Mooring Load Analysis during Ship to Ship Transfer Operations

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Study conducted by HR Wallingford in collaboration with OCIMF

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Contents

Glossary

Ballast Covers water ballast carried in ships' tanks designated for this purpose.

Breast lines Mooring lines leading ashore as nearly perpendicular as possible to the ship's fore and aft line.

Daughter ship Normally the smaller of the vessels engaged in STS transfer operations.

Discharging ship The ship containing cargo for transfer to the Receiving ship. May also be known as the Ship To Be Lightened (STBL).

Double banked ship to ship operation Also referred to as double banking, this describes an STS operation that is conducted while one ship (usually the larger of the two) is alongside a berth, dolphins or moored to buoys within port limits.

Fatigue The tendency of a material to weaken or fail during alternate tension-tension or tension-compression cycles. In cordage, particularly at loads well below the breaking strength, this degradation is often caused by internal abrasion of the fibres and yarns but may also be caused by fibre damage due to compression. Some fibres develop cracks or splits that cause failure, especially at relatively high loads.

Head lines Mooring lines leading ashore from the fore end of a ship, often at an angle of about 45 degrees to the fore and aft line.

High Modulus Polyethylene (HMPE) A manufactured fibre based on Ultra High Molecular Weight Polyethylene (UHMWPE).

Lightering ship see Receiving ship.

Line Design Break Force (LDBF) The minimum force that a new, dry, spliced mooring line will break at when tested according to Appendix B of *Mooring Equipment Guidelines, Fourth Edition (MEG4).*

Minimum breaking load (MBL) See Ship Design MBL.

Mother ship Normally the larger of the vessels engaged in STS transfer operations. In conventional STS operations, the Mother ship is the Discharging ship. However, in a reverse lightering operation, the Mother ship may be a Receiving ship.

Receiving ship The ship to which cargo is transferred from the Discharging ship. The Receiving ship may also be known as the Lightering ship or Service ship.

Safe Working Load (SWL) Generally, a load less than the yield or failure load by a safety factor defined by a code, standard or good engineering practice. SWL is not in relation to cordage or steel wire mooring lines. In *MEG4*, the SWL of a fitting is greater than or equal to the ship design MBL that contacts the fitting.

Ship Throughout this study the word ship refers to any vessel, including barges, that is designed to carry oil, liquefied gases or chemicals in bulk.

Ship design MBL The minimum breaking load of new, dry mooring lines for which a ship's mooring system is designed, to meet OCIMF standard environmental criteria restraint requirements (defined in section three of *MEG4*). The ship design MBL is the core parameter against which all the other components of a ship's mooring system are sized and designed with defined tolerances.

Ship to be lightered (STBL) See Discharging ship.

Ship to Ship (STS) transfer operation An STS transfer operation is an operation where liquid or gaseous cargo is transferred between ships moored alongside each other. Such operations may take place when one ship is at anchor or alongside or when both are underway. In general, the expression includes the approach manoeuvre, mooring, hose connection, procedures for cargo transfer, hose disconnection, unmooring and departure manoeuvre. The operation may also be referred to as Transhipment.

Spring lines Mooring lines leading in a nearly fore and aft direction to maintain the longitudinal position of the ship while in a berth. Headsprings prevent forward motion and backsprings prevent aft motion.

Stern lines Mooring lines leading ashore from the after end or poop of a ship often at an angle of about 45 degrees to the fore and aft line.

Tail A short length of synthetic rope attached to the end of a mooring line to provide increased elasticity and also ease of handling.

Tonne One tonne equals 1,000 kilograms. A unit of mass that is often also used for forces (sometimes expressed as 'tf'); 1tf = 9.81kN.

Transfer at anchor This describes an operation where a cargo transfer is carried out between ships when they are moored alongside each other and where one of the ships is at anchor.

Underway transfer An STS operation that is conducted between two ships that are underway. A ship is underway when it is not at anchor, made fast to the shore or aground. She may be either steaming or drifting freely with current and weather.

Vessel Throughout this study the word vessel has the same meaning as ship.

Working Load Limit (WLL) The maximum load that a mooring line should be subjected to in operational service, calculated from OCIMF's standard environmental criteria (defined in section 3 of *MEG4*). The WLL is expressed as a percentage of ship design MBL and should be used as a limiting value in both ship design and operational mooring analyses. During operation, the WLL should not be exceeded. In the same way that SWL is a limit for fixed equipment, the WLL value is used as a limit with the standard environmental criteria and mooring layout when designing mooring systems in establishing mooring system designs. Steel wire ropes have a WLL of 55% of the ship design MBL and all other cordage (synthetic) has a WLL of 50% of the ship design MBL. Although technically more accurate to relate the WLL to the specific mooring LDBF, the differences between ship design MBL and LDBF of varying manufacturers will be negligible. Using the ship design MBL allows for a single value for analysis and comparison.

Abbreviations

HMPE	High Modulus Polyethylene
Hs	Significant wave height equivalent to the mean of the highest one third of the waves
IWRC	Independent Wire Rope Core
MBL	Minimum Breaking Load
PP/PES	Polypropylene/Polyester
SBS	Side-by-Side
SDMBL	Ship Design Minimum Breaking Load
STS	Ship-to-Ship
Tp	Wave period of maximum wave energy
WLL	Working Load Limit

Bibliography

Mooring Equipment Guidelines, Fourth Edition (OCIMF).

STS Service Provider Management and Self Assessment, Second Edition (OCIMF).

Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases, First Edition (OCIMF, CDI, ICS, SIGTTO).

1 Introduction

1.1 Purpose and scope

Ship-to-Ship (STS) transfer operations take place under varying environmental conditions, adding to the complexity and risks associated with such transfers. Despite best efforts, mooring line failures are still a leading cause of incidents during transfers, potentially causing harm to people and environment and jeopardising the integrity of ships. This study aims to support stakeholders in making their own assessments to determine suitable weather criteria and ascertain an appropriate weather window for STS operations.

The main causes of exceeding the mooring line load limits include:

- Insufficient knowledge and understanding of the mooring line loads due to differences in mooring line materials, including the load/extension stiffness characteristics.
- Inadequate mooring line arrangement offering insufficient mooring restraint for the environmental conditions.
- Mixing mooring lines of different material, construction and strength, resulting in unequal load sharing between lines.
- Lack of understanding of the impact on mooring line loads resulting from changes in the relative direction of environmental factors such as wind or waves (particularly swell), especially during any alterations in vessel headings.
- Incorrect brake settings, faulty mooring equipment including brake test kit calibration checks, over-confidence in technologies (line tension monitors, weather forecasts, dynamic positioning).

Previous editions of the OCIMF *Ship to Ship Transfer Guide* contained some guidance on the potential impact of environmental conditions, based on a study conducted several years ago. The continued validity of such guidance has been challenged, resulting in the guidance being omitted from the latest edition of the guide.

The extensive development and maturation of mooring line load simulation technology and software programmes in recent years means that equipment and tools are now available to re-assess and re-validate the previous studies. This will allow development of baseline guidance that can then be used for more accurate assessment of mooring line loads anticipated during a scheduled STS operation. This will increase awareness of associated risk and limit environmental thresholds for safe operations, benefitting all those involved in STS operations, including STS Mooring Masters, Ship Masters, Officers, crew and vessels' technical operators/owners.

This study, conducted by HR Wallingford in collaboration with OCIMF, also supports the KPIs listed under Element 5 of *STS Service Provider Management and Self Assessment*. These can be used to do location specific risk assessment and to determine safe operating environment limits, and a suitable weather window for ship to ship cargo transfer operations, as may be needed.

2 STS study methodology

2.1 Underlying principles

When exposed to significant wave activity, with a significant wave height, Hs, greater than about 0.5m and where the peak wave period, Tp, is greater than about 6 seconds (or where the Hs is greater than about 0.2m and the Tp is greater than about 14s), ships in an STS mooring configuration may respond significantly to the waves. Depending on the environmental conditions, this can be a cause of vessel motions and, as a result, can affect mooring system integrity. Therefore, wave effects need to be considered in an appropriate manner.

This requires a full dynamic mooring assessment. In this type of analysis, the vessel hydrodynamics are fully represented along with second-order wave effects and non-linear effects of mooring lines and fenders. The forces from waves, wind and current (or vessel speed through the water) are usually determined for specific ships or ship types. These forces are used to calculate the corresponding time varying response of the moored vessel to the applied forces, in terms of motions and mooring forces. Statistical analyses can then be undertaken on the results to provide a much higher level of confidence than with static or quasi-static methods.

This full dynamic approach has been adopted in deriving mooring thresholds for STS operations for a range of ship type combinations, from coastal tankers to VLCCs, both underway and at anchor. In particular the following attributes are included:

- The interaction between the real position of the vessels, their velocity and inertia, and the waves and moorings.
- Resonance effects.
- The principal forces acting on moored ships, such as from swell, long period waves, second order waves, wind and current (vessel water speed).
- The effects of shallow water and the associated additional weight of entrained water when the vessel moves (added mass).
- Roll can be exaggerated in computational ship mooring models, especially quartering to beam seas.
- The models have been calibrated against other model results (both physical and numerical) and from site measurements, and in particular for side-by-side moored/double-banked ships.
- In the case of STS operations, the coupling effects between the two vessels are included.

The dynamic mooring assessment can therefore be used to determine statistics of line and fender loads, as well as vessel motions (and relative motions) in surge, sway, heave, roll, pitch and yaw. These results have been summarised based on limiting conditions in the form of maximum significant wave height (Hs) for a given wave peak period (Tp) and wave direction. The analysis has been carried out for the vessels at anchor as well as underway.

The thresholds are based on the following line and fender limits. In accordance with the OCIMF *Mooring Equipment Guidelines*, 4th edition *(MEG4),* the mooring working load limit (WLL) for the lines was considered as 55% of ship design MBL for steel wire lines and 50% of the ship design MBL for synthetic lines. Loads on fenders should not exceed their rated reaction force to avoid damage to fenders or an increased chance of fender failure. For the pneumatic 9.0m x 4.5m fenders used for the study this was 567t, and for the pneumatic 6.0m x 3.3m fenders this was 220t.

The thresholds are therefore indicative and represent an increased risk of line (or fender) failure.

As the thresholds are identified in terms of Hs, Tp and relative direction this can be difficult to assess operationally without detailed wave forecasting or observation equipment. To assist in quantifying the likely wave height, two tables are provided to relate fetch and wind speed to the approximate resulting wave height and period for wind waves. This is indicative only and does not, for instance, include any allowance for reflection from the shore or the effect of the water depth. The indicated wave heights are also the maximum that can occur after a prolonged period of steady wind (this is dependent on the fetch, but typically for two to three hours or longer). The indicative wave height is shown in Table 2.1 and indicative peak period in Table 2.2.

Note: Results are based on mooring lines and tails that are deployed based on recommendations made in the *STS Transfer Guide* and *MEG4*. The results only allow for a line exceeding the WLL limits and do not take chafing and other methods of mooring line fatigue into account. Deterioration of lines due to chafing and improper handling should be managed based on recommendations under relevant publications.

	Fetch (km)	Wind speed (knots)				
		5	10	15	20	25
Resulting approximate significant wave height, Hs (m)	10	0.2	0.3	0.5	0.6	0.7
	25	0.3	0.5	0.8	1.0	1.2
	50		0.8	1.2	1.5	1.8
	75			1.4	1.9	2.3
	100			1.7	2.2	2.7
	250				3.7	4.5
	500					6.6
	1000					

Table 2.1: *Indicative Hs against wind speed and fetch*

	Fetch (km)	Wind speed (knots)				
		5	10	15	20	25
Resulting approximate peak wave period, Tp (s)	10	2	2	3	3	3
	25	2	3	4	4	4
	50		4	5	5	5
	75			5	6	6
	100			6	6	7
	250				9	9
	500					12
	1000					

Table 2.2: *Indicative Tp against wind speed and fetch*

The output format is described further in Section 3.2 and the mooring configurations used for the purpose of this study have been summarised in the Appendix.

2.2 Future considerations

The thresholds presented in this document are for vessel layouts and realistic mooring configurations following best practice as far as reasonably practicable. Operational practice may deviate from this, which can lead to a reduced significant wave height threshold for particular vessel combinations or higher significant wave height thresholds, such as where bespoke mooring equipment is available (e.g. in the form of specialist mooring lines or tails provided by the operator using 22 metre long tails with HMPE lines, mooring line and tail material properties). The prevailing environmental conditions, particularly the combination of a wind sea and an underlying swell from multiple directions, can also change the significant wave height threshold.

Therefore, a fully dynamic mooring analysis should, where possible, be used to optimise the mooring thresholds for a particular location and operation against relevant ship-type combinations. This, in conjunction with the best available metocean information for the STS operation location (which can be hindcast wave statistics or forecast information of the expected wave height, period and direction), can provide additional operational guidance, as well as maximising the significant wave height threshold of the mooring configuration, hence reducing the risk of a mooring line failure.

Operational windows should be based on various considerations allowing for safe mooring, cargo transfer, disconnection and unmooring operations. Emergency protocols should also be established in case of inadvertent scenarios during ship-to-ship transfer operations.

3 STS study output

3.1 Generic findings applicable to all STS operations

The following trends apply to the STS configurations tested:

- The longer the wave period, the higher the load in the mooring lines and therefore the associated significant wave height threshold is reduced.
- The wave height threshold is lower when the waves are on the beam, so beam exposure should be avoided.
- There is a larger relative roll between the ships when the wave period is longer.
- The daughter ship lines usually exceed the WLL before the mother ship.
- It is generally the innermost lines (which tend to be shorter) that fail first.
- As wave period increases, the wave height threshold decreases to a level where the threshold is insensitive to the vessel load condition and whether it is underway or at anchor.
- In general, the smaller vessel will be protected from shorter period waves and its motion will reduce in the lee of the larger vessel. However, the larger vessel will still be affected by long period swells from either beam.

3.2 Example output format

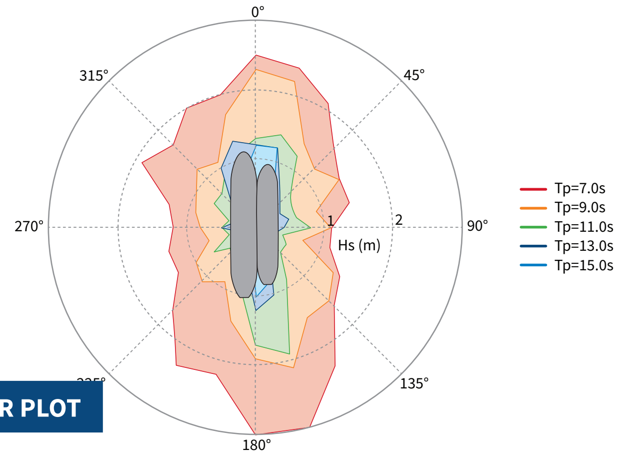
An example of the summary output from the dynamic mooring analysis is shown in Figure 3.1. The format is repeated for each ship combination and configuration and the labelled elements are as follows:

- TITLE BLOCK
  Size of daughter and mothership and draught condition (laden or ballast), as well the STS method (underway or at anchor).
- MOORING LAYOUT
  Schematic of the mooring layout and whether lines are from mother or daughterships.
- LIMITING CRITERIA
  Summary of the line type used and the associated limiting criteria which will result in an increased risk of line failure(s).
- THRESHOLD POLAR PLOT
  Significant wave height threshold plotted against relative wave direction (from bow) and peak wave period.
- THRESHOLD TABLE
  Table summarising the significant wave height threshold against peak period and relative wave direction (clockwise, from 000 to 360 degrees).
- SUMARY AND NOTES
  Observations and notes including favourable directions, as well as directions to avoid including limiting wave period and critical mooring lines. Where the text refers to a ‘low threshold’ this is typically a significant wave height of 0.5m or lower.

VLCC (Mothership, ballast) – Suezmax (Daughtership, laden) – underway

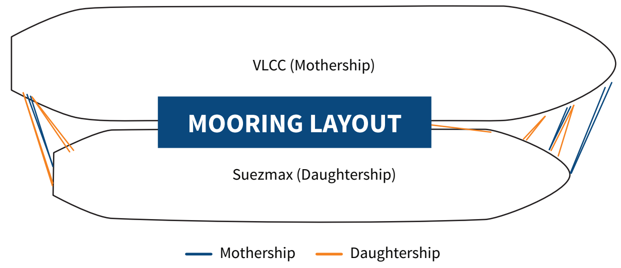
TITLE BLOCK

Polar Plot



THRESHOLD POLAR PLOT

Mooring Configuration



MOORING LAYOUT

Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix [illegible]	63.3t [illegible]%MBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%MBL)	4-2-2-4

LIMIT CITERIA

Summary

- **Most likely line failures** – Daughter inner aft breast lines, these mooring lines are exceeding the WLL less often compared to when the ships are at anchor
- **Favourable wave direction(s)** – 315° to 30°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

SUMMARY AND NOTES

Notes

- The mooring lines from the VLCC only exceed the WLL on two occasions when the waves are from ahead of the ships.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.5	2.3	1.3	1.2	1.2
45	1.6	1.2	0.7	0.4	0.5
90	1.1	[illegible]	[illegible]	0.4	0.3
135	1.6	[illegible]	[illegible]	0.2	0.3
180	3.0	1.9	1.7	1.2	1.0
225	1.7	1.1	0.4	0.3	0.2
270	1.2	0.8	0.5	0.5	0.4
315	1.7	1.2	0.7	0.5	0.5

THRESHOLD TABLE

Figure 3.1: *Summary results example layout*

3.3 Design ship characteristics

Vessel type	VLCC		Suezmax		Aframax		MR tanker	
General								
Deadweight, DWT (t)	318,325		150,037		115,711		49,997	
Length overall, LOA (m)	333.1		274.2		249.9		182.5	
Length between perps, LBP (m)	319		263		242		175	
Beam (m)	60.1		48		44		32.23	
Moulded depth (m)	30.4		22.4		21.2		19.05	
Loading conditions	**Laden**	**Ballast**	**Laden**	**Ballast**	**Laden**	**Ballast**	**Laden**	**Ballast**
Draught (m)	22.6	9.6	16.02	8.18	15.22	6.78	13.05	7.14
Block coefficient	0.84	0.77	0.85	0.68	0.83	0.76	0.83	0.78
Displacement (t)	364,452	140,834	172,719	70,363	135,023	54,550	60,765	31,295
Built (year)	2009		2004		2017		2011	
Parallel middle body								
Forward to mid-point manifold	77.1	77.1	78.1	78.1	67.7	67.7	41	41
Aft to mid-point manifold	80.6	54.1	72.6	59.8	62.1	46.1	50	40
Parallel body length	157.6	130.8	150.7	137.9	129.8	113.7	91	81
Stability characteristics								
Centre of mass from forward perpendicular (m)	149.8	154.6	124.4	124	113.4	114.8	84.6	82.2
Centre of mass over keel (m)	16.8	10.5	14	10	12.3	9.2	10.8	9.1
Radii gyration X, Kxx (m)	19.2	22.2	16	18.5	14.5	16.3	10.6	12
Radii gyration Y, Kyy (m)	79.8	79.8	66	66	58.1	62.9	42	45.5
Radii gyration Z, Kzz (m)	79.8	79.8	66	66	58.1	62.9	42	45.5
Metacentric height (m)	7.5	23.2	7	18.6	5	17.1	3	8.2

Table 3.1a: *Design ship characteristics*

Vessel type	Coastal tanker		80,000m³ VLGC		174,000m³ LNGC	
General						
Deadweight, DWT (t)	24,790		55,133		94,442	
Length overall, LOA (m)	165.2		230		295	
Length between perps, LBP (m)	155		219		282.9	
Beam (m)	26.7		36.6		46.4	
Moulded depth (m)	13.6		21.7		26.5	
Loading conditions	**Laden**	**Ballast**	**Laden**	**Ballast**	**Laden**	**Ballast**
Draught (m)	9.8	6.62	11.58	6.8	11.5	9.4
Block coefficient	0.81	0.77	0.8	0.75	0.77	0.76
Displacement (t)	32,943	21,018	74,634	40,889	119,436	95,691
Built (year)	2017		2016		2018	
Parallel middle body						
Forward to mid-point manifold	45.4	40.8	53.6	46.6	70.8	68
Aft to mid-point manifold	44.9	47	62.2	51.2	92.8	87.1
Parallel body length	90.2	87.8	115.8	97.8	163.7	155.1
Stability characteristics						
Centre of mass from forward perpendicular (m)	75.2	72.9	114.1	115.6	140.6	138.7
Centre of mass over keel (m)	8.2	7.8	12.2	11.4	16.7	12.7
Radii gyration X, Kxx,(m)	8.8	9.9	11.2	13.5	14.7	18.2
Radii gyration Y, Kyy (m)	37.2	40.3	50.8	57.6	67.3	71.6
Radii gyration Z, Kzz (m)	37.2	40.3	51.2	58.3	67.9	72.7
Metacentric height (m)	2.9	7.2	3.4	6.6	3.6	7.9

Table 3.1b: *Design ship characteristics*

Vessel type	VLCC	Suezmax	Aframax	MR tanker	Coastal tanker	80,000m³ VLGC	LNGC
Mooring line diameter (mm)	42	34	36	56	65	32	40
Mooring line type	IWRC	IWRC	HMPE	PP/PPE Mix	PP/PPE Mix	IWRC	HMPE
Mooring line MBL (tonnes)	115	80	83	68	52	65	135
Mooring tail diameter (mm)	100	80	80	N/A	N/A	60	88
Mooring tail length (m)	11	11	11	N/A	N/A	11	11
Mooring tail material	PP/PPE Mix	PP/PPE Mix	Nylon	N/A	N/A	PP/PPE Mix	PP/PPE Mix
Mooring tail MBL (tonnes)	142	110	114	N/A	N/A	81.2	190

Table 3.2: *Design ship characteristics – Mooring line characteristics*

3.4 Ship-type combination specific output

The following section comprises the summary output for each ship-type combination listed in Table 3.3 and Table 3.4 following the mooring configuration layouts shown in the Appendix.

Vessel type (DWT/Capacity)	Suezmax (160k)	Aframax (120k)	MR (55k)	Coastal (25k)	VLPG (80k m^3)	LNGC (174k m^3)
VLCC (300k)						
Suezmax (160k)						
Aframax (120k)						
MR (55k)						
VLPG (80k m^3)						
LNGC (174k m^3)						

Table 3.3: *STS combinations*

Configuration reference	Mothership			Daughtership			Water depth (m)
	Ship	Loading condition	Draught (m)	Ship	Loading condition	Draught (m)	
1	VLCC	Ballast	9.6	Suezmax	Laden	16.0	20
2	VLCC	Laden	22.6	Suezmax	Ballast	8.2	25
3	VLCC	Part-laden	15.0	Suezmax	Laden	16.0	20
4	VLCC	Part-laden	15.0	Suezmax	Ballast	8.2	25
5	VLCC	Ballast	9.6	Aframax	Laden	15.2	20
6	VLCC	Laden	22.6	Aframax	Ballast	6.8	25
7	Suezmax	Ballast	8.2	Suezmax	Laden	16.0	20
8	Suezmax	Laden	16.0	Suezmax	Ballast	8.2	20
9	Suezmax	Ballast	8.2	Aframax	Laden	15.2	20
10	Suezmax	Laden	16.0	Aframax	Ballast	6.8	20
11	Suezmax	Ballast	8.2	MR tanker	Laden	13.1	20
12	Suezmax	Laden	16.0	MR tanker	Ballast	7.1	20
13	Aframax	Ballast	6.8	MR tanker	Laden	13.1	20
14	Aframax	Laden	15.2	MR tanker	Ballast	7.1	20
15	Aframax	Ballast	6.8	25kDWT	Laden	9.8	20
16	Aframax	Laden	15.2	25kDWT	Ballast	6.6	20
17	MR tanker	Ballast	7.1	MR tanker	Laden	13.1	20
18	MR tanker	Laden	13.1	MR tanker	Ballast	7.1	20
19	MR tanker	Ballast	7.1	25kDWT	Laden	9.8	20
20	MR tanker	Laden	13.1	25kDWT	Ballast	6.6	20
21	VLGC	Ballast	6.8	VLGC	Laden	11.6	20
22	VLGC	Laden	11.6	VLGC	Ballast	6.8	20
23	LNGC	Ballast	9.4	LNGC	Laden	11.5	20
24	LNGC	Laden	11.5	LNGC	Ballast	9.4	20

Table 3.4: *Combinations considered for dynamic mooring analysis – underway and at anchor*

3.4.1 Summary outputs for each ship type combination

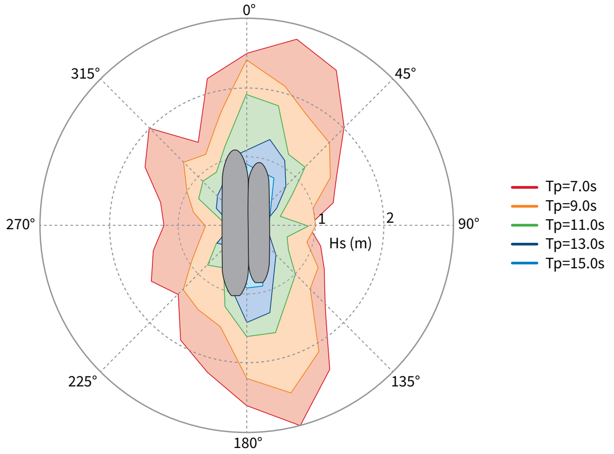
Configuration references 1-4: VLCC (Mothership) – Suezmax (Daughtership)

Summary

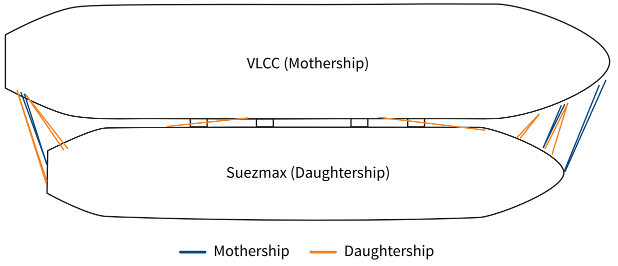
- The inner aft breast lines from Suezmax to VLCC are the predominant failure modes.
- The difference in threshold wave height between the at anchor and underway condition is greatest at 0.9m when the VLCC is part-laden and the Suezmax is laden, the difference is greater when the waves are from 0°, the difference reduces as the wave period increases.
- The threshold wave heights are highest when the VLCC is part laden and the Suezmax laden and at anchor. This is particularly the case for shorter wave periods.

1a. VLCC (Mothership, ballast) – Suezmax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 345° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270 ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

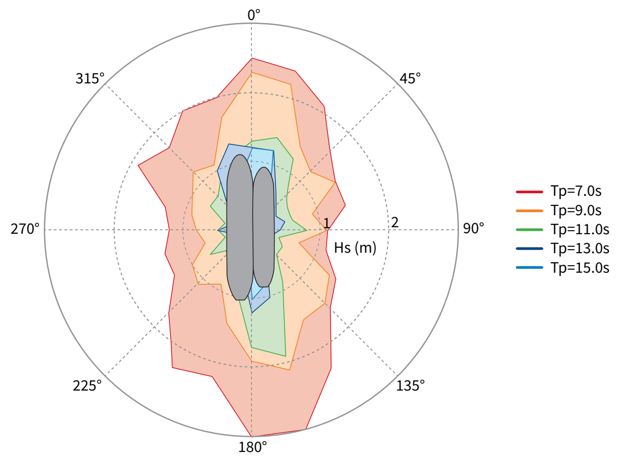
- Mooring lines from the VLCC rarely exceed the WLL.

Mooring thresholds

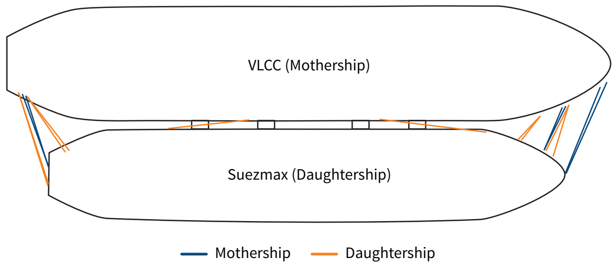
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.5	2.4	1.9	1.1	0.9
45	2.0	1.7	1.2	0.8	0.4
90	0.9	1.0	0.9	0.3	0.2
135	1.6	1.3	1.0	0.6	0.3
180	2.6	2.2	1.6	1.4	0.9
225	1.4	1.3	0.8	0.4	0.4
270	1.2	0.6	0.3	0.2	0.3
315	2	1.3	0.9	0.6	0.5

1b. VLCC (Mothership, ballast) – Suezmax (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines, these mooring lines are exceeding the WLL less frequently compared to when the ships are at anchor
- **Favourable wave direction(s)** – 315° to 30°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

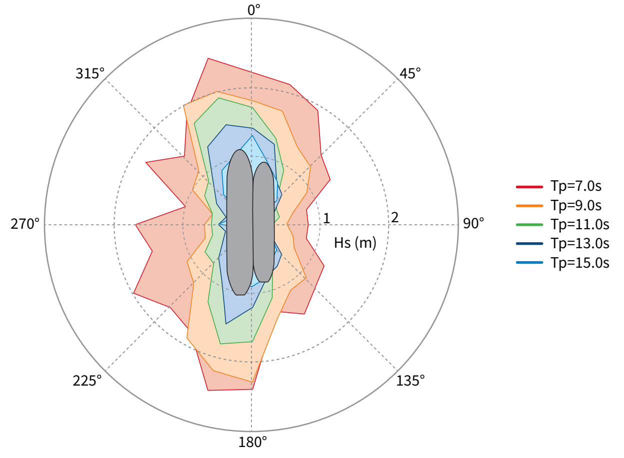
- The mooring lines from the VLCC only exceed the WLL on two occasions when the waves are from ahead of the ships.

Mooring thresholds

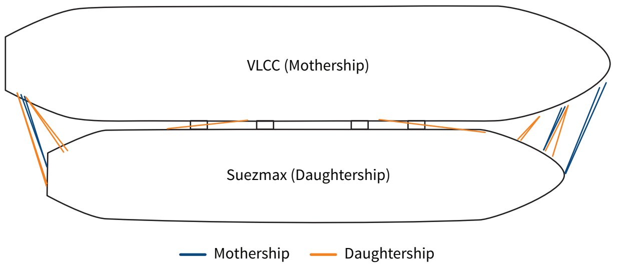
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.5	2.3	1.3	1.2	1.2
45	1.6	1.2	0.7	0.4	0.5
90	1.1	1.1	0.8	0.4	0.3
135	1.6	1.5	0.5	0.2	0.3
180	3.0	1.9	1.7	1.2	1.0
225	1.7	1.1	0.4	0.3	0.2
270	1.2	0.8	0.5	0.5	0.4
315	1.7	1.2	0.7	0.5	0.5

2a. VLCC (Mothership, laden) – Suezmax (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines, these mooring lines are exceeding the WLL less often compared to when the ships are at anchor
- **Favourable wave direction(s)** – 330° to 30°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

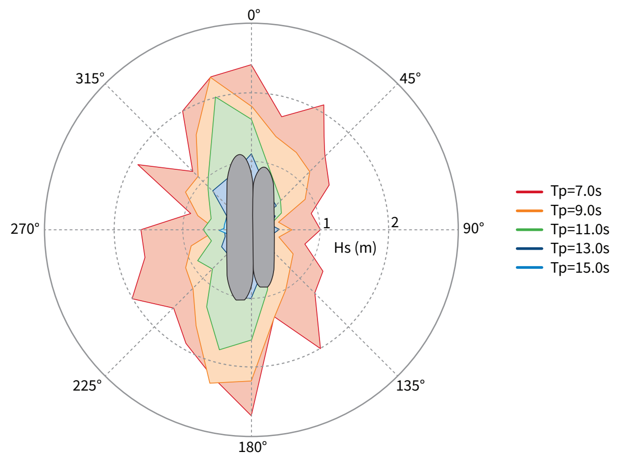
- The threshold wave height is lower for the laden VLCC compared with the ballast VLCC.
- The mooring lines from the VLCC which exceed the WLL are the outer forward and aft breast lines.

Mooring thresholds

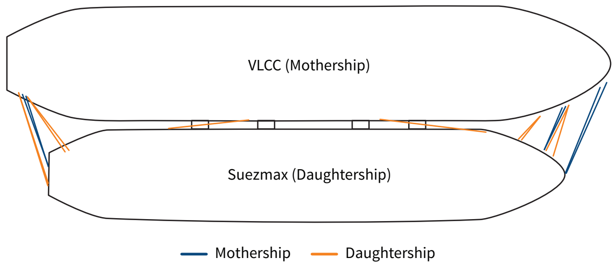
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.7	1.4	1.4	0.9
45	1.0	1.1	0.5	0.5	0.3
90	0.8	0.4	0.2	0.2	0.2
135	1.3	1.1	0.5	0.3	0.5
180	2.4	2.0	1.3	0.9	0.8
225	1.3	1.2	0.7	0.6	0.3
270	1.4	0.5	0.4	0.4	0.3
315	1.3	1.0	0.9	0.8	0.5

2b. VLCC (Mothership, laden) – Suezmax (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 330° to 30°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270°± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

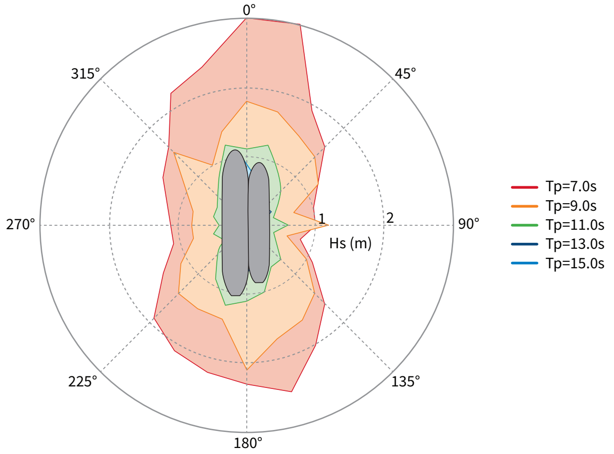
- The mooring lines from the VLCC rarely exceed the WLL, only when the waves are on the beam of the Suezmax.
- The mooring lines from the VLCC which exceed the WLL are the outer forward and aft breast lines.

Mooring thresholds

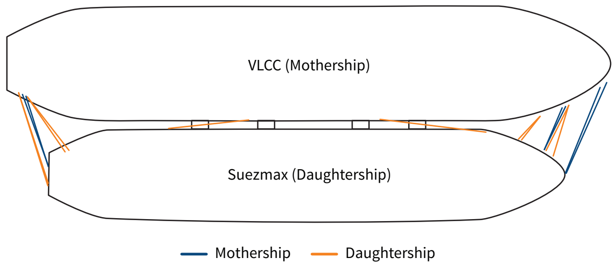
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	2.4	1.8	1.3	0.9
45	1.4	1.3	0.6	0.5	0.4
90	1.2	0.6	0.3	0.1	0.1
135	1.2	1.2	0.5	0.4	0.3
180	2.9	2.5	1.4	1.2	1.1
225	2.2	1.4	0.5	0.5	0.3
270	1.7	0.8	0.5	0.2	0.2
315	1.2	1.0	0.8	0.5	0.4

3a. VLCC (Mothership, part-laden) – Suezmax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 330° to 30°, 165° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

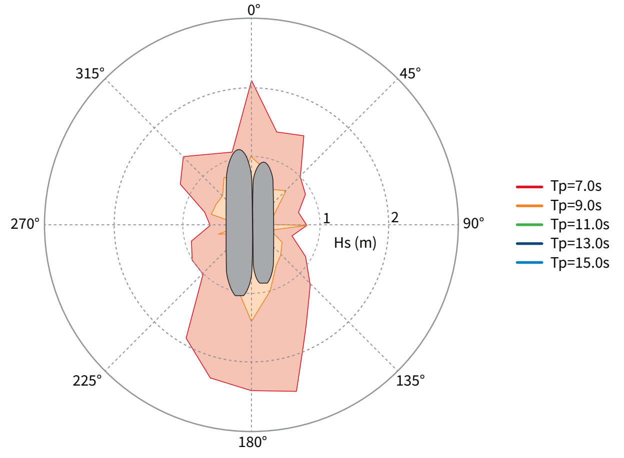
- The threshold wave height for the part laden VLCC are higher compared to the ballast or laden cases, particularly for shorter period waves.
- The mooring lines from the VLCC exceed the WLL, only when the waves are directed on the beam of the Suezmax.
- The mooring lines from the VLCC which exceed the WLL are the outer forward and aft breast lines.

Mooring thresholds

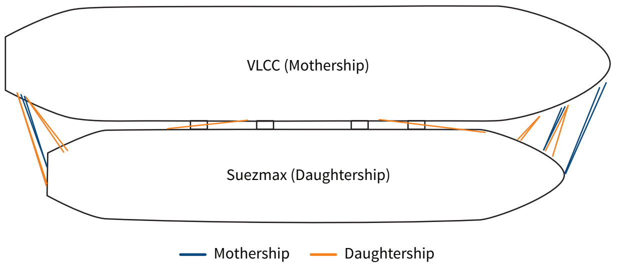
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	3.0	1.8	1.1	0.9	0.7
45	1.6	1.4	0.7	0.4	0.1
90	1.0	1.2	0.6	0.3	0.1
135	1.6	1.4	0.7	0.3	0.1
180	2.3	2.1	1.1	0.7	0.4
225	1.9	1.4	0.6	0.3	0.2
270	1.1	0.8	0.4	0.3	0.1
315	1.6	1.5	0.6	0.4	0.3

3b. VLCC (Mothership, part-laden) – Suezmax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 0° to 30°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

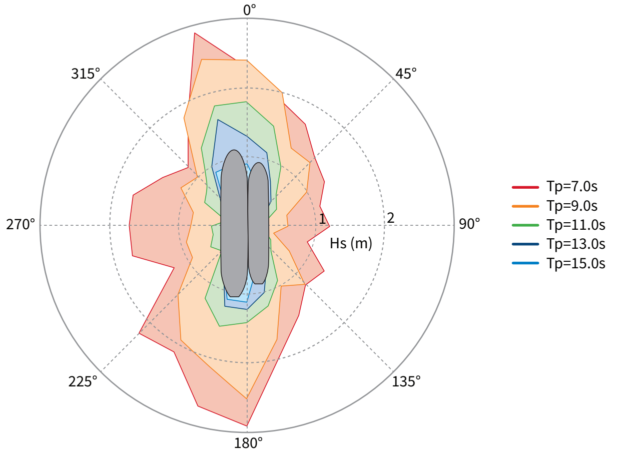
- The mooring lines from the VLCC only exceed the WLL once the wave period is greater than 11s and the waves are on the beam of the Suezmax.
- The mooring lines from the VLCC which exceed the WLL are the outer forward and aft breast lines.
- There is a reduction in the threshold wave height of 0.9m for the ships underway particularly for shorter wave periods.

Mooring thresholds

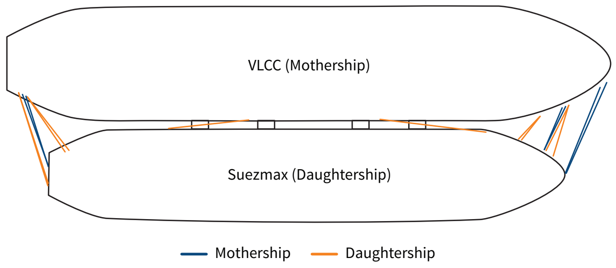
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.0	0.5	0.2	0.3
45	1.0	0.7	0.4	0.2	0.2
90	0.8	0.8	0.4	0.2	0.1
135	1.2	0.6	0.3	0.1	0.1
180	2.4	1.4	0.5	0.4	0.2
225	1.0	0.5	0.1	0.1	0.1
270	0.6	0.1	0.2	0.2	0.1
315	1.4	0.6	0.2	0.2	0.1

4a. VLCC (Mothership, part-laden) – Suezmax (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 330° to 15°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

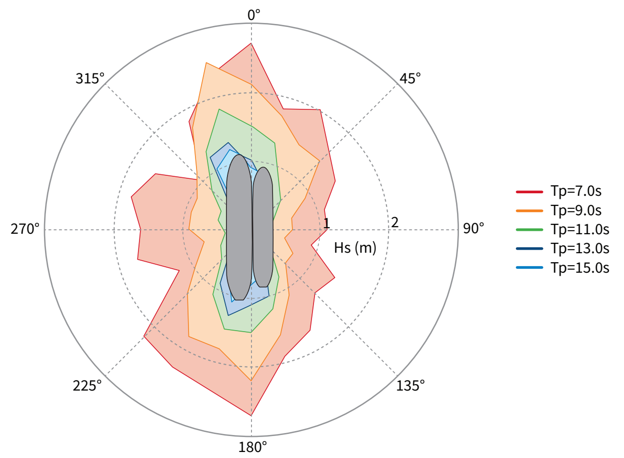
- The mooring lines from the VLCC rarely exceed the WLL, only when the waves are on the beam of the Suezmax.
- The mooring lines from the VLCC which exceed the WLL are the outer forward and aft breast lines.

Mooring thresholds

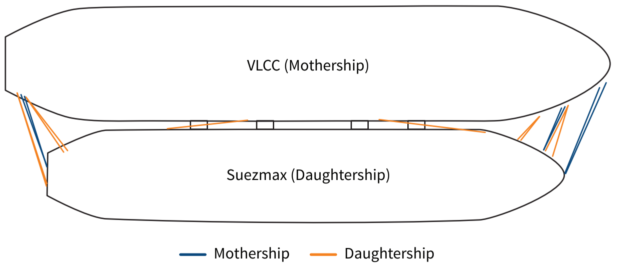
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	2.4	1.8	1.3	0.9
45	1.4	1.3	0.6	0.5	0.4
90	1.2	0.6	0.3	0.1	0.1
135	1.2	1.2	0.5	0.4	0.3
180	2.9	2.5	1.4	1.2	1.1
225	2.2	1.4	0.5	0.5	0.3
270	1.7	0.8	0.5	0.2	0.2
315	1.2	1.0	0.8	0.5	0.4

4b. VLCC (Mothership, part-laden) – Suezmax (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	115t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 330° to 45°, 150° to 225°
- **Wave direction(s) to avoid** – 90° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- The mooring lines from the VLCC only exceed the WLL once the wave period was greater than 11s and the waves are on the beam of the Suezmax.
- The lines from the VLCC which exceed the WLL are the outer aft breast lines.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.7	2.1	1.5	0.9	1.0
45	1.6	1.4	0.6	0.4	0.3
90	1.1	0.6	0.3	0.2	0.3
135	1.3	0.7	0.4	0.3	0.2
180	2.7	2.2	1.5	1.1	0.8
225	2.2	1.3	0.6	0.4	0.3
270	1.6	0.9	0.4	0.3	0.4
315	1.0	1.1	0.8	0.4	0.2

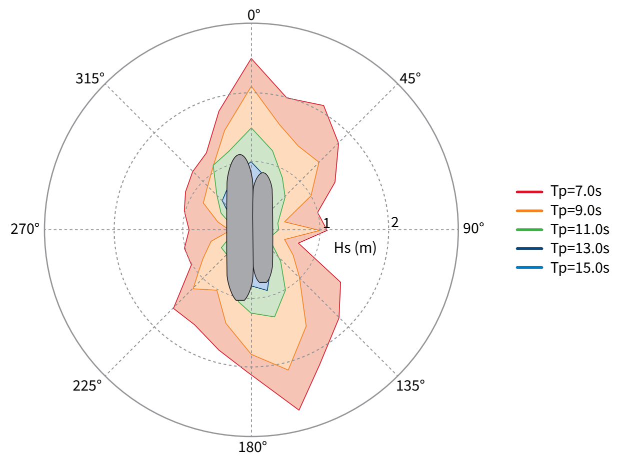
Configuration references 5-6: VLCC (Mothership) – Aframax (Daughtership)

Summary

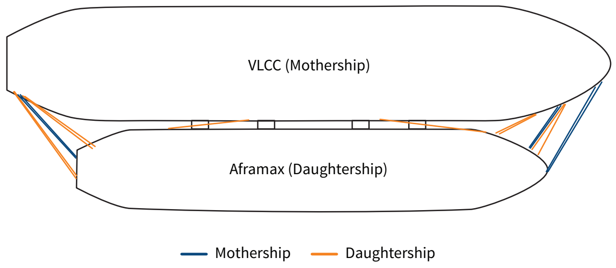
- The aft spring lines from the Aframax to the VLCC are the predominant failure modes.
- The mooring lines from the VLCC rarely exceed the WLL. These failures are limited to the outer stern breasting lines when the waves are on the beam and aft quarter of the Aframax, when the VLCC is laden.
- The threshold wave heights are lower when the wave direction is from the exposed side of the laden ship, independent of whether it is the mothership or daughtership.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.5m. The difference is greater when the waves are from 0° and reduces as the wave period lengthens.
- The threshold wave heights are highest when the VLCC is ballast and the Aframax laden and at anchor. This is particularly the case for shorter wave periods.

5a. VLCC (Mothership, ballast) – Aframax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	125t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	PP/PPE Mix (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter inner bow breasting lines
- **Favourable wave direction(s)** – 345° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

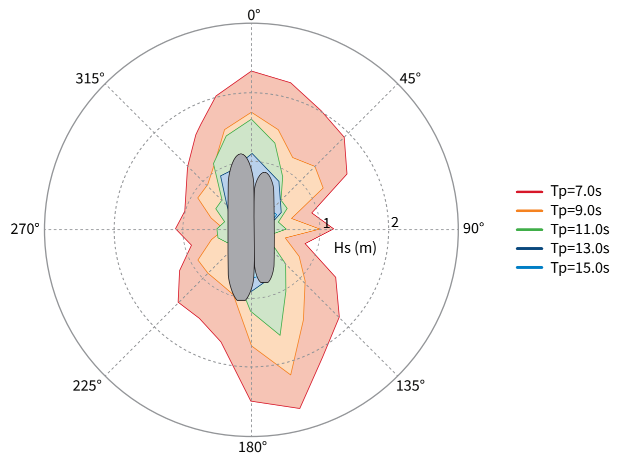
- The mooring lines from the VLCC rarely exceed the WLL
- The threshold wave heights are generally lower when the waves are directed on the VLCC

Mooring thresholds

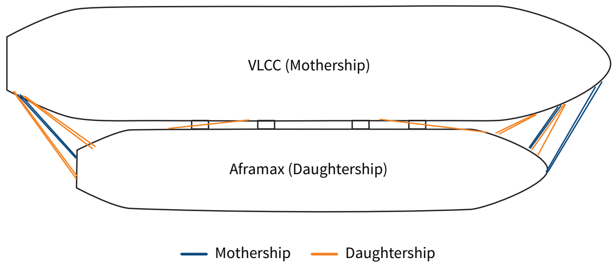
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.5	2.1	1.5	1.0	0.6
45	1.8	1.4	0.7	0.4	0.4
90	1.1	1.0	0.4	0.2	0.2
135	1.8	1.0	0.6	0.3	0.2
180	2.1	1.8	1.2	0.8	0.6
225	1.6	1.2	0.5	0.4	0.2
270	0.9	0.3	0.2	0.1	0.3
315	1.2	0.9	0.7	0.6	0.3

5b. VLCC (Mothership, ballast) – Aframax (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	125t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	PP/PPE Mix (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter middle bow breasting lines
- **Favourable wave direction(s)** – 345° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

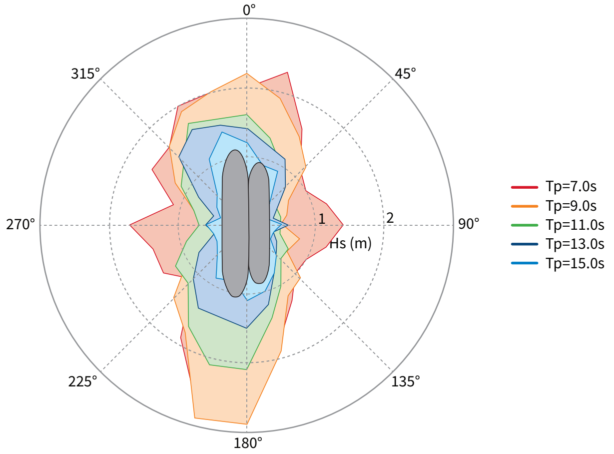
- The mooring lines from the VLCC rarely exceed the WLL
- The threshold wave heights are generally lower when the waves are directed on the VLCC

Mooring thresholds

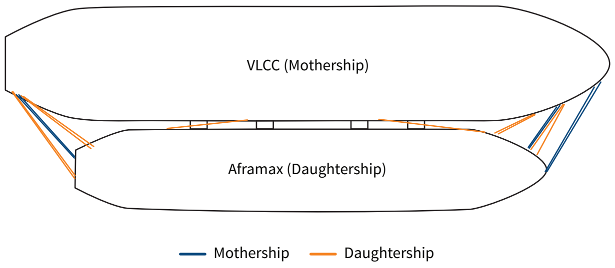
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	1.7	1.6	1.1	0.6
45	1.9	1.3	0.6	0.6	0.4
90	1.2	1.0	0.5	0.3	0.3
135	1.8	1.1	0.7	0.3	0.3
180	2.5	1.7	1.2	0.9	0.7
225	1.5	0.9	0.5	0.2	0.2
270	1.1	0.4	0.5	0.3	0.2
315	1.3	0.9	0.6	0.5	0.4

6a. VLCC (Mothership, laden) – Aframax (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	125t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	PP/PPE Mix (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter inner bow breasting lines
- **Favourable wave direction(s)** – 315° to 30°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 15s

Notes

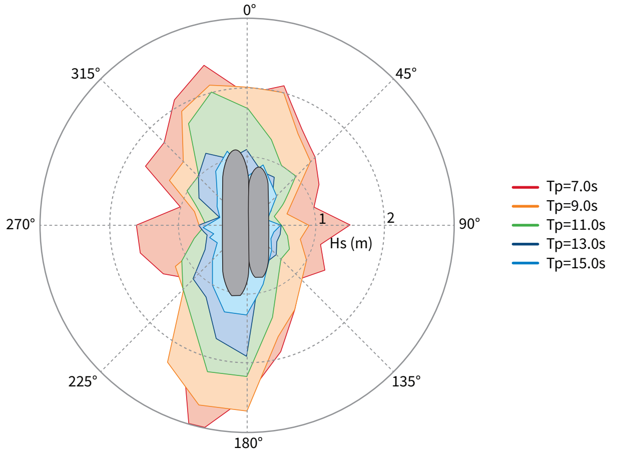
- The mooring lines from the VLCC rarely exceed the WLL, limited to high period waves when directed at the VLCC
- The threshold wave heights are lower when the waves are directed on the Aframax

Mooring thresholds

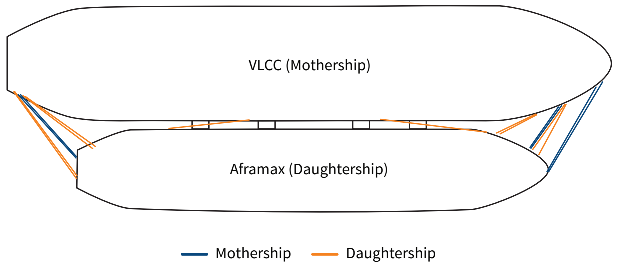
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.0	2.2	1.6	1.4	1.2
45	1.1	1.2	0.7	0.8	0.5
90	1.4	0.5	0.5	0.5	0.6
135	1.0	1.1	0.7	0.6	0.6
180	2.6	2.9	2.1	1.5	1.1
225	1.1	1.5	1.2	1.1	0.6
270	1.7	0.7	0.7	0.6	0.6
315	1.6	1.6	1.3	1.4	0.6

6b. VLCC (Mothership, laden) – Aframax (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	125t	PP/PPE Mix (11m)	63.3t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	PP/PPE Mix (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter inner bow breasting lines
- **Favourable wave direction(s)** – 315° to 30°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 15s

Notes

- The mooring lines from the VLCC rarely exceed the WLL, limited to high period waves when directed at the VLCC
- The threshold wave heights are lower when the waves are directed on the Aframax

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	2	1.7	1.1	0.7
45	1.4	1.3	1	0.5	0.6
90	1.5	0.9	0.5	0.5	0.5
135	1.1	1.1	0.7	0.6	0.5
180	2.5	2.7	2.2	1.9	1.3
225	1.1	1.3	1.3	1.1	0.7
270	1.6	0.7	0.6	0.7	0.6
315	1.7	1.3	1	1	0.6

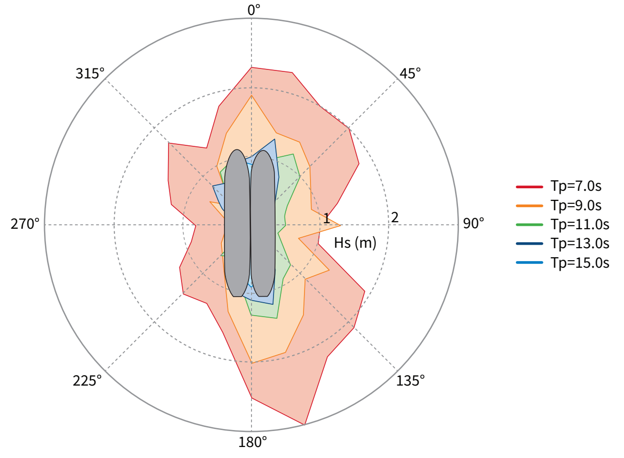
Configuration references 7-8: Suezmax (Mothership) – Suezmax (Daughtership)

Summary

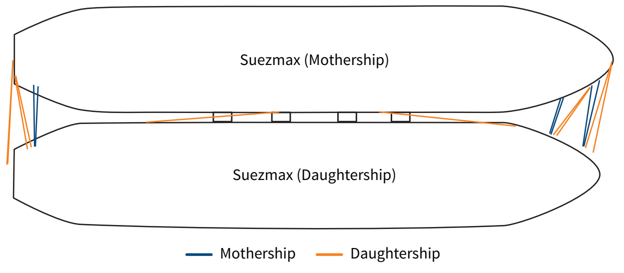
- More mooring lines reach their WLL as the wave period increases, particularly when the waves are on the beam.
- The outer head and aft breast lines from the daughtership to the mothership are the predominant failure modes.
- The lines from the mothership which exceed the WLL are the forward breast lines.
- The threshold wave height for the laden mothership and ballast daughtership loading condition is higher compared to when the mothership is ballast and the daughtership is laden.
- The threshold wave height is higher when the waves are directed on the laden Suezmax, independent of whether the ship is the mother or daughtership.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.7m when the mothership is ballast and daughtership is laden. The difference reduces as the wave period lengthens.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of only 0.2m when the mothership is laden and daughtership is ballast.
- The difference in the threshold wave heights between the at anchor and underway cases is greater when the mothership is ballast and the daughtership is laden.

7a. Suezmax (Mothership, ballast) – Suezmax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines and mother inner head breast lines
- **Favourable wave direction(s)** – 0° to 60°, 135° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

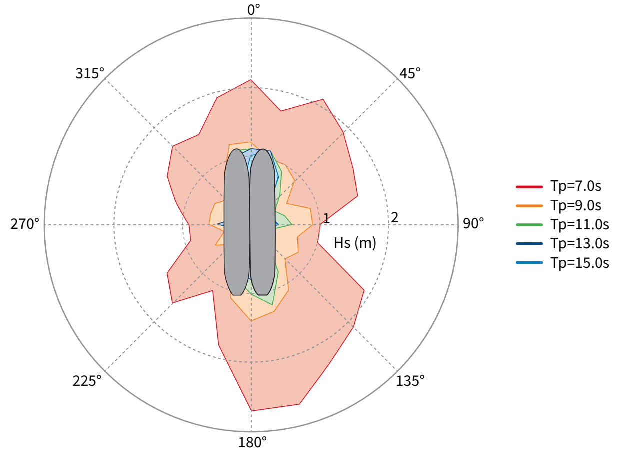
- More mooring lines reach their safe working load as the wave period increases particularly when the waves are on the beam.
- The threshold wave height is higher when the waves are directed on the laden Suezmax.

Mooring thresholds

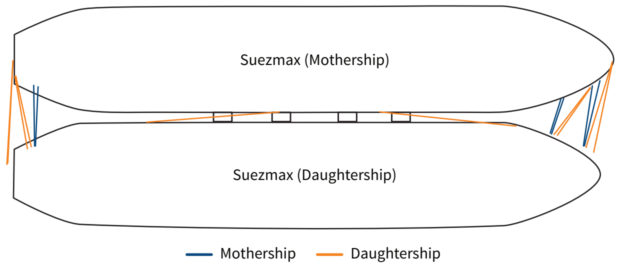
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	1.9	0.9	1.0	0.6
45	2.0	1.2	1	0.5	0.3
90	1.0	1.3	0.5	0.2	0.2
135	2.1	1.1	0.8	0.3	0.2
180	2.5	2	1.3	1.1	0.9
225	1.4	0.6	0.6	0.4	0.3
270	0.8	0.3	0.2	0.3	0.3
315	1.7	0.4	0.5	0.8	0.3

7b. Suezmax (Mothership, ballast) – Suezmax (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter outer head and aft breast lines and mother forward breast lines
- **Favourable wave direction(s)** – 315° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

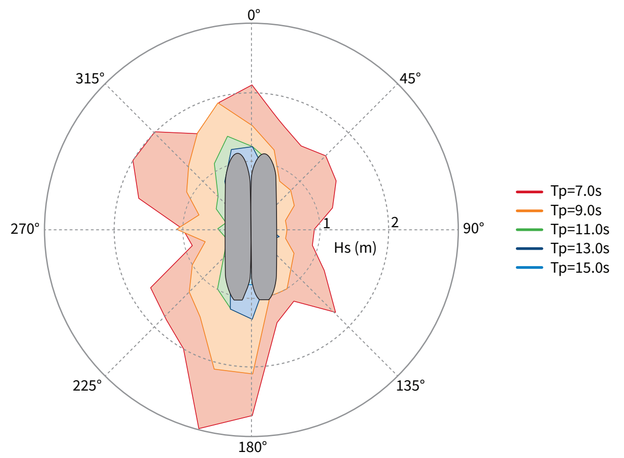
- The threshold wave height is lower at shorter wave periods for this condition compared to when the ships are at anchor. As wave period increases the difference in the threshold wave heights between the conditions reduces.
- The threshold wave height is higher when the waves are directed on the laden Suezmax.

Mooring thresholds

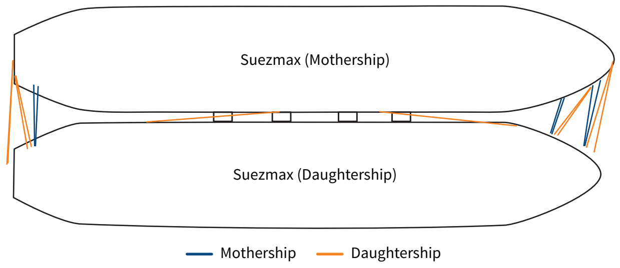
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.2	1.1	1.1	1.0
45	1.9	0.9	0.6	0.4	0.3
90	1.0	0.9	0.6	0.4	0.4
135	2.1	0.7	0.4	0.2	0.2
180	2.7	1.4	1.0	0.7	0.8
225	1.6	0.4	0.2	0.1	0.2
270	0.9	0.6	0.4	0.3	0.5
315	1.6	0.5	0.5	0.4	0.3

8a. Suezmax (Mothership, laden) – Suezmax (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines and outer head breast lines and mother inner head breast lines
- **Favourable wave direction(s)** – 180° to 210°, 315° to 0°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

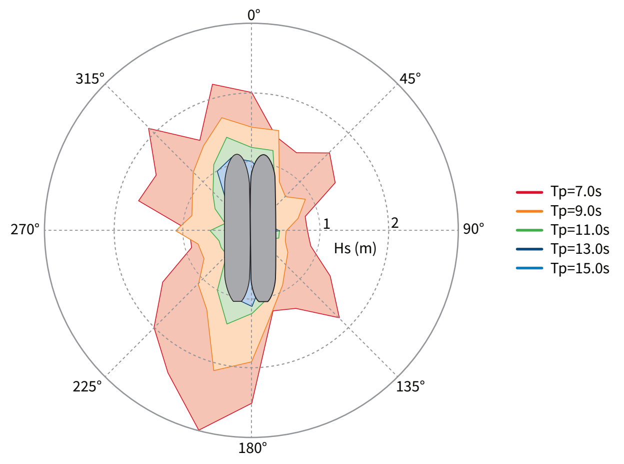
- More mooring lines reach their WLL as the wave period increases, particularly when the waves are on the beam.
- The threshold wave height is higher when the waves are directed on the laden Suezmax.

Mooring thresholds

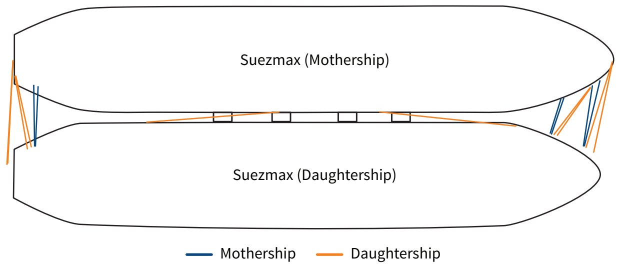
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.5	1.2	1.2	0.5
45	1.5	0.8	0.5	0.5	0.4
90	0.9	0.5	0.3	0.2	0.2
135	1.7	0.8	0.4	0.4	0.3
180	2.7	2.1	1.2	1.3	0.8
225	1.8	1.3	0.6	0.3	0.2
270	1	1.1	0.5	0.2	0.1
315	2	1.3	0.7	0.5	0.2

8b. Suezmax (Mothership, laden) – Suezmax (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter outer head and aft breast lines and mother forward breast lines
- **Favourable wave direction(s)** – 180° to 210°, 315° to 0°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- The threshold wave height for this loading condition is higher compared to when the Suezmax mothership is ballast and the Suezmax daughtership is laden.
- The threshold wave height is higher when the waves are directed on the laden Suezmax.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.0	1.5	1.2	1.0	0.8
45	1.6	0.7	0.4	0.3	0.3
90	0.8	0.5	0.4	0.4	0.3
135	1.8	0.7	0.4	0.2	0.2
180	2.5	1.9	1.2	1.1	0.7
225	2.0	1.1	0.5	0.3	0.3
270	0.9	1.1	0.6	0.3	0.2
315	2.1	1.2	0.8	0.5	0.3

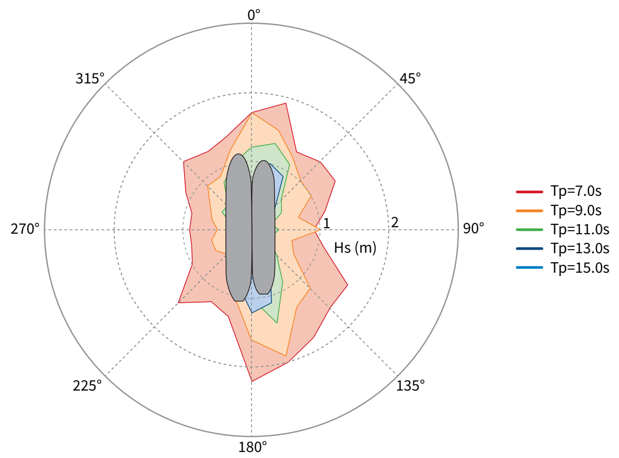
Configuration references 9-10: Suezmax (Mothership) – Aframax (Daughtership)

Summary

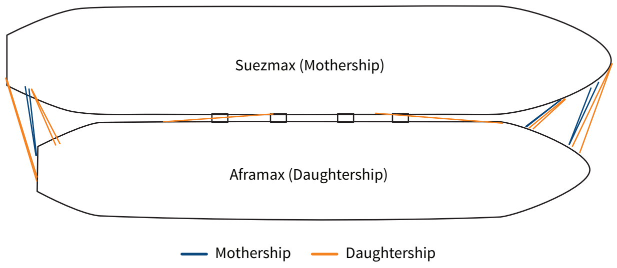
- The inner aft breast lines from Aframax to Suezmax are the predominant failure modes.
- The mooring lines from the Suezmax rarely exceed the WLL.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.4m. The difference reduces as the wave period lengthens.
- The difference in the threshold wave heights is comparable between the laden and ballast cases when the ships are at anchor.
- The threshold wave height when the Suezmax is laden and the Aframax is ballast is higher than the other loading condition when the ships are underway, particularly when the waves are from the exposed side of the Suezmax.

9a. Suezmax (Mothership, ballast) – Aframax (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines
- **Favourable wave direction(s)** – 315° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 225° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

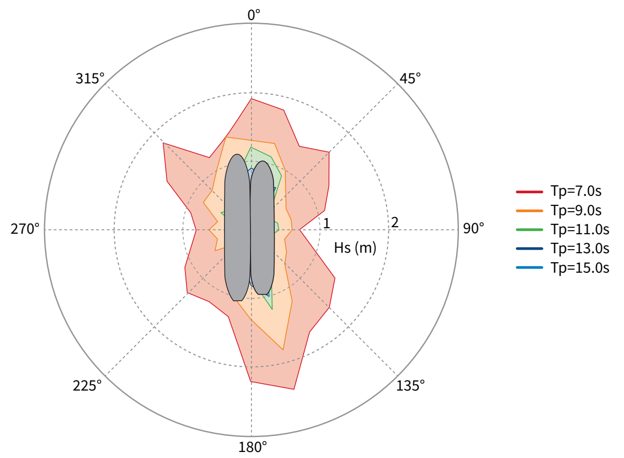
- The mooring lines from the Suezmax rarely exceed the WLL.

Mooring thresholds

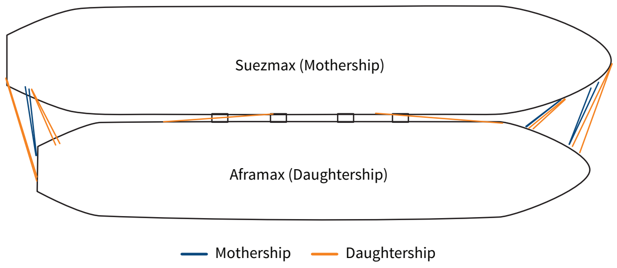
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.7	1.7	1.2	0.7	0.5
45	1.4	1	0.6	0.5	0.4
90	0.9	1	0.4	0.2	0.2
135	1.6	1.2	0.5	0.2	0.2
180	2.2	1.6	1	1.2	0.7
225	1.5	0.5	0.4	0.4	0.3
270	0.9	0.5	0.3	0.3	0.3
315	1.4	0.9	0.5	0.4	0.3

9b. Suezmax (Mothership, ballast) – Aframax (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines and daughter outer breast lines
- **Favourable wave direction(s)** – 345° to 30°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 225° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

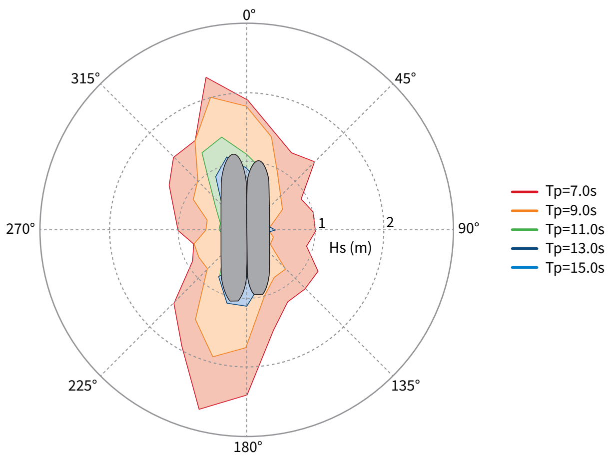
- The mooring lines from the Suezmax rarely exceed the WLL.

Mooring thresholds

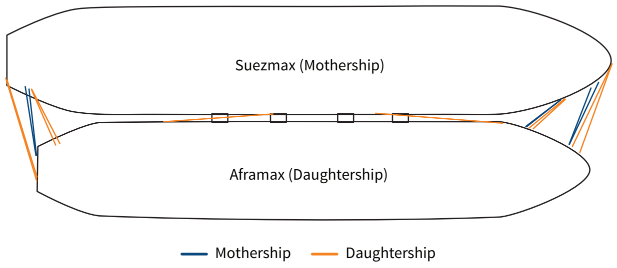
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	1.3	1.2	0.9	0.5
45	1.6	0.7	0.4	0.3	0.4
90	0.7	0.6	0.4	0.2	0.1
135	1.6	0.7	0.4	0.2	0.1
180	2.2	1.3	0.7	0.8	0.6
225	1.3	0.3	0.3	0.2	0.2
270	0.8	0.6	0.3	0.3	0.4
315	1.8	0.8	0.4	0.3	0.3

10a. Suezmax (Mothership, laden) – Aframax (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines and daughter outer breast lines
- **Favourable wave direction(s)** – 330° to 15° 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

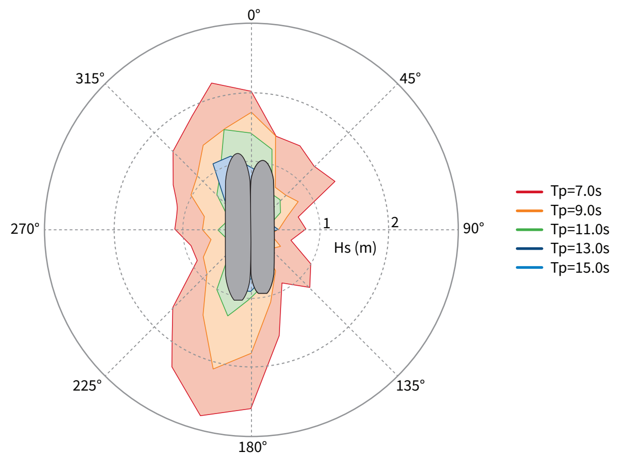
- The mooring lines from the Suezmax rarely exceed the WLL.

Mooring thresholds

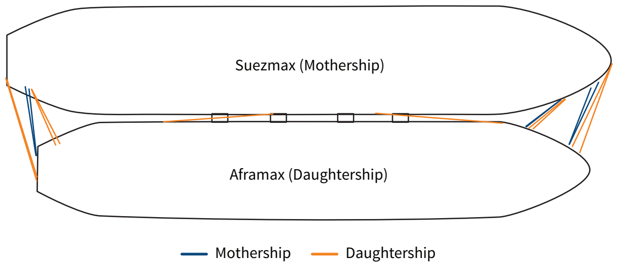
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	1.8	1.1	0.9	0.5
45	1.4	0.7	0.4	0.4	0.3
90	1	0.3	0.2	0.4	0.2
135	1.2	0.8	0.4	0.4	0.2
180	2.4	1.7	1.1	1.1	0.4
225	1.5	0.8	0.5	0.3	0.3
270	1	0.6	0.4	0.2	0.1
315	1.5	1	0.7	0.5	0.2

10b. Suezmax (Mothership, laden) – Aframax (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner aft breast lines and daughter outer breast lines
- **Favourable wave direction(s)** – 315° to 15°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- The mooring lines from the Suezmax rarely exceed the WLL.
- The threshold wave heights are higher than other cases particularly when the waves are from the exposed side of the mothership

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2	1.7	1.4	0.9	0.5
45	1.3	0.7	0.6	0.4	0.4
90	0.8	0.4	0.4	0.4	0.3
135	1.2	0.4	0.3	0.3	0.3
180	2.6	1.8	1	0.9	0.6
225	1.6	0.9	0.4	0.4	0.2
270	1.1	0.7	0.5	0.3	0.1
315	1.6	1.1	0.7	0.5	0.2

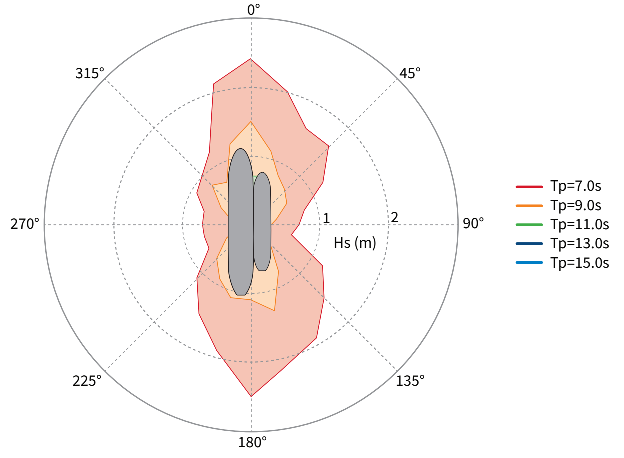
Configuration references 11-12: Suezmax (Mothership) – MR Tanker (Daughtership)

Summary

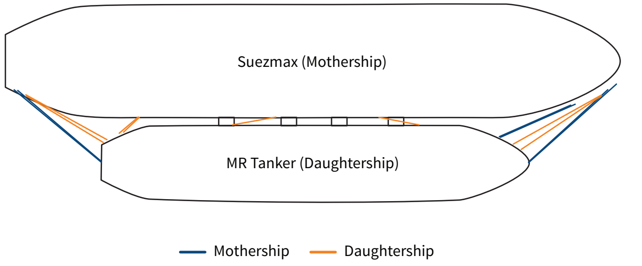
- The outer aft breast lines from the MR Tanker to the Suezmax are the predominant failure mode.
- The mooring lines from the Suezmax rarely exceed the WLL.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.6m. The difference is greater when the waves are from ahead of the ships (0°), the difference reduces as the wave period increases.
- The difference in threshold wave height between the laden and ballast conditions is at maximum 0.9m when the ships are at anchor and the wave period is 7s. This reduces to 0.2m for longer wave periods.
- The difference in threshold wave height is comparable between the laden and ballast conditions when the ships are underway.

11a. Suezmax (Mothership, ballast) – MR Tanker (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines
- **Favourable wave direction(s)** – 345° to 45°, 150° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

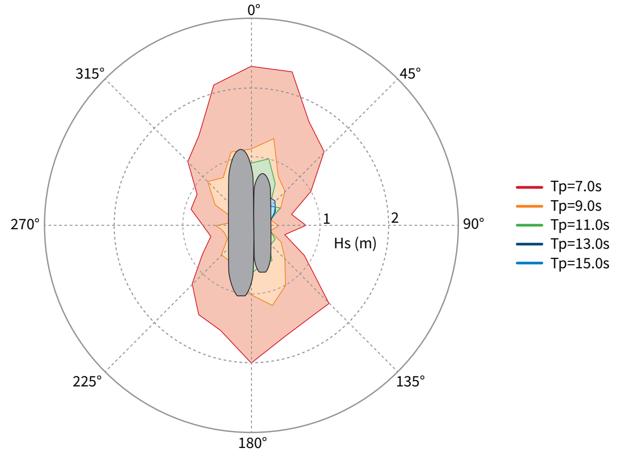
- The mooring lines from the Suezmax rarely exceed the WLL.

Mooring thresholds

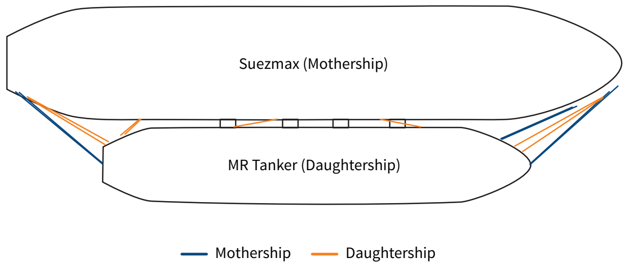
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.4	1.5	0.7	0.3	0.2
45	1.6	0.7	0.4	0.1	0.1
90	0.7	0.3	0.1	0.1	0
135	1.5	0.4	0.3	0.1	0.1
180	2.5	1.1	0.5	0.3	0.2
225	1.1	0.7	0.4	0.2	0.1
270	0.7	0.2	0.1	0.1	0
315	1.0	0.8	0.3	0.2	0.1

11b. Suezmax (Mothership, ballast) – MR Tanker (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines
- **Favourable wave direction(s)** – 330° to 30°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

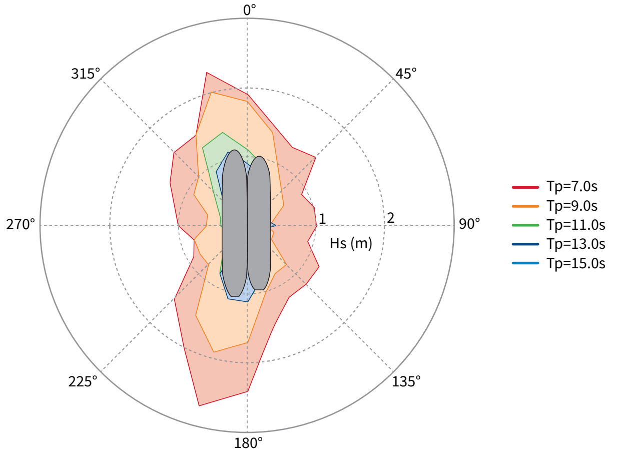
- The mooring lines from the Suezmax rarely exceed the WLL.

Mooring thresholds

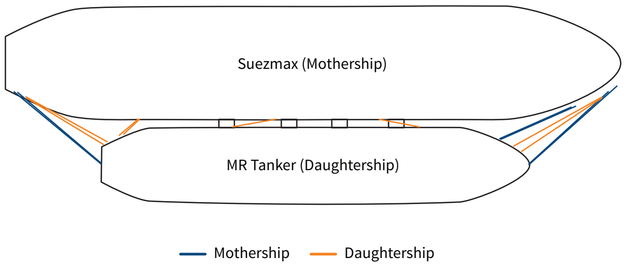
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	1.1	0.9	0.4	0.3
45	1.5	0.7	0.4	0.5	0.3
90	0.8	0.4	0.3	0.2	0.2
135	1.6	0.7	0.4	0.3	0.1
180	2	1	0.7	0.3	0.2
225	1.2	0.6	0.3	0.1	0.1
270	0.7	0.5	0.3	0.1	0.1
315	1.3	0.9	0.4	0.3	0.2

12a. Suezmax (Mothership, laden) – MR Tanker (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines
- **Favourable wave direction(s)** – 330° to 15°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

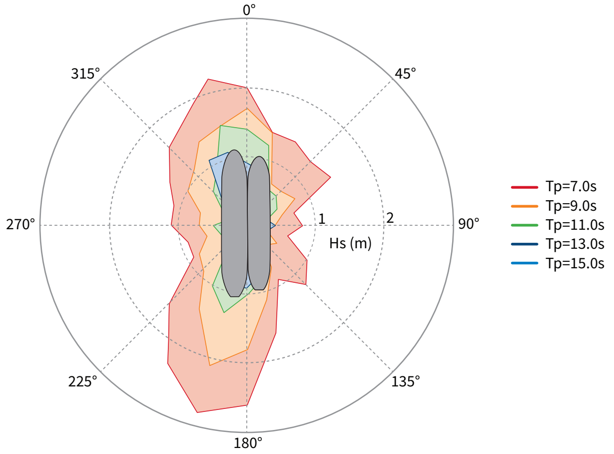
- The threshold wave height is lower for this loading condition (ie when compared to when the Suezmax is ballast and the MR Tanker is laden) when the wave period is less than 9s. As the wave period increases the difference in the threshold wave heights between the loading conditions decreases.

Mooring thresholds

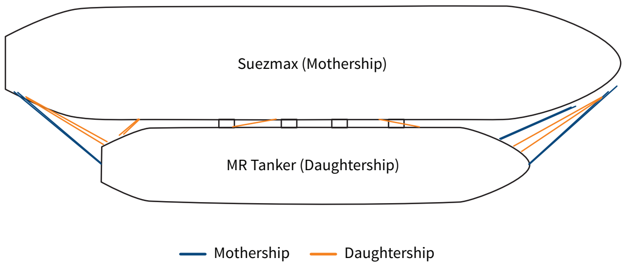
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.5	1	0.5	0.4	0.3
45	1.3	0.4	0.1	0.2	0.2
90	0.5	0.4	0.2	0.2	0.2
135	1.1	0.4	0.1	0.1	0.1
180	1.7	0.9	0.4	0.5	0.3
225	0.8	0.5	0.2	0.1	0.1
270	0.7	0.3	0.2	0.2	0.2
315	0.8	0.6	0.3	0.2	0.1

12b. Suezmax (Mothership, laden) – MR Tanker (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	80t	PP/PPE Mix (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines
- **Favourable wave direction(s)** – 315° to 15°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

- The mooring lines from the Suezmax rarely exceed the WLL.
- The threshold wave height is lower for this loading condition, when the wave period is less than 9s, (ie as compared to when the Suezmax is ballast and the MR Tanker is laden).

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	0.7	0.2	0.2	0.3
45	1.3	0.4	0.1	0.1	0.2
90	0.7	0.4	0.2	0.2	0.2
135	1.1	0.3	0.1	0.1	0.1
180	1.9	0.6	0.2	0.1	0.2
225	1.1	0.5	0.2	0.1	0.2
270	0.7	0.4	0.3	0.2	0.3
315	0.9	0.7	0.3	0.2	0.2

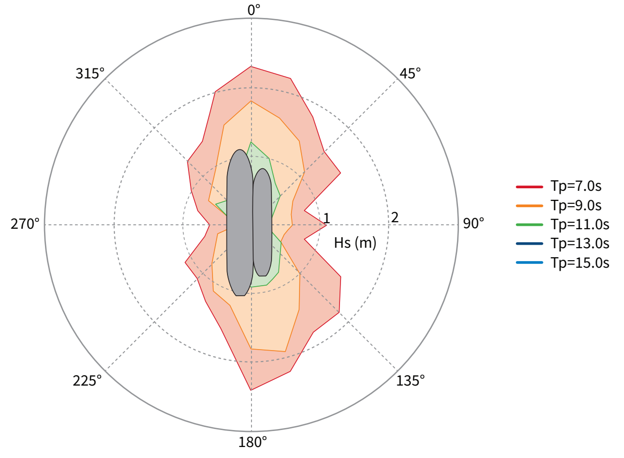
Configuration references 13-14: Aframax (Mothership) – MR Tanker (Daughtership)

Summary

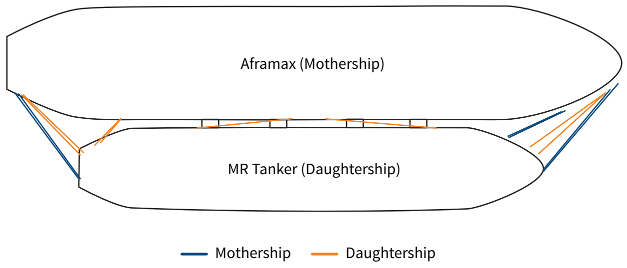
- The inner aft breast lines and aft spring lines from MR Tanker to the Aframax are the predominant failure modes.
- The mooring lines from the Aframax which exceed the WLL occur in the inner forward and outer aft breast lines.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.5m. The difference reduces as the wave period increases.
- The difference in threshold wave height between the laden and ballast conditions is a maximum of 0.6m when the ships are at anchor. This reduces to 0.2m when the wave period increase to 15s.
- The difference in threshold wave height between the laden and ballast conditions is comparable when the ships are underway.

13a. Aframax (Mothership, ballast) – MR Tanker (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	44t (55%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter Inner aft breast lines and daughter aft spring lines when the wave period is 9s or less
- **Favourable wave direction(s)** – 345° to 30°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

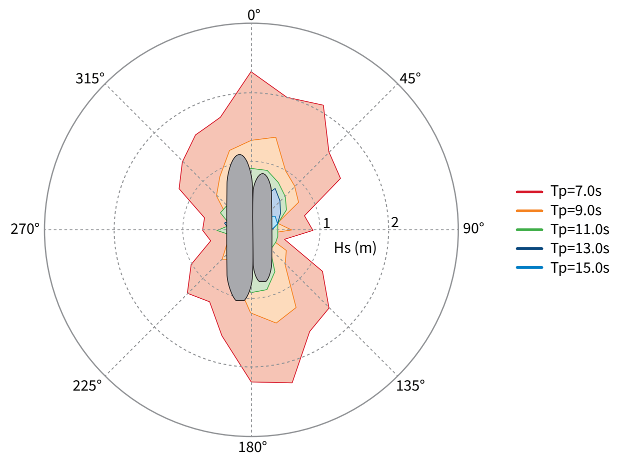
- Mooring lines from the Aframax which exceeded the WLL were the inner forward breast lines.

Mooring thresholds

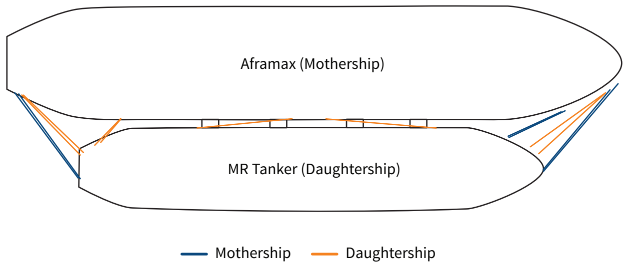
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	1.8	1.2	0.7	0.3
45	1.5	1.1	0.6	0.2	0.2
90	1.1	0.6	0.3	0.1	0.1
135	1.8	1.0	0.6	0.2	0.1
180	2.4	1.8	0.9	0.5	0.3
225	1.1	0.8	0.5	0.3	0.2
270	0.6	0.2	0.3	0.2	0.1
315	1.3	0.8	0.5	0.3	0.2

13b. Aframax (Mothership, ballast) – MR Tanker (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter Inner aft breast lines and daughter aft spring lines
- **Favourable wave direction(s)** – 345° to 30°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

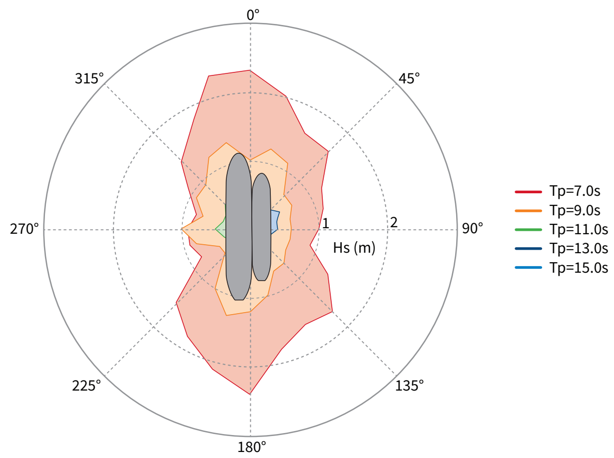
- Mooring lines from the Aframax which exceeded the WLL were the inner forward breast lines.

Mooring thresholds

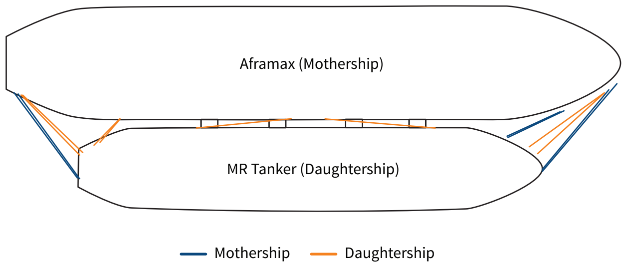
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	1.3	0.9	0.4	0.2
45	1.6	0.9	0.7	0.6	0.3
90	0.9	0.6	0.4	0.3	0.3
135	1.6	0.7	0.4	0.4	0.3
180	2.2	1.2	0.9	0.4	0.2
225	1.3	0.6	0.4	0.2	0.1
270	0.7	0.4	0.5	0.3	0.3
315	1.4	0.7	0.5	0.4	0.2

14a. Aframax (Mothership, laden) – MR Tanker (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter Inner aft breast lines and daughter aft spring lines when the wave period is 9s or less
- **Favourable wave direction(s)** – 330° to 30°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

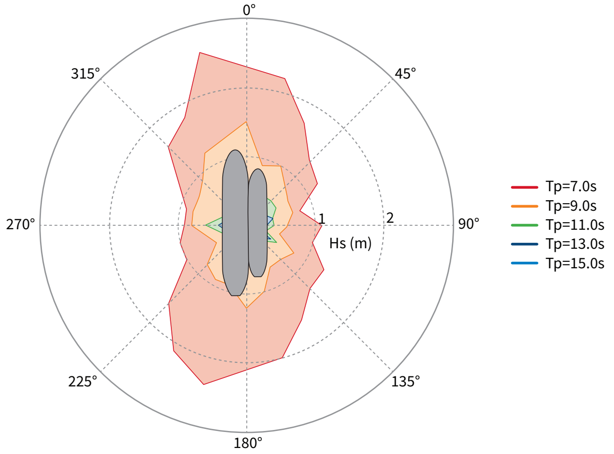
- Mooring lines from the Aframax which exceeded the WLL were the inner forward breast lines.

Mooring thresholds

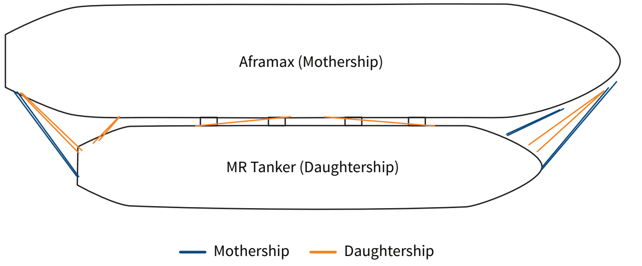
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2	0.8	0.3	0.5	0.4
45	1.5	0.7	0.3	0.3	0.3
90	0.8	0.5	0.2	0.3	0.3
135	1.5	0.5	0.1	0.2	0.2
180	2.8	0.8	0.3	0.4	0.4
225	1.4	0.8	0.2	0.2	0.2
270	0.7	0.7	0.5	0.4	0.3
315	1.3	0.9	0.4	0.4	0.2

14b. Aframax (Mothership, laden) – MR Tanker (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter Inner aft breast lines
- **Favourable wave direction(s)** – 330° to 30°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- Mooring lines from the Aframax which exceeded the WLL were the inner forward breast lines.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	0.9	0.2	0.4	0.5
45	1.8	0.8	0.3	0.3	0.3
90	1.2	0.6	0.4	0.3	0.2
135	1.8	0.8	0.4	0.3	0.4
180	2.5	0.6	0.2	0.2	0.3
225	1.5	0.6	0.2	0.2	0.2
270	1.2	0.7	0.4	0.4	0.3
315	1.5	0.9	0.3	0.3	0.2

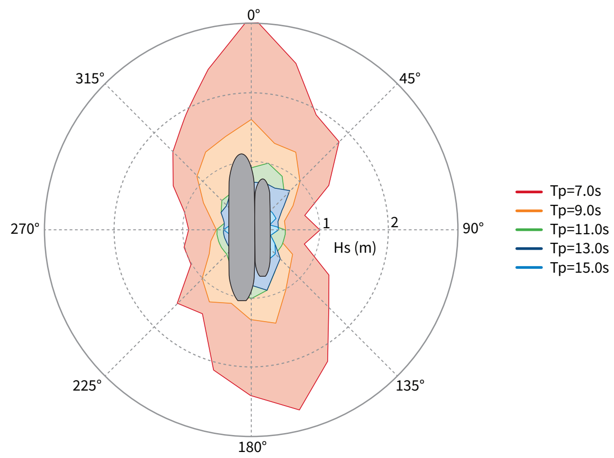
Configuration references 15-16: Aframax (Mothership) – 25k DWT/Coastal Tanker (Daughtership)

Summary

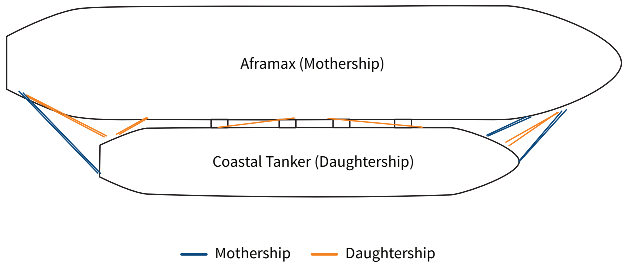
- The outer aft breast lines and inner forward breast lines from the Coastal Tanker to the Aframax are the predominant failure mode.
- The mooring lines from the Aframax very rarely exceed the WLL in this case.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.6m. The difference reduces as the wave period lengthens.
- The difference in threshold wave height between the laden and ballast conditions is a maximum of 0.6m when the ships are at anchor and 0.9m when the ships are underway. This reduces to 0.2m for both cases when the wave period lengthens to 15s.

15a. Aframax (Mothership, ballast) – 25k DWT/Coastal Tanker (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines when the wave period was less than 11s.
- **Favourable wave direction(s)** – 330° to 30°, 150° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

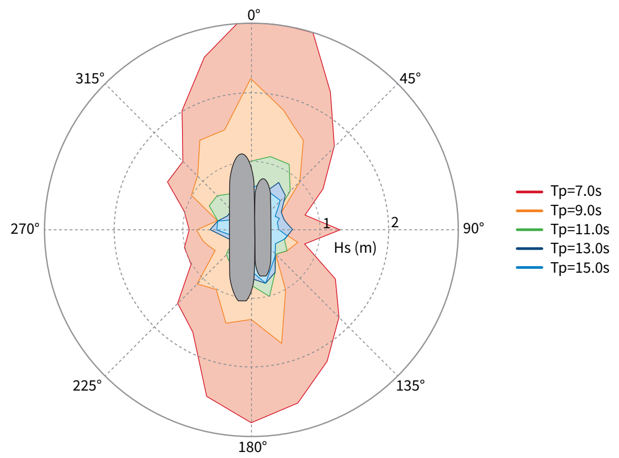
- Mooring lines from the Aframax rarely exceed the WLL.

Mooring thresholds

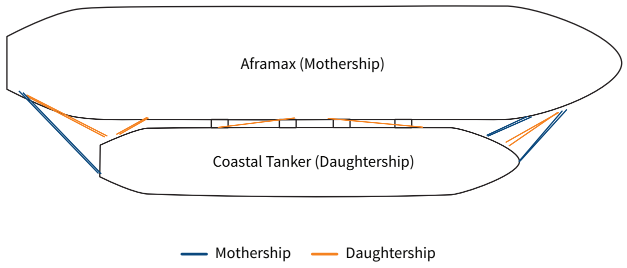
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	3.1	1.6	0.9	0.7	0.5
45	1.8	1	0.7	0.8	0.4
90	1	0.5	0.5	0.4	0.4
135	1.6	0.8	0.5	0.6	0.5
180	2.4	1.3	1	0.8	0.5
225	1.5	1	0.5	0.4	0.4
270	0.9	0.5	0.5	0.4	0.4
315	1.6	1.1	0.6	0.5	0.4

15b. Aframax (Mothership, ballast) – 25k DWT/Coastal Tanker (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines and daughter aft spring lines when the wave period was less than 11s.
- **Favourable wave direction(s)** – 330° to 30°, 150° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

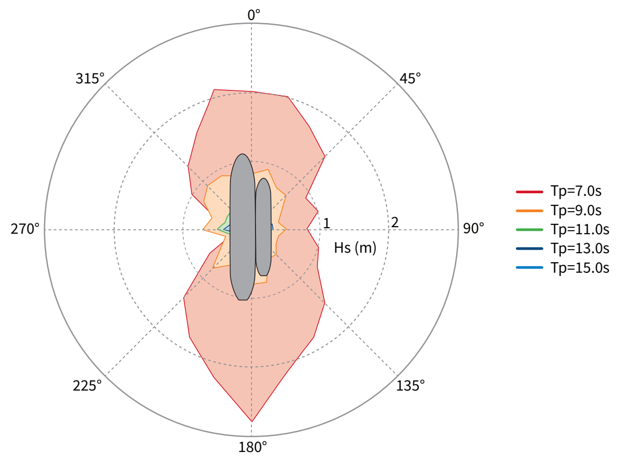
- Mooring lines from the Aframax rarely exceed the WLL.

Mooring thresholds

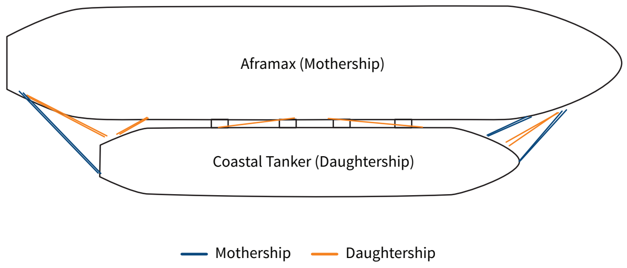
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	3.2	2.2	1	0.6	0.6
45	1.7	1	0.8	0.7	0.6
90	1.3	0.4	0.5	0.6	0.6
135	1.8	0.5	0.5	0.5	0.5
180	2.8	1.3	0.8	0.7	0.6
225	1.5	1.1	0.5	0.4	0.3
270	0.9	0.8	0.6	0.5	0.6
315	1.4	1.1	0.7	0.4	0.4

16a. Aframax (Mothership, laden) – 25k DWT/Coastal Tanker (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines
- **Favourable wave direction(s)** – 330° to 30°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

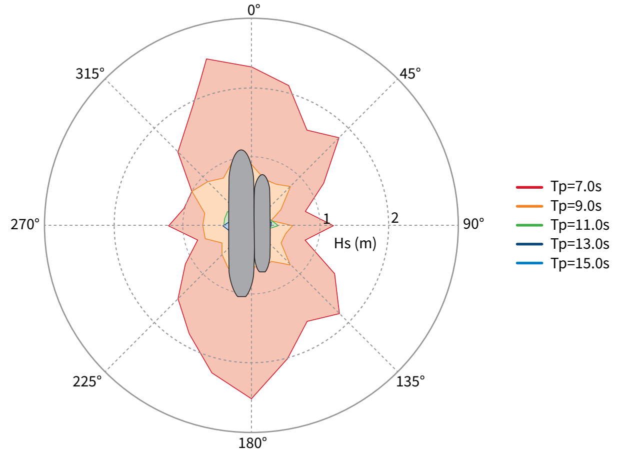
- Mooring lines from the Aframax rarely exceed the WLL.

Mooring thresholds

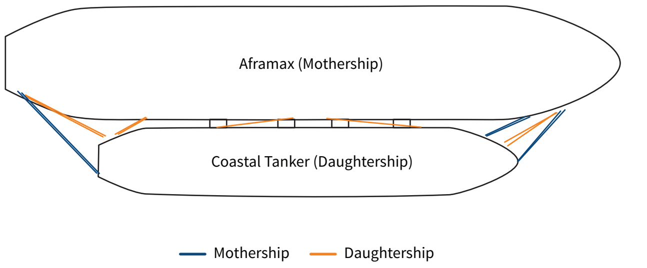
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2	0.8	0.3	0.5	0.4
45	1.5	0.7	0.3	0.3	0.3
90	0.8	0.5	0.2	0.3	0.3
135	1.5	0.5	0.1	0.2	0.2
180	2.8	0.8	0.3	0.4	0.4
225	1.4	0.8	0.2	0.2	0.2
270	0.7	0.7	0.5	0.4	0.3
315	1.3	0.9	0.4	0.4	0.2

16b. Aframax (Mothership, laden) – 25k DWT/Coastal Tanker (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	83t	Nylon (11m)	41.5t (50%SDMBL)	4-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter outer aft breast lines
- **Favourable wave direction(s)** – 330° to 15°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- Mooring lines from the Aframax rarely exceed the WLL.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.3	0.9	0.2	0.4	0.5
45	1.8	0.8	0.3	0.3	0.3
90	1.2	0.6	0.4	0.3	0.2
135	1.8	0.8	0.4	0.3	0.4
180	2.5	0.6	0.2	0.2	0.3
225	1.5	0.6	0.2	0.2	0.2
270	1.2	0.7	0.4	0.4	0.3
315	1.5	0.9	0.3	0.3	0.2

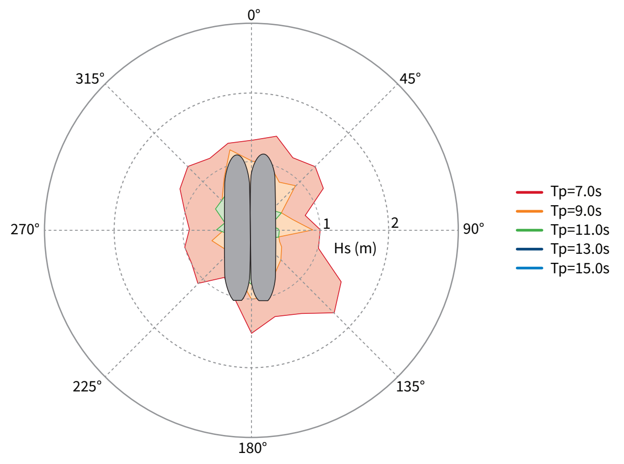
Configuration references 17-18: MR Tanker (Mothership) – MR Tanker (Daughtership)

Summary

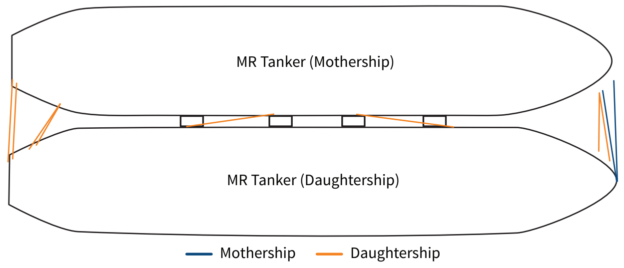
- The outer aft breast lines from daughtership to the mothership are the predominant failure modes when the mothership is laden.
- The inner forward breasting lines from daughtership to the mothership are the predominant failure modes when the daughtership is laden.
- Wave height thresholds are higher when waves are on the side of the laden ship.
- The lines from the mothership to daughtership only exceed the WLL when the relative wave direction is on the bow.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.4m. The difference reduces as the wave period increases.
- The difference in threshold wave height between the laden and ballast conditions is at maximum 0.5m when the ships are at anchor and the wave period is 7s, this reduces to 0.2m for longer period waves.

17a. MR Tanker (Mothership, ballast) – MR Tanker (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-0
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter inner forward breasting lines
- **Favourable wave direction(s)** – 345° to 45°, 135° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°, 315°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

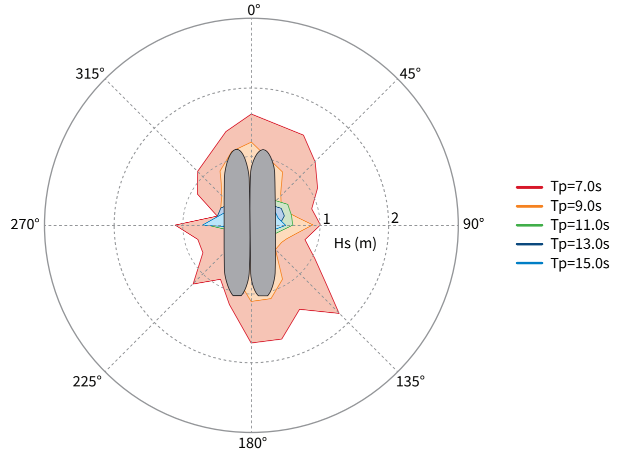
- Wave height thresholds are higher when waves are on the side of the daughtership.
- Longer period waves cause significantly lower wave height thresholds.
- Wave height thresholds are lowest when the relative wave direction is on the shoulders or quarters.
- Mooring lines from the MR Tanker mothership rarely exceed the WLL.

Mooring thresholds

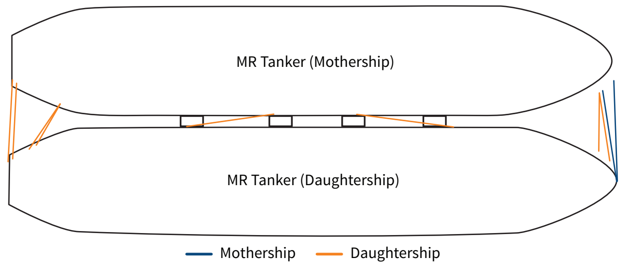
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.3	1	0.8	0.6	0.3
45	1.3	0.9	0.4	0.2	0.2
90	1	0.9	0.4	0.1	0.1
135	1.7	0.6	0.4	0.2	0.2
180	1.5	1	0.8	0.6	0.3
225	1.1	0.4	0.4	0.3	0.3
270	0.9	0.4	0.5	0.3	0.2
315	1.3	0.6	0.6	0.3	0.2

17b. MR Tanker (Mothership, ballast) – MR Tanker (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-0
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter inner forward breasting lines
- **Favourable wave direction(s)** – 0° to 45°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

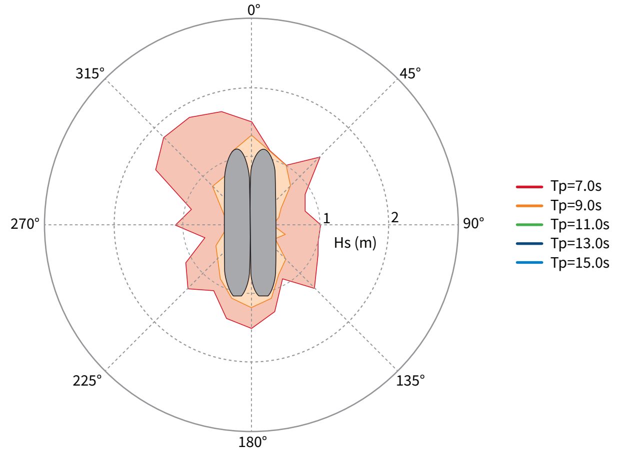
- Wave height thresholds are higher when waves are on the side of the daughtership.
- Longer period waves cause significantly lower wave height thresholds.
- Wave height thresholds are lowest when the relative wave direction is on the shoulders or quarters.
- Mooring lines from the MR Tanker mothership rarely exceed the WLL.

Mooring thresholds

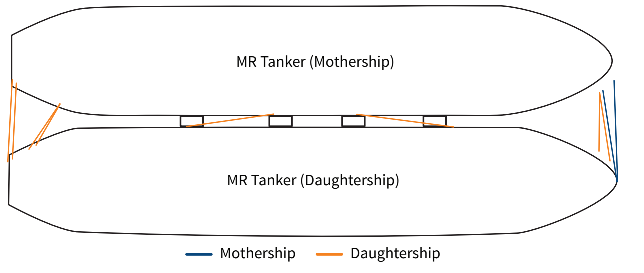
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.6	1.2	0.5	0.2	0.2
45	1.3	0.6	0.5	0.4	0.5
90	1	0.9	0.6	0.4	0.5
135	1.8	0.5	0.4	0.3	0.3
180	1.7	1.1	0.5	0.2	0.2
225	1.2	0.5	0.3	0.1	0.2
270	1.1	0.4	0.6	0.4	0.7
315	1.1	0.6	0.4	0.4	0.3

18a. MR Tanker (Mothership, laden) – MR Tanker (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-0
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter inner forward breasting lines
- **Favourable wave direction(s)** – 180° to 225°, 315° to 0°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

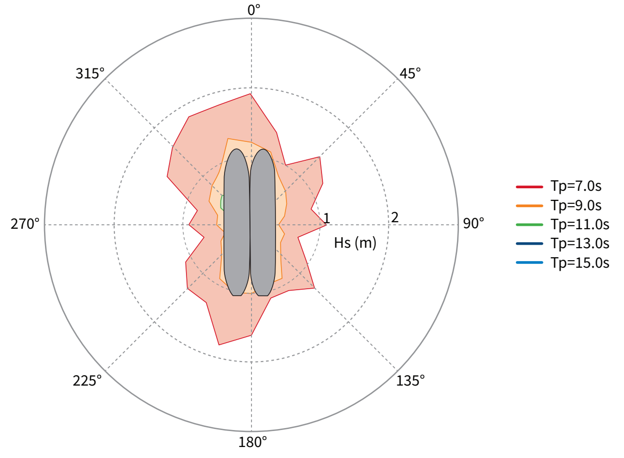
- Wave height thresholds are higher when waves are on the side of the mothership.
- Longer period waves cause significantly lower wave height thresholds.
- Wave height thresholds are lowest when the relative wave direction is on the shoulders or quarters.
- Mooring lines from the MR Tanker mothership rarely exceed the WLL.

Mooring thresholds

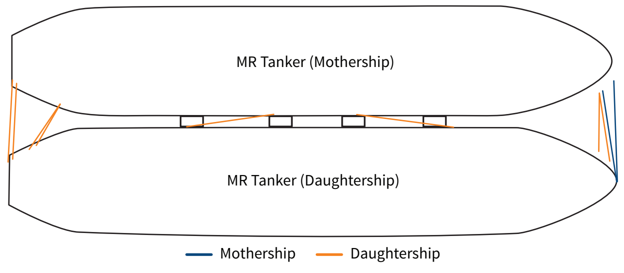
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.5	1.3	0.6	0.3	0.3
45	1.4	0.8	0.3	0.2	0.2
90	1	0.3	0.2	0.2	0.2
135	1.3	0.7	0.3	0.2	0.2
180	1.5	1.2	0.5	0.3	0.3
225	1.3	0.7	0.3	0.2	0.3
270	1.1	0.3	0.2	0.2	0.2
315	1.8	0.8	0.3	0.2	0.3

18b. MR Tanker (Mothership, laden) – MR Tanker (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-0
Daughtership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-2-2-4

Summary

- **Most likely line failures** – Daughter inner forward breasting lines
- **Favourable wave direction(s)** – 135° to 225°, 315° to 0°
- **Wave direction(s) to avoid** – 45° ± 30°, 90° ± 30°, 270 ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- Wave height thresholds are higher when waves are on the side of the mothership.
- Longer period waves cause significantly lower wave height thresholds.
- Wave height thresholds are lowest when the relative wave direction is on the shoulders or quarters.
- Mooring lines from the MR Tanker mothership rarely exceed the WLL.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	1.2	0.4	0.2	0.2
45	1.4	0.7	0.3	0.1	0.2
90	1.1	0.4	0.3	0.2	0.2
135	1.3	0.6	0.4	0.3	0.2
180	1.6	1	0.4	0.2	0.2
225	1.3	0.6	0.3	0.2	0.3
270	0.9	0.5	0.3	0.2	0.3
315	1.6	0.8	0.6	0.4	0.4

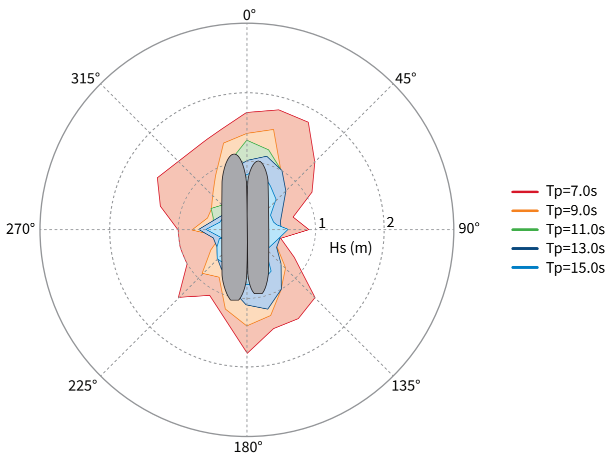
Configuration references 19-20: MR Tanker (Mothership) – 25kDWT/Coastal Tanker (Daughtership)

Summary

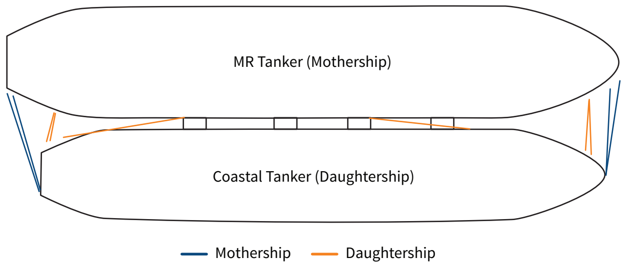
- The aft breast lines and spring lines from the Coastal Tanker to the MR tanker are the predominant failure modes.
- The mooring lines from the MR tanker rarely exceed the WLL and those that do are the aft breast lines.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.5m. The difference reduces as the wave period increases.

19a. MR Tanker (Mothership, ballast) – 25kDWT/Coastal Tanker (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and daughter forward and aft spring lines
- **Favourable wave direction(s)** – 345° to 30°, 135° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

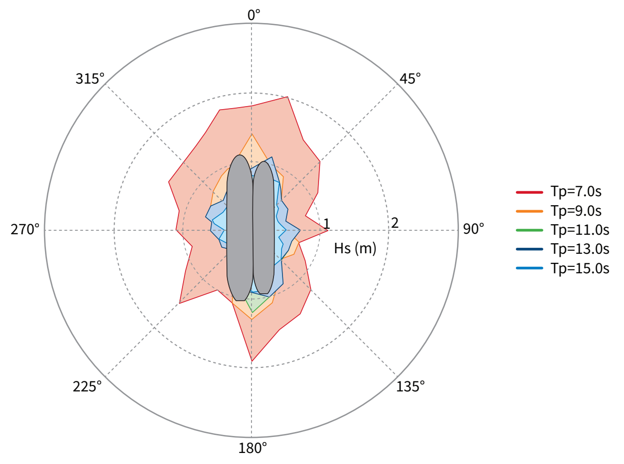
- The mooring lines from the MR tanker rarely exceed the WLL. The lines which do are the aft breast lines.
- The difference in threshold wave height with increasing wave period is lower compared to other ship combinations.

Mooring thresholds

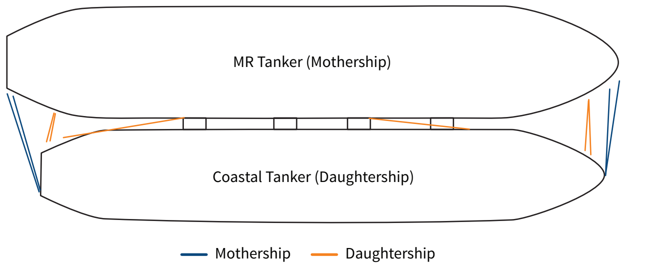
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	–	1.7	1.4	1.3	1
45	–	1.4	0.6	0.6	0.8
90	–	0.9	0.4	0.4	0.5
135	–	1.4	0.8	0.5	0.7
180	–	1.8	1.4	1	1.1
225	–	1.4	0.9	0.6	0.6
270	–	1	0.8	0.5	0.7
315	–	1.4	0.7	0.5	0.5

19b. MR Tanker (Mothership, ballast) – 25kDWT/Coastal Tanker (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and daughter forward and aft spring lines
- **Favourable wave direction(s)** – 330° to 30°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 11s

Notes

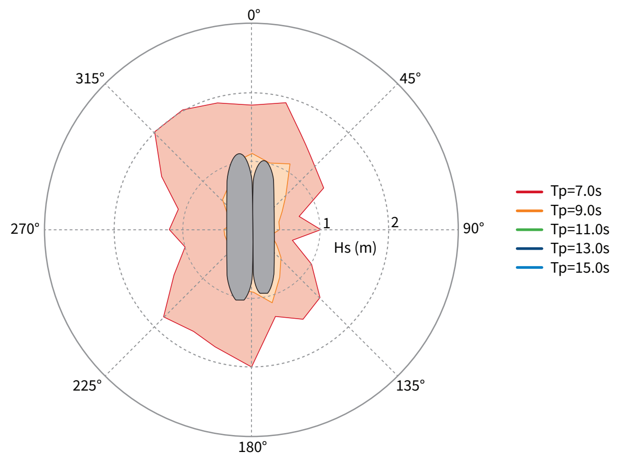
- The mooring lines from the MR tanker rarely exceed the WLL. The lines which do are the aft breast lines.
- The difference in threshold wave height with increasing wave period is lower compared to other ship combinations.

Mooring thresholds

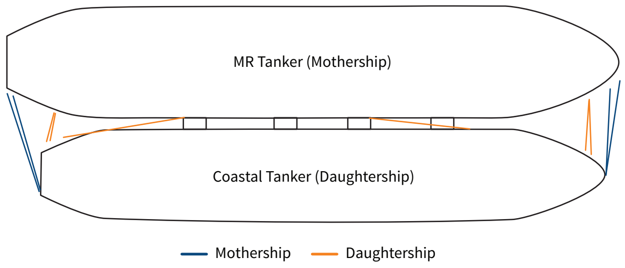
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.8	1.4	0.8	0.9	0.8
45	1.4	0.6	0.6	0.6	0.5
90	1.1	0.5	0.5	0.6	0.7
135	1.2	0.6	0.6	0.6	0.6
180	1.9	1.3	1.2	0.9	0.9
225	1.5	0.4	0.3	0.4	0.4
270	1.1	0.6	0.5	0.4	0.6
315	1.4	0.8	0.6	0.6	0.5

20a. MR Tanker (Mothership, laden) – 25kDWT/Coastal Tanker (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and daughter forward and aft spring lines
- **Favourable wave direction(s)** – 315° to 30° 180° to 225°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

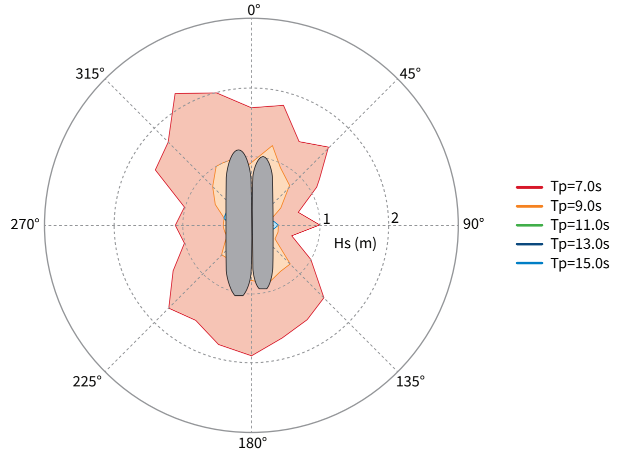
- The mooring lines from the MR tanker rarely exceed the WLL. The lines which do are the aft breast lines.
- The threshold wave height for this condition is lower compared to when the MR tanker is ballast and the Coastal Tanker is laden when the wave period is greater than 7s.

Mooring thresholds

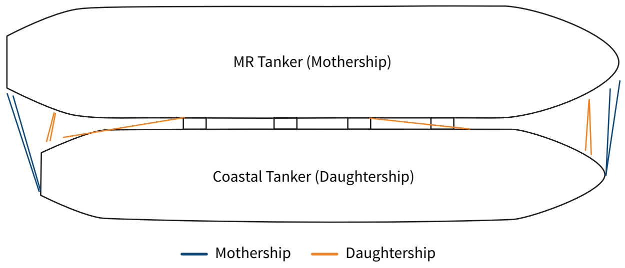
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	1.1	0.5	0.4	0.4
45	1.6	0.6	0.3	0.3	0.3
90	1	0.3	0.1	0.2	0.2
135	1.4	0.5	0.2	0.2	0.2
180	1.8	0.9	0.4	0.3	0.3
225	1.2	0.5	0.2	0.2	0.2
270	1.1	0.3	0.1	0.2	0.2
315	1.9	0.6	0.2	0.2	0.3

20b. MR Tanker (Mothership, laden) – 25kDWT/Coastal Tanker (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	PP/PPE Mix	68t	N/A	34t (50%SDMBL)	2-0-0-2
Daughtership	PP/PPE Mix	52t	N/A	26t (50%SDMBL)	2-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and daughter forward and aft spring lines
- **Favourable wave direction(s)** – 315° to 15°, 150° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 7s

Notes

- The mooring lines from the MR tanker rarely exceed the WLL. The lines which do are the aft breast lines.
- The threshold wave height for this condition is lower compared to when the MR tanker is ballast and the Coastal Tanker is laden when the wave period is greater than 9s.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.7	0.9	0.4	0.3	0.4
45	1.6	0.8	0.3	0.2	0.3
90	1	0.4	0.2	0.3	0.4
135	1.5	0.8	0.4	0.3	0.3
180	1.9	0.8	0.3	0.3	0.5
225	1.7	0.6	0.3	0.3	0.3
270	1.1	0.4	0.2	0.3	0.3
315	1.7	0.8	0.5	0.4	0.4

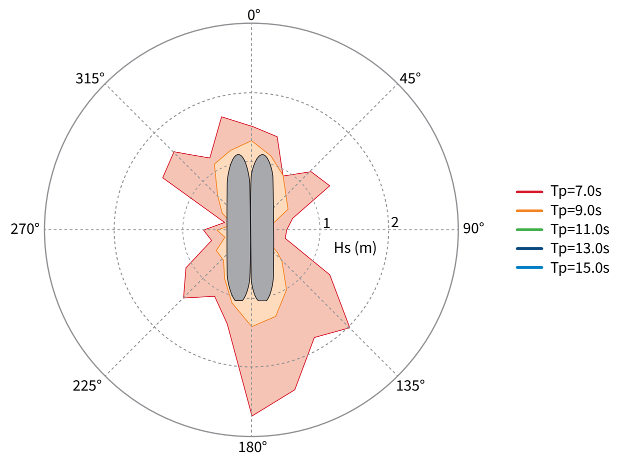
Configuration references 21-22: VLGC/80k LPG (Mothership) – VLGC/80k LPG (Daughtership)

Summary

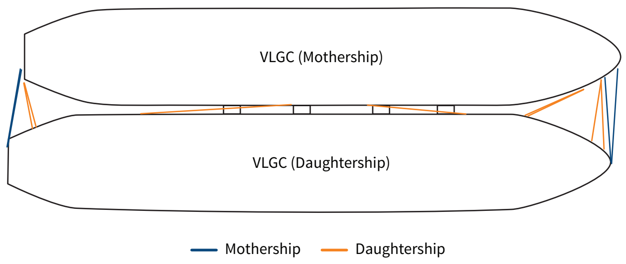
- This combination of ships generally led to a lower threshold wave height compared to other ship combinations.
- The forward and aft breast lines from the 80k LPG mothership fail more often compared to other ship combinations.
- The aft breast and spring lines from the 80k LPG daughtership are the predominant failure modes for this ship.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.4m, the difference is greater when the waves are from 0°, the difference reduces as the wave period lengthens.
- The difference in threshold wave height between the laden and ballast conditions is a maximum of 0.5m when the ships are at anchor and the wave period is 7s, this reduces to 0.2m for longer wave periods.
- The difference in threshold wave height is comparable between the laden and ballast conditions when the ships are underway.

21a. VLGC/80k LPG (Mothership, ballast) – VLGC/80k LPG (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	65t	PP/PPE Mix (11m)	43.3t (55%SDMBL)	2-0-0-2
Daughtership	IWRC	65t	PP/PPE Mix (11m)	43.3t (55%SDMBL)	4-2-2-2

Summary

- **Most likely line failures** – Daughtership aft breast and spring lines and Mothership forward and aft breast lines
- **Favourable wave direction(s)** – 315° to 15°, 135° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Mooring thresholds

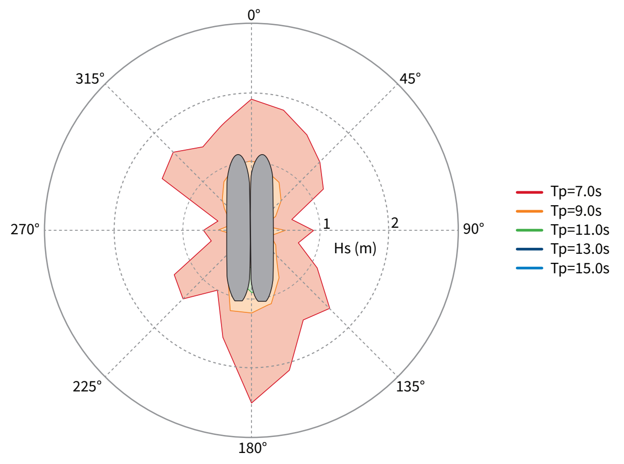
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.5	1.3	0.7	0.6	0.5
45	1.2	0.7	0.4	0.2	0.2
90	0.5	0.3	0.1	0.2	0.2
135	2	0.6	0.3	0.2	0.1
180	2.7	1.4	0.8	0.7	0.6
225	1.4	0.6	0.4	0.2	0.2
270	0.7	0.5	0.2	0.2	0.2
315	1.6	0.7	0.3	0.2	0.2

Notes

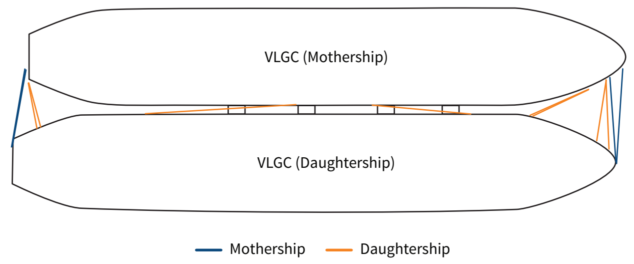
- The threshold wave height for this combination is lower when compared to other ship combinations.

21b. VLGC/80k LPG (Mothership, ballast) – VLGC/80k LPG (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	65t	PP/PE Mix (11m)	43.3t (55%SDMBL)	2-0-0-2
Daughtership	IWRC	65t	PP/PE Mix (11m)	43.3t (55%SDMBL)	4-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and spring lines and mother forward and aft breast lines
- **Favourable wave direction(s)** – 315° to 30°, 150° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

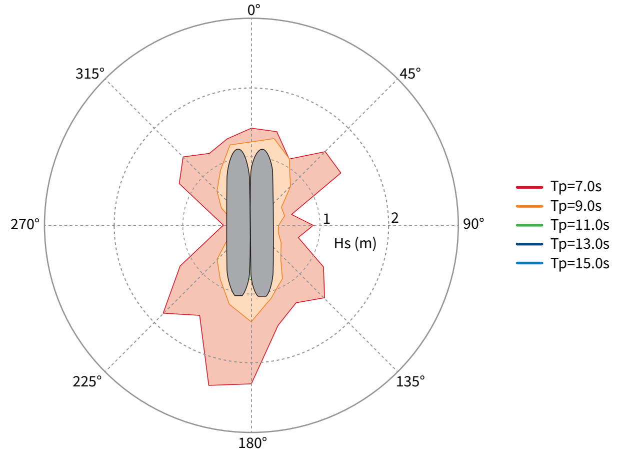
- The threshold wave height for this combination is lower compared to other ship combinations.

Mooring thresholds

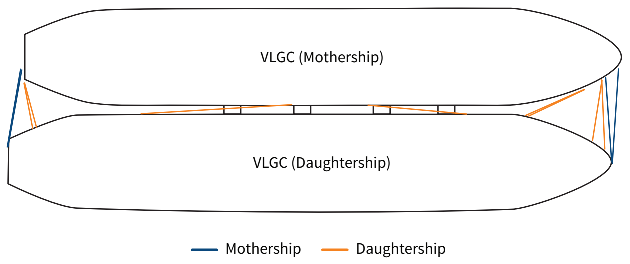
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.9	1	0.5	0.4	0.3
45	1.4	0.6	0.3	0.3	0.3
90	0.9	0.5	0.2	0.2	0.2
135	1.6	0.5	0.2	0.3	0.2
180	2.5	1.2	0.9	0.6	0.5
225	1.4	0.4	0.2	0.2	0.1
270	0.7	0.5	0.2	0.3	0.3
315	1.6	0.7	0.3	0.2	0.2

22a. VLGC/80k LPG (Mothership, laden) – VLGC/80k LPG (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	79t	PP/PE Mix (11m)	43.3t (55%SDMBL)	2-0-0-2
Daughtership	IWRC	79t	PP/PE Mix (11m)	43.3t (55%SDMBL)	4-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and spring lines and mother forward and aft breast lines
- **Favourable wave direction(s)** – 315° to 45°, 150° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

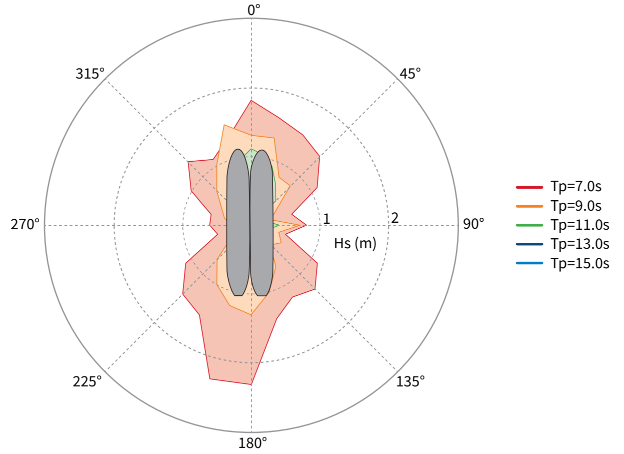
- The threshold wave height for this combination is lower compared to other ship combinations.

Mooring thresholds

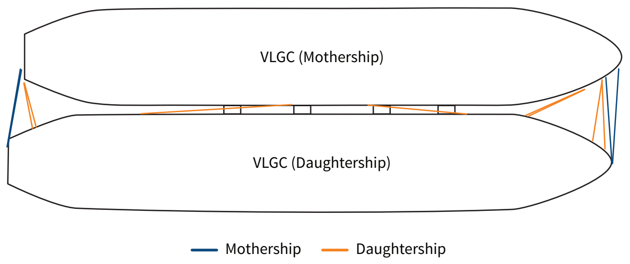
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.4	1.2	0.7	0.5	0.4
45	1.5	0.8	0.3	0.3	0.2
90	0.9	0.4	0.3	0.3	0.2
135	1.5	0.6	0.3	0.2	0.2
180	2.3	1.4	0.8	0.6	0.4
225	1.8	0.7	0.3	0.2	0.2
270	0.4	0.3	0.2	0.2	0.2
315	1.4	0.7	0.3	0.2	0.2

22b. VLGC/80k LPG (Mothership, laden) – VLGC/80k LPG (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	IWRC	65t	PP/PE Mix (11m)	43.3t (55%SDMBL)	2-0-0-2
Daughtership	IWRC	65t	PP/PE Mix (11m)	43.3t (55%SDMBL)	4-2-2-2

Summary

- **Most likely line failures** – Daughter aft breast and spring lines and mother forward and aft breast lines
- **Favourable wave direction(s)** – 0° to 45°, 180° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- The threshold wave height for this combination is lower compared to other ship combinations.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.8	1.3	1.1	0.5	0.3
45	1.4	0.8	0.5	0.2	0.2
90	0.8	0.7	0.4	0.3	0.3
135	1.3	0.4	0.3	0.2	0.3
180	2.3	1.3	0.7	0.4	0.3
225	1.4	0.7	0.2	0.2	0.2
270	0.6	0.3	0.3	0.3	0.4
315	1.3	0.7	0.3	0.3	0.2

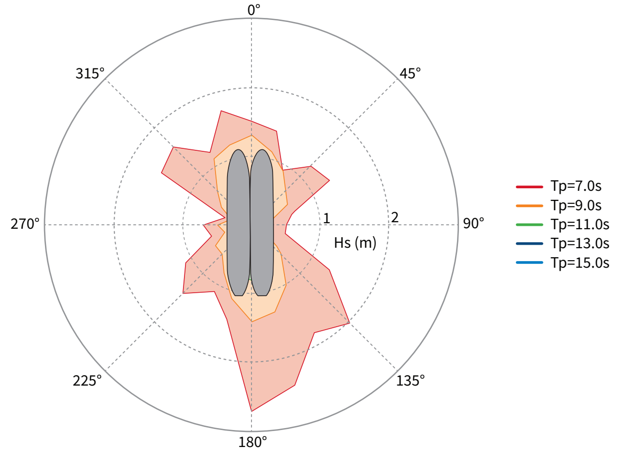
Configuration references 23-24: LNGC (Mothership) – LNGC (Daughtership)

Summary

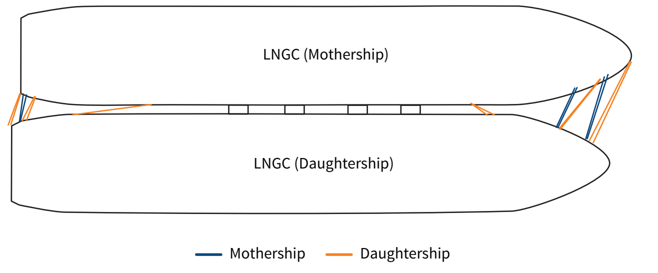
- The inner aft breast lines from daughtership to the mothership are the predominant failure modes.
- The mooring lines from the mothership rarely exceed the WLL.
- The difference in threshold wave height between the at anchor and underway condition is a maximum of 0.5m. The difference reduces as the wave period increases.
- The difference in threshold wave height between the laden and ballast conditions is at maximum 0.8m when the ships are at anchor and the wave period is 7s. This reduces to 0.2m for longer wave periods.
- The difference in threshold wave height is comparable between the laden and ballast conditions when the ships are underway.

23a. LNGC (Mothership, ballast) – LNGC (Daughtership, laden) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-0-0-2
Daughtership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter inner stern breast lines and mother inner head breast lines
- **Favourable wave direction(s)** – 330° to 15°, 135° to 180°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

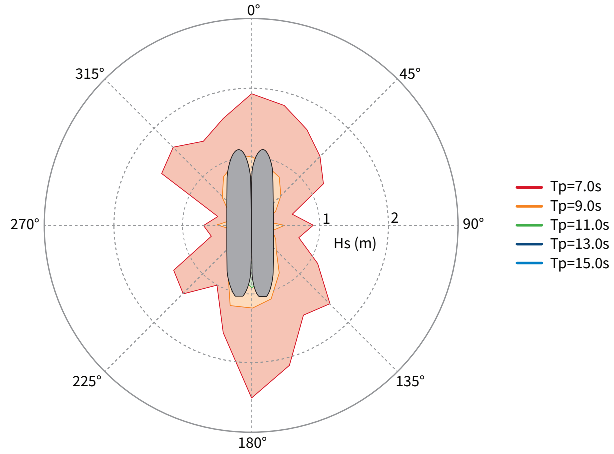
- The threshold wave height is higher when the waves are from the exposed side of the laden daughtership.

Mooring thresholds

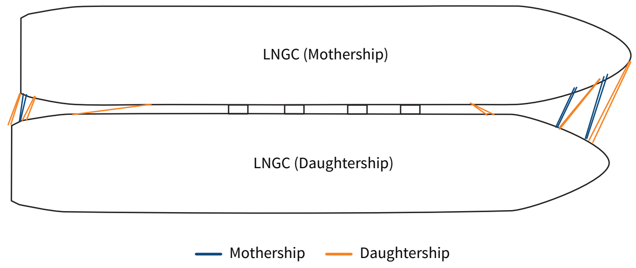
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.5	1.9	1.3	0.6	0.6
45	1.6	1.1	0.6	0.3	0.3
90	0.7	0.5	0.2	0.1	0.1
135	1.7	1	0.6	0.3	0.1
180	3.0	1.9	0.9	0.6	0.5
225	1.3	0.8	0.5	0.3	0.2
270	0.7	0.5	0.2	0.2	0.1
315	1.8	1.1	0.7	0.4	0.2

23b. LNGC (Mothership, ballast) – LNGC (Daughtership, laden) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-0-0-2
Daughtership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter outer head and stern breast lines and mother forward breast lines
- **Favourable wave direction(s)** – 330° to 45°, 150° to 195°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

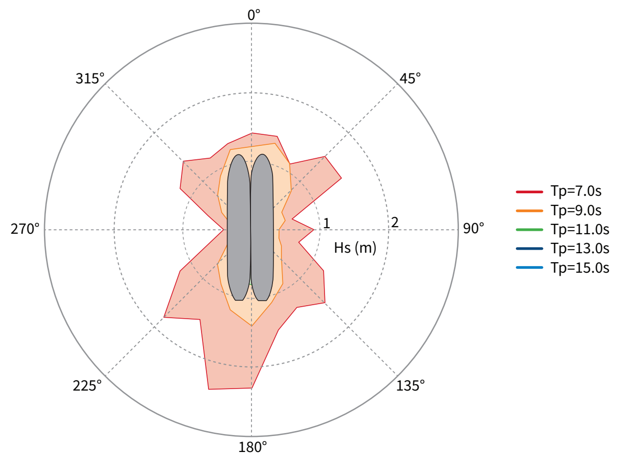
- The threshold wave height is lower at shorter wave periods for this condition compared to when the ships are at anchor. As wave period increases the difference in the threshold wave heights between the conditions reduces.
- The threshold wave height is higher when the waves are from the exposed side of the laden daughtership.

Mooring thresholds

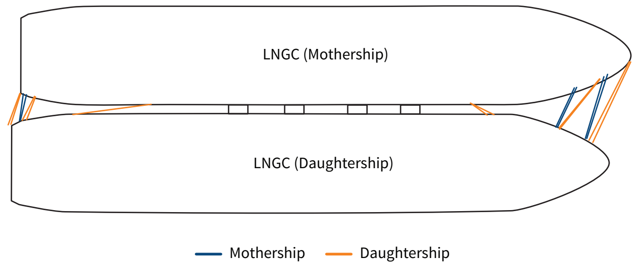
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.9	1.1	0.6	0.5
45	1.6	0.8	0.6	0.5	0.4
90	0.9	0.6	0.4	0.2	0.2
135	1.7	0.7	0.4	0.2	0.2
180	2.8	1.7	1	0.7	0.5
225	1.6	0.7	0.4	0.3	0.2
270	0.9	0.6	0.3	0.2	0.2
315	1.8	1	0.6	0.4	0.2

24a. LNGC (Mothership, laden) – LNGC (Daughtership, ballast) – at anchor

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-0-0-2
Daughtership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter inner aft breasting lines
- **Favourable wave direction(s)** – 315° to 15°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

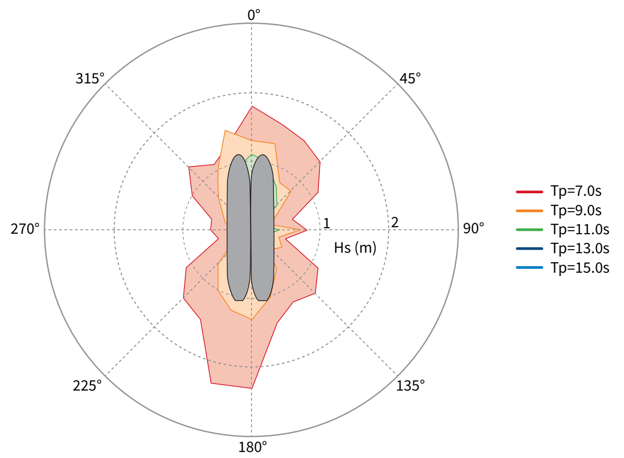
- Mooring lines from the LNGC mothership rarely exceed the WLL.

Mooring thresholds

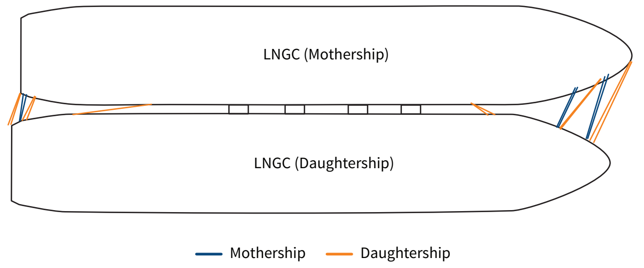
Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	1.8	1.6	1	1	0.7
45	1.5	1.1	0.7	0.5	0.2
90	0.9	0.6	0.4	0.1	0.2
135	1.8	1	0.5	0.3	0.2
180	2.6	1.5	0.9	0.6	0.7
225	1.4	0.9	0.6	0.3	0.2
270	0.6	0.4	0.2	0.1	0.1
315	1.6	0.8	0.6	0.3	0.2

24b. LNGC (Mothership, laden) – LNGC (Daughtership, ballast) – underway

Polar Plot



Mooring Configuration



Ship	Line type	SDMBL	Tails	WLL	Mooring arrangement
Mothership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-0-0-2
Daughtership	HMPE	135t	PP/PE Mix (11m)	67.5t (50%SDMBL)	4-2-2-4

Summary

- **Most likely line failures** – Daughter aft spring lines and daughter inner aft breasting lines
- **Favourable wave direction(s)** – 330° to 45°, 165° to 210°
- **Wave direction(s) to avoid** – 90° ± 30°, 270° ± 30°
- **Impact of wave period** – Low thresholds at periods greater than 9s

Notes

- Mooring lines from the LNGC mothership rarely exceed the WLL.

Mooring thresholds

Angle of waves (° rel. to bow) acting on the vessels	Wave period (Tp, s)				
	7s	9s	11s	13s	15s
	Maximum wave height (Hs, m)				
0	2.1	1.4	0.6	0.7	0.8
45	1.5	0.9	0.4	0.3	0.2
90	0.8	0.6	0.4	0.2	0.2
135	1.7	0.8	0.4	0.2	0.1
180	3	1.5	0.9	0.7	0.5
225	1.5	0.7	0.3	0.2	0.1
270	0.8	0.4	0.2	0.2	0.2
315	2.1	0.7	0.5	0.3	0.2

Appendix A: Mooring configurations used for the STS study

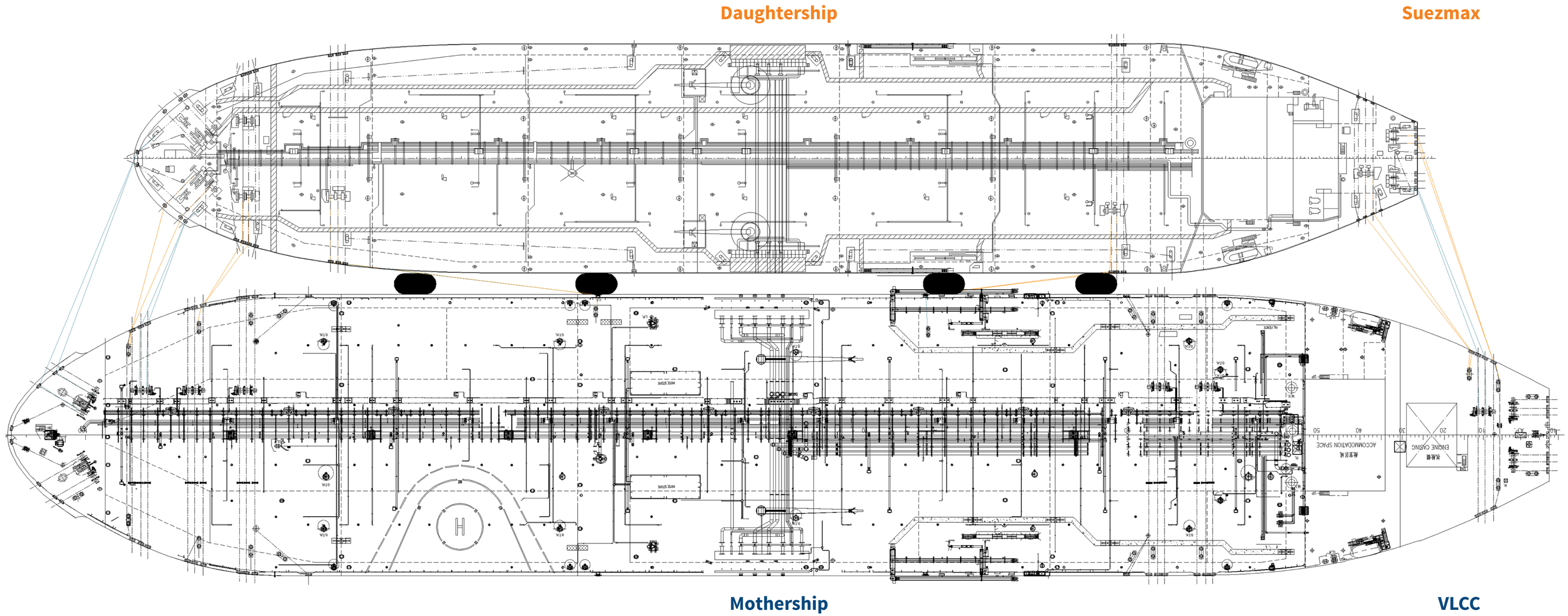


Figure A1: *VLCC and Suezmax mooring arrangement*

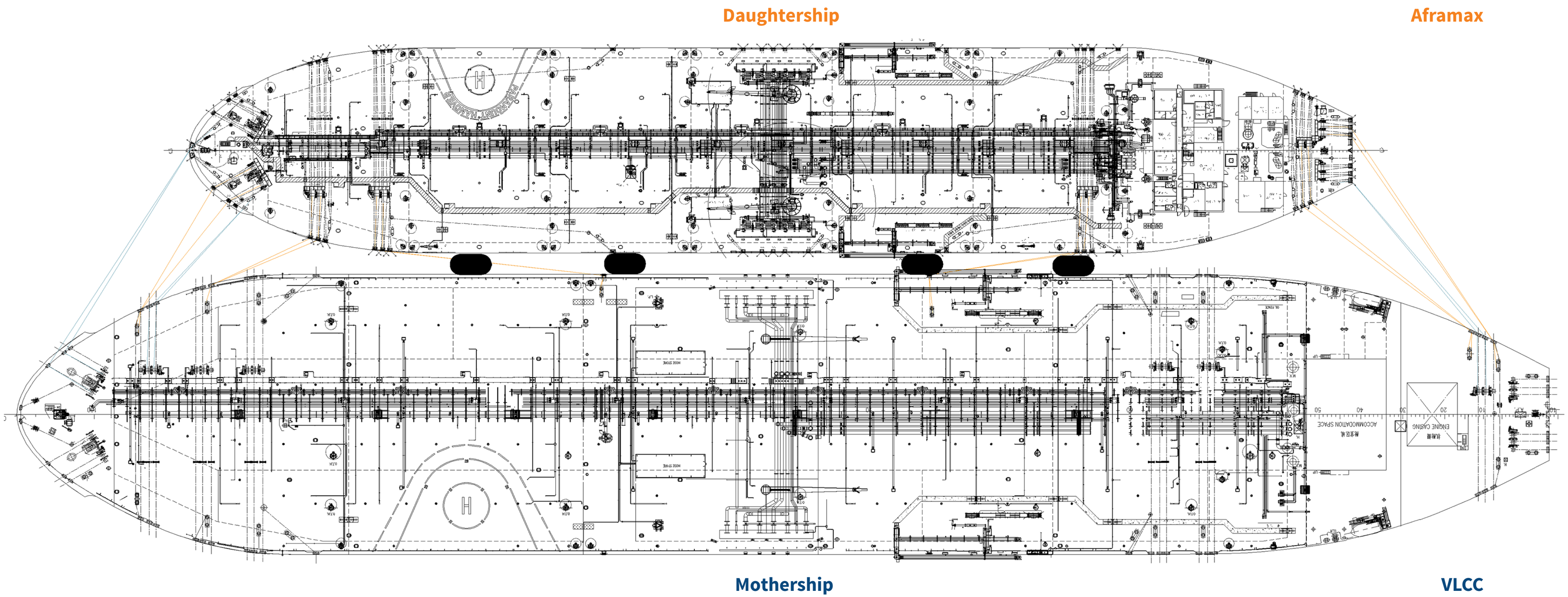


Figure A2: *VLCC and Aframax mooring arrangement*

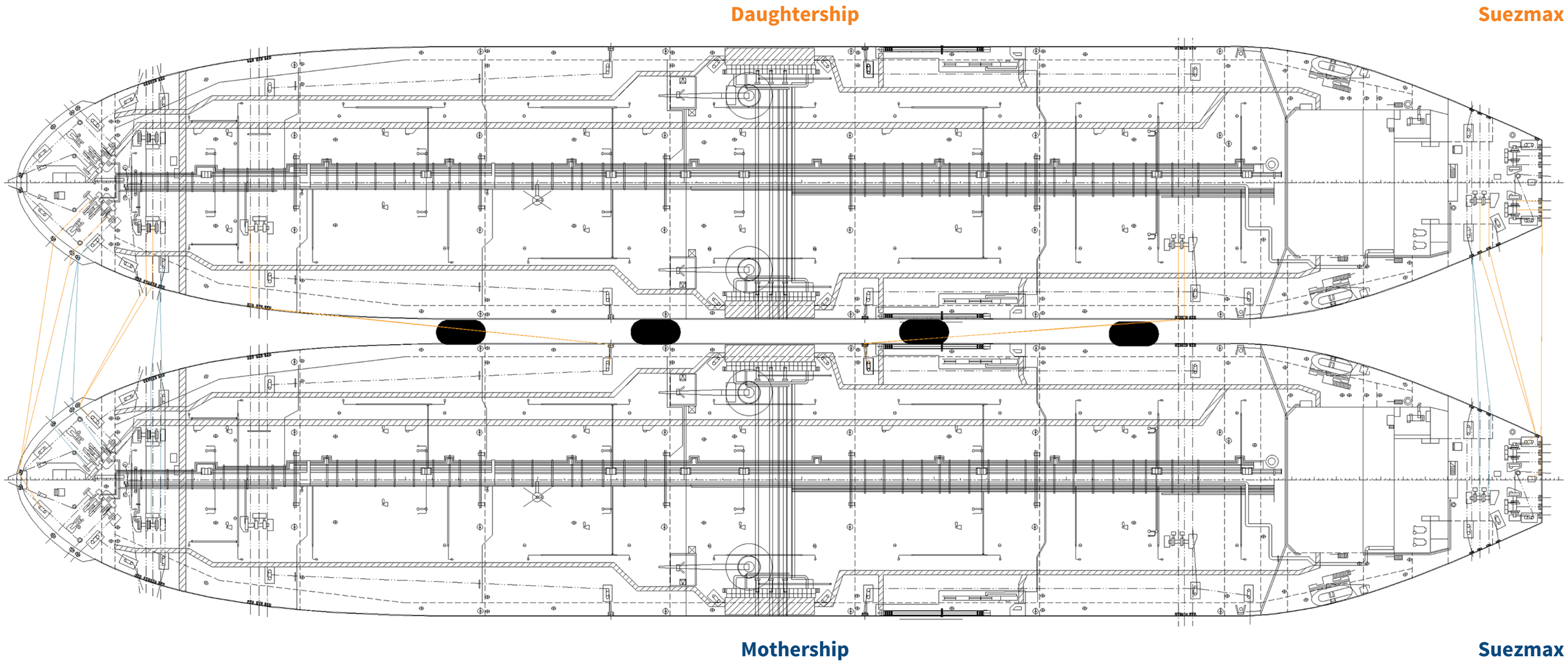


Figure A3: *Suezmax and Suezmax mooring arrangement*

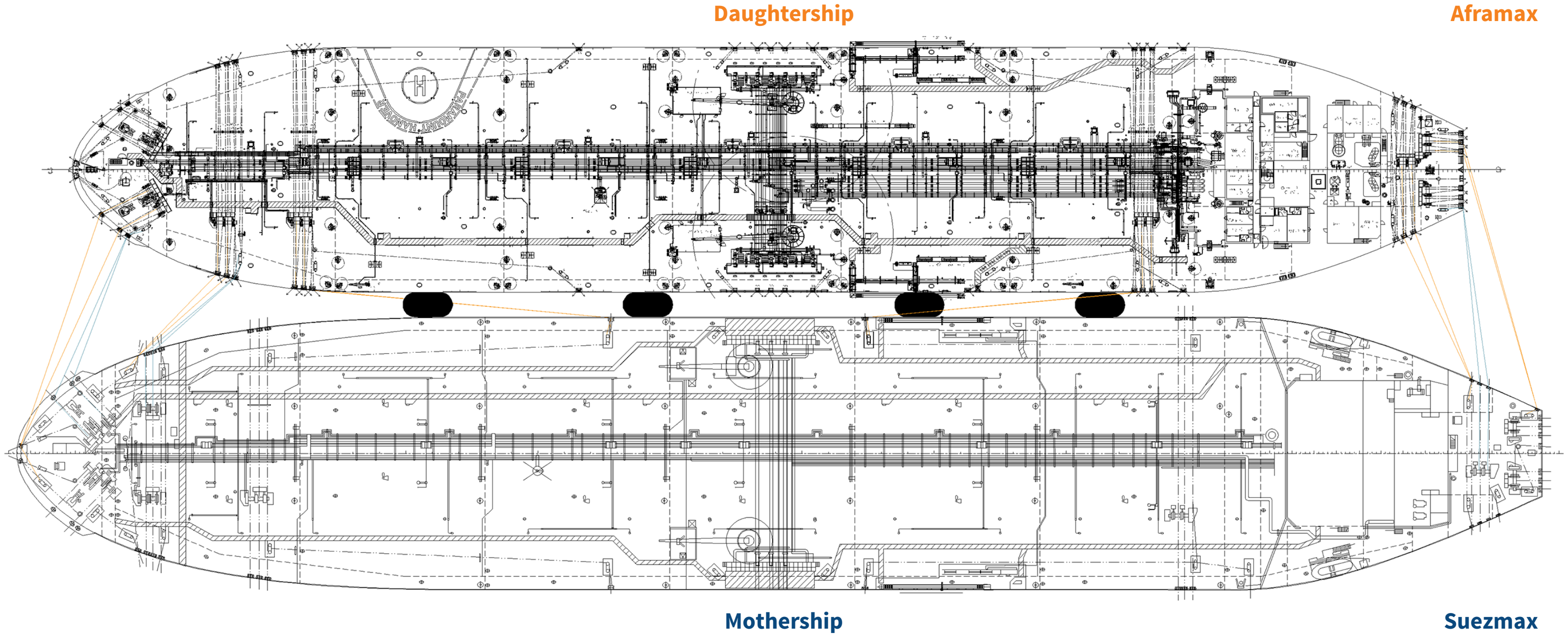


Figure A4: *Suezmax and Aframax mooring arrangement*

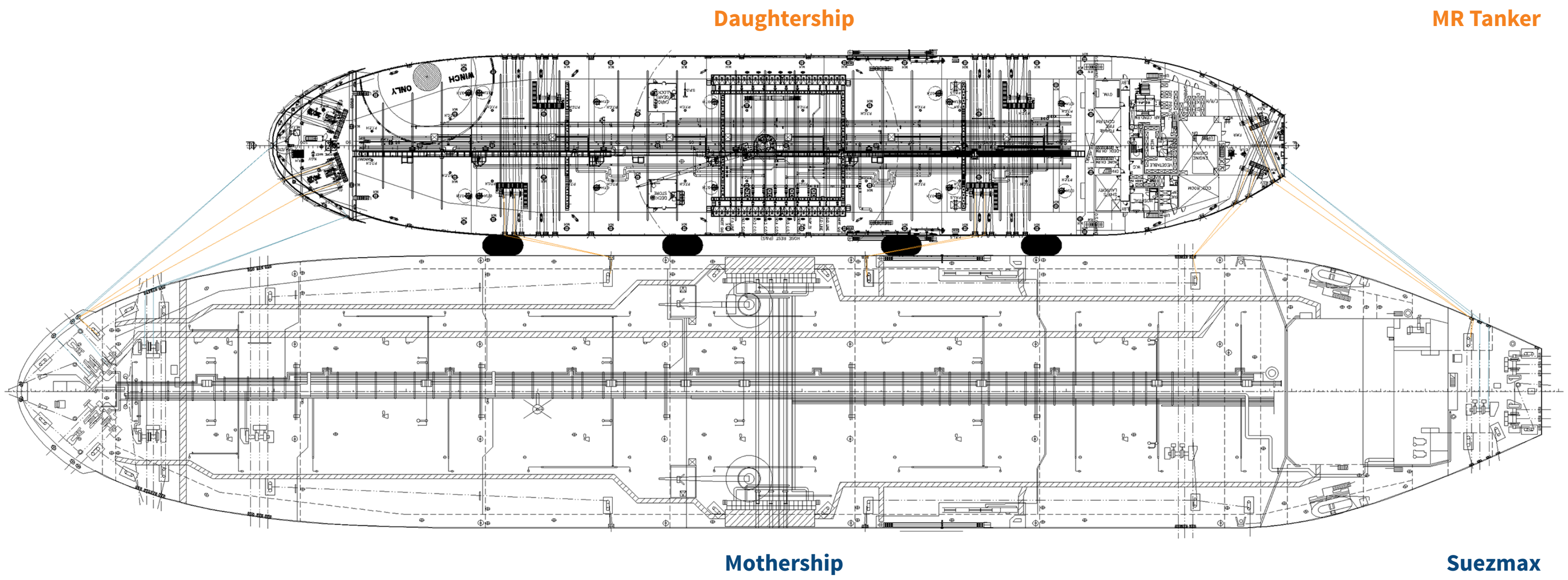


Figure A5: *Suezmax and MR tanker mooring arrangement*

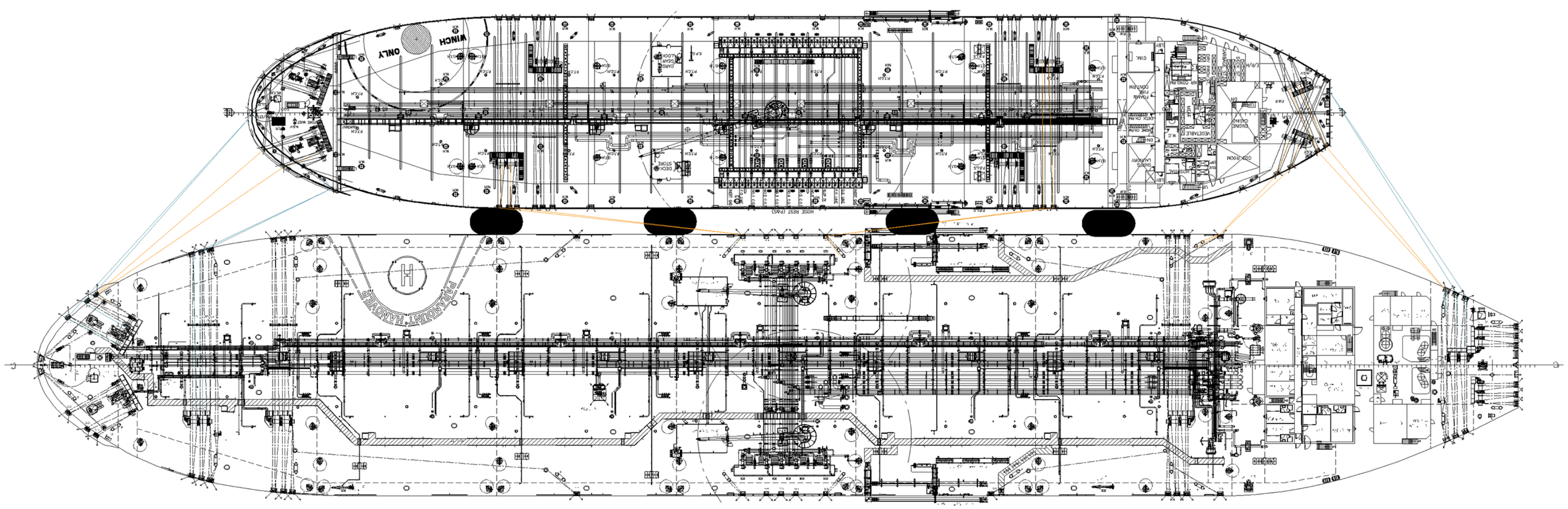


Figure A6: *Aframax and MR tanker mooring arrangement*

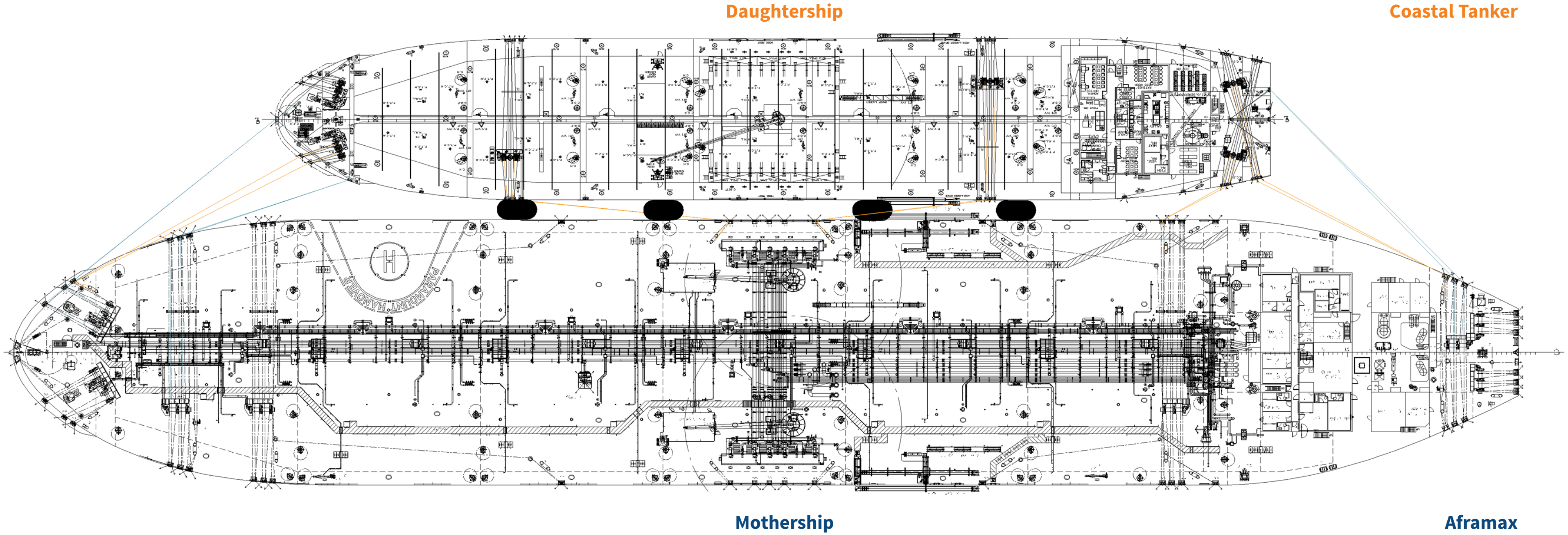


Figure A7: *Aframax and coastal tanker mooring arrangement*

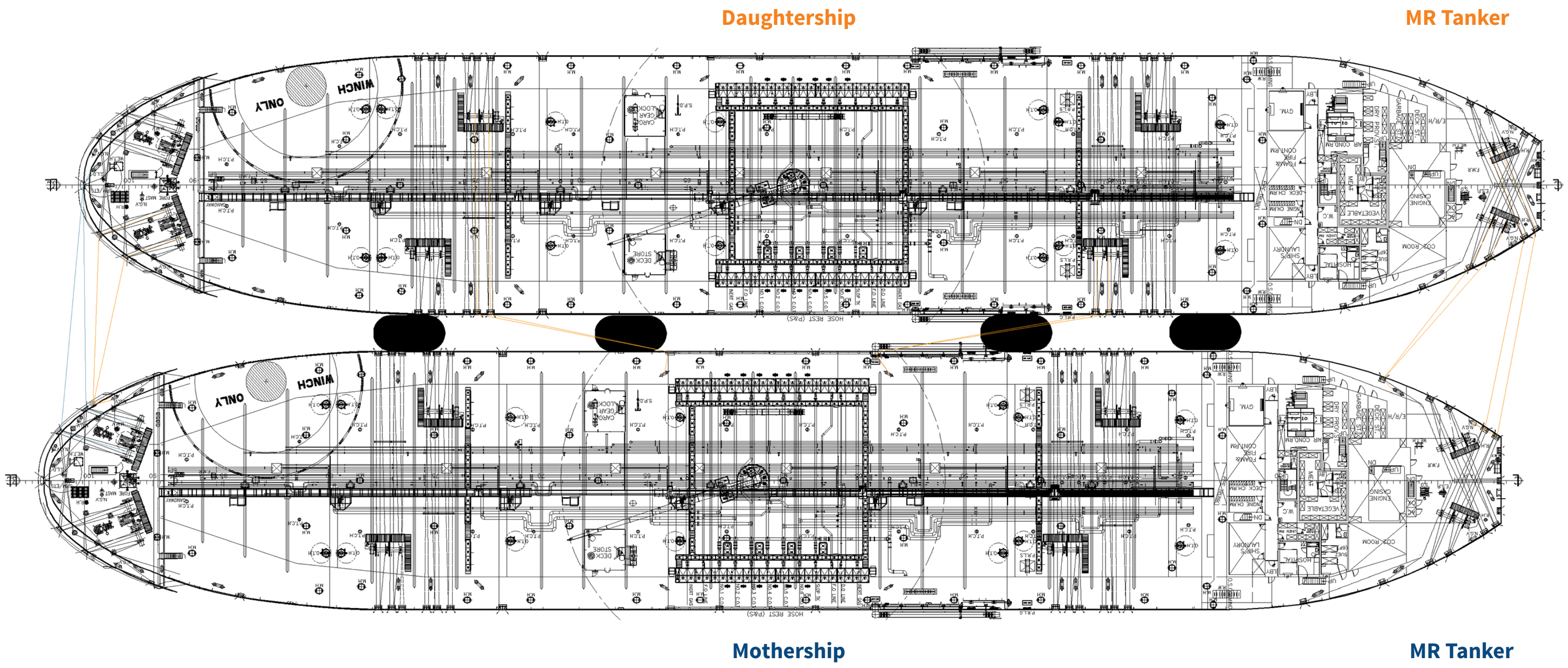


Figure A8: *MR tanker and MR tanker mooring arrangement*

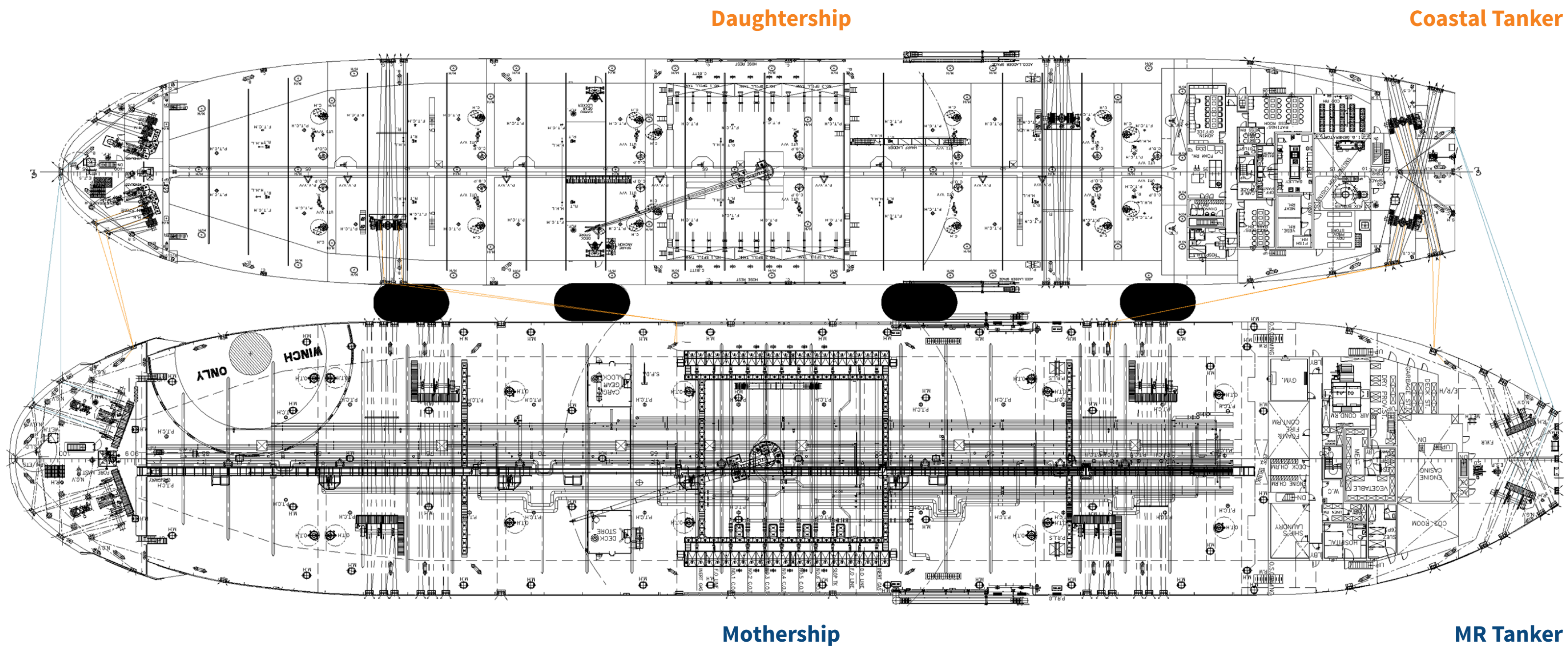


Figure A9: *MR tanker and coastal tanker mooring configuration*

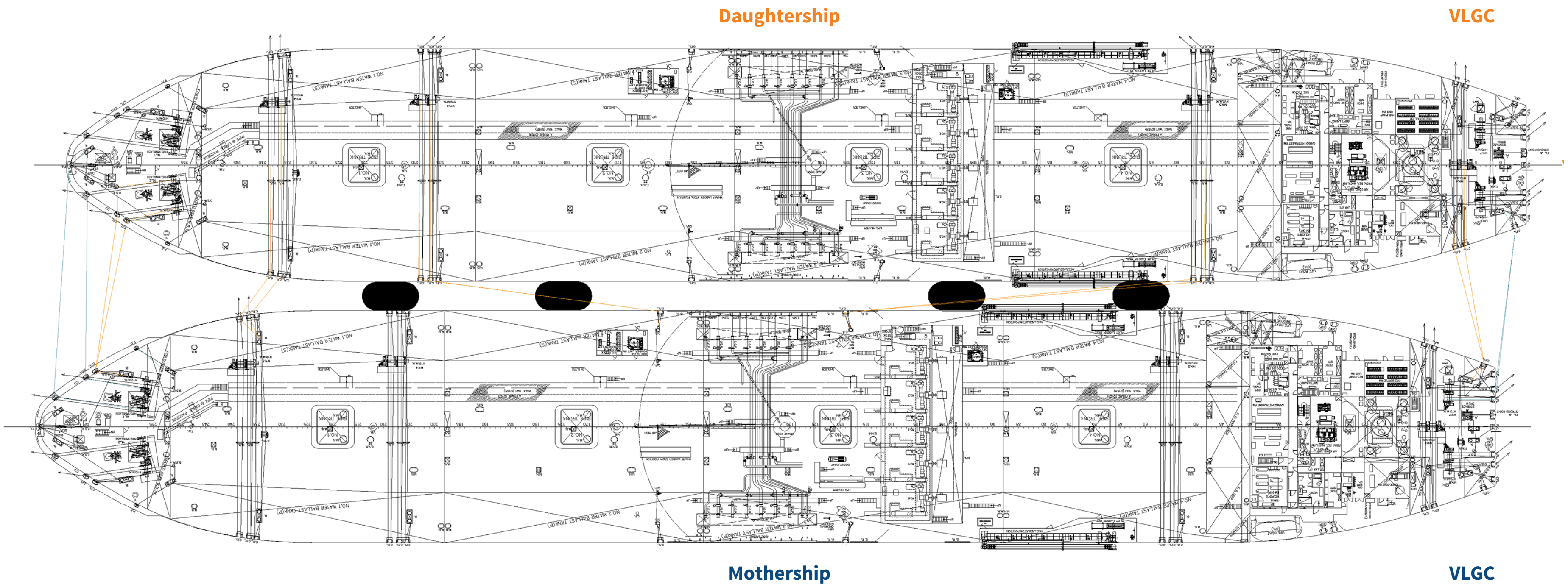


Figure A10: *VLGC and VLGC mooring arrangement*

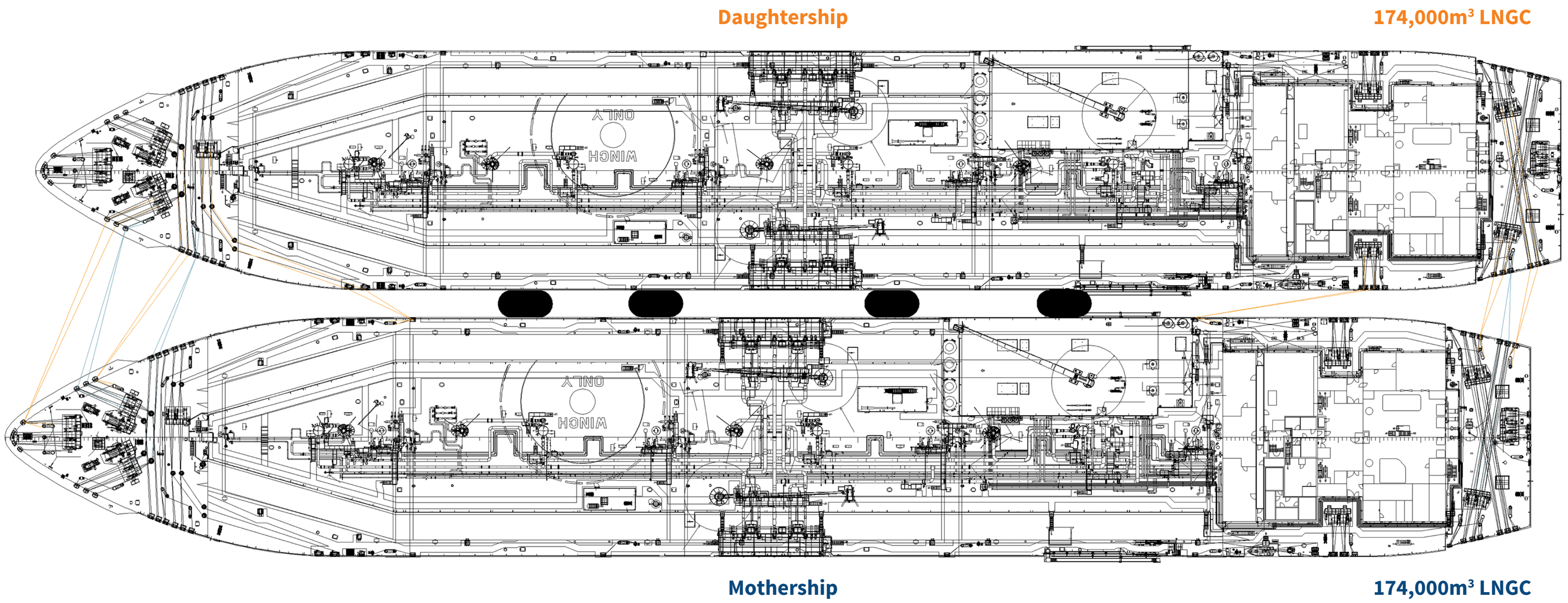


Figure A11: *LNGC and LNGC mooring arrangement*

Our vision

A global marine industry that causes no harm to people or the environment

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