6. FENDER SELECTION

6.1 Ship-to-Ship Berthing Energy

The berthing energy can be calculated by the following formula.

$$E = \frac{1}{2} M_{AB} \times V_r^{\,2} \times C_e \times SF$$

where

- E is berthing energy
- M_{AB} is equivalent displacement coefficient
- V_r is relative approaching velocity
- C_e is eccentricity factor
- SF is safety factor

■ M_{AB}

$$M_{AB} = \frac{M_{VA} \times M_{VB}}{M_{VA} + M_{VB}} \qquad M_{VB} = M_B \times C_{MB} \qquad M_{VA} = M_A \times C_{MA}$$

where

- M_A is water displacement of the berthing ship A (tons)
- M_B is water displacement of the berthing ship B (tons)
- C_{MA} is added mass coefficient of ship A
- C_{MB} is added mass coefficient of ship B

■ Added Mass Coefficient

$$C_M = 1 + \frac{2d}{B} \qquad \text{or} \qquad C_m = 1 + \frac{\pi}{4C_h} \times \frac{D}{B}$$

where

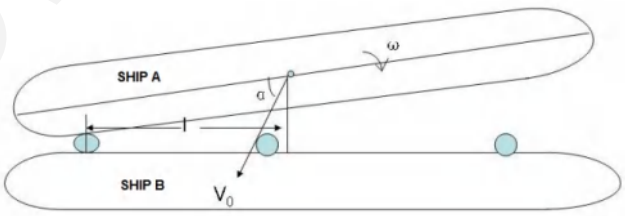
- d is full load draft (m, ft)
- B is molded breadth (m, ft)
- C_b is block coefficient

■ Eccentricity Factor

$$C_e = \frac{l^2 + r^2 \cos^2 \alpha}{l^2 + r^2} \qquad r = (0.19C_b + 0.11)L$$

where

- l is radius of rotation of the vessel (usually 1/4) of the vessel's length)
- α is the angle degree
- C_b is block coefficient
- L is length of ship
- r is distance of the line paralleled to wharf measured from the vessel's center fo gravity to the point of contact



■ Safety Factor

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

■ Relative Approaching

The berthing energy needs to be calculated considering weather conditions, categorized by the three conditions Calm, Moderate and Rough, and the approaching velocity to calculate the berthing energy are assumed to be as the follow table. These information are obtained from various industry references and standards.

DWT	Calm	Moderate	Rough
	0-1.25	1.25-2.5	2.5-4.0
Less 10,000	0.3 m/s	0.4 m/s	0.5 m/s
10,000 - 50,000	0.25 m/s	0.325 m/s	0.4 m/s
50,000 - 100,000	0.2 m/s	0.25 m/s	0.3 m/s
over 100,000	0.15 m/s	0.2 m/s	0.25 m/s

6.2 Ship-to-Jetty Berthing Energy

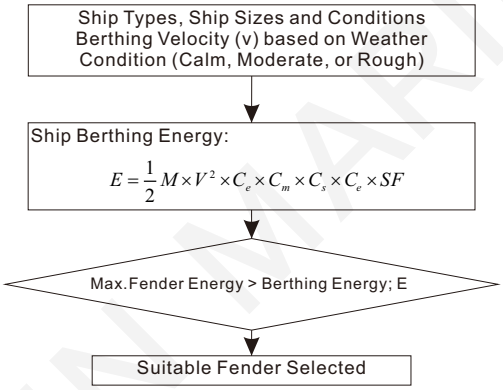
The selection of a pneumatic fender system (sizes and installation methods) for a jetty is determined based on several design parameters for each ship berthing and mooring condition.

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.

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

where

- *E* is ship berthing energy (kNm)
- *W* is displacement (ton)
- *V* is berthing velocity (m/s)
- *d* is draft (m)
- *B* is breadth (m)
- *Ce* is eccentricity factor
- *Cm* is virtual mass factor, $Cm = 1 + \frac{2d}{B}$
- *Cs* is softness coefficient
- *Cc* is beth configuration factor
- *SF* is safety factor



■ Cs Softness Coefficient

This is the portion of berthing energy which is absorbed by the deformation of the vessel's hull and fender. When a soft fender is used, Cs can be ignored. Otherwise, we can assume a valve for Cs=0.9.

■ Cc Berthing Configuration Factor

This is the portion of berthing energy which is absorbed by the cushion effect of water between the approaching vessel and the quay wall. The smaller the draft of the vessel is, or the large the under keel clearance, the more trapped water can escape under the vessel, and would give a higher Cc Valve. Also, if the berthing angle of the vessel is greater than 5 degree, we can consider Cc=1.

■ Safety Factor

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

6.3 OCIMF Table Selection

For the quick reference selection, it is based on initial internal pressure of the fender shall be 50kPa (Pneumatic 50) and the design based on Calm weather condition, therefore if the weather is confirmed as Calm, the fender system can be simply selected from the tables. Equivalent displacement coefficient; ''C'' is calculated, and fenders are selected tentatively by using the table in OCIMF Ship-to-Ship Transfer Guide;

$$C = \frac{2A \bullet B}{A + B}$$

Where,

A, B is the deadweight of the two berthing ships (DWT).

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

PETROLEUM				
Equivalent Displacement Coefficient (C)	Relative Velocity	Berthing Energy	Suggested Fenders	
Tonnes	m/s	Tonnes.m	Dia x Length (m)	Quantity
1,000	0.30	2.4	1.0 x 2.0	3 or more
3,000	0.30	7.0	1.5 x 3.0	3 or more
6,000	0.30	14.0	2.5 x 5.5	3 or more
10,000	0.25	17.0	2.5 x 5.5	3 or more
30,000	0.25	40.0	3.3 x 6.5	4 or more
50,000	0.20	48.0	3.3 x 6.5	4 or more
100,000	0.15	54.0	3.3 x 6.5	4 or more
150,000	0.15	71.0	3.3 x 6.5	5 or more
200,000	0.15	93.0	3.3 x 6.5	5 or more
330,000	0.15	155.0	4.5 x 9.0	4 or more
500,000	0.15	231.0	4.5 x 9.0	4 or more
LIQUIFIED GAS				
Equivalent Displacement Coefficient (C)	Relative Velocity	Berthing Energy	Suggested Fenders	
Tonnes	m/s	Tonnes.m	Dia x Length (m)	Quantity
1,000	0.30	4	1.0 x 2.0	3
3,000	0.30	12	1.5 x 3.0	3
5,000	0.30	24	2.0 x 3.5	3
8,000	0.25	25	2.0 x 3.5	3
20,000	0.25	61	3.3 x 4.5	3
40,000	0.20	74	3.3 x 4.5	4
80,000	0.15	78	3.3 x 4.5	4

Notes:

1. ''Ship-to-Ship Transfer Guide (Petroleum), 4th edition, 2005, OCIMF''

2. ''Ship-to-Ship Transfer Guide (Liquefied gases), 2nd edition, 1995, OCIMF''

6.4 Small and Medium Ships Selection

Fenders can be chosen according to ship tonnage, in reference of below table.

Ship Tonnage (G.T)	Fender size selected DxL (m)
100	0.5X1.0 ~ 1.0x1.5
200	1.2x1.8 ~ 1.2x2.0
300~500	1.2x2.0 ~ 1.5x2.5
1,000	1.5x2.5 ~ 1.7x3.0
3,000	2.0x3.0 ~ 2.0x3.5
10,000	2.0x3.5 ~ 2.5 x 5.0

6.5 Reference Usage Sample

The below table is the reference usage sample of pneumatic rubber fenders for large-scale tankers.

Ship A (DWT)	Ship B (DWT)	Supposed Berthing Speed (m/s)	Berthing Energy (KJ)	Fender Size DxL (m)
300,000	200,000	0.15	1,230	3.3x6.5
	150,000	0.15	1,030	3.3x6.5
	100,000	0.15	781	3.3x6.5
200,000	150,000	0.15	882	3.3x6.5
	100,000	0.15	693	3.0x6.0
	85,000	0.15	618	3.0x5.0
150,000	100,000	0.15	626	3.0x5.0
	85,000	0.15	564	3.0x5.0
	50,000	0.18	573	3.0x5.0
100,000	85,000	0.17	617	3.0x5.0
	50,000	0.18	511	3.0x5.0
	40,000	0.2	544	3.0x5.0
50,000	40,000	0.2	425	2.5x5.0
	30,000	0.22	437	2.5x5.0
	20,000	0.25	443	2.5x5.0
20,000	15,000	0.27	318	2.2x4.5
	10,000	0.3	309	2.2x4.5
	5,000	0.35	253	2.2x4.5
10,000	5,000	0.35	212	2.2x4.5
	3,000	0.4	196	2.0x3.5
	1,000	0.5	127	2.0x3.5