YOKOHAMA
PNEUMATIC
FENDER

ISO17357-1:2014
PIANC:2002

YOKOHAMA


NO SMOKING

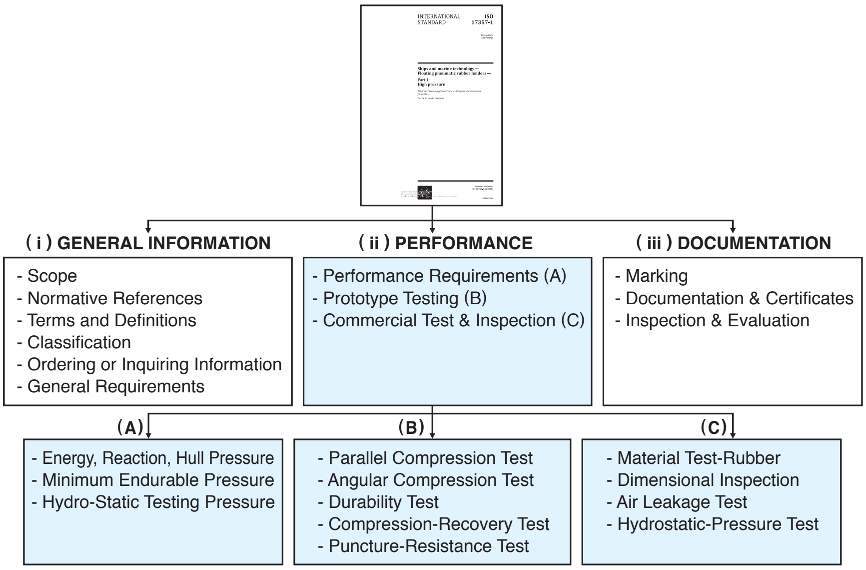
CONTENTS

1. INTRODUCTION

The "Yokohama Pneumatic Rubber Fender" was developed in 1958 based on a rubber company's technology for automobile tires and rubber aircraft fuel tanks. Progress in the development of such floating pneumatic rubber fenders is closely related to the progress and development of ship technology, and has to continuously cope with progressively larger oil tankers such as VLCC's, ULCC's, large gas carriers, bulk carriers and floating structures. Floating pneumatic fenders are used world wide for ship-to-ship (STS) transfer operations, terminals, and for all kinds of ships. Since its creation until today, more than 60,000 fenders have been supplied worldwide both for ship-to-ship and ship-to-dock operations serving our valuable customers.
These fenders play a critical role in the safe operation of ship berthing and mooring.

2. COMPLIANCE WITH ISO17357-1:2014

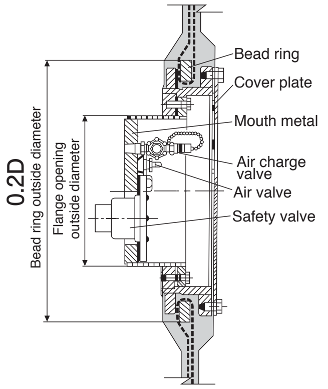
ISO17357:2002, “the standard of high pressure of floating pneumatic rubber fenders”, had been published in 2002 under growing needs for international standardization specified material, performance and dimensions of floating pneumatic fenders to prevent variety of originally designed products with low quality had been introduced into the market.
In 2014, ISO17357:2002 had been renewed as 1st edition of ISO17357-1:2014 to strengthen its standard concerning design, material and certification of floating pneumatic fender.
Although the structure is maintained from ISO17357:2002 to ISO17357-1:2014 as shown in Fig , new requirements and new design listed below are added in ISO17357-1:2014 aiming at higher berthing operation safe.
The Yokohama Rubber Co., Ltd. confirms that its Pneumatic Rubber Fenders, Pneumatic P50 & P80, fully comply with all requirements of ISO17357-1:2014.



Remarks:
The Yokohama Rubber Co., Ltd confirms that all its Pneumatic 50 and 80 fully comply with all requirements of ISO17357-1:2014.
Performance Confirmation of Prototype fender test shall be done every ten years.

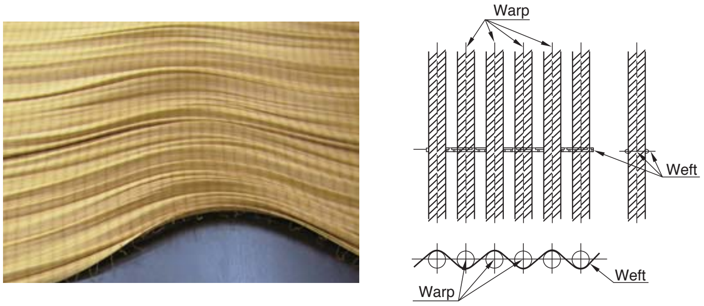
New Requirement

(1) Diameter of the bead ring or other steel material around the flange opening shall be less than 0.20 D (D: fender diameter) to make metal parts safe from permanent deformation when it gets over compression near to 80%.

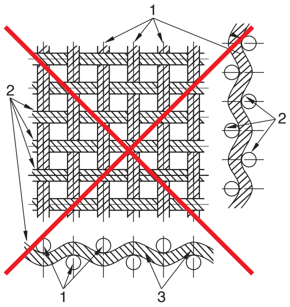


(2)The performance confirmation of prototype fender test shall be done every ten years.

(3) Layer made of synthetic-tyre-cord fabric, which maintains the internal air pressure of the fender. The canvas fabric shall not be used for the high pressure pneumatic floating fender.



Synthetic-tyre-cord

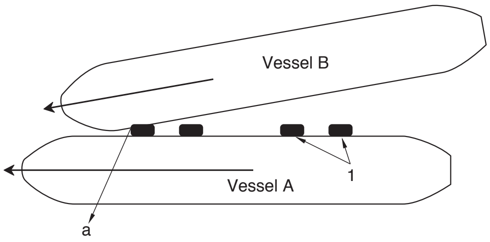


Canvas fabric

New design

Type I Single — Net type and one end with no flange opening and no metal parts

The flange opening shall be at only one end for Type I Single and no metal parts shall be at the other end to make that end safe from permanent deformation when it gets over compression.



3. ADVANTAGES

3.1 Safety and Reliability

Yokohama Pneumatic Rubber Fenders are constructed of several layers of strong tire-cord, and are thus resistant to pressure and cutting. The safety factor adopted in the design of this fender is based on accepted theory and has been proven by extensive experimentation. Operational experience over a long period of time attests to its high safety and reliability, and hydraulic pressure tests have proven the strength to be suitable. Furthermore, large-size fenders are equipped with a safety valve to release the inside air in the event of accidental over-pressure. The figure below shows data obtained from many destructive pressure tests at various percentage compressions. Such data are used to establish a basic minimum endurable pressure (MEP) curve for pneumatic rubber fenders.

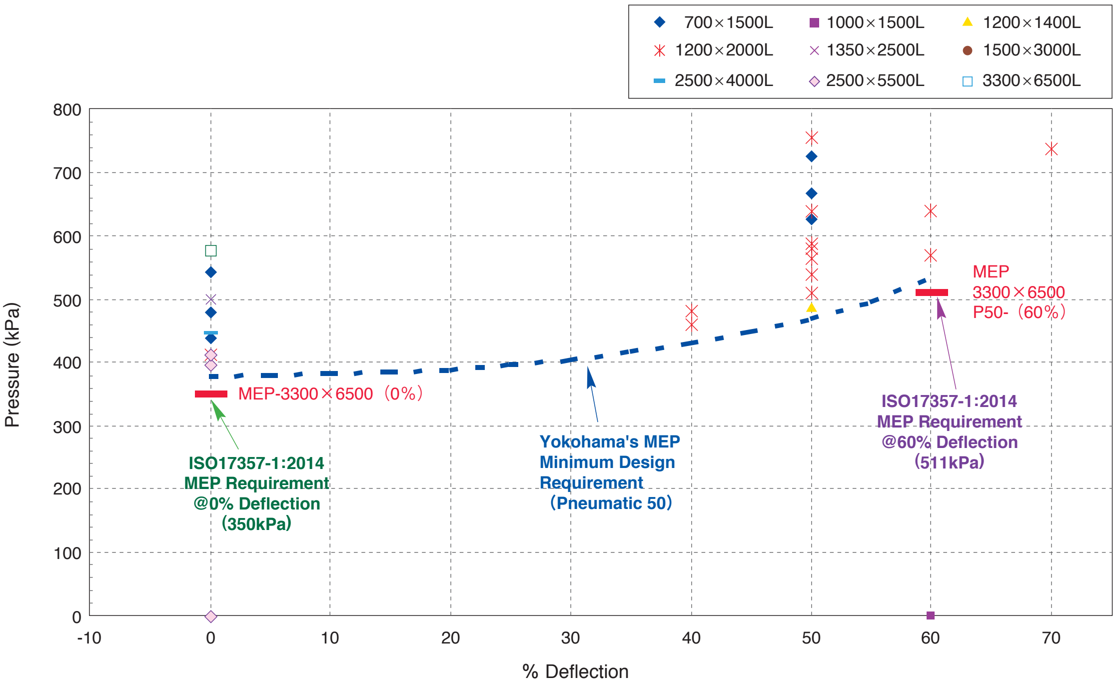


Fig.3-1 Burst Test Data to determine Minimum Design Requirements of MEP

Fig.3.2 Burst Test at 0% Deflection

Fig.3.3 Burst Test at 60% Deflection

3.2 No Deterioration or Variation in Performance

Yokohama Pneumatic Rubber Fenders utilize the compressive elasticity of air, therefore performance deterioration due to fatigue is absent.

In the case of solid rubber fenders or foam-filled fenders, based on data were taken from comparison tests of Yokohama Fenders, there are variations in performance. Such performance variations are associated to changes of rubber or foam hardness occurring as a result of cyclic compression and temperature change.

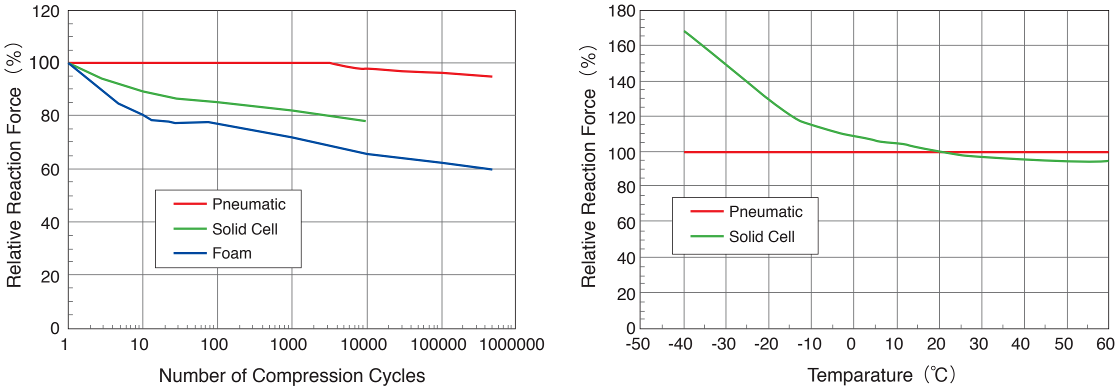


Fig.3-4 Variation in Performance on Cyclic Compression and Temperature

In the case of Yokohama Pneumatic Rubber Fenders, if the pressure is maintained properly, such variations are absent.

Yokohama Pneumatic Rubber Fenders also fully comply with the durability test required by ISO17357-1:2014. After 3000 repetitive cycles, there must be no cracks or other harmful defects on any part of the fender. Any reduction of the guaranteed energy absorption (GEA) is not accepted.

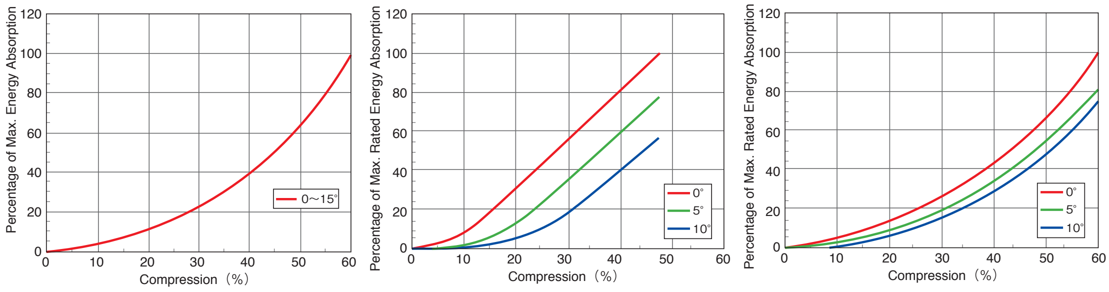
Table 3-1 Cyclic Compression Results for Yokohama Pneumatic Rubber Fenders

Items	original	After 3000cycles
GEA (index)	1	1
Reaction force at GEA (index)	1	1.04
Deflection at GEA (%)	60	60.4

The good performance of the Yokohama Pneumatic Rubber Fenders remains unchanged even at temperatures under -50 degrees Centigrade (-58 degrees Fahrenheit).

3.3 Advantages at Inclined Berthing

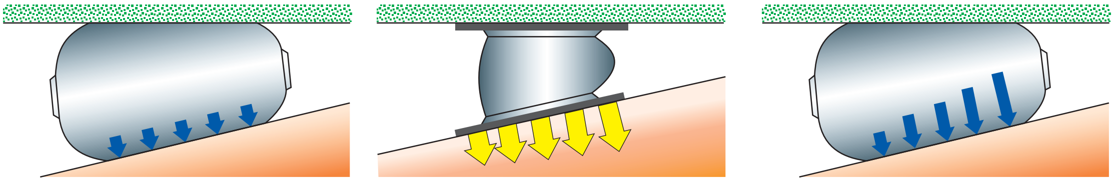
Ships usually make initial contact with the dock or another ship on STS operations at an oblique angle. In the case of solid rubber fenders or foam fenders, rated reaction force and energy absorption decreases considerably at inclined compressions compared with parallel compression. In order to compensate for the decrease of energy absorption at inclined compression, it is necessary to use larger sizes in the case of solid rubber fenders or foam fenders.



(a) Pneumatic Fender (b) Solid Fender (c) Foam Fender

Fig.3-5 Reduction of Energy Absorption at Inclined Berthing for Pneumatic, Solid and Foam Fender

In the case of Yokohama Pneumatic Rubber Fenders, energy absorption does not decrease at inclined compression up to 15 degrees.



(a) Pneumatic Fender (b) Solid Fender (c) Foam Fender

Fig.3-6 Load Distribution at Inclined Berthing for Pneumatic, Solid and Foam Fender

Distribution of load is also comparatively even because of the molecular freedom of air and high flexibility of the multi-layered cord-reinforced rubber membrane. This makes the body of a pneumatic rubber fender more shape conformant compared to solid or foam fenders, and thus able to better distribute the load along the hull of a ship or jetty structure during inclined compression.

3.4 Most Cost Competitive System

The utilization of the compressive elasticity of air, unlike other fenders which need protector panels, provides completely uniform surface pressure on contact, making Yokohama Pneumatic Rubber Fenders ideal. The surface pressure of the Yokohama Pneumatic Rubber Fenders is equal to the internal air pressure. The pressure of some is below 150kN/m^2 (15 ton/m^2). Due to low and uniform surface pressure properties, the Yokohama Pneumatic Rubber Fenders are popular at LNG-ship terminals.

Fig.3-7 Yokohama Pneumatic Fender ϕ3300×6500L

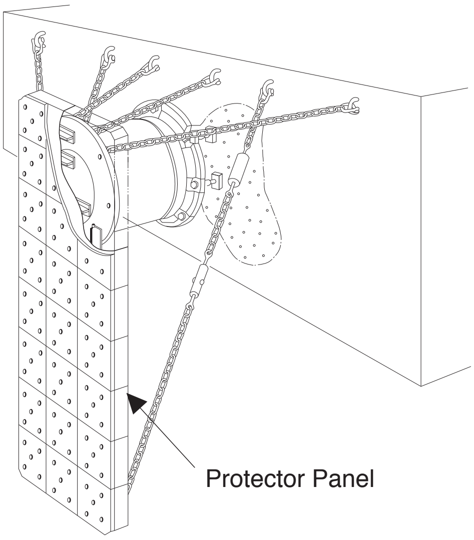


Fig.3-8 Yokohama Solid Fender RBF2000H

Table 3-2 Cost Competitiveness Comparison based on Uniform Surface Pressure

Item	Pneumatic Fender	Solid Fender
Fender Body	70	60
Chain net	25	-
Protector Panel	-	75 - 160
Chain, Anchor	5	15 - 30
Total	**100**	**150 - 250**

Remarks : The above comparison has been made based on data of Yokohama Pneumatic fender ϕ3300×6500L and Yokohama Solid fender RBF2000H

3.5 Soft Reaction Force for Ship and Jetty Structure

Although all fenders should be used within their maximum load limit, it often happens that fenders accidentally receive excess load. The reaction force of Yokohama Pneumatic Rubber Fenders does not increase sharply, even under excess load conditions. Therefore, the Yokohama Pneumatic Rubber Fenders perform well in such cases, and protect ships and mooring facilities. In contrast, the reaction force of solid rubber fenders, including buckling-type fenders, increases sharply under excess load conditions. The excess load turns the solid-type fender into a solid rubber block, which cannot perform as a fender. This often leads to damage of the ship and mooring facilities.

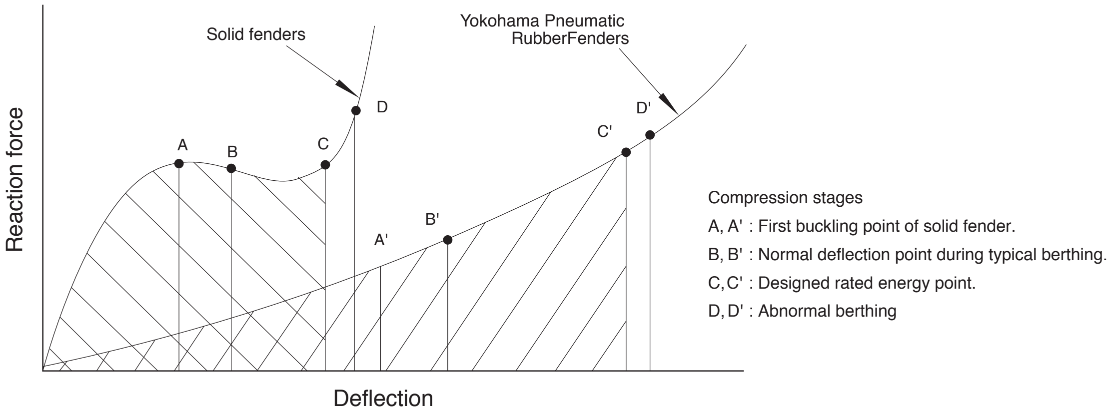


Fig.3-9 Soft Reaction Force for Ship and Jetty Structure

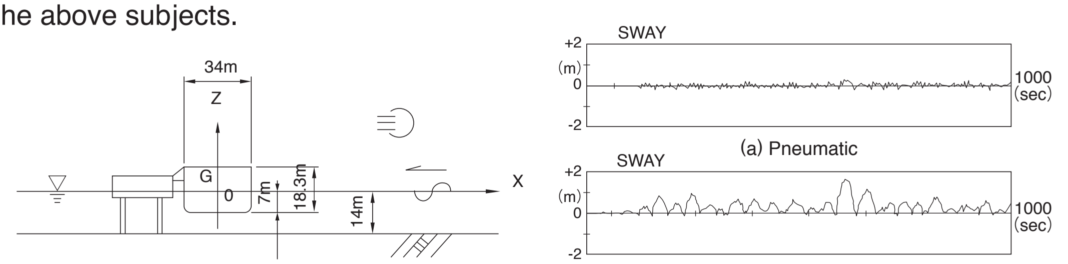
Fig.3-9 above compares the reaction force generated by a typical solid rubber fender to a pneumatic rubber fender at different compression stages during a typical berthing operation. The curves are derived from the performance of a solid rubber fender and a pneumatic rubber fender with the same energy absorption performance. Points A', B', C', and D' along the reaction curve for the pneumatic fender represent matching energy absorption performance at point A, B, C, and D on the reaction curve for the solid rubber fender.

The table below compares the typical reaction loads and hull pressure imposed by solid and pneumatic type fenders at various compression stages, and it can be seen that the Yokohama Pneumatic Rubber Fenders are ideal as fender system because of gentle treatment of ships.

Compression Stage	Comparison
A, A' : Buckling point of solid fender	Pneumatic fender has lower reaction force and exerts lower hull pressure compared to the solid rubber fender
B, B' : Normal deflection point	Pneumatic fender has lower reaction force and exerts lower hull pressure compared to the solid rubber fender
C, C' : Designed rated energy point	Pneumatic fender has slightly higher reaction force only at this point
D, D' : Abnormal berthing point	Pneumatic fender has lower reaction force and exerts lower hull pressure compared to the solid rubber fender

3.6 Lower Mooring Forces under Rough Weather Conditions

During mooring under rough weather conditions such as high waves and strong wind, large ship motions are induced by high waves, long period waves or a resonant effect between the natural period of a ship and the predominant period of the waves.
This movement results in compression and shearing forces on fenders. The reaction force and deflection of solid-type fenders under rough weather conditions easily reaches their respective maximums. Therefore, repeated compression with shearing force resulting from the movement of ships causes fatigue and often damages solid-type fenders. On the other hand, the reaction force and deflection of Yokohama Pneumatic Rubber Fenders do not easily reach the maximum because the reaction force increases slowly and allowable deflection is wide. Thus, the Yokohama Pneumatic Rubber Fenders safely protect ships and mooring facilities even under rough weather conditions.
The use of Pneumatic Rubber Fenders sometimes eliminates the necessity of constructing a breakwater in the harbor. There are many studies and reports relating to the above subjects.



(a) Pneumatic

(b) Solid (Buckling)

Fig.3-10 Model Studies on Ship's Movement with Yokohama Pneumatic Rubber Fender & with Buckling Fender

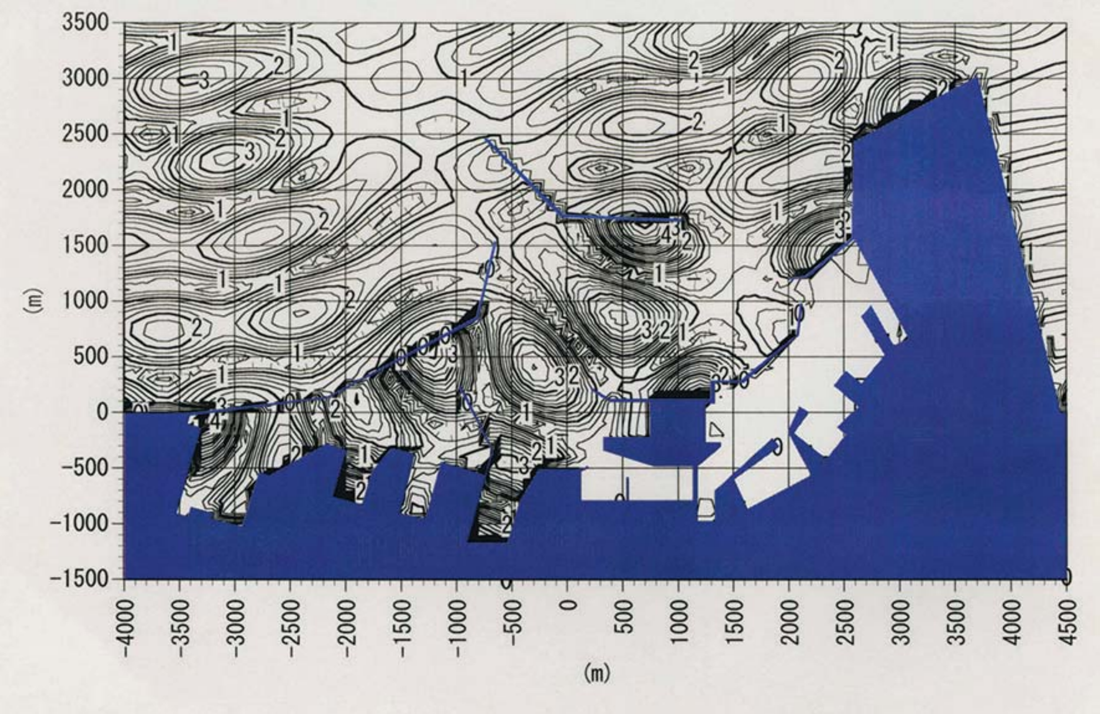


Fig.3-11 Calculation Results of Harbor Oscillations for Ship Motions moored along Quay Walls

3.7 Stronger against Shearing Force

After contacting a dock, a ship is usually shifted to the correct mooring position. The shifting exerts shearing and compression forces on the fenders. This combined force is very severe in the case of solid rubber fenders because they are not reinforced against such force. In contrast, Yokohama Pneumatic Rubber Fenders are adequately reinforced using strong tire-cord to cope against such forces as well as internal pressure.

Fig.3-12 Stronger against Shearing Force

3.8 Adaptable to the Tide

Yokohama Pneumatic Rubber Fenders basically float on the water in an unrestricted vertical plane corresponding to the tidal range and ship's vertical movement.
This means that energy absorption always takes place at the most suitable position, and that only one fender is required per dolphin.

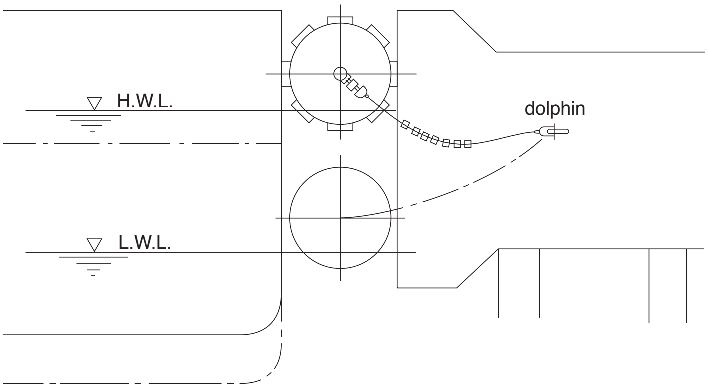


Fig.3-13 Adaptable to Tide

3.9 Simple and Low Cost Installation

The weight of Yokohama Pneumatic Rubber Fenders is supported by the water on which it floats. Therefore, the fender can be moored simply by means of a guy rope or chain, requiring minimal extra cost. It can be removed easily to a suitable jetty or quay when not in use, or transferred to another mooring point whenever required.

Fig.3-14 ϕ2500×4000L-P50 Yokohama Pneumatic Rubber Fenders installed at a dolphin

3.10 Low Maintenance Cost

Maintenance cost is very low. Although the internal pressure will vary with seasonal changes, the air leakage is so minimal that it is sufficient to check the air pressure only once a year. The chain net needs to be replaced only once in 3 or 4 years, depending on ambient conditions.

3.11 Shipping Cost Minimization

In order to minimize the shipping cost of Yokohama Pneumatic Rubber Fenders, the fenders are usually packed and shipped in containers or on pallets in vacuumed and folded down state.

Fig.3-15 Vacuumed and Folded Down Condition for ϕ4500×9000L-P80

4. PRESSURE RATING, TYPES, AND VARIATIONS

4.1 Pressure Rating

There are two initial pressure ratings for Yokohama Pneumatic Rubber Fenders :

1) Pneumatic 50 (P50, Initial internal pressure 50kPa)

2) Pneumatic 80 (P80, Initial internal pressure 80kPa)

4.2 Type Ⅰ (Net Type)

Net-type fenders (Type Ⅰ) are covered with a chain net, wire net or fiber net for small size fenders. Usually these nets have used-tires together with rubber sleeves for additional protection, except fiber net which has only rubber sleeves. Chain nets last longer against corrosion, while wire nets are light and more easily repaired.

4.2.1 Ring Shackle

For fender sizes ϕ500×1000L～ϕ1350×2500L, each end of longitudinal chains or wires of nets is linked together with rings and shackles.

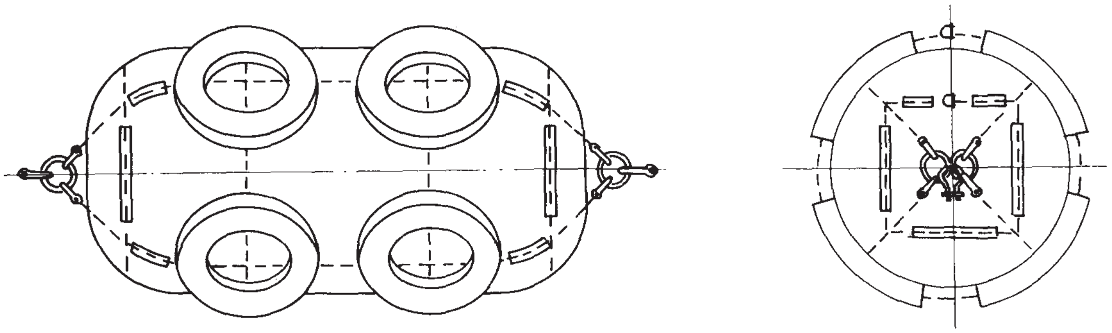


Fig.4-1 Ring Shackle (Fender Size : ϕ500×1000L～ϕ1350×2500L)

4.2.2 Towing Ring

For fender sizes ϕ1500×3000L～ϕ3300×6500L, each end of longitudinal chains or wires of nets is linked together with a towing ring.

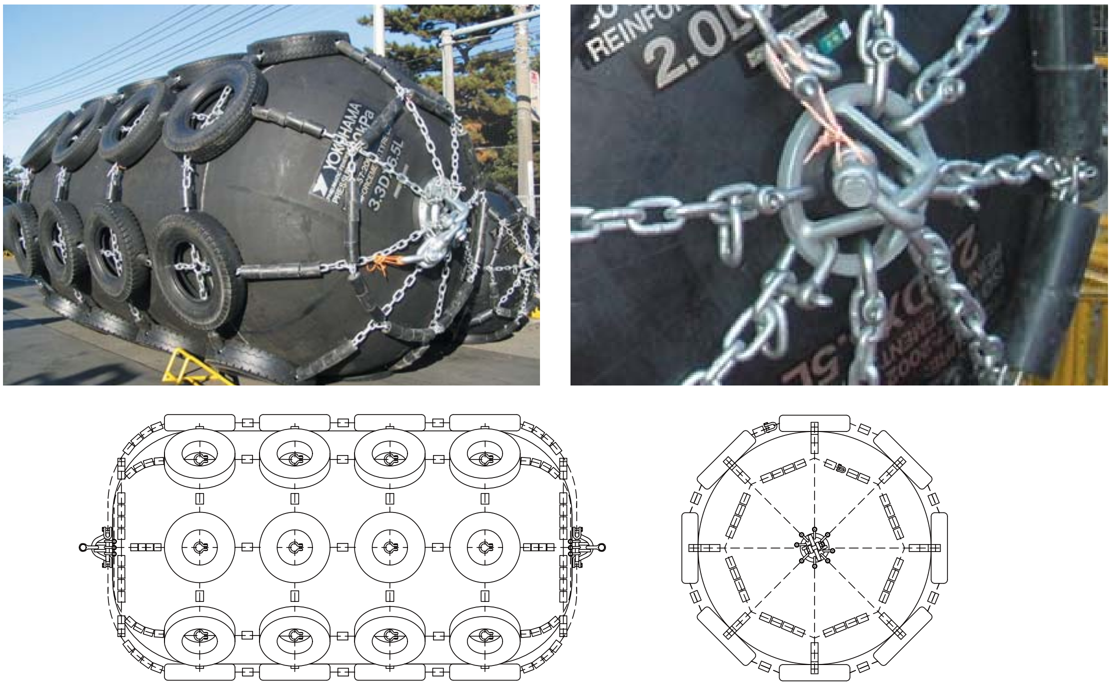


Fig.4-2 Towing Ring（Fender Size：ϕ1500×3000L～ϕ3300×6500L）

4.2.3 Special Towing Ring

For fender sizes ϕ3300×10600L～ϕ4500×12000L, each end of longitudinal chains or wires of nets is linked together with a special towing ring which contains a special built-in swivel joint.

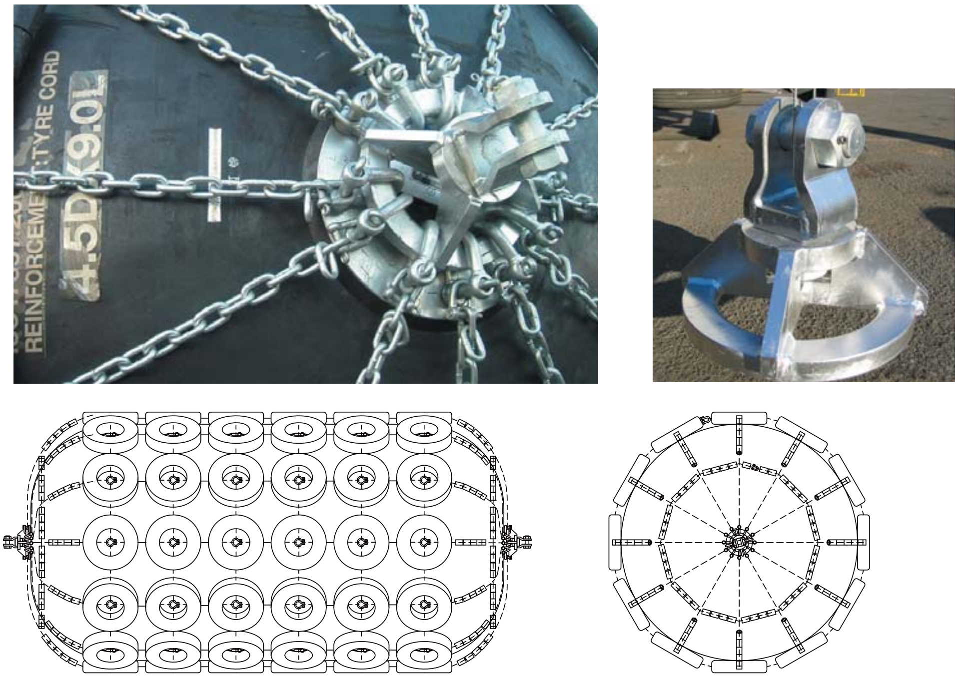


Fig.4-3 Special Towing Ring（Fender Size：ϕ3300×10600L～ϕ4500×12000L）

4.3 Type Ⅱ (Sling Type)

Sling-type fenders (Type Ⅱ) ϕ500×1000L ～ ϕ4500×12000L have an attachment eye on each end for lifting and installation. Handling of sling type fenders is easy due to their lightweight.

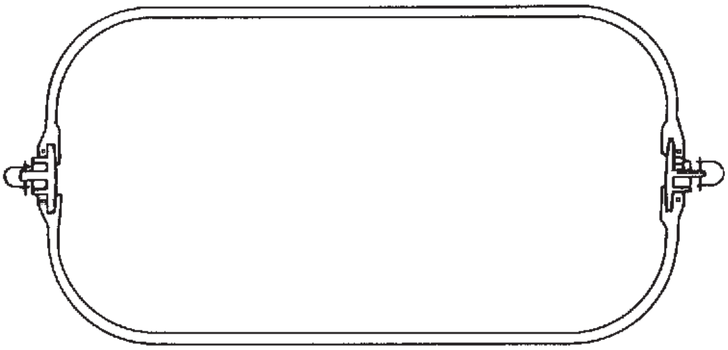


Fig.4-4 Sling Type（Fender Size : ϕ500×1000L～ϕ4500×12000L）

4.4 Design Variations

4.4.1 Net Variations

4.4.1.1 Rubber Sleeve Net

Rubber sleeve nets cover the chain net completely by strong rubber sleeves. The rubber sleeve is made of rubber reinforced with synthetic-tire-cord. The standard colors of the rubber sleeve are black and orange.

4.4.1.2 Aircraft Tire Chain Net

Aircraft tire chain nets use air craft tires, instead of automobile tires, to keep larger stand-off distance and enough protection for the fender body.

4.4.1.3 Rubber Jacket (Up to ϕ2.0m)

Rubber jackets are popular for Oil tankers, LPG-ships and cruise ships applications because of the low risk of spark or damage to the ship's hull.

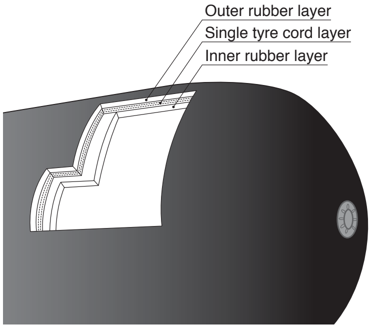
4.4.2 Outer Rubber Variations

4.4.2.1 Grey Rubber

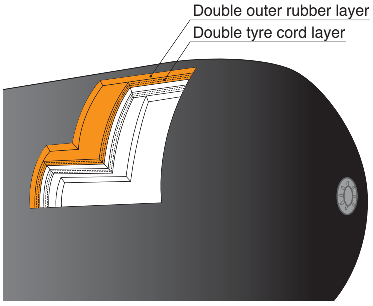
Grey rubber is a specially formulated rubber with color compound added. Creamy white color can be requested instead of grey color as an alternative.

4.4.2.2 Double Cover (ϕ2.5m, ϕ3.3m)

Double cover consists of a single cover with an extra tyre cord layer and outer rubber. It is better resistance to operational damage such as abrasion, cuts and gauges.



Single Cover Construction



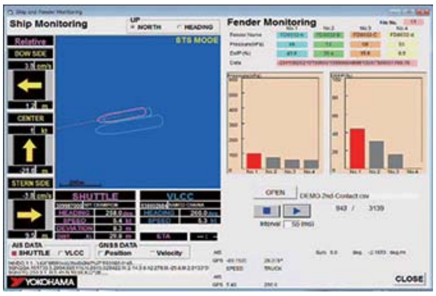
Double Cover Construction

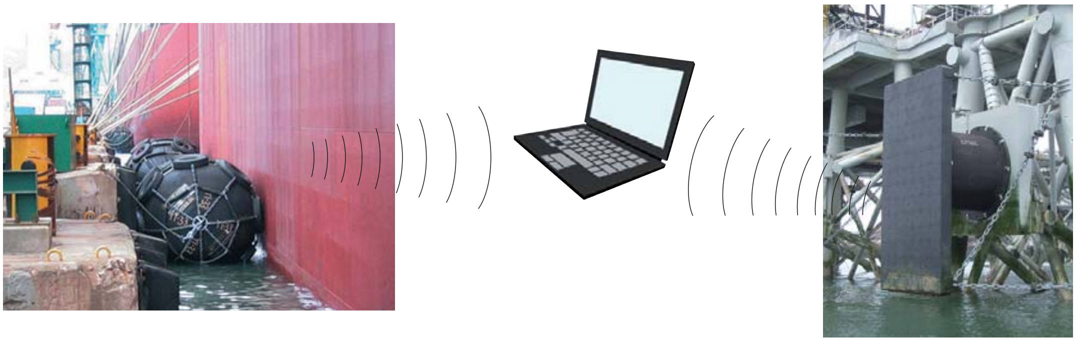
4.4.3 Fender Monitoring System (FMS)

Fender Monitoring System has been developed to monitor offshore Ship-To-Ship (STS) operation. The system incorporates technology from the design of pneumatic fenders and the numerical simulation analysis of dynamic ship motion.

The system can simultaneously monitor the state of pneumatic fenders used as shock absorber between the two ships and the behavior of both ships. This wireless fender-monitoring system

can be also applied to onshore Ship-to-Dock operation anywhere in the world.





4.4.4 Low-Pressure (LP)

The Low-Pressure fender type is a pneumatic fender designed with a lighter body construction. It is popular for application requiring large clearance between the ship and jetty or between two ships but not necessarily needing the high performance of a standard high-pressure pneumatic fender.

4.4.5 Light-Weight

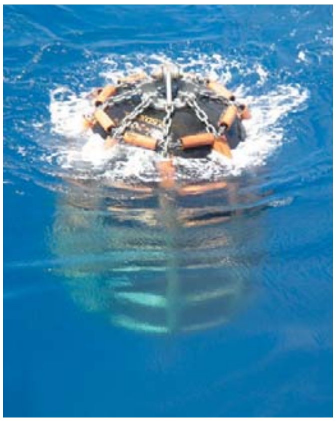
Light-Weight fenders are focused on portability, and are small and light for convenient use with cruise ships, pleasure boats, and other small boats.

4.4.6 Vertical

Vertical-Pneumatic Rubber fenders are specially designed pneumatic fenders that can be water-ballasted and installed vertically.
They are popular with vessels whose berthing point is below the water line such as catamaran ships, semi-submersibles platforms or other submersibles.

4.4.7 Globuoy

Globuoy is a modified pneumatic fender for use as a surface or sub-sea buoy in equipment installation, mooring, anchoring and various offshore operations. It can be used with higher working pressure or can be filled with pressure resistant material for various under water applications. The pneumatic design of the Globuoy makes it easy to handle and launch due to its light weight. Also, because of the flexible reinforced rubber body, it is less prone to damaging or being damaged by the decks or hulls of vessels. It is a non-collapsible buoy in case of over-submergence.



5. BASIC CONSTRUCTION

The Floating-type Yokohama Pneumatic Rubber Fenders are kind of a cylindrical air bag with hemispherical heads at both ends. Basic body construction of this fender consists of an outer rubber layer, cord layers and an inner rubber layer. All of these are vulcanized together, and then proven by hydraulic pressure test.

5.1 Outer Rubber

The outer rubber layer protects the cord layers and inner rubber layer from abrasion and other external forces. This compound has sufficient tensile and tear strength to withstand any weather condition and hard usage as shown in Table 5-1. Standard color is black, but other colors such as grey and creamy white are available on request.

5.2 Synthetic-tire-cord Layer

The reinforcement cord layers, which are made of Synthetic-tire-cord, are arranged at ideal angles to hold the internal pressure and to distribute the stress evenly. As the main fibers of the synthetic-tire-cord are not braided like synthetic canvas fabric or synthetic belt fabric as shown in Fig.5-2, there are advantages for its fatigue-resistance performance and pressure-holding performance.

5.3 Inner Rubber

The inner rubber layer seals the air inside, utilizing a compound equivalent to that of the liner or tube of an automobile tire. The specifications are shown in Table 5-1.

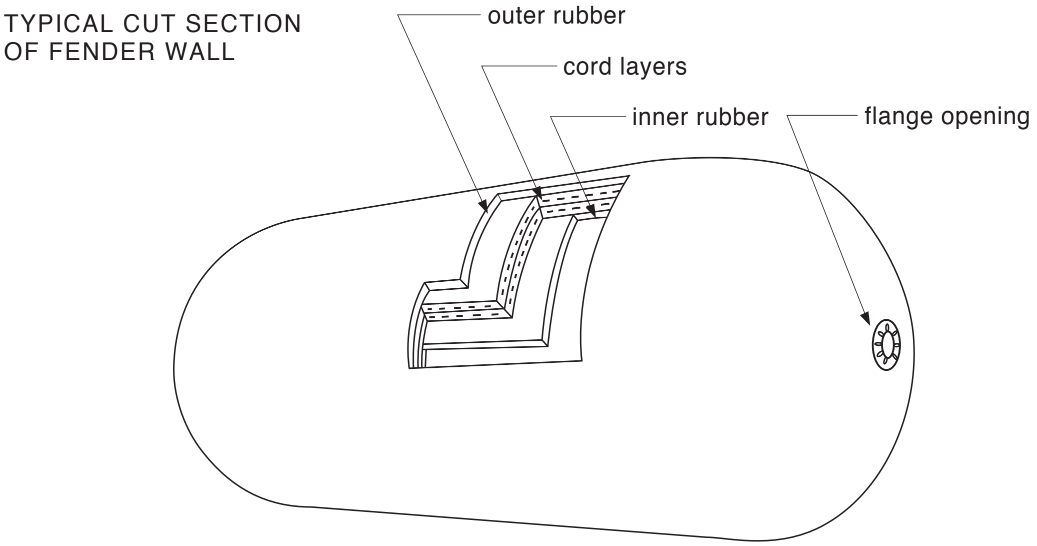


Fig.5-1 Basic Construction of Floating-type Pneumatic Rubber Fenders

Table 5-1 Properties of Outer and Inner Rubber Material

Test Item		Inspection Methods	Outer Rubber	Inner Rubber
Before Aging	Tensile strength	ISO 37 : 2011	18 Mpa or more	10 Mpa or more
	Elongation	ISO 37 : 2011	400% or more.	400% or more.
	Hardness	ISO 7619-1 : 2010	60 ±10 (Durometer hardness Type A)	50 ±10 (Durometer hardness Type A)
After Aging Test method ISO188:1998 70±1C° × 96 hrs	Tensile strength	ISO 37 : 2011	Not less than 80% of the original property	Not less than 80% of the original property
	Elongation	ISO 37 : 2011	Not less than 80% of the original property	Not less than 80% of the original property
	Hardness	ISO 7619-1 : 2010	Not to exceed the original property by more than 8	Not to exceed the original property by more than 8
Tear resistance		ISO 34-1 : 2010	400 N/cm or more	No requirement
Compression test		ISO 815-1 : 2008	30% (70±1C° for 22 hrs) or less	No requirement
Static ozone aging test		ISO 1431-1 : 2012	No cracks after elongation by 20% and exposure to 50 pphm at 40C° for 96 hrs	No requirement

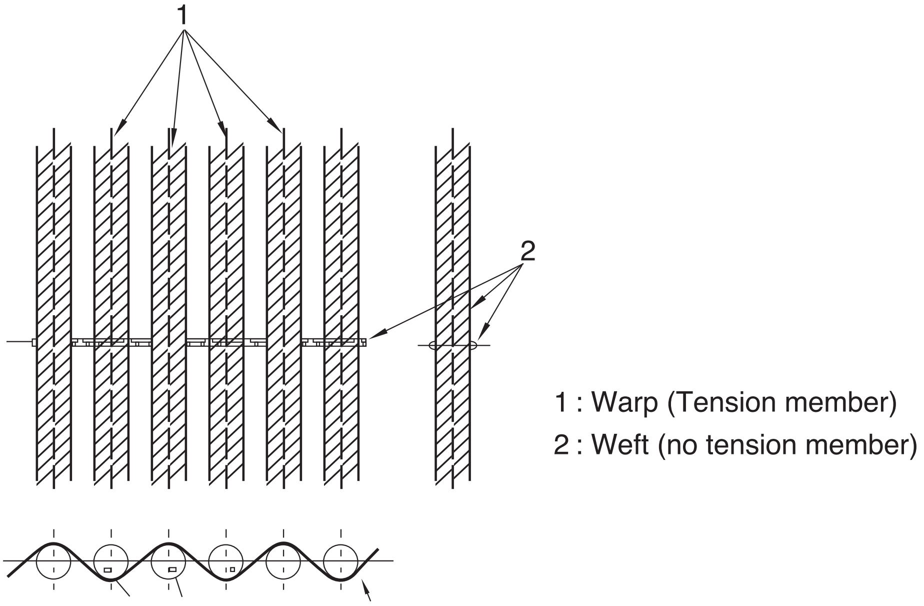


Fig.5-2 Basic Construction of Tyre-Cords

5.4 Bead Ring and Flange Opening

5.4.1 Bead Ring

A steel ring is placed at one or both ends of the fender to hold the end of the reinforcement cord layers. The outside diameter of the bead ring has been designed smaller than 20% of the fender diameter to maintain the fender's safe compression up to 80%.

5.4.2 Flange Opening

A steel flange to which air valves are attached is mounted on the fender to serve as flange opening. The flange opening is designed smaller than 12% of the fender diameter to maintain safe compression up to 80% compression.

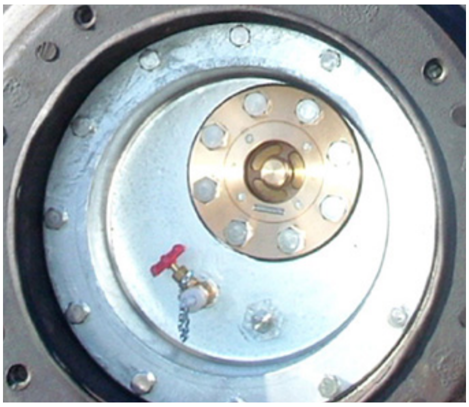
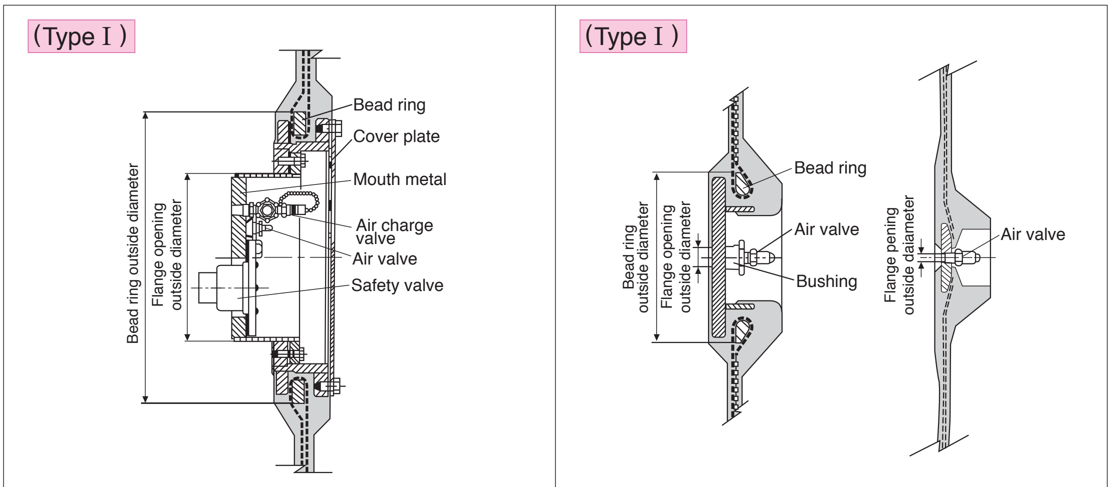
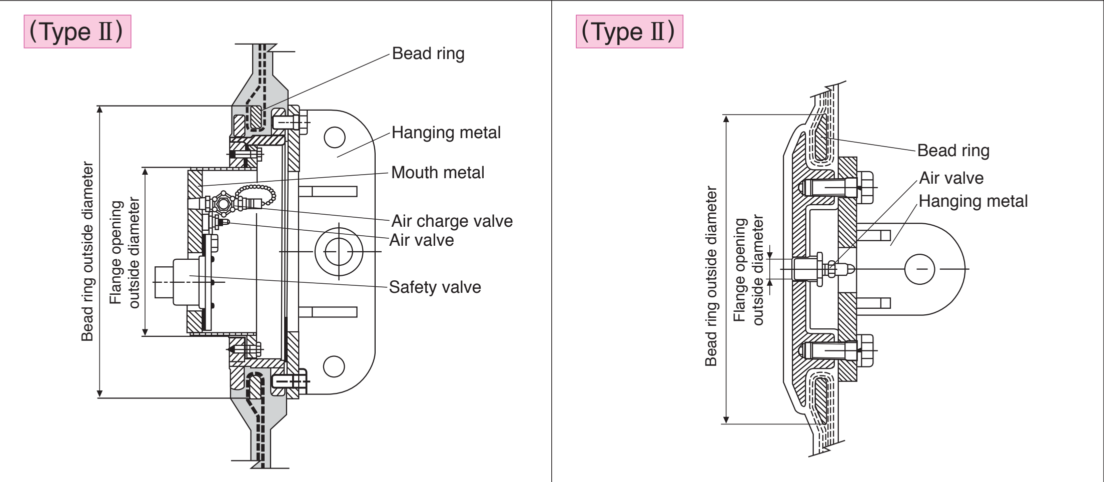


Fig.5-3 Flange Opening for ϕ3300



(Large size)

(Medium and small size)



(Large size)

(Medium and small size)

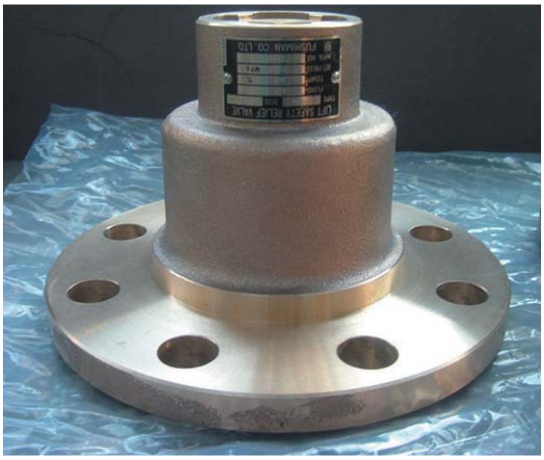
Fig.5-4 Construction of Flange Opening

5.5 Turn-up System

The reinforcement cord layers are turned upward around a bead, which is built-in near the flange opening, except for small sized fenders. This system was originally invented for automobile tires and is quite reliable for distributing loads evenly without any concentration of stress on cord layers.

5.6 Air Valve and Safety Valve

Medium and small sized Floating-type Yokohama Pneumatic Rubber Fenders are equipped with a small air valve, which is the same in size and construction as the air valve of an automobile tire. This valve serves as both air-check, air charge and release valve. On the large size fenders, the small air valve, a globe valve and a safety valve are equipped, the small valve serves for an air-check, the globe valve having a one touch joint coupler serves for air charge and release, and the safety valve serves for releasing excess internal pressure when the fender is accidentally over compressed.



(a) Safety valve for ϕ2500- ϕ3300 fenders

(c) Air valve for air charging and air check

(b) Safety valve for ϕ4500 fenders

Fig.5-5 Air Valve and Safety Valves for Yokohama Floating-type Pneumatic Rubber Fenders

6. SIZES AND PERFORMANCES

6.1 Standard Sizes

The Yokohama Pneumatic Rubber Fenders are available in the following sizes, which are generally expressed in terms of diameter by length.

Fig.6-1 ϕ4500×9000L -P80 Yokohama Pneumatic Rubber Fenders

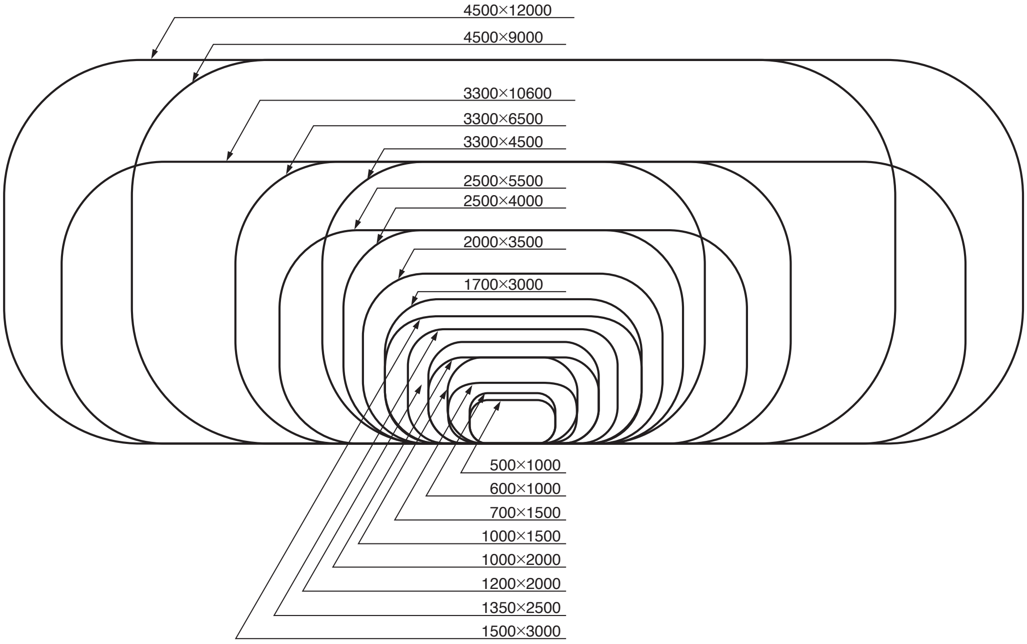


Fig.6-2 Standard Sizes of Yokohama Pneumatic Rubber Fender

6.2 Performance Table

6.2.1 Pneumatic 50 (Metric)

Table 6-1(a) Pneumatic 50 Standard Sizes

Nominal Size	Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
							Approx. Fender Body Weight	Approx. Weight of Net			
Diameter × Length		E	R	p				Chain Net	Wire Net	Synthetic Fiber Net	
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kPa)	(kg)	(kg)	(kg)	(kg)	(kg)
500 × 1000	50	6	64	132	-	200	22	110	30	20	28
600 × 1000	50	8	74	126	-	200	25	120	30	22	32
700 × 1500	50	17	137	135	-	200	45	150	40	37	51
1000 × 1500	50	32	182	122	-	200	73	200	80	51	89
1000 × 2000	50	45	257	132	-	200	88	220	140	57	104
1200 × 2000	50	63	297	126	-	200	131	320	190	68	147
1350 × 2500	50	102	427	130	-	200	200	350	200	-	229
1500 × 3000	50	153	579	132	-	200	250	530	350	-	279
1700 × 3000	50	191	639	128	-	200	290	580	440	-	320
2000 × 3500	50	308	875	128	-	200	405	960	640	-	459
2500 × 4000	50	663	1381	137	175	250	902	1240	910	-	1080
2500 × 5500	50	943	2019	148	175	250	1090	1850	1160	-	1320
3300 × 4500	50	1175	1884	130	175	250	1460	1710	1270	-	1800
3300 × 6500	50	1814	3015	146	175	250	1870	2570	1910	-	2180
3300 × 10600	50	3067	5257	158	175	250	2560	4660	3300	-	3060
4500 × 9000	50	4752	5747	146	175	250	3940	5390	3520	-	4560
4500 × 12000	50	6473	7984	154	175	250	4790	6990	5190	-	-

Table 6-1(b) Pneumatic 50 Popular Non Standard Sizes

Nominal Size	Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
							Approx. Fender Body Weight	Approx. Weight of Net			
Diameter × Length		E	R	p				Chain Net	Wire Net	Synthetic Fiber Net	
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kPa)	(kg)	(kg)	(kg)	(kg)	(kg)
400 × 1500	50	6	87	151	-	200	23	-	-	-	33
600 × 1200	50	10	93	132	-	200	28	-	-	-	35
800 × 1200	50	16	116	122	-	200	48	240	-	-	54
1200 × 1800	50	55	262	122	-	200	123	310	-	-	139
1350 × 3500	50	152	641	141	-	200	255	600	-	-	284
1500 × 2500	50	123	464	126	-	200	221	440	-	-	250
2000 × 3000	50	255	727	122	-	200	367	900	-	-	421
2000 × 4500	50	418	1188	137	-	200	480	1200	-	-	534
2500 × 7700	50	1350	2951	157	175	250	1370	3020	-	-	1600
3300 × 8600	50	2443	4138	154	175	250	2220	3710	-	-	2720
4500 × 6400	50	3238	3796	133	175	250	3400	3900	-	-	3620

Note : 1. Figures on the table comply with requirements of ISO17357-1:2014.
2. Weight of fender body and net may vary ±10%.
3. Special sizes are available upon request.

6.2.2 Pneumatic 80 (Metric)

Table 6-2(a) Pneumatic 80 Standard Sizes

Nominal Size	Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
							Approx. Fender Body Weight	Approx. Weight of Net			
Diameter × Length		E	R	p				Chain Net	Wire Net	Synthetic Fiber Net	
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kPa)	(kg)	(kg)	(kg)	(kg)	(kg)
500 × 1000	80	8	85	174	-	250	24	110	30	20	30
600 × 1000	80	11	98	166	-	250	27	120	30	22	34
700 × 1500	80	24	180	177	-	250	47	150	40	37	53
1000 × 1500	80	45	239	160	-	250	76	200	80	51	92
1000 × 2000	80	63	338	174	-	250	92	220	140	57	108
1200 × 2000	80	88	390	166	-	250	135	320	190	68	151
1350 × 2500	80	142	561	170	-	250	205	350	200	-	234
1500 × 3000	80	214	761	174	-	250	277	530	350	-	306
1700 × 3000	80	267	840	168	-	250	316	580	440	-	346
2000 × 3500	80	430	1150	168	-	250	413	970	690	-	467
2500 × 4000	80	925	1815	180	230	300	1010	1250	910	-	1190
2500 × 5500	80	1317	2653	195	230	300	1230	1860	1170	-	1460
3300 × 4500	80	1640	2476	171	230	300	1720	1720	1280	-	2050
3300 × 6500	80	2532	3961	191	230	300	2200	2580	1990	-	2530
3300 × 10600	80	4281	6907	208	230	300	3030	4660	3300	-	3520
4500 × 9000	80	6633	7551	192	230	300	4380	5440	3580	-	-
4500 × 12000	80	9037	10490	202	230	300	5330	7030	5230	-	-

Table 6-2(b) Pneumatic 80 Popular Non Standard Sizes

Nominal Size	Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
							Approx. Fender Body Weight	Approx. Weight of Net			
Diameter × Length		E	R	p				Chain Net	Wire Net	Synthetic Fiber Net	
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kPa)	(kg)	(kg)	(kg)	(kg)	(kg)
400 × 1500	80	9	114	199	-	250	24	-	-	-	34
600 × 1200	80	14	122	174	-	250	30	-	-	-	37
800 × 1200	80	23	153	160	-	250	50	240	-	-	56
1200 × 1800	80	77	344	160	-	250	127	310	-	-	143
1350 × 3500	80	213	842	185	-	250	261	600	-	-	290
1500 × 2500	80	171	610	166	-	250	244	440	-	-	273
2000 × 3000	80	356	955	160	-	250	375	900	-	-	429
2000 × 4500	80	584	1560	179	-	250	488	1210	-	-	542
2500 × 7700	80	1884	3876	206	230	300	1550	3030	-	-	1780
3300 × 8600	80	3410	5437	202	230	300	2620	3710	-	-	3110
4500 × 6400	80	4518	4988	174	230	300	3760	3910	-	-	-

Note : 1. Figures on the table comply with requirements of ISO17357-1:2014.
2. Weight of fender body and net may vary ±10%.
3. Special sizes are available upon request.

6.2.3 Pneumatic 50 (U.S. Customary)

Table 6-3(a) Pneumatic 50 Standard Sizes

Nominal Size		Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type I)				Weight of Sling Type (Type II)
Diameter × Length			E	R	p			Approx. Fender Body Weight	Approx. Weight of Net			
									Chain Net	Wire Net	Synthetic Fiber Net	
(ft × ft)	(mm × mm)	(kips)	(kips)	(kips)	(kips/ft^2)	(psi)	(psi)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1.6 × 3	500 × 1000	7.3	4.4	14.4	2.72	-	29.0	49	243	66	44	62
2 × 3	600 × 1000	7.3	5.9	16.7	2.59	-	29.0	55	265	66	49	71
2.3 × 5	700 × 1500	7.3	12.5	30.8	2.78	-	29.0	99	331	88	82	112
3 × 5	1000 × 1500	7.3	23.6	41.0	2.51	-	29.0	161	441	176	112	196
3 × 6.5	1000 × 2000	7.3	33.2	57.8	2.72	-	29.0	194	485	309	126	229
4 × 6.5	1200 × 2000	7.3	46.5	66.8	2.59	-	29.0	289	706	419	150	324
4.4 × 8	1350 × 2500	7.3	75.3	96.1	2.67	-	29.0	441	772	441	-	505
5 × 10	1500 × 3000	7.3	113	130	2.72	-	29.0	551	1169	772	-	615
5.6 × 10	1700 × 3000	7.3	141	144	2.63	-	29.0	639	1279	970	-	705
6.5×11.5	2000 × 3500	7.3	227	197	2.63	-	29.0	893	2117	1411	-	1012
8 × 13	2500 × 4000	7.3	489	311	2.82	25.4	36.3	1989	2734	2007	-	2381
8 × 18	2500 × 5500	7.3	696	454	3.04	25.4	36.3	2403	4079	2558	-	2911
11 × 15	3300 × 4500	7.3	867	424	2.67	25.4	36.3	3219	3771	2800	-	3969
11 × 21	3300 × 6500	7.3	1339	678	3.00	25.4	36.3	4123	5667	4212	-	4807
11 × 35	3300 × 10600	7.3	2264	1183	3.25	25.4	36.3	5645	10275	7277	-	6747
15 × 30	4500 × 9000	7.3	3507	1293	3.00	25.4	36.3	8688	11885	7762	-	-
15 × 40	4500 × 12000	7.3	4777	1796	3.17	25.4	36.3	10562	15413	11444	-	10054

Table 6-3(b) Pneumatic 50 Popular Non Standard Sizes

Nominal Size		Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type I)				Weight of Sling Type (Type II)
Diameter × Length			E	R	p			Approx. Fender Body Weight	Approx. Weight of Net			
									Chain Net	Wire Net	Synthetic Fiber Net	
(ft × ft)	(mm × mm)	(kips)	(kips)	(kips)	(kips/ft^2)	(psi)	(psi)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1.3 × 5	400 × 1500	7.3	4.4	19.6	3.11	-	29.0	51	-	-	-	73
2 × 4	600 × 1200	7.3	7.4	20.9	2.72	-	29.0	62	-	-	-	77
2.6 × 4	800 × 1200	7.3	11.8	26.1	2.51	-	29.0	10	529	-	-	119
4 × 6	1200 × 1800	7.3	40.6	59.0	2.51	-	29.0	271	684	-	-	306
4.4×11.5	1350 × 3500	7.3	112	144	2.90	-	29.0	562	1323	-	-	626
5 × 8	1500 × 2500	7.3	90.8	104	2.59	-	29.0	487	970	-	-	551
6.5 × 10	2000 × 3000	7.3	188	164	2.51	-	29.0	809	1985	-	-	928
6.5 × 15	2000 × 4500	7.3	309	267	2.82	-	29.0	1058	2646	-	-	1177
8 × 25	2500 × 7700	7.3	996	664	3.23	25.4	36.3	3021	6659	-	-	3528
11 × 28	3300 × 8600	7.3	1803	931	3.17	25.4	36.3	4895	8181	-	-	5998
15 × 21	4500 × 6400	7.3	2390	854	2.74	25.4	36.3	7497	8600	-	-	7981

Note : 1. Figures on the table comply with requirements of ISO17357-1:2014.
2. Weight of fender body and net may vary ±10%.
3. Special sizes are available upon request.

6.2.4 Pneumatic 80 (U.S. Customary)

Table 6-4 (a) Pneumatic 80 Standard Sizes

Nominal Size		Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
Diameter × Length			E	R	p			Approx. Fender Body Weight	Approx. Weight of Net			
									Chain Net	Wire Net	Synthetic Fiber Net	
(ft × ft)	(mm × mm)	(kips)	(kips)	(kips)	(kips/ft^2)	(psi)	(psi)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1.6 × 3	500 × 1000	11.6	5.9	19.1	3.58	-	36.3	53	243	66	44	66
2 × 3	600 × 1000	11.6	8.1	22.1	3.41	-	36.3	60	265	66	49	75
2.3 × 5	700 × 1500	11.6	17.7	40.5	3.64	-	36.3	104	331	88	82	117
3 × 5	1000 × 1500	11.6	33.2	53.8	3.29	-	36.3	168	441	176	112	203
3 ×6.5	1000 × 2000	11.6	46.5	76.1	3.58	-	36.3	203	485	309	126	238
4 ×6.5	1200 × 2000	11.6	64.9	87.8	3.41	-	36.3	298	706	419	150	333
4.4 × 8	1350 × 2500	11.6	105	126	3.50	-	36.3	452	772	441	-	516
5 × 10	1500 × 3000	11.6	158	171	3.58	-	36.3	611	1169	772	-	675
5.6 × 10	1700 × 3000	11.6	197	189	3.46	-	36.3	697	1279	970	-	763
6.5×11.5	2000 × 3500	11.6	317	259	3.46	-	36.3	911	2139	1521	-	1030
8 × 13	2500 × 4000	11.6	683	408	3.70	33.4	43.5	2227	2756	2007	-	2624
8 × 18	2500 × 5500	11.6	972	597	4.01	33.4	43.5	2712	4101	2580	-	3219
11 × 15	3300 × 4500	11.6	1210	557	3.52	33.4	43.5	3793	3793	2822	-	4520
11 × 21	3300 × 6500	11.6	1869	891	3.93	33.4	43.5	4851	5689	4388	-	5578
11 × 35	3300 × 10600	11.6	3160	1554	4.28	33.4	43.5	6681	10275	7277	-	7762
15 × 30	4500 × 9000	11.6	4896	1699	3.95	33.4	43.5	9658	11995	7894	-	-
15 × 40	4500 × 12000	11.6	6670	2360	4.16	33.4	43.5	11753	15501	11532	-	-

Table 6-4 (b) Pneumatic 80 Popular Non Standard Sizes

Nominal Size		Initial Internal Pressure	Guaranteed Energy Absorption (GEA)	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting pressure	Testing Pressure	Weight of Net Type (Type Ⅰ)				Weight of Sling Type (Type Ⅱ)
Diameter × Length			E	R	p			Approx. Fender Body Weight	Approx. Weight of Net			
									Chain Net	Wire Net	Synthetic Fiber Net	
(ft × ft)	(mm × mm)	(kips)	(kips)	(kips)	(kips/ft^2)	(psi)	(psi)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1.3 × 5	400 × 1500	11.6	6.6	25.7	4.09	-	36.3	53	-	-	-	75
2 × 4	600 × 1200	11.6	10.3	27.5	3.58	-	36.3	66	-	-	-	82
2.6 × 4	800 × 1200	11.6	17.0	34.4	3.29	-	36.3	110	529	-	-	123
4 × 6	1200 × 1800	11.6	56.8	77.4	3.29	-	36.3	280	684	-	-	315
4.4×11.5	1350 × 3500	11.6	157	189	3.81	-	36.3	576	1323	-	-	639
5 × 8	1500 × 2500	11.6	126	137	3.41	-	36.3	538	970	-	-	602
6.5 × 10	2000 × 3000	11.6	263	215	3.29	-	36.3	827	1985	-	-	946
6.5 × 15	2000 × 4500	11.6	431	351	3.68	-	36.3	1076	2668	-	-	1195
8 × 25	2500 × 7700	11.6	1391	872	4.24	33.4	43.5	3418	6681	-	-	3925
11 × 28	3300 × 8600	11.6	2517	1223	4.16	33.4	43.5	5777	8181	-	-	6858
15 × 21	4500 × 6400	11.6	3335	1122	3.58	33.4	43.5	8291	8622	-	-	-

Note : 1. Figures on the table comply with requirements of ISO17357-1:2014.
2. Weight of fender body and net may vary ±10%.
3. Special sizes are available upon request.

6.2.5 Light-Weight

Nominal size Diameter × Length	Initial Internal Pressure	Guaranteed Energy Absorption GEA	Reaction Force at GEA	Hull Pressure at GEA	Testing Pressure	Weight of Sling Type (Type Ⅱ)
		E	R	p		
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kg)
500 × 1000	80	8	85	174	250	24
1000 × 1500	80	45	239	160	250	65

(U.S.Customary)

Nominal size Diameter × Length		Initial Internal Pressure	Guaranteed Energy Absorption GEA	Reaction Force at GEA	Hull Pressure at GEA	Testing Pressure	Weight of Sling Type (Type Ⅱ)
			E	R	p		
(ft × ft)	(mm × mm)	(psi)	(ft-kips)	(kips)	(kips/ft^2)	(psi)	(lbs)
1.6 × 3	500 × 1000	11.6	5.9	19.1	3.58	36.3	53
3 × 5	1000 × 1500	11.6	33.2	53.8	3.29	36.3	143

6.2.6 Low-Pressure

Nominal size Diameter × Length	Initial Internal Pressure	Guaranteed Energy Absorption GEA	Reaction Force at GEA	Hull Pressure at GEA	Testing Pressure	Weight of Sling Type (Type Ⅱ)
		E	R	p		
(mm × mm)	(kPa)	(kNm)	(kN)	(kPa)	(kPa)	(kg)
2500 × 9100	10	676	1901	88	40	1190
3300 × 12700	10	1565	3439	89	40	1930

(U.S.Customary)

Nominal size Diameter × Length		Initial Internal Pressure	Guaranteed Energy Absorption GEA	Reaction Force at GEA	Hull Pressure at GEA	Safety Valve Setting Pressure	Testing Pressure	Weight of Sling Type (Type Ⅱ)
			E	R	p			
(ft × ft)	(mm × mm)	(psi)	(ft-kips)	(kips)	(kips/ft^2)	(psi)	(psi)	(lbs)
8 × 30	2500 × 9100	1.5	499	427.7	1.81	-	5.8	2624
11 × 42	3300 × 12700	1.5	1155	773.8	1.83	-	5.8	4366

6.2.7 Vertical-Pneumatic

Nominal size Diameter × Length	Initial Internal Pressure	Weight of Body
(mm × mm)	(kPa)	(kg)
2000 × 6000	50	1000
2500 × 9100	50	2200
3300 × 6500	50	3000
3300 × 8600	50	3600
3300 × 10600	50	4100
4500 × 9000	50	5810
4500 × 12000	50	7680

(U.S.Customary)

Nominal size Diameter × Length		Initial Internal Pressure	Weight of Body
(ft × ft)	(mm × mm)	(psi)	(lbs)
6.5 × 20	2000 × 6000	7.3	2205
8 × 30	2500 × 9100	7.3	4851
11 × 21	3300 × 6500	7.3	6615
11 × 28	3300 × 8600	7.3	7938
11 × 35	3300 × 10600	7.3	9041
15 × 30	4500 × 9000	7.3	12811
15 × 40	4500 × 12000	7.3	16934

6.3 Safety Design and Pressure Requirements

6.3.1 Over-compression

The guaranteed energy absorption of Yokohama Pneumatic Rubber Fenders is the energy absorption at 60% deflection. This figure should be observed in engineering design and in actual operation. However, even if the fender is accidentally over-deflected beyond this guaranteed value, the Yokohama Pneumatic Rubber Fender has a wide safety margin as shown in Fig.6-4 and Table 6-5 below. These curves and table express the capacity for energy absorption and reaction force until the time of ultimate deflection when the deflection of fender reach the largest diameter of mouthpiece metal parts. This is shown by using the guaranteed energy absorption and reaction force as the index value of 1.

The figures and table show the wide safety margin of our pneumatic fenders in absorbing energy and low reaction force.

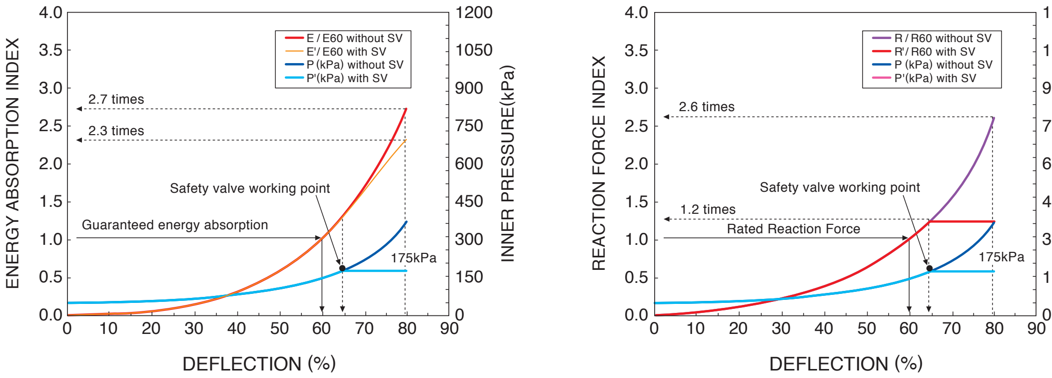


Fig.6-4 Safety Design at Over-compression

Table 6-5 Safety Design at Over-compression

	At Guaranteed Energy Absorption	At Safety Valve Operating Point (Approx)	–	–	At Deflection limited by Mouthpiece Metal (Approx.)
With Safety Valve (SV) :					
Energy Absorption (Index)	1.0	1.3	1.6	2.0	2.3
Reaction Force (Index)	1.0	1.2	1.2	1.2	1.2
Internal Pressure (kPa)	146	175	175	175	175
DEF (%)	60 (%)	65 (%)	70 (%)	75 (%)	80 (%)
Without Safety Valve (SV) :					
Energy Absorption (Index)	1.0	1.3	1.7	2.1	2.7
Reaction Force (Index)	1.0	1.2	1.5	2.0	2.6
Internal Pressure (kPa)	146	175	215	274	367
DEF (%)	60 (%)	65 (%)	70 (%)	75 (%)	80 (%)

Note : 1. Table shows study results based on a ϕ3300 × 6500L pneumatic 50 fender.
2. They are studied based on the condition that air release capacity of the safety valve is not exceeded.

6.3.2 Endurable Pressure at 0% and 60% Deflection

Minimum endurable pressure, the safety valve pressure and the test pressure for each size of Pneumatic 50 and Pneumatic 80 are shown below.

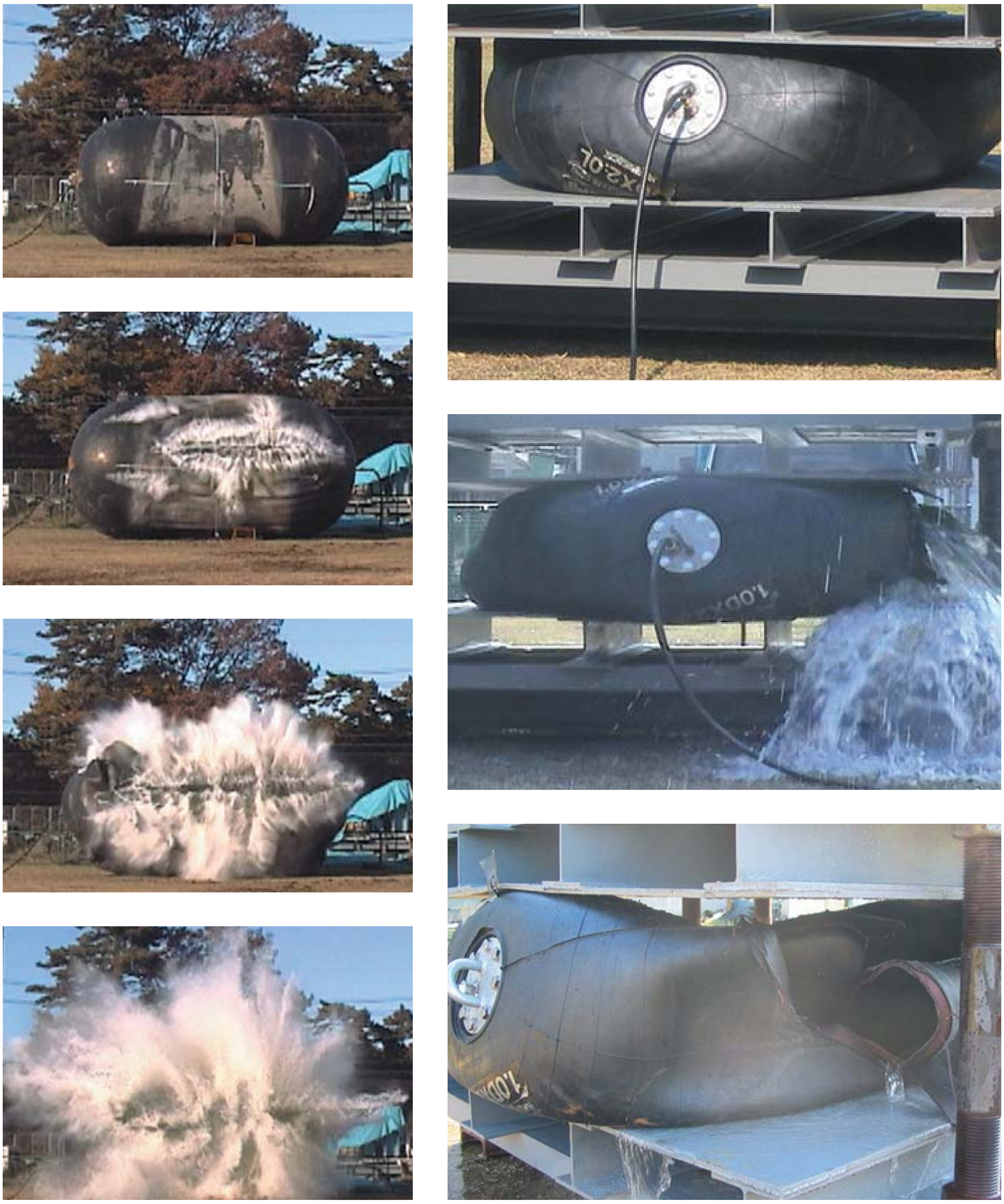
Table 6-6 Pressure Requirements (Pneumatic 50)

Nominal size Diameter × Length (mm × mm)	Internal pressure		Minimum endurable pressure		Safety-valve pressure setting (kPa)	Test pressure at 0% deflection (kPa)
	at 0% deflection (kPa)	at 60% deflection (kPa)	at 0% deflection (kPa)	at 60% deflection (kPa)		
500 × 1000	50	132	300	462	-	200
600 × 1000	50	126	300	441	-	200
700 × 1500	50	135	300	473	-	200
1000 × 1500	50	122	300	427	-	200
1000 × 2000	50	132	300	462	-	200
1200 × 2000	50	126	300	441	-	200
1350 × 2500	50	130	300	455	-	200
1500 × 3000	50	132	300	462	-	200
1700 × 3000	50	128	300	448	-	200
2000 × 3500	50	128	300	448	-	200
2500 × 4000	50	137	350	480	175	250
2500 × 5500	50	148	350	518	175	250
3300 × 4500	50	130	350	455	175	250
3300 × 6500	50	146	350	511	175	250
3300 × 10600	50	158	350	553	175	250
4500 × 9000	50	146	350	511	175	250
4500 × 12000	50	154	350	539	175	250

Table 6-7 Pressure Requirements (Pneumatic 80)

Nominal size Diameter × Length (mm × mm)	Internal pressure		Minimum endurable pressure		Safety-valve pressure setting (kPa)	Test pressure at 0% deflection (kPa)
	at 0% deflection (kPa)	at 60% deflection (kPa)	at 0% deflection (kPa)	at 60% deflection (kPa)		
500 × 1000	80	174	480	609	-	250
600 × 1000	80	166	480	581	-	250
700 × 1500	80	177	480	620	-	250
1000 × 1500	80	160	480	560	-	250
1000 × 2000	80	174	480	609	-	250
1200 × 2000	80	166	480	581	-	250
1350 × 2500	80	170	480	595	-	250
1500 × 3000	80	174	480	609	-	250
1700 × 3000	80	168	480	588	-	250
2000 × 3500	80	168	480	588	-	250
2500 × 4000	80	180	560	630	230	300
2500 × 5500	80	195	560	683	230	300
3300 × 4500	80	171	560	599	230	300
3300 × 6500	80	191	560	669	230	300
3300 × 10600	80	208	560	728	230	300
4500 × 9000	80	192	560	672	230	300
4500 × 12000	80	202	560	707	230	300

The minimum endurable pressures at 0% compression and 60% compression are the most important parameter in the design of a pneumatic fender. Therefore, more than twenty prototype fenders have been burst to establish the design standard to keep this pressure strength for all Yokohama Pneumatic Rubber Fenders.



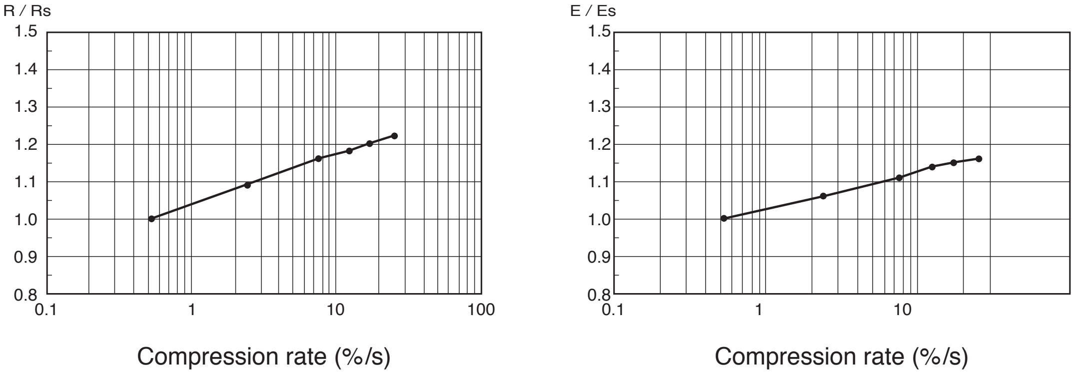
(a) Burst test at 0% deflection

(b) Burst test at 60% deflection

Fig.6-5 Burst Tests for Yokohama Pneumatic Rubber Fender

6.4 Fender Compression Speed

Performance requirements of reaction force and energy absorption for Yokohama Pneumatic Rubber Fenders are basically evaluated for static conditions with a constant slow compression speed of 0.001m/s. However, during actual ship berthing operations, the Yokohama Pneumatic Rubber Fenders are dynamically compressed at speeds over 0.05m/s. The Fig.6-6 below shows the effect of compression speed at 60% deflection against the static rated values on reaction force and energy absorption. The reaction force and energy absorption increase together with compression rate. In actual ship berthing conditions those values are about 20% higher compared to those of static compression.



(a) Reaction force

(b) Energy absorption

Fig.6-6 Compression Speed Effect on Performance for Yokohama Pneumatic Rubber Fenders

6.5 Temperature Effect

The performance of Yokohama Pneumatic Rubber Fenders is engineered based on air pressure. Therefore, the performance of the fenders is stable relative to temperature variations when the initial internal pressure is set to be the specified pressure.

7. FENDER SELECTION

7.1 Ship-to-Ship

The fender selection procedure for ship-to-ship operations is outlined below.
Two ship types, sizes and weather conditions such as Calm, Moderate and Rough are initially confirmed.

7.1.1 OCIMF Table Selection

Equivalent displacement coefficient ; "C" is calculated, and fenders are selected tentatively by using the table in OCIMF Ship-to-Ship Transfer Guide ; "**OCIMF Table Selection**", Table 7-1. In this case, initial internal pressure of the fender shall be 50kPa (Pneumatic 50). The selections are designed based on Calm weather condition, therefore if the weather is confirmed as Calm, the fender system can be simply selected from the tables.

Table 7-1 Quick Reference Guide to Fender Selection for STS Operations

PETROLEUM, CHEMICALS and LIQUEFIED GASSES				
Equivalent Displacement Coefficient (C)	Relative Velocity	Berthing Energy	Suggested Fenders	
Tonnes	m / s	Tonnes.m	Diameter × Length (m)	Quanitity
1,000	0.30	2.4	1.0 × 2.0	3 or more
3,000	0.30	7.0	1.5 × 3.0	〃
6,000	0.30	14.0	2.5 × 5.5	〃
10,000	0.25	17.0	2.5 × 5.5	〃
30,000	0.25	40.0	3.3 × 6.5	4 or more
50,000	0.20	48.0	3.3 × 6.5	〃
100,000	0.15	54.0	3.3 × 6.5	〃
150,000	0.15	71.0	3.3 × 6.5	5 or more
200,000	0.15	93.0	3.3 × 6.5	〃
330,000	0.15	155.0	4.5 × 9.0	4 or more
500,000	0.15	231.0	4.5 × 9.0	〃

Notes : 1. "Ship-to-Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases, CDI, ICS, OCIMF, SIGTTO 2013"

2. "C" is calculated as per equation ; $C = \frac{2 \times DisplacementShipA \times DisplacementShipB}{DisplacementShipA + DisplacementShipB}$

3. If the C is between two coefficients, the fender size shall be selected for the larger coefficient. in the tables.

7.1.2 Berthing Energy Selection

Berthing energy of the two ships is then calculated ; "**Berthing Energy Selection**". If energy absorption capacity of the tentative selected fender (Ef) is larger than the calculated berthing energy (E), it is confirmed that a suitable fender selection has been made. If the fender energy absorption capacity is less than the calculated berthing energy, the tentatively selected fender shall be upgraded.

7.1.3 Fender Selection procedure

Fender selection procedure for ship-to-ship operations is illustrated below.

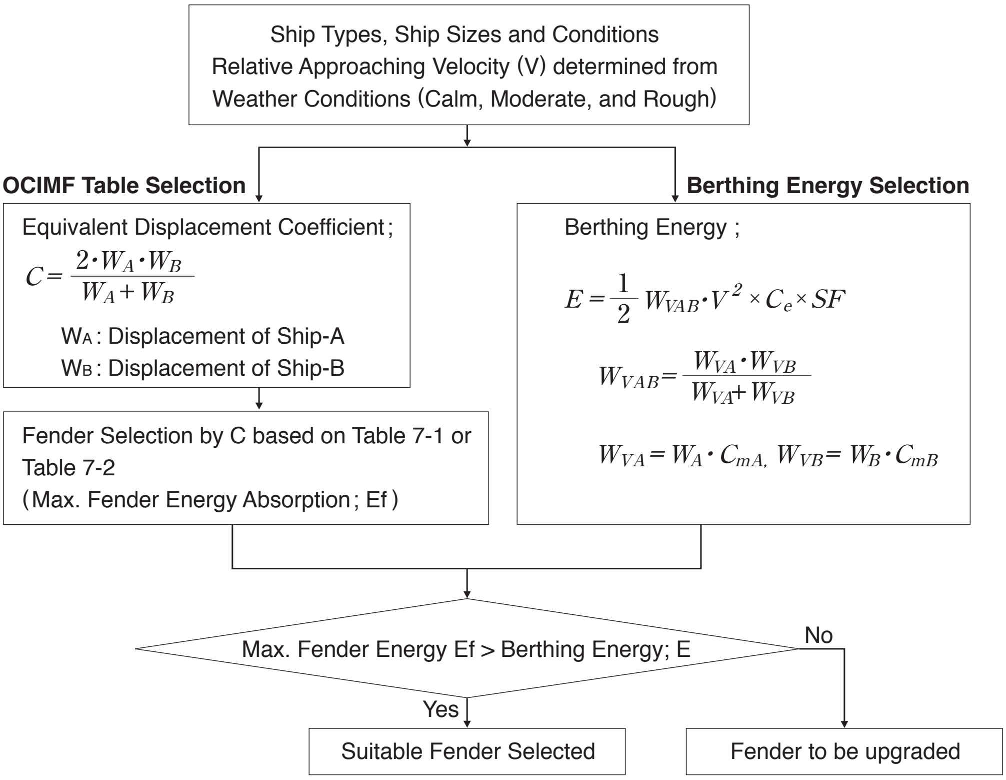


Fig.7-1 Fender Selection for Ship-to-Ship Usage

7.1.4 Equivalent Displacement Coefficient

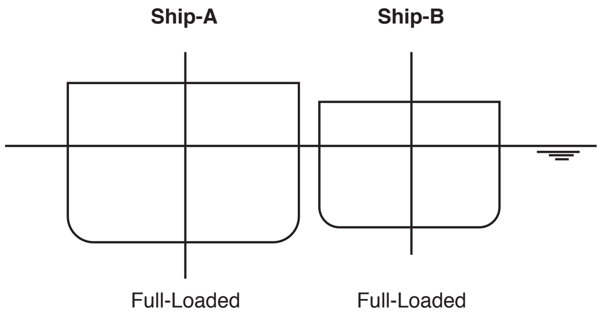
The equivalent displacement coefficient will vary depending on each ship particulars and the type of Ship-to-Ship operation. The three types of Ship-to-Ship operations are described in Table 7-2 below.

Table 7-2 Quick Reference Guide to Fender Selection for STS Operations

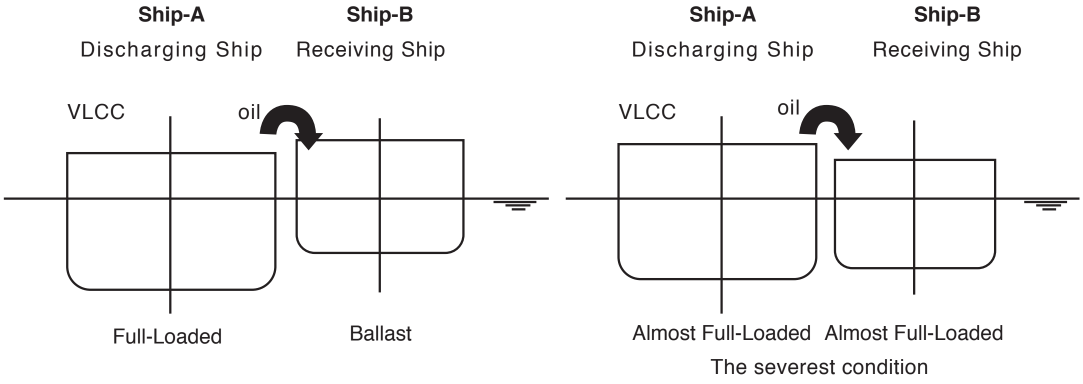
	Ship-A Larger Ship	Ship-B Smaller Ship
(i) Full-Full berthing	Discharging ship ; (Full)	Receiving ship (Full)
(ii) Ordinary lightering	Discharging ship ; (Full)	Receiving ship (Ballast)
(iii) Reverse lightering	Receiving ship ; (Ballast)	Discharging ship (Full)

It is obvious from Fig.7-2 below that ship's displacement at the ordinary lightering or the reverse lightering operation is smaller compared to that for the full-full berthing, however, at the severest condition when the two vessels are both almost full, the displacement become similar to condition of the full-full berthing and therefore the fender system should be selected considering the full-full berthing even in case of the ordinary lightering and the reverse lightering operation.

(i) Full Covered Berthing



(ii) Ordinary lightering



(iii) Reverse lightering

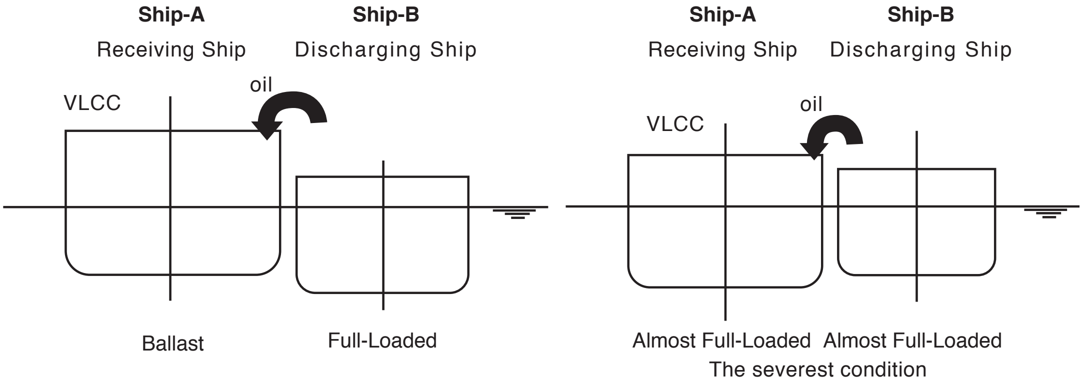


Fig.7-2 Equivalent Displacement Coefficient in Ship-to-Ship Operations

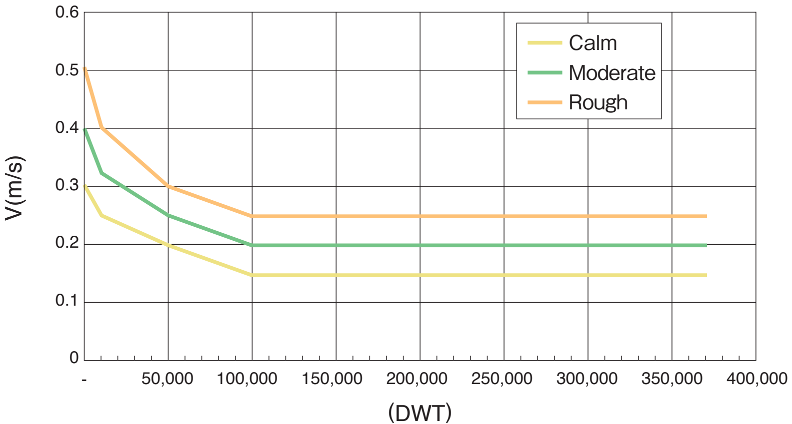
7.1.5 Berthing Energy

The berthing energy needs to be calculated considering weather conditions, categorized by the three conditions Calm, Moderate and Rough, and the approaching velocities to calculate the berthing energy are assumed to be as shown in Table 7-3 and Fig.7-3. These are obtained from various industry references and standards. The three different weather conditions are defined by sea state and significant wave height as shown in Table 7-3.

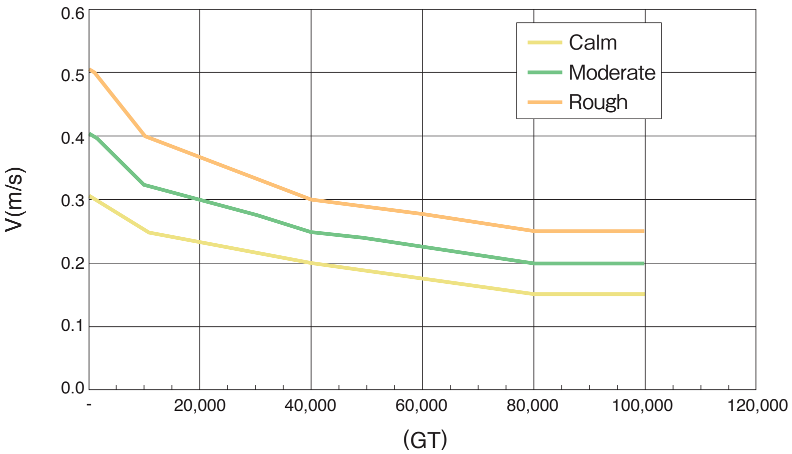
This table shows figures for tankers, but it can be applied to other kinds of ships, if their virtual weights correspond to those in the table.

Table 7-3 Relative Approaching Velocity for Each Weather Condition in STS Operations

DWT	Calm Sea State : 0-3 Wave Height (m) : 0-1.25	Moderate Sea State : 4 Wave Height (m) : 1.25-2.5	Rough Sea State : 5 Wave Height (m) : 2.5-4.0
Less than 10,000	0.30 m/s	0.40 m/s	0.50 m/s
10,000 – 50,000	0.25 m/s	0.325 m/s	0.40 m/s
50,000 – 100,000	0.20 m/s	0.25 m/s	0.30 m/s
Over 100,000	0.15 m/s	0.20 m/s	0.25 m/s



(a) Petroleum and others



(b) Liquefied Gases

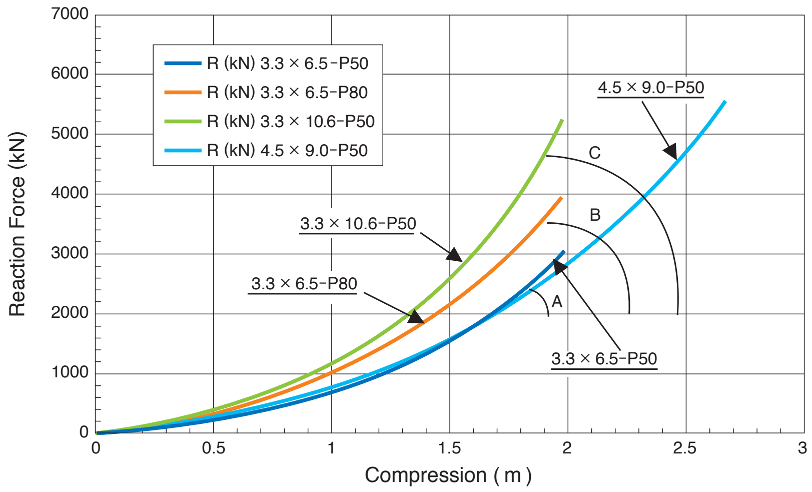
Fig.7-3 Relative Approaching Velocity Based on Weather Condition in STS Operations

7.1.6 Safety factor

A safety factor (SF) value from 1.0 to 2.0 for the berthing energy shall be considered for abnormal berthing conditions.

7.1.7 Fender upgrade

When the fenders need to be upgraded, increasing the fender diameter is preferable. Increasing the length or initial internal pressure from pressure 50kPa to 80kPa is not recommended. If the length or internal pressure is increased, the reaction force and energy absorption are increased. However, the gradient of the curves become steeper without providing any significant increase in allowable compression capacity as shown in Fig.7-4. On the other hand, in the case of using a larger diameter fender keeping the pressure 50kPa, the performance curves of the fenders have almost the same gradient, and the allowable compression capacity is increased. Therefore the larger diameter fender is preferable to keep safe stand-off distance between two ships during berthing and mooring.



Option	Increase Diameter	Increase Pressure	Increase Length
Curve Gradient	A	B	C
Effectiveness	Best	Acceptable	Not Recommendable

Fig.7-4 Fender Performances relating to Size in Length and Diameter, and Initial Internal Pressure

7.1.8 Fender Selection Tables

Tables 7.4 through 7.9 show the fender selection tables for various kinds of tankers coming alongside lightering ships at three weather conditions; Calm, Moderate and Rough, for each ship size. In the tables, the berthing energy, equivalent displacement coefficient and suitable fender system for each case are indicated. This table shows figures for tankers, but it can be applied to other kinds of ships if their virtual weights correspond to those in the table.

In the tables, a safety factor SF=1.0 is used, but if a higher SF value is to be considered, the energy value is to be multiplied by the desired SF value and the fender selected according to the revised energy value.

Table 7- 4 Fender Selection at Calm Condition (Petroleum)

		SHIP B																							
	DWT	1,000	2,000	3,000	4,000	5,000	6,000	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000	200,000	250,000	300,000	330,000	370,000
SHIP A DWT	Displacement Ton (DT)	1,590	3,080	4,530	5,970	7,390	8,800	11,600	14,300	17,100	21,100	27,800	34,400	41,000	54,000	66,800	79,500	105,000	130,000	154,000	191,000	251,000	311,000	370,000	406,000	453,000
1,000	1,590	32 (1,590)	1000×2000 −P50, 3pcs																							
2,000	3,080	42 (2,097)	59 (3,080)																							
3,000	4,530	47 (2,354)	70 (3,667)	84 (4,530)	1500×3000 −P50, 3pcs																					
4,000	5,970	50 (2,511)	78 (4,064)	95 (5,151)	106 (5,970)																					
5,000	7,390	53 (2,617)	83 (4,348)	104 (5,617)	117 (6,605)	126 (7,390)																				
6,000	8,800	54 (2,693)	88 (4,563)	111 (5,981)	126 (7,114)	137 (8,034)	144 (8,800)																			
8,000	11,600	56 (2,797)	93 (4,868)	120 (6,516)	139 (7,883)	154 (9,028)	163 (10,008)	174 (11,600)																		
10,000	14,300	58 (2,862)	97 (5,068)	127 (6,880)	149 (8,423)	166 (9,744)	178 (10,895)	192 (12,809)	196 (14,300)	2500×5500 −P50, 3pcs																
12,000	17,100	59 (2,909)	100 (5,220)	132 (7,163)	157 (8,850)	176 (10,320)	189 (11,620)	207 (13,823)	214 (15,575)	231 (17,100)																
15,000	21,100	60 (2,957)	103 (5,375)	138 (7,459)	165 (9,307)	187 (10,946)	202 (12,420)	224 (14,970)	234 (17,047)	255 (18,891)	275 (21,100)															
20,000	27,800	61 (3,008)	107 (5,546)	144 (7,791)	174 (9,829)	199 (11,676)	218 (13,368)	245 (16,370)	259 (18,886)	285 (21,175)	312 (23,991)	344 (27,800)														
25,000	34,400	61 (3,040)	109 (5,654)	148 (8,006)	180 (10,174)	207 (12,166)	228 (14,015)	260 (17,350)	277 (20,202)	308 (22,844)	340 (26,156)	380 (30,750)	400 (34,400)													
30,000	41,000	62 (3,061)	110 (5,730)	151 (8,159)	184 (10,422)	213 (12,523)	236 (14,490)	271 (18,084)	291 (21,204)	325 (24,134)	363 (27,862)	410 (33,134)	435 (37,411)	452 (41,000)												
40,000	54,000	62 (3,089)	112 (5,828)	155 (8,359)	190 (10,751)	222 (13,001)	247 (15,134)	286 (19,098)	310 (22,612)	350 (25,975)	395 (30,344)	453 (36,704)	488 (42,027)	513 (46,611)	532 (54,000)											
50,000	66,800	63 (3,106)	113 (5,888)	157 (8,485)	194 (10,960)	227 (13,308)	254 (15,551)	297 (19,767)	324 (23,557)	368 (27,230)	420 (32,070)	488 (39,261)	532 (45,413)	564 (50,813)	594 (59,722)	593 (66,800)	3300×6500 −P50, 4pcs									
60,000	79,500	63 (3,118)	114 (5,930)	159 (8,572)	197 (11,106)	232 (13,523)	259 (15,846)	305 (20,246)	335 (24,240)	382 (28,146)	438 (33,349)	515 (41,195)	566 (48,021)	605 (54,100)	646 (64,315)	652 (72,599)	653 (79,500)									
80,000	105,000	63 (3,133)	115 (5,984)	161 (8,685)	200 (11,298)	235 (13,808)	265 (16,239)	313 (20,892)	345 (25,172)	396 (29,410)	457 (35,139)	543 (43,961)	602 (51,822)	649 (58,973)	702 (71,321)	718 (81,653)	726 (90,488)	656 (105,000)								
100,000	130,000	63 (3,142)	116 (6,017)	162 (8,755)	202 (11,416)	239 (13,985)	269 (16,484)	319 (21,299)	353 (25,766)	407 (30,224)	472 (36,307)	566 (45,805)	632 (54,404)	686 (62,339)	750 (76,304)	776 (88,252)	794 (98,663)	725 (116,170)	631 (130,000)							
120,000	154,000	63 (3,148)	116 (6,039)	163 (8,801)	204 (11,494)	241 (14,103)	271 (16,649)	323 (21,575)	359 (26,170)	415 (30,782)	483 (37,115)	582 (47,098)	653 (56,238)	712 (64,759)	786 (79,962)	820 (93,181)	845 (104,865)	779 (124,865)	684 (140,986)	746 (154,000)						
150,000	191,000	64 (3,154)	117 (6,062)	164 (8,850)	205 (11,578)	243 (14,229)	274 (16,825)	328 (21,872)	365 (26,608)	423 (31,390)	495 (38,002)	599 (48,536)	677 (58,300)	743 (67,509)	828 (84,196)	872 (98,982)	906 (112,270)	845 (135,507)	750 (154,704)	826 (170,516)	924 (191,000)	3300×6500 −P50, 5pcs				
200,000	251,000	64 (3,160)	117 (6,085)	165 (8,899)	207 (11,663)	245 (14,357)	277 (17,004)	332 (22,175)	371 (27,058)	431 (32,019)	507 (38,928)	618 (50,056)	703 (60,507)	775 (70,486)	874 (88,879)	930 (105,518)	977 (120,753)	922 (148,062)	830 (171,286)	923 (190,884)	1,048 (216,928)	1,211 (251,000)				
250,000	311,000	64 (3,164)	117 (6,100)	165 (8,930)	208 (11,715)	246 (14,437)	279 (17,116)	335 (22,366)	375 (27,343)	437 (32,418)	515 (39,519)	631 (51,038)	720 (61,948)	797 (72,449)	905 (92,022)	971 (109,978)	1,027 (126,630)	978 (156,995)	888 (183,356)	996 (205,996)	1,143 (236,657)	1,340 (277,797)	1,498 (311,000)			
300,000	370,000	64 (3,166)	118 (6,109)	166 (8,950)	208 (11,750)	247 (14,491)	280 (17,191)	337 (22,495)	378 (27,536)	441 (32,689)	520 (39,923)	639 (51,714)	731 (62,948)	812 (73,820)	927 (94,245)	999 (113,168)	1,062 (130,879)	1,019 (163,579)	931 (192,400)	1,052 (217,481)	1,216 (251,943)	1,442 (299,098)	1,627 (337,944)	1,780 (370,000)	4500×9000 −P50,4spcs	
330,000	406,000	64 (3,168)	118 (6,114)	166 (8,960)	209 (11,767)	248 (14,516)	281 (17,227)	338 (22,556)	379 (27,627)	442 (32,818)	522 (40,115)	643 (52,037)	737 (63,426)	820 (74,479)	938 (95,322)	1,014 (114,724)	1,080 (132,964)	1,039 (166,849)	953 (196,940)	1,080 (223,300)	1,254 (259,786)	1,495 (310,216)	1,695 (352,206)	1,862 (387,165)	1,952 (406,000)	
370,000	453,000	64 (3,169)	118 (6,118)	166 (8,970)	209 (11,785)	248 (14,543)	282 (17,265)	339 (22,621)	380 (27,725)	444 (32,956)	525 (40,322)	647 (52,385)	743 (63,944)	828 (75,194)	949 (96,497)	1,029 (116,431)	1,100 (135,262)	1,062 (170,484)	978 (202,024)	1,111 (229,858)	1,297 (268,705)	1,556 (323,020)	1,774 (368,804)	1,958 (407,315)	2,057 (428,214)	2,175 (453,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000＜C＜3,000	🟨
3,000＜C＜6,000	🟦
6,000＜C＜10,000	🟨
10,000＜C＜30,000	🟦
30,000＜C＜50,000	🟨
50,000＜C＜100,000	🟦
100,000＜C＜150,000	🟦
150,000＜C＜200,000	🟧
200,000＜C＜330,000	🟨
330,000＜C＜500,000	🟪

Energy Absorption:kNm
(C:tons)

Table 7- 5 Fender Selection at Moderate Condition (Petroleum)

			SHIP B																								
		DWT	1,000	2,000	3,000	4,000	5,000	6,000	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000	200,000	250,000	300,000	330,000	370,000
	DWT	Displacement Ton (DT)	1,590	3,080	4,530	5,970	7,390	8,800	11,600	14,300	17,100	21,100	27,800	34,400	41,000	54,000	66,800	79,500	105,000	130,000	154,000	191,000	251,000	311,000	370,000	406,000	453,000
SHIP A	1,000	1,590	57 (1,590)																								
	2,000	3,080	75 (2,097)	105 (3,080)	1500×3000 −P50, 3pcs																						
	3,000	4,530	84 (2,354)	125 (3,667)	147 (4,530)																						
	4,000	5,970	90 (2,511)	139 (4,064)	168 (5,151)	186 (5,970)																					
	5,000	7,390	94 (2,617)	148 (4,348)	183 (5,617)	205 (6,605)	220 (7,390)																				
	6,000	8,800	96 (2,693)	156 (4,563)	194 (5,981)	221 (7,114)	239 (8,034)	249 (8,800)																			
	8,000	11,600	100 (2,797)	166 (4,868)	212 (6,516)	245 (7,883)	268 (9,028)	283 (10,008)	299 (11,600)	2500×5500 −P50, 3pcs																	
	10,000	14,300	102 (2,862)	173 (5,068)	223 (6,880)	262 (8,423)	289 (9,744)	308 (10,895)	330 (12,809)	332 (14,300)																	
	12,000	17,100	104 (2,909)	178 (5,220)	233 (7,163)	275 (8,850)	306 (10,320)	328 (11,620)	355 (13,823)	361 (15,575)	387 (17,100)																
	15,000	21,100	106 (2,957)	184 (5,375)	242 (7,459)	289 (9,307)	325 (10,946)	350 (12,420)	385 (14,970)	395 (17,047)	427 (18,891)	461 (21,100)															
	20,000	27,800	108 (3,008)	189 (5,546)	253 (7,791)	305 (9,829)	347 (11,676)	377 (13,368)	421 (16,370)	437 (18,886)	478 (21,175)	524 (23,991)	569 (27,800)														
	25,000	34,400	109 (3,040)	193 (5,654)	260 (8,006)	316 (10,174)	361 (12,166)	395 (14,015)	446 (17,350)	468 (20,202)	515 (22,844)	571 (26,156)	629 (30,750)	662 (34,400)													
	30,000	41,000	110 (3,061)	196 (5,730)	265 (8,159)	324 (10,422)	372 (12,523)	409 (14,490)	464 (18,084)	491 (21,204)	544 (24,134)	608 (27,862)	677 (33,134)	719 (37,411)	741 (41,000)												
	40,000	54,000	111 (3,089)	199 (5,828)	272 (8,359)	334 (10,751)	386 (13,001)	427 (15,134)	491 (19,098)	524 (22,612)	586 (25,975)	662 (30,344)	749 (36,704)	807 (42,027)	841 (46,611)	849 (54,000)											
	50,000	66,800	111 (3,106)	201 (5,888)	276 (8,485)	341 (10,960)	396 (13,308)	440 (15,551)	510 (19,767)	548 (23,557)	617 (27,230)	704 (32,070)	807 (39,261)	879 (45,413)	925 (50,813)	948 (59,722)	927 (66,800)	3300×6500 −P50, 4pcs									
	60,000	79,500	112 (3,118)	203 (5,930)	279 (8,572)	346 (11,106)	403 (13,523)	449 (15,846)	523 (20,246)	565 (24,240)	640 (28,146)	735 (33,349)	851 (41,195)	935 (48,021)	991 (54,100)	1,030 (64,315)	1,019 (72,599)	1,041 (79,500)									
	80,000	105,000	112 (3,133)	205 (5,984)	282 (8,685)	351 (11,298)	410 (13,808)	458 (16,239)	537 (20,892)	583 (25,172)	663 (29,410)	767 (35,139)	897 (43,961)	995 (51,822)	1,063 (58,973)	1,119 (71,321)	1,121 (81,653)	1,159 (90,488)	1,098 (105,000)								
	100,000	130,000	113 (3,142)	206 (6,017)	285 (8,755)	355 (11,416)	416 (13,985)	465 (16,484)	547 (21,299)	597 (25,766)	682 (30,224)	792 (36,307)	935 (45,805)	1,044 (54,404)	1,123 (62,339)	1,197 (76,304)	1,213 (88,252)	1,266 (98,663)	1,214 (116,170)	1,121 (130,000)							
	120,000	154,000	113 (3,148)	206 (6,039)	286 (8,801)	357 (11,494)	419 (14,103)	470 (16,649)	555 (21,575)	606 (26,170)	695 (30,782)	810 (37,115)	961 (47,098)	1,079 (56,238)	1,167 (64,759)	1,254 (79,962)	1,281 (93,181)	1,348 (104,865)	1,304 (124,865)	1,215 (140,986)	1,327 (154,000)	3300×6500 −P50, 5pcs					
	150,000	191,000	113 (3,154)	207 (6,062)	288 (8,850)	360 (11,578)	423 (14,229)	475 (16,825)	562 (21,872)	617 (26,608)	708 (31,390)	829 (38,002)	991 (48,536)	1,119 (58,300)	1,217 (67,509)	1,321 (84,196)	1,362 (98,982)	1,446 (112,270)	1,414 (135,507)	1,333 (154,704)	1,468 (170,516)	1,642 (191,000)					
	200,000	251,000	113 (3,160)	208 (6,085)	290 (8,899)	363 (11,663)	427 (14,357)	480 (17,004)	570 (22,175)	627 (27,058)	723 (32,019)	850 (38,928)	1,022 (50,056)	1,162 (60,507)	1,270 (70,486)	1,394 (88,879)	1,454 (105,518)	1,559 (120,753)	1,545 (148,062)	1,475 (171,286)	1,642 (190,884)	1,863 (216,928)	2,153 (251,000)				
	250,000	311,000	113 (3,164)	209 (6,100)	291 (8,930)	364 (11,715)	429 (14,437)	484 (17,116)	575 (22,366)	634 (27,343)	732 (32,418)	863 (39,519)	1,042 (51,038)	1,189 (61,948)	1,306 (72,449)	1,444 (92,022)	1,517 (109,978)	1,638 (126,630)	1,638 (156,995)	1,578 (183,356)	1,771 (205,996)	2,032 (236,657)	2,381 (277,797)	2,663 (311,000)	4500×9000 −P50, 4pcs		
	300,000	370,000	113 (3,166)	209 (6,109)	291 (8,950)	366 (11,750)	431 (14,491)	486 (17,191)	579 (22,495)	638 (27,536)	738 (32,689)	872 (39,923)	1,056 (51,714)	1,209 (62,948)	1,331 (73,820)	1,479 (94,245)	1,562 (113,168)	1,695 (130,879)	1,707 (163,579)	1,656 (192,400)	1,869 (217,481)	2,162 (251,943)	2,563 (299,098)	2,892 (337,944)	3,164 (370,000)		
	330,000	406,000	113 (3,168)	209 (6,114)	292 (8,960)	366 (11,767)	432 (14,516)	487 (17,227)	580 (22,556)	641 (27,627)	741 (32,818)	876 (40,115)	1,063 (52,037)	1,218 (63,426)	1,343 (74,479)	1,496 (95,322)	1,584 (114,724)	1,723 (132,964)	1,741 (166,849)	1,695 (196,940)	1,919 (223,300)	2,229 (259,786)	2,657 (310,216)	3,013 (352,206)	3,310 (387,165)	3,469 (406,000)	
	370,000	453,000	114 (3,169)	209 (6,118)	292 (8,970)	367 (11,785)	433 (14,543)	488 (17,265)	582 (22,621)	643 (27,725)	744 (32,956)	881 (40,322)	1,070 (52,385)	1,228 (63,944)	1,356 (75,194)	1,514 (96,497)	1,608 (116,431)	1,755 (135,262)	1,779 (170,484)	1,739 (202,024)	1,976 (229,858)	2,306 (268,705)	2,766 (323,020)	3,154 (368,804)	3,481 (407,315)	3,658 (428,214)	3,868 (453,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000＜C＜3,000	🟨
3,000＜C＜6,000	🟦
6,000＜C＜10,000	🟨
10,000＜C＜30,000	🟦
30,000＜C＜50,000	🟨
50,000＜C＜100,000	🟦
100,000＜C＜150,000	🟦
150,000＜C＜200,000	🟧
200,000＜C＜330,000	🟨
330,000＜C＜500,000	🟪

Energy Absorption:kNm
(C:tons)

Table 7- 6 Fender Selection at Rough Condition (Petroleum)

			SHIP B																								
		DWT	1,000	2,000	3,000	4,000	5,000	6,000	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000	200,000	250,000	300,000	330,000	370,000
	DWT	Displacement Ton (DT)	1,590	3,080	4,530	5,970	7,390	8,800	11,600	14,300	17,100	21,100	27,800	34,400	41,000	54,000	66,800	79,500	105,000	130,000	154,000	191,000	251,000	311,000	370,000	406,000	453,000
SHIP A	1,000	1,590	89 (1,590)	1500×3000 −P50, 3pcs																							
	2,000	3,080	117 (2,097)	164 (3,080)																							
	3,000	4,530	131 (2,354)	195 (3,667)	230 (4,530)																						
	4,000	5,970	140 (2,511)	216 (4,064)	261 (5,151)	288 (5,970)																					
	5,000	7,390	146 (2,617)	231 (4,348)	284 (5,617)	319 (6,605)	340 (7,390)																				
	6,000	8,800	150 (2,693)	242 (4,563)	303 (5,981)	343 (7,114)	369 (8,034)	383 (8,800)	2500×5500 −P50, 3pcs																		
	8,000	11,600	156 (2,797)	259 (4,868)	330 (6,516)	380 (7,883)	414 (9,028)	435 (10,008)	455 (11,600)																		
	10,000	14,300	160 (2,862)	269 (5,068)	348 (6,880)	406 (8,423)	447 (9,744)	473 (10,895)	502 (12,809)	503 (14,300)																	
	12,000	17,100	163 (2,909)	277 (5,220)	362 (7,163)	426 (8,850)	473 (10,320)	504 (11,620)	541 (13,823)	547 (15,575)	585 (17,100)																
	15,000	21,100	165 (2,957)	286 (5,375)	377 (7,459)	448 (9,307)	502 (10,946)	539 (12,420)	586 (14,970)	598 (17,047)	646 (18,891)	696 (21,100)															
	20,000	27,800	168 (3,008)	295 (5,546)	394 (7,791)	473 (9,829)	535 (11,676)	580 (13,368)	640 (16,370)	663 (18,886)	724 (21,175)	790 (23,991)	854 (27,800)														
	25,000	34,400	170 (3,040)	301 (5,654)	405 (8,006)	490 (10,174)	558 (12,166)	608 (14,015)	679 (17,350)	709 (20,202)	780 (22,844)	861 (26,156)	944 (30,750)	989 (34,400)													
	30,000	41,000	171 (3,061)	305 (5,730)	413 (8,159)	502 (10,422)	574 (12,523)	629 (14,490)	707 (18,084)	744 (21,204)	824 (24,134)	917 (27,862)	1,017 (33,134)	1,074 (37,411)	1,094 (41,000)	3300×6500 −P50, 4pcs											
	40,000	54,000	173 (3,089)	310 (5,828)	423 (8,359)	518 (10,751)	596 (13,001)	657 (15,134)	747 (19,098)	793 (22,612)	887 (25,975)	998 (30,344)	1,126 (36,704)	1,206 (42,027)	1,242 (46,611)	1,239 (54,000)											
	50,000	66,800	174 (3,106)	313 (5,888)	430 (8,485)	529 (10,960)	612 (13,308)	677 (15,551)	776 (19,767)	830 (23,557)	934 (27,230)	1,061 (32,070)	1,212 (39,261)	1,313 (45,413)	1,366 (50,813)	1,384 (59,722)	1,335 (66,800)										
	60,000	79,500	175 (3,118)	316 (5,930)	435 (8,572)	537 (11,106)	623 (13,523)	691 (15,846)	797 (20,246)	857 (24,240)	969 (28,146)	1,108 (33,349)	1,279 (41,195)	1,397 (48,021)	1,464 (54,100)	1,503 (64,315)	1,467 (72,599)	1,520 (79,500)	3300×6500 −P50, 5pcs								
	80,000	105,000	175 (3,133)	318 (5,984)	440 (8,685)	545 (11,298)	634 (13,808)	705 (16,239)	817 (20,892)	883 (25,172)	1,005 (29,410)	1,156 (35,139)	1,347 (43,961)	1,486 (51,822)	1,570 (58,973)	1,634 (71,321)	1,615 (81,653)	1,692 (90,488)	1,654 (105,000)								
	100,000	130,000	176 (3,142)	320 (6,017)	443 (8,755)	551 (11,416)	642 (13,985)	716 (16,484)	834 (21,299)	904 (25,766)	1,033 (30,224)	1,194 (36,307)	1,404 (45,805)	1,560 (54,404)	1,659 (62,339)	1,747 (76,304)	1,746 (88,252)	1,849 (98,663)	1,828 (116,170)	1,752 (130,000)							
	120,000	154,000	176 (3,148)	321 (6,039)	446 (8,801)	554 (11,494)	647 (14,103)	723 (16,649)	844 (21,575)	918 (26,170)	1,052 (30,782)	1,221 (37,115)	1,444 (47,098)	1,612 (56,238)	1,723 (64,759)	1,831 (79,962)	1,845 (93,181)	1,968 (104,865)	1,964 (124,865)	1,899 (140,986)	2,073 (154,000)						
	150,000	191,000	177 (3,154)	323 (6,062)	448 (8,850)	559 (11,578)	653 (14,229)	731 (16,825)	856 (21,872)	934 (26,608)	1,073 (31,390)	1,251 (38,002)	1,488 (48,536)	1,672 (58,300)	1,797 (67,509)	1,928 (84,196)	1,962 (98,982)	2,111 (112,270)	2,130 (135,507)	2,083 (154,704)	2,293 (170,516)	2,566 (191,000)	4500×9000 −P50, 4pcs				
	200,000	251,000	177 (3,160)	324 (6,085)	451 (8,899)	563 (11,663)	659 (14,357)	739 (17,004)	868 (22,175)	950 (27,058)	1,094 (32,019)	1,281 (38,928)	1,535 (50,056)	1,735 (60,507)	1,876 (70,486)	2,035 (88,879)	2,094 (105,518)	2,276 (120,753)	2,327 (148,062)	2,304 (171,286)	2,565 (190,884)	2,912 (216,928)	3,365 (251,000)				
	250,000	311,000	177 (3,164)	325 (6,100)	453 (8,930)	565 (11,715)	663 (14,437)	744 (17,116)	876 (22,366)	960 (27,343)	1,108 (32,418)	1,301 (39,519)	1,565 (51,038)	1,777 (61,948)	1,929 (72,449)	2,107 (92,022)	2,184 (109,978)	2,391 (126,630)	2,467 (156,995)	2,466 (183,356)	2,767 (205,996)	3,175 (236,657)	3,721 (277,797)	4,162 (311,000)		4500×9000 −P80, 5pcs	
	300,000	370,000	177 (3,166)	325 (6,109)	454 (8,950)	567 (11,750)	665 (14,491)	747 (17,191)	881 (22,495)	967 (27,536)	1,118 (32,689)	1,314 (39,923)	1,586 (51,714)	1,806 (62,948)	1,966 (73,820)	2,158 (94,245)	2,249 (113,168)	2,475 (130,879)	2,570 (163,579)	2,587 (192,400)	2,921 (217,481)	3,379 (251,943)	4,004 (299,098)	4,519 (337,944)	4,944 (370,000)		
	330,000	406,000	177 (3,168)	325 (6,114)	454 (8,960)	568 (11,767)	667 (14,516)	749 (17,227)	883 (22,556)	970 (27,627)	1,122 (32,818)	1,321 (40,115)	1,596 (52,037)	1,820 (63,426)	1,983 (74,479)	2,183 (95,322)	2,280 (114,724)	2,516 (132,964)	2,622 (166,849)	2,648 (196,940)	2,999 (223,300)	3,483 (259,786)	4,152 (310,216)	4,709 (352,206)	5,171 (387,165)	5,421 (406,000)	
	370,000	453,000	177 (3,169)	326 (6,118)	455 (8,970)	569 (11,785)	668 (14,543)	750 (17,265)	886 (22,621)	974 (27,725)	1,127 (32,956)	1,328 (40,322)	1,607 (52,385)	1,835 (63,944)	2,003 (75,194)	2,210 (96,497)	2,315 (116,431)	2,562 (135,262)	2,679 (170,484)	2,717 (202,024)	3,087 (229,858)	3,603 (268,705)	4,323 (323,020)	4,929 (368,804)	5,439 (407,315)	5,715 (428,214)	6,043 (453,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000＜C＜3,000	🟨
3,000＜C＜6,000	🟦
6,000＜C＜10,000	🟨
10,000＜C＜30,000	🟦
30,000＜C＜50,000	🟨
50,000＜C＜100,000	🟦
100,000＜C＜150,000	🟦
150,000＜C＜200,000	🟧
200,000＜C＜330,000	🟨
330,000＜C＜500,000	🟪

Energy Absorption:kNm
(C:tons)

Table 7- 7 Fender Selection at Calm Condition (Liquefied Gas)

			SHIP B																			
		GT	1,000	2,000	3,000	4,000	5,000	6,000	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000
SHIP A	GT	Displacement Ton (DT)	2,480	4,570	6,530	8,420	10,200	12,000	15,500	18,900	22,200	27,000	34,800	42,400	49,800	64,100	78,100	91,700	118,000	144,000	169,000	206,000
	1,000	2,480	50 (2,480)	1500×3000 –P50, 3pcs																		
	2,000	4,570	65 (3,215)	88 (4,570)																		
	3,000	6,530	73 (3,595)	104 (5,377)	122 (6,530)																	
	4,000	8,420	77 (3,831)	114 (5,924)	137 (7,356)	150 (8,420)																
	5,000	10,200	81 (3,990)	122 (6,312)	148 (7,962)	165 (9,225)	176 (10,200)	2000×3500 –P50, 3pcs														
	6,000	12,000	83 (4,110)	128 (6,619)	164 (8,458)	177 (9,896)	190 (11,027)	198 (12,000)														
	8,000	15,500	86 (4,276)	136 (7,059)	178 (9,189)	195 (10,912)	212 (12,304)	223 (13,527)	235 (15,500)													
	10,000	18,900	88 (4,385)	142 (7,360)	188 (9,706)	208 (11,650)	228 (13,249)	242 (14,680)	258 (17,032)	263 (18,900)												
	12,000	22,200	90 (4,462)	146 (7,580)	196 (10,092)	218 (12,209)	241 (13,978)	256 (15,579)	276 (18,255)	284 (20,418)	301 (22,200)	3300×4500 –P50, 3pcs										
	15,000	27,000	92 (4,543)	151 (7,817)	204 (10,517)	229 (12,837)	255 (14,806)	273 (16,615)	298 (19,694)	309 (22,235)	330 (24,366)	351 (27,000)										
	20,000	34,800	93 (4,630)	156 (8,079)	214 (10,997)	242 (13,559)	271 (15,776)	294 (17,846)	325 (21,447)	340 (24,496)	367 (27,107)	395 (30,408)	419 (34,800)									
	25,000	42,400	95 (4,686)	159 (8,251)	220 (11,317)	251 (14,050)	283 (16,444)	308 (18,706)	344 (22,701)	363 (26,146)	394 (29,142)	428 (32,991)	460 (38,226)	475 (42,400)								
	30,000	49,800	95 (4,725)	162 (8,372)	224 (11,546)	257 (14,405)	291 (16,932)	318 (19,340)	358 (23,642)	380 (27,401)	416 (30,710)	454 (35,016)	492 (40,970)	513 (45,803)	519 (49,800)							
	40,000	64,100	96 (4,775)	165 (8,532)	229 (11,853)	265 (14,885)	301 (17,599)	331 (20,216)	375 (24,964)	402 (29,193)	442 (32,978)	488 (37,996)	535 (45,110)	563 (51,039)	575 (56,052)	547 (64,100)						
	50,000	78,100	97 (4,807)	166 (8,635)	233 (12,052)	270 (15,201)	308 (18,043)	340 (20,804)	387 (25,866)	417 (30,435)	461 (34,573)	512 (40,127)	567 (48,147)	602 (54,962)	618 (60,819)	593 (70,411)	573 (78,100)	3300×4500 –P50, 4pcs				
	60,000	91,700	97 (4,829)	168 (8,706)	236 (12,192)	273 (15,424)	313 (18,358)	346 (21,223)	396 (26,518)	429 (31,341)	476 (35,746)	531 (41,717)	592 (50,453)	632 (57,988)	652 (64,546)	631 (75,455)	613 (84,355)	571 (91,700)				
	80,000	118,000	98 (4,858)	169 (8,799)	239 (12,375)	278 (15,718)	320 (18,777)	355 (21,785)	409 (27,401)	445 (32,581)	496 (37,369)	558 (43,945)	629 (53,749)	677 (62,384)	704 (70,041)	689 (83,073)	675 (93,991)	633 (103,201)	523 (118,000)			
	100,000	144,000	98 (4,876)	171 (8,859)	241 (12,493)	282 (15,910)	325 (19,051)	361 (22,154)	418 (27,987)	456 (33,414)	511 (38,469)	577 (45,474)	655 (56,054)	710 (65,511)	742 (74,006)	732 (88,711)	723 (101,273)	682 (112,048)	568 (129,710)	623 (144,000)		
	120,000	169,000	99 (4,888)	171 (8,899)	243 (12,574)	284 (16,041)	328 (19,239)	365 (22,409)	424 (28,396)	464 (33,998)	521 (39,245)	591 (46,561)	674 (57,715)	734 (67,792)	771 (76,931)	766 (92,946)	760 (106,830)	721 (118,890)	605 (138,969)	666.8797 (155,502)	718 (169,000)	
	150,000	206,000	99 (4,901)	172 (8,942)	245 (12,659)	287 (16,179)	332 (19,438)	370 (22,679)	431 (28,831)	473 (34,623)	533 (40,081)	606 (47,742)	696 (59,542)	762 (70,325)	804 (80,210)	805 (97,776)	804 (113,260)	766 (126,908)	649 (150,049)	721 (169,509)	781 (185,675)	856 (206,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000 < C < 3,000	🟨
3,000 < C < 5,000	🟦
5,000 < C < 8,000	⬜
8,000 < C < 20,000	🟦
20,000 < C < 40,000	🟨
40,000 < C < 80,000	🟪
C > 80,000	🟩

Energy Absorption:kNm
(C:tons)

Table 7- 8　Fender Selection at Moderate Condition (Liquefied Gas)

			SHIP B																			
		GT	1,000	2,000	3,000	4,000	5,000	6,000	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000
SHIP A	GT	Displacement Ton (DT)	2,480	4,570	6,530	8,420	10,200	12,000	15,500	18,900	22,200	27,000	34,800	42,400	49,800	64,100	78,100	91,700	118,000	144,000	169,000	206,000
	1,000	2,480	89 (2,480)	1500×3000 –P50, 3pcs																		
	2,000	4,570	115 (3,215)	157 (4,570)																		
	3,000	6,530	129 (3,595)	185 (5,377)	214 (6,530)	2000×3500 –P50, 3pcs																
	4,000	8,420	137 (3,831)	204 (5,924)	241 (7,356)	264 (8,420)																
	5,000	10,200	143 (3,990)	217 (6,312)	261 (7,962)	289 (9,225)	306 (10,200)															
	6,000	12,000	147 (4,110)	227 (6,619)	277 (8,458)	310 (9,896)	331 (11,027)	343 (12,000)														
	8,000	15,500	153 (4,276)	242 (7,059)	301 (9,189)	342 (10,912)	369 (12,304)	386 (13,527)	403 (15,500)													
	10,000	18,900	157 (4,385)	253 (7,360)	318 (9,706)	365 (11,650)	397 (13,249)	419 (14,680)	443 (17,032)	444 (18,900)	3300×4500 –P50, 3pcs											
	12,000	22,200	160 (4,462)	260 (7,580)	330 (10,092)	383 (12,209)	419 (13,978)	444 (15,579)	475 (18,255)	479 (20,418)	505 (22,200)											
	15,000	27,000	163 (4,543)	269 (7,817)	344 (10,517)	402 (12,837)	444 (14,806)	474 (16,615)	512 (19,694)	522 (22,235)	554 (24,366)	587 (27,000)										
	20,000	34,800	166 (4,630)	278 (8,079)	360 (10,997)	425 (13,559)	473 (15,776)	509 (17,846)	557 (21,447)	574 (24,496)	616 (27,107)	661 (30,408)	694 (34,800)									
	25,000	42,400	168 (4,686)	283 (8,251)	370 (11,317)	440 (14,050)	493 (16,444)	533 (18,706)	590 (22,701)	613 (26,146)	662 (29,142)	716 (32,991)	762 (38,226)	778 (42,400)								
	30,000	49,800	170 (4,725)	288 (8,372)	378 (11,546)	451 (14,405)	508 (16,932)	551 (19,340)	614 (23,642)	642 (27,401)	697 (30,710)	760 (35,016)	816 (40,970)	841 (45,803)	833 (49,800)							
	40,000	64,100	171 (4,775)	292 (8,532)	387 (11,853)	465 (14,885)	525 (17,599)	573 (20,216)	644 (24,964)	679 (29,193)	742 (32,978)	816 (37,996)	887 (45,110)	923 (51,039)	923 (56,052)	854 (64,100)	3300×4500 –P50, 4pcs					
	50,000	78,100	172 (4,807)	296 (8,635)	393 (12,052)	474 (15,201)	537 (18,043)	588 (20,804)	665 (25,866)	705 (30,435)	774 (34,573)	857 (40,127)	941 (48,147)	986 (54,962)	992 (60,819)	927 (70,411)	919 (78,100)					
	60,000	91,700	173 (4,829)	298 (8,706)	397 (12,192)	480 (15,424)	546 (18,358)	599 (21,223)	681 (26,518)	724 (31,341)	798 (35,746)	888 (41,717)	982 (50,453)	1,036 (57,988)	1,047 (64,546)	986 (75,455)	982 (84,355)	944 (91,700)				
	80,000	118,000	174 (4,858)	301 (8,799)	403 (12,375)	489 (15,718)	558 (18,777)	614 (21,785)	702 (27,401)	751 (32,581)	833 (37,369)	933 (43,945)	1,042 (53,749)	1,109 (62,384)	1,130 (70,041)	1,076 (83,073)	1,082 (93,991)	1,047 (103,201)	929 (118,000)			
	100,000	144,000	175 (4,876)	303 (8,859)	407 (12,493)	495 (15,910)	566 (19,051)	625 (22,154)	717 (27,987)	770 (33,414)	857 (38,469)	965 (45,474)	1,086 (56,054)	1,163 (65,511)	1,175 (74,006)	1,144 (88,711)	1,158 (101,273)	1,128 (112,048)	1,010 (129,710)	1,107 (144,000)	4500×9000 –P50, 4pcs	
	120,000	169,000	175 (4,888)	305 (8,899)	409 (12,574)	499 (16,041)	572 (19,239)	632 (22,409)	728 (28,396)	784 (33,998)	874 (39,245)	988 (46,561)	1,118 (57,715)	1,203 (67,792)	1,238 (76,931)	1,196 (92,946)	1,218 (106,830)	1,191 (118,890)	1,185 (138,969)	1185.564 (155,502)	1,276 (169,000)	
	150,000	206,000	176 (4,901)	306 (8,942)	412 (12,659)	504 (16,179)	578 (19,438)	640 (22,679)	740 (28,831)	799 (34,623)	894 (40,081)	1,014 (47,742)	1,154 (59,542)	1,249 (70,325)	1,292 (80,210)	1,257 (97,776)	1,288 (113,260)	1,267 (126,908)	1,272 (150,049)	1,282 (169,509)	1,388 (185,675)	1,521 (206,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000＜C＜3,000	🟨
3,000＜C＜5,000	⬜
5,000＜C＜8,000	▨
8,000＜C＜20,000	🟦
20,000＜C＜40,000	🟧
40,000＜C＜80,000	🟪
C＞80,000	🟩

Energy Absorption:kNm
(C:tons)

Table 7- 9 Fender Selection at Rough Condition (Liquefied Gas)

			SHIP B																			
		GT	1,000	2,000	3,000	4,000	5,000	6,00	8,000	10,000	12,000	15,000	20,000	25,000	30,000	40,000	50,000	60,000	80,000	100,000	120,000	150,000
	GT	Displacement Ton (DT)	2,480	4,570	6,530	8,420	10,200	12,000	15,500	18,900	22,200	27,000	34,800	42,400	49,800	64,100	78,100	91,700	118,000	144,000	169,000	206,000
SHIP A	1,000	2,480	139 (2,480)	1500×3000 –P50, 3pcs																		
	2,000	4,570	180 (3,215)	245 (4,570)	2000×3500 –P50, 3pcs																	
	3,000	6,530	201 (3,595)	288 (5,377)	333 (6,530)																	
	4,000	8,420	215 (3,831)	317 (5,924)	375 (7,356)	410 (8,420)																
	5,000	10,200	224 (3,990)	337 (6,312)	406 (7,962)	449 (9,225)	473 (10,200)	3300×4500 –P50, 3pcs														
	6,000	12,000	230 (4,110)	354 (6,619)	431 (8,458)	481 (9,896)	511 (11,027)	527 (12,000)														
	8,000	15,500	240 (4,276)	377 (7,059)	468 (9,189)	530 (10,912)	570 (12,304)	594 (13,527)	614 (15,500)													
	10,000	18,900	246 (4,385)	393 (7,360)	495 (9,706)	566 (11,650)	614 (13,249)	644 (14,680)	674 (17,032)	672 (18,900)												
	12,000	22,200	250 (4,462)	405 (7,580)	514 (10,092)	593 (12,209)	647 (13,978)	683 (15,579)	723 (18,255)	726 (20,418)	761 (22,200)	3300×4500 –P50, 4pcs										
	15,000	27,000	255 (4,543)	418 (7,817)	536 (10,517)	624 (12,837)	685 (14,806)	729 (16,615)	779 (19,694)	790 (22,235)	835 (24,366)	879 (27,000)										
	20,000	34,800	260 (4,630)	432 (8,079)	561 (10,997)	659 (13,559)	730 (15,776)	783 (17,846)	849 (21,447)	870 (24,496)	929 (27,107)	989 (30,408)	1,039 (34,800)									
	25,000	42,400	263 (4,686)	441 (8,251)	577 (11,317)	683 (14,050)	761 (16,444)	820 (18,706)	898 (22,701)	929 (26,146)	998 (29,142)	1,073 (32,991)	1,140 (38,226)	1,150 (42,400)								
	30,000	49,800	265 (4,725)	448 (8,372)	589 (11,546)	700 (14,405)	784 (16,932)	848 (19,340)	935 (23,642)	973 (27,401)	1,052 (30,710)	1,138 (35,016)	1,222 (40,970)	1,242 (45,803)	1,221 (49,800)							
	40,000	64,100	268 (4,775)	455 (8,532)	602 (11,853)	721 (14,885)	811 (17,599)	882 (20,216)	981 (24,964)	1,028 (29,193)	1,119 (32,978)	1,222 (37,996)	1,328 (45,110)	1,363 (51,039)	1,353 (56,052)	1,230 (64,100)						
	50,000	78,100	269 (4,807)	460 (8,635)	612 (12,052)	734 (15,201)	829 (18,043)	905 (20,804)	1,013 (25,866)	1,068 (30,435)	1,168 (34,573)	1,283 (40,127)	1,408 (48,147)	1,456 (54,962)	1,455 (60,819)	1,335 (70,411)	1,345 (78,100)	4500×9000 –P50, 4pcs				
	60,000	91,700	270 (4,829)	464 (8,706)	618 (12,192)	744 (15,424)	843 (18,358)	922 (21,223)	1,036 (26,518)	1,097 (31,341)	1,204 (35,746)	1,330 (41,717)	1,469 (50,453)	1,529 (57,988)	1,536 (64,546)	1,420 (75,455)	1,439 (84,355)	1,410 (91,700)				
	80,000	118,000	272 (4,858)	469 (8,799)	627 (12,375)	758 (15,718)	861 (18,777)	945 (21,785)	1,069 (27,401)	1,138 (32,581)	1,256 (37,369)	1,397 (43,945)	1,559 (53,749)	1,638 (62,384)	1,657 (70,041)	1,549 (83,073)	1,584 (93,991)	1,564 (103,201)	1,452 (118,000)			
	100,000	144,000	273 (4,876)	472 (8,859)	633 (12,493)	767 (15,910)	874 (19,051)	961 (22,154)	1,092 (27,987)	1,167 (33,414)	1,293 (38,469)	1,445 (45,474)	1,625 (56,054)	1,717 (65,511)	1,748 (74,006)	1,647 (88,711)	1,696 (101,273)	1,685 (112,048)	1,579 (129,710)	1,730 (144,000)		
	120,000	169,000	274 (4,888)	474 (8,899)	638 (12,574)	774 (16,041)	883 (19,239)	972 (22,409)	1,108 (28,396)	1,188 (33,998)	1,319 (39,245)	1,479 (46,561)	1,673 (57,715)	1,777 (67,792)	1,816 (76,931)	1,722 (92,946)	1,783 (106,830)	1,779 (118,890)	1,680 (138,969)	1,852 (155,502)	1,993 (169,000)	
	150,000	206,000	274 (4,901)	476 (8,942)	642 (12,659)	781 (16,179)	892 (19,438)	985 (22,679)	1,126 (28,831)	1,210 (34,623)	1,348 (40,081)	1,518 (47,742)	1,727 (59,542)	1,844 (70,325)	1,894 (80,210)	1,810 (97,776)	1,886 (113,260)	1,892 (126,908)	1,803 (150,049)	2,003 (169,509)	2,168 (185,675)	2,377 (206,000)

Equivalent Displacement Coefficient (C:tons)	Color
1,000 < C < 3,000	🟨
3,000 < C < 5,000	⬜
5,000 < C < 8,000	⬜
8,000 < C < 20,000	🟦
20,000 < C < 40,000	🟨
40,000 < C < 80,000	🟪
C > 80,000	🟩

Energy Absorption:kNm
(C : tons)

7.1.9 Fender Selection by Numerical Simulation for Two Ships Berthing and Mooring

Fender quantity and size will be determined by calculating the berthing energy, derived from the calculated virtual mass and the relative berthing speed between the two ships.

In some cases large ship motions are induced by waves, wind and current. Consequently, excess loads are given to the fenders. In severe weather conditions, fenders used for ship berthing or ship mooring need to be selected after a more thorough investigation of the ship's motions under dynamic conditions. Furthermore, when two ships are moored together during STS operations, not only the fenders but also the system of mooring lines needs to be studied as it has the important role of keeping a proper standoff distance between the two ships.

The Yokohama Rubber Co., Ltd. developed the numerical simulation software IAMOS (Integrated Approach, Mooring and Operation Simulation for Ship/FPSO to Ship Operation), and will provide the analysis for customers on special request. Fig.7-5 through 7-8 show details of the IAMOS process.

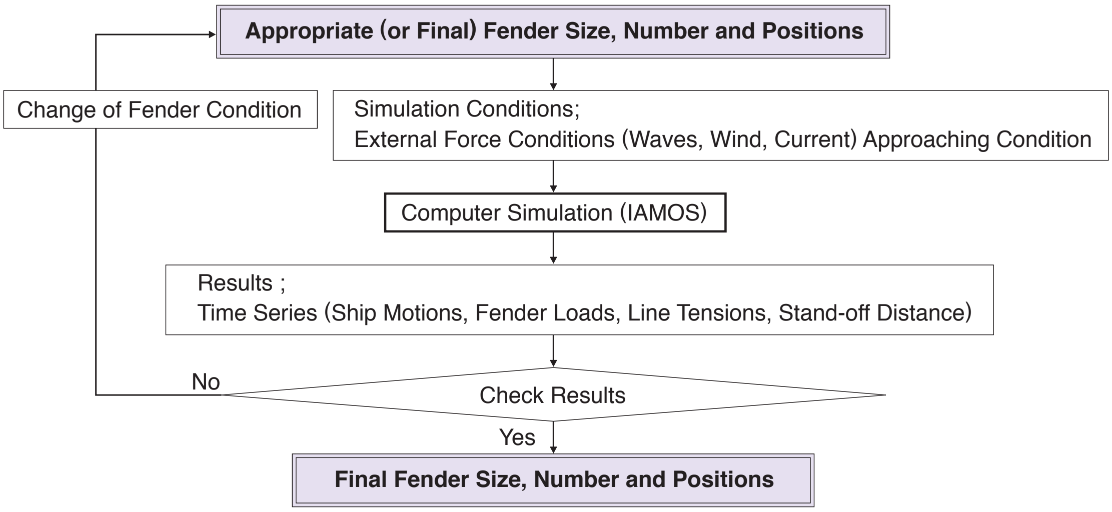


Fig.7-5 Fender Selection by Numerical Simulation (IAMOS) for Ship-to-Ship Usage

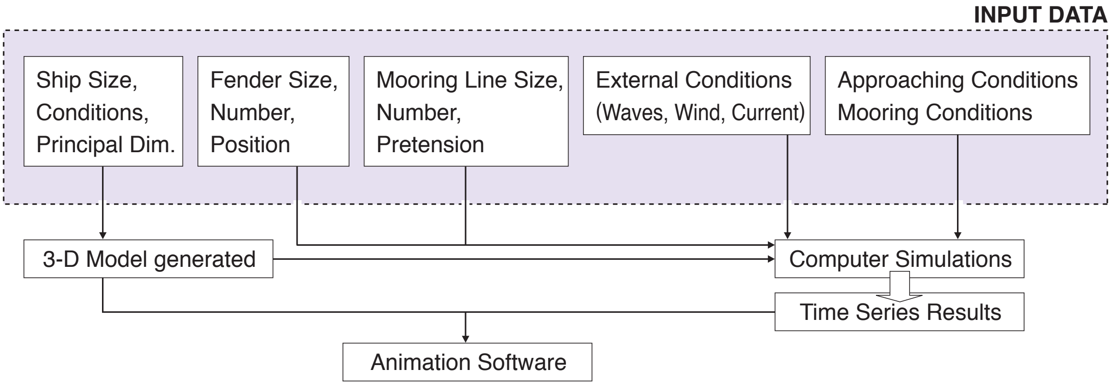
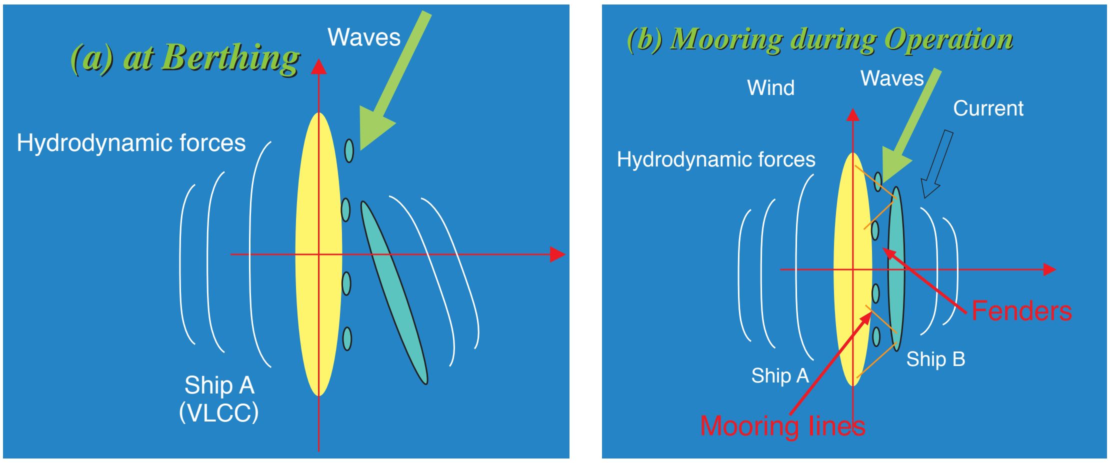


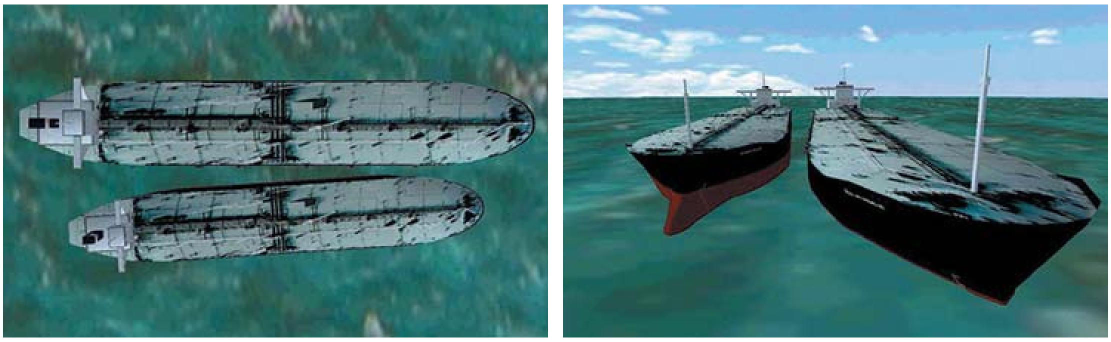
Fig.7-6 Numerical Simulation for Two Ships Berthing and Mooring (IAMOS)



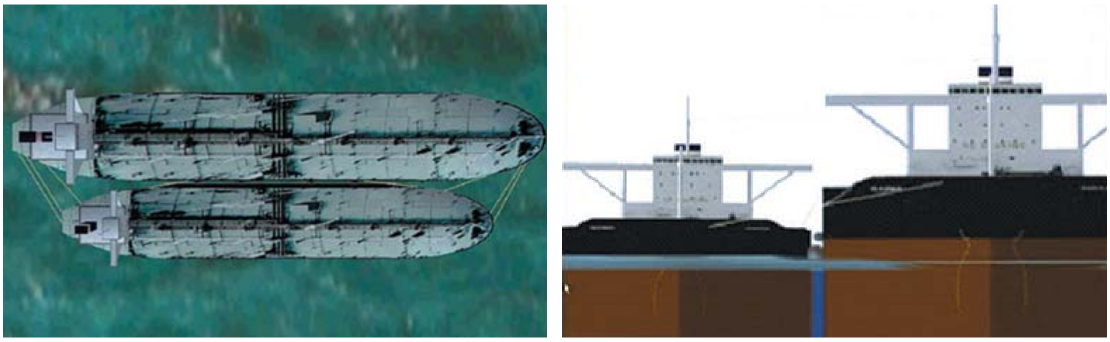
$$\sum_{j=1}^{12}\left\{M_{ij}+m_{ij}(\infty)\right\}\ddot{x}_j(t)+\sum_{j=1}^{12}\int_{-\infty}^{t}\dot{x}_j(\tau)\cdot L_{ij}(t-\tau)d\tau+\sum_{j=1}^{12}D_{ij}\cdot\dot{x}_j(t)$$

$$+\sum_{j=1}^{12}C_{ij}\cdot x_j(t)+G_i=F_i(t),(i=1,2........,12)$$

Fig.7-7 Applicable Conditions for Two Ships (IAMOS)



(a) Two-Ships Berthing



(b) Two-Ships Mooring

Fig.7-8 Animation Display Results for Two Ships (IAMOS)

7.2 Ship-to-Jetty

The selection of a pneumatic fender system (sizes and installation methods) for a jetty is determined based on several design parameters for each ship berthing and mooring condition.

7.2.1 Fender Selection for Berthing and Mooring of Ships

Ship size and condition, as well as berthing velocity are at first determined.
Then berthing energy "E" is calculated, and a fender is selected based on the berthing energy requirement.

A safety factor (SF) value from 1.0 to 2.0 for the berthing energy shall be considered for abnormal berthing conditions. Fender selection procedure for ship-to-jetty operations is illustrated as Fig.7-9 below.

$$E = \frac{1}{2} W \cdot V^2 \times C_e \times C_m \times C_s \times C_c \times SF$$

E : Ship berthing energy (kNm)
W : Displacement (ton)
V : Berthing velocity (m/s)
d : draft (m)
B : Breadth (m)
Ce : Eccentricity factor

Cm : Virtual mass factor, $C_m = 1 + \frac{2\,d}{B}$

Cs : Softness coefficient
Cc : Berth configuration factor
SF : Safety factor

Fender Selection

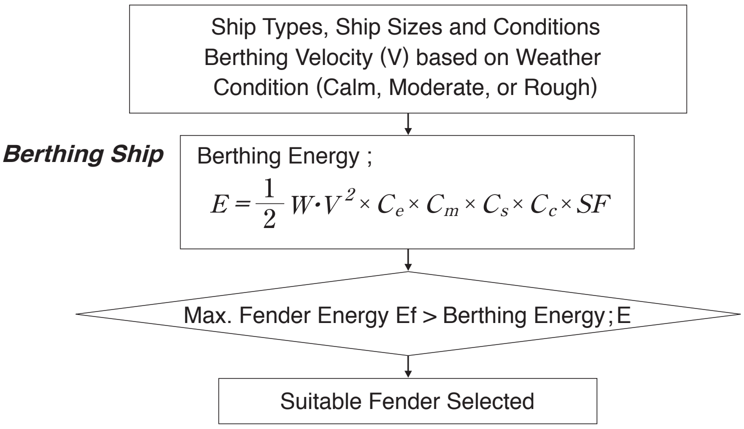


Fig.7-9 Fender Selection for Ship-to-Jetty Usage

7.2.2 Berthing Energy Tables

Tables 7-11 through 7-17 show the berthing energy for various kinds of ships and sizes at different approaching speeds corresponding to Calm, Moderate and Rough weather conditions as shown in Table 7-10.

In the tables, a safety factor SF=1.0 is used, and if a higher SF value is to be considered, the energy value is to be multiplied by the desired SF.

Table 7-10 shows figures for tankers, but it can be applied to other kinds of ships, if their virtual weights correspond to those in the table.

Table 7-10 Berthing Velocity for Ship-to-Jetty Operations

DWT	Calm	Moderate	Rough
Less than 10,000	– 0.15 m/s	0.18 – 0.30 m/s	0.40 m/s –
10,000 – 50,000	– 0.12 m/s	0.15 – 0.25 m/s	0.30 m/s –
50,000 – 100,000	– 0.10 m/s	0.12 – 0.18 m/s	0.20 m/s –
Over 100,000	– 0.10 m/s	0.12 – 0.18 m/s	0.20 m/s –

Table 7-11 Berthing Energy for Oil Tanker (kNm)

DWT	V (m/s) VW (T)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
1,000	2,849	7.1	10.3	16.0	23.1	28.5	44.5	64.1	114
2,000	5,486	13.7	19.8	30.9	44.4	54.9	85.7	123	219
3,000	8,042	20.1	29.0	45.2	65.1	80.4	126	181	322
4,000	10,573	26.4	38.1	59.5	85.6	106	165	238	423
5,000	13,064	32.7	47.0	73.5	106	131	204	294	523
6,000	15,533	38.8	55.9	87.4	126	155	243	350	621
8,000	20,427	51.1	73.5	115	165	204	319	460	817
10,000	25,136	62.8	90.5	141	204	251	393	566	1,005
12,000	30,013	75.0	108	169	243	300	469	675	1,201
15,000	36,966	92.4	133	208	299	370	578	832	1,479
20,000	48,590	121	175	273	394	486	759	1,093	1,944
25,000	60,017	150	216	338	486	600	938	1,350	2,401
30,000	71,427	179	257	402	579	714	1,116	1,607	2,857
40,000	93,856	235	338	528	760	939	1,466	2,112	3,754
50,000	118,692	297	427	668	961	1,187	1,855	2,671	4,748
60,000	144,622	362	521	814	1,171	1,446	2,260	3,254	5,785
80,000	181,483	454	653	1,021	1,470	1,815	2,836	4,083	7,259
100,000	224,293	561	807	1,262	1,817	2,243	3,505	5,047	8,972
120,000	265,315	663	955	1,492	2,149	2,653	4,146	5,970	10,613
150,000	328,475	821	1,183	1,848	2,661	3,285	5,132	7,391	13,139
200,000	430,676	1,077	1,550	2,423	3,488	4,307	6,729	9,690	17,227
250,000	532,685	1,332	1,918	2,996	4,315	5,327	8,323	11,985	21,307
300,000	632,829	1,582	2,278	3,560	5,126	6,328	9,888	14,239	25,313
330,000	693,880	1,735	2,498	3,903	5,620	6,939	10,842	15,612	27,755
370,000	773,508	1,934	2,785	4,351	6,265	7,735	12,086	17,404	30,940

🟨 Calm condition 🟩 Moderate condition 🟧 Rough condition

Table 7-12 Berthing Energy for Gas Carrier (kNm)

	V (m/s)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
GT	VW (T)								
1,000	4,454	11.0	16.0	25.1	36.1	44.5	69.6	100	178
2,000	8,183	20.5	29.5	46.0	66.3	81.8	128	184	327
3,000	11,672	29.2	42.0	65.7	94.5	117	182	263	467
4,000	15,031	37.6	54.1	84.5	122	150	235	338	601
5,000	18,191	45.5	65.5	102	147	182	284	409	728
6,000	21,384	53.5	77.0	120	173	214	334	481	855
8,000	27,586	69.0	99.3	155	223	276	431	621	1,103
10,000	33,604	84.0	121	189	272	336	525	756	1,344
12,000	39,440	98.6	142	222	319	394	616	887	1,578
15,000	47,921	120	173	270	388	479	749	1,078	1,917
20,000	61,687	154	222	347	500	617	964	1,388	2,467
25,000	75,086	188	270	422	608	751	1,173	1,689	3,003
30,000	88,121	220	317	496	714	881	1,377	1,983	3,525
40,000	109,372	273	394	615	886	1,094	1,709	2,461	4,375
50,000	129,723	324	467	730	1,051	1,297	2,027	2,919	5,189
60,000	149,117	373	537	839	1,208	1,491	2,330	3,355	5,965
80,000	185,834	465	669	1,045	1,505	1,858	2,904	4,181	7,433
100,000	221,472	554	797	1,246	1,794	2,215	3,461	4,983	8,859

Table 7-13 Berthing Energy for Bulk Carrier (kNm)

	V (m/s)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
DWT	VW (T)								
1,000	2,757	6.9	9.9	15.5	22.3	27.6	43.1	62.0	110
2,000	5,290	13.2	19.0	29.8	42.9	52.9	82.7	119	212
3,000	7,743	19.4	27.9	43.6	62.7	77.4	121	174	310
4,000	10,154	25.4	36.6	57.1	82.2	102	159	228	406
5,000	12,508	31.3	45.0	70.4	101	125	195	281	500
6,000	14,859	37.1	53.5	83.6	120	149	232	334	594
8,000	19,464	48.7	70.1	109	158	195	304	438	779
10,000	23,936	59.8	86.2	135	194	239	374	539	957
12,000	28,403	71.0	102	160	230	284	444	639	1,136
15,000	35,185	88.0	127	198	285	352	550	792	1,407
20,000	46,054	115	166	259	373	461	720	1,036	1,842
25,000	56,728	142	204	319	459	567	886	1,276	2,269
30,000	67,389	168	243	379	546	674	1,053	1,516	2,696
40,000	88,325	221	318	497	715	883	1,380	1,987	3,533
50,000	108,145	270	389	608	876	1,081	1,690	2,433	4,326
60,000	131,611	329	474	740	1,066	1,316	2,056	2,961	5,264
80,000	169,503	424	610	953	1,373	1,695	2,648	3,814	6,780
100,000	209,372	523	754	1,178	1,696	2,094	3,271	4,711	8,375
120,000	248,131	620	893	1,396	2,010	2,481	3,877	5,583	9,925
150,000	306,202	766	1,102	1,722	2,480	3,062	4,784	6,890	12,248
200,000	401,077	1,003	1,444	2,256	3,249	4,011	6,267	9,024	16,043
250,000	494,051	1,235	1,779	2,779	4,002	4,941	7,720	11,116	19,762
300,000	586,918	1,467	2,113	3,301	4,754	5,869	9,171	13,206	23,477

🟨 Calm condition 🟩 Moderate condition 🟧 Rough condition

Table 7-14 Berthing Energy for General Cargo Ship (kNm)

DWT	V (m/s) VW (T)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
1,000	2,908	7.3	10.5	16.4	23.6	29.1	45.4	65.4	116
2,000	5,672	14.2	20.4	31.9	45.9	56.7	88.6	128	227
3,000	8,395	21.0	30.2	47.2	68.0	83.9	131	189	336
4,000	11,065	27.7	39.8	62.2	89.6	111	173	249	443
5,000	13,714	34.3	49.4	77.1	111	137	214	309	549
6,000	16,356	40.9	58.9	92.0	132	164	256	368	654
8,000	21,558	53.9	77.6	121	175	216	337	485	862
10,000	26,715	66.8	96	150	216	267	417	601	1,069
12,000	31,894	79.7	115	179	258	319	498	718	1,276
15,000	39,514	98.8	142	222	320	395	617	889	1,581
20,000	52,221	131	188	294	423	522	816	1,175	2,089
25,000	64,629	162	233	364	523	646	1,010	1,454	2,585
30,000	77,090	193	278	434	624	771	1,205	1,735	3,084
40,000	101,768	254	366	572	824	1,018	1,590	2,290	4,071
50,000	126,208	316	454	710	1,022	1,262	1,972	2,840	5,048

Table 7-15 Berthing Energy for Container Ship (kNm)

DWT	V (m/s) VW (T)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
7,000	18,273	45.7	65.8	103	148	183	286	411	731
8,000	20,699	51.7	74.5	116	168	207	323	466	828
10,000	25,734	64.3	92.6	145	208	257	402	579	1,029
12,000	30,782	77.0	111	173	249	308	481	693	1,231
15,000	38,115	95.3	137	214	309	381	596	858	1,525
20,000	50,376	126	181	283	408	504	787	1,133	2,015
25,000	62,504	156	225	352	506	625	977	1,406	2,500
30,000	74,489	186	268	419	603	745	1,164	1,676	2,980
40,000	98,838	247	356	556	801	988	1,544	2,224	3,954
50,000	126,047	315	454	709	1,021	1,260	1,969	2,836	5,042
60,000	145,611	364	524	819	1,179	1,456	2,275	3,276	5,824
80,000	186,920	467	673	1,051	1,514	1,869	2,921	4,206	7,477
100,000	227,756	569	820	1,281	1,845	2,278	3,559	5,125	9,110

🟨 Calm condition 🟩 Moderate condition 🟧 Rough condition

Table 7-16 Berthing Energy for Passenger Ship (kNm)

GT	VW (T) \ V (m/s)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
1,000	1,468	3.7	5.3	8.3	11.9	14.7	22.9	33.0	58.7
2,000	2,807	7.0	10.1	15.8	22.7	28.1	43.9	63.2	112
3,000	4,120	10.3	14.8	23.2	33.4	41.2	64.4	92.7	165
4,000	5,394	13.5	19.4	30.3	43.7	53.9	84.3	121	216
5,000	6,654	16.6	24.0	37.4	53.9	66.5	104	150	266
6,000	7,895	19.7	28.4	44.4	63.9	78.9	123	178	316
8,000	10,360	25.9	37.3	58.3	83.9	104	162	233	414
10,000	12,795	32.0	46.1	72.0	104	128	200	288	512
12,000	15,207	38.0	54.7	85.5	123	152	238	342	608
15,000	18,737	46.8	67.5	105	152	187	293	422	749
20,000	24,676	61.7	88.8	139	200	247	386	555	987
25,000	29,492	73.7	106	166	239	295	461	664	1,180
30,000	34,086	85.2	123	192	276	341	533	767	1,363
40,000	42,826	107	154	241	347	428	669	964	1,713
50,000	51,283	128	185	288	415	513	801	1,154	2,051
60,000	59,341	148	214	334	481	593	927	1,335	2,374
80,000	74,952	187	270	422	607	750	1,171	1,686	2,998

Table 7-17 Berthing Energy for Ferry (kNm)

GT	VW (T) \ V (m/s)	0.10	0.12	0.15	0.18	0.20	0.25	0.30	0.40
1,000	1,838	4.6	6.6	10.3	14.9	18.4	28.7	41.3	73.5
2,000	3,653	9.1	13.2	20.6	29.6	36.5	57.1	82.2	146
3,000	5,469	13.7	19.7	30.8	44.3	54.7	85.4	123	219
4,000	7,278	18.2	26.2	40.9	59.0	72.8	114	164	291
5,000	9,094	22.7	32.7	51.2	73.7	90.9	142	205	364
6,000	10,901	27.3	39.2	61.3	88.3	109	170	245	436
8,000	14,529	36.3	52.3	81.7	118	145	227	327	581
10,000	18,109	45.3	65.2	102	147	181	283	407	724
12,000	21,701	54.3	78.1	122	176	217	339	488	868
15,000	27,184	68.0	97.9	153	220	272	425	612	1,087
20,000	36,153	90.4	130	203	293	362	565	813	1,446
25,000	45,159	113	163	254	366	452	706	1,016	1,806
30,000	54,194	135	195	305	439	542	847	1,219	2,168
40,000	72,336	181	260	407	586	723	1,130	1,628	2,893

🟨 Calm condition 🟩 Moderate condition 🟧 Rough condition

7.2.3 Fender Selection by Numerical Simulation for Ship Motions Moored along Jetty

Fender quantity and size will be determined by calculating the berthing energy, derived from the calculated virtual mass and berthing speed.

During mooring of a ship, large ship motions are induced by waves, especially long-period waves and harbor oscillations, and in some cases breaking accident of mooring lines or fenders occur. In order to check for a suitable fender and mooring system under severe weather conditions, a computer simulation for evaluating ship motions and mooring loads on fenders and mooring lines under dynamic condition should be conducted.

The YOKOHAMA RUBBER CO., LTD. developed the numerical simulation software IMOS (Integrated Mooring and Operation Simulation for Ship to Jetty Operation) and will provide the analysis for customers on special request. Fig.7-10 through 7-14 show details of the IMOS.

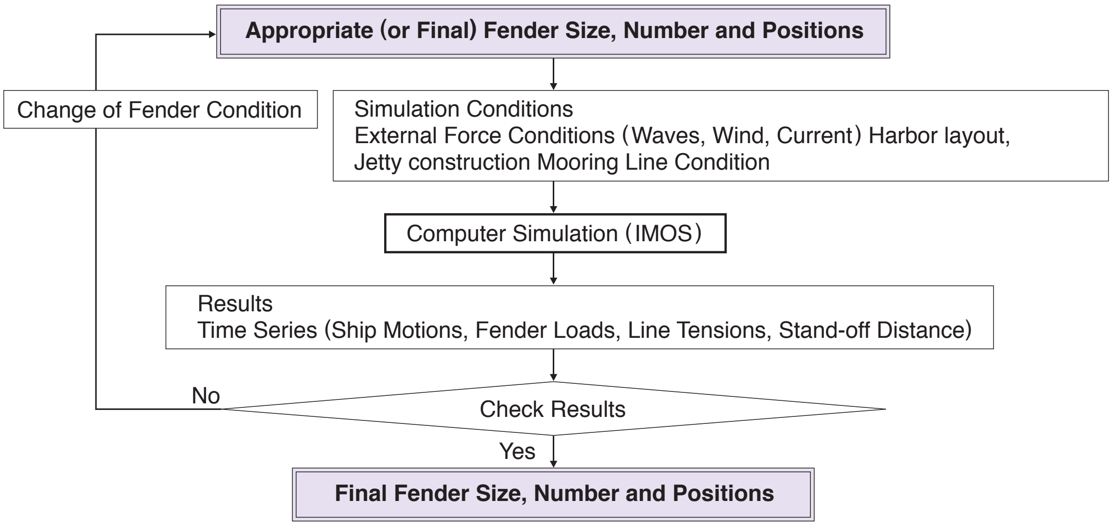


Fig.7-10 Fender Selection by Numerical Simulation (IMOS) for Ship-to-Jetty Usage

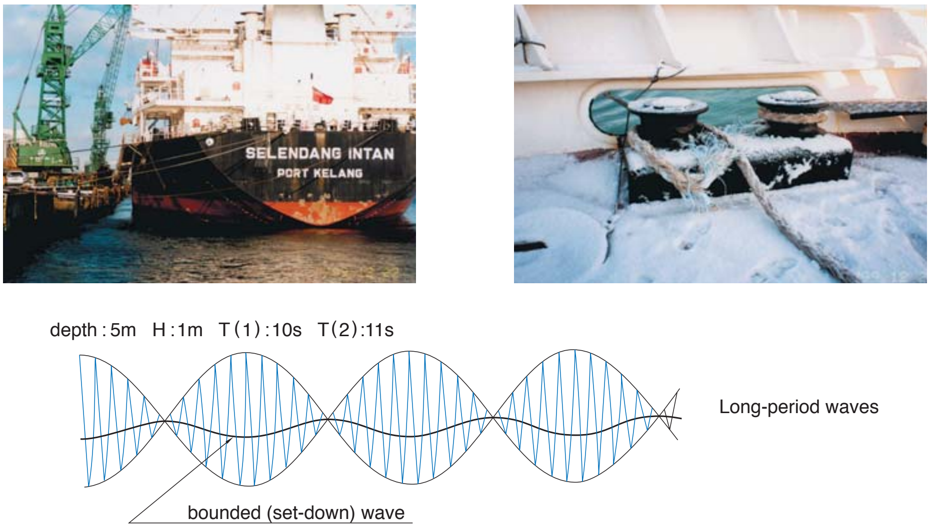


Fig.7-11 Mooring Line Accident during Long-period Waves

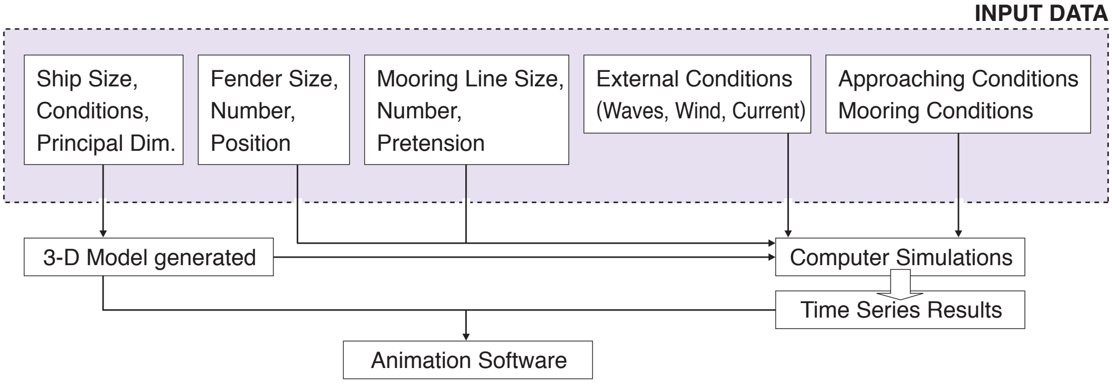
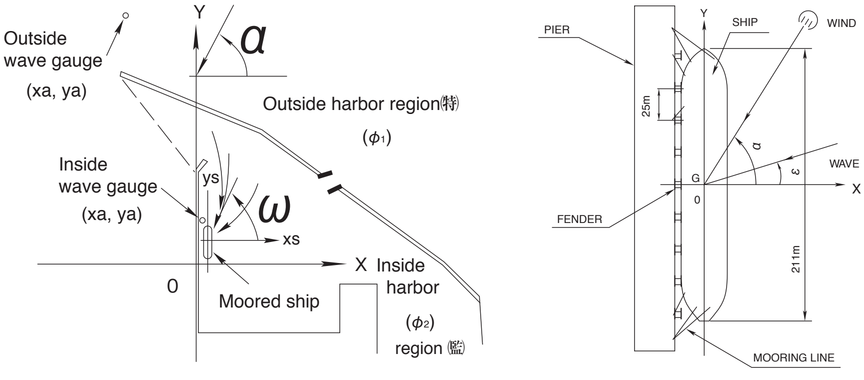


Fig.7-12 Numerical Simulation for Ship Motions Moored along Jetty (IMOS)



(a) Harbor Layout (b) Mooring Arrangement

$$\sum_{j=1}^{6}\left\{M_{ij}+m_{ij}(\infty)\right\}\ddot{x}_j(t)+\sum_{j=1}^{6}\int_{-\infty}^{t}\dot{x}_j(\tau)\cdot L_{ij}(t-\tau)d\tau+\sum_{j=1}^{6}D_{ij}\cdot\dot{x}_j(t)$$
$$+\sum_{j=1}^{6}C_{ij}\cdot x_j(t)+G_i=F_i(t),(i=1,2........,6)$$

Fig.7-13 Applicable conditions for Ship moored along Jetty (IMOS)

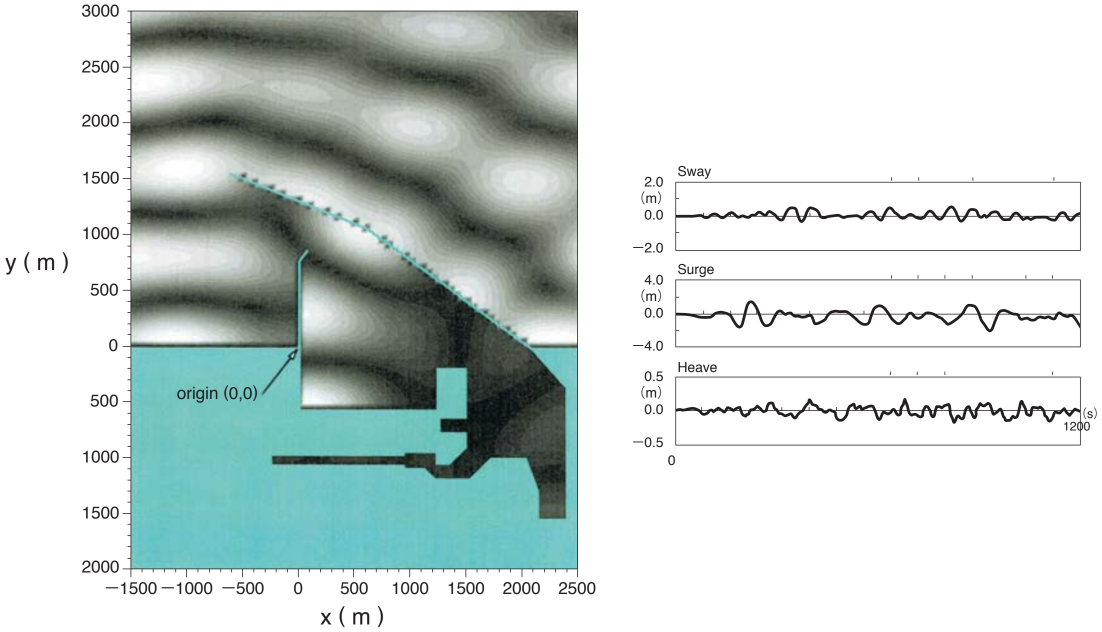


Fig.7-14 Simulation Results of Harbor Oscillations and Moored Ship Motions (IMOS)

7.3 Required Data for Securing Fenders

If assistance is required in selecting the proper fender for a particular application, select the appropriate data sheet and submit the completed sheet together with your query.

7.3.1 Ship-to-Ship Use

	Fender Selection Data Form for Ship-to-Ship Use		
1.	Location of site		
2.	Potential sea state		
3.	Potential beaufort scale		
4.	Type of lightering e.g. ordinary lightering or reverse lightering		
5.	Water depth around STS ops.	m (ft)	
		Ship-A	Ship-B
6.	Type of ship e.g. tanker, ore carrier, gas carrier, etc.		
7.	Role of lightering e.g. discharging ship (STBL), receiving ship		
8.	Displacement tonnage (full loaded)	ton	ton
9.	Displacement tonnage (at start of STS ops.)	ton	ton
10.	Gross tonnage (GT)	GT	GT
11.	Dead weight tonnage (DWT)	DWT	DWT
12.	Length of ship (over-all length) (Loa)	m (ft)	m (ft)
13.	Length of ship (length between P.P.) (Lpp)	m (ft)	m (ft)
14.	Beam	m (ft)	m (ft)
15.	Depth	m (ft)	m (ft)
16.	Draft (full loaded)	m (ft)	m (ft)
17.	Draft (at start of STS ops.)	m (ft)	m (ft)
18.	Freeboard when coming in contact	m (ft)	m (ft)
19.	Relative approaching velocity of ships	m/s (ft/s)	
20.	Mooring line sizes	mm	
21.	Mooring line pretensions	ton	
22.	Number of mooring lines		
23.	Other information		

7.3.2 Ship-to-Jetty Use

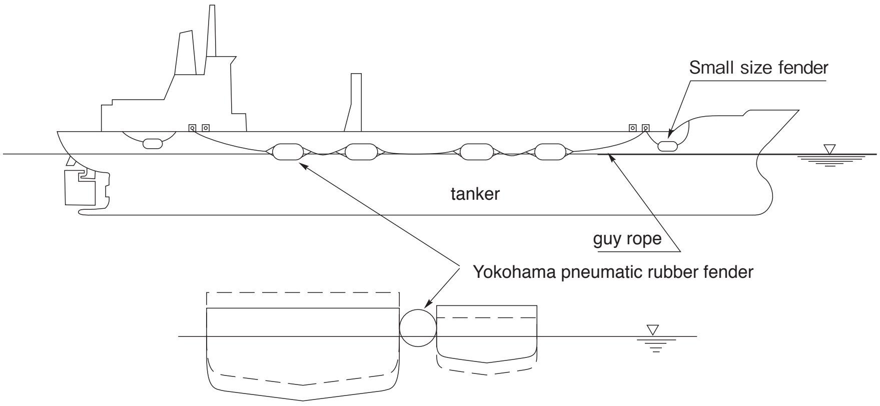
	Fender Selection Data Form for Ship-to-Jetty Use		
1.	Location of site		
2.	Loading or unloading berth		
		Large ship	Small ship
3.	Type of ship e.g. tanker, ore carrier, gas carrier, etc.		
4.	Displacement tonnage (full loaded)	ton	ton
5.	Disp. tonnage when coming in contact	ton	ton
6.	Gross tonnage (GT)	GT	GT
7.	Dead weight tonnage (DWT)	DWT	DWT
8.	Length of ship (over-all length) (Loa)	m (ft)	m (ft)
9.	Length of ship (length between P.P.) (Lpp)	m (ft)	m (ft)
10.	Beam	m (ft)	m (ft)
11.	Depth	m (ft)	m (ft)
12.	Draft (full loaded)	m (ft)	m (ft)
13.	Draft when coming in contact	m (ft)	m (ft)
14.	Freeboard when coming in contact	m (ft)	m (ft)
15.	Berthing velocity to dock	m/s (ft/s)	m/s (ft/s)
16.	Berthing angle	degree	degree
17.	Required energy	kNm (ft-kips)	kNm (ft-kips)
18.	Berthing point of ship from bow end	m (ft)	m (ft)
19.	Kind of docks e.g. jetty or quay, dolphins, etc.		
20.	Top level from sea bed	m (ft)	
21.	Bottom elevation from sea level if bottom is elevated from sea bed	m (ft) m (ft)	
22.	Length of jetty or quay	m (ft)	
23.	Width of dolphin	m (ft)	
24.	Height of dolphin	Dolphins	
25.	Number of dolphins	m (ft)	
26.	Spacing of dolphins	ton (kips)	
27.	Permissible reaction force of dock	ton/m² (kips/ft²)	
28.	Permissible hull pressure	m (ft)	
29.	Permissible standoff of fender	m (ft)	
30.	Tidal range : HWL, High water level LWL, Low water level	m (ft) m (ft)	
31.	Water depth around dock	m (ft)	
32.	Maximum wave height at mooring	m (ft)	
33.	Swell period	s	
34.	Long wave period	m/s	
35.	Maximum wind speed at mooring		
36.	Drawings: Attached or not		
37.	Required fender type Floating fender, ABF-P, others		
38.	Required quantity of fenders	mm	
39.	Mooring line sizes	ton	
40.	Mooring line pretensions		
41.	Number of mooring lines		
42.	Other information		

8. SHIP-TO-SHIP APPLICATIONS

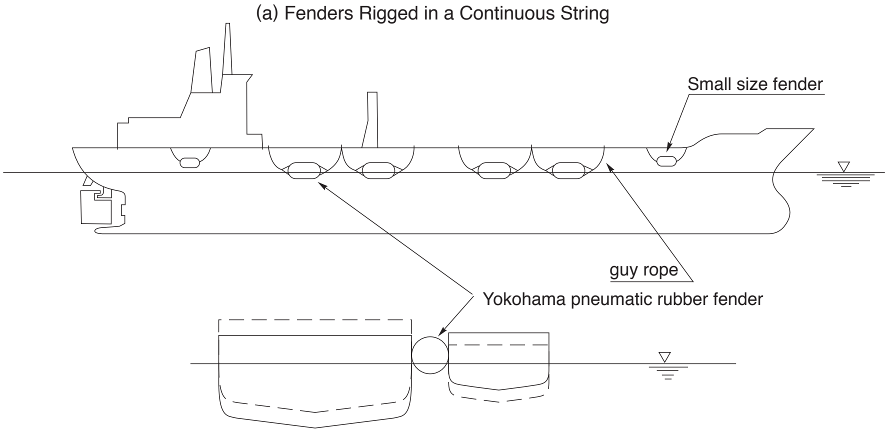
8.1 Installation examples

Four large-size fenders are usually floated at the water line as primary fenders to absorb impact energy at berthing and keep proper stand-off distance between two ships.

Two small-size fenders (secondary fenders) are hung high on the hull at both bow and stern of smaller ship to prevent contact from rolling of ships due to swell and wind. "STS Transfer Guide", published by CDI, ICS, OCIMF, SIGTTO, is a good reference for further information. Fig.8-1and 8-2 show the installation examples.



(a) Fenders Rigged in a Continuous String



(b) Fenders guyed individually

Fig.8-1 Installation Method in case of Ship-to-Ship Transfer Operations

Fig.8-2 Actual Installation Method in case of Ship-to-Ship Transfer Operations

8.2 Equipments

At both ends of the fender, first shackles need to be installed to connect a guy chain or guy rope, Table 8-1 shows the recommended shackle size for each fender size. The first shackle at each end is supplied together with the fenders.

Table 8-1 End Shackle for Chain / Wire Net Type & Sling Type

Size	Initial Internal Pressure	Type of Both Ends of net Chain Net & Wire Net	Shackle	Shackle
			In Case of Chain Net & Wire Net	In Case of Sling Type
	(kPa)		mm (inches)	mm (inches)
500 × 1000	50	Double Ring	22 (7/8)	SB16 (5/8)
	80		22 (7/8)	SB16 (5/8)
600 × 1000	50		22 (7/8)	SB16 (5/8)
	80		22 (7/8)	SB16 (5/8)
700 × 1500	50		22 (7/8)	SB16 (5/8)
	80		22 (7/8)	SB16 (5/8)
1000 × 1500	50		22 (7/8)	SB16 (5/8)
	80		22 (7/8)	SB16 (5/8)
1000 × 2000	50		22 (7/8)	SB16 (5/8)
	80		22 (7/8)	SB16 (5/8)
1200 × 2000	50		25 (1)	SB16 (5/8)
	80		25 (1)	SB16 (5/8)
1350 × 2500	50		25 (1)	SB18 (11/16)
	80		25 (1)	SB18 (11/16)
1500 × 3000	50	Towing Ring	SB24 (15/16)	SB18 (11/16)
	80		SB24 (15/16)	SB20 (13/16)
1700 × 3000	50		SB24 (15/16)	SB20 (13/16)
	80		SB24 (15/16)	SB20 (13/16)
2000 × 3500	50		SB26 (1)	SB20 (13/16)
	80		SB28 (1-1/8)	SB24 (13/16)
2500 × 4000	50		SB32 (1-1/4)	SB28 (1-1/8) × 2
	80		SB34 (1-5/16)	SB30 (1-3/16) × 2
2500 × 5500	50		SB34 (1-5/16)	SB32 (1-1/4) × 2
	80		SB40 (1-9/16)	SB36 (1-7/16) × 2
3300 × 4500	50		SB36 (1-7/16)	SB32 (1-1/4) × 2
	80		SB40 (1-9/16)	SB34 (1-5/16) × 2
3300 × 6500	50		SB44 (1-3/4)	SB40 (1-9/16) × 2
	80		SB48 (1-7/8)	SB44 (1-3/4) × 2
3300 × 10600	50	Special Towing Ring	-	-
	80		-	-
4500 × 9000	50		-	-
	80		-	-
4500 × 12000	50		-	-
	80		-	-

8.3 Installation Photographs

Production Platform ϕ3300×4500L

FPSO ϕ2500×5500L

FPSO ϕ3300×6500L

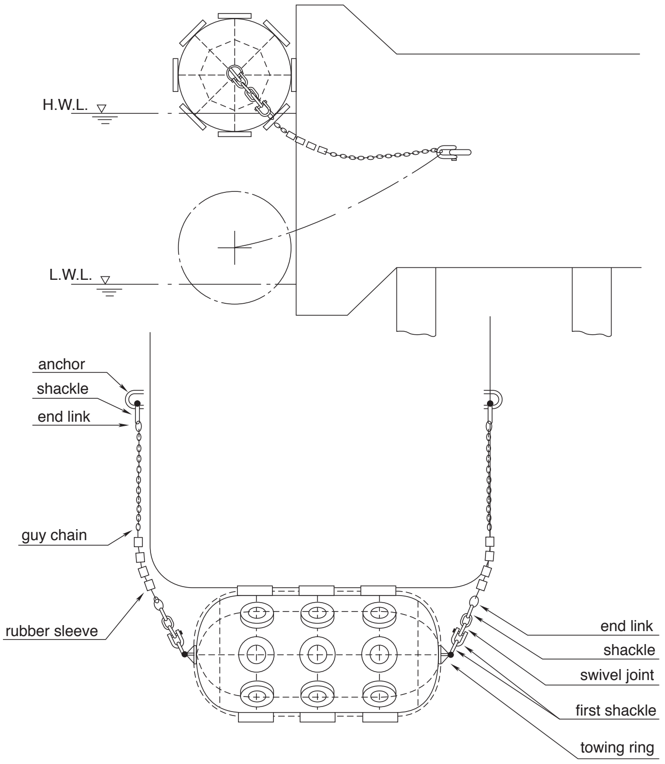
FPSO ϕ3300×6500L

9. SHIP-TO-JETTY APPLICATIONS

9.1 Installation Methods

At both ends of the fender, first shackles, then swivel joints, followed by a further shackle should be installed. A guy chain or guy rope is secured to the outer shackle. The swivel joint prevents twisting of the guy chain or wire.

a) Dolphin



b) Continuous quay

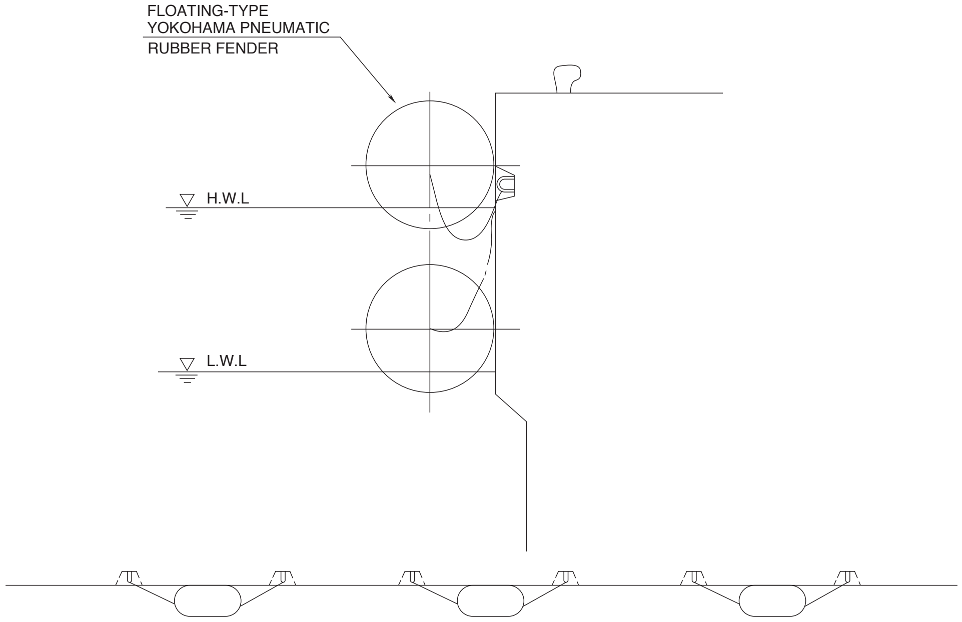


Fig.9-1 Installation Methods for Ship-to-Jetty Applications

9.2 Equipments

9.2.1 Typical installation

Typical installation equipment and necessary parts for installations are shown below. The first shackles at each end of a fender are supplied with the fenders. Guy chains and guy ropes, as well as shackles, swivel, rubber sleeves and anchors are not supplied with the fenders, but they can be purchased separately upon request.

Fig.9-2 Equipments of Typical Installation for Ship-to-Jetty Applications.

9.2.2 Chain net type (Type Ⅰ) Small Sizes

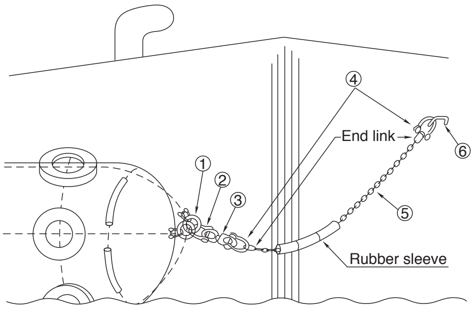


Table 9-1 Installation Recommendation for Chain net type (Type Ⅰ) Small Sizes

Parts			①*	②*	③	④	⑤		⑥
Nominal Size Dia. × Length	Type	Initial Pressure	Ring Diameter	First Shackle Diameter	Swivel Diameter	2nd, 3rd Shackle Diameter (SB)	Guy Rope (JIS-G3525) (6 × 24-G) Diameter	Guy Chain (SBC490) Diameter	Anchor Diameter
(m)		(kPa)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)
0.5 × 1.0	Ⅰ	50	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
0.6 × 1.0	Ⅰ	50	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
0.7 × 1.5	Ⅰ	50	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
1.0 × 1.5	Ⅰ	50	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
1.0 × 2.0	Ⅰ	50	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
1.2 × 2.0	Ⅰ	50	22 7/8	25 1	22 7/8	22 7/8	16 5/8	16 5/8	25 1
1.35 × 2.5	Ⅰ	50	22 7/8	25 1	22 7/8	22 7/8	18 11/16	16 5/8	25 1
0.5 × 1.0	Ⅰ	80	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
0.6 × 1.0	Ⅰ	80	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
0.7 × 1.5	Ⅰ	80	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
1.0 × 1.5	Ⅰ	80	19 3/4	22 7/8	19 3/4	22 7/8	16 5/8	16 5/8	25 1
1.0 × 2.0	Ⅰ	80	19 3/4	22 7/8	19 3/4	22 7/8	18 11/16	16 5/8	25 1
1.2 × 2.0	Ⅰ	80	22 7/8	25 1	22 7/8	22 7/8	18 11/16	16 5/8	25 1
1.35 × 2.5	Ⅰ	80	22 7/8	25 1	22 7/8	22 7/8	20 13/16	16 5/8	25 1

Note: ①* The Ring and ②* The first shackle at each end of a fender are supplied.
Other equipment can be purchased upon request.

9.2.3 Chain net type (Type Ⅰ) Medium and Large Sizes

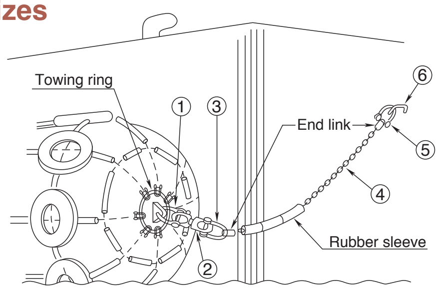


Table 9-2 Installation Recommendation for Chain net type (Type Ⅰ) Medium and Large Sizes

Parts			①*	②	③	④		⑤	⑥
Nominal Size Dia. × Length	Type	Initial Pressure	First Shackle Diameter (SB)	Swivel Diameter	2nd Shackle Diameter (SB)	Guy Rope (JIS-G3525) (6 × 24-G) Diameter	Guy Chain (SBC490) Diameter	3rd Shackle Diameter (SB)	Anchor Diameter
(m)		(kPa)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)
1.5 × 3.0	Ⅰ	50	24 15/16	25 1	24 15/16	20 13/16	19 3/4	24 15/16	32 1-1/4
1.7 × 3.0	Ⅰ	50	24 15/16	25 1	24 15/16	22 7/8	19 3/4	24 15/16	32 1-1/4
2.0 × 3.5	Ⅰ	50	26 1	28 1-1/8	26 1	24 15/16	22 7/8	26 1	32 1-1/4
2.5 × 4.0	Ⅰ	50	32 1-1/4	32 1-1/4	32 1-1/4	30 1-3/16	26 1	32 1-1/4	42 1-5/8
2.5 × 5.5	Ⅰ	50	34 1-5/16	38 1-1/2	34 1-5/16	34 1-5/16	32 1-1/4	34 1-5/16	44 1-3/4
3.3 × 4.5	Ⅰ	50	36 1-7/16	38 1-1/2	36 1-7/16	34 1-5/16	30 1-3/16	36 1-7/16	44 1-3/4
3.3 × 6.5	Ⅰ	50	44 1-3/4	44 1-3/4	44 1-3/4	42 1-5/8	38 1-1/2	44 1-3/4	55 2-3/16
3.3 × 10.6	Ⅰ	50	Special Towing Ring pin Dia. 70 2-3/4			52 2-1/16	48 1-7/8	60 2-3/8	75 3
4.5 × 9.0	Ⅰ	50	Special Towing Ring pin Dia. 70 2-3/4			54 2-1/8	50 2	60 2-3/8	75 3
4.5 × 12.0	Ⅰ	50	Special Towing Ring pin Dia. 72 2-13/16			65 2-9/16	58 2-5/16	65 2-9/16	80 3-1/8
1.5 × 3.0	Ⅰ	80	24 15/16	25 1	24 15/16	24 15/16	20 13/16	24 15/16	32 1-1/4
1.7 × 3.0	Ⅰ	80	24 15/16	25 1	24 15/16	24 15/16	20 13/16	24 15/16	32 1-1/4
2.0 × 3.5	Ⅰ	80	28 1-1/8	28 1-1/8	28 1-1/8	28 1-1/8	24 15/16	28 1-1/8	36 1-7/16
2.5 × 4.0	Ⅰ	80	34 1-5/16	38 1-1/2	34 1-5/16	32 1-1/4	30 1-3/16	34 1-5/16	42 1+5/8
2.5 × 5.5	Ⅰ	80	40 1-9/16	44 1-3/4	40 1-9/16	40 1-9/16	36 1-7/16	40 1-9/16	50 2
3.3 × 4.5	Ⅰ	80	40 1-9/16	44 1-3/4	40 1-9/16	38 1-1/2	34 1-5/16	40 1-9/16	50 2
3.3 × 6.5	Ⅰ	80	48 1-7/8	50 2	48 1-7/8	46 1-13/16	42 1-5/8	48 1-7/8	60 2-3/8
3.3 × 10.6	Ⅰ	80	Special Towing Ring pin Dia. 70 2-3/4			60 2-3/8	54 2-1/8	65 2-9/16	75 3
4.5 × 9.0	Ⅰ	80	Special Towing Ring pin Dia. 72 2-13/16			65 2-9/16	58 2-5/16	65 2-9/16	75 3
4.5 × 12.0	Ⅰ	80	Special Towing Ring pin Dia. 90 3-9/16			75 3	68 2-11/16	75 3	85 3-3/8

Note: ①* The first shackle at each end of a fender is supplied.
Other equipment can be purchased upon request.

9.2.4 Sling type (Type Ⅱ)

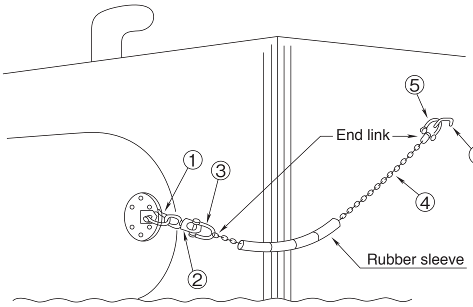


Table 9-3 Installation Recommendation for Sling type (Type Ⅱ)

Parts			①	②	③	④		⑤	⑥
Nominal Size Dia. × Length	Type	Initial Pressure	First Shackle Diameter (SB)	Swivel Diameter	2nd Shackle Diameter (SB)	Guy Rope (JIS-G3525) (6 × 24-G) Diameter	Guy Chain (SBC490) Diameter	3rd Shackle Diameter (SB)	Anchor Diameter
(m)		(kPa)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)	(mm) (inch)
0.5 × 1.0	Ⅱ	50	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
0.6 × 1.0	Ⅱ	50	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
0.7 × 1.5	Ⅱ	50	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.0 × 1.5	Ⅱ	50	16 5/8	19 3/4	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.0 × 2.0	Ⅱ	50	16 5/8	19 3/4	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.2 × 2.0	Ⅱ	50	16 5/8	19 3/4	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.35 × 2.5	Ⅱ	50	18 11/16	19 3/4	22 7/8	18 11/16	16 5/8	22 7/8	25 1
1.5 × 3.0	Ⅱ	50	18 11/16	22 7/8	24 15/16	20 13/16	19 3/4	24 15/16	32 1-1/4
1.7 × 3.0	Ⅱ	50	20 13/16	25 1	24 15/16	22 7/8	19 3/4	24 15/16	32 1-1/4
2.0 × 3.5	Ⅱ	50	20 13/16	28 1-1/8	26 1	24 15/16	22 7/8	26 1	32 1-1/4
2.5 × 4.0	Ⅱ	50	28 × 2 1-1/8	32 1-1/4	32 1-1/4	30 1-3/16	26 1	32 1-1/4	42 1-5/8
2.5 × 5.5	Ⅱ	50	32 × 2 1-1/4	38 1-1/2	34 1-5/16	34 1-5/16	32 1-1/4	34 1-5/16	44 1-3/4
3.3 × 4.5	Ⅱ	50	36 + 32 1-7/16+1-1/4	38 1-1/2	36 1-7/16	34 1-5/16	30 1-3/16	36 1-7/16	44 1-3/4
3.3 × 6.5	Ⅱ	50	40 × 2 1-9/16	44 1-3/4	44 1-3/4	42 1-5/8	38 1-1/2	44 1-3/4	55 2-3/16
3.3 × 10.6	Ⅱ	50	Special Towing Ring pin Dia. 70 2-3/4			52 2-1/16	48 1-7/8	60 2-3/8	75 3
0.5 × 1.0	Ⅱ	80	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
0.6 × 1.0	Ⅱ	80	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
0.7 × 1.5	Ⅱ	80	16 5/8	16 5/8	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.0 × 1.5	Ⅱ	80	16 5/8	19 3/4	22 7/8	16 5/8	16 5/8	22 7/8	25 1
1.0 × 2.0	Ⅱ	80	16 5/8	19 3/4	22 7/8	18 11/16	16 5/8	22 7/8	25 1
1.2 × 2.0	Ⅱ	80	16 5/8	19 3/4	22 7/8	18 11/16	16 5/8	22 7/8	25 1
1.35 × 2.5	Ⅱ	80	18 11/16	19 3/4	22 7/8	20 13/16	16 5/8	22 7/8	25 1
1.5 × 3.0	Ⅱ	80	20 13/16	25 1	24 15/16	24 15/16	20 13/16	24 15/16	32 1-1/4
1.7 × 3.0	Ⅱ	80	20 13/16	25 1	24 15/16	24 15/16	20 13/16	24 15/16	32 1-1/4
2.0 × 3.5	Ⅱ	80	22 7/8	28 1-1/8	28 1-1/8	28 1-1/8	24 15/16	28 1-1/8	36 1-7/16
2.5 × 4.0	Ⅱ	80	30 × 2 1-3/16	38 1-1/2	34 1-5/16	32 1-1/4	30 1-3/16	34 1-5/16	42 1-5/8
2.5 × 5.5	Ⅱ	80	36 × 2 1-7/16	44 1-3/4	40 1-9/16	40 1-9/16	36 1-7/16	40 1-9/16	50 2
3.3 × 4.5	Ⅱ	80	36 + 34 1-7/16+1-5/16	44 1-3/4	40 1-9/16	38 1-1/2	34 1-5/16	40 1-9/16	50 2
3.3 × 6.5	Ⅱ	80	44 × 2 1-3/4	50 2	48 1-7/8	46 1-13/16	42 1-5/8	48 1-7/8	60 2-3/8
3.3 × 10.6	Ⅱ	80	Special Towing Ring pin Dia. 70 2-3/4			60 2-3/8	54 2-1/8	65 2-9/16	75 3

Note: ①* The first shackle at each end of a fender is supplied.
Other equipment can be purchased upon request.

9.3 Dimension of Jetty for Installation

Rubber fender should be in a state of plane contact, as shown below, even when it is deflected.

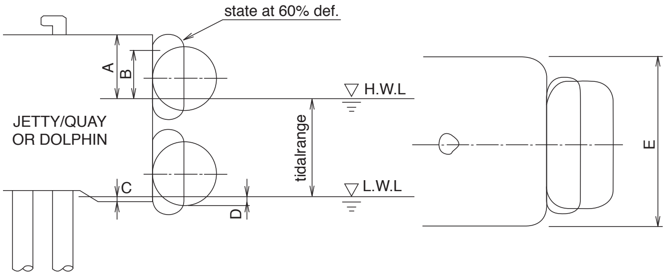


Table 9-4 Dimension of jetty for installation

Size	Initial* Pressure (kPa)	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)
500 × 1000	50	420	320	160	170	1300
600 × 1000	50	530	410	150	170	1300
700 × 1500	50	530	390	270	290	1950
1000 × 1500	50	840	640	300	330	1950
1000 × 2000	50	890	690	250	280	2600
1200 × 2000	50	1060	820	320	350	2600
1350 × 2500	50	1250	980	290	330	3250
1500 × 3000	50	1410	1110	310	350	3900
1700 × 3000	50	1620	1280	320	370	3900
2000 × 3500	50	1920	1520	360	420	4550
2500 × 4000	50	2440	1940	420	490	5200
2500 × 5500	50	2460	1960	400	470	7150
3300 × 4500	50	3300	2640	480	570	5850
3300 × 6500	50	3360	2700	420	510	8450
3300 × 10600	50	3400	2740	380	470	13780
4500 × 9000	50	4660	3760	480	610	11700
4500 × 12000	50	4710	3810	430	560	15600
500 × 1000	80	410	310	170	180	1300
600 × 1000	80	520	400	160	180	1300
700 × 1500	80	530	390	270	290	1950
1000 × 1500	80	840	640	300	330	1950
1000 × 2000	80	890	690	250	280	2600
1200 × 2000	80	1060	820	320	350	2600
1350 × 2500	80	1250	980	290	330	3250
1500 × 3000	80	1400	1100	320	360	3900
1700 × 3000	80	1610	1270	330	380	3900
2000 × 3500	80	1910	1510	370	430	4550
2500 × 4000	80	2420	1920	440	510	5200
2500 × 5500	80	2450	1950	410	480	7150
3300 × 4500	80	3270	2610	510	600	5850
3300 × 6500	80	3330	2670	450	540	8450
3300 × 10600	80	3370	2710	410	500	13780
4500 × 9000	80	4640	3740	500	630	11700
4500 × 12000	80	4690	3790	450	580	15600

Note : Above figures are obtained using weights of chain net type, and the difference between the figures for wire net type is small, therefore, the above figures may be used also for wire net type as well.

9.4 Installation Photographs


LNG Terminal ϕ3300×6500L


LNG Terminal ϕ3300×4500L


Coal Terminal ϕ4500×9000L


Ship yard ϕ3300×6500L


High Speed Ferry ϕ2000×3500L


IRONSTONE TERMINAL ϕ3300×10600L

Terminal ϕ3300×4500L

Ferry Terminal ϕ1000×2000L ϕ700×1500L

Terminal:Pneumatic Cell ABF-P

LNG Terminal:Pneumatic Cell ABF-P

10. MAINTENANCE TOOLS

The following maintenance tools can be purchased upon request.

10.1 Small and medium-size (Size : ϕ500mm～ϕ2000mm).

A. Repair Tool Kit

1) Rubber sheet	0.5 m^2
2) Rubber plugs	10 pcs.
3) Brush	1 pc.
4) Sandpaper	1 sheet
5) Tool for inserting rubber plug	1 pc.
6) Hand roller	1 pc.

Repair Tool Kit for Small and Medium size Fenders

B. Installation Tool Kit

1) Air pressure gauge with air chuck	1 set
2) Air filling hose with air chuck	10 m
3) Box spanner for removing air valve	1 pc.
4) Valve core screw driver	1 pc.
5) Spare valve (air valve)	1 pc.

Installation Tool Kit for Small and Medium size Fenders

C. Manuals

D. Fender logbook

Remarks: Adhesive (cement) is not included in repair kits because of short life time and transportation problems, and therefore TIP TOP SC 2000 or SC4000 needs to be purchased locally.

10.2 Large-size (Size：φ2500mm～φ4500mm).

A. Repair Tool Kit

1) Rubber sheet	1 m^2(0.5m^2×2)
2) Brush	2 pcs.
3) Sandpaper	2 sheets
4) Wire brush	1 pc.
5) Hand roller	1 pc.

Repair Tool Kit for Large size Fenders

B. Installation Tool Kit

1) Air pressure gauge with air chuck	1 set
2) Air filling hose with air chuck	20 m
3) Box spanner for removing air valve	1 pc.
4) Valve core screw driver	1 pc.
5) Spare valve (air valve)	1 pc.

Installation Tool Kit for Large size Fenders

C. Manuals

D. Fender logbook

E. Safety valve logbook

Remarks: Adhesive (cement) is not included in repair kits because of short life time and transportation problems, and therefore TIP TOP SC 2000 or SC4000 needs to be purchased locally.

11. PRECAUTIONS ON HANDLING

(1) Because the pneumatic rubber fender is usually shipped in deflated condition (as shown in the pictures below), it should be immediately inflated to the pressure 20～30kPa upon arrival at its destination.

(2) When storing the fender more than three months without use, reduce internal pressure to about half of initial pressure (20～30kPa) so that the pressure will not rise too high due to a rise in the atmospheric temperature. Do not deflate or fold.

(3) For further instructions about handling, please refer to the handling and maintenance manual that is provided with each fender purchase, or please contact The Yokohama Rubber Co., Ltd for assistance.

Fig.11-1 φ4500×9000L-P80 Transportation on Steel Pallet

Fig.11-2 φ3300×6500L-P80 Transportation by Open-top Container

Fig.11-3 φ2500×5500L-P50 Transportation by Open-top Container

Fig.11-4 φ3300×6500L-P50 Body Only under the deflated condition

Appendix
TYPICAL SHIP CHARACTERISTICS

Ap-1 Oil Tanker

DWT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	1,590	2,849	61	57	10.2	4.5	4.0	1.792	0.662
2,000	3,080	5,486	76	72	12.6	5.7	4.9	1.781	0.676
3,000	4,530	8,042	87	82	14.3	6.6	5.5	1.775	0.684
4,000	5,970	10,573	95	90	15.6	7.3	6.0	1.771	0.691
5,000	7,390	13,064	102	96	16.7	7.9	6.4	1.768	0.696
6,000	8,800	15,533	108	102	17.7	8.4	6.8	1.765	0.701
8,000	11,600	20,427	118	112	19.3	9.3	7.4	1.761	0.708
10,000	14,300	25,136	127	121	20.7	10.1	7.9	1.758	0.711
12,000	17,100	30,013	134	128	21.9	10.7	8.3	1.755	0.718
15,000	21,100	36,966	144	137	23.5	11.6	8.8	1.752	0.721
20,000	27,800	48,590	158	151	25.7	12.8	9.6	1.748	0.728
25,000	34,400	60,017	169	162	27.5	13.9	10.3	1.745	0.734
30,000	41,000	71,427	179	172	29.1	14.8	10.8	1.742	0.739
40,000	54,000	93,856	196	188	31.9	16.4	11.8	1.738	0.746
50,000	66,800	118,692	210	203	32.3	17.7	12.5	1.777	0.794
60,000	79,500	144,622	223	215	32.3	18.9	13.2	1.819	0.845
80,000	105,000	181,483	244	236	39.5	20.9	14.4	1.728	0.765
100,000	130,000	224,293	262	253	42.3	22.6	15.3	1.725	0.771
120,000	154,000	265,315	277	268	44.8	24.1	16.2	1.723	0.772
150,000	191,000	328,475	297	288	48.0	26.1	17.3	1.720	0.779
200,000	251,000	430,676	326	316	52.5	28.8	18.8	1.716	0.785
250,000	311,000	532,685	349	340	56.2	31.2	20.0	1.713	0.792
300,000	370,000	632,829	370	361	59.5	33.2	21.1	1.710	0.796
330,000	406,000	693,880	381	372	61.3	34.4	21.7	1.709	0.800
370,000	453,000	773,508	395	386	63.5	35.8	22.5	1.708	0.803

Ap-2 Gas Carrier

GT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	2,480	4,454	71	65	111.6	5.7	4.6	1.796	0.685
2,000	4,570	8,183	88	82	14.3	7.3	5.7	1.791	0.676
3,000	6,530	11,672	100	93	16.1	8.4	6.4	1.787	0.671
4,000	8,420	15,031	109	101	17.6	9.3	6.9	1.785	0.667
5,000	10,200	18,191	117	109	18.8	10.1	7.4	1.783	0.661
6,000	12,000	21,384	124	115	19.8	10.8	7.8	1.782	0.660
8,000	15,500	27,586	135	126	21.6	11.9	8.4	1.780	0.658
10,000	18,900	33,604	145	136	23.1	12.9	9.0	1.778	0.657
12,000	22,200	39,440	153	144	24.4	13.8	9.5	1.777	0.655
15,000	27,000	47,921	164	154	26.0	14.9	10.1	1.775	0.651
20,000	34,800	61,687	179	169	28.4	16.5	11.0	1.773	0.648
25,000	42,400	75,086	192	181	30.3	17.9	11.7	1.771	0.646
30,000	49,800	88,121	203	192	32.0	19.1	12.3	1.770	0.644
40,000	64,100	109,372	222	210	34.8	21.2	12.3	1.706	0.695
50,000	78,100	129,723	238	225	37.2	22.9	12.3	1.661	0.738
60,000	91,700	149,117	252	239	39.3	24.5	12.3	1.626	0.775
80,000	118,000	185,834	275	261	42.8	27.1	12.3	1.575	0.836
100,000	144,000	221,472	295	281	45.7	29.4	12.3	1.538	0.890

Ap-3 Bulk Carrier

DWT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	1,510	2,757	68	62	9.4	5.3	3.9	1.826	0.647
2,000	2,910	5,290	83	76	11.7	6.5	4.8	1.818	0.665
3,000	4,270	7,743	94	86	13.3	7.4	5.4	1.813	0.675
4,000	5,610	10,154	102	94	14.5	8.0	5.9	1.810	0.683
5,000	6,920	12,508	108	101	15.5	8.6	6.3	1.808	0.688
6,000	8,230	14,859	114	106	16.4	9.1	6.6	1.805	0.694
8,000	10,800	19,464	124	116	18.0	9.9	7.2	1.802	0.701
10,000	13,300	23,936	132	124	19.3	10.6	7.7	1.800	0.706
12,000	15,800	28,403	139	131	20.4	11.2	8.1	1.798	0.710
15,000	19,600	35,185	148	140	21.9	11.9	8.7	1.795	0.720
20,000	25,700	46,054	161	152	23.9	13.0	9.5	1.792	0.727
25,000	31,700	56,728	171	163	25.6	13.9	10.1	1.790	0.732
30,000	37,700	67,389	181	172	27.1	14.7	10.7	1.787	0.738
40,000	49,500	88,325	196	187	29.7	16.0	11.6	1.784	0.747
50,000	61,100	108,145	209	200	32.3	17.1	12.4	1.770	0.741
60,000	72,600	131,611	220	211	32.3	18.1	13.1	1.813	0.790
80,000	95,400	169,503	239	230	36.8	19.7	14.3	1.777	0.768
100,000	118,000	209,372	254	246	39.5	21.1	15.3	1.774	0.775
120,000	140,000	248,131	268	260	41.8	22.2	16.1	1.772	0.780
150,000	173,000	306,202	286	278	44.8	23.8	17.2	1.770	0.787
200,000	227,000	401,077	310	303	49.0	25.9	18.8	1.767	0.796
250,000	280,000	494,051	330	324	52.5	27.7	20.1	1.764	0.801
300,000	333,000	586,918	348	342	55.5	29.2	21.2	1.763	0.808

Appendix
TYPICAL SHIP CHARACTERISTICS

Ap-4 General Cargo Ship

DWT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	1,690	2,908	67	62	10.8	5.8	3.9	1.721	0.625
2,000	3,250	5,672	84	78	13.1	7.2	4.9	1.745	0.634
3,000	4,770	8,395	95	88	14.7	8.1	5.6	1.760	0.641
4,000	6,250	11,065	104	97	15.9	8.8	6.1	1.770	0.644
5,000	7,710	13,714	111	104	17.0	9.5	6.6	1.779	0.647
6,000	9,160	16,356	118	110	17.8	10.0	7.0	1.786	0.649
8,000	12,000	21,558	129	121	19.3	10.9	7.7	1.797	0.653
10,000	14,800	26,715	138	130	20.6	11.6	8.3	1.805	0.655
12,000	17,600	31,894	146	137	21.6	12.3	8.8	1.812	0.659
15,000	21,700	39,514	156	147	23.0	13.2	9.4	1.821	0.661
20,000	28,500	52,221	171	162	24.9	14.4	10.4	1.832	0.666
25,000	35,100	64,629	183	173	26.5	15.3	11.2	1.841	0.668
30,000	41,700	77,090	194	184	27.9	16.2	11.8	1.849	0.670
40,000	54,700	101,768	212	201	30.2	17.7	13.0	1.860	0.674
50,000	67,500	126,208	227	216	32.2	18.9	14.0	1.870	0.678

Ap-5 Container Ship

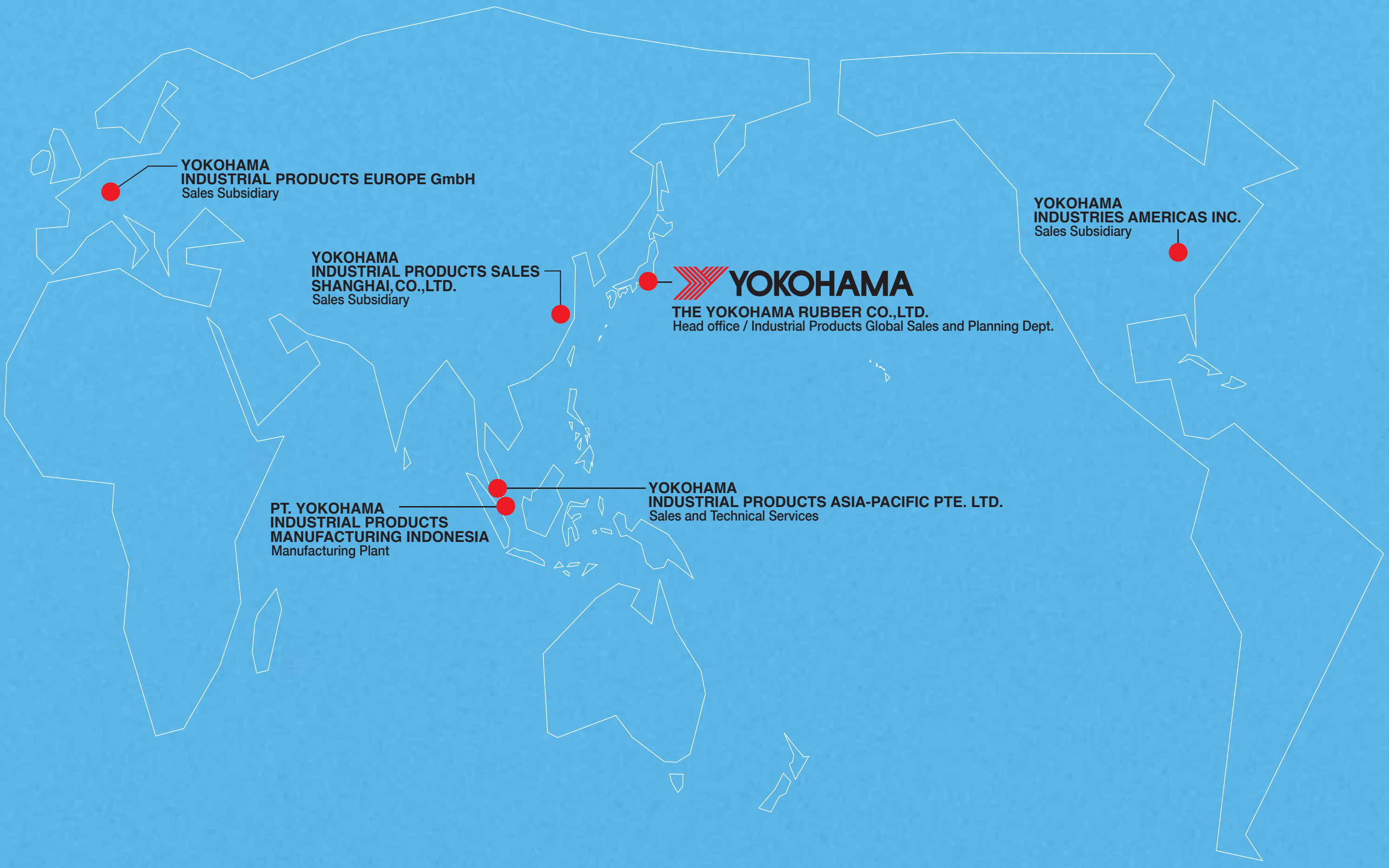
DWT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
7,000	10,700	18,273	122	114	20.3	9.8	7.2	1.708	0.624
8,000	12,100	20,699	129	121	21.1	10.4	7.5	1.711	0.619
10,000	15,000	25,734	141	132	22.4	11.3	8.0	1.716	0.617
12,000	17,900	30,782	151	142	23.5	12.2	8.5	1.720	0.617
15,000	22,100	38,115	165	155	25.0	13.3	9.1	1.725	0.612
20,000	29,100	50,376	185	174	27.1	14.9	9.9	1.731	0.609
25,000	36,000	62,504	202	191	28.7	16.3	10.6	1.736	0.606
30,000	42,800	74,489	217	205	30.2	17.5	11.2	1.740	0.603
40,000	56,300	98,838	243	230	32.3	19.6	12.2	1.756	0.606
50,000	69,700	126,047	266	252	32.3	21.4	13.1	1.808	0.641
60,000	82,900	145,611	285	271	36.5	23.0	13.8	1.756	0.594
80,000	109,000	186,920	320	304	39.4	25.8	14.1	1.715	0.629
100,000	135,000	227,756	349	332	41.9	28.2	14.4	1.687	0.657

Ap-6 Passenger Ship

GT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	1,030	1,468	64	60	12.1	4.9	2.6	1.425	0.539
2,000	1,910	2,807	81	75	14.4	6.3	3.4	1.470	0.509
3,000	2,750	4,120	93	86	15.9	7.4	4.0	1.498	0.493
4,000	3,550	5,394	103	95	17.1	8.3	4.4	1.520	0.481
5,000	4,330	6,654	111	102	18.1	9.0	4.9	1.537	0.472
6,000	5,090	7,895	119	108	19.0	9.7	5.2	1.551	0.464
8,000	6,580	10,360	131	119	20.4	10.8	5.8	1.574	0.454
10,000	8,030	12,795	142	128	21.5	11.7	6.4	1.593	0.445
12,000	9,450	15,207	151	136	22.5	12.6	6.9	1.609	0.439
15,000	11,500	18,737	163	146	23.8	13.7	7.5	1.629	0.429
20,000	14,900	24,676	180	161	25.6	15.3	8.4	1.656	0.420
25,000	18,200	29,492	194	173	27.1	16.7	8.4	1.620	0.451
30,000	21,400	34,086	207	184	28.3	17.9	8.4	1.593	0.477
40,000	27,600	42,826	229	202	30.5	19.9	8.4	1.552	0.521
50,000	33,700	51,283	247	218	32.2	21.7	8.4	1.522	0.559
60,000	39,600	59,341	263	231	33.7	23.3	8.4	1.498	0.591
80,000	51,200	74,952	291	254	36.2	26.0	8.4	1.464	0.646

Ap-7 Ferry

GT (ton)	DT (ton)	VW (ton)	Loa (m)	Lpp (m)	B (m)	D (m)	d (m)	Cm	Cb
1,000	1,240	1,838	67	61	14.3	5.5	3.4	1.482	0.405
2,000	2,440	3,653	86	78	17.0	6.8	4.2	1.497	0.424
3,000	3,630	5,469	99	91	18.8	7.7	4.8	1.506	0.436
4,000	4,810	7,278	110	101	20.2	8.4	5.2	1.513	0.444
5,000	5,990	9,094	119	110	21.3	9.0	5.5	1.518	0.451
6,000	7,160	10,901	127	117	22.3	9.5	5.8	1.523	0.457
8,000	9,500	14,529	141	131	24.0	10.4	6.3	1.529	0.466
10,000	11,800	18,109	153	142	25.4	11.1	6.8	1.535	0.472
12,000	14,100	21,701	164	152	26.5	11.8	7.2	1.539	0.478
15,000	17,600	27,184	177	165	28.0	12.6	7.6	1.545	0.487
20,000	23,300	36,153	197	183	30.1	13.8	8.3	1.552	0.496
25,000	29,000	45,159	213	199	31.9	14.7	8.9	1.557	0.503
30,000	34,700	54,194	228	213	33.3	15.6	9.4	1.562	0.510
40,000	46,100	72,336	253	236	35.8	17.1	10.2	1.569	0.521



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