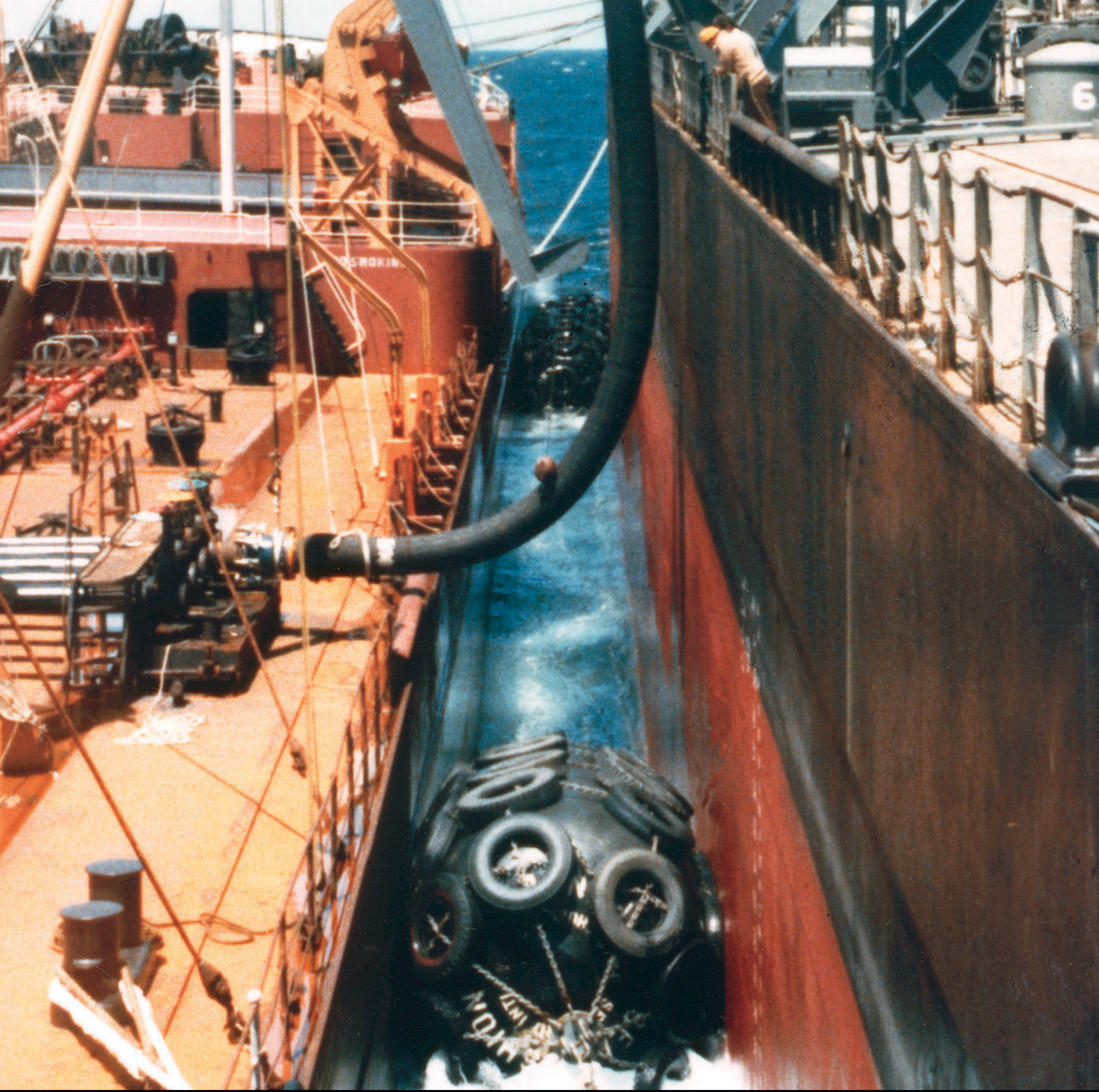

FENDER TECHNOLOGY ASSESSMENT STUDY

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by

Seaward International, Inc.
3470 Martinsburg Pike
Clearbrook, Virginia 22624
(540) 667-5191

Worldwide Leader in
Elastomer & Plastics Technology

for

JJMA, Inc.
4300 King Street, Suite 400
Alexandria, Virginia 22202
(703) 418-0100

FINAL REPORT
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Performed Under Office of Naval Research BAA 01-023
"Skin-to-Skin Connected Replenishment"

Fender Technology Assessment Study

Introduction

This study was performed by Seaward International, Inc., under a subcontract from John J. McMullen Associates, Inc. (JJMA), under Office of Naval Research BAA 01-023 “Skin-to-Skin Connected Replenishment”.

The purpose of the study was to review the current fendering technology for ship-to-ship cargo transfers. The study involved a review of information available in catalogs and other publicly available data. This report presents a summary of the sizes, characteristics, and costs of all known large fenders on the market. Additionally, we have provided estimates of the practical size limits of current fender technology, and described further research recommended to extend the current fender size/performance practical limits.

The study focuses on foam-filled fenders and pneumatic fenders, which are the only types currently used in ship-to-ship cargo transfer operations.

General Features of Fenders

Construction: Foam-filled fenders for lightering operations are typically constructed with a solid foam body, which is completely enclosed with a resilient elastomer skin of sufficient thickness to withstand the rigors of fendering. The body is enclosed in a chain and tire net, with the chain intersections protected by truck or aircraft tires. The horizontal chains are attached to end fittings, to which the attachment lines are connected. The chains are the strength members, which are sufficiently large to resist the shear and towing loads on the fenders. Figure 1 shows a typical fender configuration.

Large pneumatic fenders utilize similar designs for the net. In a pneumatic fender, the fender skin is a pressure boundary and must be carefully bonded to the end fittings, which contain the fill ports and safety valves. Typically, only the larger pneumatic fenders (2.5 m diameter and greater) have safety valves.

Other types of foam-filled fenders and pneumatic fenders are built without nets, but these have more application as secondary fenders, or for ship-to-dock applications. The large, low-pressure fender manufactured by Dunlop does not have a net around it, and is not normally used for commercial lightering operations because of its light duty service factor (Figure 2). This type of fender has been used by the U. S. Navy for mooring alongside casualty vessels in calm to moderate seas. Other fenders have been made with rigid pipes through the axis, but these not recommended because of the possibility of a fender getting turned between the ships and causing a hull puncture.

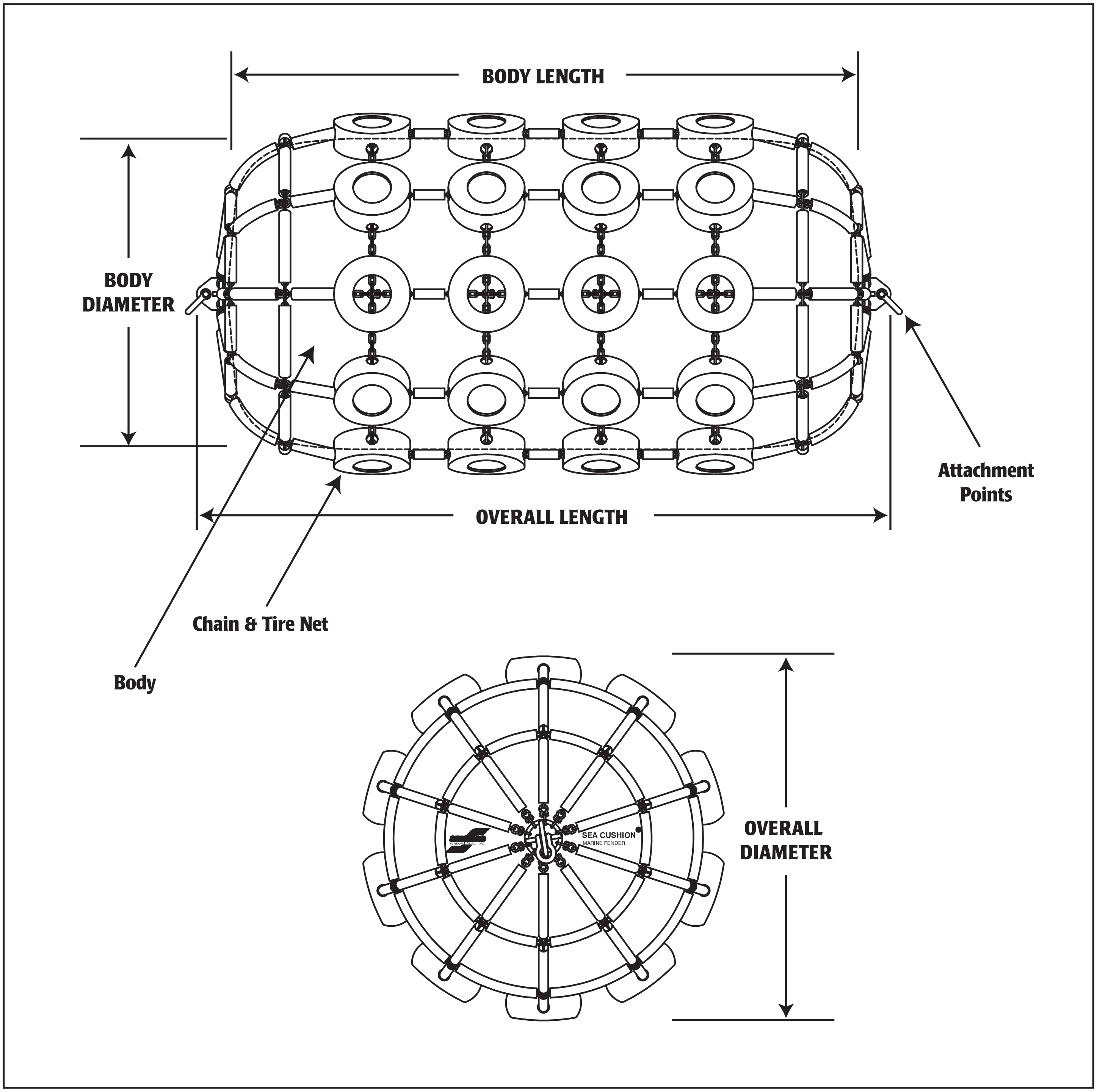
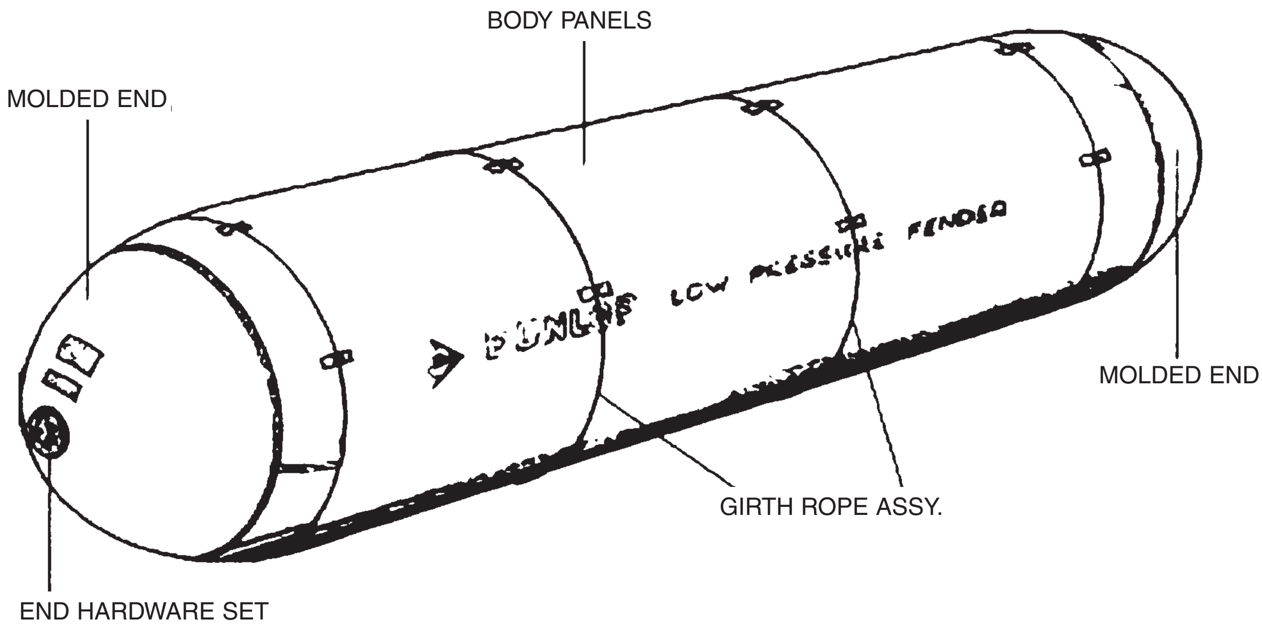


Figure 1 - Typical fender configuration



MOLDED END LOW PRESSURE FENDER

Figure 2 - Typical low-pressure pneumatic fender

Rated compression: Fenders develop their rated energy when compressed perpendicular to their axis by approximately 55 % to 60 % of their original diameter. Performance at other degrees of compression are usually provided by performance curves showing energy absorption and reaction force as a function of compression. Examples of fender performance curves for the same size foam-filled and pneumatic fenders (3300 mm diameter by 6500 mm long) are shown in Figure 3.

Angular compression: The amount of energy absorption changes with the vertical (or horizontal) compression angle. The new value can be estimated from tables provided by the manufacturers based on a particular reference point on the fender. For foam-filled fenders manufactured by Seaward International, Inc., the reference point for a horizontal compression angle is at the shoulder on the most compressed end. Therefore, energy absorption will be less with horizontal angular compression because all compression is less than the 60% at the reference point. For vertical angular compression, the reference point is at the centerline of the fender, such that the upper half of the fender will have compression greater than 60%, while the lower half will have compression less than 60%. Therefore, energy absorption will be greater with vertical angular compression if the compression at the centerline is 60%. Correction factors to be applied to the maximum rated energy absorption capacity for typical Seaward foam-filled fenders are shown in Figure 4.

With pneumatic fenders, the energy absorption is a function of the volume reduction within the fender body, as determined by the ideal gas law relationship, $PV^k = C$. In this equation, P is the absolute pressure, V is the volume, C is a constant, and k is the ratio of specific heats (k for air at normal operating conditions is approximately 1.40). The relationship of energy absorption to vertical and horizontal angles of compression is similar to that of foam-filled fenders.

Reaction pressure: On both foam-filled and pneumatic fenders, the reaction pressure increases as the compression increases. With a pneumatic fender, the reaction pressure on the ship is constant over the contact (footprint) area, and is the same as the pressure existing inside the fender. The reaction pressure for a 0.5-kg/cm^2 (49 kPa), or 7-psi, (initial pressure) pneumatic fender at the rated compression of 60% ranges from 121 kPa to 157 kPa (17.5 psi to 22.8 psi), depending on the size. For a foam-filled fender, the reaction pressure varies over the footprint, and is highest where the maximum degree of compression exists. The average reaction pressure of foam-filled fenders (standard foam) is approximately 172 kPa (25 psi) at the rated compression of 60%.

Over-compression capacity: Foam-filled fenders can be compressed 70% or more with significantly greater energy absorption than the rated energy (at 60% compression). In this case there is an increased risk of damage to the fender. However, even with some skin damage the fender will continue to absorb energy because the closed-cell resilient foam on the inside is absorbing the energy. Pneumatic fenders can also be over-compressed to a certain extent, but the relief valve prevents excessive overpressure. However, the loss of air that occurs after the relief valve discharges will reduce the energy absorption capacity (at a given deflection) for subsequent

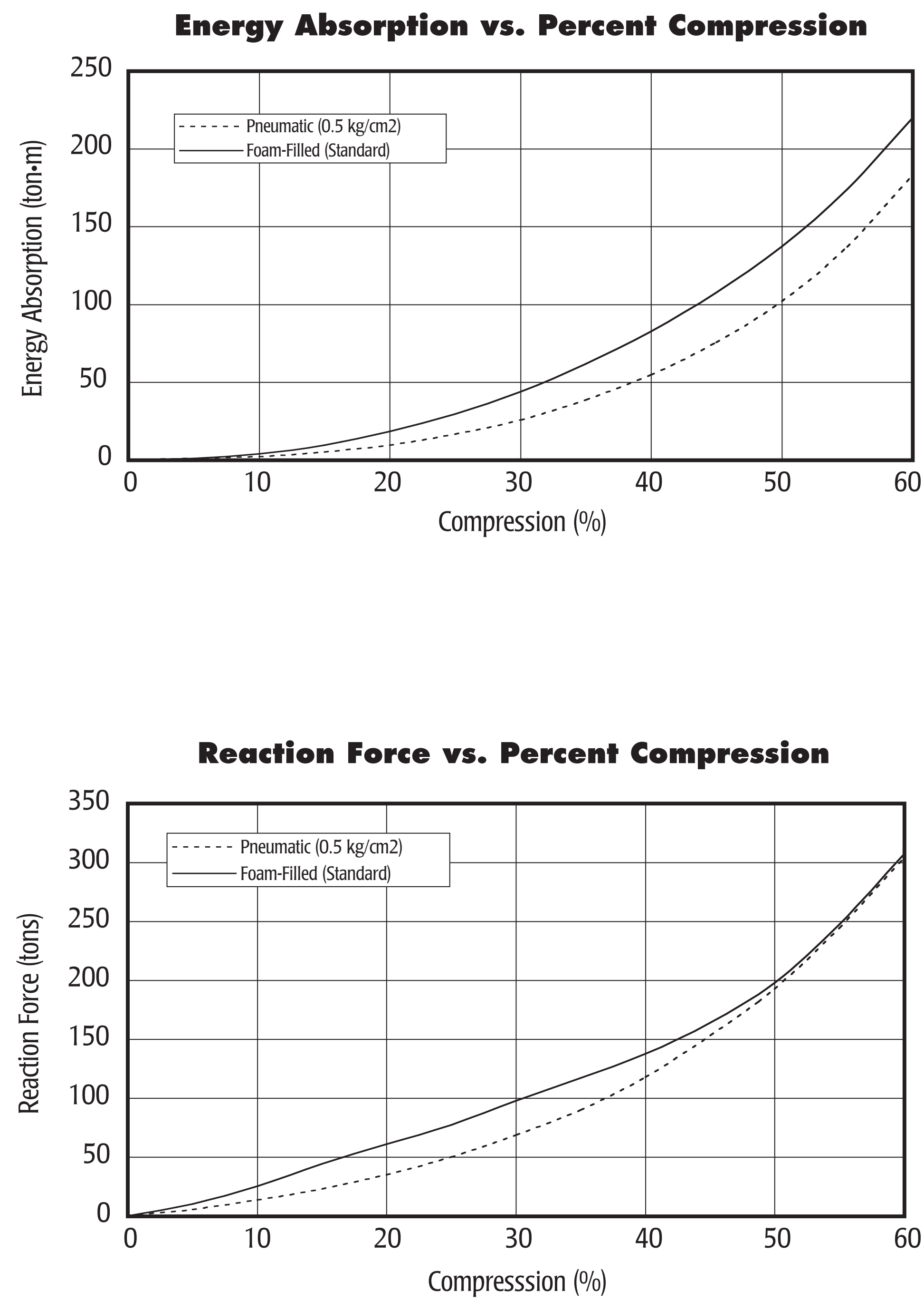
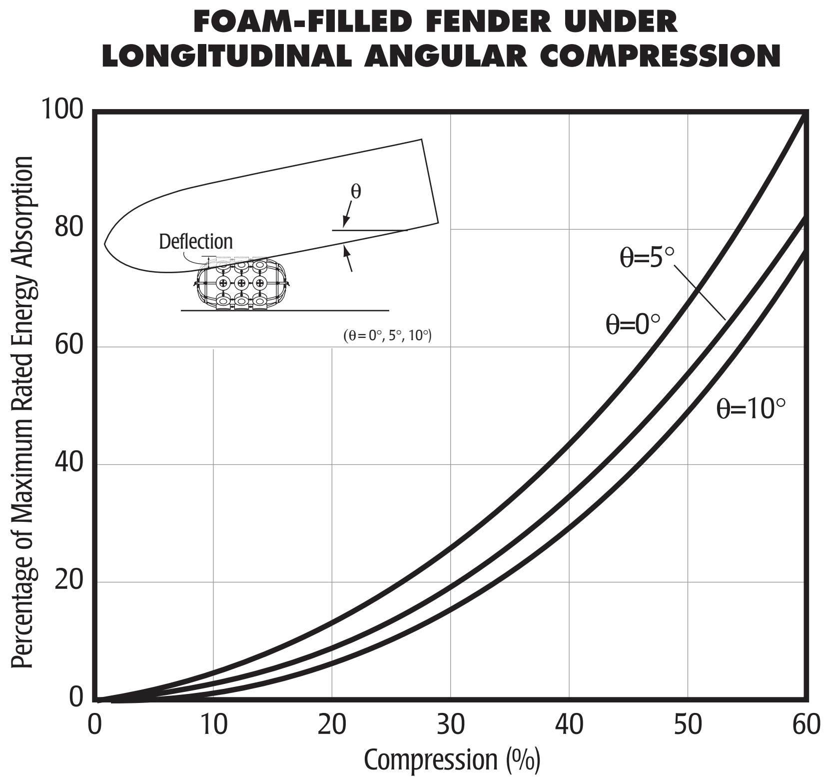


Figure 3 - Typical performance curves for 3300 mm by 6500 mm fenders



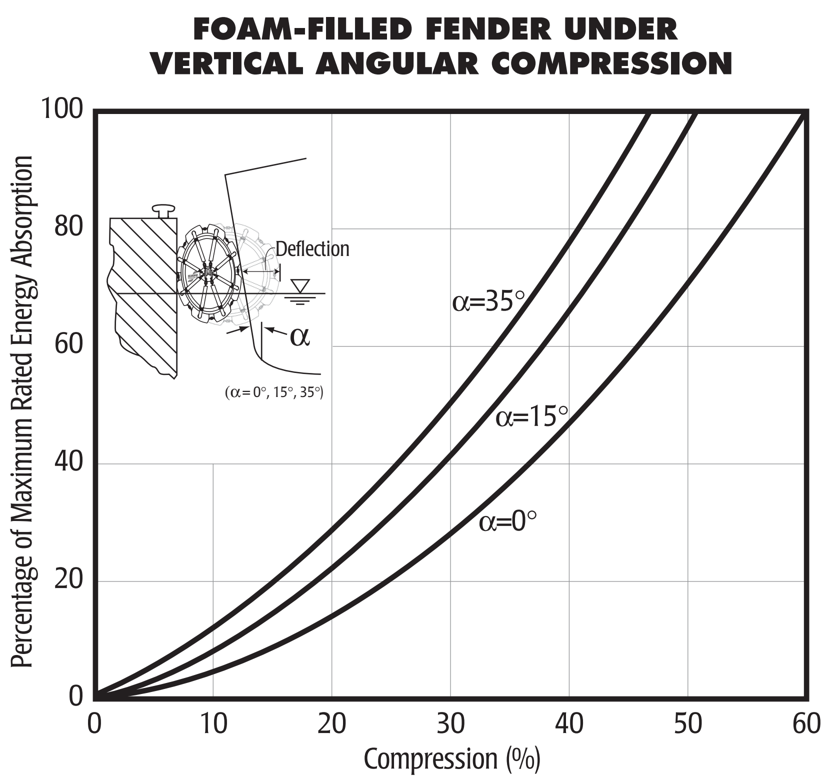


Figure 4 - Correction factors for typical foam-filled fender angular compression curves

compressions. If the relief valve fails to discharge, the fender skin can be ruptured with a complete loss of fendering capability and possible risk of injury to personnel and equipment. In actual practice, with properly sized fenders, moderate environmental conditions, and trained lightering personnel, none of these problems are likely to be encountered.

Advantages of foam-filled fenders and pneumatic fenders

Foam-filled fenders: There is no energy absorption loss if punctured. The resilient foam is closed-celled so that a puncture or tear does not reduce the fendering capacity.

Foam fenders have less "bounce" than pneumatic fenders. The foam used in the fender is visco-elastic, and actually absorbs a certain amount of energy through hysteresis during the compression and recovery cycle. A pneumatic fender acts as a nearly perfect spring, giving back on the recovery phase of the cycle all of the energy absorbed during the compression phase of the cycle.

In general, foam-filled fenders tend to require less maintenance than pneumatic fenders. Usually, the only maintenance required is to repair the net if the chain becomes damaged or corroded, or to replace the tires if they become worn. Repairs to the skin are easily made in the field using repair kits provided by the manufacturers. Because the skin of a foam-filled fender is not a pressure-carrying boundary, relatively inexperienced personnel can generally make adequate repairs. Pneumatic fenders require maintenance on the valves and sealing surfaces, as well as maintenance to the net. Temporary repairs of minor damage to the skin can be made using repair kits provided by the manufacturers. Severe damage to the skin is not easily repaired in the field and the fender may have to be sent back to the factory or to a facility specializing in vulcanized repairs. If the damage penetrates through the reinforcing, the fender may have to be scrapped.

Foam-filled fenders employ a flexible manufacturing process, which can produce almost any size fender up to the size capabilities of the machinery and facilities. Pneumatic fenders are limited to the available molds, which are expensive to manufacture and may not be justified if only a few units of a new size are required.

Pneumatic fenders: Pneumatic fenders typically have a lower purchase price than foam-filled fenders. The pneumatic fender body contains no foam and is typically fabricated from sheets of reinforced rubber in a conventional vulcanizing process. This reduces the manufacturing cost. However, the marine fender market is very competitive, and foam-filled fenders can often be purchased at prices competitive with pneumatic fenders.

Pneumatic fenders weigh less than the same size foam-filled fender. Again, the absence of foam reduces the weight of the fender. To give a pneumatic fender more mass to reduce liveliness in a seaway, water can also be added to the interior. However, this also reduces the energy absorption capacity, although it may be justified in certain cases.

This is only practical if the fenders will be towed out to the transfer site and the water can be added in port where calm conditions prevail. Removing the water later on is not a simple operation, even in port, but it can be done. Attempting to lift a water-filled fender back on deck after an operation is completed could induce high stresses in the skin and might be damaging to the fender.

The pneumatic fender holds its original shape. Being a nearly perfect spring, the pneumatic fender returns to its original shape after compression, whereas a foam-filled fender retains a certain degree of compression set after being compressed the first few times. If a pneumatic fender is compressed to the extent that the safety valve is discharged, or if there is a slow leak at a seal or valve, there will be less air in the fender, but the shape could remain basically the same. Like an automotive tire, a pneumatic fender could be dangerously under-inflated and not be noticed by the operators. Therefore, the pressure inside each pneumatic fender should be monitored prior to each operation.

Comparison of netted fenders with non-netted fenders

Netted fenders give the best strength and durability for lightering operations. Nets are usually composed of galvanized chains joined together with shackles or joining links. Large truck or aircraft tires are typically located at the intersection of the chains to provide some protection to the ship against damage to the coating system. At exposed locations the chains are usually covered with a heavy-duty rubber sleeve or hose. The ends of the longitudinal chains are attached at each end to a towing fitting. The strength and quantity of longitudinal chains determines the design strength of the net, and determines the design of the towing fitting. Figure 5 shows a typical fender with a chain and tire net.

Nets for smaller fenders are sometimes made from wire rope or synthetic belting. With synthetic nets, there is no need for tires to protect the ship from chain and shackle damage. However, the extra standoff provided by the tires is lacking with this design. Wire rope nets are also sometimes constructed without tires, although the wire is covered with rubber sleeves to minimize damage to the ship. Maintenance of a wire rope net is higher than for a chain net because of the increased corrosion problems.

A chain and tire net makes a less “lively” fender (more damped motions) in waves. This is because of the extra mass (including the mass of water contained in the tire casing) and the high form drag and frictional drag of the tires. Experience with large fenders without nets have shown this type of fender to be too lively for commercial lightering operations. Also, damaging skin stresses can be developed at the ends of the fender where the towing lines are attached because of the constant wave-induced cyclic loads from the towing line.

Smaller non-netted fenders do have an application as secondary fendering for the topsides of the ship, where the fenders can be suspended above the waterline. The secondary fenders prevent contact during rolling motions. In this case, the lack of a net

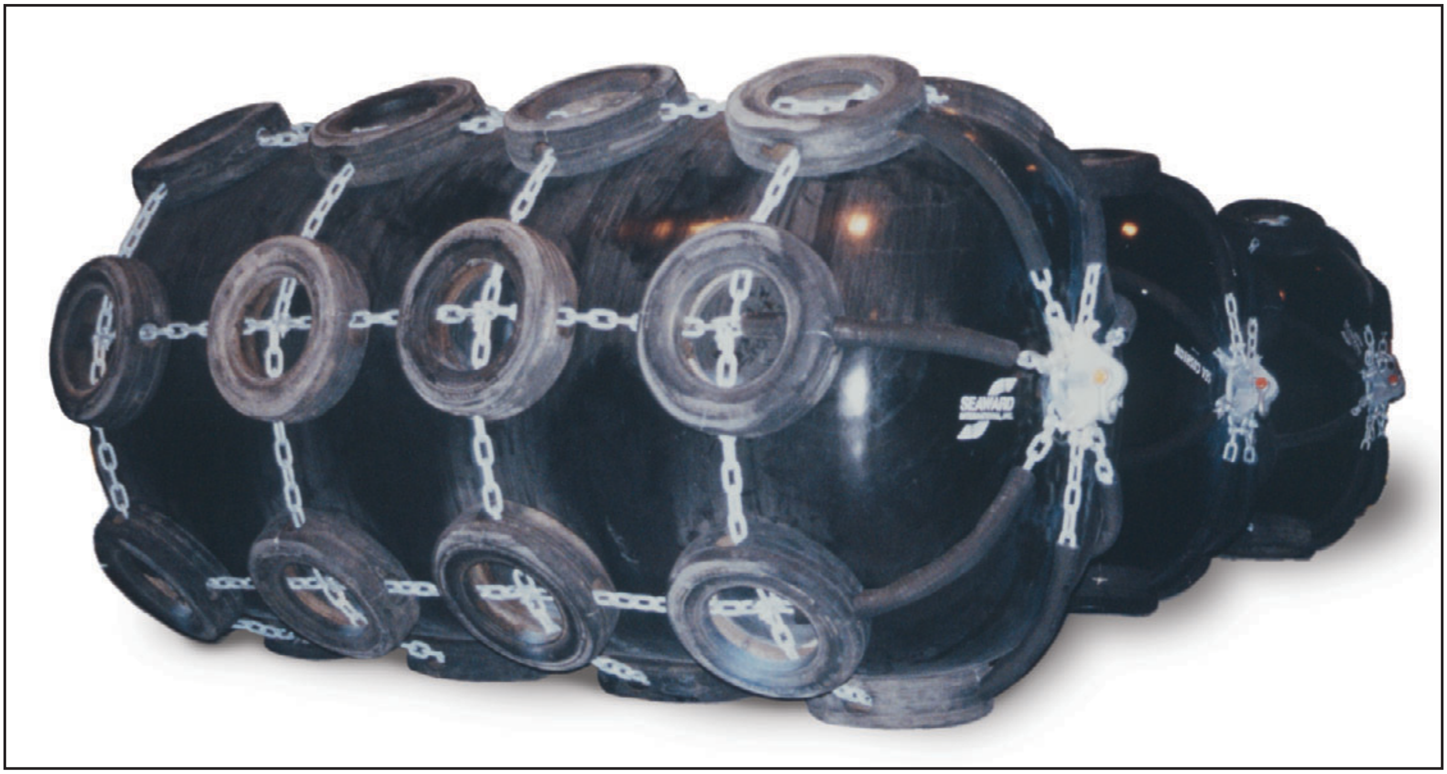


Figure 5 - Typical fender with chain and tire net

reduces the weight. The energy requirements are difficult to estimate, so usually a conservative estimate is made for fender selection. Figure 6 shows a typical non-netted fender that could be used as a secondary fender.

Chain and tire nets present additional maintenance problems (chain and tire replacement), but prolong the life of the energy-absorbing fender body. Chain corrosion is the main problem, requiring replacement of the corroded chain segments. Some operators periodically replace the entire net, tires and all. Stainless steel chains could be used, but they are usually cost prohibitive in the sizes required for large fenders.

Summary of sizes, characteristics and costs for large fenders

Tables 1 and 2 shows typical sizes of foam-filled and pneumatic fenders with chain and tire nets. For reference, the Dunlop 14-ft (4,270-mm) diameter by 60-ft (18,300-mm) long low-pressure netless fender has an energy absorption capacity of only 1,570 kN·m (1,158 ft·kips) at a reaction force of 2,889 kN (650 kips). This is nearly equivalent to a 3300-mm x 6500-mm standard pneumatic fender with 0.5 kg/cm^2 initial pressure.

Some manufacturers of foam-filled fenders only make a netless fender (with a tensile strength member through the axis), and add a chain and tire net only if required by the specifications. If this type of fender is towed by the netless fender connection instead of by the net itself, the motions can cause large stresses on the skin around the end fitting, with the possibility of causing permanent and irreparable damage to the fender. At the present stage of development, a netless fender is only recommended as a secondary fender for topsides use and not as a primary lightering fender. The primary fenders should be designed at the outset to have a chain and tire net carrying the structural loads.

Table 3 shows approximate costs for a range of sizes of foam-filled and pneumatic fenders, all with heavy-duty chain and tire nets. In some cases the costs are estimated. Foam-filled fender costs are based on the standard foam interior; high-capacity foam fenders cost approximately 20% more and low-reaction fenders cost approximately 10% less than the values shown. The pneumatic fender costs are for the more common 49 kPa (0.5 kg/cm^2) initial pressure fenders; the 79 kPa initial pressure fenders are expected to cost approximately 25% to 30% more than the values shown.

Fender Manufacturers

Foam-filled fenders:

The following manufacturers currently produce foam-filled fenders with chain and tire nets:

- Seaward International Inc. (USA)—Seaward fenders are rated using the same approaches being proposed by PIANC for buckling-element fender systems. The effects of deflection rate and repeated compressions are included in the performance predictions. Temperature effects are also included.
- Urethane Products Corp. (USA)

Figure 6 - Non-netted fender

Table 1 - Typical foam-filled fender sizes

The values presented in these tables are based on the maximum recommended working compression of 60%. This compression should not be exceeded.

SIZE DIAMETER x LENGTH		ENERGY ABSORPTION AT 60% COMPRESSION			REACTION FORCE AT 60% COMPRESSION			WEIGHT WITH CHAIN AND TIRE NET	
ft	mm	ft•kip	kN•m	ton•m	kip	kN	ton	lb	kg
3 x 6	0 915 x 1 830	36	49	5	56	248	25	1 324	601
4 x 8	1 220 x 2 440	85	115	12	98	436	44	2 266	1 028
5 x 10	1 525 x 3 050	164	223	23	152	676	69	3 736	1 695
6 x 12	1 830 x 3 660	282	382	39	217	966	98	4 548	2 063
7 x 14	2 135 x 4 270	445	603	62	294	1 306	133	6 487	2 943
8 x 12	2 440 x 3 660	465	630	64	268	1 193	122	6 554	2 973
8 x 16	2 440 x 4 875	661	896	91	381	1 696	173	8 871	4 024
9 x 18	2 745 x 5 490	937	1 270	130	480	2 136	218	12 604	5 717
10 x 16	3 050 x 4 875	976	1 324	135	450	2 003	204	11 473	5 204
10 x 20	3 050 x 6 100	1 280	1 736	177	590	2 626	268	14 431	6 546
11 x 22	3 350 x 6 700	1 697	2 302	235	711	3 165	323	16 103	7 304
12 x 24	3 660 x 7 320	2 196	2 978	304	844	3 752	383	23 118	10 486
13 x 26	3 960 x 7 920	2 784	3 774	385	987	4 389	447	27 872	12 643
14 x 28	4 270 x 8 535	3 379	4 582	467	1 128	5 018	512	32 038	14 532

SIZE DIAMETER x LENGTH		ENERGY ABSORPTION AT 60% COMPRESSION			REACTION FORCE AT 60% COMPRESSION			WEIGHT WITH CHAIN AND TIRE NET	
mm	ft	ft•kip	kN•m	ton•m	kip	kN	ton	lb	kg
1 000 x 2 000	3.3 x 6.6	48	65	7	67	299	31	1 440	653
1 200 x 2 000	3.9 x 6.6	64	87	9	76	339	35	1 904	864
1 350 x 2 500	4.4 x 8.2	103	140	14	109	483	49	2 435	1 105
1 500 x 3 000	4.9 x 9.8	155	210	21	146	649	66	3 682	1 670
1 700 x 3 000	5.6 x 9.8	196	265	27	162	718	73	4 055	1 839
2 000 x 3 500	6.6 x 11.5	317	429	44	222	986	101	4 831	2 191
2 000 x 4 000	6.6 x 13.1	371	502	51	259	1 153	118	5 315	2 411
2 200 x 4 500	7.2 x 14.8	500	678	69	321	1 426	145	6 893	3 127
2 500 x 4 000	8.2 x 13.1	541	734	75	305	1 355	138	7 093	3 217
2 500 x 5 500	8.2 x 18.0	793	1 076	110	447	1 987	203	9 691	4 396
3 000 x 6 000	9.8 x 19.7	1 213	1 645	168	571	2 539	259	14 244	6 461
3 300 x 4 500	10.8 x 14.8	1 007	1 365	139	430	1 912	195	11 828	5 365
3 300 x 6 500	10.8 x 21.3	1 581	2 144	219	675	3 003	306	17 032	7 726
4 200 x 8 400	13.8 x 27.6	3 322	4 505	459	1 109	4 933	503	31 580	14 325

Tables taken from SEA CUSHION Marine Fenders Technical Manual (SCTM-3), page 9.

Table 2 - Typical pneumatic fender sizes

Table2-1
(A) Technical Performance (PNEUMATIC 50)

Nominal size	Initial internal pressure	Guaranteed energy absorption (E) Reaction force (R) and Hull pressure (P) at 60%def.			Safety valve pressure setting	Testing Pressure	Weight of net type (Type-A)				Approx. weight of sling type (Type-B)
							Approx fender body weight	Approx. weight of net			
Diameter x Length		E	R	P				Chain net	Wire net	Synthetic fiber net	
mm	kPa (kgf/cm²)	kN-m (tf-m)	kN (tf)	kPa (tf/m²)	kPa (kgf/cm²)	kPa (kgf/cm²)	kg	kg	kg	kg	kg
500 x 1,000	49 (0.5)	5.9 (0.6)	64 (6.5)	131 (13.4)	-	147 (1.5)	22	-	30	20	32
600 x 1,000	49 (0.5)	7.8 (0.8)	74 (7.5)	125 (12.7)	-	147 (1.5)	25	-	30	22	36
700 x 1,500	49 (0.5)	16.7 (1.7)	135 (13.8)	133 (13.6)	-	147 (1.5)	45	150	40	37	55
1,000 x 1,500	49 (0.5)	31.4 (3.2)	179 (18.3)	121 (12.3)	-	147 (1.5)	75	190	80	51	105
1,000 x 2,000	49 (0.5)	45.1 (4.6)	255 (26.0)	131 (13.4)	-	147 (1.5)	90	230	140	68	120
1,200 x 2,000	49 (0.5)	61.8 (6.3)	294 (30.0)	125 (12.7)	-	147 (1.5)	110	300	190	-	140
1,350 x 2,500	49 (0.5)	100 (10.2)	423 (43.1)	128 (13.1)	-	147 (1.5)	170	330	200	-	210
1,500 x 3,000	49 (0.5)	151 (15.4)	574 (58.5)	131 (13.4)	-	147 (1.5)	225	490	350	-	265
1,700 x 3,000	49 (0.5)	189 (19.3)	633 (64.5)	127 (12.9)	-	147 (1.5)	270	580	440	-	290
2,000 x 3,500	49 (0.5)	304 (31.0)	867 (88.4)	127 (12.9)	-	147 (1.5)	395	980	640	-	450
2,500 x 4,000	49 (0.5)	654 (67)	1,363 (139)	135 (13.8)	177 (1.8)	196 (2.0)	1,010	1,260	910	-	1,080
2,500 x 5,500	49 (0.5)	932 (95)	2,001 (204)	147 (15.0)	177 (1.8)	196 (2.0)	1,200	1,630	1,160	-	1,320
3,300 x 4,500	49 (0.5)	1,157 (118)	1,863 (190)	129 (13.2)	177 (1.8)	245 (2.5)	1,620	1,630	1,270	-	-
3,300 x 6,500	49 (0.5)	1,795 (183)	2,981 (304)	144 (14.7)	177 (1.8)	245 (2.5)	2,030	2,680	1,910	-	-
3,300 x 10,600	49 (0.5)	3,030 (309)	5,207 (531)	157 (16.0)	177 (1.8)	245 (2.5)	2,720	4,670	3,300	-	-
4,500 x 9,000	49 (0.5)	4,688 (478)	5,688 (580)	144 (14.7)	177 (1.8)	245 (2.5)	4,270	4,810	3,520	-	-
4,500 x 12,000	49 (0.5)	6,394 (652)	7,904 (806)	153 (15.6)	177 (1.8)	245 (2.5)	5,120	7,240	5,190	-	-

Notes:
1. Type-A indicates net-type fender, and Type-B indicates sling-type fender with lifting hooks.
2. Guaranteed energy absorption represents the Guaranteed energy absorption at 60% deflection.
3. Tolerance of reaction force and deflection at guaranteed energy absorption are as follows: Reaction force: ±10% Deflection: ±5%
4. Each reaction force and energy absorption are measured under static condition.
5. Testing pressure rate indicates the testing pressure at factory.
6. Weight of fender body may vary ±10%. Net's weight may vary depend on the tire's construction used for the net.
7. Special sizes are available upon request.

Table 3 - Approximate costs for typical fender sizes

Foam-Filled Fenders

Size	Estimated Cost
mm x mm	(USA)
2000 x 3500	$ 18,200
2000 x 4000	20,500
2200 x 4500	25,500
2500 x 4000	26,700
2500 x 5500	40,500
3000 x 6000	57,600
3300 x 4500	50,300
3300 x 6500	69,800
4200 x 8400	137,000

Pneumatic Fenders

Size	Estimated Cost	
mm x mm	(Korea)	(Japan)
2000 x 3500	$ 10,440	$ 12,000
2500 x 4000	16,300	
2500 x 5500	18,960	25,000
3300 x 4500	16,680	
3300 x 6500	28,320	45,000
3300 x 10600	56,760	75,000
4500 x 9000		120,000
4500 x 12000		

Foam-filled fender costs are based on Standard Capacity fenders with heavy-duty chain and tire nets. Costs are FOB USA manufacturing site.

Pneumatic fender costs are based on standard fenders (0.5 kg/cm^2 starting pressure)"with heavy-duty chain and tire nets. Costs are FOB Korea or Japan port, as appropriate." Japan costs are estimated. Cost data not available on all models.

- CRP Marine (UK)
- Balmoral (UK)
- Hippo Marine (UK)

Contact information is included in the appendix.

Pneumatic fenders:

The following manufacturers currently produce large pneumatic fenders. For a given size fender, two different pressures are usually listed as the initial pressures. For the higher initial pressures, the fenders are provided with stronger and heavier skins.

- Yokohama Rubber Corp (Japan)
- Shibata (Japan)
- Kum Nam Chemical (Korea)
- HS R&A (Korea)
- Dunlop (UK---low pressure fender without net)

Contact information is included in the appendix.

Estimates of practical size limits for current fender technology

- Larger standard types of pneumatic fenders would require larger molds (and probably larger autoclave curing facilities) than are currently available. Therefore, the largest practical size using pneumatic technology is 4.5 m diameter (14.75 ft) by 12.0 m long (39.4 ft). Only Yokohama Rubber in Japan currently has the capacity to manufacture this size of pneumatic fender. Other pneumatic fender manufacturers are limited to 3.3 m diameter (10.8 ft) by 6.5 m long (21.3 ft).
- Larger foam-filled fenders would require larger manufacturing facilities than are currently available. (The current size limit for foam-filled fenders is approximately 13.8 ft diameter by 35 ft long.) However, existing equipment could be set up at a remote location to produce larger fenders, if necessary, thus avoiding shipping difficulties. Some minor equipment modifications would also be required. Therefore, foam-filled fenders could also be manufactured in sizes as large as, if not larger, than pneumatic fenders.
- Shipping of very large foam-filled fenders from the factory becomes more difficult and costly due to transportation limitations. Foam-filled fenders can be shipped without the net installed, but handling facilities must be available at the delivery site to install the chain and tire net. Pneumatic fenders can be deflated to make a smaller package for transportation, even with the chain and tire net installed. However, care must be taken during inflation to keep the net in place. Fenders should be inflated within one week of delivery to avoid reducing the service life because of folds and creases. Pneumatic fenders should be stored in a partially deflated condition, covered with canvas to prevent sunlight deterioration.

Recommended research to extend current size/performance limits

Additional research directions may depend on the results of computer simulations of ship motion studies, which are being studied in another phase of this project. The additional research should consider how the ancillary equipment involved in the cargo transfer operations, including the winches, lines, booms, and control systems, could affect the fendering requirements, and, conversely, how new fender designs could affect the ancillary equipment design. The topics below are preliminary suggestions that appear worthy at this time, and may be amended or supplanted with additional topics later on.

- Develop more energy efficient foams with lower density. Closed-cell resilient foams attain most of their energy absorption after cell wall buckling, through compression of the gas contained within the cells. A foam designed to absorb more of the energy through cell wall buckling instead of gas compression could produce lower reaction pressures on the hull at maximum design compression. This would result in more energy absorption for the same size fender without exceeding hull pressure limitations. Multiple foam densities might also be used within the same fender to optimize desired characteristics.
- Develop thinner and stronger containment envelopes (skins) through the use of new elastomer reinforcing technology and improved manufacturing methods.
- Optimize foam-filled fender shape using cross-sections other than cylindrical. Cylindrical shapes do not compress all of the foam equally, so there is an efficiency loss. However, this “inefficiency” also provides a more gradual buildup of reaction force with compression, which may be beneficial in lightering operations. The main advantage of cylindrical fenders is in the ease of manufacturing (this applies to both foam-filled and pneumatic fenders), which reduces the cost. Research should be performed to determine optimal fender shapes for minimizing relative motions of two ships during cargo transfer operations.
- Develop a hybrid foam/pneumatic fender that can be “tuned” for various conditions by changing the inflation pressure.

APPENDIX

- Manufacturer Contact Information
- SEA CUSHION® Marine Fenders Technical Manual (SCTM-3), Seaward International, Inc., Clearbrook, VA USA (A CD version of the manual is included.)
- Manual for Yokohama Pneumatic Rubber Fenders (Handling Manual No. FD 04), The Yokohama Rubber Co., Ltd., Tokyo, Japan

Manufacturer Contact Information

Seaward International, Inc.
PO Box 98
3470 Martinsburg Pike
Clearbrook, VA 22603
USA

Telephone:	540-667-5191
Fax:	540-667-7987
E-mail:	mail@seaward.com
Web site:	www.seaward.com

Urethane Products Corp.
9076 Rosecrans Ave.
Bellflower, CA 90706
USA

Telephone:	562-630-4982
Fax:	562-630-6974
E-mail:	jthermos@urethaneproducts.com
Web site:	www.urethaneproducts.com

Hippo Marine
1 Gilston Road
Saltash Industrial Estate
Saltash, Cornwall, PL12 6TW
UK

Telephone:	01752 843333 or 44 1508 482691
Fax:	01752 843339
E-mail:	sales@fendercare.com
Web site:	www.fendercare.com/Hippo/marine

CRP Group Ltd.
Stanley Way
Stanley
Skelmersdale
Lancashire WN8 8EA
UK

Telephone:	44 (0)1695 712000
Fax:	44 (0)1695 712111
E-mail:	sales@crpgroup.co.uk
Web site:	www.crpgroup.co.uk

Balmoral Group Ltd.
Balmoral Park
Loirston
Aberdeen AB12 3GY
Scotland
Telephone: 44 (0)1224 859000
Fax: 44 (0)1224 859059
E-mail: group@balmoral.co.uk
Web site: www.balmoral-group.com

The Yokohama Rubber Company, Ltd.
MB Overseas Sales Dept.
Shuuwa-Onarimon Building, 7th floor
Shimbashi 6-1-11
Minato-ku, Tokyo 105-8685
Tokyo 105-8685
Japan
Telephone: 81-3-5400-4816
Fax: 81-3-5400-4830
E-mail: wan@hpt.yrc.co.jp
Web site: www.yrc.co.jp/marine

Shibata Industrial Co. Ltd.
Rotary Building 1–27
Kanda Nishiki-cho
Chiyda-Ku, Tokyo 101
Japan
Telephone: 81-3-3292-3863
Fax: 81-3-3292-3869
E-mail: infosys@sbt.co.jp
Web site: www.sbt.co.jp

Kum Nam Chemical Inc.
348-3, Chung Chun-Ri, Chillye-Myun,
Kimhae, Kyungnam
Korea
Telephone: 82-55-346-3131
Fax: 82-55-346-3137
E-mail: kumnamkorea@kumnamkorea.com
Web site: www.kumnamkorea.com

HS R&A, Co. Ltd.
147-1 Kyou-Dong
Yangsan-Shi Kyong Nam 626-210
Korea

Telephone:	82-55-370-3331/4
Fax:	82-55-387-8870/2
E-mail:	qjean@hsra.co.kr
Web site:	www.hsra.co.kr

Dunlop Precision Rubber
Ashby Road, Shepshed, Loughborough
Leicester LE12 9EQ
UK

Telephone:	44 (0) 1509-500000
Fax:	44 (0) 1509-500150
E-mail:	info@dunlop-precision.co.uk
Web site:	www.dunlop-precision.co.uk