Ship Maneuvering Technical Reference

Panama Canal Gatun Lock

INDEX

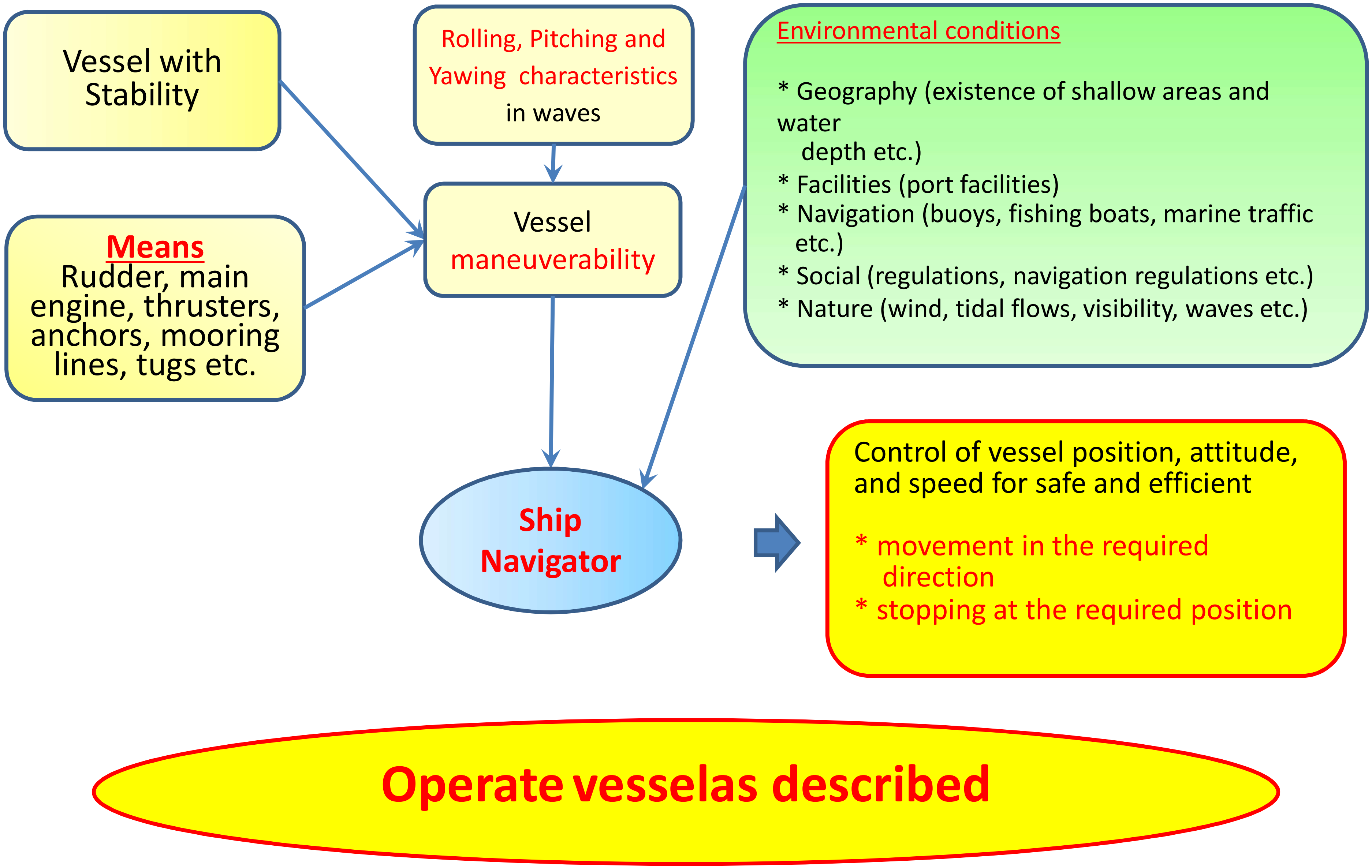
§ 1 What is Vessel Handling?

Vessel handling is based on the basic knowledge that a vessel floats in the water and returns to its original position after a list.

It is maneuvered with the assistance of the rudder, main engine(s) and other auxiliary equipment, using knowledge of the rolling, pitching and yawing characteristics of the vessel in waves.

In handling the vessel it is necessary to consider the effects of environmental conditions while controlling the position of the vessel, its attitude, and its speed, to move the vessel in the designed direction in a safe and efficient manner, and to stop at the intended position.

(Theory and Practice of Ship Handling, Kinzo Inoue, Honorary Professor, Kobe University).


Vessel with Stability
Rolling, Pitching and Yawing characteristics in waves
Environmental conditions
* Geography (existence of shallow areas and water depth etc.)
* Facilities (port facilities)
* Navigation (buoys, fishing boats, marine traffic etc.)
* Social (regulations, navigation regulations etc.)
* Nature (wind, tidal flows, visibility, waves etc.)
Means
Rudder, main engine, thrusters, anchors, mooring lines, tugs etc.
Vessel maneuverability
Ship Navigator
Control of vessel position, attitude, and speed for safe and efficient
* movement in the required direction
* stopping at the required position
Operate vesselas described

§ 1.1 Investigation of Environmental Conditions (harbour conditions)

Harbour conditions must be investigated each time a port is entered, not only just the first time.

For liner services, conditions must also be investigated and verified at appropriate intervals as well.

Such investigation requires the collection of as much data as possible and verifying it with the local agent.

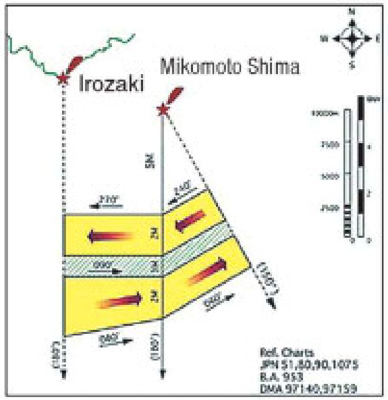
Recently it has been possible to find information out via the Internet.

However, many vessels do not have an Internet connection, and it is therefore desirable that a shore team collects the relevant data and provides it to the vessel.

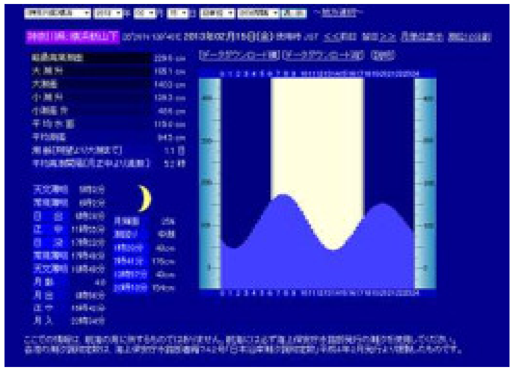
1.1.1 Investigation of Geographical Conditions and Conditions Associated with Harbour Facilities

1.1.2 Investigation of the Navigation Environment (e.g. buoys, fishing vessels, fishing reefs, shipping movements)

1.1.3 Investigation of the Social Environment (local regulations and navigation restrictions)



1.1.4 Investigation of the Natural Environment (e.g. wind, tides, visibility, wave direction)



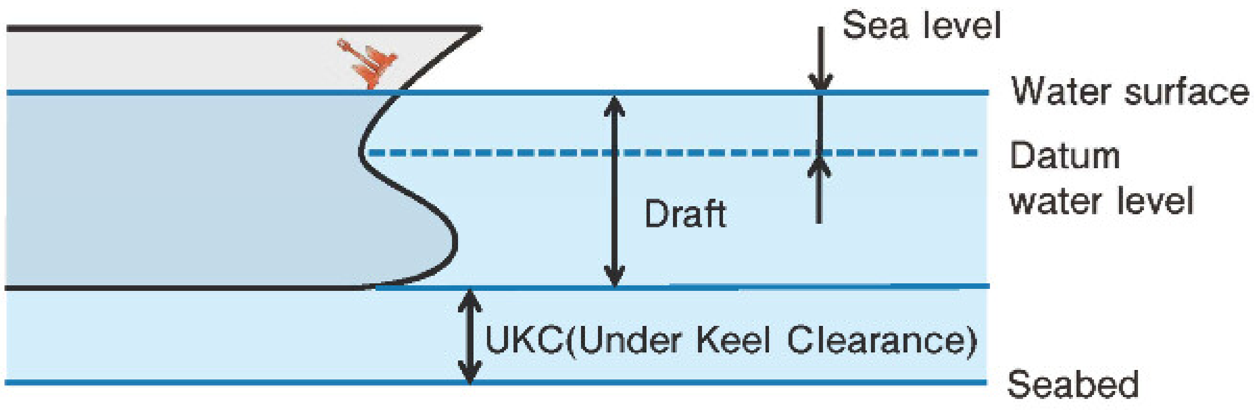
Tidal Information through the Internet

§ 1.2 Example of Investigation of Geographical Conditions

(1) Maximum Permissible Draft and Under Keel Clearance (UKC)

Maximum permissible draft and **Under Keel Clearance (UKC)** are important information in making decisions on safe entry of the vessel to harbour.

As shown below, UKC is a value indicating the margin between the sea bottom and the bottom of the hull. For example, if the water depth and draft are the same (UKC = 0), there is a possibility that the vessel may run aground, and entry to harbour is therefore unsafe.



= Relationship Between Maximum Permissible Draft and UKC =

The relationship between maximum permissible draft and Under Keel Clearance is as shown by the following calculation.

Maximum permissible draft < Channel draft + sea level - UKC

The maximum permissible draft must consider **errors and a safety factor** together with the variables in the calculation. It is also necessary to investigate the maximum permissible draft for each harbour (or each berth) to determine problems.

＝ UKC ＝

Most harbours set guidelines for UKC, and many harbours throughout the world manage UKC together with data on **weather and sea conditions** to ensure a margin for navigation.

In Japan, many harbours employ **fixed UKC** which is a proportion of the draft, or a set value in meters.

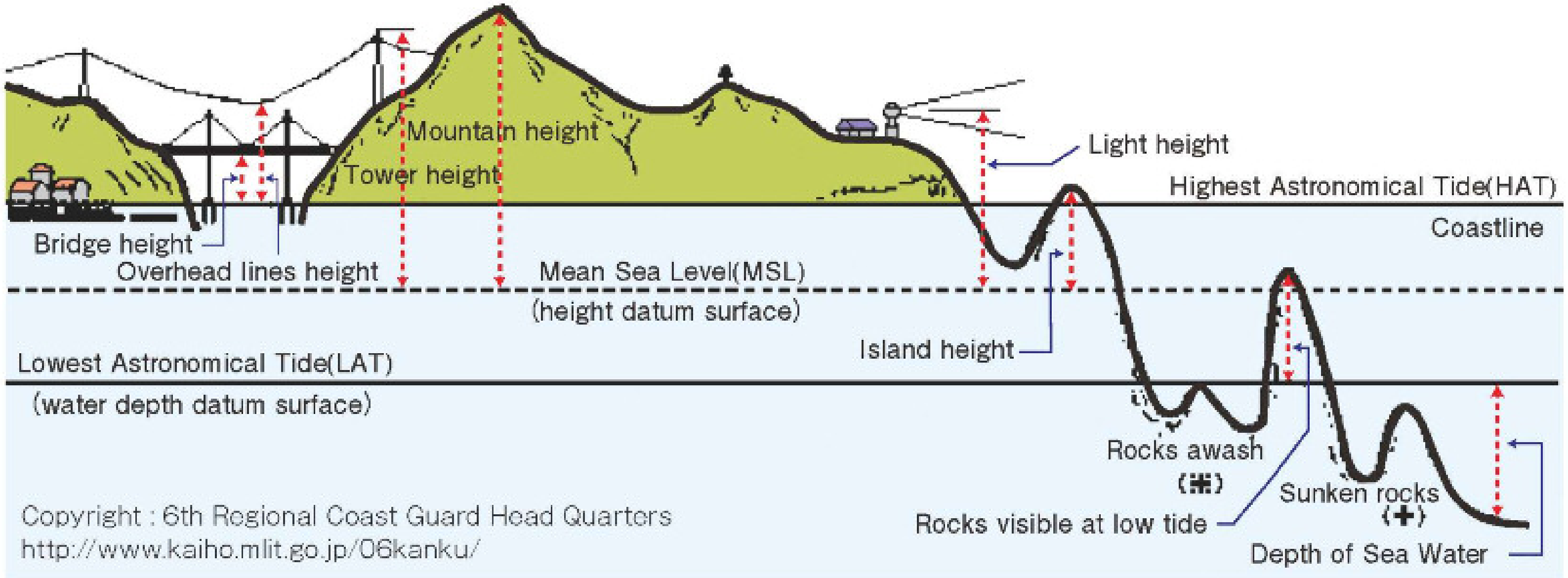
The European Maritime Pilots' Association and the Japanese harbour technical criteria employ the following guidelines.

Navigation within harbours
10%
of maximum draft of vessel

Navigation outside harbours
15%
of maximum draft of vessel

Ocean navigation
20%
of maximum draft of vessel

= Water Depth and Tide level =

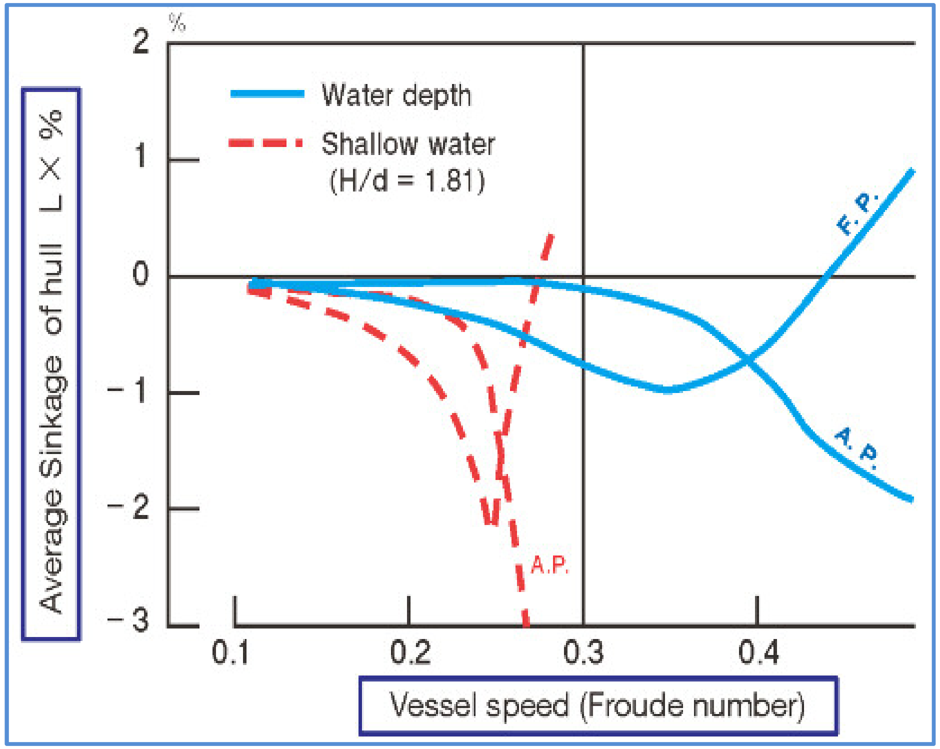


On charts, **the allowable limit for error** in water depth at the international depth datum is as follows.

Water depth to 20m	: Up to 0.3m
Water depth to 100m	: Up to 1.0m
Water depth to 100m or more	: 10% of water depth

The actual water depth is the depth on the chart, plus or minus the tide level. The tide level is obtained from the tide table. Since this tide level is a predicted value which can be calculated from a fixed datum, it must be considered that the actual tide level may differ. If the diurnal inequality and abnormal weather conditions etc. are ignored, **the accuracy of the tide table is within 0.3m** of the actual value.

= Vessel's Sinkage While Underway =



$$\text{Froude number} = V / \sqrt{L \times g}$$

V : Vessel speed (m/sec)

L : Vessel length (m)

g : Acceleration of gravity (m/sec^2)

When a vessel begins moving the distribution of water pressure around it changes, and the hull lowers slightly in the water.

When navigating in harbours, therefore, the amount of this sinkage of the vessel in the water must be added to the draft while at berth.

This amount becomes greater as the water becomes shallower, and as speed increases, as shown in the following graph.

Large vessels are operated at low speed (S/B speed) in harbours, and it is therefore appropriate to estimate the sinkage of the vessel as **0.1 – 0.2% of the length of the vessel.**

It is also necessary to consider sinkage of the vessel due to rolling, pitching and yawing of the vessel with wind and waves, and swell.

= Example Calculation to Decide Whether or Not to Enter Harbour =

LOA = 200m, draft = 12.00m

- Maximum draft of vessel: Draft at departure (or expected draft at arrival) + amount of sinkage of vessel (0.2% of LOA)

  12m + 200m x 0.2%(0.4m) = 12.40m

- Safety factor for water depth on chart: 0.6m (water depth error + tide level error)

- UKC: 10 – 20% of maximum draft (depending on sailing area),
  15% in calculation = 12.40m x 15% = 1.86m

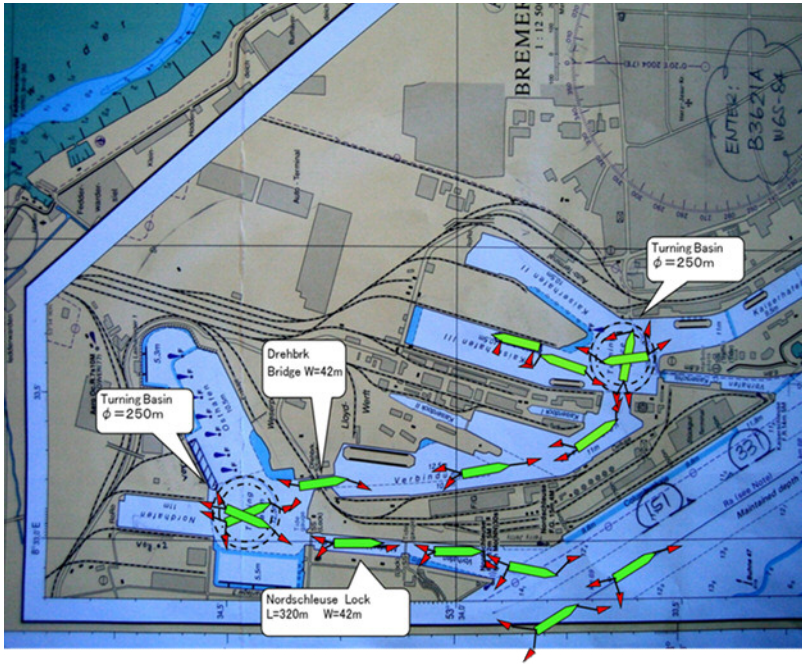
Minimum Required Water depth = 12.40m + 0.60m + 1.86m **= 14.86m**

Do not simply evaluate by applying the UKC ratio to the harbor entry and exit draft, but also include the vessel's sinkage while underway, and the error in depth measurements on charts, to determine on the side of safety.

(2) Turning Basins

When entering and leaving most harbours, the vessel will use its own power, or auxiliary facilities such as tugs or bow thrusters, for turning. The Japanese harbour design criteria guidelines specify as standard **a circle of a diameter three times the length of the vessel** when turning under its own power, and twice the length when turning with the assistance of tugs.

Many harbours do not provide sufficient area as shown in the following diagram. In such cases, it is necessary to investigate the relevant points sufficiently in advance (verifying the number of tugs required, and determining the procedure for turning the vessel., etc.)



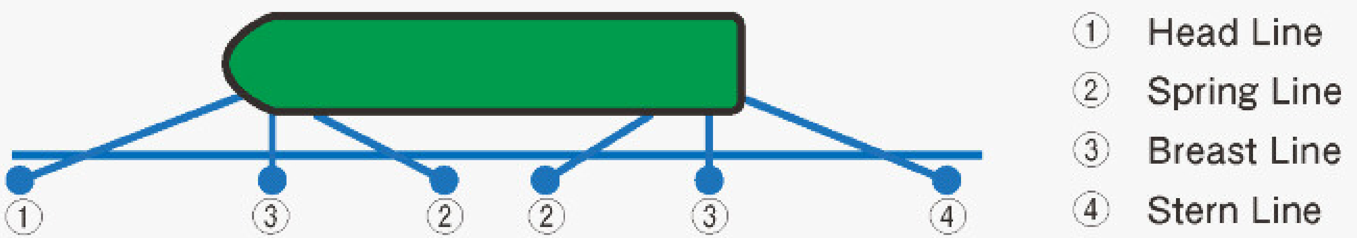
§ 1.3 Example of Investigation of Port Facilities

(1) Maximum Size of Acceptable Vessel at Pier

= Design Criteria for Harbour Facilities =

Technical criteria for harbour facilities according to Japanese ministerial ordinances are as follows. Verify that sufficient pier length is available based on the length of the vessel. The same considerations apply in other countries.

- Water depth = Maximum draft + water depth margin (UKC: 10%)
- Pier length = LOA + 1.0 to 1.7 × breadth (B)
  - Coefficient of 1.0: Angle between mooring lines and pier of 45°
  - Coefficient of 1.7: Angle between mooring lines and pier of 30°



(2) Strength of Mooring Bitts

It is also necessary to verify that the mooring bitts on the pier are able to withstand mooring of the vessel. Strength of mooring bitts in accordance with Japanese harbour technical design standards are as follows.

Tension Applied to Mooring Bitts
(technical criteria for harbour facilities) (units: tonf)

Vessel type (GT)	Curved bitts	Straight bitts
500 - 1,000	15	25
1,000 - 2,000	15	35
2,000 - 3,000	25	35
3,000 - 5,000	25	50
5,000 - 10,000	35 (25)	70
10,000 - 15,000	50 (25)	100
15,000 - 20,000	50 (35)	100
20,000 - 50,000	70 (35)	150
50,000 - 100,000	100 (50)	200

(3) Fenders

Fenders are also an important item of equipment for safe mooring of the vessel. Particularly when a swell enters the harbour, insufficient fenders may result in damage to the pier and to the hull of the vessel.

If damaged fenders are discovered after entering harbour, they should be photographed to guard against claims later on.

(4) Tugs

Tugs are an important means of assistance when maneuvering while entering and leaving harbour. Verifying the number and power of tugs is an important part of the investigation of harbour conditions.

= Power and Number of Tugs =

- Size and loading condition of the vessel
- Conditions of main engines, rudders, and anchors of the vessel
- Weather and sea conditions (wind direction, wind force, direction and speed of tidal flow, waves)
- Method of approaching and leaving the pier (mooring toward the direction of arrival and departure)
- Water depth in the area (consider effects of shallow water)
- Availability of thrusters
- Area available for maneuvering

Guidelines are commonly set for the number of tugs required at each harbour. Use this information for reference.

When no guidelines have been set, use the following equation to determine the necessary power in conjunction with the deadweight of the vessel.

Equation: Total required horsepower = $7.4 \times (DWT)^{0.6}$

Conditions: 10m/sec offshore wind, maximum speed approaching pier 15cm/sec

Deadweight and power requirements

- Up to 50,000DWT : Approximately 3,000HP × 2 tugs
- 50,000 – 100,000DWT : Approximately 3,000HP × 3 tugs
- Over 100,000DWT : Approximately 3,000HP × 3 - 4 tugs
- VLCCs : Approximately 3,000HP × 5 - 6 tugs

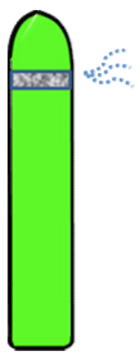
Tugs have approximately 100HP/tonne, however this varies with the propilsion device used.

It is possible to reduce the number of tugs if they are fitted with thrusters.

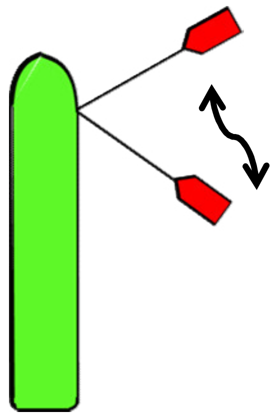
While bow thrusters operate only in the transverse direction, tugs have a significant difference in that they allow towing and pushing at an angle.

It is important to increase the number of tugs used when entering or leaving harbour without hesitation in bad weather and sea conditions.

Bow thruster



Tug (towing and pushing at an angle)



§ 2 Vessel Maneuverability

Approximately 70% of incidents of damage to harbour facilities involve damage to piers and fenders, however most are due to mistakes in operation of the vessel.

Such mistakes in confined harbours with limited area available for maneuvering are due to the following;

(1) Inability to accurately determine the effects of external forces such as wind and tides.

(2) Mistakes in speed control and turning of the vessel while using engines and tugs.

The ship navigator gradually reduces speed in accordance with the distance remaining, and is required to adjust speed and turn the vessel while considering its type, size, loading condition, inertia, maneuverability, and the effects of external forces.

§ 2.1 Effects of External Forces (wind)

=Transverse Movement and Turning Under Wind Pressure While Underway=

① Straight ahead if no external forces are acting in windless conditions.

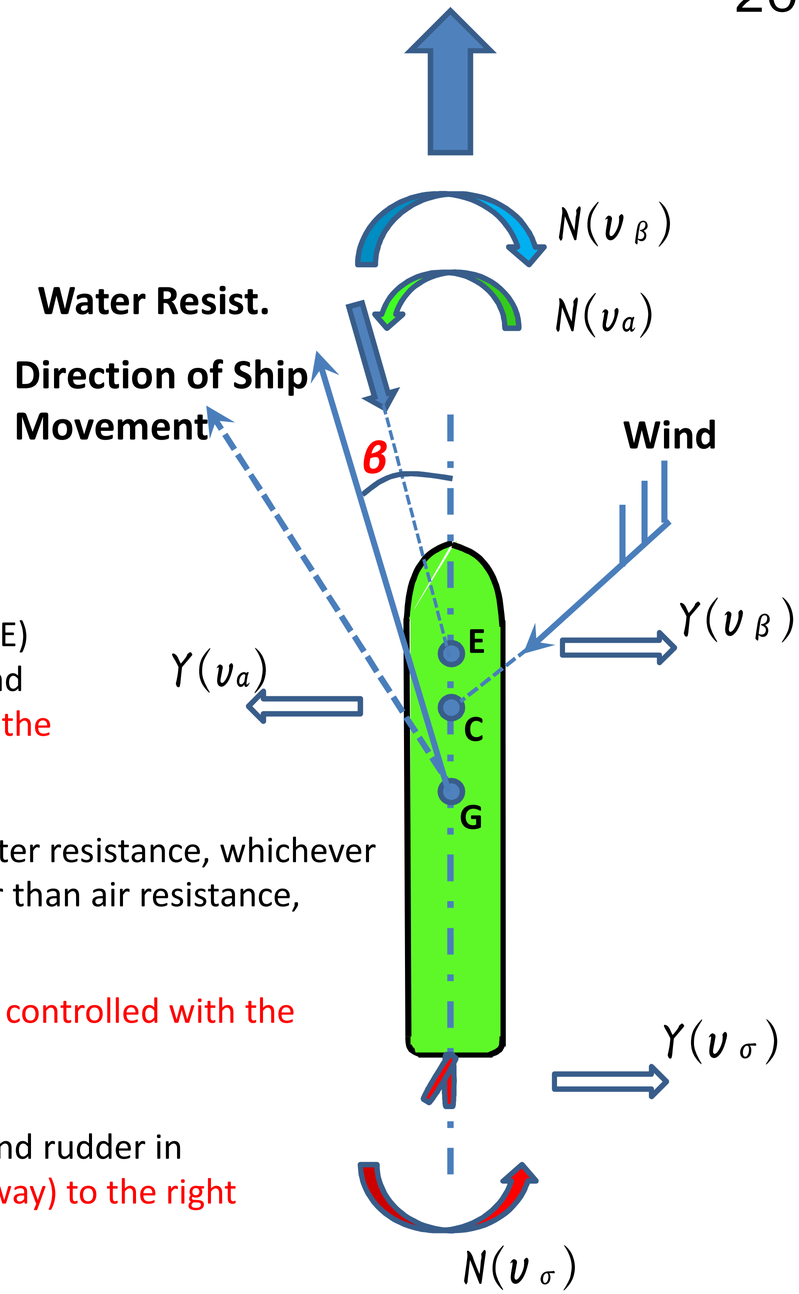
② When the wind is at 45° to starboard, the vessel is pressed to leeward. The point at which the wind acts (C) is ahead of the vessel's center of gravity (G), and a turning moment (*N (Vα)*) acts to turn the vessel in the leeward direction.

③ When the vessel begins drifting (diagonally) leeward, water resistance is generated on the leeside of the bow. The point (E) at which this force acts is ahead of the point at which the wind pressure acts (C), and a turning moment *(N (Vβ))* acts to turn the vessel in the windward direction.

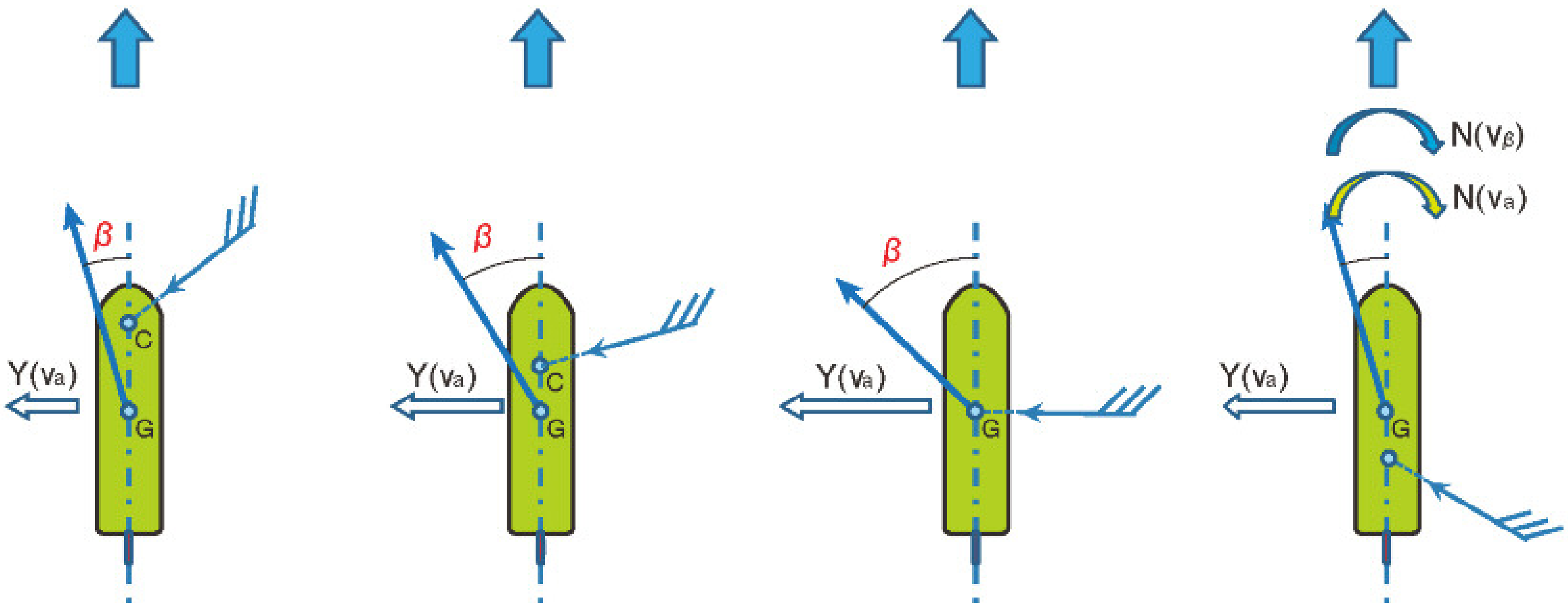
④ The vessel turns under the turning moment of the wind or water resistance, whichever is the greater. Since water resistance is normally much greater than air resistance, ***the vessel begins to turn windward. (N (Vβ) > N (Vα))***

⑤ The rudder acts against the turning moment, i.e. the vessel is controlled with the moment *N (Vσ)* generated by the rudder angle (σ).

⑥ Finally, with turning moment of the wind, water resistance, and rudder in equilibrium, the vessel maintains a course at the angle *β* (leeway) to the right ahead, and proceeds with drifting leeward.

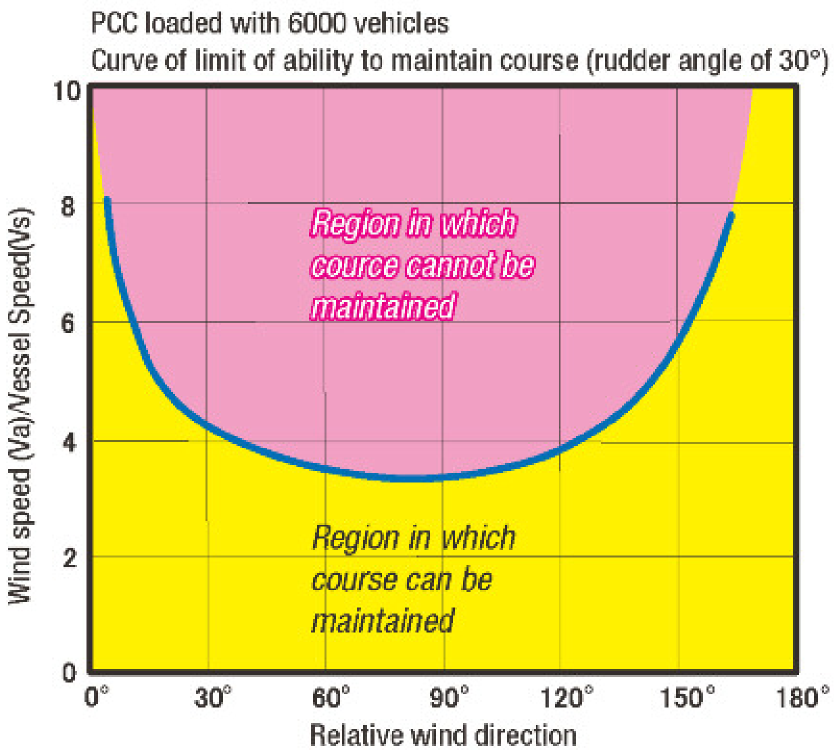


The point (C) at which the wind acts approaches the vessel's center of gravity (G) the closer the relative wind is to the transverse axis of the vessel. At 90° (abeam) it acts almost entirely on the vessel's center of gravity. As a result, the turning moment *N (Vα)* acting in the leeward direction is reduced (turn), and the force *Y (Vα)* acting on the vessel in the leeward direction increases (drift), and the diagonal angle increases, increasing the turning moment *N (Vβ)* due to water resistance.



Furthermore, when the relative wind moves from the transverse to the rearward direction, the point (C) at which the wind acts moves from the vessel's of gravity towards the stern, the turning moment *N (Vα)* rounds up the bow, and acts in the same direction as the water resistance.

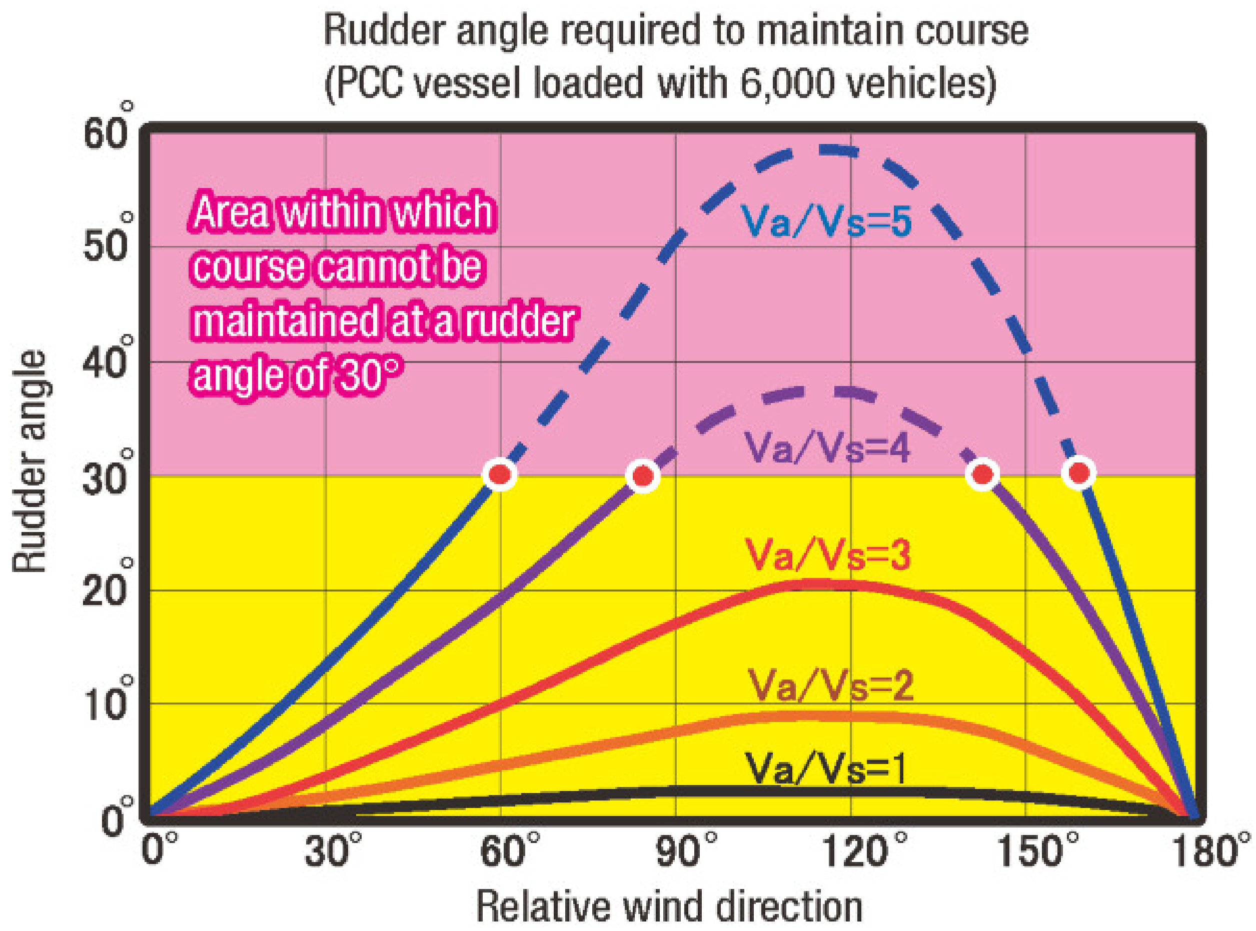
The course can be maintained if the moment derived from the wind and water resistance can be controlled with the rudder. If such control is not possible, an increase in the turning moment due to water resistance increases, **and the course can no longer be maintained.**



This graph shows the ratio of wind speed (Va) to speed of the vessel (Vs) on the vertical axis, and the relative wind angle on the horizontal axis, and indicates the regions in which the course can and cannot be maintained with a rudder angle of 30° . If the ratio of wind speed to vessel speed exceeds 3.7, a region occurs in which the course cannot be maintained due to the relative wind angle.

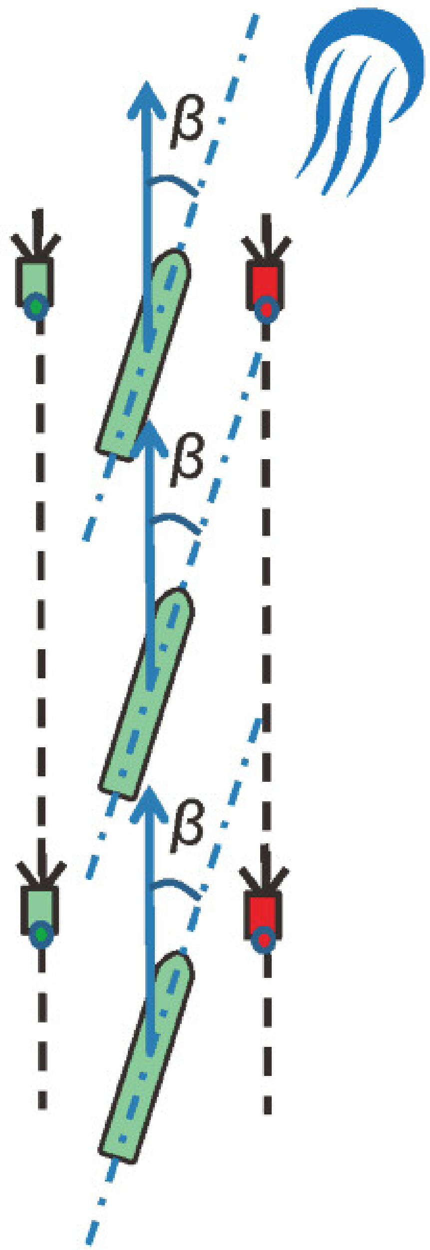
At vessel speeds of 6 – 8 knots (3.1 – 4.1m/sec) inside the harbour, a wind speed of 11 – 15m/sec results in a ratio of wind speed to vessel speed of 3.7, and the course may not be able to be maintained in these conditions depending on the direction of the relative wind.

In the following graph, rudder angle is shown on the vertical axis, and the regions in which the course can and cannot be maintained for each ratio of wind speed to vessel speed. When the ratio of wind speed to vessel speed (Va/Vs) reaches 4, depending on the angle of the relative wind, a region in which the course cannot be maintained occurs, despite a rudder angle of 30° .

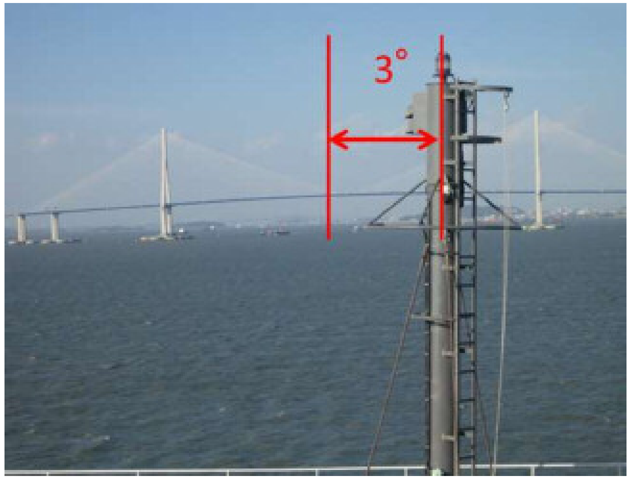


It is important to maneuver the vessel while considering the rounding up angle leeway *(β)* when navigating in a channel without the assistance of tugs under wind pressure.

In such cases, wind direction and speed, and vessel speed, must be considered, and an investigation conducted to determine **whether or not maneuvering is possible in the region in which the course can be maintained.**

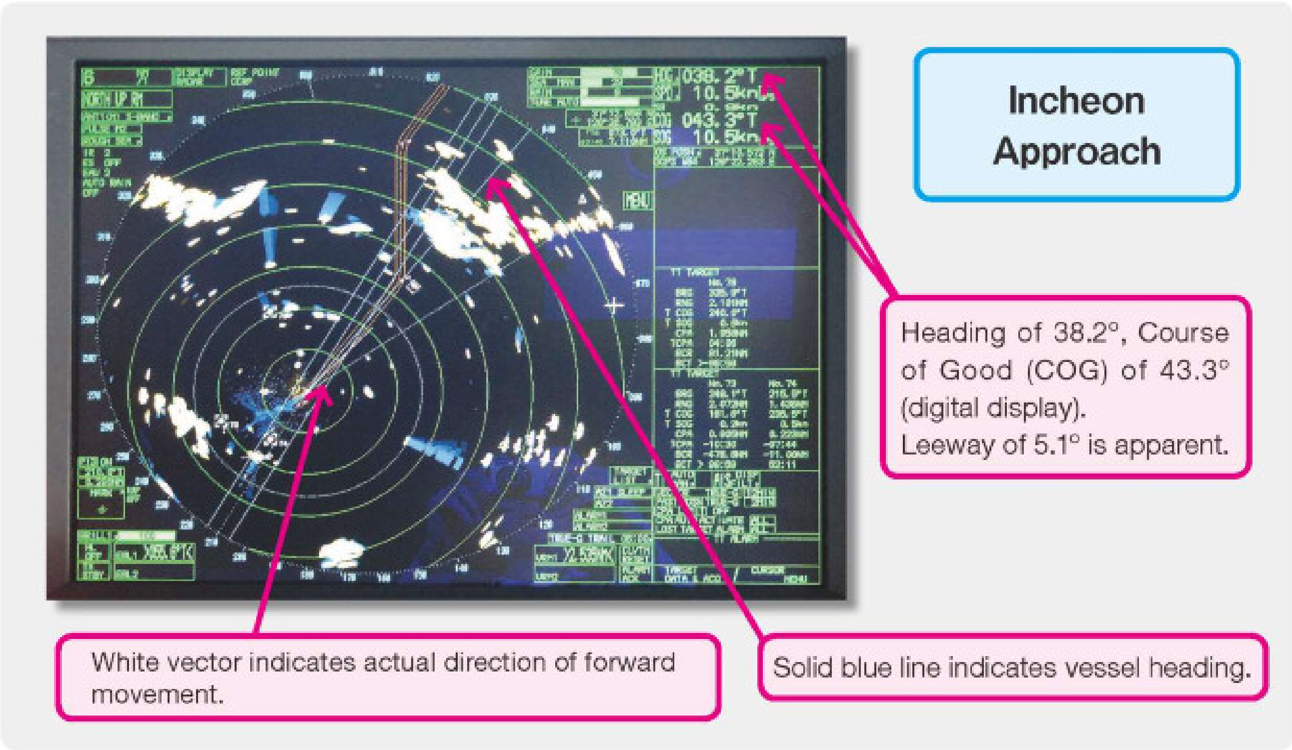


The maximum allowable wind speed for entering and leaving the harbour is very often set, however hull shape etc. should be considered together with the criteria established for the harbour in question.



Leeway of 3° to starboard to ensure passage under center of bridge. (Incheon Port)

Modern radar with advanced technology displays generally incorporates GPS information. If this function is used skillfully the leeway angle and direction of drift can be understood in numerical terms. This information is effective in maneuvering the vessel.



§ 2.2 Turning the vessel

(1)Turning the Vessel using 1(one) Tug Boat(Free of External Force)

When turning with one tug pushing at the stern (or bow), the center of the turn is the pivot point (P), rather than the center of gravity (G). Turning the vessel on the spot in a circle of radius 1/2L (L being the vessel length) is therefore not possible.

The radius of area required for turning can be found with the following equation.

Turning radius (R) = GP + 1/2L

$GP = k^2/GC$

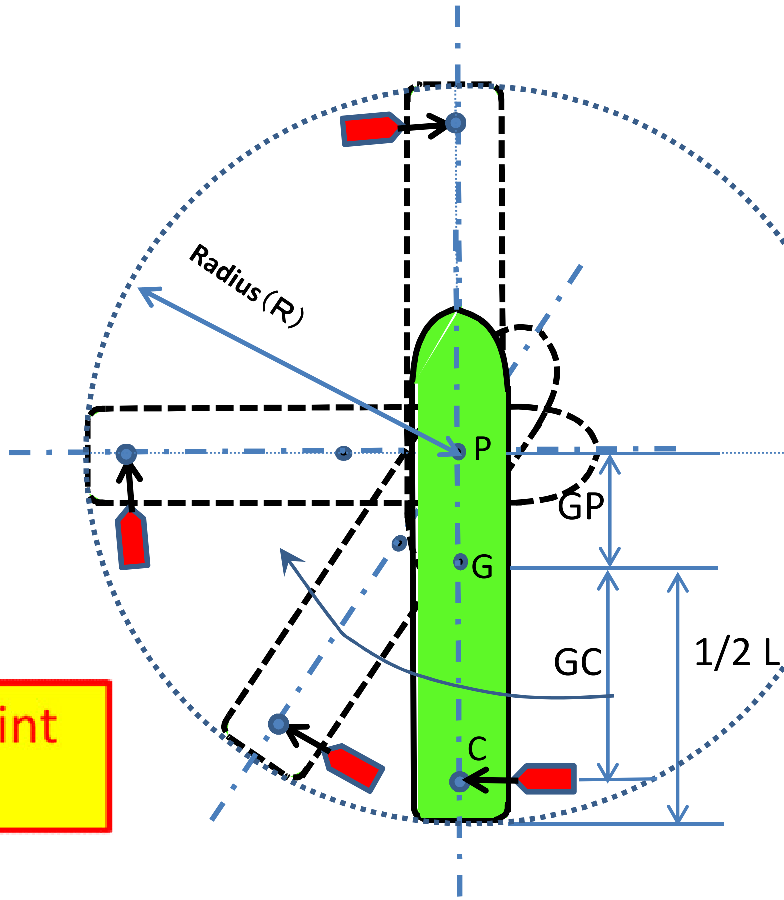
k: Turning radius of moment of inertia around vertical axis through center of gravity (G)

≒ 0.35L

P: Pivot point, center of rotation when turning vessel

G: Center of gravity

C: Point at which tug acts on vessel

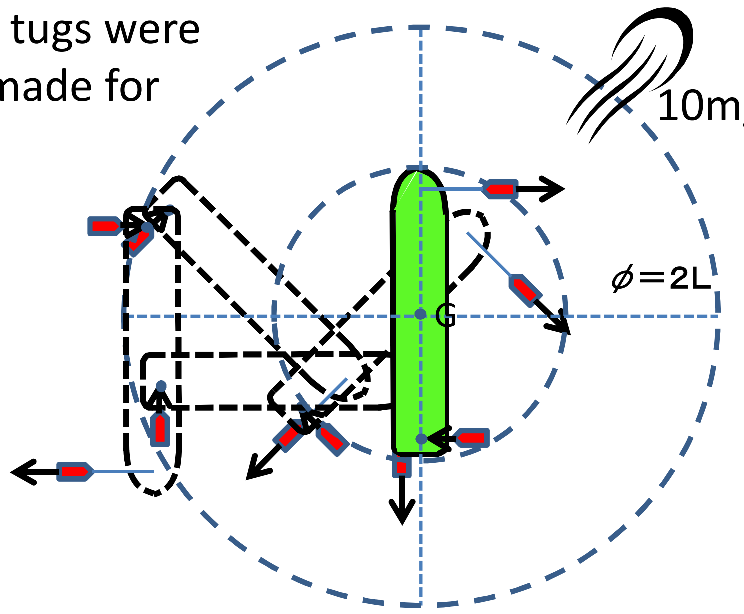


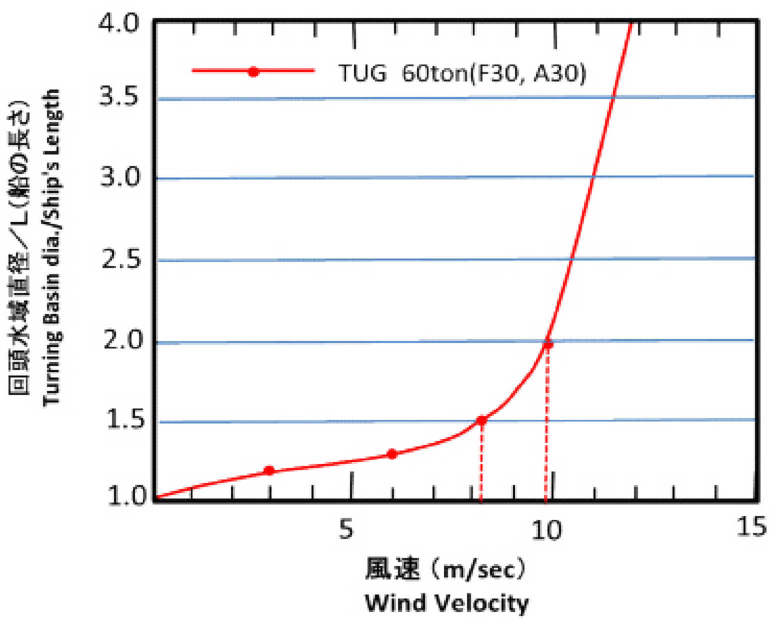
Understand the turning radius at each point at which the tug acts.

(2) Turning within a circle of diameter 1L using 2 tugs under Wind Effect external Force

A simulation was run of turning a container vessel of 246m in length subject to winds of 10m/sec at 45° to starboard at the beginning of the turn, using two tugs. The tugs were used solely for turning, and no adjustment was made for drift.

While dependent on hull shape and vessel type, a wind speed of 10m/sec is the limit, even if a 2L circle is available for turning this vessel. A larger area is required for turning at wind speeds in excess of 10m/sec.





Loa(m)		246.27
Lpp(m)		230.00
Bredth(m)		32.24
Depth(m)		21.20
Draft(m)		11.50
Disp.(KT)		53,875
Trim(m)		0.00
G position		−5.5
Wind	Front(㎡)	850
Project.	Side(㎡)	6,090

Simulator (Container)

§ 2.3 Speed Control

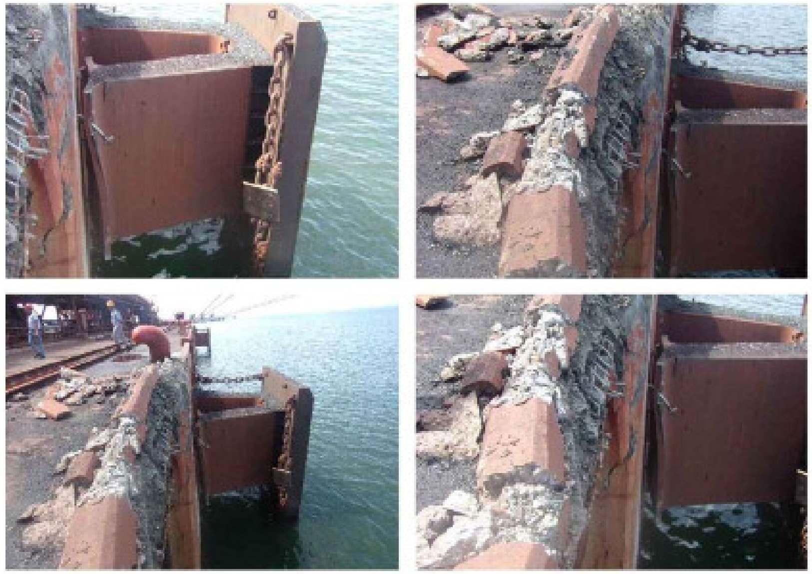
Incidents of failing to control a ship's speed while entering harbour, with the vessel consequently colliding with the pier causing major damage to the pier, shore cranes, and the vessel itself, never cease.

Ships differ from motor vehicles in that they are **not fitted with a braking mechanism** to reduce speed. Control of speed must therefore rely on controlling the speed of the main engine, reversing the main engine, or the assistance of a tug.

In order to ensure that the vessel stops precisely at the scheduled point, the ship navigator is required to consider its type, size, loading condition, inertia, and maneuverability, and the effects of external forces etc. when adjusting speed.

These factors are obviously not formally calculated while the vessel is approaching the pier, and lack of communication between the pilot and captain is a cause of incidents, as is insufficient advice from the captain.

Both the captain and pilot are required to have a quantitative, rather than an intuitive exchange of information, based on experience, understanding of the stopping distance and the time required to stop.



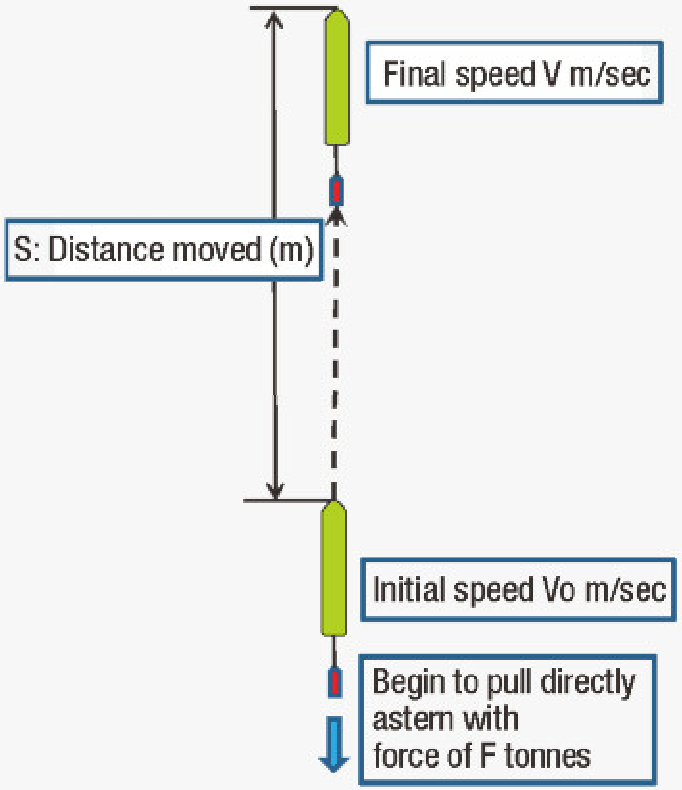
(1) Basics of Stopping Distance, Vessel Weight, and Acceleration

Hull shape and resistance must be considered when determining details such as stopping distance and the time required to stop, however approximate values can be derived with the following equation based on the principle of conservation of energy.

$$F = \frac{1}{2} \times \frac{W}{g \cdot S} \times (V^2 - V_0^2) = \alpha \times \frac{W}{g}$$

$$S = \frac{1}{2} \times (V + V_0) \times t = \frac{1}{2} \times \frac{W}{g \cdot F} \times (V^2 - V_0^2)$$

$$\alpha = \frac{(V - V_0)}{t} = \frac{g}{W} \times F$$



W : Apparent displacement (displacement + additional mass*) (tons)
Vo : Initial speed (m/sec)
V : Final speed (m/sec)
F : Forces acting (tug thrust and reverse engine thrust) (tons)
T : Elapsed time (seconds)
S : Forward movement (m)
A : Acceleration applied to vessel (m/sec^2)

* Additional mass

When accelerating and decelerating the vessel, the vessel itself moves, while at the same time, the water in the vicinity also moves as a result of this movement.

Power is therefore not only required to move the vessel, but to move a part of the water in the vicinity.

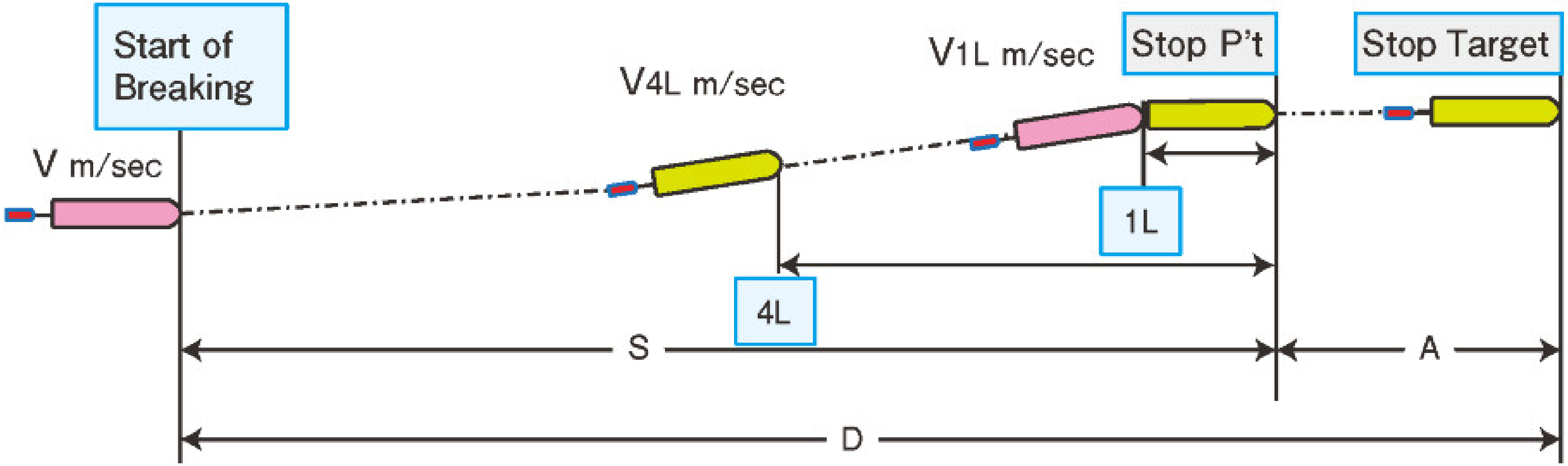
This is, in effect, the same as moving a vessel of increased mass. This increased mass is referred to as ‘additional mass’.

(2) Speed Reduction Plan for Vessel Approaching Pier in Direction of Arrival (example)

When approaching parallel to the pier in the direction of arrival it is necessary to determine in advance when to stop the engine, and to understand guidelines for evaluating whether or not speed through the primary waypoints is excessive while approaching the berth.

For example, while moving forward at dead slow ahead as shown in the following image, when stopping the engine with simultaneous braking applied by a stern tug, and with a distance to the stop position of 4L and 1L, it is necessary to determine beforehand the speed at which it is possible to stop at the scheduled point.

While incorporating a safety margin in the distance to the berth noted above, it is also needed to reduce speed by increasing the braking effect of the tug or by reversing the engine if the approach to the berth is at a greater speed.

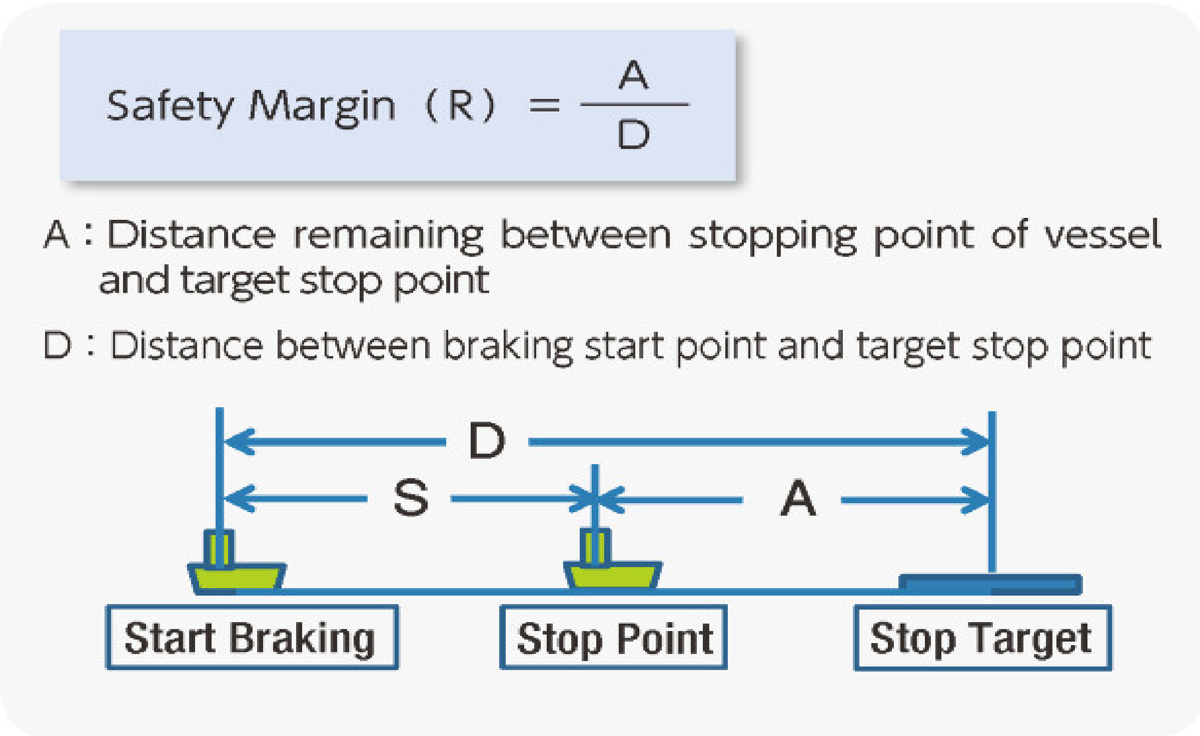


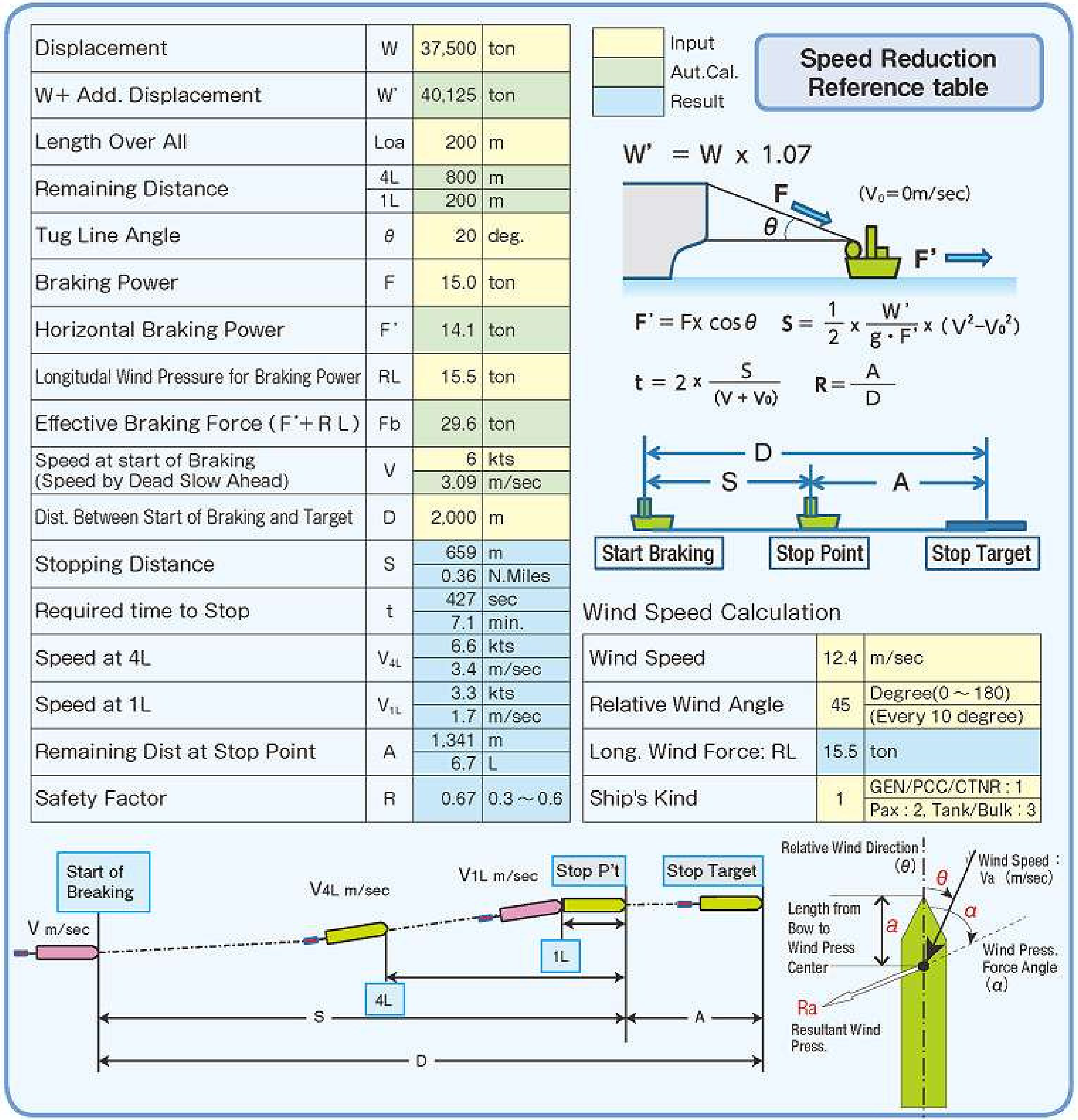
In practice, rather than maneuvering the vessel to stop at the stop point, braking is applied while controlling speed so that the vessel stops at the target at the front of the berth without losing control.

Verify displacement of vessel, power at engine astern, and power of tug, verify the distance and time required to stop during maneuvering for approach, and maneuver the vessel with a safety margin.

(3) Reference Values for Reducing Speed

The spreadsheet below presents the equation in (4)-1 in a format ready for data entry. Enter the necessary data to calculate approximate values for stopping distance and stopping time, and safety margin. It is important to recognize reference values for the stopping distance of the vessel using simple spreadsheets. Early braking by tug or reversing the engine is necessary if the safety margin is 0.3 or less.





Speed Reduction Reference table

Input / Aut.Cal. / Result

Displacement	W	37,500	ton
W+ Add. Displacement	W'	40,125	ton
Length Over All	Loa	200	m
Remaining Distance	4L	800	m
	1L	200	m
Tug Line Angle	θ	20	deg.
Braking Power	F	15.0	ton
Horizontal Braking Power	F'	14.1	ton
Longitudal Wind Pressure for Braking Power	RL	15.5	ton
Effective Braking Force (F'+RL)	Fb	29.6	ton
Speed at start of Braking (Speed by Dead Slow Ahead)	V	6	kts
		3.09	m/sec
Dist. Between Start of Braking and Target	D	2,000	m
Stopping Distance	S	659	m
		0.36	N.Miles
Required time to Stop	t	427	sec
		7.1	min.
Speed at 4L	V_{4L}	6.6	kts
		3.4	m/sec
Speed at 1L	V_{1L}	3.3	kts
		1.7	m/sec
Remaining Dist at Stop Point	A	1,341	m
		6.7	L
Safety Factor	R	0.67	0.3～0.6

$$W' = W \times 1.07$$

$$F' = F \times \cos\theta \qquad S = \frac{1}{2} \times \frac{W'}{g \cdot F'} \times (V^2 - V_0^2)$$

$$t = 2 \times \frac{S}{(V + V_0)} \qquad R = \frac{A}{D}$$

Wind Speed Calculation

Wind Speed	12.4	m/sec
Relative Wind Angle	45	Degree(0～180) (Every 10 degree)
Long. Wind Force: RL	15.5	ton
Ship's Kind	1	GEN/PCC/CTNR : 1 Pax : 2, Tank/Bulk : 3

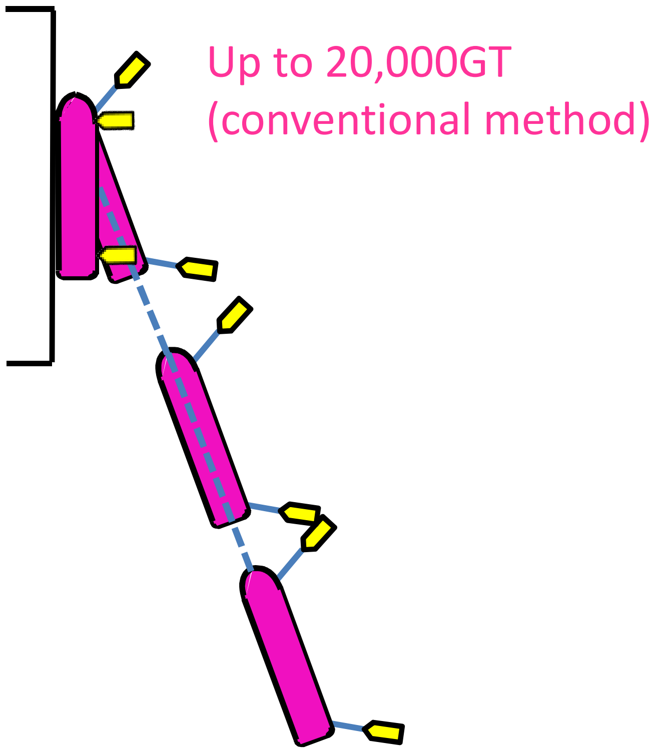
In addition to this spreadsheet, it is also effective to consider the maneuverability of the vessel in preparing speed reduction guidelines in graphic format.

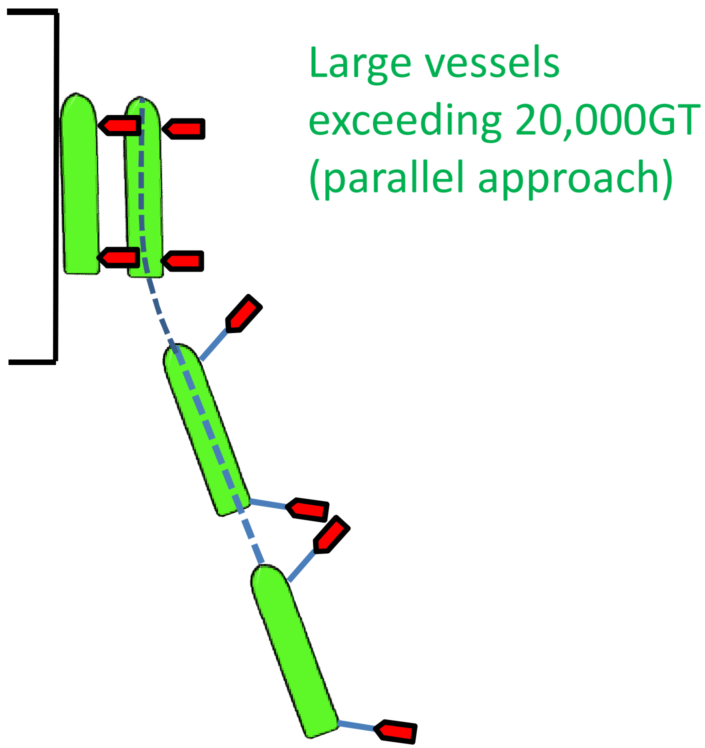
The guidelines should be posted on the bridge, with copies kept in storage. The guidelines can be provided to the pilot as reference material for information exchange upon boarding to assist in communication.

(4) Control of Berthing Velocity When Approaching the Pier

Conventionally, the vessel approaches at an angle on a face line of the pier, the bow line is taken, and the stern is pushed to the pier. This method is still used with vessels of up to 20,000GT.

However larger vessels generally approach and position parallel to the pier at a distance of 1.5 – 2 times the beam, and are then pushed sideways onto the pier by a tug (parallel approach).





= Advantages and disadvantages of the parallel approach =

[Advantages]

- While this depends on the layout of the pier, a mistake in reducing speed does not result in damage to the pier. When the pier is of considerable length, a mistake in speed control simply results in overrunning the scheduled stop position, and does not result in damage to the pier.
- With the conventional method, container ships etc. with large bow flares sometimes damage cranes etc. overhanging the pier. This risk is much reduced with the parallel approach.
- The attitude of the vessel is more easily controlled with the parallel approach, facilitating response to rapid changes in external forces.

[Disadvantages]

- An extra 10 – 20 minutes is required to reach the pier.

(5) Berthing Velocity Control

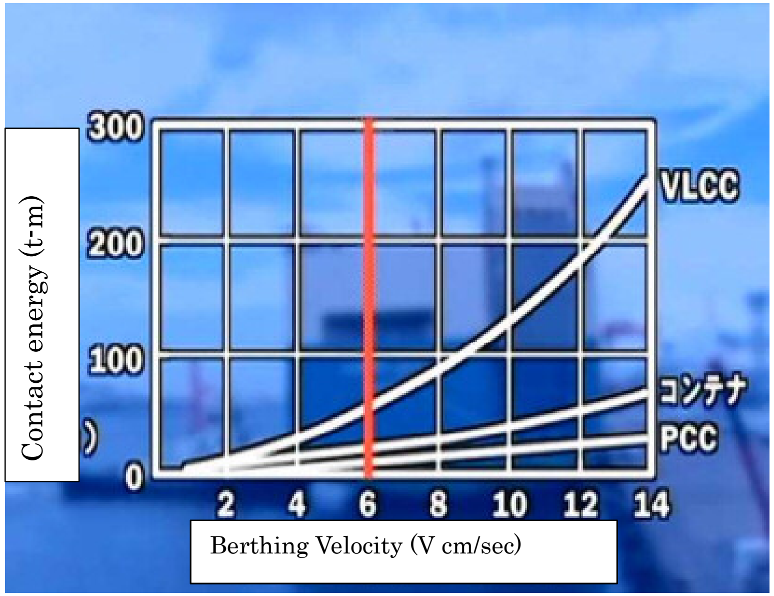
The energy of the vessel when contacting the pier can be calculated with the following equation, and is proportional to the square of the speed of contact.

$$E = \frac{1}{2} \times \frac{W'}{g} \times V^2 \times C$$

E : Contact energy (ton-m)
W’ : W (displacement (tons) × transverse additional mass coefficient (1-0 – 2.0)
G : Acceleration due to gravity (m/sec^2)
V : Berthing Velocity (m/sec)
C : Energy diminution coefficient due to turning etc.

Using an additional mass coefficient of 1.8, and C of 0.5 in the above equation, a container vessel with a displacement of 50,000 tons approaching the pier at a speed of 10cm/sec has a contact energy of approximately 23 ton-m.

This is equivalent to a 1 ton motor vehicle colliding with a wall at 80km/h.



Vessels generally approach at a maximum speed of **10cm/sec**, with large vessels and VLCCs approaching at **5cm/sec.**

These speeds allow absorption of the energy of the vessel when contacting the pier fenders, and prevent damage to the hull and the pier.

§ 2.4 Preventing Damage to Harbour Facilities

- Grasp **External forces**

- Control the **attitude and speed of the vessel** appropriately while maneuvering.

- It is necessary for the captain to plan the procedure for entry and exit in advance.

- **Bridge Resource Management** During Harbour Entry and Exit S/B

  When the pilot boards the vessel, present the pilot card, and explain draft, displacement and other points of special note.

  Officers stationed at the bow and stern report repeatedly on **movement of the tugs.**

- Bridge Resource Management During Arriving and and Departure S/B in Harbour

Consult with the navigator on the day prior to harbour entry for **a briefing on harbour entry and exit procedures.**

When the pilot boards the vessel, present the **pilot card , and explain draft, displacement and other points of special note.**

Obtain information from the pilot on where the **tug is to be taken up**, whether the pier is to be approached on **the ship's port or starboard side**, and the **number of mooring lines** etc. to be used. If there is time available, verify the requirements for maneuvering of the vessel (e.g. turning point).

- Ensure **that the officer on the bridge reports engine speed** (when engines are operated), and that the **helmsman reports rudder status** as appropriate. When the engine is stopped in the final stages of approaching the pier, the officer may begin tidying up the bridge and he / she may neglect to report the berthing velocity of the vessel. It is important that the required information (e.g. ahead/astern speed, berthing velocity) is reported appropriately until an instruction is received from the captain that it is no longer necessary.

- **Officers stationed at the bow and stern report repeatedly on movement of the tugs.**
  In non-English-speaking regions in particular, the pilot and captain of the tug frequently converse in the local language, and information on movement of the tug may not reach the captain of the vessel. It is important that officers stationed at the bow and stern report concisely whether the tugs are pushing or pulling the vessel, and in which direction etc.

- **Mooring lines are set in consultation with the pilot or Master.** Even after the lines are tied on the bitts, they are generally left un-tensioned (with no slack).
  It is important to follow the instructions of the ship navigator when winding in mooring lines to control the attitude of the vessel.

It is always necessary to verify any doubts. This applies not only the captain, but also to the crew. The captain is responsible for creating an atmosphere in which this behavior is encouraged.

§ 3 Dragging Anchor

§ 3.1 The reason why an anchor drags

A ship's anchor drags

The impact of external forces > The holding power of the anchor and cable.

Masters and deck officers should be aware of how various parameters, such as the scope of cable in relation to the depth of water and **the effects of wind, wave and tidal forces on the vessel,** can in turn exert excessive forces on **the anchor and cable system** leading to break-out of the anchor from the ground and dragging.

Empirical or Rule of Thumb Methods for Assessing the Minimum Required Length of Anchor Chain

d: Water depth(m)
L: Minimum Required Length of Anchor Chain(m)

- Japanese publication Theory of Ship Operation

Fine weather : $L = 3d + 90$ m
Rough weather: $L = 4d + 145$ m

- United Kingdom publication Theory of Ship Operation

$$L = 39 \times \sqrt{d} \text{ m}$$

Traditional means of detecting a dragging anchor

① Checking the ship's position, to confirm whether it is placed outside of a turning circle.

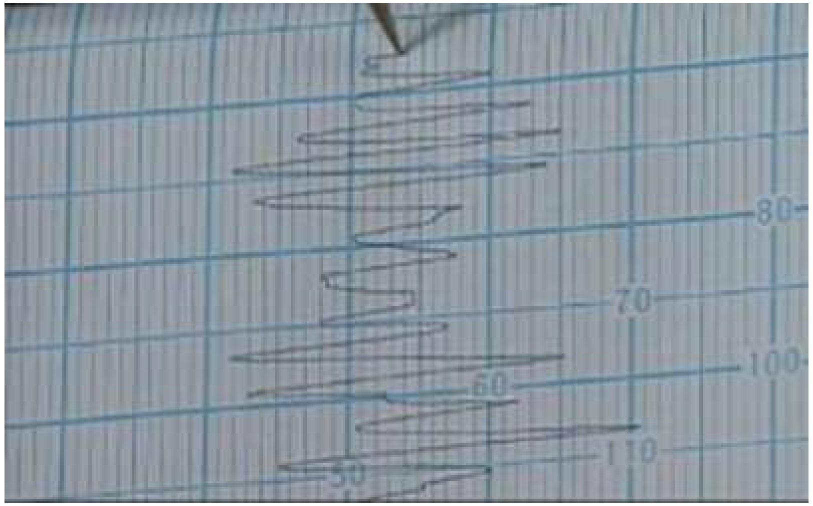
② The bow cannot stand against the wind.

③ The ship's side against the wind hasn't changed.

④ Checking to see there is no slacking of chains just before a ship's side against the wind turns.

⑤ Checking whether there are extraordinary vibrations through the anchor chains.

⑥ Checking the course recorder in case it does not indicate a "figure-of-eight" motion locus.



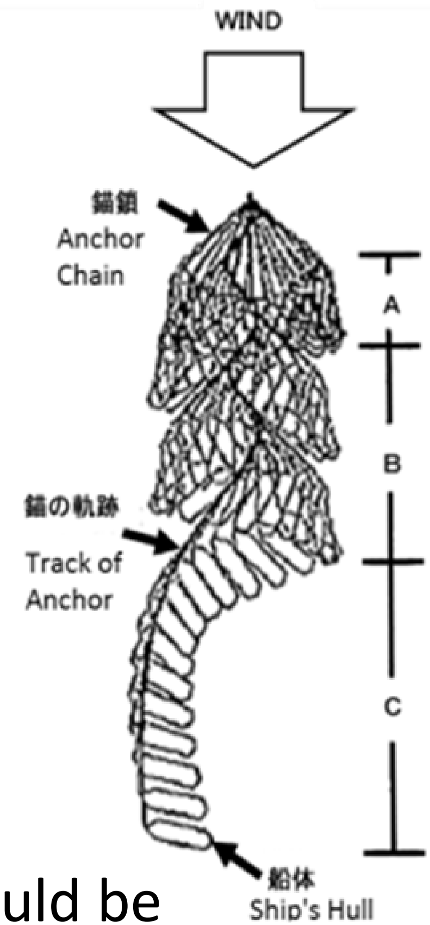
The above methods remain well-tried but, of course, only confirm that the anchor is dragging. They do not predict when dragging is likely to commence.

According to one current study, an analysis of anchor dragging has shown that there are two associated phenomena, or stages, to the process which indicate that dragging may be about to occur before it is detected by the more usual methods outlined above.

・The First Stage : Dragging Anchor with Yaw and Sway

Yaw and sway motion of a vessel when lying to an anchor is sometimes referred to as "horsing". Area [A] in the diagram shows the situation where the ship is lying at anchor and yawing in a "figure-of-eight" motion.

It has been found that as wind pressure force begins to exceed the anchor's holding power, the ship yaws and is pressed to leeward, as shown by area [B] in the diagram.



It is suggested that, during this period, it should be relatively **<u>easy to control the maneuverability of a ship in such a state and to weigh the anchor.</u>**

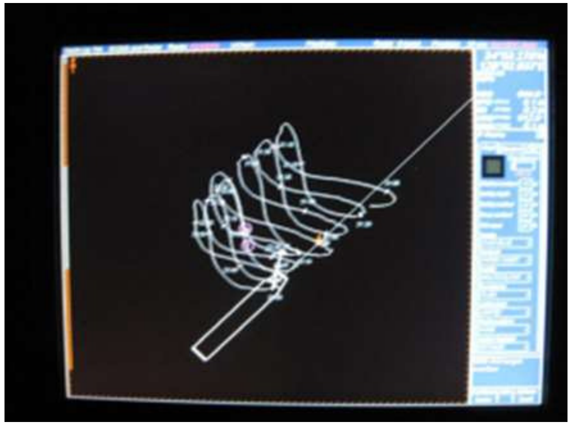
- **The Second Stage : Anchor Dragging caused by Wind Pressure**

Where wind pressure force gradually becomes stronger, one side of the ship turns against the wind and is then pressed and moves to leeward at a certain speed, as shown in area [C] in the diagram.

It is suggested that, during this stage, it is difficult to weigh anchor and, even if possible, this takes a considerable amount of time. If weighing the anchor cannot be accomplished, the ship loses its maneuverability.

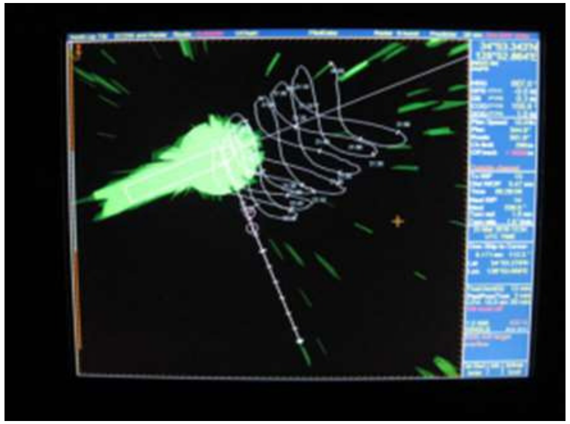
Dragging anchor may not be detected by the Traditional Methods until the vessel has entered the second stage described above, by which time it may be too late to avoid a dangerous situation from developing.

Early prediction and detection of the dragging of an anchor is also possible using the ship's wake indicators in the **ECDIS, RADAR and GPS displays.** Therefore, counter measures for the safety are required to be taken as earlier as possible.



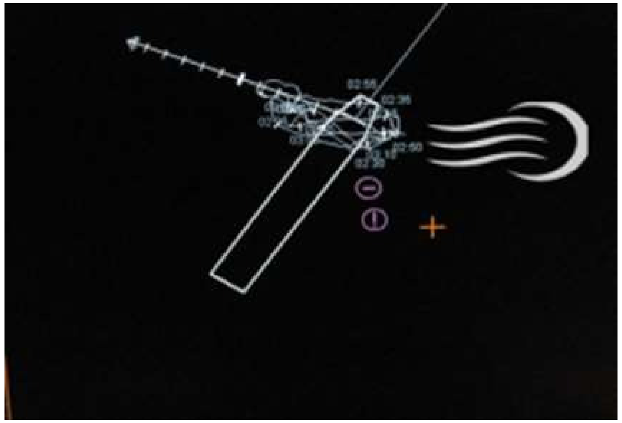
ECDIS

AREA「B」



RADAR

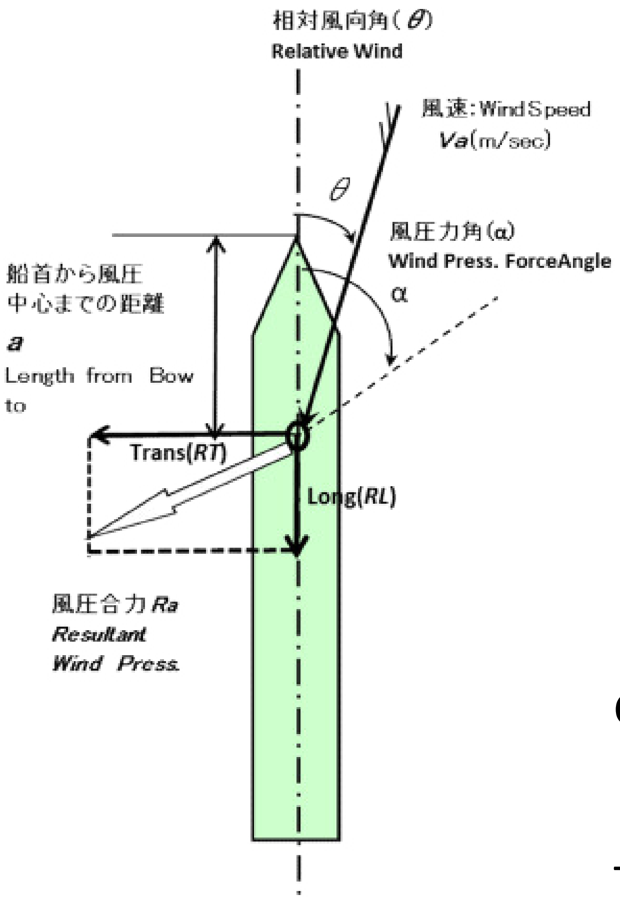
AREA「B」



GPS

AREA「C」

§ 3.2 Wind Pressure Force Calculation



Hughes Formula

$$Ra = \frac{1}{2} \times \rho \times C_{Ra} \times Va^2 \times (A \cos^2\theta + B \sin^2\theta)/1000 \text{ (ton)}$$

- θ : Wind direction from bow [degree](Relative Wind Direction)
- Va : Headwind speed [m/sec]
- ρ : Air density [0.125kg・sec^2 /m^4]
- A : Ship's projected area from bow above waterline [m^2]
- B : Ship's projected area from side above waterline [m^2]
- a : Length from bow to wind pressure center [m] (Point of Action)
- Ra : Resultant wind pressure force[kg] → divided by 1,000 to be "ton" (Total Wind Force)
- α : Wind pressure force angle[degree](Angle of Action)
- C_{Ra} : Wind pressure force coefficient.

Passenger : $1.142 - 0.142\cos 2\theta - 0.367\cos 4\theta - 0.133\cos 6\theta$

General Cargo : $1.325 - 0.050\cos 2\theta - 0.350\cos 4\theta - 0.175\cos 6\theta$

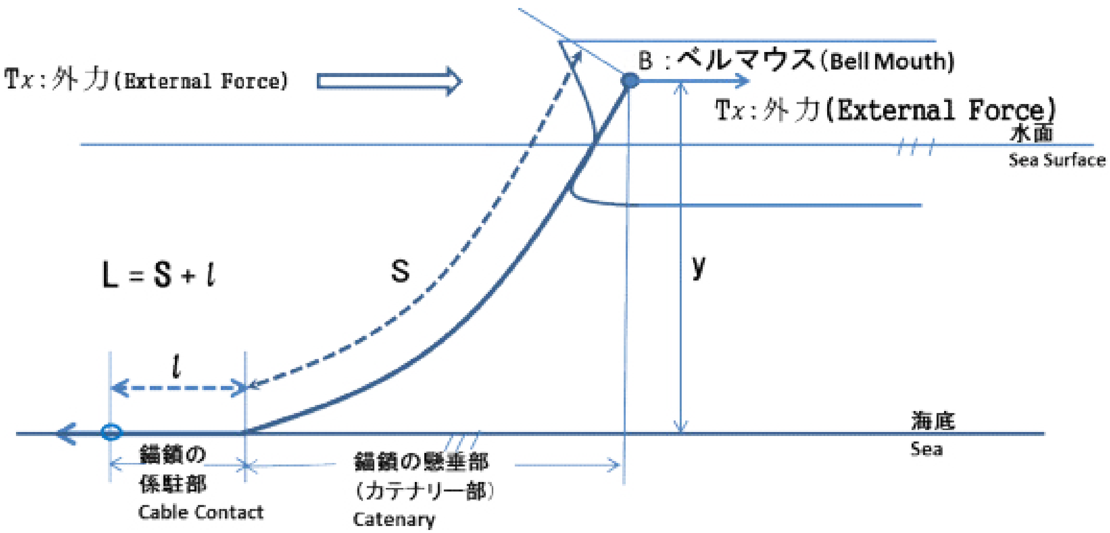
Tanker & Bulk carrier

: $1.200 - 0.083\cos 2\theta - 0.250\cos 4\theta - 0.117\cos 6\theta$

Resultant wind pressure force is proportional to the square of wind speed.

§ 3.3 Holding Power created by Anchor and Anchor Chain

S : Catenary length against the external force (m)
y : Water depth + Hawsepipe height from sea surface (m)
l : Minimum Required Contacted length of the chain (m)
L : Minimum Required Length of Anchor Chain (m) (= S + l)
Tx : External force (kgf)



H (Holding Power created by Anchor and Anchor Chain)
$= Ha + Hc = \lambda a \times Wa' + \lambda c \times Wc' \times l$

H : Holding power created by Anchor and Anchor Chain (kgs)
Ha : Holding power by Anchor (kgs)
Hc : Holding power by Anchor Chain (kgs) (Resistance of cable)

Wa : Anchor Weight in Air (kgs)
Wc : Anchor Chain Weight per m in Air (kgs)
Wa’ : Anchor Weight in Water (kgs) = 0.87 x Wa (kgs)
Wc’ : Anchor Chain Weight per m in Water (kgs) = 0.87 x Wc (kgs)
l : Minimum Required Length of Anchor Chain (m)

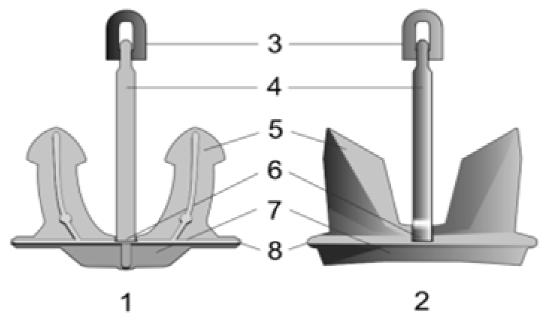
λa : Anchor Holding Factor
λc : Anchor Chain Holding Factor

λ a : Anchor Holding Factor

Type	Sand	Mud	Dragging
JIS	3.5	3.2	1.5
AC14	7.0	10.6	2.0

λ c : Anchor Chain Holding Factor

Holding	Dragging	
	Sand	Mud
0.75～1.0	0.75	0.60



JIS AC14

§ 3.4 Calculating the Catenary Length of an Anchor Chain

$$S = \sqrt{y^2 + 2\left(\frac{Tx}{Wc'}\right)y}$$

S : Catenary length against the external force (m)

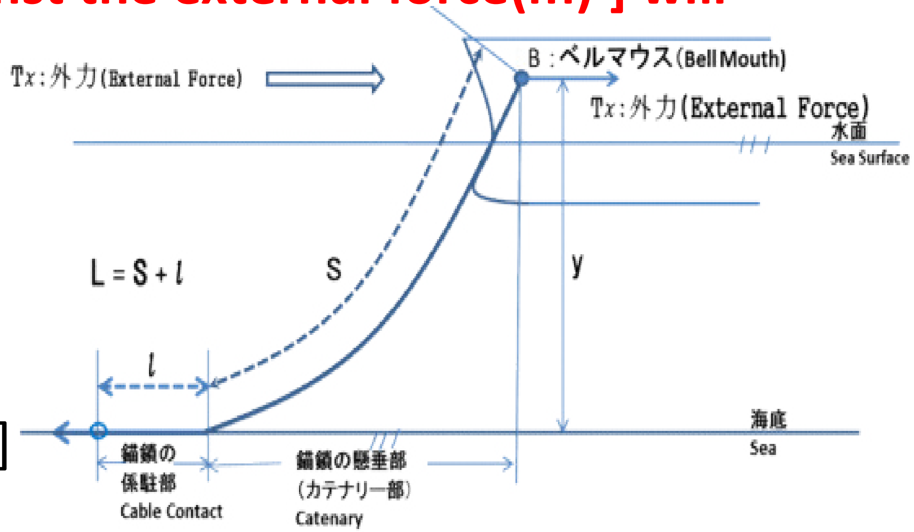
y : Water Depth + Hawsepipe height from sea surface (m)

Wc' : Anchor Chain Weight per m in Water (kgs)
= 0.87 x Wc (kgs)

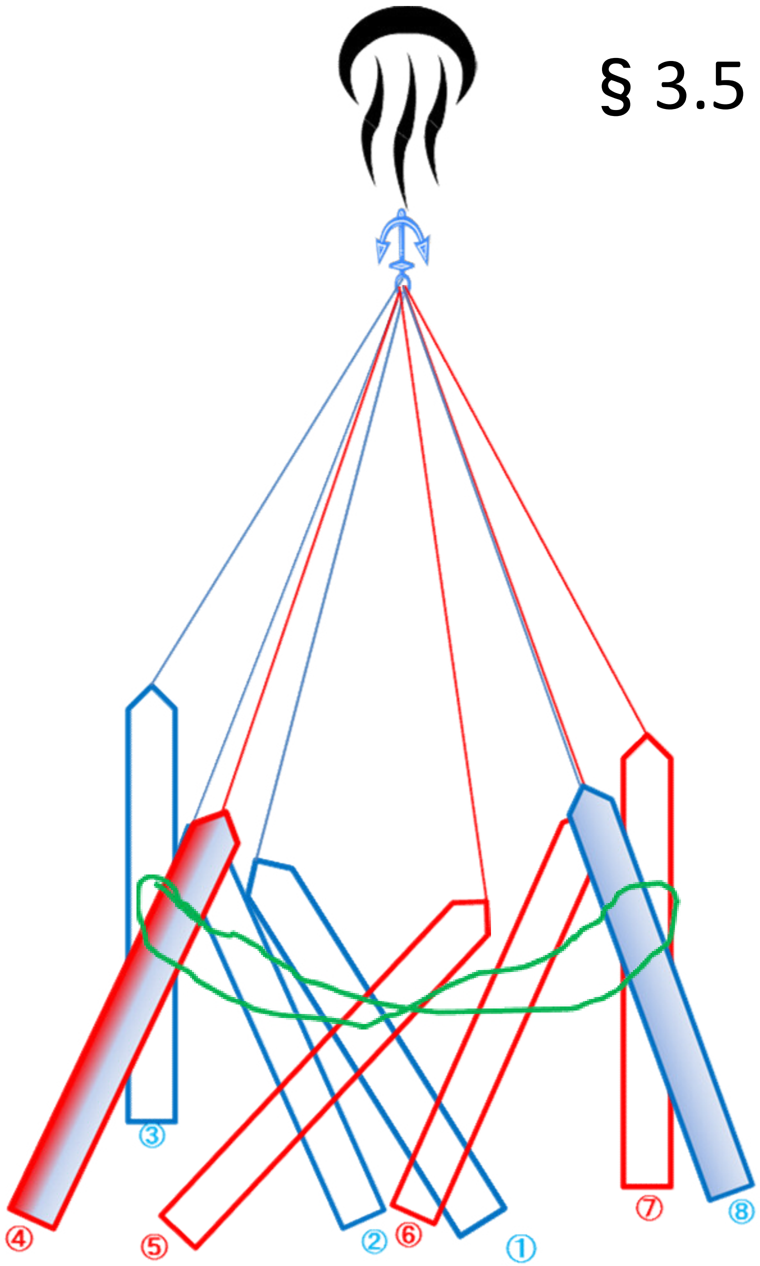
Tx : External force (kgf)

Under the condition that L [Minimum Required Length of Anchor Chain (S + l)] is fixed at a certain level, **if Tx [External force (kgf)] increases, S [Catenary length against the external force(m)] will also increase.**

On the contrary, however, l [Minimum Required Contacted length of the chain (m)] decreases so that H[Holding power created by Anchor and Anchor Chain (kgs)] will be diminished.



§ 3.5 Horsing (Yawing and Swaying) Motion and Impact Force



①→② From right to left. Anchor chain is tight condition

③ Left side position. Anchor chain become relaxes.

④ Biggest Impact Force

⑤→⑥ From left to right. Anchor chain is tight condition

⑦ Right side position. Anchor chain become relaxes.

⑧ Biggest Impact Force

In this way, the ship’s center of gravity is moving in a “figure-of-eight” pattern as illustrated by the green track in the diagram.

風圧力計算 参考値(Wind Pressure Force Cal.:Just Reference)

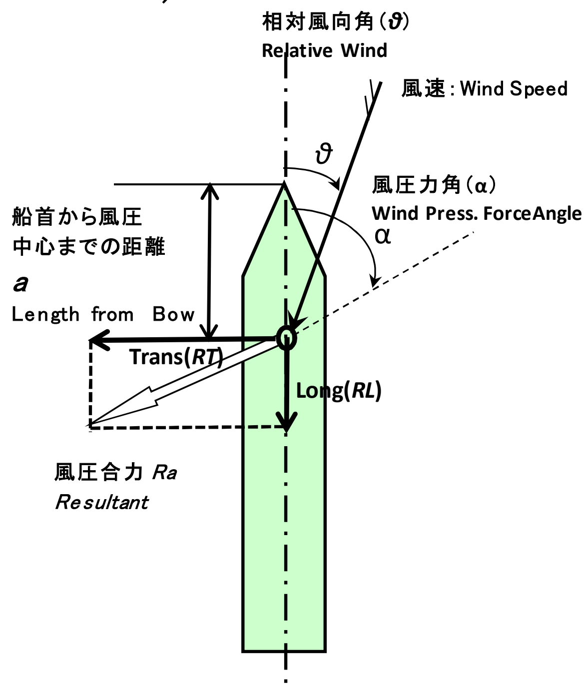
1 本船が受ける風圧力を風向別に自動計算する表です。
This formula calculate the wind force of your vessel at the wind speed.

2 船種別の風圧係数は自動的に計算されます。
The wind force coefficient in each kind of ship is calculated automatically.

3 下記を入力してください。(Input following data)

Loa(m)	200
正面投影面積(Projected area (Front)) (m2) (A)	800
側面投影面積(Projected area (Side)) (m2) (B)	5,500
風速(Wind Speed)(m/s)	30.0
船種(Kind of ship) 下記から選ぶ (Genl, PCC, Ctnr: 1 Passenger: 2 Tanker, Bulker: 3)	1

(Ave.Wind Speed x 1.25 or 1.50)



＊ 風速は以下を目安にして入力してください。(Input Wind Speed by below ref. data)
平穏時(Less than 8 m/s) : 平均風速(Ave. Wind Speed)
強風対策(Strong Wind:8～13m/sec) : 平均風速(Ave. Wind Speed) x 1.25
暴風対策(Storm Wind: More than 13m/sec) : 平均風速(Ave. Wind Speed) x 1.50

計算結果(RESULTS)

風向角(θ) Wind direction from bow (deg)	風圧力合計(Ra) Total wind force (t)	船首尾方向(RL) Longitudinal(t)	正横方向(RT) Transverse(t)	作用点(a) Point of action(m)	作用角(α) Angle of action(deg)	係数(CRa) Factor
0	33.75	33.75	0.00	58.20	0.00	0.75
10	48.86	43.37	22.51	62.80	27.43	0.92
20	99.72	69.74	71.28	67.40	45.62	1.31
30	183.30	92.57	158.21	72.00	59.67	1.65
40	267.24	90.73	251.37	76.60	70.15	1.73
50	315.24	67.27	307.98	81.20	77.68	1.58
60	328.43	40.97	325.86	85.80	82.83	1.35
70	338.32	22.36	337.58	90.40	86.21	1.22
80	359.08	10.02	358.94	95.00	88.40	1.19
90	371.25	0.00	371.25	99.60	90.00	1.20
衝撃力(Impact)	202.50	正面風圧抵抗(上記表のθ＝0 の値の6倍, Tanker/Bulkerは4倍) Wind Force on Front(θ＝0) x 6, Tanker/Bulker x 4))				

風圧係数(CRa)		
1	2	3
0.750000	0.500000	0.750000
0.922400	0.660925	0.871994
1.313421	1.035993	1.151506
1.650000	1.387500	1.400500
1.732710	1.528709	1.479010
1.575075	1.445025	1.390836
1.350000	1.263500	1.249500
1.215025	1.120549	1.161670
1.191369	1.060798	1.144983
1.200000	1.050000	1.150000

衝撃力 : PCC/CTNR船の場合、正面風圧力の5～6倍、その他の船では3～4倍
Impact Force : Wind Force on Front x 5～6 for PCC/CTNR/Passenger ship, x 3～4 for Tanker/Bulker

錨・錨鎖による把駐力計算 参考値(Anchor Holding Power Calculation：Just Reference)

1 予想される外力に対し係止出来る必要最低限の錨鎖長さを計算します。
The formula in this page are to calculate the holding power of your vessel's anchor and anchor chain.

2 但し、予想外力が錨の把駐力(Wa' x λa)より小さい場合は、下記計算式による繰り出し錨鎖量としています。
In case of External Force<Anchor Holding Power(Wa' x λa), required length of chain is to calculate by following formula.

Required Length of Chain = 3 x d + 90 m (Only External Force < Wa' x λa)

3 予想最大外力の入力(Expected total external force)

予想最大外力は、衝撃力の大きさを使用すること。PCC/CTNR船の場合、正面風圧力の5～6倍、その他の船では3～4倍
Expected total external force should be input by Maximum Impact force. For PCC/CTNR Ship : Wind Pressure on front x 5～6,
Other type of ship : Wind Pressure on front x 3～4

＊ 例： 風圧外力計算で相対風向0度の場合の風圧力が15トン ： 予想最大衝撃外力 15x5～6＝ 75～90トン(PCC/CTNR)
IE) As per Wind force Cal., Relative Wind Direction θ=0 : 15ton : Max Impact Force 15 x 5～6 for PCC/CTNR= 75～90 tons

情報入力(Input Data)

予想される最大外力(トン) ： Tx(衝撃力) Expected total external Max. force (MT):(Tx Impact Force)	85.6	
錨の空中自重(トン) ： (Wa) Anchor weight (MT) in Air : (Wa)	10.5	
錨鎖1mあたりの空中における重さ(トン)：(Wc) Anchor chain weight in Air (MT/m) : (Wc)	0.166 ton	
アンカーの種類(JIS型...1、AC14...2) Kind of Ancher (1: JIS, 2: AC14)	2	
使用する側の錨鎖保有長さ(シャックル) Total Length(Shackles) of using Chain on board	12 ss	
水深(m) ： d Water depth (m) : d	20.0 m	
水面からホースパイプまでの高さ(m) ： h Hawsepipe height from the sea surface (m) : h	5.0 m	
錨の把駐係数：(λa) Anchor Holding Factor:(λa)	AC14	7.0
錨鎖の把駐係数：(λc) Anchor Chain Holding Factor:(λc)	1.0	

計算結果(Result of Calculation)

海底から錨鎖孔までの高さ：(y) Total height (Bottom to Hawsepipe): (y)	25 m	
外力に対応するカテナリー長さ：(S) Catenary length against the external force : (S)	174 m	
錨鎖による把駐部の最小要求長さ：ℓ Minimum Required Contacted length of the chain: ℓ	150 m	
計算上必要な錨鎖繰り出し長さ： L＝S＋ℓ Minimum Required Length of Anchor Chain : L＝S＋ℓ	324 m	12 ss

Notice

守錨直を励行してください。
Keep Anchor Watch Strictly

錨の把駐係数(λa)は、計算式を使用するか、マニュアル入力すること。
Anchor Holding Factor(λa):Use Calculation Formula or Input by mannual.

錨鎖の把駐係数(λc)は0．75～1．0
Anchor Chain Holding Factor(λc) : 0.75～1.0

§ 3.6 Ship's operational safety measures for anchorage and their effects

Counter measures	Effectiveness	Remarks
Increase draught by taking in ballast water	Ship's weight is increased so that vessel's motions (Horsing) are decreased.	Consider stability issues.
Trim by the head	The point of action shifts afterward and tends to decrease the horsing motion.	Consider stability issues. Maintain propeller immersion.
Veer more anchor cable	Increases anchor chain holding factor. Extended catenary length absorbs more external force on anchor.	Consider that weighing anchor is difficult in rough sea conditions and **more time will be required to weigh the anchor.**

Counter measures	Effectiveness	Remarks
Drop the other anchor	Can reduce yawing and horsing motion by half, and reduce force on anchor by 30%～40%.	Consider amount of second cable required is one and a half times the depth of water. Consider the **possibility of fouling the cables**, particularly when pitching heavily.
From the outset of anchoring, to deploy both anchors	Riding to two anchors is said to increase holding power and to decrease horsing motion.	Danger of fouling an anchor if the vessel is turned under the influence of wind and/or tide.

Counter measures	Effectiveness	Remarks
Use of bow thrusters	By stemming the wind, this can effectively reduce the horsing motion and ease cable tension. If the power of the bow thruster is **80% of the wind force on the bow,** it is said that width of oscillating motion and impact force are diminished by about 40%.	**The possibility that extended use of the bow thrusters may not be possible for technical reasons.** Ensure that the bow thrusters are kept submerged when the ship is pitching and rolling.

Counter measures	Effectiveness	Remarks
Use of the main engine in combination with steering	This can be an effective deterrent to the horsing motion and will relieve the tension on the anchor and cable system.	Do not allow the vessel to pay-off suddenly when the tension on the anchor cable has been eased **as a sudden increase in tension may break-out the anchor.** Do not allow the vessel to override the anchor, particularly in shallow water where the vessel could impact on the anchor if pitching.

=Example calculation of the increase in holding power when cable is veered =

Ship's type : PCC laden with 6,000 units

Anchor Weight in Air (Wa) : 10.5ton ⇒ 9.135ton in Water

Anchor Holding Factor (λa) : 7.0

Anchor Chain Weight per meter in Air (Wc) : 0.166ton/m ⇒ 0.144ton in Water

Water Depth + Hawsepipe height from sea surface (y) : 25.0m

Length of one shackle of anchor cable : 27.5m

Ship's Projected area from bow above waterline (A) : 800sqm

Wind pressure force Coefficient (C_{Ra}) : 0.75

Air density (ρ) : $0.125 kg/sec^2/m^4$

The anchor cable is assumed to have formed a catenary with no cable lying on the ground.

Anchor Holding Power = Impact Force (external force) : 63.90tonf

＊Impact Force (external force) = Wind Force from ahead x 6

The Wind Force from ahead : 10.65tonf

Catenary Length(S') : 150.90m (5.5shackles)

The critical wind speed can be calculated from the Hughes Formula

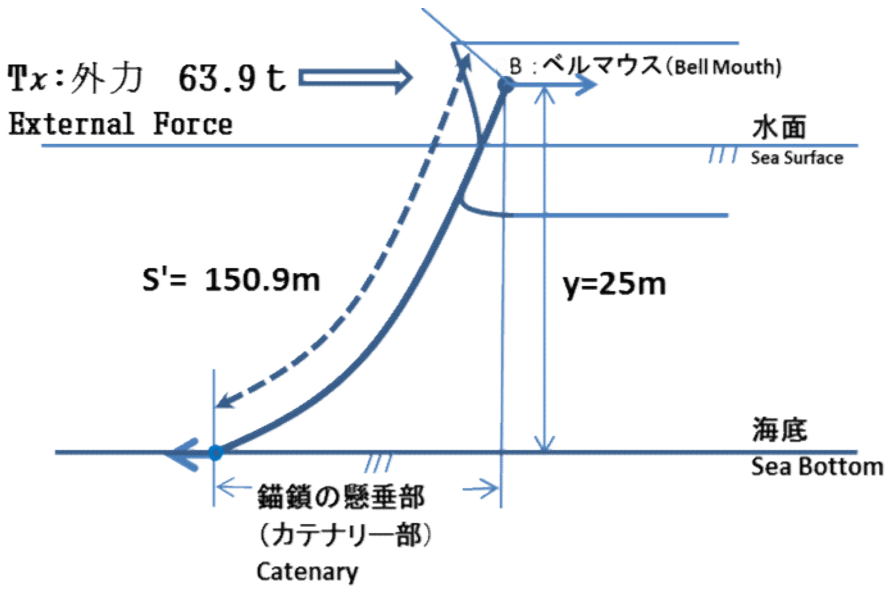
: 16.90m/sec.

The average wind speed

11.3m/sec ～ 13.5m/sec.

The critical wind speed =

Average wind speed x 1.25～1.50



(Situation after one additional shackle(27.5m) of cable is veered)

After a further shackle of cable is veered, the critical wind speed will be increased.

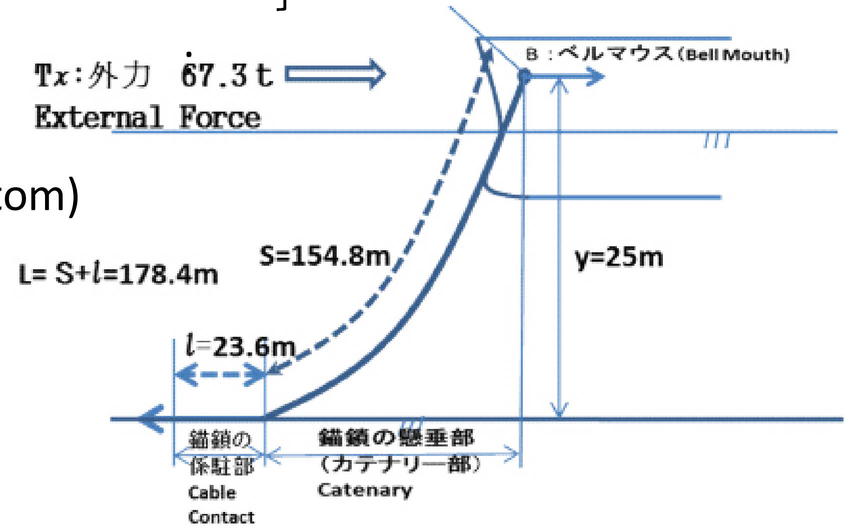
Only part of the longer cable system will lay along the ground with the remainder forming part of a new catenary.

$$S' + (27.5\text{m} - l) = \sqrt{y^2 + 2 \times \left[\frac{Wa' \times \lambda a + Wc' \times \lambda c \times l}{Wc'}\right] \times y}$$

S' : Catenary Length before one shackle is veered
150.90m(5.5 shackles)

l : Contacted length of the chain (laid over the bottom)
23.6m

Additional New Catenary 3.9m



The holding power created by the anchor and cable system = 67.3ton

The wind force from ahead = 11.23 tonf.

The critical wind speed = 17.3 m/sec.

The average wind speed = 11.5m/sec ～13.8m/sec.

In comparison with the average wind speed before one shackle of cable is veered, there are increases of 0.2 m/sec ～0.3m/sec to the critical wind speed.

Importantly for those on the bridge, the critical wind speed is not increased as much as might be expected even if the anchor cable is veered considerably.

a full length of cable (12shackles) is veered)

The average wind speed = **13.1m/sec ～15.7m/sec.**

Increase of 1.8 m/sec ～2.2m/sec

§ 3.7 The Critical Wind Speed

While looking into various reference books, there is

no concrete indication.

Reasons

- The holding power of each vessel's anchor is dependent upon the condition of the ground in the immediate vicinity.
- The actual holding power may not always conform to the theoretical value obtained by calculation.
- Continuing changes in the direction of the anchor cable and the angle of action on the mooring system. The result is that the anchor cable may be subjected to shock stresses as the cable sags and then tightens.
- The horsing motion may not be constant and the motion may even be accelerated.

After taking into consideration all the factors set out above the safe and prudent decision may well be **not to anchor.**

§ 3.8 Emergency measures taken and their effectiveness after dragging anchor

① Veering an Additional cable and use of the second anchor

Adding cable to the first anchor is not seen as an effective means of stopping a ship from being pressed and drifting to leeward.

② Use of bow thruster

The minimum thruster power must be equal to the wind force on the bow.

③ Use of the main engine and steering

The required power of the main engine

Steering : Hard Over	Wind speed	: Engine Order
	20m/sec	: Slow Ahead
	25m/sec	: Half Ahead
	30m/sec	: Full Ahead

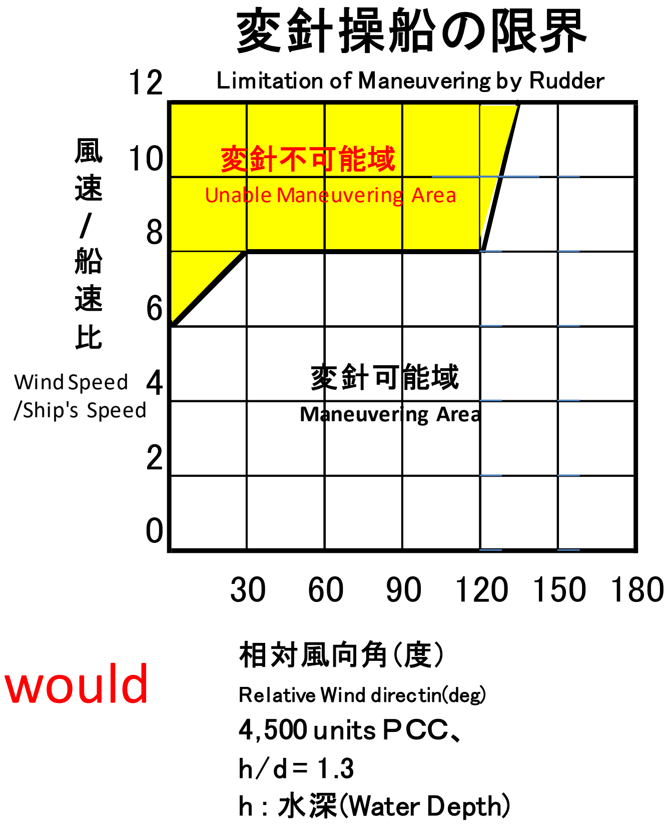
§ 3.9 Difficulty in maintaining maneuverability

It should be remembered that when the propeller is working the effect of the bow thruster will be decreased by about 20% per 1knot of ahead speed. In other words, at about 5 knots, the effect of the bow thruster is negated.

Limitation of maneuvering by rudder

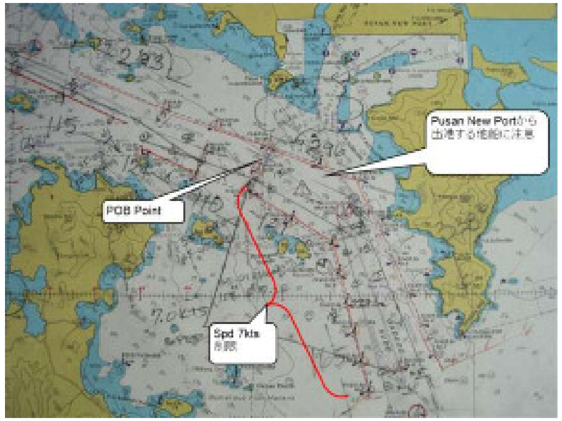
Numbers entered in the vertical axis are wind speed per ship's speed and the wind force angle is entered along the horizontal axis. **The yellow zone shows the area under the curve in which the effect of the rudder is lost.**

Wind speed of **20m/sec**, the ship's speed would have to be more than **5knots (2.5m/sec)**



§ 3.10 Preparation for safe anchorage

(1) The following considerations must be taken into account:



To select a sheltered good anchorage

- Land configuration
- The bottom configuration
- Holding grounding condition
- An appropriate depth
- Sufficient room
- Sheltered from such an external force as wind and sea
- Degree of congestion of other ships at anchorage

To prevent an accident in the event that the anchor drags

- Keep a safe distance from other ships
- Keep a safe distance from shallows/other facilities

§ 3.11 Anchor Operation

Recently there has been an increase in the number of accidents involving anchor cables becoming entangled or anchors and cables being lost. These accidents have mostly been caused by mistakes that were made during the operation of letting go the anchor. In particular, most accidents have been caused by not controlling the running-out speed of the anchor cable, that is, without braking when the anchor is let go.

Test results show that the speed of anchor free fall reaches 10m/sec after 50m when an anchor is let go without braking. That is to say, 12 shackles (=330m) could totally run out in 33 seconds.

According to investigation results, although most mariners involved in anchor-related accidents stated that the brake did not work well, thorough investigations on site have established that a bent brake shaft and / or lack of maintenance were the cause. The crew were unable to properly apply the brake.

To ensure safe anchoring, the veering rate must be limited to a brake force of 5 to 6 m/sec.

If the depth at an anchorage exceeds 20m, the possibility of damage to or loss of the anchor and its cable becomes greater due to excessive running out speed if the anchor is allowed to free fall. To avoid this hazard, the anchor should be lowered by walking back into the water until the anchor reaches about 5m above the bottom.

When letting go, the brake should be applied in order to slow the veering rate until the length veered is about 2m - 3m more than the water depth. This should prevent the cable from piling onto the anchor.

After the anchor touches the bottom, the ship's sternway should be limited to about 0.5k - 1knot in order to avoid imposing excessive strain on the cable and also to further avoid piling. The aim is to lay the cable across the ground in an orderly fashion and without imposing any excessive stress on the system. (Ideally, repeat stretching, little by little, every time until it becomes taut.)

Anchor Cable Veering Rate･Scope of Cable To Be Paid Out･Brake Force of Windlass

The Graph on the next page shows the relationship between brake force, scope of cable and veering rate determined during trials on board a 230,000dwt VLCC when anchor and cable are paid out using the brake. During the trial, the cable was first released with half brake applied. The brake was applied 3 seconds after letting go the anchor and was fully applied again after another 5 seconds in order to stop veering completely. As can be seen, the length of cable veered this time is about 21m.

If the anchor is let go by free fall and the veering rate exceeds 10m/sec, it becomes difficult to arrest the cable and the brake lining may be damaged. If, however, the veering rate is limited to about 5-6m/sec by the timely application of half brake, such damage will be avoided.

Result of VLCC Anchoring

Examples of entangling

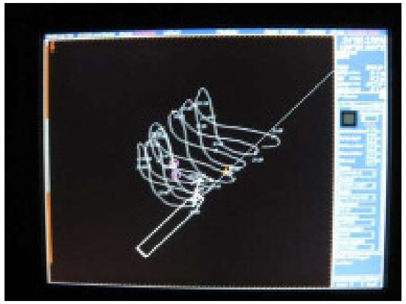
§ 3.12 Technical Measures for Anchoring

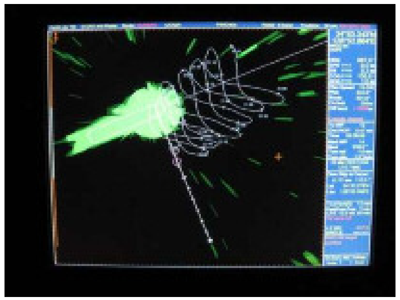
(1) Technical measures while lying at anchor

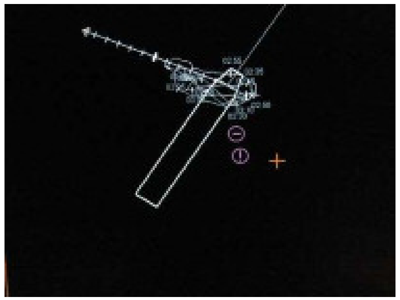
- External forces associated with wind speeds and directions
- wave height and period
- Flow direction and velocity
- Ship's type, Hull dimensions, draught, trim
- Understanding the holding power of the anchor system
- Quantitative assessment of wind pressure forces
- Management of the main propulsion systems

(2) Prediction and early detection of dragging anchor

- Understand fully the relationship between holding power and external forces
- To detect dragging anchor by observing the horsing motion
- To use track display function of ECDIS・RADAR・GPS







Ref. : Vessel Turning Motion and Control for High Speed vessels under Full Speed conditions

Taking into account Turning Motion in the event that a high speed vessel (container ship or PCC etc.) is operating at full-loaded capacity and at full speed.

Failure as a result of rapid turning during operation at high speed

For example, the following problems may occur when a container ship operating at 22 knots steers its rudder to full (hard-over).

- If the main engine is in over-load (torque rich) and also in MO operation mode, main engine rpm decreases together with the sounding of the Slow Down alarm.

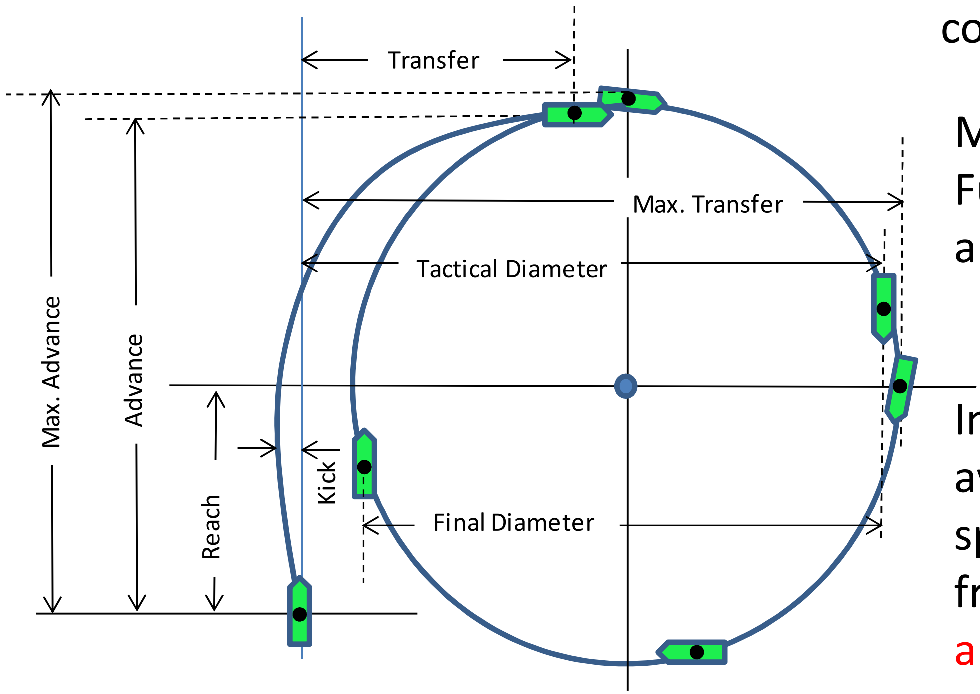
- Outer heel increases due to centrifugal force. Because GoM of a container ship is between 1.2 and 1.8 meters at full load, outer heel increases due to rapid rotation, which may cause a dangerous situation.

So as not to cause the above failure, it is a requirement that the vessel navigate at a restricted rate-of-turn speed at 5-10 degrees per minute (15 degrees per minute at max.).

Regarding the method of turning circle, which is measured during a sea trial and displayed in the bridge, in the event that it is a container ship: Max. Advance or a Max. Transfer etc., the Final Diameter at the time when rudder is steered to full, is generally 3.5 to 4 times that of the hull length.

However, this information is based on a vessel carrying ballast (ballast condition) and most of them navigate at a speed of approximately 15 kts. There is no data available for when a vessel is fully loaded and at full speed.

Turning Circle



These specifications are invaluable for the helmsman in the event of rapid turning at S/B being necessary (e.g. to prevent a collision or grounding).

Maneuvering with rudder Hard Over at Full Speed is not realistic because the above-described trouble may occur.

In such a situation, in order to carry out avoidance maneuvering safely at full speed and to remain at a safe distance from the shore, take into account the sea area while paying careful attention to rate-of-turn speed.

Focus on the rate-of-turn speed during the ship's hull turning round moment

Although it will differ depending on a ship's hull construction, speed and stability, the rate-of-turn speed, which neither causes deceleration or engine harm, is approximately 10 degrees per minute.

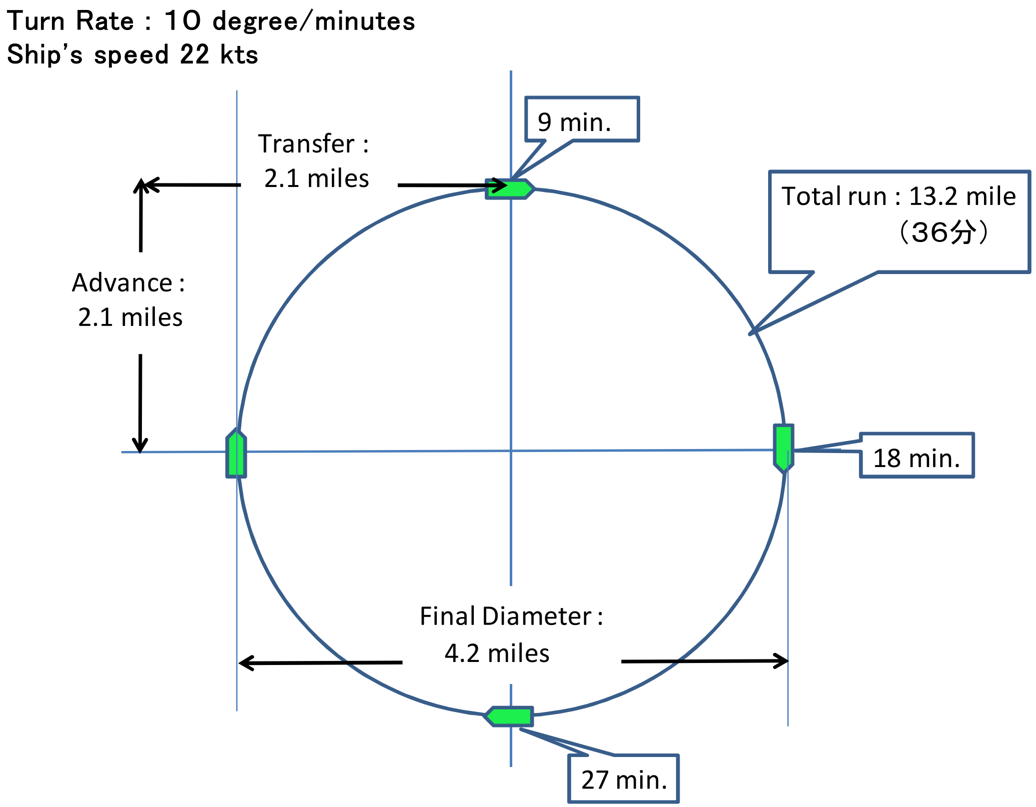
Conditions : Steer at a controlled limit of 22 kts and 10 degrees per minute for rate-of-turn speed.

- Time required for turning round at 360 degrees
  ＝ 36 minutes (0.6 hours)

- Running distance over 36 minutes
  ＝ 13.2 nautical miles (22 knots x 0.6 hours）

For example, in the event of avoiding a crossing vessel, it is necessary to consider the sea area and time required for turning round at 90 degrees.

Otherwise, calculate estimated size of sea area, required for one turning round, by drawing and formula and checking it by drawing it on the nautical chart.



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