consider the caisson closure as a rectangular slab supported at side and bottom edges with free top edge. For approximate determinations of principal moments, shears, and reactions, assume the design length as a mean of the top and keel lengths and apply elastic theory for a rectangular plate supported on three sides. Determine also the distribution of shears and moments in individual frames and girders, stiffeners, and plating.

9-3.4.2 Framing.

Main framing should consist of a series of vertical trusses or frames attached to horizontal girders or frames at panel points. Make a bulkhead frame near each end watertight for trim tanks. Only the machinery/safety and weather deck horizontal girders are made watertight. Space vertical frames about 8 ft (2.5 m) on centers, with spacing of horizontal girders preferably not exceeding 10 ft (3.1 m). Place short intermediate horizontal girders, usually called breasthooks, in the upper half near the caisson ends, for better distribution of shears and end reactions.

9-3.4.2.1 Vertical Frames.

For construction details, see Figure 9-3.

Design as follows:

- Design vertical frames to resist caisson shears and bending moments in vertical directions and local bending between girders. The part of the total vertical caisson bending moment applicable to a frame is determined from the approximate analysis (refer to Section 9-3.4 above entitled “Design Analysis”). Chord stresses are determined by beam analysis.
- Local bending moments between girders on the outboard side result from water pressure loads brought to the vertical frames by hull plating and stringers.
- Web member stresses are found by assuming the distributed vertical pressure loadings to be concentrated at panel points and computing the consequent shears.

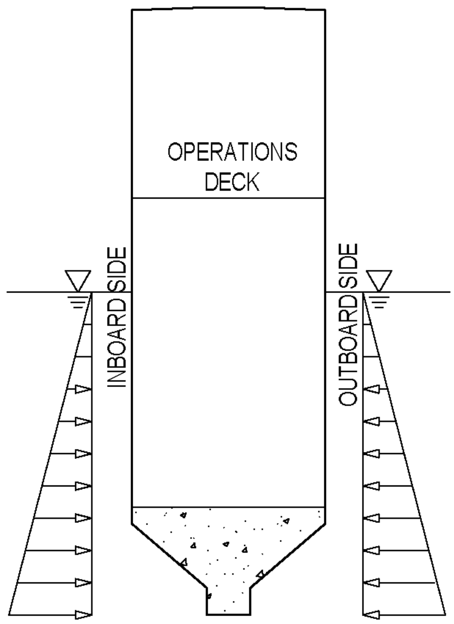
- Diagonal web members should preferably be tee sections; horizontal strut members angle sections; and chord members wide angle sections formed by bent plates or a web plate with a welded flange.
- Web member connections should be fillet welded.

9-3.4.2.2 Horizontal Girders.

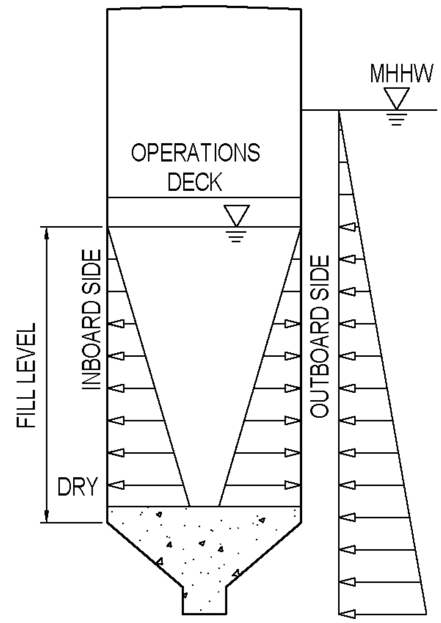
See Figure 9-4 for details of a typical girder. Design as follows:

- Design horizontal girders similarly to vertical frames. In general, they are the same type of construction.
- Girder flanges should be combination tee and wide-angle sections and, for computing stresses from girder action, include all adjacent hull plating.
- Members of safety and top decks must resist local loads introduced by secondary framing and deck plating at those locations.
- Webs at the girder ends are longitudinally stiffened plating for required shear resistance.
- Weather decks should be cambered to provide drainage and designed for specified uniform live loadings and concentrated vehicular loads normal to the girder plane.
- Design machinery decks (safety decks) for water pressures and machinery loads.
- Horizontal members in ballast and trim tanks should be designed such that air will not be trapped beneath the members as the tanks are flooded, and water will not be trapped above the members as the tanks are dewatered. Steel in air pockets will not be protected by the cathodic protection system when the tanks are flooded. Pooled water will hinder inspection and maintenance when the tanks are dewatered. Install vent/drain holes in unstressed areas of horizontal members, as required, to prevent these problems.

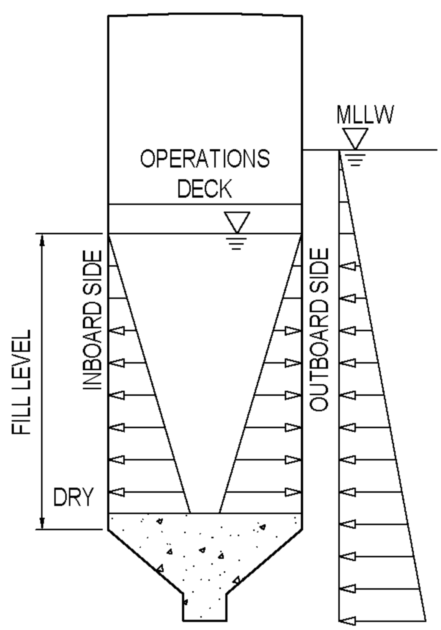
Figure 9-5 Example Load Cases for Caisson – 1 of 2



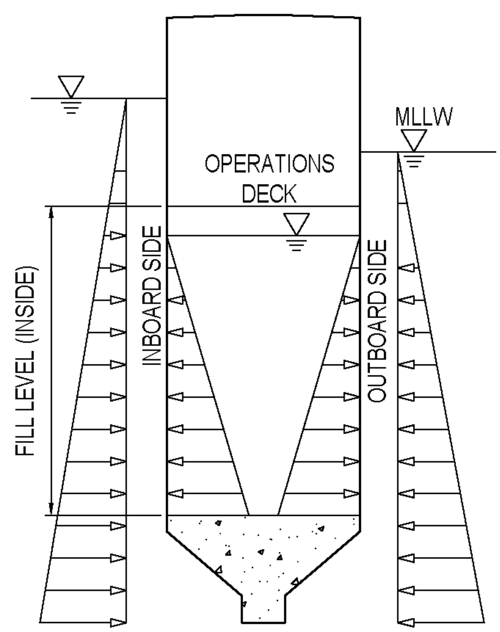
OPERATING LOAD CASE A
ALL TANKS DRY, FREE FLOATING



OPERATING LOAD CASE B1
MEAN HIGHER HIGH WATER LEVEL OUTSIDE, DOCK DRY,
A. END TANKS FULL & CENTER TANK FULL
B. END TANKS FULL & CENTER TANK DRY
C. END TANKS DRY & CENTER TANK FULL

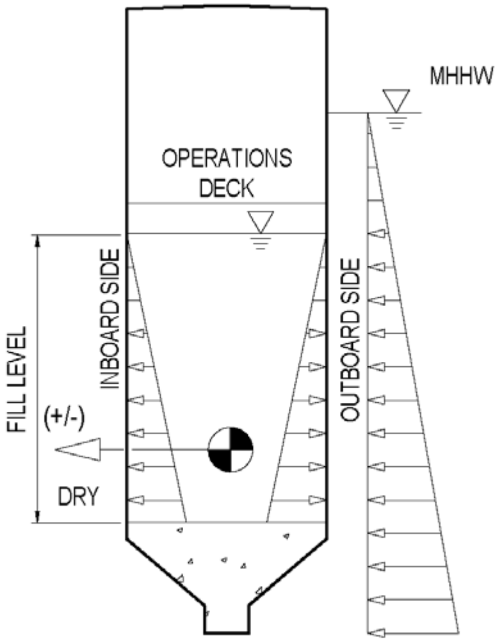


OPERATING LOAD CASE B2
MEAN LOWER LOW WATER LEVEL, DOCK DRY,
A. END TANKS FULL & CENTER TANK FULL
B. END TANKS FULL & CENTER TANK DRY
C. END TANKS DRY & CENTER TANK FULL

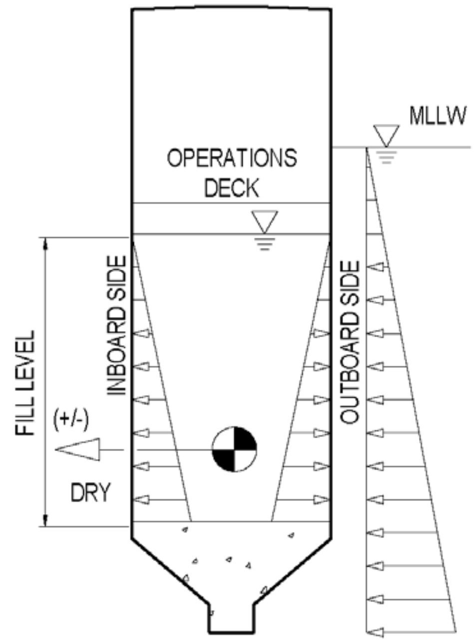


OPERATING LOAD CASE C
MEAN LOWER LOW WATER LEVEL OUTSIDE, DOCK SUPER
FLOODED, END TANKS FULL & CENTER TANK FULL

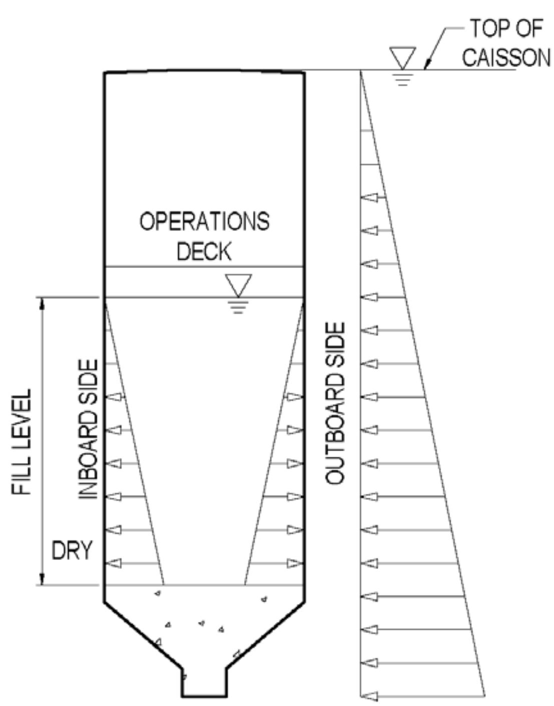
Figure 9-6 Example Load Cases for Caisson – 2 of 2



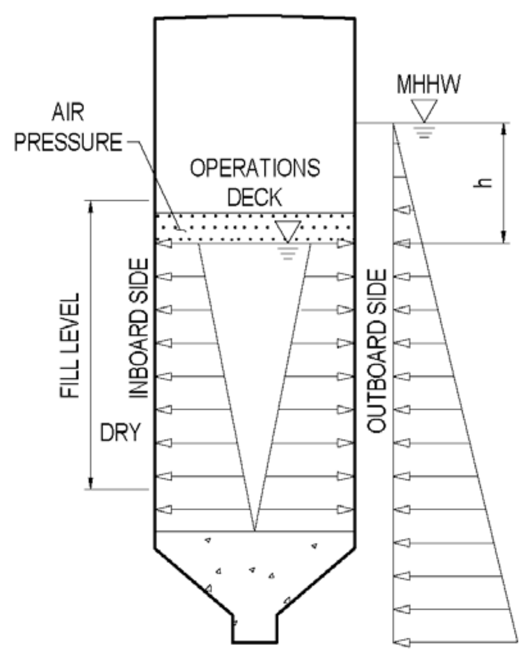
EXTREME LOAD CASE D1
MEAN HIGHER HIGH WATER,
DOCK DRY, EARTHQUAKE, ALL TANKS FULL



EXTREME LOAD CASE D2
MEAN LOWER LOW WATER,
DOCK DRY, EARTHQUAKE, ALL TANKS FULL



EXTREME LOAD CASE E
FLOOD STAGE OUTSIDE,
DOCK DRY, ALL TANKS FULL



EXTREME LOAD CASE F
MEAN HIGHER HIGH WATER,
DOCK DRY, ALL TANKS FULL TO TOP OF VENT OPEN

9-3.4.2.1 Secondary Framing.

Make shell plate stringers of flat bars, structural tees (ST or MT), bulb flats or angles running horizontally. At keel, provide web plate stiffeners in a vertical direction, spaced about 2 ft (0.6 m) on centers, between vertical frames. Design stringers as continuous beams to resist local water pressure transmitted by plating. Stringers for both weather and machinery decks (safety decks) should run in the long direction of the caisson. Design them as continuous beams.

9-3.4.2.2 Plating.

Stresses in shell plating are biaxial, due to bending in two directions. Determine maximum stresses in plating by combining stresses from overall bending and twisting of the caisson and bending stresses from local water pressure loading. Assume twisting moments resisted only by shearing stresses in the plating. Determine principal stresses by combining shear resulting from twisting, stresses produced by bending in both vertical and horizontal directions, and stresses due to local bending.

9-3.4.2.3 Stems and Keels.

Stems and keels distribute hydrostatic pressures on caissons to the masonry of dry dock seats. Keels are to be filled solid with concrete ballast, and stiffened with diaphragm plates.

9-3.4.2.4 Allowance for Corrosion of Steel Structure.

Steel caisson structure must be designed with a corrosion allowance such that allowable stresses will not be exceeded when corrosion has reduced structural component cross sectional areas by the amount of the corrosion allowance. Steel caisson structures will corrode during use regardless of coating systems and cathodic protection systems used. The use of a corrosion allowance (addition) during design should allow many years of use before costly structural repairs are required. The minimum corrosion allowance is listed in ABS Rules for Building and Classing Steel Vessels Under 90 meters 3-2-6/1.6.4(b).

9-3.4.2.5 Welding.

All caisson welded connections must be continuous to develop maximum strength and to facilitate cleaning and coating for corrosion protection. Skip welding must not be used in ballast and trim tanks or on the caisson exterior.

9-3.4.2.6 Maintainability.

The caisson must be designed and constructed such that all structural steel surfaces are readily accessible for maintenance and repair of protective coatings.

9-3.4.3 Gaskets and Seats.

The bearing of caisson ends and keel is taken through special molded, steel reinforced, rubber seals set on both faces of caisson keel and stem. Contact NAVFAC EXWC for details. See Figure 9-7.

9-3.4.3.1 Graving Dry Dock Seats.

For cruiser, auxiliary, and carrier docks, build recesses into the dry dock entrance floor 2 ft (0.6 m) and into the dry dock entrance side walls 2-1/2 ft (0.8 m), to form docking seats. For destroyer and submarine docks, these depths may be decreased respectively 6 in. (152 mm). Protect the bearing surface with either type 316 or monel armor plating.

9-3.4.3.2 Super-flooding Feature.

For dry dock designs including the super-flooding feature, face the dry dock seat recesses inboard and outboard to provide bearing reaction from either direction (refer to CHAPTER 6).

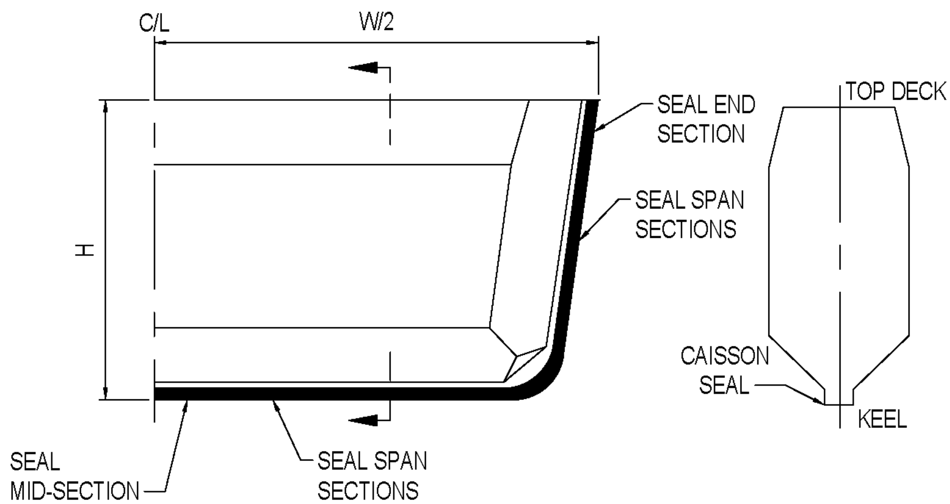
9-3.4.4 Side Docking Keels.

The caisson design must include side docking keels located approximately at the turn of the bilge on both sides of the caisson. The side docking keels provide a horizontal bearing surface for bilge blocks when the caisson is drydocked for maintenance or repair. See Figure 9-8. Side docking keels must be designed to accommodate two blocking plans such that the portion of the caisson that bears on the bilge blocks in the first docking plan is fully exposed to facilitate maintenance when the caisson is docked in the second docking plan. Design analysis must ensure adequate caisson stability while drydocked per NSTM Chapter 997, Docking Instructions and Routine Work in Dock.

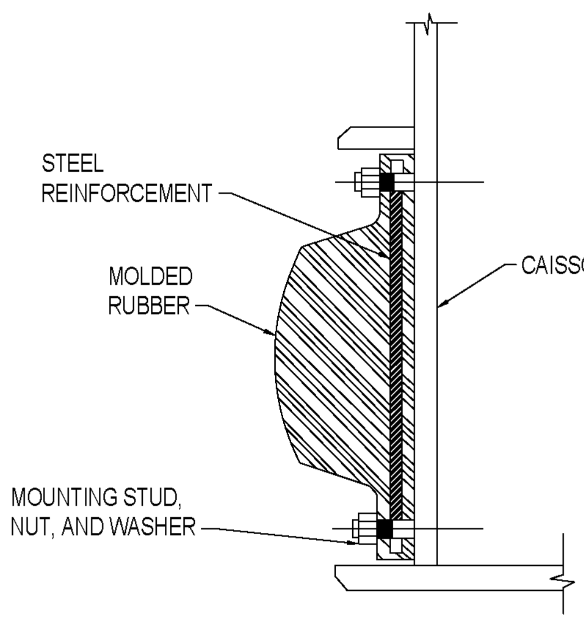
9-3.5 Equipment.

Mechanical and electrical equipment must conform to the same specifications as the corresponding equipment in the dry dock pumpwell.

Figure 9-7 Detail of Gasket for Caisson

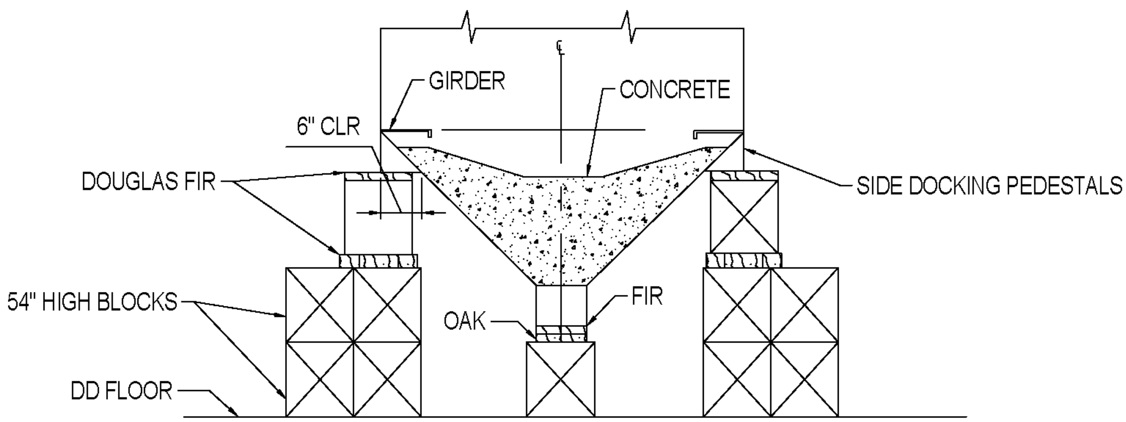


a) CAISSON SEAL LOCATIONS



b) SEAL ASSEMBLY

Figure 9-8 Caisson Side Docking Keels



9-3.5.1 Major Equipment.

Provide the following major items of equipment. Each system (caisson tank flooding, caisson tank dewatering, dry dock flooding, etc.) must consist of at least two parallel and independent systems for redundancy:

- Vertical shaft pumping units as required. Control by start-stop pushbutton mounted on or near the floor stand and/or at the control console.
- Gate valves or butterfly valves as required for water control. Use motor operated, except for small valves which may be hand operated. Provide sea connection with screens and gratings.
- Check valves in discharge pipes of main pump units.
- Inclinometers of suitable type to show both list and trim.
- Gauges for indicating the water level in each ballast compartment and draft.
- Heating and ventilating systems to suit climatic conditions.
- Dock flooding via piping through the caisson and 36 in. (76.2 mm) valves with controls. Two valves are required in each pipe. Use valves suitable for pressure from both sides to accommodate rotation of the caisson. Locate pipes high enough to avoid sucking mud and debris on the harbor bottom into the pipes. Consideration should be given to angling the ends of pipes down to prevent the movement of ship blocking. Install flanges on

the caisson shell on both sides of the caisson to facilitate the installation of blanks over the pipes. Refer to CHAPTER 6.

- Pumps and piping systems must be designed such that individual system components can be removed for repair and replaced without cutting and welding.

9-3.5.2 Electrical Equipment.

Supply 480 volts nominal, 3-phase, 60 Hertz per second electric current from the dry dock system to shore connection receptacles on the caisson. Operate main motors at 460 volts. Operate heater and fan motors on 120 volts, obtained from a transformer provided in each starter. Operate lights and convenience receptacles on 120 volts, obtained from 460/120-volt transformers. Provide controls, circuit breakers, and similar items, as necessary.

9-3.5.3 Ballast Tank Alarms.

Provide high and low water alarms for the main ballast tanks. Both alarms must annunciate locally and at the shipyard operations center.

9-3.5.4 Miscellaneous Fittings.

The following miscellaneous fittings are required:

- Companionway ladder or ladders with railings
- Vertical fenders to ballast compartments
- Timber composite or rubber fenders both sides of hull.
- Cast steel chocks and cleats on the weather deck. If the elevation of the weather deck is significantly higher than the pier elevation when the caisson ballast tanks are empty, consider also installing mooring fittings in the caisson shell at the appropriate elevation. The use of these fittings when mooring the caisson pier side for extended periods will eliminate problems with extreme vertical angles on mooring lines
- Non-skid surfacing on weather deck. Do not use a bituminous surface.
- Hinged or portable ramps (where required) for providing pedestrian access or vehicular access to roadway on caisson.
- Curb lights
- Hand railing (galvanized or other corrosion resistance)
- Access manholes and machinery hatches. Machinery hatches in the weather deck and machinery deck (safety deck) must be sized and located to facilitate the removal and reinstallation of all pumps and valves

- Capstan installations for line handling and warping out of and into dry dock seat or to mooring location, if necessary
- Visible and audible water alarm on weather deck.

9-3.5.5 Cathodic Protection.

All metal surfaces of the caisson that are normally immersed in sea water including the exterior shell plating, main ballast tank(s), and trim tanks should be protected from corrosion by a sacrificial anode type cathodic protection system. UFC 3-570-01, Cathodic Protection, provides guidance on system design. Consider using aluminum anodes for caisson cathodic protection rather than the commonly used zinc anodes. Aluminum anodes are both more efficient (three times as many amps-hours per pound consumed) and provide more protection (better protective potential for longer time) than conventional zinc anodes. Zinc is an environmental contaminant of concern in seawater, and the use of zinc anodes may cause problems with environmental regulators. Aluminum is not a contaminant of concern in seawater, so utilizing aluminum anodes instead of zinc anodes should eliminate this issue. However, some aluminum anodes contain mercury,so be sure to specify aluminum anodes that contain no mercury.

9-3.5.6 Protective Coatings.

Epoxy protective coatings meeting either MIL-DTL-24441D or MIL-PRF-23236D must be used to protect all caisson steel.

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CHAPTER 10 CONSTRUCTION

10-1 CRITERIA.

This chapter presents data and information as criteria for the construction of a dry dock body, the entrance closure, supporting facilities and accessories, and mechanical and electrical equipment.

10-1.1 Approach.

Criteria for the dry dock body are intended to guide the designer by indicating basic construction problems encountered, depending on the type of dry dock chosen. They are also intended to assist in the preparation of construction specifications as well as design drawings. References to construction of the dry dock body are based on the use of concrete. Phases of construction are presented in chronological order of the work.

10-2 DRY DOCK BODY.

10-2.1 Clearing and Demolition.

A site must be cleared of all interfering structures above and below water. Dispose of removed material according to contract requirements. Remove all objects that will interfere with excavation.

10-2.2 Rerouting Utility Lines.

Essential mechanical and electrical services that will be interrupted by construction work must be rerouted before demolition. Possible extensions of the services to the new dry dock, when completed, must be considered in rerouting.

10-2.3 Excavation.

Excavation is the first major step in the construction of a dry dock. It is necessary to make room for construction of the dry dock body, and often the removal of unsuitable foundation materials is required. Excavation may be done by dredging or in the dry, depending on the type of material, method of dewatering, or intention to construct the dry dock by underwater methods. Dredging is generally the most economical method.

10-2.3.1 Dredging.

A Department of the Army, Corps of Engineers permit must be obtained for dredging work in navigable waters and material disposal. Dredging may be done by hydraulic methods, or mechanical methods such as clamshell bucket or dragline. If soil is removed by hydraulic dredging, it may be piped to approved disposal areas, to yard locations for fill, or to stockpiles for future use. If dredging is done by clamshell or dragline, the removed soil must be barged to a disposal point.

Hydraulic dredging is not feasible for certain soils such as stiff clays or those containing boulders or rock. Blasting may be necessary for very hard materials, after which a clamshell or dragline is used for its removal. For additional information on dredging operations, refer to UFC 4-150-06, *Military Harbors and Coastal Facilities*.

10-2.3.2 Water Removal.

If water can be removed and kept excluded from a site with reasonable effort, construct dry docks in the dry. This method affords the greatest economies in material and the best quality of completed construction. The method of handling water percolation depends on the type of enclosure and on the nature of surrounding and underlying soils. For dry docks constructed in the dry, continued exclusion of water is most important. (Refer to the Section 10-2.4 entitled “Cofferdams”.)

10-2.3.3 Dry Excavation.

For hard materials, dry excavation is preferred. Where dewatering a site must be done by tiers of well points, excavation in the dry is initiated after the water table in the bank has been lowered. Excavation in the dry may be done by power shovels, draglines, clamshells, bulldozers, tractor drawn pans, or combinations of these methods.

10-2.3.4 Fine Grading.

Fine grading is done by hand tools, bulldozers, and scrapers. Replace over-excavation by well-consolidated material or lean concrete.

10-2.4 Cofferdams.

Cofferdams usually consist of sheet pile or earth structures, or both combined. The function of a cofferdam is to surround a site and to cut off, or minimize, water inflow. Portions of a cofferdam may become permanent parts of the finished dry dock. At the dry dock entrance end, a cofferdam must be removable to allow access for vessels when the dry dock is in operation. There are several types of cofferdams, four of which are described in the sections below.

10-2.4.1 Excavated Pit Cofferdam.

Where most of a dry dock is on land, and the soil in the area is sufficiently impervious and mostly of granular character, a hole may be dug and dewatered by means of well points or deep wells, or a combination of both.

10-2.4.1.1 Entrance Closure.

The entrance closure may be an earth-dike, with or without a line of sheet pile cutoff, or it may consist of a line of earth filled sheet pile cells.

10-2.4.1.2 Clay and Rock Foundations.

The open pit method is generally not suitable for clays. Dry docks built in rock fall into this category, except that water influx is usually small and can be collected in sumps to be pumped out by conventional pumps, see (d.) of Figure 4-1.

10-2.4.2 Earth Dike Cofferdam.

If suitable foundation and borrow material is available, a simple earth dike may suffice to exclude water from a site, even where dry docks will be located well out in the water. Usually, however, a sheet pile cutoff is provided as a dike core. Where sheet pile cutoffs can penetrate to impervious material, earth dikes are ideal. Where earth dikes are used, also provide for lowering the water table by well points and/or deep wells. For an example of a dry dock constructed with this type of cofferdam, see (e.) of Figure 4-1.

10-2.4.3 Cellular Sheet Pile Cofferdam.

For particularly unfavorable soil conditions (for example, where embankment material in place, or available, is very pervious or otherwise unsuitable), a continuous wall of cellular sheet piles may be used to enclose an entire dry dock site. Normally, do not choose this type of construction because the cost is relatively high. This method may prove feasible for shipbuilding docks of semi-permanent character where sheet pile cells become incorporated into the dock structure. See (a.) of Figure 4-2.

10-2.4.4 Internally Braced Sheet Pile Cofferdam.

The use of this type depends on special foundation conditions. The bottom must be relatively impervious and must have the strength to resist a blow. One example of this type of bottom is firm clay into which sheet piles can be driven to a substantial depth for cutoff. The clay must be firm enough so that the depth of material surrounded by the sheet piles has sufficient strength to resist uplift. Design as follows:

- Sheet piles of the Z-type are usually used because of the high ratio of rigidity to weight.
- Internal bracing must be placed in two directions and in vertical tiers spaced to accommodate the strength of sheet piles. Wales and struts may be of wood or steel or a combination of both. Steel is usually required below the top tier.

10-2.5 Foundation Piles.

Piles may be required to help support dry dock structures constructed on weak soil types. They may also be used to help hold down a dry dock floor slab against uplift pressures. Piles may be needed for track and capstan supports.

10-2.5.1 Types.

Piles may be of wood, steel, or concrete. Wood piles that are not completely covered must be treated.

10-2.5.2 Driving.

Piles may be driven either in the dry or underwater. Steel piles placed underwater are usually driven to a predetermined top elevation. Timber piles driven underwater may be cut to a predetermined top elevation by an underwater saw operated by a barge mounted motor and guide frame.

10-2.5.3 Length.

Because piles will vary in length at any given location, the lengths ordered must be sufficient to allow for possible variations. Piles may or may not penetrate into a structural foundation slab, depending on design anchorage requirements.

10-2.5.4 Locations.

The accurate positioning of each pile is important to maintain the validity of design assumptions and make possible the installation of prefabricated items.

10-2.5.5 Precautions in Driving and Handling.

Be sure that piles are undamaged by handling prior to driving, and substitute sound piles for those damaged in driving. Creosoted timber piles and precast concrete piles are particularly susceptible to handling and driving damage.

10-2.6 Foundation Course.

To stabilize soft bottom material, place a foundation course consisting of a layer of gravel or crushed rock several feet thick. For dry docks with relieved floors, grade the foundation course material to function as a filter. Where drainage pipes are used in conjunction with the filter course, the material around the pipes must be carefully placed and carefully compacted, to preclude damage to the pipes.

10-2.7 Foundation Slabs.

Foundation slabs may be poured either by the tremie method or in the dry.

10-2.7.1 Tremie Method.

For the tremie method, divide the floor slab into reasonable size placements by forms placed underwater. Place as follows:

- Each placement must be placed through multiple pipes to minimize the distance of concrete flow after emerging from the tremie pipe end. Pipes should be no more than 12 ft (3.7 m) apart.
- Water must be excluded from tremie pipes before they are filled with concrete. Water may be kept out by special foot valves or expelled by various go-devil devices that separate water from the concrete columns in the pipes as the columns build up with introduced concrete.
- Tremie concrete must be brought to within 1.5 to 2 ft (0.46 to 0.61 m) (nominally) of the top of the finished slab. Pour the remainder of the finished slab in the dry. This procedure allows cleaning the top of the tremie concrete after dewatering, embedment of various floor fixtures, and a final accurate floor finish and elevation.

10-2.7.2 In the Dry Method.

When docks are constructed in the dry, the floor is placed to full thickness in one operation, and contains the embedded items.

10-2.7.3 Field Verification of Weight.

For full hydrostatic docks, verify the actual weight of concrete and reinforcing steel being placed during construction, in order to ascertain the possible necessity for additional weight for conformity with design computations.

10-2.8 Sidewalls and Abutments.

Construct all abutments and sidewalls in the dry. For walls constructed on tremie placed slabs, the walls must be built within dewatered cofferdams placed on top of the tremie slabs. See Figure 5-1 for examples of cofferdams on tremie slabs.

10-2.9 Miscellaneous Items.

Other structures built in connection with a graving dock (such as capstan, bollard, and crane rail foundations) present no unusual problems and may be constructed in accordance with accepted practice. Care must be taken to ensure accurate positioning of items to be embedded in concrete, and watertightness of such structures as capstan pits, pumpwells, and service galleries. All holes left by removal of items (such as from ties) should be patched, because such unevenness in concrete surfaces accelerates deterioration and may cause leakage.

10-2.10 Backfill.

Backfill may be placed in the water or in the dry next to sidewalls and abutments. For tremie docks, it may be expeditious to place backfill in the wet. In the dry, backfill should be placed in shallow layers and each layer thoroughly compacted. Backfills comprise foundations for roadways, laydown area, and other structures built directly on them, and must have sufficient strength to support such loads.

10-3 ENTRANCE CLOSURES.

10-3.1 Construction and Use.

Entrance closures (caissons) are usually built of welded steel construction, but may also be built of reinforced concrete. Construction may be by a naval shipyard, but is usually done by a private contractor. Being adaptable for towing, a caisson may be built some distance away, in a yard particularly suited to economical prefabrication, and subsequently towed to the graving dock site.

10-3.2 Dimensions.

It is important to accurately check dry dock seat dimensions against those of the proposed closure, particularly for clearances. This is essential in the case of new caissons for existing docks. Contract documents for caisson construction should require that as-built caisson dimensions be within 1/4 in. (6.3 mm) of molded dimensions. Seal bearing surfaces should be within 1/8 in. (3.2 mm) of a vertical plane (or the designed shape if the seat is not planar). Measurements should be made during construction to verify that the as-built dimensions are within tolerance.

10-3.3 Ballast.

Permanent ballast necessary for proper operation and stability of a caisson is usually provided prior to an inclining test, and additional ballast, if necessary, is added at testing time.

10-3.4 Launching.

Caissons may be constructed in a graving or floating dry dock or on shipbuilding ways. Some small caissons can be built on piers and placed, by crane, in the water.

10-3.5 Steel Caissons.

Methods and operations used in prefabrication, assembly, and launching of steel caissons are very similar to those of other welded steel floating vessels.

10-3.6 Concrete Caissons.

Several prototype concrete caissons were built using practices developed for construction of concrete vessels and ships. These practices differ from standard concrete construction methods in the unusual care needed to achieve a watertight, durable, and structurally sound caisson. The service record of concrete caissons should be evaluated prior to proceeding with new designs. The concrete caisson may be placed in the outer seat while the steel caisson is being overhauled.

10-3.7 Closure Tests.

Five types of tests are required as described in the sections below.

10-3.7.1 Watertightness Test.

Watertightness must be made prior to launching, either by filling a caisson with water or by use of low pressure air.

10-3.7.2 Seating Test.

After launching, caissons must be seated and then raised several times with both faces toward the dock, to validate caisson operational performance. Tests should include the operation of all equipment (pumps, valves, capstans, etc.) and the dock should be pumped dry to validate performance of the rubber seals. If the dock is equipped for superflooding, it should be superflooded to the maximum design level with both caisson faces toward the dock.

10-3.7.3 Deflection Test.

Deflections at various points of a caisson under full load (high tide with a graving dock empty) must be determined in comparison with no-load positions, and then checked against original design data. For a convenient reference line, use a wire stretched along the caisson centerline and fastened at the caisson ends.

10-3.7.4 Inclination Test.

Inclination tests are used to determine the stability of a caisson under light conditions. The tests are on a caisson equipped and ready for operation, by moving known weights off center and recording the resulting caisson inclination angles. Angles are indicated by plumb bob pendulums, and obtained at light drafts only. Occasionally, a change in the amount of permanent ballast may be necessary because of such tests.

10-3.7.5 Submergence Test.

In a submergence test the caisson ballast and trim tanks are fully flooded. This test validates the airtight and watertight integrity of the machinery deck (safety deck) and ensures that the ballast tank dip pipes are cut to the proper length. This test also ensures that the caisson can sink deep enough to be seated at mean high water, and that the caisson weather deck will be above sea level when the tanks are fully flooded.

10-4 SUPPORTING FACILITIES AND ACCESSORIES.

10-4.1 Crane Rails.

Provide complete crane foundations, anchor bolts, and rails for portal cranes. Rails must be factory bent to required curvatures. Thermite weld or weld rail joints in accordance with alternate methods subject to NAVFAC approval. Refer to typical installation details in UFC 4-152-01.

10-4.2 Cranes.

Dry dock cranes are usually obtained by separate contracts with firms specializing in this type of equipment. Because of size, cranes are assembled at sites by manufacturers, from prefabricated sections. Performance tests are required after assembly.

10-4.3 Railroad Tracks.

Installation of ballasted dockside railroad tracks should follow standard railroad construction practice. Other railroad tracks are supported by a dock wall or special foundations, such as piles.

10-4.4 Bollards and Bitts.

An important construction problem in the installation of accessory anchorages is that of correct positioning of anchor bolts during concrete placements. Since changing positions of embedded bolts after the concrete has set causes difficulties and expense, and is undesirable structurally, every possible precaution should be taken against disturbing such bolts during placement.

Accessories subject to corrosion must have basic corrosion resistant shop coats of paint after manufacture, with finish coats on installation prior to acceptance.

10-4.4.1 Bollards and Cleats.

Space bollards and cleats to suit classes of vessels using the docks. Bollard foundations consist of large blocks of solid concrete, which generally rest on piles or are anchored directly to dock structures or crane track foundations. Embed anchor bolts in the concrete. Set bollard castings by crane on layers of mortar placed on the concrete foundations.

10-4.5 Ladders.

Use replaceable corrosion resistant ladders, and anchor ladders with 0.75 in. (19 mm) diameter Type 316 anchors to walls. Refer to 29 CFR 1910.23 for ladder requirements.

10-4.6 Manhole Steps.

Manhole steps may be built into either concrete or brick masonry. If the spacing and stagger pattern of steps is constant, it is usually economical to fabricate special stepholding forms as reusable standard wall panels.

10-4.7 Draft Boards.

Do not install ceramic tile draft boards at the same time a concrete wall is placed, but form the concrete to allow for subsequent tile installation. Set individual tiles flush with the wall in a bed of mortar. The gauge zero usually coincides with the elevation of the blocking 4 to 6 ft (1.2 to 1.9 m) above floor level.

10-4.8 Marking Plates.

Where marking plates already have centerlines, it is practically impossible to set them accurately at the time concrete is placed. Therefore, either form the concrete for subsequent plate installation or set plates in the placement and stamp on the centerlines afterwards.

10-4.9 Fenders and Chafing Strips.

Fenders, chafing strips, and other fittings used for protective purposes (such as timber or metal guards around stairways, floodlights, and similar items) are customarily furnished and installed by contractors. Individual guard units should be preassembled, as completely as possible, and then fastened by anchor bolts embedded in concrete. Because of exposed positions and repeated submergence, treat all timber and coat all metal with corrosion resistant material.

10-5 MECHANICAL AND ELECTRICAL EQUIPMENT.

10-5.1 Installation.

Mechanical and electrical equipment for graving docks is manufactured, and to a large extent assembled, at manufacturers' plants. Installation of such equipment may be done under the direction of manufacturer superintendents, general contractor, subcontractor, or yard forces. Installation of mechanical and electrical equipment is generally in accordance with standard building practices. Only those installation features peculiar to graving docks are considered below.

10-5.2 Capstans.

Placement of heavy capstan machinery usually should be done with truck or locomotive cranes. To maintain an even bearing, place a layer of grout between machinery foundations and concrete bases containing the anchor bolts.

10-5.3 Pumping Machinery.

Pumping machinery is usually installed by the manufacturer. Because of the complexity of running performance tests on main pumps, detailed tests are made at the factory. Usually, only one main pump is tested in sufficient detail to obtain all necessary data for plotting suitable performance curves.

10-5.3.1 Shaft Alignment.

It is extremely important to install pumps, pump motors, connecting shafts, and shaft support bearings so the shafts are correctly aligned with no unbalanced stresses imposed on the bearings.

10-5.3.2 Running Test.

After installation, perform a thorough running test on the entire pumping plant. Fire pumps should be tested in accordance with NFPA 20, Standard for the Installation of Stationary Pumps for Fire Protection.

10-5.4 Piping and Flow Control Equipment.

Piping and flow control equipment should be purchased, installed, and tested by a separate contractor under the general contractor. Valves larger than 6" should be motor operated. All motor operated valves and sluice gates should have a handwheel that allows manual operation in the event of a power failure. All valve and sluice gate manual handwheels should operate such that turning the handwheel in the clockwise direction when viewed from in front or above closes the valve or sluice gate.

10-5.4.1 Installation Practice.

Large diameter piping is supported above the floor by small concrete piers. Small diameter piping is generally hung from ceilings or walls by a variety of suitable pipe hangers or brackets. An alternate method of installing small diameter piping is to run the pipes along racks that are attached to masonry walls by expansion bolts or structural steel. In areas subject to earthquakes, the brackets and connections must be capable of resisting seismic forces.

10-5.4.2 Installation Timing.

Because of the character of mechanical or piping installation, and general lack of sufficient working space to improve efficiency, the mechanical work should be done after the structural work has been nearly completed. This phase is particularly applicable when separate contracts are let for structural and mechanical work.

APPENDIX A BEST PRACTICES

Consult NAVFAC EXWC SME for best practices.

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APPENDIX B GLOSSARY

B-1 ACRONYMS.

AASHTO	American Association of State Highway and Transportation Officials
ABS	American Bureau of Shipping
ACI	American Concrete Institute
AOA	Analysis of Alternatives
ASCE	American Society of Civil Engineers
ASD	Allowable Stress Design
ASTM	American Society of Testing and Materials
AT/FP	Anti-terrorism/Force Protection
AWWA	American Water Works Association
BFE	Base Flood Elevation (1.0% annual chance of exceedance)
CHT	Collection-Holding-Transfer
DFE	Design Flood Elevation
DFPE	Designated Fire Protection Engineer
EFE	Extreme Flood Elevation
EHW	Extreme High Water (Highest water level expected on station)
ELW	Extreme Low Water (Lowest water level expected on station)
ESLE	Extreme Sea Level Elevation
EXWC	Engineering and Expeditionary Warfare Center
FDC	Fire Department Connection
FEA	Finite Element Analysis
FEMA 0.2%	0.2% annual chance of exceedance flood
FS	Factor of Safety
LED	Light Emitting Diode

MHW	Mean High Water
MHHW	Mean Higher High Water
MIL-STD	Military Standard
MLW	Mean Low Water
MLLW	Mean Lower Low Water
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NSTM	Naval Ship's Technical Manual
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PVC	Polyvinyl Chloride
PWD	Public Works Department
SHT	Special Hull Treatment
SLC	Sea Level Change
SME	Subject Matter Expert
SSBN	Ballistic Missile Submarine (nuclear-powered)
SSGN	Guided Missile Submarine (nuclear-powered)
SSN	Attack Submarine (nuclear-powered)
SSI	Soil Structure Interaction
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UNS	Unified Numbering System (alloy designation system)
USACE	U.S. Army Corps of Engineers

VFD	Variable Frequency Drive
2D	Two-dimensional
3D	Three-dimensional

B-2 ABBREVIATIONS AND SYMBOLS.

ea	each
ft	foot
ft^2	square foot
fpm	feet per minute
ft/s	feet per second
ft^3/min	cubic foot per min
g	gravity
gpm	gallons per minute
hp	horsepower
in.	inch
k	kip, kips (1,000 lbs)
kg	kilogram (force)
km/h	kilometer per hour
kN	kilonewton
kN/m	kilonewton per meter
kN/m^2	kilonewton per square meter
kN/m^3	kilonewton per cubic meter
kPa	kilopascal
ksf	kips per square foot
lb	pound
lb/ft	pound per foot
lb/ft^2	pound per square foot
lb/ft^3	pound per cubic foot
lb/in^2	pound per square inch

LT	Long Ton (2,240 lbs)
m	meter
m^2	square meter
m/s	meter per second
m^3/s	cubic meter per second
m^3/h	cubic meter per hour
mil	0.001 in.
mm	millimeter
mm^2	square millimeter
MPa	megapascal
MPa/m	megapascal per meter
mph	miles per hour
P	Port (left side of vessel when facing forward)
pci	pound per cubic inch
pcf	pound per cubic foot
plf	pound per linear foot
psf	pound per square foot
psi	pound per square inch
S	Starboard
sec	second
ST	Short Ton (2,000 lbs)
t	tonne = metric ton = 1000 kg
V	Velocity

B-3 DEFINITION OF TERMS.

Bilge: The curve of a ship's hull joining the side and the bottom.

Bitts: A pair of vertical wooden/iron posts mounted either aboard a ship or on a wharf, pier or quay.

Bollard: A short vertical post used on a ship or a quay for mooring.

Bulkhead: A dividing wall or barrier between compartments in a ship.

Capstan: A revolving cylinder with a vertical axis powered by a motor used to supply force to ropes and cables.

Captive Crane: A traveling crane limited to use at one facility because of the absence of track connections to other facilities.

Cavitation: The formation of cavities in a fluid flow due to low pressures attending high velocities in the fluid.

Chafing Strip: Strips of wood or other material placed on sides of waterfront structures, fittings, or vessels to protect against chafing from contact with other structures, ropes, or chains.

Cleat: A T-shaped piece of metal or wood on a pier or vessel to which ropes are attached.

Cribbing: A framework, usually of timber, designed to distribute concentrated ship loads and to provide longitudinal stability to the keel blocks.

Elastic Mat: Structural slab on ground (usually of concrete) supporting separated vertical loads. The elastic deflections of the mat are correlated with resulting nonuniform soil reaction in computing stresses in the mat and the earth pressures.

Fairlead: A fitting through which a line may be led so as to preserve or change its direction without inducing excessive friction.

Go-Devil: A tight plug in a pipe, utilized to clear a pipe of liquid or debris.

Gypsy Head: A small auxiliary drum at the side or top of a winch.

Keel: The principal bottom structural element of a ship extending along the centerline for the full length of the ship.

Mortar Intrusion Concrete: Concrete made by injecting cement or sand-cement mortar into the interstices of previously placed aggregate (it can be placed in the dry or underwater).

Skeg: Vertical projection extending below the hull of a vessel to reduce yawing.

Sonar Dome: A bulge or appendage on the keel of a ship, usually forward, for housing sonar equipment.

Stoplog: A dam consisting of a piece or pieces in slots in the sides of a waterway to shut off flow.

Trash Rack: A grille, usually of vertical metal bars, used to screen out debris from the entrance to a waterway.

Tremie Concrete: Concrete placed underwater in such a manner that there is no free drop of the concrete through the water. This can be accomplished by pouring through a pipe or placing with special bottom-dump bucket. See Tremie Pipe.

Tremie Pipe: A vertical pipe through which concrete is placed underwater. In operation, water must be expelled from the pipe (so as not to mix with the concrete) by a go-devil (see above) placed ahead of the concrete, or the pipe must be freed of water before placing concrete and kept dry by means of a special flap valve at the bottom. During concrete placing, the bottom end of the pipe is kept buried in the concrete mass being placed to prevent backflow of water into the pipe.

Weep Hole: Opening provided in a wall or bulkhead to facilitate drainage of water. It usually serves to reduce hydrostatic pressure behind the structure.

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APPENDIX C REFERENCES

C-1 GOVERNMENT PUBLICATIONS.

**DEPARTMENT OF DEFENSE,
MILITARY SPECIFICATIONS, STANDARDS, AND PUBLICATIONS (ASSIST)**

https://assist.dla.mil/online/start/

MIL-DTL-24441D(SH), *Paint, Epoxy-Polyamide, General Specification for*

MIL-PRF-23236D, *Coating Systems for Ship Structures*

MIL-STD-1625D(SH), *Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U. S. Navy Ships*

NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC)

https://www.navfac.navy.mil/

NAVFAC Instruction (NAVFACINST) 11230.1, *Inspection, Certification, and Audit of Crane and Railroad Trackage*

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

https://www.navsea.navy.mil/

S9086-7G-STM-010/CH-997R3, *NSTM Chapter 997, Docking Instructions and Routine Work in Dry Dock*

S0570-AC-CCM-010/8010, *Industrial Ship Safety Manual for Fire Prevention and Response*

S9086-CL-STM-010, *NSTM Chapter 077, Personnel Protection Equipment*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

https://www.osha.gov

29 CFR 1910.23, Ladders

29 CFR 1910.29, Fall Protection Systems and Falling Object Protection- Criteria and Practices

29 CFR 1915, Occupational Safety and Health Standards for Shipyard Employment

29 CFR 1915.82, Lighting

UNIFIED FACILITIES CRITERIA (UFC)

https://www.wbdg.org/ffc/dod

UFC 1-200-01, *DoD Building Code*

UFC 3-190-06, *Protective Coatings and Paints*

UFC 3-220-01, *Geotechnical Engineering*

UFC 3-230-01, *Water Storage and Distribution*

UFC 3-240-01, *Wastewater Collection and Treatment*

UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*

UFC 3-430-09, *Exterior Mechanical Utility Distribution*

UFC 3-570-01, *Cathodic Protection*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*

UFC 4-025-01, *Waterfront Security Design*

UFC 4-150-02, *Dockside Utilities for Ship Service*

UFC 4-150-06, *Military Harbors and Coastal Facilities*

UFC 4-152-01, *Piers and Wharves*

UFC 4-159-03, *Moorings*

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

https://www.wbdg.org/ffc/dod

UFGS 03 31 29, *Marine Concrete with Service Life Modelling*

UFGS 03 31 30, *Marine Concrete*

UFGS Division 26, *Electrical*

UFGS 35 59 13.14 20, *Polymeric Piles*

U.S. ARMY CORPS OF ENGINEERS (USACE)

https://www.usace.army.mil/

EM 1110-2-6053, *Earthquake Design and Evaluation of Concrete Hydraulic Structures*

EM 1110-2-2503, *Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures*

C-2 NON-GOVERNMENT PUBLICATIONS.

AMERICAN BUREAU OF SHIPPING (ABS)

https://ww2.eagle.org/en.html

ABS Rules for Building and Classing Steel Vessels under 90 meters (295 ft) in Length

AMERICAN CONCRETE INSTITUTE (ACI)

https://www.concrete.org

ACI 207.1R, *Guide to Mass Concrete*

ACI 207.2R, *Report on Thermal and Volume Change Effects on Cracking of Mass Concrete*

ACI 207.4R, *Cooling and Insulating Systems for Mass Concrete*

ACI 318, *Building Code Requirements For Structural Concrete And Commentary*

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

http://www.asce.org/

ASCE 61, *Seismic Design of Piers and Wharves*

AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM) INTERNATIONAL

http://www.astm.org/

ASTM A615/A615M, *Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement*

ASTM A706/A706M, *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://www.nfpa.org/

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*

NFPA 70, *National Electrical Code (DoD adopted)*

C-3 AUTHORED PUBLICATIONS.

Abbett, R.W. (1956) *American Civil Engineering Practice*, *Volume II*. John Wiley and Sons Inc.