Preparing Activity: NAVFAC

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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SECTION 35 59 13.17

FOAM-FILLED MARINE FENDERS

11/21

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SECTION 35 59 13.17

FOAM-FILLED MARINE FENDERS
11/21

NOTE: This guide specification covers the requirements for foam-filled marine fenders.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

NOTE: Fender type should be selected based on the following considerations:

1. Performance, including energy, berthing angle, reaction, and hull pressure.

2. Geometry, including stand-off, dock configuration, vessel configuration, and tidal variation.

3. Configuration and construction, including corrosion resistance, netted vs not netted, magnetic permeability, buoyancy and portability.

The following information shall be shown on the project drawings:

1. Location, size,and mounting elevation (if applicable) of each fender type.

2. Connection details to the waterfront structure. Include connection sizes, material type, embedment, plate sizes and hole sizes and locations, as applicable.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN BUREAU OF SHIPPING (ABS)

ABS 2	(2019) Rules for Building and Classing Steel Vessels

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	(2020; Errata 1 2021) Structural Welding Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M	(2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153/A153M	(2023) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM D412	(2016; R 2021) Standard Test Methods for

	Vulcanized Rubber and Thermoplastic Elastomers - Tension
ASTM D470	(2013) Crosslinked Insulations and Jackets for Wire and Cable
ASTM D1052	(2009; R 2019) Measuring Rubber Deterioration-Cut Growth Using Ross Flexing Apparatus
ASTM D1630	(2006; R 2012) Rubber Property - Abrasion Resistance (Footware Abrader)
ASTM D1667	(2022) Standard Specification for Flexible Cellular Materials - Poly (Vinyl Chloride) Foam (Closed-Cell)
ASTM D2240	(2015; E 2017) Standard Test Method for Rubber Property - Durometer Hardness
ASTM D3575	(2020) Standard Test Methods for Flexible Cellular Materials Made from Olefin Polymers
ASTM F2192	(2005; R 2022) Standard Test Method for Determining and Reporting the Berthing Energy and Reaction of Marine Feeders

INTERNATIONAL NAVIGATION ASSOCIATION (PIANC)

PIANC 2002	(2002) Guidelines for the Design of Fender Systems: 2002

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS RR-C-271	(Rev H; Am 1) Chains and Attachments, Carbon And Alloy Steel

1.2 SYSTEM DESCRIPTION

1.2.1 Foam-Filled Fenders

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NOTE: Foam-filled fenders are typically used at berths that support ships of various sizes and with a variety of hull curvatures. Due to the wide variety of ship types that berth at Naval facilities, the foam-filled fenders are typically the fender of choice.

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Foam-Filled fenders are fenders typically manufactured by wrapping closed cell foam with a nylon reinforcement embedded in a polyurethane coating. The fenders typically used for fendering have an internal chain, though fenders having an external chain/tire netting have also been used. The fenders are typically used for berthing of medium to large vessels; vessels with considerable hull curvature; and at berths that support various ship types and sizes. The fenders can be used as stand-alone fenders, fendering between ships, or between a ship and a berthing

structure.

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G". Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Foam-Filled Fenders; G[, [_____]]

SD-05 Design Data

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NOTE: Performance requirements: the rated energy of the fender shall be no less than the calculated berthing energy and the rated fender reaction shall not exceed the allowable load on the structure

supporting it.

The maximum reaction divided by the corresponding contact area, shall be less than or equal to the maximum specified hull pressure for fender panels.

Deflected standoff at specified energy must be greater than or equal to minimum specified standoff. The undeflected standoff, including nets if any, shall not be greater than any specified undeflected standoff.

Fender design load shall be less than the rated reaction of the fender. Static shear force shall use the minimum static coefficient of friction. Dynamic shear force for foam-filled, pneumatic and hydro-pneumatic shall be the rated reaction times the difference between the coefficient of friction between the structure and fender and the coefficient between the fender and vessel times a factor of safety of 1.5. Dynamic shear force for rubber fenders for slicing surfaces shall be twice the maximum published dynamic coefficient of friction. For UHMW against steel, use 0.20 or the maximum published for the coefficient of friction.

The ultimate elastomeric elongation shall be at least three times the maximum elongation anticipated at maximum design conditions. The bond strength of the elastomer to its substrate shall be greater than the elastomer's tensile strength at the ultimate elongation.

Structural components shall be sized with a design load that does not exceed 80 percent of yield. Panel loads shall be based on the greater of:

1. Horizontal line contact applied at any elevation over the flat height of the panel.

2. Simultaneous horizontal line contacts at top and bottom edge of the front face of the panel.

Design factor for attachment points, restraints and nets shall be based on 1.5 times the dynamic shear. The end attachment load shall not exceed 80 percent of yield. Restraints shall be sized such that the load applied to the weakest component does not exceed 50 percent of its breaking strength.

A weak link, preferably a shackle, swivel or other readily replaceable, cost effective component shall be designed to fail first. Concrete embedments shall have a break out capacity of at least 1.5 times the characteristic load of the weakest link.

Mechanical hardware, such as fasteners shall be sized with a design working load that does not exceed 60 percent of the lower of the yield or

breaking load.

Foam-filled fenders should have at least 50 percent of the contact dimension in bearing on the supporting structure, or as recommended by the manufacturer. The contact surface for all floating fenders when not under load, should have low abrasion characteristics. Typically UHMWPE or plastic is used to face concrete or composite elements in the wear area.

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Foam-Filled Marine Fenders; G[, [_____]]

SD-06 Test Reports

Fender Cyclic-Compression Test; G[, [_____]]

Fender Sustained-Load Test; G[, [_____]]

Fender Pull-Through Test; G[, [_____]]

Skin Thickness Core Test; G[, [_____]]

Foam Core Density Test

SD-08 Manufacturer's Instructions

Installation Instructions

SD-10 Operation and Maintenance Data

Fender Manual

SD-11 Closeout Submittals

Foam-Filled Fenders - Warranty; G

1.4 DELIVERY, HANDLING AND STORAGE

Fenders must be undamaged when delivered and must be handled and stored so as to prevent damage, such as bending or abrading end fittings, cutting of rubber, or damage to coating of hardware. Protect fenders from exposure to damaging liquids, oils, greases and extended exposure to sunlight.

1.4.1 Rejection

Fenders that are delivered to the site in a damaged condition or that are not in conformance with this specification are subject to rejection. Remove and replace any rejected materials with suitable materials, at no additional cost to the Government.

1.4.2 Fender Marking

Unless otherwise specified, all fenders must be identified in readable characters at least 25 mm 1 inch high, either directly or on corrosion- and sunlight resistant permanently attached tags. The markings must include the following:

a. full or abbreviated manufacturer name,

b. fender size model or part number designation,

c. fender serial number,

d. other information as the purchase specification or contract requires.

1.4.3 Fender Instructions and Manual

Provide installation instructions and a fender manual describing maintenance requirements for each fender type.

1.4.4 Handling Coated Material

Store, handle, and place coated material in a manner that will minimize damage to the coating and will not reduce its effective protective value. Repair damaged surfaces as directed and per the Manufacturer's recommendations. Handle coated work which is flexible in a manner that will prevent flexing sufficient to crack coating, especially when temperature is below 4 degrees C 40 degrees F. Do not place coated surfaces on strips or skids until coating has hardened thoroughly. Wide fabric slings used for lifting, and strips, slings, blocks, skids, cradles, and other supports must provide ample bearing areas. In transporting, fasten and protect coated materials in a manner that will prevent movement and preclude chafing and rubbing, and when unloading, do not dump or drop. Place coated material in position carefully on suitably prepared beds and with a minimum of handling.

1.5 QUALITY ASSURANCE

1.5.1 Elastomer Skin

The elastomer skin of the fender must be free from cracks, burrs, warpage, checks, chipped or blistered surfaces, and have a smooth surface.

1.5.2 Foam Core

The foam core must be homogeneous and of one piece fabricated construction and not be in chip or granular form. The foam core must not contain scraps, strips, or sheets of foam either rolled or stuffed into the required shape unless pieces are bonded together in layers of uniform patterns to form a homogeneous, one piece core. Foam widths less than 48 inches are not acceptable. Homogeneous foam rings of adequate thickness to insure performance of the fender are acceptable if a minimum 5-year performance of similar fenders is provided.

1.5.3 Steel Fabrication

The steel used in fabrication must be free from kinks, sharp bends, and other conditions which would be detrimental to the finished product. Manufacturing processes must not reduce the strength of the steel to a value less than intended by the design. Manufacturing processes must be done neatly and accurately. Make bends by controlled means to insure uniformity of size and shape.

1.5.4 Welding

AWS D1.1/D1.1M. Provide welds of sufficient size and shape to develop the

full strength of the parts connected by the welds. Welds must transmit stress without permanent deformation or failure when the parts connected by the weld are subjected to proof and service loadings.

1.6 FOAM-FILLED FENDERS - WARRANTY

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NOTE: The warranty requirements in this guide specification have been approved by a Level I Contracting Officer in accordance with the requirements of Naval Facilities Acquisition Supplement (NFAS).

NFAS can be found at the following link: https://www.navfac.navy.mil/

The paragraphs in this guide specification may be used without further approval.

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Furnish the manufacturer's warranty. Issue the warranty directly to the Government. It must not be limited in dollar value. The warranty period must not be less than 1 year from the date of Government acceptance of the work.

PART 2 PRODUCTS

2.1 FOAM-FILLED FENDERS

Prior to fabrication, submit copies of the manufacturer's catalog data including reaction, energy and percent compression curves, dimensions material specifications, and method of manufacture.

2.1.1 Configuration

Fenders must have cylindrical mid-bodies with conical or hemispherical shaped ends terminating in an end fitting on the cylinder's centerline at each end. The diameter of the mid-body must be 60 inches minimum, and the length of the mid-body must be 73 inches minimum. If conical ends are provided, they must have an angle of 60 to 75 degrees, when measured from the central axis of the fender. The fittings at either end must be connected through the center of the fender by a chain, must terminate in a clevis fitting sized for the indicated shackle and must swivel to allow the end fitting to rotate freely on the axis of the fender. Design end fitting as small as possible to transmit the ultimate load of the shackle to the fender. Size the end fitting so as not to contact loading surfaces when the fender is compressed to 30 percent of its original diameter (70 percent compression). Each end fitting must not be a continuous member; however, each independent end fitting must be of sufficient length to span all of 3 feet in the center of the fender. Permanently affix the end fitting to the fender core with urethane elastomer prior to applying the skin. Fill interior of the fender with energy absorbing closed-cell foam as specified. The use of chipped or particulate foam is not acceptable.

Dimensional tolerance: plus or minus 4 percent for diameter and length.

2.1.2 Foam Core

The energy absorbing foam core must be a closed-cell cross-linked

polyethylene foam with the following properties:

a. Density, ASTM D1667, [52 to 104] [[_____] to [_____]] kg/m^3 [3.3 to 6.5] [[_____] to [_____]] lbs/ft^3

b. Tensile strength, ASTM D3575 or ASTM D412, [550] [_____] kPa [80] [_____] psi minimum

c. Elongation (ultimate), ASTM D3575 or ASTM D412, [40 percent] [_____] to [_____] minimum

d. Water absorption percent volume after 24 hour exposure, ASTM D1667, [5.0 percent] [_____] maximum

e. Continuous service temperature, [minus 54 to 49 degrees C] [minus 65 to 120 degrees F] [_____] to [_____]

f. 25 percent compressive set, ASTM D1667, [8 percent] [_____] maximum *

g. 50 percent compressive set, ASTM D3575, [12 percent] [_____] maximum *

* Option: Compressive Set of foam core material must be based on either the 25 percent or the 50 percent requirement listed.

2.1.3 Fender Skin

The outer fender skin must be minimum [32] [_____] mm [1.25] [_____] inches thick and constructed of elastomer as specified. Produce the fender skin with a singular homogeneous material. Multiple material types or layers are not permitted. Reinforcing is mandatory. Reinforcement utilizing a fabric is prohibited. Filament reinforcing is required. [Twelve][_____] separate filament reinforcing wraps must be applied as specified under Filament Wrap. Evenly distribute the filament wraps in the inner 80 percent to 90 percent of the coating thickness. The outer 10 percent to 20 percent of elastomer must have no filament reinforcing. Apply the elastomer and filaments in a continuous manner to assure adhesion between the various layers. Design and size the connection of the skin to the end fittings to transmit twice the safe tensile capacity of the chain into the fender skin.

Dimensional Tolerance: -10 percent

2.1.3.1 Elastomer

The elastomer used in the fender skin must be non-marking solvent free 100 percent PTMEG (polytetramethyleneether glycol) polyether urethane elastomer, ultraviolet stabilized with 2.5 percent carbon black or equivalent, with the following unreinforced properties:

a. Shore A. hardness, ASTM D2240, [80 to 95] [_____] to [_____].

b. Tensile strength, ASTM D412, [19.3] [_____] MPa [2800] [_____] psi minimum.

c. Elongation (ultimate), ASTM D412, [300 percent] [_____] minimum.

d. Tear strength, ASTM D470, [1.25] [_____] kg per mm [70] [_____] lbs/inch minimum.

e. Flex life (Ross), ASTM D1052, [200,000] [_____] cycles minimum.

f. Abrasion resistance (NBS), ASTM D1630, [100] [_____] minimum.

2.1.3.2 Filament Wrap

Construct each filament reinforcing wrap of continuous filaments applied in a helical pattern, at a helix angle of 0.79 to 1.05 rad 45 to 60 degrees to the longitudinal axis of the buoy. A wrap must consist of two such filament helixes of equal but opposing helix angles. The spacing between the filaments in the same helix must be no more than 3 mm 1/8 inch, measured in a direction parallel to the longitudinal axis of the fender. Each wrap must extend along the entire longitudinal axis of the fender and also encase the fender end fittings and secure them to the fender body. The reinforcing filaments must be nylon tire cord of 0.00028 kg per m 2540 denier weight with the following properties:

a. Breaking strength, [235] [_____] N [53] [_____] pounds

b. Elongation (ultimate), [18] [_____] percent

2.1.3.3 Color

Fender skin color must be black throughout the entire thickness. Galvanized hardware must be unpainted.

2.1.3.4 Repairability

The fender casing must be repairable in the event of tears or punctures in the elastomer skin. The repaired area must have not less than 90 percent of the properties as specified in paragraph ELASTOMER. Required repair materials must be readily available from the fender manufacturer.

2.1.4 Internal Hardware

The internal chain connecting the two end fittings and the two end fittings must be galvanized in accordance with ASTM A123/A123M or ASTM A153/A153M as appropriate. The chain and end clevis fitting must have a minimum ultimate tensile capacity of [640,000] [_____] N [144,000] [_____] pounds. The internal chain and end clevis fitting must have a minimum ultimate tensile capacity of [578,000] [_____] N [130,000] [_____] pounds. Shackles must be [45] [_____] mm [1 3/4] [_____] inches and have a minimum ultimate tensile capacity of [289,000] [_____] N [65,000] [_____] pounds.

2.1.5 Performance Requirements

Each foam-filled fender must have the following performance characteristics:

SIZE	ENERGY ABSORPTION	REACTION FORCE
	at 60 percent compression	at predicted energy attainment
[_____]mm x [_____]mm [_____]ft x [_____]ft	[_____] kN-m [_____] ft-kips	[_____]kN x [_____] [_____] kips

Design the resilient, foam filled marine fenders so that when compressed across its diameter by two parallel flat plates extending the full length and width of the fender, the fender absorbs [221,500] [_____] foot-pounds of energy plus 15 percent when [60] [_____] percent compressed (i.e. to a dimension of [40] [_____] percent of its original diameter) with a corresponding load of not more than [712,000] [_____] N [160,000] [_____] pounds plus 15 percent. Also design the fender to withstand a sustained reaction force of 667,200 [_____] N [150,000] [_____] pounds for a duration of not less than 24 hours each occurrence for at least 200 occurrences during its 10-year predicted life.

Submit the foam-filled marine fenders rated performance data (RPD) and published performance curves per ASTM F2192 or PIANC 2002.

2.1.6 Test Reports

Perform tests on the specified fender within 5 years of submittal of the reports for approval. Test reports must be accompanied by notarized certificates from the manufacturer certifying that the tested material is of the same type, size, quality, manufacture and make as that proposed to be supplied. Perform the following tests:

2.1.6.1 Fender Cyclic-Compression Test

Compress the fender along its diameter between two parallel flat plate surfaces to a compressed dimension of 40 percent of its original diameter. Repeat the compression and release cyclic loadings for a minimum of 10 full cycles of compression. Permanent deformation, cracking, or tearing of the fender skin, fender core, or end fittings must constitute failure of this test.

2.1.6.2 Fender Sustained-Load Test

Apply a [667,000] [_____] N [150,000] [_____] pound compressive load and hold this load for 24 hours. Record load and deflection each hour. Immediately after release of the load, measure rebound of the fender. Continue to record fender rebound for 24 hours. Failure of the fender or foam core to rebound to 90 percent of its original diameter after 24 hours must constitute failure of this test. If the foam core is not bonded to the skin of the fender, devise and execute a means for measuring rebound of the foam core and for measuring the void between the foam core and the skin. The maximum rate of compression per minute must be 20 percent of the total reaction force at 60 percent compression. The full compression cycle, not including rebound, must take a minimum of 5 minutes.

2.1.6.3 Fender Pull-Through Test

Devise and perform a test which will measure the resistance of the end fittings and internal chain to pull through the longitudinal axis of the fender. Failure of the chain, end fittings, or skin to resist at least

[178,000] [_____] N [40,000] [_____] pounds of pull-through tension must constitute failure of this test. After loading, evidence of permanent deformation, cracking, or tearing of the fender or end fittings must also constitute failure of this test.

2.1.6.4 Skin Thickness Core Test

****

NOTE: The suggested number of fenders that should be tested is as follows:

Fenders Procured	Number to Test
1 - 3	1
4 - 8	2
9 - 20	3
21 and above	4

****

[After fabrication of all of the fenders and prior to fender shipment to the construction site, perform a minimum of [3] [_____] skin thickness tests per fender for each of [1] [2] [3] [4] fenders to be selected at random by the Contracting Officer.]Test locations on the fenders will be selected by the Contracting Officer. Verify testing by an ABS inspector prior to fender shipment. Each test must consist of taking a 6 mm 1/4 inch diameter (minimum) to 13 mm 1/2 inch diameter (maximum) core from the fender skin which can be removed from the skin and examined for thickness of elastomer and placement of reinforcing (when reinforcing is required). Take skin thickness measurements from the core sample and record measurements noting placement of reinforcing. Where the skin thickness measurement is less than the specified minimum, or the minimum required by the design (whichever is greater) by more than 10 percent, reject the fender. In addition, if the average of skin thickness tests for one fender is not equal to or greater than the specified minimum, or the minimum required by the design (whichever is greater), reject the fender. If tested fender is rejected, at the option of the Contracting Officer, the conduct thickness tests for additional fenders. Replace rejected fenders with fenders meeting the provisions of this specification. Test replacement fenders for skin thickness as specified herein. Skin thickness tests will be witnessed by the Contracting Officer. Notify the Contracting Officer 10 working days prior to conducting skin thickness tests. After skin thickness testing, patch core holes with elastomer of the same composition and thickness as the specified elastomer skin. Nylon reinforcing is not required in core hole patches.

2.1.6.5 Foam Core Density Test

During the skin thickness testing the fender must be cored to the center of the fender (up to the internal chain). A hole saw long enough to reach the center of the fender must be used to extract the foam sample. The fender manufacturer must provide the ABS inspector with the appropriate hole saw to perform the test. Test the foam sample at one-foot incremental depths to determine the conformance to the density requirements of this specification. Reject fenders with nonconforming

foam.

After skin thickness and foam core testing, patch core holes with foam of the same density (provided by the fender manufacturer with the delivery of the fenders) and elastomer of the same composition and thickness as the specified elastomer skin. Nylon reinforcing is not required in core hole patches.

Testing must be verified by an ABS inspector prior to fender shipment.

2.1.7 Connecting Hardware

The connecting chain, swivel and shackles must be galvanized in accordance with ASTM A123/A123M or ASTM A153/A153M, as appropriate. The hardware must be as follows:

Item	Type
Chain	ABS 2, Grade 2, Stud Link or Open Link
Shackle	FS RR-C-271, Type IVA, Class 3, Grade A
Swivel	FS RR-C-271, Type VII, Class 2

All connecting bolts and pins must be of mild steel, matching the properties of the shackle bow. For Class 3 shackles, secure the bolt or pins in place with stainless steel (Type 316) cotter pins or locking pins.

PART 3 EXECUTION

3.1 FOAM-FILLED FENDERS

Install fenders as indicated on the drawings and in accordance with the manufacturer's specifications and shop drawings. Tighten bolts an additional 1/3 turn of the nut, from the snug tight condition, and secured with cotter pins.

3.2 WELDING

Perform welding in accordance with AWS D1.1/D1.1M.

3.3 CONNECTIONS

3.3.1 Antiseize Compound

Coat threads of bolts prior to applying washers and nuts. Recoat bolt thread projection beyond nut after tightening.

-- End of Section --