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USACE / NAVFAC / AFCEC / NASA	**UFGS-35 59 13.16 (May 2011)** **Change 1 - 08/12**
Preparing Activity: NAVFAC	**Superseding** **UFGS-35 59 13.16 (August 2008)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021

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SECTION 35 59 13.16

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05/11, CHG 1: 08/12

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-- End of Section Table of Contents --

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SECTION 35 59 13.16

MARINE FENDERS
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****
NOTE: This guide specification covers the requirements for marine fenders. This specification includes four different fender types. Each type is typically used for a different application. The author should choose the applicable fender types for the project. The subpart titles indicate the applicable fender type. The author should delete any subpart not applicable to the project.

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.

****

PART 1 GENERAL

1.1 REFERENCES

****

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. Do not use the Reference Wizard's Check Reference feature to update the issue dates, as this document is specific to the standards listed. This guide specification will be updated when the standards are updated.

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.

****

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) Structural Welding Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel

ASTM A123/A123M	(2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153/A153M	(2016a) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A307	(2014; E 2017) Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
ASTM A479/A479M	(2020) Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
ASTM A563	(2015) Standard Specification for Carbon and Alloy Steel Nuts
ASTM B695	(2004; R 2016) Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
ASTM D256	(2010; R 2018) Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
ASTM D412	(2016) Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
ASTM D470	(2013) Crosslinked Insulations and Jackets for Wire and Cable
ASTM D624	(2000; R 2020) Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
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	(2017) Standard Specification for Flexible Cellular Materials - Poly (Vinyl Chloride) Foam (Closed-Cell)
ASTM D1894	(2014) Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting
ASTM D2000	(2018) Standard Classification System for Rubber Products in Automotive Applications
ASTM D2240	(2015; E 2017) Standard Test Method for Rubber Property - Durometer Hardness

ASTM D3575	(2020) Flexible Cellular Materials Made From Olefin Polymers
ASTM F593	(2017) Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
ASTM F594	(2009; R 2020) Standard Specification for Stainless Steel Nuts
ASTM F844	(2007a; R 2013) Washers, Steel, Plain (Flat), Unhardened for General Use
ASTM F2192	(2005; R 2017) Standard Test Method for Determining and Reporting the Berthing Energy and Reaction of Marine Feeders

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 34-1	(2015) Rubber, Vulcanized rr Thermoplastic -- Determination of Tear Strength -- Part 1: Trouser, Angle and Crescent Test Pieces
ISO 37	(2017) Rubber, Vulcanized or Thermoplastic -- Determination of Tensile Stress-Strain Properties
ISO 815-1	(2019) Rubber, Vulcanized or Thermoplastic -- Determination of Compression Set -- Part 1: At Ambient or Elevated Temperatures
ISO 17357-1	(2014) Ships and Marine Technology - Floating Pneumatic Rubber Fenders - Part 1: High Pressure

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-PRF-907	(2020; Rev H) Antiseize Thread Compound, High Temperature

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS RR-C-271	(Rev G) Chains and Attachments, Carbon And Alloy Steel

1.2 SYSTEM DESCRIPTION

1.2.1 Extruded Fenders

****

NOTE: Extruded fender systems typically absorb a minimum amount of energy. Therefore, they are typically used at the wale elevation of fender pile systems. They have also been used as festoon fenders, rub strips and as an energy absorbing element in a separator.

****

Extruded fenders are elements typically manufactured in a long length by

an extrusion process. After manufacture, the elements are cut to length. These fender elements are typically used as fenders for small craft, rub strips on marine structures,and energy absorbing elements at the wale. Examples of extruded fender shapes are 'Side Mounted Hollow Bore', 'Cylindrical', 'D', 'Square', 'W' and 'Wing'.

1.2.2 Molded Fenders

****

NOTE: Molded fenders are typically mounted to the vertical face of a marine structure. These systems are used to berth ships of similar size and hull curvature. Therefore, they are usually found in commercial ports.

****

Molded fenders are elements manufactured by the molded process. They typically have embedded metal plates cast into the molds. The fender elements are typically used as fenders for medium to large, flat sided vessels. The elements can be used as stand-alone fenders, combined with multiple fenders and a face panel, and energy absorbing elements at the wale. They include the shear fenders which absorb energy by deflecting parallel to the attachment plane. Examples of molded fender shapes are 'Arch Fender', 'Circle', 'Circular Dock', 'Fender Bars', 'Hexagonal', and the 'buckling fender' types, such as 'MV', 'V Leg' and 'V Section'.

1.2.3 Foam-Filled Fenders

****

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.

****

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.

1.2.4 Pneumatic and Hydro-pneumatic Fenders

****

NOTE: Pneumatic fenders are inflated with air and float on the surface of the water to serve as a protective buffer for ships. Hydro-pneumatic fenders are similar, but contain water in addition to the pressurized air, with a counterweight at one end so the fender is partially submerged and are specifically designed for the berthing of submarines.

****

Pneumatic and hydro-pneumatic fenders are constructed of an inner rubber layer, reinforcing cord layers and an outer rubber layer that form a synthetic-cord-rubber sheet, which forms a cylindrical air-bag with hemispherical heads at each end,which can be inflated with air. These fenders can be used as stand-alone fenders, fendering between ships, or between a ship and a berthing structure. In hydro-pneumatic fenders, the upper hemispherical head has a top plate that allows internal placement of water and air into the bag, and the lower hemispherical head has a bottom plate that provides a connection location for the counterweight. The air-bag typically has a long cylindrical shape and is counter-weighted to float vertically. Hydro-pneumatic fenders are typically used as fenders for submarines, acting as buffers between submarines and berthing structures and as separators between submarines. Hydro-pneumatic fenders can be used in combination with foam-filled fenders or pneumatic fenders to support both ships and submarines at the same berth, if designed appropriately.

1.3 SUBMITTALS

****

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.

****

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-02 Shop Drawings

Panels; G[, [_____]]

SD-03 Product Data

Stainless Steel Hardware; G[, [_____]]

Galvanized Steel Hardware; G[, [_____]]

Include Manufacturer's product data for all fender hardware, including bolts, anchor bolts, inserts, nuts, washers, chains, turnbuckles, dimensions, material specifications, working loads and ultimate loads, as applicable. For anchor bolts and inserts, include methods and materials for installation.

Restraint Chains; G[, [_____]]

Facing; G[, [_____]]

EXTRUDED FENDERS, MOLDED FENDERS

Extruded fender; G[, [_____]]

Molded fender; G[, [_____]]

Include dimensions, material specifications, and method of manufacture.

FOAM-FILLED FENDERS

Resilient, foam-filled marine fenders; G[, [_____]]

Prior to fabrication, copies of the manufacturer's catalog data including reaction, energy and percent compression curves, dimensions material specifications, and method of manufacture shall be submitted for approval. Include dimensions, material specifications, and method of manufacture.

PNEUMATIC AND HYDRO-PNEUMATIC FENDERS

Resilient, pneumatic fenders; G[, [_____]]

Resilient, hydro-pneumatic fenders; G[, [_____]]

Prior to fabrication, copies of the manufacturer's catalog data, performance curves per ISO 17357-1, dimensions, material specifications, and method of manufacture shall be submitted for approval.

SD-05 Design Data

****

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 center of the footprint of the fender element against the panel.
2. Vertical line contact applied at the vertical center of the footprint of the fender element against the panel.
3. 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 fist. Concrete embedments shall have a breaking load at least 1.25 times the breaking load of the weakest component attached to

them.

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, pneumatic and hydro-pneumatic 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.

****

EXTRUDED FENDERS, MOLDED FENDERS

Design data for rubber fenders; G[, [_____]]

Submit rated performance data (RPD) and published performance curves per ASTM F2192.

FOAM-FILLED FENDERS

Design data for foam filled marine fenders; G[, [_____]]

Submit rated performance data (RPD) and published performance curves per ASTM F2192.

PNEUMATIC AND HYDRO-PNEUMATIC FENDERS

Design data for pneumatic fenders; G[, [_____]]

Design data for hydro-pneumatic fenders; G[, [_____]]

Submit rated performance data (RPD) and published performance curves per ISO 17357-1.

SD-06 Test Reports

EXTRUDED FENDERS, MOLDED FENDERS

Ozone Resistance; G[, [_____]]

Low Temperature Impact Resistance; G[, [_____]]

Water Absorption; G[, [_____]]

Heat Resistance; G[, [_____]]

Tests shall have been performed on the specified fender within 5 years of submittal of the reports for approval. Test reports shall be accompanied by notarized certificates from the manufacturer certifying that the tested material is of the same type, quality, manufacture and make as that proposed to be supplied.

FOAM-FILLED FENDERS

Fender cyclic-compression test; G[, [_____]]

Fender sustained-load test; G[, [_____]]

Fender pull-through test; G[, [_____]]

Skin thickness core test; G[, [_____]]

Submit copies of reports of tests specified herein. The tests shall have been performed within three years of submittal of the reports for approval. Also, submit reports for tests specified in referenced documents which are applicable to the particular material furnished for use.

PNEUMATIC AND HYDRO-PNEUMATIC FENDERS

Prototype fender performance confirmation; G[, [_____]]

****

NOTE: Prototype fender performance confirmation includes the following tests: (1) performance; 2) angular compression; (3) durability; (4) compression recovery; and (5) puncture resistance.

****

Material test of rubber; G[, [_____]]

Dimensional inspection; G[, [_____]]

Air-leakage test; G[, [_____]]

Hydrostatic-pressure test; G[, [_____]]

Pressure Relief Valve Test

Design Proof; G[, [_____]]

Submit copies of reports of tests specified herein. Also, submit reports for tests specified in referenced documents which are applicable to the particular material furnished for use.

SD-07 Certificates

Stainless Steel Hardware; G[, [_____]]

Galvanized Steel Hardware; G[, [_____]]

Submit certificates of compliance certifying that materials meet the requirements specified herein. In addition, when the coating is shop applied, submit certificates of conformance or compliance certifying that surface preparation, coverage, and thickness meet the requirements specified.

Pneumatic fenders; G[, [_____]]

Submit certificates of compliance certifying that materials meet the requirements specified herein.

Hydro-pneumatic fenders; G[, [_____]]

Submit certificates of compliance certifying that materials meet the requirements specified herein.

SD-08 Manufacturer's Instructions

Installation Instructions

Provide installation instructions for each fender type.

SD-10 Operation and Maintenance Data

Fender Manual

Provide fender manual for each fender type.

1.4 DELIVERY, HANDLING AND STORAGE

Fenders shall be undamaged when delivered and shall 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. Any rejected materials shall be replaced with suitable materials, at no additional cost to the Government.

1.4.2 Fender Marking

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

a. full or abbreviated manufacturer name,

b. fender size model or part number designation,

c. fender serial number,

d. ASTM designation (including type, grade and class) or ISO number and year, as applicable,

e. initial or rated internal pressure (pneumatic and hydro-pneumatic fenders only,

f. rated performance (energy and reaction), and

g. type of reinforcement layer (pneumatic and hydro-pneumatic fenders only,) and

h. 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 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 shall 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 Extruded Fenders, Molded Fenders

Fender elements shall be molded of rubber, homogeneous and free from any defects, impurities, pores or cracks. Where internal plates are used, the rubber shall be bonded to integral steel mounting plates. The plates shall be fully encased in rubber to a minimum thickness of 1.6 mm 1/16 inch.

1.5.2 Elastomer Skin

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

1.5.3 Foam Core

The foam core shall be homogeneous and of one piece fabricated construction and shall not be in chip or granular form. The foam core shall 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. Homogeneous foam rings of adequate thickness to insure performance of the fender are acceptable provided the Contractor can show a minimum 5-year performance of similar fenders.

1.5.4 Steel Fabrication

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

1.5.5 Welding

AWS D1.1/D1.1M. Welds shall be of sufficient size and shape to develop

the full strength of the parts connected by the welds. Welds shall 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, PNEUMATIC AND HYDRO-PNEUMATIC FENDERS - WARRANTY

****

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://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_forbusinesse
The paragraphs in this guide specification may be used without further approval.

****

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

PART 2 PRODUCTS

2.1 EXTRUDED AND MOLDED FENDERS

2.1.1 Configuration

2.1.1.1 Extruded Fender

Fenders shall be extruded and continuous in the length indicated. The fenders shall be black in color. The fenders shall have a truncated "A" cross section shape and be attached to the structure at the base, the widest dimension, of the arch. The connecting hardware shall be fully exposed. No encased hardware or molded fenders shall be allowed. The fender and hardware shall be designed and factory tested to the loads per linear meter foot of fender specified in paragraph entitled "Performance," for angles of approach of 0 and 0.26 rad 0 and 15 degrees. Fender anchor bolts and method of anchorage shall be of the size and spacing required by the manufacturer's design and testing; however, the size and spacing of anchor bolts indicated on the drawings shall be construed to be the minimum required, unless exceeded by the requirements of the fender manufacturer's design.

2.1.1.2 Molded Fender

Fenders shall be molded and continuous in the length indicated. The fenders shall be black in color. Each fender shall be molded of rubber, homogeneous and free from any defects, impurities, pores or cracks, and bonded to integral, steel mounting plates. The mounting plates shall be fully encased in rubber with a minimum thickness of 1.6 mm 1/16 inch. The fender and hardware shall designed for and be factory tested to the loads specified. Fender anchor bolts and method of anchorage shall be of the size and spacing dimensions required by the manufacturer's design and testing; however, the size and spacing of anchor bolts indicated on the drawings shall be construed to be the minimum required, unless exceeded by the requirements of the fender manufacturer's design.

2.1.2 Elastomer

The elastomer shall be the ethylene propylene dimonomer (EPDM), as specified in ASTM D2000, with the following line callout:

****

NOTE: Coordinate values with calculated design requirements. The 3BA 720 compound is the typical compound. The 3BA 620 compound has approximately 70 percent of the energy capacity and a reduced reaction. Other compounds may be available.

****

a. 3BA 720 A_{14} B_{13} C_{12} EA_{14} $F1_7$
[b. 3BA 620 A_{14} B_{13} C_{12} EA_{14} $F1_7$]

Tests shall include Ozone Resistance, Low Temperature Impact Resistance, Water Absorption, Heat Resistance.

2.1.3 Performance Requirements

****

NOTE: This performance criteria should be tailored for extruded and molded shapes. Coordinate values with calculated design requirements.

****

Each of the rubber fenders shall have the following performance characteristics:

SIZE	ENERGY ABSORPTION	REACTION FORCE
	at 48 percent compression	at predicted energy attainment
[[_____] kN-m] [[_____]' x [_____]']	[[_____] kN] [[_____] ft-kips]	[[_____] m x [_____]] [[_____] kips]

When vertically compressed by a plate extending the full length and width of a 300 mm one foot section of the fender, the fender shall absorb[_____] [_____] newton-meters [_____] foot-pounds of energy plus10 percent when [48] [_____] percent compressed (i.e., to a dimension of [52] [_____] percent of its original height) with a corresponding load of not more than [_____] [_____] N [_____] [_____] pounds plus10 percent.

2.1.4 Break-In Deflection

Break-in deflection is required for buckling type fenders with reaction ratings of 100 tonnes or more, or if the energy-absorbing material has a reaction decrease of more than 10 percent between its original deflection and and its fifth deflection. Break-in deflection shall be to at least the manufacturer's rated deflection. The number of break-in cycles shall be sufficient to assure each elements first on-dock reaction will not exceed it fully broken-in reaction by more than 5 percent.

2.1.5 Stainless Steel Hardware

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NOTE: It is recommended that all concrete inserts be of stainless steel materials.
****

2.1.5.1 Plates and Angles

ASTM A479/A479M, Type 316L stainless steel for plates, angles, and miscellaneous hardware required to attach the fenders to the structure.

2.1.5.2 Bolts, Nuts, and Washers

ASTM F593 or ASTM F594, Group 2 (316 alloy) stainless steel for nuts and bolts. ASTM F844 for washers, except fabricate washers of 316 alloy stainless steel.

2.1.5.3 Antiseize Compound

MIL-PRF-907.

2.1.6 Galvanized Steel Hardware

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NOTE: Galvanized steel hardware may be used at locations where the hardware can be easily replaced.
****

All hardware shall be hot-dip galvanized in accordance with ASTM A123/A123M, ASTM A153/A153M or ASTM B695, as applicable.

2.1.6.1 Plates

ASTM A36/A36M.

2.1.6.2 Bolts, Nuts and Washers

Bolts shall be ASTM A307. Nuts shall be ASTM A563, grade A heavy hex. Washers shall be ASTM F844 of carbon steel.

2.1.7 Restraint Chains and Shackles

Chain and shackles shall meet the requirements of FS RR-C-271. The chain assembly shall have a design safety factor of 3:1 based on minimum breaking strength.

2.1.8 Panels

Panel design shall be of closed box construction for optimum strength and corrosion resistance. Material thickness shall be 9.5 mm 3/8 inch minimum when one side is exposed and 12.7 mm 1/2 inch minimum when both sides are exposed.

2.1.8.1 Facing

Facing on the panels shall be UHMWPE (ultra high molecular weight polyethylene), ultraviolet stabilized with 2.5 percent carbon black or equivalent, minimum 12.7 mm 1/2 inch wear thickness, with a 0.20 maximum coefficient of friction per ASTM D1894. The UHMWPE shall exhibit no failure when tested per ASTM D256, Method B. The facing connections shall be configured to account for the thermal properties of the polyethylene.

2.2 FOAM-FILLED FENDERS

2.2.1 Configuration

Fenders shall have cylindrical mid-bodies with conical or hemispherical shaped ends terminating in an end fitting on the cylinder's centerline at each end. If conical ends are provided, they shall have an angle of 60 to 75 degrees, when measured from the central axis of the fender. The fittings at either end shall be connected through the center of the fender by a chain, shall terminate in a clevis fitting sized for the indicated shackle and shall 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. End fitting shall be sized so as not to contact loading surfaces when the fender is compressed to 30 percent of its original diameter (70 percent compression). Fill interior of the fender with energy absorbing closed-cell foam as specified. The use of chipped or particulate foam is not acceptable.

2.2.2 Foam Core

The energy absorbing foam core shall 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 *

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

2.2.3 Fender Skin

The outer fender skin shall be minimum [32] [_____] mm [1.25] [_____] inches thick and constructed of elastomer as specified. Filament reinforcing is required. [Twelve] [_____] separate filament reinforcing wraps shall be applied as specified under Filament Wrap. The filament wraps shall be evenly distributed in the inner 80 percent to 90 percent of the coating thickness. The outer 10 percent to 20 percent of elastomer shall have no filament reinforcing. The elastomer and filaments shall be applied in a continuous manner to assure adhesion between the various layers. The connection of the skin to the end fittings shall be designed and sized to transmit twice the safe tensile capacity of the chain into

the fender skin.

2.2.3.1 Elastomer

The elastomer used in the fender skin shall be 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.

2.2.3.2 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 shall consist of two such filament helixes of equal but opposing helix angles. The spacing between the filaments in the same helix shall be no more than 3 mm 1/8 inch, measured in a direction parallel to the longitudinal axis of the fender. Each wrap shall extend along the entire longitudinal axis of the fender and shall also encase the fender end fittings and secure them to the fender body. The reinforcing filaments shall 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

2.2.3.3 Color

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

2.2.3.4 Repairability

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

2.2.4 Internal Hardware

The internal chain connecting the two end fittings and the two end fittings shall be galvanized in accordance with ASTM A123/A123M or ASTM A153/A153M as appropriate. The chain and end clevis fitting shall have a minimum ultimate tensile capacity of [640,000] [_____] N [144,000]

[_____] pounds. The internal chain and end clevis fitting shall have a minimum ultimate tensile capacity of [578,000] [_____] N [130,000] [_____] pounds. Shackles shall be [45] [_____] mm [1 3/4] [_____] inches and shall have a minimum ultimate tensile capacity of [289,000] [_____] N [65,000][_____] pounds.

2.2.5 Performance Requirements

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

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

The resilient, foam filled marine fenders shall be designed so that when compressed across its diameter by two parallel flat plates extending the full length and width of the fender, the fender shall absorb [300,265] [_____] newton-meters [221,500] [_____] foot-pounds of energy plus15 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 plus15 percent. The fender shall also be designed 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.

2.2.6 Source Quality Control

2.2.6.1 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 shall constitute failure of this test.

2.2.6.2 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 shall 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 shall be 20 percent of the total reaction force at 60 percent compression. The full compression cycle, not including rebound, shall take a minimum of 5 minutes.

2.2.6.3 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 shall constitute failure of this test. After loading, evidence of permanent deformation, cracking, or tearing of the fender or end fittings shall also constitute failure of this test.

2.2.6.4 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 delivery of all of the fenders to the construction site and before fender installation, 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.] [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. Each test shall 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 Contractor's 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 Contractor's design (whichever is greater), reject the fender. If tested fender is rejected, at the option of the Contracting Officer, the Contractor shall then 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. The Contractor shall 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.

2.2.7 Connecting Hardware

The connecting chain, swivel and shackles shall be galvanized in accordance with ASTM A123/A123M or ASTM A153/A153M, as appropriate. The hardware shall 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 shall be of mild steel, matching the properties of the shackle bow. For Class 3 shackles, the bolt or pins shall be secured in place with stainless steel (Type 316) cotter pins or locking pins.

2.3 PNEUMATIC AND HYDRO-PNEUMATIC FENDERS

2.3.1 Configuration

Fenders shall be manufactured in accordance with ISO 17357-1. Fenders shall have cylindrical mid-bodies with hemispherical shaped ends terminating in an end fitting on the cylinder's centerline at each end. The flange opening fittings shall be sized (not to exceed 12 percent of fender diameter) so as not to contact loading surfaces when the fender is compressed to 20 percent of its original diameter (80 percent compression). Pneumatic and Hydro-Pneumatic fenders shall incorporate a safety valve for fenders 2500mm 8 feet diameter or larger and pressure monitoring system in their manufacture.

2.3.2 Dimensions

Diameter and length as indicated.

2.3.3 Fender Skin

The fender skin shall have a minimum strength in accordance with ISO 17357-1. When designing the skin thickness, the Manufacturer shall consider skin strength and the stress induced by the internal operating and berthing pressure, and the abrasion and impact loads caused by handling and berthing operations. The Manufacturer shall ensure an adequate margin of safety is incorporated for the fender's intended use. The connection of the skin to the end fittings shall be designed to resist the specified minimum endurable pressure at 60 percent compression in ISO 17357-1 for the respective operating pressure. For hydro-pneumatic fenders, the Minimum Endurable Pressure value in Table 5 of ISO 17357-1 (Pneumatic 80 fender pressure requirements) should be used.

2.3.3.1 Elastomer

The elastomer shall meet the requirements of ISO 17357-1, material test of rubber.

****

NOTE: After aging refers to air oven aging at 70

degrees C 158 degrees F plus/minus 1 degree C 33.8 degrees F, 96 hours.
****

Per ISO 17357-1, the elastomer used in the outer skin shall be rubber, with the following unreinforced properties:

a. Durometer Hardness, Shore A	
(ASTM D2240 or ISO 37)	
Before Aging	[50 to 70] [_____]
After Aging	Not to exceed the original property by more than 8

b. Minimum Tensile strength	
(ASTM D412 or ISO 37)	
Before Aging	[18] MPa [2600] psi [_____]
After Aging	Not less than 80 percent of original property

c. Minimum Elongation (ultimate)	
(ASTM D412 or ISO 37)	
Before Aging	[400 percent] [_____]
After Aging	Not less than 80 percent of original property

d. Minimum Tear strength	[400] [_____] N per cm [228 lbs/inch] [_____]
(ASTM D624 or ISO 34-1)	

e. Compression set	30 percent(70 degrees C 158 degrees F plus/minus 1 degree C 33.8 degrees F, 22 hours) or less
(ISO 815-1)	

f. Static ozone aging test	No cracks after elongation by 20 percent and exposure to 50 pphm (parts of ozone per hundred million of air by volume) at 40 degrees C 104 degrees F for 96 hours

The elastomer used in the inner skin shall be rubber, with the following unreinforced properties:

1. Durometer Hardness, Shore A	
(ASTM D2240 or ISO 37)	
Before Aging	[40 to 60] [_____]
After Aging	Not to exceed the original property by more than 8

2. Minimum Tensile strength	
(ASTM D412 or ISO 37)	
Before Aging	[10] MPa [1450] psi [_____]
After Aging	Not less than 80 percent of original property

3. Minimum Elongation (ultimate)	
(ASTM D412 or ISO 37)	
Before Aging	[400 percent] [_____]
After Aging	Not less than 80 percent of original property

2.3.3.2 Color

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

2.3.3.3 Repairability

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

2.3.4 Performance Requirements

The performance of each fender shall be meet the requirements of ISO 17357-1. The performance of the fender shall be confirmed with a prototype fender performance confirmation per ISO 17357-1. The tests shall include a parallel performance, angular compression, durability, compression-recovery and puncture-resistance.

2.3.4.1 Design Proof

Design proof shall document minimum endurable pressure based on at least 30 test samples that cover entire range of compression from 0 percent to 60 percent deflection

2.3.4.2 Pneumatic Fenders

****

NOTE: Refer to ISO 17357-1 for guaranteed energy absorption and reaction force values for nominal size of fender under consideration.
****

Each pneumatic fender shall have the following performance characteristics:

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

2.3.4.3 Hydro-pneumatic Fenders

****
NOTE: The performance of the hydro-pneumatic fenders vary according to the size, water/air ratio and internal pressure. The Manufacturer should be consulted in the selection of the desired performance characteristics.
****

****
NOTE: Refer to ISO 17357-1 for guaranteed energy absorption and reaction force values for nominal size of fender under consideration.
****

Each hydro-pneumatic fender shall have the following performance characteristics:

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

2.3.5 Source Quality Control

2.3.5.1 Dimensional Inspection

The dimensions of all fenders shall be inspected. They shall meet the requirements of ISO 17357-1.

****
NOTE: The dimensional tolerances per ISO 17357-18 are as follows:
- length: plus 10 percent, minus 5 percent
- diameter: plus 10 percent, minus 5 percent

The diameter shall be obtained from the average of at least two different measurements taken at the middle of the cylindrical section of the fender.
****

2.3.5.2 Air-leakage Test

Air leakage tests shall be performed per ISO 17357-1. The test shall confirm that there is no air leakage when the initial pressure is held for more than 30 minutes.

2.3.5.3 Hydrostatic-pressure Test

Each pneumatic and hydro-pneumatic fender shall be hydrostatic-pressure tested for its rated operating pressure (internal pressure at 0 percent deflection). Testing shall be in accordance with ISO 17357-1.

2.3.5.4 Pressure Relief Valve Test

The pressure relief valve shall be mounted to a test chamber for a pressure relief test. After mounting, the chamber internal pressure shall be slowly increased until the specified relief pressure is attained. The pressure relief valve shall be set to relieve pressure according to the manufacturers recommendations. If the pressure relief valve opens at a higher or lower pressure than allowed, it shall be adjusted as required and tested again until within the specified limits. A written test procedure and records pertaining to this test shall be maintained.

2.3.6 Connecting Hardware

The connecting chain, swivel and shackles have same requirements as those specified for foam filled fenders.

2.3.6.1 Hydro-pneumatic Guy Chain

Guy chains shall be provided for attachment from the upper fender end fitting assembly to the pier. That portion of the chain extending from the fender itself shall be covered with protective rubber sleeves to a point beyond which the fender will be contacted for fender body protection. Size and lengths shall be as indicated on the Drawings.

2.3.6.2 Hydro-pneumatic Hanging Chain

Hanging chains shall be provided for attachment from the counterweight to the pier. Size and lengths shall be as indicated on the Drawings.

2.3.6.3 Hydro-pneumatic Lower End Fitting Assembly

The lower end fitting shall be fabricated of steel and shall provide connecting points for the connecting chain and the hanging chain.

2.3.6.4 Hydro-pneumatic Upper End Fitting Assembly

The upper end fitting shall be fabricated of steel and shall be designed to house all necessary valves and fitting necessary to charge and discharge the fender body with air and water necessary for proper installation and operation of the deployed fender. This shall include the air charging assembly, the water charging assembly, the pressure safety

relief valve assembly and lifting eyes adequately sized for guy chain attachment. All valves and related hardware shall be attached to the inner assembly plate. An outer assembly blind flange plate shall be included to provide protection during handling and operations. The pressure relief valve shall be bronze, shall be adjustable to ensure maintenance of the proper setting, and shall be capable of adequate flow (volume of air released per second) to maintain a safe internal pressure.

2.3.6.5 Hydro-pneumatic Counterweight

A steel counterweight shall be provided for attachment to the fender's lower flange assembly by two shackles. It shall include an upper eye for shackle attachment of the hanging chain and shall be coated with a marine coating system. The counterweight shall be sized per the Manufacturer's recommendation.

PART 3 EXECUTION

3.1 EXTRUDED FENDERS AND MOLDED FENDERS

Install the fenders in the position and at the spacing indicated on the drawings. Tighten the bolts per the manufacturers requirements.

3.2 FOAM-FILLED FENDERS

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

3.3 PNEUMATIC AND HYDRO-PNEUMATIC FENDERS

The fendering system shall be installed in accordance with the Drawings, manufacturer's specifications and shop drawings. Bolts shall be tightened an additional 1/3 turn of the nut, from the snug tight condition, and secured with cotter pins or screw lock.

3.4 WELDING

Welding shall be performed in accordance with AWS D1.1/D1.1M.

3.5 CONNECTIONS

3.5.1 Antiseize Compound

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

-- End of Section --