P&I Loss Prevention Bulletin
Preventing an Anchor from Dragging

The Japan Ship Owners' Mutual Protection & Indemnity Association
Loss Prevention and Ship Inspection Department
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Preface

According to the investigation by the Japan Marine Accident Tribunal in 2004, 40% of ships anchoring under typhoon conditions experienced their anchors dragging.

Generally speaking, dragging the anchor happens in rough weather and weighing the anchor may take some time in such circumstances. Even if the anchor can be successfully raised in rough weather conditions, further time may be required to restore the ship to full manoeuverable condition. The usual weighing operation, therefore, may be abruptly transformed into an emergency procedure requiring experienced skills and cool judgment.

This refers to how and why dragging the anchor occurs and how to deal with a dragging situation.

§ 1　Accidents Involving Ships at Anchor

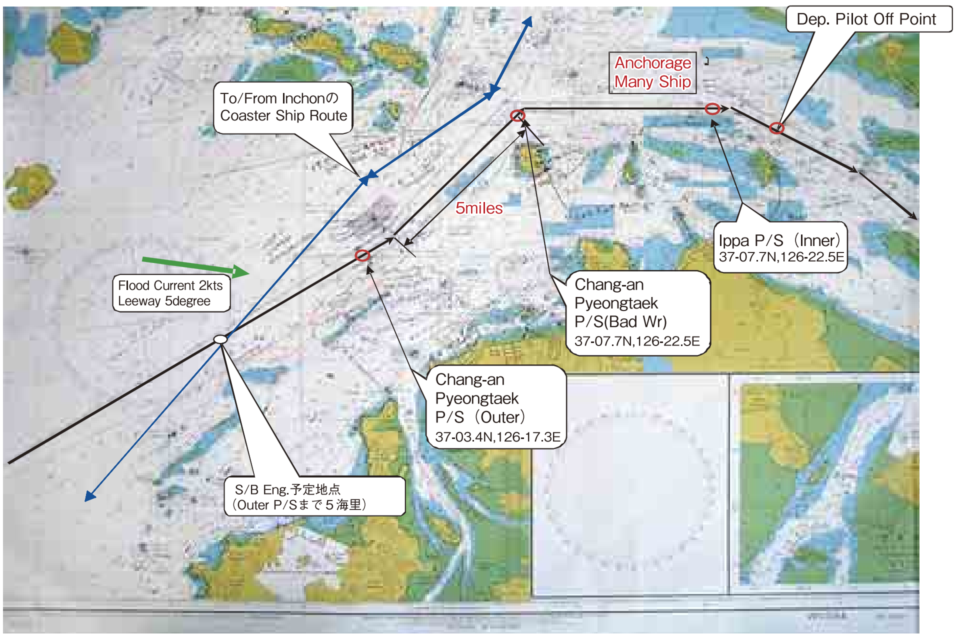
Accidents involving ships at anchor usually occur when the anchor drags and the vessel drifts without holding power, leading to collisions and/or groundings or strandings.　The following considerations should be taken into account:-

① It can take some time to realise the anchor is dragging, despite the ship drifting. A vigilant bridge watch is, therefore, essential.

② It takes some time to weigh the anchor and restore the ship to full manoeuverable condition, even though the ship may be drifting for that period. Contingency plans　must be in place to ensure rapid response times.

③ During the period beginning with the detection of dragging to the time full control is achieved over the ship's manoeuverability, the vessel may run dangerously close aboard, or into another ship or structure, or into shoal water.

Unless heavy weather causes the vessel to capsize, no serious accident should occur just because a ship is dragging its anchor, provided there is enough space around it for manoeuverability and enough time available to restore it to a fully controlled condition.



Pyeongtaek Anchorage and Approach

The considerations outlined above become of even greater importance in the case of a crowded anchorage where there may be insufficient space between vessels to deal timely with emergencies such as dragging anchor and drifting out of control.　The master of an arriving vessel should satisfy himself first that the anchorage is safe in all respects before committing himself to anchoring.
Masters and deck officers are advised to　familiarise themselves with the following concepts in order to prevent as far as possible a ship from dragging its anchor:-

① How and why dragging the anchor occurs.
② Difficulties with vessel manoeuverability while dragging an anchor.
③ The assessment of what constitutes a safe anchorage, including contingency plans involving the time and space required to regain control of the vessel if the anchor drags.

§ 2 The Reason Why an Anchor Drags

A ship's anchor drags due to the impact of external forces on it which exceeds 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. In the above connection, there still remain some empirical or "rule of thumb" methods of assessing the scope of anchor cable required under various circumstances of water depth and expected weather conditions, for example:-

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

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

・Japanese Publication Theory of Ship Operation
Fine weather: $L=3d+90m$
Rough weather: $L=4d+145m$

・United Kingdom Publication Theory of Ship Operation
$L=39 \times \sqrt{d}$

Traditional Means of Detecting a Dragging Anchor

① Checking the ship's position, to confirm whether it is placed outside of a turning circle.
(The most currently reliable way of checking whether the anchor is dragging is to carefully monitor the vessel's position by visual and electronic means to confirm whether it remains within a swinging circle defined by the scope of anchor cable and the distance from the forecastle to the bridge. If it deviates from the circle, the ship is likely to be dragging its anchor. Reliance should not be placed on a single method of fixing the ship's position. Cross-check whenever possible with an alternative means.)

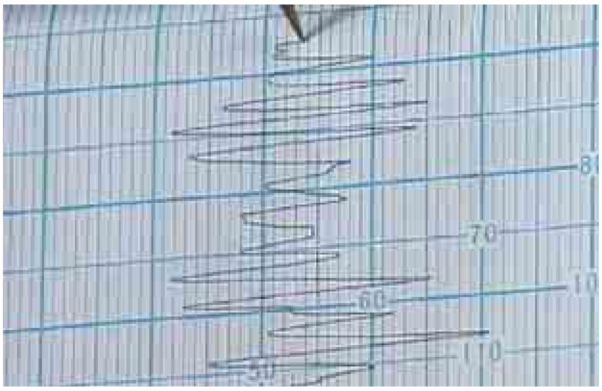
② The bow cannot stand against the wind.

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.

⑤Checking 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.



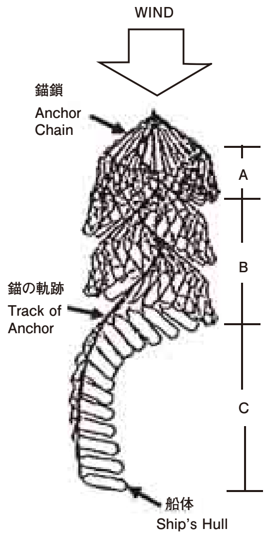
レコーダー／ Recorder

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 following considerations exclude those cases where the initial position of the anchor, rather than the ship, has been fixed and subsequently monitored.)

・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 easy to control the manoeuverability of a ship in such a state and to weigh the anchor.



段階図 /diagram

・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 manoeuverability.

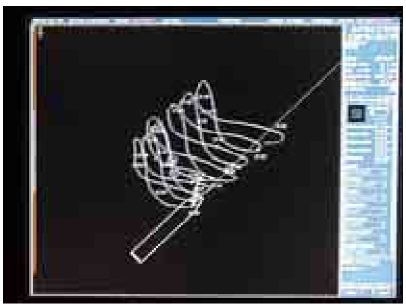
Very large vessels, such as loaded container ships and car carriers have a large windage area. In their case, full control may be lost even though the ship's main engine and bow thruster have been utilised when weighing anchor.

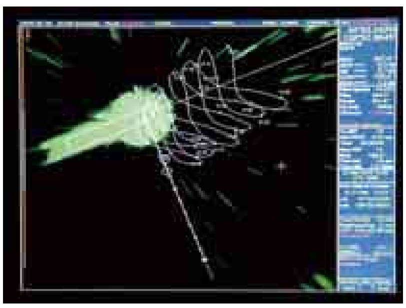
Dragging anchor may not be detected by the usual methods until the vessel has entered the second stage described above, by which time it may be too late to avoid a dangerous situation from developing.

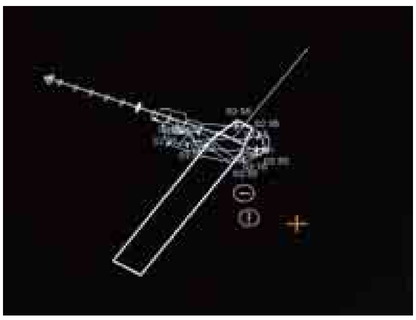
Personal computers, nowadays, can be used to calculate external forces on the anchor and cable system. The calculations utilise catenary equations which take into account the water depth as variable, the anchor holding power, the type of anchor, environmental forces and the forces acting on the windlass and cable stopper. The results of the calculations are used to show the minimum required length of anchor chain and the area needed around the ship for a safe anchorage.

In addition to the usual methods of checking the vessel's position by reference to fixed points described above, 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.

The following images are examples of GPS-plotted wakes on ECDIS and RADAR screens, showing the anchor dragging with yawing:-


ECDIS


RADAR


圧流走錨開始
Initiation of dragging anchor by wind pressure force

The display depicts the moment the ship's starboard bow turns against the wind.
GPS indicates direction and speed of the ship's movement by vectors.

§ 3 Wind Pressure Force Calculation

Hughes Formula

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

θ : Wind direction from bow [degree] (Relative Wind Direction)

Va : Headwind speed [m/sec]

ρ : Air density [0.125 kg・sec ^{2} /m ^{4}]

A : Ship's projected area from bow above waterline [m²]

B : Ship's projected area from side above waterline [m²]

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

α : Wind pressure force angle [degree] (Angle of Action)

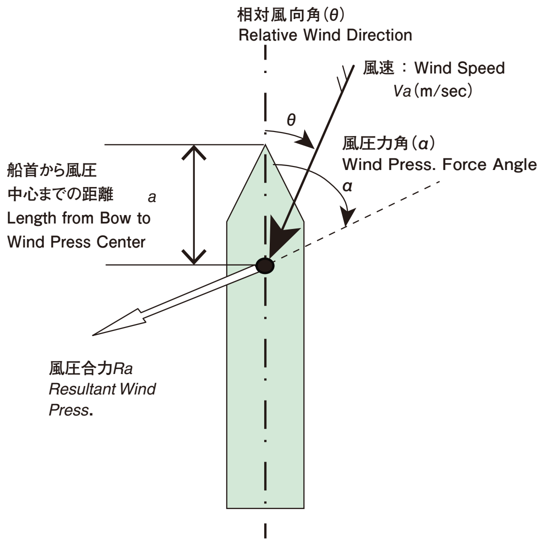
CRa : Wind pressure force coefficient
: This varies for different ship types, as follows.

Passenger
: $1.142 - 0.142\cos2\theta - 0.367\cos4\theta - 0.133\cos6\theta$

General Cargo

: $1.325 - 0.050\cos2\theta - 0.350\cos4\theta - 0.175\cos6\theta$

Tanker & Bulk Carrier
: $1.200 - 0.083\cos2\theta - 0.250\cos4\theta - 0.117\cos6\theta$

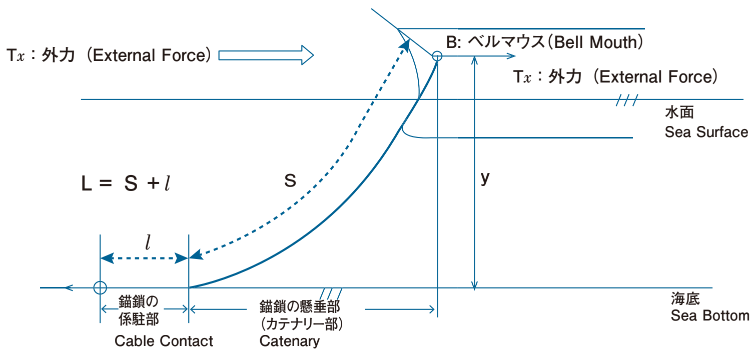


Resultant wind pressure force is proportional to the square of wind speed.

§ 4 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×Wa (kgs)

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

l : Minimum Required Length of Anchor Chain (m)

λ a : Anchor Holding Factor

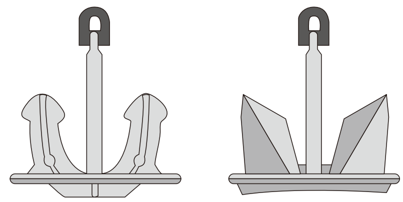
λ c : Anchor Chain Holding Factor

λ a : Anchor Holding Factor

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

λ c : Anchor Chain Holding Factor

	Holding	Dragging	
		Sand	Mud
λ c	0.75 ～ 1.0	0.75	0.60



§ 5 Calculating the Catenary Length of an Anchor Chain

The following formula provides the catenary length of an anchor chain. It should be noted that the external force becomes greater as the catenary length increases.

$$S = \sqrt{y^2 + 2\,(Tx / Wc')\,y}$$

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×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.

§ 6 Examples of Anchor and Anchor Chain Stowed on Board

Examples of anchors and chains stowed on board typical kinds of ships are shown below. The anchor and cable outfit is determined in accordance with the Equipment Number of each ship which is set by the Classification Society rules. The minimum weight of anchor chain per meter length may be estimated by the formula $0.0219d^2$. The actual as fitted details of a vessel's anchor and cable outfit should be included in the ship's documents.

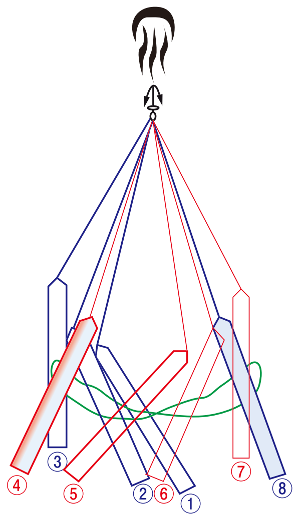
Examples of Anchor and Anchor Chain Outfits

Type of ship	Weight of anchor	錨鎖	
		径	1m あたりの最小重量
230,000DWTVLCC	18.7tons	102mm	228kgs
6,000units PCC	10.5tons	87mm	166kgs
8,000TEUCTNR	15.0tons	98mm	210kgs
25,000GTCTNR	8.3tons	81mm	144kgs
5,000GTG.CARGO	2.7tons	56mm	69kgs

§ 7 Excel Spreadsheet Calculation of Wind Pressure Force

(Please refer to attached excel file)

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



The vessel is oscillating about the anchor with a yawing and swaying motion from side to side, as indicated by the movement from ① → ② in the diagram. At this stage, the anchor cable is under tension.

At position in the diagram additional weight comes on the system as the vessel is brought up sharply and “snubs” the cable. As tension then relaxes, the ship’s bow tends to pay-off in the opposite direction (position ③ to ④ in the diagram).

The pattern of oscillations continues through positions ⑤ , ⑥ , ⑦ and ⑧ in the diagram and is then repeated.

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.

§ 9 Excel Spreadsheet Example of Anchor Holding Power Calculation

(Please refer to attached excel file)

§ 10 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) ared ecreased.	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.
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 isturned under the influence of wind and/ or tide.
Useofbowthrusters	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 diminishe dy 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.
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.

(1) Example Calculation of the Increase in Holding Power When Cable is Veered

The critical wind speed under the following preconditions
when one shackle of anchor cable is veered from a PCC laden
with 6,000 units is calculated as follows:-

(Preconditions)

(Wa) ／ Anchor Weightin Air (Wa)
: 10.5ton (λ a) 7.0
⇒ (Wa') ／ Anchor Weight in Water 9.135 ton (Wa')

(Wc) ／ Anchor Chain Weight per min Air(Wc)
: 0.166 ton/m Anchor Chain Holding Factor (λ c) 1.0
⇒Anchor Chain Weight per m in Water 0.144 ton/m (Wc')

(y) ／ Water Depth + Hawsepipe Height from Sea Surface (y)
: 25.0m

Length of One Shackle of Anchor Cable
: 27.5m

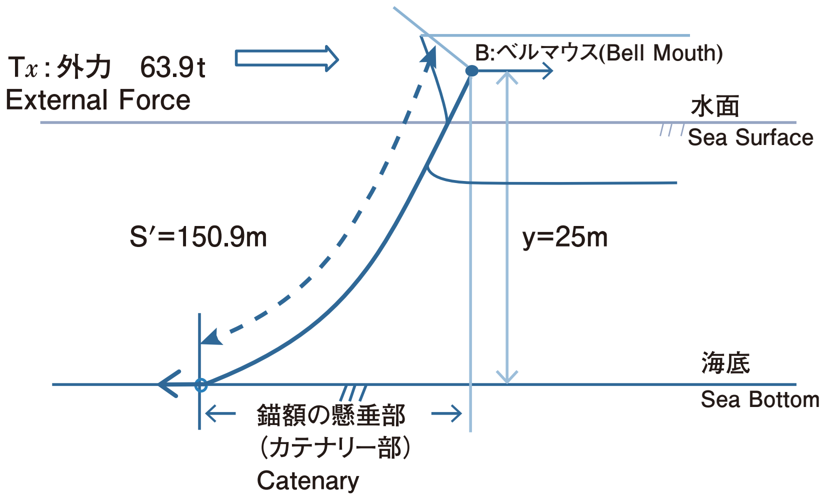
Ship's Projected Area from Bow Above Waterline (A)
: 800 sqm

Wind Pressure Force Coefficient (CRa)
: 0.75

Air Density (ρ)
: 0.125kg/sec ^{2} /m ^{4}

(Situation Prior to Veering Additional Cable)

Before any additional cable is veered, the ship remains in a stable position by virtue of the anchor holding power, which is equal to impact force on the anchor and cable system. The anchor cable is assumed to have formed a catenary with no cable lying on the ground. Before determining the critical wind speed, the wind force on from ahead must be calculated.
It can be demonstrated that the impact force (which, in this case, is the same as the anchor holding power) should be divided by 6.



Anchor Holding Power Being Equivalent to Impact Force (external force)

: 63.9 tonf

⇒ the Wind Force from Ahead 10.65 tonf

Catenary Length (S')

: 150.9 m (5.5ss)

The critical wind speed can be calculated from the Hughes Formula as 16.90m/sec.

The average wind speed can then be calculated as 11.3m/sec – 13.5m/sec.

The critical wind speed can be converted into the average wind speed which is solved that the critical wind speed be divided by 1.5 or 1.25.

These average wind speeds are the maximum limits under which the vessel in this example can lay safely at anchor without exerting more force on the anchor and cable system than it can withstand.

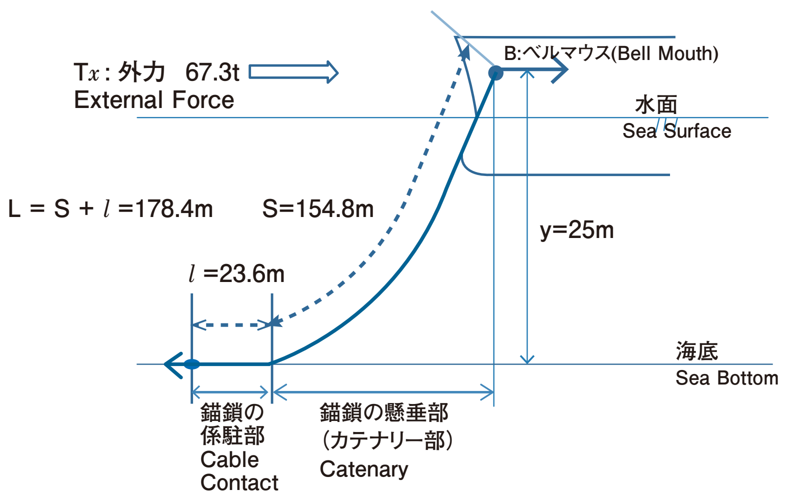
<u>(Situation After One Additional Shackle of Cable is Veered)</u>

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, which will now be longer as it will be extended by the increased external force caused, in turn, by the increased critical wind speed.

There is a minimum required contacted length of chain, that is, the minimum length of chain in contact with the ground to ensure the anchor is properly embedded. This length (l) can be determined by the following formula:-

$$S' + (27.5m - l) = \sqrt{y2 + 2 \times \left[\frac{Wa' \times \lambda a + Wc' \times \lambda c \times l}{Wc'}\right] \times y}$$



S' (Catenary Length before One Shackle is Veered)

: 150.9m (5.5 shackles)

l : Contacted Length of the Chain (laid over the bottom) One shackle of cable (27.5 m) veered consists of " *l* " for 23.6m and a part of catenary for 3.9 m.

(S) Catenary Length

: 154.8m

(l) Contacted Length of the Chain (laid over the bottom)

: 23.6m

(L) Length of Anchor Chain (after one shackle of cable is veered)

: 178.4m (6.5 shackles)

The holding power created by the anchor and cable system in this case becomes 67.3 tonf and is equivalent to the impact force.
Because of the extension for 23.6m, the impact force has been increased by 3.4 tonf （ = 67.3 tonf - 63.9 tonf）
The wind force from ahead is, therefore, solved as 11.23 tonf.

The critical wind speed can be calculated as 17.3 m/sec.
[This is 0.4 m/sec more than before the additional cable was veered （17.3m/sec -16.9m/sec） .]
The average wind speed can then be calculated as 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.

(Example considering the case when a full length of cable (12shackles) is veered)

If twelve shackles are veered, the critical wind speed is computed as follows;-

（S） Catenary Length
: 175.0m
（l ） Contacted Length of the Chain （laid over the bottom）
: 155.0m （+22.4 tonf）
（L） Length of Anchor Chain
: 330.0m （12 shackles）

Holding power created by anchor and anchor chain in this case becomes 86.3 tonf being equivalent to impact force. The wind force on front is 14.38 tonf.

The critical wind speed in this case is 19.6m （+2.7m/sec） .
The average wind speed becomes 13.1m/sec ～ 15.7m/sec.
This is an increase of 1.8m/sec ～ 2.2m/sec.

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.

(2) Example of Reducing Horsing Motion by Using the Bow Thruster

The wind force from ahead (a PCC laden with 6,000 units), in an example where the wind speed is 16m/sec, is 22 tonf (gusting in storm conditions could result in a maximum instantaneous wind velocity of about 24m/sec, say, one and half times as strong as in the example). Generally speaking, in order to cope with the above wind force, the following horsepower (assuming 1ton=100hp or PS and 80% of this capacity is required), would be necessary:-

$22 \times 0.8 \times 100 = 1{,}760$PS

From the practical view point, so as to enable the bridge personnel to reduce horsing motion, the most efficient way of using the thruster, and its prolonged use, should be discussed with the engineering department so as to avoid damage to the equipment.

(3) Reducing Horsing Motions by Using the Main Engine and Steering

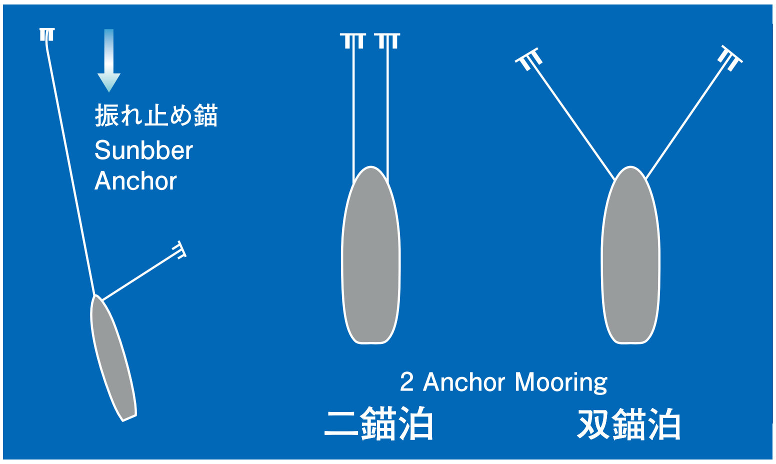
In theory, an effective method of reducing horsing motions is to stem the wind by working the main engine in conjunction with use of the rudder. In practice, however, when this is done, it should be remembered that the wind speed is approaching the critical limit. Care must be taken, therefore, to avoid a situation where the anchor cable repeatedly slackens and then becomes taught as this may impose excessive impact forces on the anchor.

(4) Using the Second Anchor As a Snubber・Riding to Two Anchors

To drop the second anchor to act as a check, or snubber, is said to effectively reduce the so-called horsing motion. A suitable scope for the snubber is one and a half times the depth of water.

Nevertheless, it is impossible to completely stop the horsing motion. Care should be exercised when deploying a second anchor to avoid entangling the cables and creating a foul hawse, particularly when the vessel is pitching heavily.

When riding to two anchors, there is a possibility that the cables may become entangled resulting in a foul hawse. This method is not recommended for large ships because of the practical difficulties involved in disentangling large and heavy anchor cables and it is likely that outside assistance will be required. Smaller vessels may be able to clear a foul hawse themselves.



§ 11 The Critical Wind Speed

While looking into various reference books, there is no concrete indication.

Reasons

- Within a single anchorage, the holding power of each vessel’s anchor is dependent upon the condition of the ground in the immediate vicinity, and this may vary from location to location within the anchorage.

- Holding power is created, not only by the anchor, the flukes of which must bite into the ground firmly and remain buried at their designed angle, but also by the resistance of the cable laid over the ground. Bearing in mind the possible variations in the composition of the sea bed, the actual holding power may not always conform to the theoretical value obtained by calculation.

- Further, complex combinations of ship motions, such as heel due to wind pressure, pitching, heaving, surging, swaying and yawing in the wave pattern, together with restraints imposed by the stress on the anchor cable, cause 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.

- In practice wind direction and speed are likely to change so that the horsing motion may not be constant and the motion may even be accelerated.

It should be remembered, therefore, that the value of wind pressure force and impact force derived from the formula may not reflect the actual state. This may be misleading and ship’s staff are advised to treat with prudence the computations set out on §9, which are offered as guidance, only.

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

§ 12 Emergency Measures Taken and Their Effectiveness After Dragging Anchor

Once an anchor starts to drag, immediate counter-measures should be taken. These include weighing the anchor in order to restore a maneuvoerable condition and then re-anchoring, seeking sheltering in an area where drifting is safe, or returning to the open sea.

Should there be space around the ship with no other vessels lying at anchor, there may be time to restore a controlled condition by stemming the wind and weighing anchor. However, analysis of cases of anchor dragging reveals that, major accidents such as collisions with other ships and groundings are almost always the result of a ship dragging its anchor because control was not restored in the way described above.

(1) Veering an Additional Cable and Use of the Second Anchor

Once a ship starts to be pressed to leeward, inertia increases and more power is required to overcome it. At the very early stage of dragging, when the horsing motion becomes apparent, and before the ship is pressed to leeward with increasing speed, it may be beneficial to veer more cable, or to deploy a second anchor. Nevertheless, as discussed above, the addition of more cable is not expected to increase significantly the holding power of the system.

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

While dragging anchor and being forced to leeward, the use of bow thrusters to make the ship come up into the wind may be effective. However, to be successful, the minimum thruster power must be equal to the wind force on the bow.
For example, in the case of a pure car carrier, and assuming that the downwind movement is initiated with an average wind speed of 18m/sec, the required thruster power is about 28ton (2,800hp or PS).

(3) Use of the Main Engine and Steering

In order to maintain a ship's head into the wind, in conjunction with large rudder angles, the required power of the main engine is approximately as follows:-

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

In rough weather with the vessel rolling, pitching and yawing, etc., different engine settings may be needed, always bearing in mind the need to avoid propeller racing.

§ 13 Difficulty in Maintaining Manoeuverability

If the ship swings broad on to the wind and begins to move to leeward, considerable time and space may be required before effective control can be restored by using the main engine, rudder and bow thruster.
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 Manoeuvering by Rudder

Considering a pure car carrier laden with 4,500 units sailing across the wind using 15°of rudder, diagram1 illustrates the limitations on manoeuverability imposed by various wind strengths compared to the vessel's speed.

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.

In an example where the car carrier is, say, dragging her anchor and the wind is on the beam (relative angle 90 degrees) and she tries to turn into the wind, it is likely that this will be unsuccessful if the wind speed is eight times the ship's speed. In other words, should the ship be successful in weighing anchor and obtaining some speed, stemming the wind would remain extremely difficult. With a wind speed of 20m/sec, the ship's speed would have to be more than 5knots (2.5m/sec), in order to stand a chance of stemming the wind.

Diagram2 also indicates that, when dragging anchor under the influence of a wind speed of 20~25m/sec the ship will move to leeward at a speed of some 3~4knots as shown in area [C] in the diagram.

It is estimated that, in the case of the car carrier, the maximum ratio of wind speed to ship's speed which will permit the vessel to maintain a given course is 2.8~3.8. This should not be confused with limitation of manoeuvering by rudder.

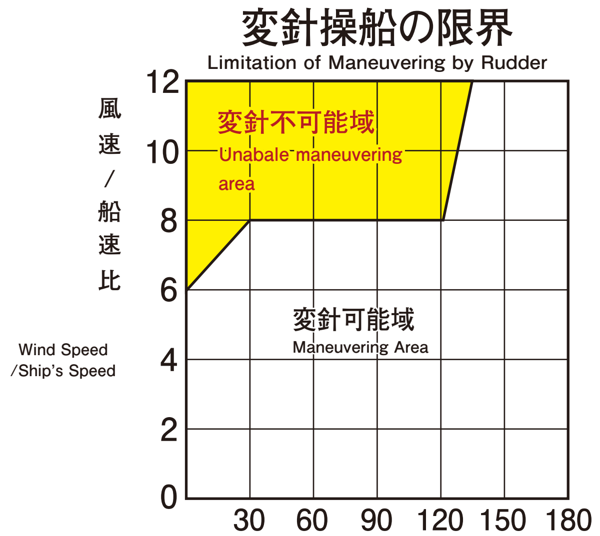


図1／diagram1

相対風向角(度)
Relative Wind Direction (deg)

4,500Unit Load PCC, h/d=1.3
h：水深 (Water depth)　d：喫水 (Draft)

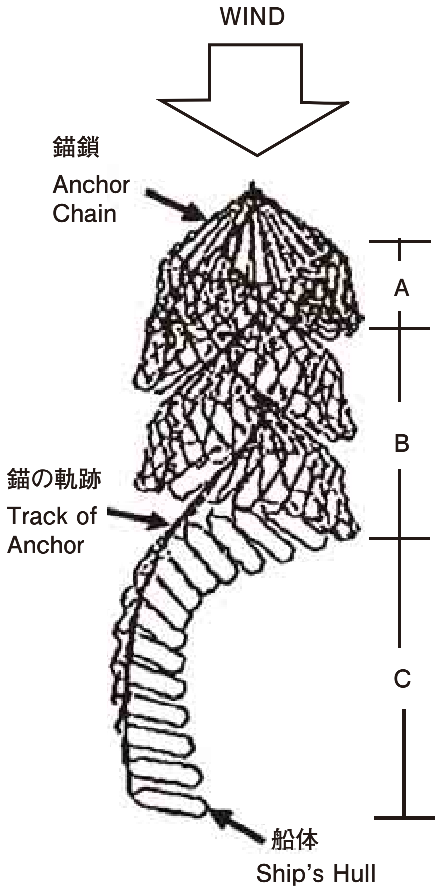


図2／diagram 2

§14 Preparation for Safe Anchorage

Accidents involving ships lying at anchor usually occur in the form of dragging anchor and drifting without anchor holding power followed by collision and/or grounding/stranding. The basic way of preventing such accidents is as follows:-

<u>(1) When Anchoring is Anticipated, the Following Considerations Must Be Taken into Account:-</u>

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

(2) Technical Measures While Lying at Anchor
・External forces associated with wind speeds, directions, wave height, wave period, flow direction and flow velocity
・Ship 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

(3) 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

(4) The Counter-measures To Be Taken After Dragging Anchor is Detected
・To weigh anchor and establish manoeuverability as soon as possible
・To weigh anchor during the period of the swinging motion

§15 Safe Distance from Other Ships, Shallows and Other Facilities

Although it is essential to decide on the anchor position so as to avoid an accident, even after dragging anchor, regrettably, there are no definite criteria to gauge the safe distance from other vessels, shoals and other obstructions.

Mariners should take the following items into consideration when assessing the area which may be needed while restoring manoeuverability by using the main engine/rudder/bow thrusters if the anchor drags.

1. A radius of swinging circle
   A circle with a radius of minimum required length of anchor chain + the ship's LOA

2. The speed of dragging anchor under wind pressure force
   This is approximately 3 ～ 4 knots.

3. Required time to weigh anchor
   In general, an anchor cable will be retrieved at a rate of about 9m/min
   To retrieve 1 shackle takes about 3minutes.
   It may not be possible to heave in a taught cable continuously, thus prolonging the operation of weighing anchor.

4. Required time to prepare the main engine for use.
   To have the main engine on standby beforehand, if dragging anchor is predicted.

5. The required time to attain sufficient propelling speed when restoring manoeuverability after the vessel has been forced to leeward with the wind on the beam.

Case study

Case 1

Weighing anchor after dragging anchor is detected

（diagram 3、green vessel）

・The ship's LOA is 200m.
・She is lying at anchor with 8 shackles.
・Time to weigh anchor is 1.5 times longer than usually required.
・During that period, the ship is being brought to leeward at 4 knots.
・After weighing anchor, it takes 15minutes until the ship's speed reaches 5 knots.
・In the interval, the ship's side has been pressed by the wind.
・The main engine and bow thruster are ready prior to dragging anchor.
・Whilst weighing anchor, both are available.
・The wind speed is 20m/sec.

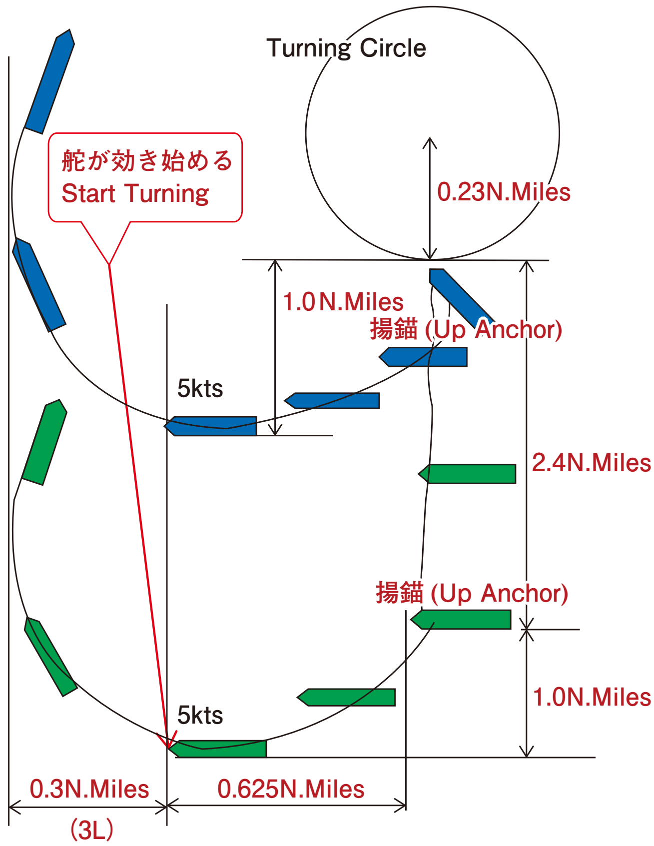


図 3 ／ diagram 3

1. The radius of the swinging circle is:-
   8 shackles (220m) + 200m =420m=0.23 miles

2. Required time for weighing anchor:-
   Whilst weighing anchor, it is deemed that the ship' manoeuverability is uncontrollable.
   The anchor cable recovery rate in moderate weather is known to be 9m per minute.
   Therefore it would take about 24 minutes to weigh anchor in moderate weather. However, in this situation, it would take 1.5 times as long or about 36 minutes. In this interval, the distance which the ship is pressed to leeward is about 2.4 miles (distance covered in 36 minutes at 4 knots).

3. After the anchor is aweigh, further 15 minutes elapse before the vessel's speed reaches 5 knots. During this period, the vessel will drift about 1 mile to leeward (distance covered in 15 minutes at 4 knots).

   The distance sliding horizontally
   (0knot +5knots)÷2 × 0.25 hours = 0.625miles
   Required distance to turn ship's head is 3 times as long as the ship's LOA (=200m)
   200m × 3 = 600m = 0.30miles
   Total： 0.925 miles

Required distance from the anchor position is illustrated in diagram3.

Vertical direction (to leeward) ：3.63 miles （= 0.23miles +2.4 miles+1 mile）
Horizontal direction ：0.93 miles （= 0.625miles +0.3 miles）

Most accidents such as collisions and groundings involving ships occur when anchor drags because insufficient sea room has been allowed for.

Case 2
(diagram 3、blue vessel)

Dragging is detected during the horsing phase and (Blue ship) weighing anchor is commenced immediately.

At the initial stage of swing motion, the ship can weigh anchor and even though the ship's side stands against the wind, the required area for attaining manoeuverability is 1 mile to leeward and 0.625miles horizontally outside of the initial swinging circle.

Vertical direction (to leeward) ：1.23 miles (=0.23 miles +1 mile) Horizontal direction ：0.93 miles (=0.625 miles +0.3 miles)

In practice, the distance to leeward could be shorter than illustrated in diagram3 since the main engine, rudder and bow thruster may be used to advantage. It should be remembered, however, that the use of large rudder angles will decrease the ship's speed.

Detect dragging anchor within the earlier time frame of the swinging motion and decide whether to weigh anchor immediately and leave the anchorage or to re-drop the anchor at another location.

§16 Dropping 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 being made in 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. So to say, 12 shackles (=330m) could totally run out at 33seconds.

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 force.

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

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, as shown in the picture.

After the anchor touches the bottom, the ship's sternway should be limited to about 0.5knot ～ 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.

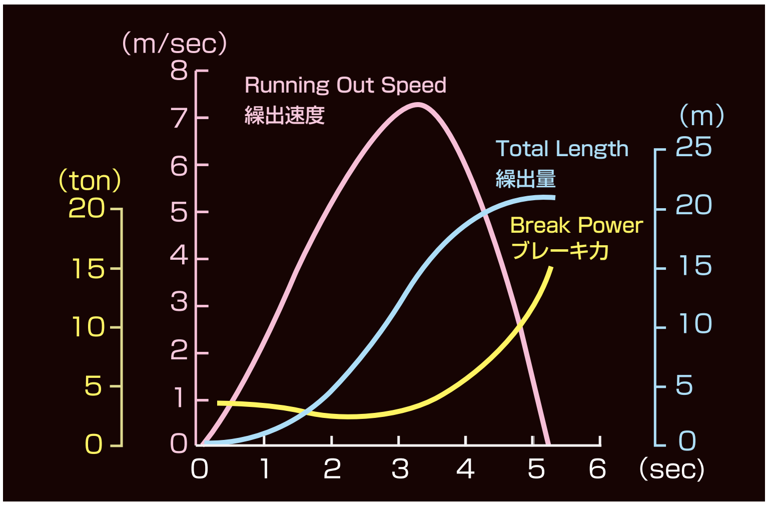
§ 17　The Anchor Cable Veering Rate・Scope of Cable To Be Paid Out・Brake Force of Windlass

Graph1 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 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 in this time 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.



ＶＬＣＣ　投錨実験結果／ Result of VLCC Anchoring
グラフ１／ graph 1

Reference Books
・Theory and Practice of Ship Handling, by Dr. Kinzo Inoue
・Navigation Handbook
・Japan Captains' Association [A Guide to Ship Handling]
・Ship Handling, by Dr. Keinosuke Honda
・Ship Handling, by Dr. Satoshi Iwai
・Study of Ship Anchoring Supporting system (Kobe University)
・Various reference pictures provided by Japan Captains' Association and Nippon Yusen Kaisha

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