of July, at 15:00 JST, the Typhoon Response Committee recommended preparing for evacuation by issuing the first warning. Moreover, because the strong wind area was predicted to reach the port within 24 hours, on the 24th, at 13:00, they issued the second warning. They recommended that ships in the port take strict precautionary measures by taking shelter outside of the port and so on.

On the afternoon of July 23rd when the first warning was issued, the Master had a meeting with the person in charge at the local agent and decided to take shelter at Kagoshima Bay.
On the following day, July 24th, when the cargo was unloaded 17,194 tons, cargo handling was interrupted and the Vessel C left the wharf at 10:40.
The Master was thinking that he had not experience with entering Kagoshima Bay, it would take 11 hours as a round-trip and there was a risk of being close to the centre of the typhoon according to the forecast of the typhoon's path, then. He also judged that the force would decay judging by the information from NAVTEX. Because there was ample spare time until the typhoon approached, the Master decided to choose the anchorage according to the movement of the typhoon from the following three choices as his original plan: ① head for Kagoshima Bay, ② stay anchored at Shibushi Bay without navigating a direct course to Kagoshima Bay or ③ seek shelter offshore. As a result, at 11.30, the vessel dropped her starboard anchor at 6 shackles <056> 2.0 nautical miles off of Birou Island and 2.1 nautical miles off Shibushi south breakwater, light house <193>, where the sea bottom was sand with a water depth of around 25 metres.

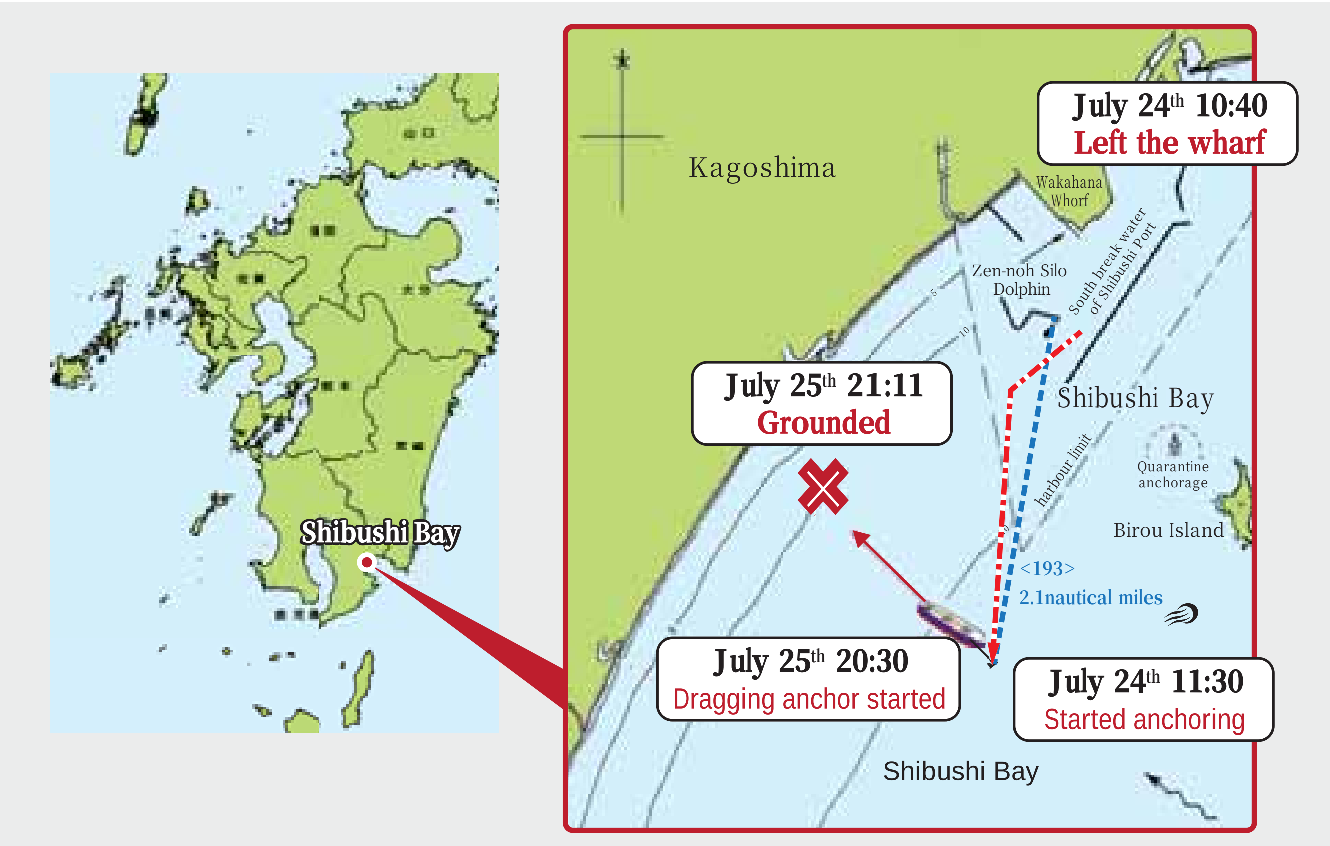


Fig. 54

Afterwards, partly because a similar size of ship, Vessel M started anchoring at Shibushi Bay, Vessel C also continued single anchor mooring with 6 shackles of anchor cable. However, contrary to expectation, the force of the typhoon did not decrease and Shibushi Bay gradually entered the storm area and the right semicircle of the typhoon. Due to the violent storm and swell encroaching on the Bay, at 20:30 on July 25th, dragging anchor occurred and they grounded at 21:11.

Photograph 55 EPIRB

Regarding the damage, cargo holds, between No. 5 and No. 6, near the centre of the hull there was breakage and No. 2 Fuel Oil Tank under No. 5 cargo hold was damaged. Immediately, at the same time as he activated the distress signal by operating the EPIRB, the Master reported the distress to the Japan Coast Guard via international VHF radio communications.
The Master judged that there would be a danger of the damaged part of the hull ending up sideways. At 21:30, the Master commanded all of the crew to wear helmets and life vests in order to abandon the ship. Then they lowered the lifeboats outfitted on both sides of the deck respectively, all of the crew boarded the lifeboat on the starboard side (leeway side) and then they started to lower the lifeboat.

Photograph 56　Breakage

However, the lifeboat was violently beaten against the shell plating of Vessel C due to the gale force winds and high waves while lowering. Also, some crew were injured when their bodies were beaten in the lifeboat. Due to the constant buffeting, all of the crew evacuated from the lifeboat and jumped into the sea. As a result, although 15 out of 19 crew members managed to swim to the nearby coast, 4 (one second engineer, two ABs and one C/Cook) were deceased.

Path of Typhoon No. 9 in 2002: Asian name is FENGSHEN

On the 14th of July 2002, a tropical depression formed in the sea around the Marshall Islands and changed into Typhoon No. 9 accelerating in force and heading north. She took a westerly path in the vicinity of 15 degrees north in latitude and, by the 20th, reached the vicinity of 200 nautical miles southwest of Minami-Tori-Shima island and changed to a northwesterly path nearing the Ogasawara Bonin Islands while gradually increasing in speed.

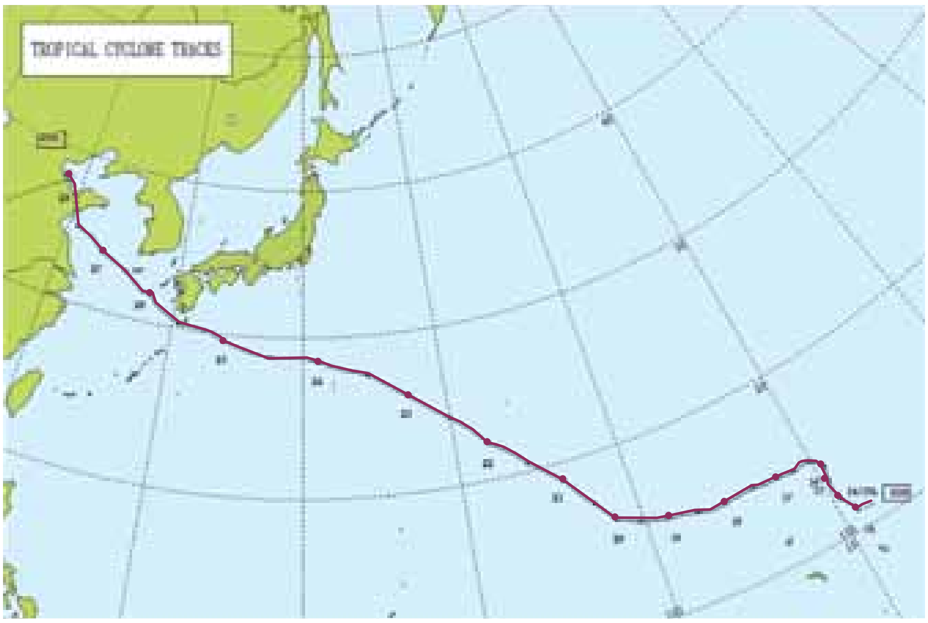


Fig. 57　Path of Typhoon No.9

(1) July 24th

Regarding Typhoon No.9, according to an observation at 00:00 JST, weather information provided by NAVTEX announced that at 03:00, she was located in the vicinity of the northeast at 100 nautical miles away from Chichijima Island of Ogasawara Bonin Islands. She developed into a "strong typhoon" with a central pressure of 945hPa and a maximum wind speed of 41m/s close to the centre. The storm area was 120 nautical miles moving northerly at 25m/s with a strong wind area of 250 nautical miles and a wind speed of more than 15m/s as she advanced into southern Kyushu taking a westerly path at 15 knots.

(2) July 25th

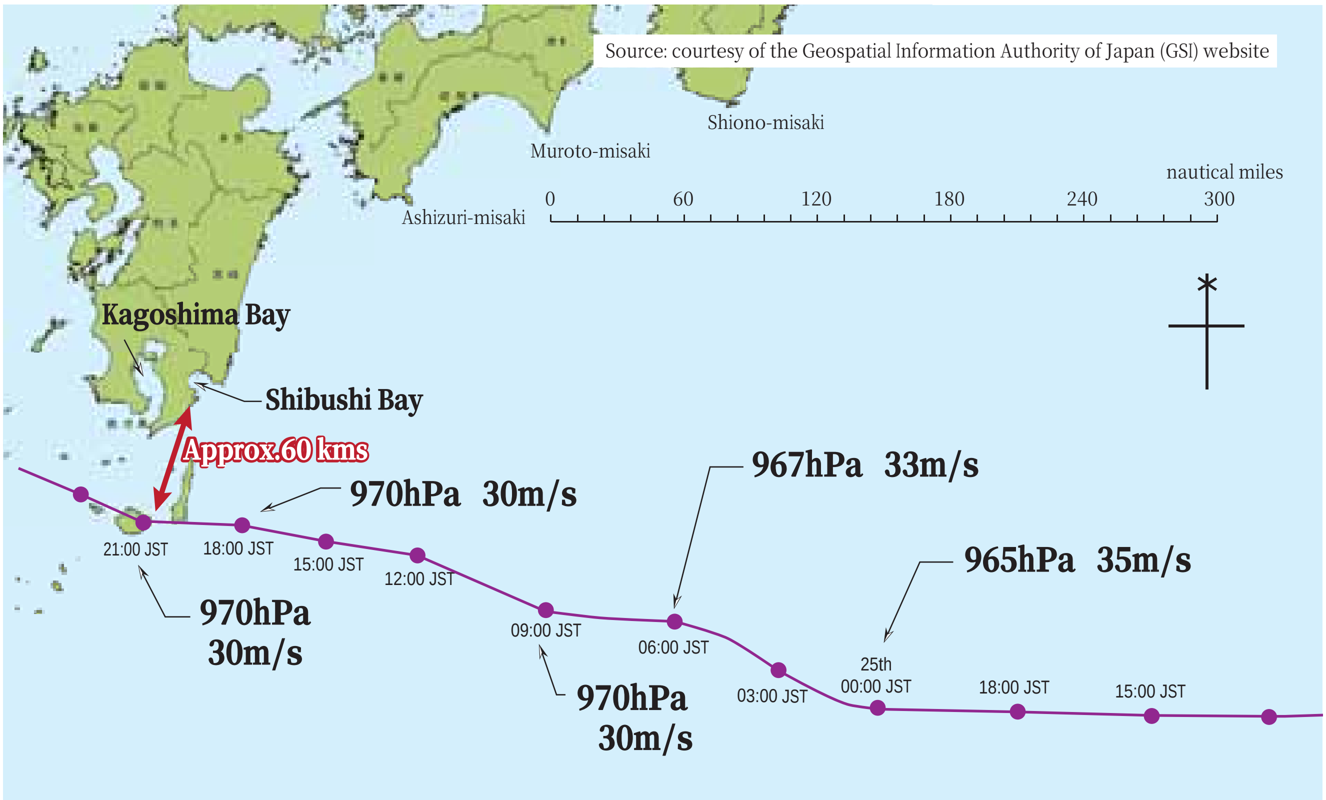


Fig. 58 Path of Tyhoon No.9

On the following day of the 25th, by 00:00, Typhoon No.9 was already in the vicinity of the east-southeast 350 nautical miles from Shibushi Bay, with a central pressure of 965hPa, a maximum wind speed of 35m/s, a storm area of 80 nautical miles and a strong wind area 250 nautical miles. She approached southern Kyushu taking a westerly path and maintained a speed of 11 knots. At 06:00, she reached the vicinity of 240 nautical miles east-southeast of Shibushi Bay and the bay was now in the strong wind area.

Later, by 09:00, Typhoon No.9 was located in the vicinity of <124> 191 nautical miles from the point where Vessel C had anchored in Shibushi Bay and the force had more or less decayed with a central pressure of 970hPa, a maximum wind speed of 30m/s, a storm area of 80 nautical miles and a strong wind area of 270 nautical miles. However, she moved west-northwesterly at a speed of 17 knots and was predicted to pass 50 to 60 nautical miles south of Shibushi Bay between 19:00 and 20:00, if she proceeded on the same path and at the same speed. There was even the possibility Shibushi Bay would be exposed the storm area, in particular the "right semicircle of the typhoon": "a Dangerous semicircle".

On the other hand, although the maximum wind speed was at 33m/s according to an observation at 06:00 by NAVTEX, by 09:00, it had decayed to 30m/s, according to further observation. Due to this, the international notation of Typhoon No. 9 was changed from a “T” to an “STS” (one category down). The maximum wind speed was also forecast to have decreased to 28m/s within the next 24 hours. (Note: please refer to the notes below)

Yet, the storm area of 80 nautical miles did not change, and, at 12:00, Typhoon No.9 was still located in the vicinity of <128> 135 nautical miles from the point where Vessel C had anchored. She proceeded west-northwest at 18 knots with increasing speed, maintaining a central pressure of 970hPa and a maximum wind speed of 30m/s. Then, it was highly likely that shortly Shibushi Bay would come in range of the 80 nautical mile storm area.

By 15:00, with the force of the typhoon still unabated and with a central pressure of 970hPa with a maximum wind speed of 30m/s, she approached the vicinity of <141> 93 nautical miles from the anchored point of the vessel. At approximately 16:30, she reached the vicinity of <150> 80 nautical miles (estimated position) from the anchored point, and the outer edge of the storm area encroached on Shibushi Bay.

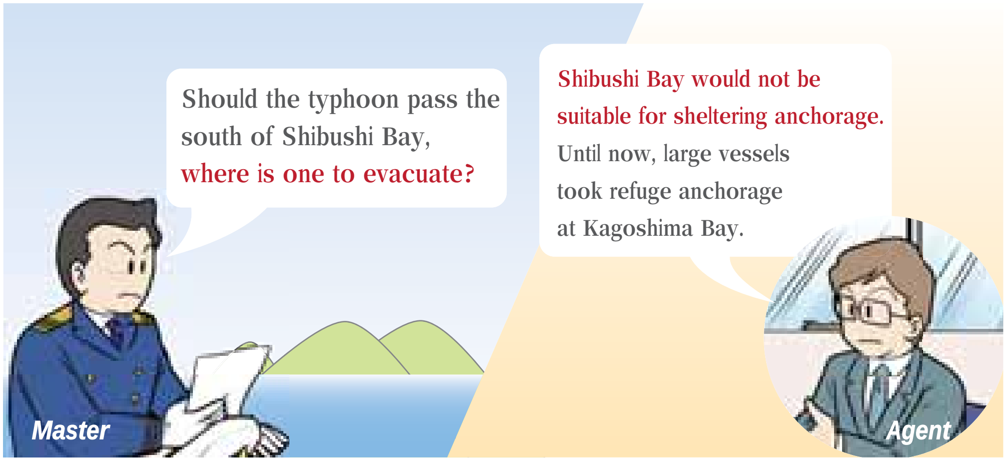
At 18:00, Typhoon No.9 reached the vicinity of 30 nautical miles southeast of Tanegashima Island of Kagoshima Prefecture which was in the vicinity of <162> 73 nautical miles from the anchored point. And then, she moved west. At approximately 19:30, she passed the vicinity of <180> 67 nautical miles from the anchored point, the closest she had been to Shibushi Bay. Furthermore, at 21:00, she reached Yakushima Island in the same prefecture.

Note: In Japan, as explained in page. 2 - 3, it is categorized as a “Typhoon” when its maximum wind speed is greater than 17m/s (wind force 8) and as a “Tropical cyclone” when it is less than 17m/s. On the other hand, according to the international scale, typhoons and storms are classified into the following three categories.

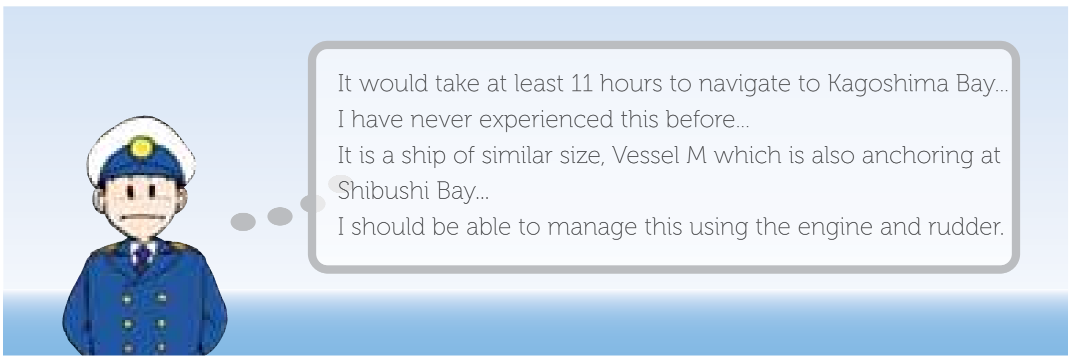
① The maximum wind speed is more than 33m/s (wind force 12): TYPHOON (T)
② The maximum wind speed is more than 25m/s (wind force 10) but less than 33m/s: SEVERE TROPICAL STORM (STS)
③ The maximum wind speed is more than 17m/s, but less than 25m/s: TROPICAL STORM (TS)

In addition, a tropical cyclone that has a maximum wind speed of less than 17m/s is categorized as a TROPICAL DEPRESSION (TD).

Movement of Vessel C

July 21st 01：06	Vessel C arrived at Shibushi Bay. Anchored in the bay in order to adjust the time for berthing.
July 22nd 06：34	A pilot registered with the Kagoshima Licensed Pilot's Association embarked.
07：36	Berthed at the quay of Zen-Noh Silo Corporation and started cargo discharging work. Total of 9 crew members (the chief officer [Indian national] and 8 other members (Filipino nationals) disembarked. Total of 5 crew members (the successor chief officer [Indian national] and 4 other members [Filipino nationals]) embarked. Note: Decrease of four crew members
July 23rd 15：00	Because the strong wind area of Typhoon No.9 was predicted to reach Shibushi Bay within 48 hours, the Typhoon Response Committee issued the first warning and announced the recommendation of preparing for evacuation. Later, the Master and the person in charge at the local agent discussed the following items in their meeting.  As a result, the Master decided to leave the wharf on the following morning and shelter from the typhoon in Kagoshima Bay. At the same time, in order to carry out draft adjustment, the Master changed the discharging plan in order to complete the cargo discharge of No.2 and No.6. He also arranged for the ballast tanks to be filled so as to adjust departure condition fore draft 8.00m and aft 11.60m.
July 24th 10：40	After completing discharge of No.6 cargo, filling ballast was also completed. At the time when 17,194 tons had been unloaded, the cargo handling was interrupted in order for the ship to leave the wharf (with a remaining 40,280 tons still loaded).

11：30	After the pilot disembarked, the Master decided to anchor at Shibushi Bay without taking a direct course to Kagoshima Bay that was originally planned as a sea area of sheltering. The Master decided to observe the movement of the typhoon and anchor using the starboard anchor at 6 shackles at 2.1 nautical miles from south of the breakwater. The water was at a depth of 25m and the sand type was sea bottom sedimentary. The reason for the change of plan, as mentioned above, was because the following three anchoring methods were planned. Paying attention to the movement of the typhoon, the Master decided to observe the situation while anchoring at Shibushi Bay. ● To anchor at Shibushi Bay ● Avoided sailing into the open sea to keep a distance between the ship and the typhoon ● To shelter at Kagoshima Bay
13：00	Because the strong wind area was predicted to reach Shibushi Bay within 24 hours, the Typhoon Response Committee issued a second warning.
	In the evening, the Master got to know that a ship of similar size, Vessel M (38,567 tons), left the wharf in a similar way and started anchoring at Shibushi Bay.
July 25rd 06:00 (observed)	The strong wind area encroached on Shibushi Bay. Typhoon No.9 was in the vicinity of <117> 243 nautical miles from the anchored point and she was proceeding west-northwesterly at 16 knots. Because Shibushi Bay had entered the storm area at 250 nautical miles, if she continued to proceed on course, it was estimated she would pass at approximately 50 nautical miles south of Shibushi Bay between 19:00 to 20:00.
09：00 (observed)	There was a possibility that Shibushi Bay would enter the storm area of the right semicircle of the typhoon. Typhoon No. 9 was proceeding west-northwesterly at 17 knots close to the vicinity of <124> 191 nautical miles from the anchored point and it was estimated that there was a possibility of Shibusi Bay entering the storm area of the right semicircle of the typhoon.
	The Master only used the typhoon information provided by NAVTEX. Although the Master wrote down the position, path and speed of the typhoon on the nautical chart, he did not write down the fact that the ship was in a strong wind area or a storm area. In addition, the Master obtained the following information from NAVTEX. ● Category of the typhoon was downgraded by one category from T to STS. ● It was forecast that the wind speed would decrease to 28m/s within the coming 24 hours. Furthermore, because it was still observed that the wind speed was less than 10m/s and the wave height was at 2m, the Master decided to stay sheltered at Shibushi Bay.



12：00 (observed)	The Master obtained the information from NAVTEX that Typhoon No.9 was proceeding west-northwesterly maintaining a force of 970hp and a storm area of more than 30m/s.
16：00	North wind suddenly became strong and the wind speed exceeded 15m/s. Also, the height of the swells which encroached the bay mouth increased. Anchoring watch was enforced, however, the Master stayed sheltering at Shibushi Bay without evacuating to the open sea.
16：24	Started use of engine keeping 6 shackles of anchor cable.
16：30	Shibushi Bay entered the storm area at the right semicircle of the typhoon.
17：00	Wind direction changed to northeast. Wave height at 3 meters.
19：30	The typhoon moved the closest at this point, with a wind direction now changed to east-northeast. Wind speed was 17m/s, maximum instantaneous wind speed was 28m/s and wave height was 5m.
20：30	Started dragging anchor. Wind speed was 25m/s, the maximum instantaneous wind speed was 35 to 41m/s and the highest wave height was 8m.
20：40	Confirmed anchor dragging via radar. Started weighing the anchor, but this became constrained when heaving the cable to 2 shackles of 6 shackles. It was because the cable was extremely tense, even with the engine at full speeded ahead. Tried to prevent drift by using the engine. Even if it was temporarily effective, it was not possible to stop it completely.
21：11	Aft part was grounded at the point of south <238> 1.9 nautical miles from the breakwater in Shibushi Bay, water depth at 10m. Immediately after this, cargo holds between No.5 and No.6 near the centre of the hull were broken and the No.2 Fuel Oil Tank under the No.5 cargo hold was damaged. The Master judged that there was a possibility that the damaged aft part might rollover. Then, as was described above, at the same time of activating the distress signal via EPIRB, the Master reported the distress to the Japan Coast Guard by VHF.
21：30	The Master commanded all crew to wear life vests and started abandoning ship with the lifeboat outfitted on the starboard side (leeway side). However, the lifeboat was violently beaten and damaged due to the gale and high waves. Because some were injured, all crew jumped into the sea, however, 4 crew members out of all 19 members were confirmed as deceased.

= Quoted from the Marine Accident Inquiry Agency (MAIA) determination =
Provisional translation

The following were analyzed as main accident causes.

① Insufficient realization regarding the typhoon

- Wishful observation that the typhoon's force would decay because of the typhoon information provided by NAVTEX.
- Lack of crisis consciousness regarding the entering of a storm area, changes of wind direction and encroachment of gale and high waves.
- Lack of awareness towards typhoons by the Master and each navigation officer

② Insufficient information of sea area for sheltering etc.

The Master decided to take refuge at Kagoshima Bay, because when the Master and the local agent had a meeting, the Master of Vessel C asked the person in charge of the local agent where he should sheltering and he was advised by that person that "Shibushi Bay was not suitable for sheltering anchorage. Until now, large vessels took refuge anchorage at Kagoshima Bay". In fact, as described above, the Master did not navigate to Kagoshima Bay and stayed anchored at Shibushi Bay.

- The Master made his judgement based on only what the local agent told him and typhoon information supplied by NAVTEX.
- Thus, there was insufficient typhoon information (such as the range of strong wind or storm areas, wind direction, wind speed etc.)
- One of the reasons to keep anchoring at Shibushi Bay was that it would take an extra 11 hours to sail in the storm to Kagoshima Bay and, once again, the vessel was to return the Shibushi Bay, if the typhoon was to pass.
- The Maser was hesitant to enter Kagoshima Bay, as he was not familiar with the area.
- According to typhoon information provided by NAVTEX, the category of the typhoon was downgraded by one rank to category "STS". With this information, the Master judged that the typhoon would decay naturally, however, the wind speed did not decrease and a large swell encroached into the bay again.

③ The Master had a false sense of security because a vessel whose size was similar was also anchoring.

- The Master felt a false sense of security, because a foreign registered Vessel M (38,567 tons) was anchoring at the Port of Fukushima off in the northeast part of Shibushi Bay.
- Vessel M was advised: "If there is a wind from the East, Fukushima port off in the northeastern area of Shibushi Bay should be suitable" by their pilot, and conducted single anchor mooring with 9 to 10 shackles at that port. Although she dragged anchor due to a violent storm and swell, she managed not to get grounded.

3－4 Questionnaire conducted by the Marine Accident Inquiry Agency (MAIA) for Masters of the coastal vessels that experienced sheltering from the typhoon

When the Marine Accident Inquiry Agency (MAIA) at that time issued their Maritime Casualty Analysis Report (Vol. 6): “Typhoons and Marine Accidents”, they conducted a questionnaire for Masters of the coastal vessels that actually experienced sheltering from typhoon. Some of them are introduced here, as there were many practical comments.

There were many comments, such as
“Matters to note when sheltering from a typhoon”

◉ Paying attention to the distance between one’s own vessel and the one anchored nearby, the Master was cautious regarding both the anchoring of his own ship and other ships.

◉ While the typhoon was nearby, the Master was careful to observe changes in wind direction following her passing and the strong wind that would be blowing back.

◉ Because a foreign registered ship tends to conduct single anchor mooring and can easily drag anchor, the Master tried not to anchor in the vicinity of those ships. He especially avoided being leeward in relation to the position of those ships.

◉ Using the engine, steering and thruster, the Master tried to stand bow against the wind.

◉ Commenced anchoring watch and stand-by of the engine at an early stage.

◉ Because a strong wind was predicted and there were many anchoring ships in a narrow anchorage, in an attempt to not cause horsing (yawing and swaying), the Master conducted two-anchor mooring in order to increase the holding power.

◉ The Master wrote down the vessel names of the anchoring ships nearby, in case there was an incident of dragging anchor, it would have been possible to contact the other ships via VHF or telephone.

◉ Estimated the wind direction at the time of maximum wind speed, and applied two-anchor mooring in that wind direction.

In addition, other specific comments will be introduced.

In the event of wind speed exceeding 35m/s, it is dangerous to carry out an anchoring work at foreward station. Thus, the Master judged it would be difficult to heave up anchor because it was in excess of 40m/s. Therefore, the Master weighed the anchor before the wind became strong and heaved-to while keeping course so as to receive the wind at the right ahead with a headway speed to some extent.　(Large ferry)

The Master dared to conduct single anchor mooring, because Hakodate Bay was predicted to have high waves sooner or later. Because she dragged anchor at a wave height of 3m, the Master managed to keep not getting pressed by using the engine. Single anchor mooring is desirable, if we are to prevent collision accidents due to another vessel’s dragging anchor. It is impossible to prevent accidents using two-anchor mooring. (4,000 G/T Coastal Tanker)

Because the wind speed exceeded 20 m/s, the chief engineer was stationed in order to prepare for S/B engine. While the hull was yawing in a "figure-of-eight" movement, the angular velocity of blowing back was faster than that of the large cargo ship, thus it was originally a mistake to judge that the holding power would be strong enough, which resulted in the subsequent response. At that moment, the Master should have judged that a strong wind force was to press instantaneously on the side of the vessel and prepared the engine and thruster. (Large ferry)

If the fore station operation was deemed to be dangerous at the time of weighing the anchor, pressure could have been prevented by using the engine. When contacting the Japan Coast Guard regarding anchorage location and to ascertain information about anchorage, they kindly responded and even gave information about where the typhoon was heading. (3,552 G/T Coastal Tanker)

Judging from the path of the typhoon, the Master carefully judged as to whether it was a suitable place to anchor by considering which direction the wind would blow and condition of gales and waves that may affect where the ship was planning to anchor. After having anchored, the Master made sure to write down the names, positions etc. of other ships nearby so that he may contact them immediately in case of an emergency. Regarding how harsh nature can be, it is a must to always consider countermeasures because one can never be well-prepared enough.

Because the vessel was too concerned with cargo handling, the commencement of sheltering was delayed. Cargo handling should have been suspended, and the crew should have taken refuge earlier evacuating to Mutsu Bay if it was possible. Off the coast of Kitaura (off the Oshika Peninsula) was not a suitable choice for anchorage because the kind of sea bottom was too rocky for anchorage, and fishing equipment was set up in the vicinity. Anchor as early as possible. It would be difficult to lower anchor as planned after the typhoon had come into close proximity and the wind force had increased. Also, it would be constraining to find a suitable position in relation to other ships. It is important to plan for anchoring not only for during the night but also during the daytime.

§ 4　Mechanism of dragging anchor

The following are important extracts from our Loss Prevention Bulletin Vol.25 titled " Preventing an Anchor from Dragging " which was published on the 13th July, 2013. For details, please refer to this guide.

4−1　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 realize the anchor is dragging, despite the fact that the ship is drifting.
②	It takes some time to weigh the anchor and restore the ship to full manoeuvrable condition, even though the ship may be drifting for that period.
③	During the period beginning with the detection of dragging to the time full control is achieved over the ship's manoeuvrability, 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 manoeuvrability and enough time available. The above three considerations may also be applied to the cases introduced in the previous chapter (excluding vessel capsize due to heavy weather).

4−2　The reasons as to why an anchor drags

A ship's anchor drags due to the impact of external forces on it which exceed the holding power of the anchor and cable. That is, dragging anchor occurs as a result of a relatively simple reason: "When an external force exceeds that of the anchor's holding power, it will drag".

Holding power < External force ▶▶ Dragging anchor

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

The following is a well-known method for assessing the Minimum Required Length of Anchor Cable, however, factors related to ship type, actual wind speed etc. are not found in this method. It can be considered that those factors were consolidated in the process of formulating this method for the minimum required length of an anchor cable.

Japanese Publication Theory of Ship Operation

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

United Kingdom Publication Theory of Ship Operation

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

L：Minimum required length of anchor cable(m)

d：Water depth(m): up to a wind speed of around 30 m/s.

According to the Marine Accident Inquiry Agency (MAIA), at that time the wind speed and wave height which corresponds to the Japanese theory are introduced as simulation results and actual statistical data regarding the anchoring situation of 700 coastal vessels, when the landed typhoons (10 typhoons) passed in 2004, are documented in their publication titled Maritime Casualty Analysis Report (Vol. 6): Typhoons and marine accidents (in 2006). The findings are as follows. Naturally, because this theory or guideline will vary depending on the type of sea bottom and anchorage conditions regarding one's ship and the other ships, actual minimum required length of anchor cable is to be determined, with safety being the priority.

Fine weather

When, L = 3d + 90m → Wind speed 20m/s and wave height up to 1m

Rough weather

When, L = 4d + 145m →

- Ferries etc. Wind speed 25m/s and wave height up to 2.5m
- Others Wind speed 30m/s and wave height up to 2.0m

The above guidelines will vary depending on the type of sea bottom and the condition of sourrounding ships in anchorage.

In addition, in the publication of the Maritime Casualty Analysis Report, the simulation results are introduced and attempt to answer question regarding the difference in the anchoring limit between "being exposed to wind only" and "being exposed to wind and swell" concerning cases in (3-3) in reference to Vessel C.

When exposed to only wind from the ahead

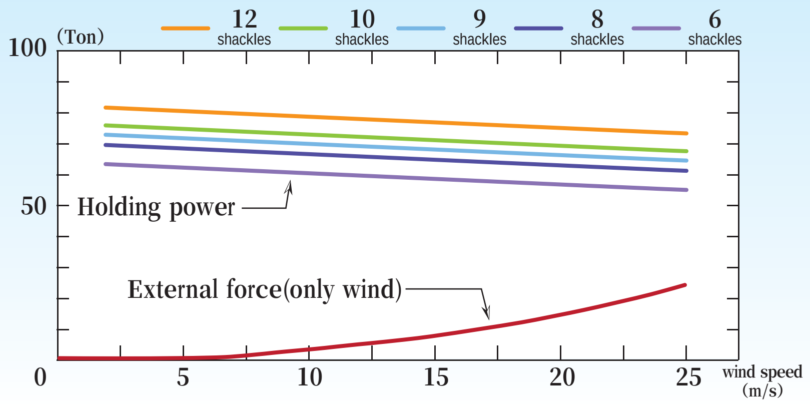


Fig. 59

As can be seen from the anchor holding power of the anchor and anchor chain, which will be referred to later, because the bottom part of the anchor chain decreases when wind pressure increases, it was found that the anchor does not drag until the wind speed is 25m/s and when the minimum required length of anchor chain in the water is more than 6 shackles, although anchor holding power does decrease.

When exposed to wind and swell (wave height 5m and wave length 200m) from the ahead

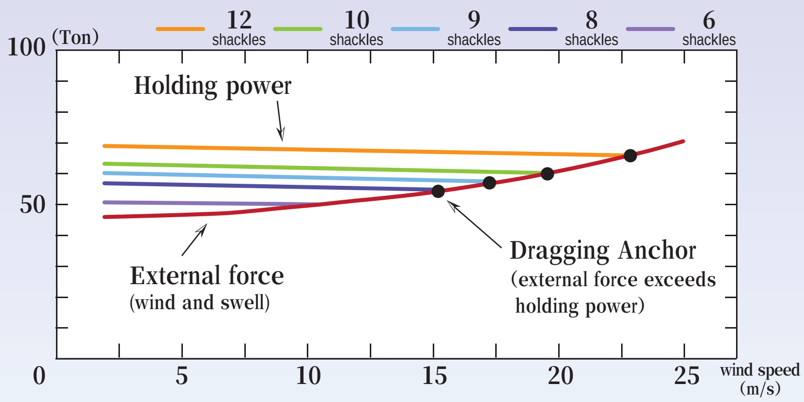


Fig. 60

In the event that a swell is added, due to Wind pressure force + Wave drift force (the force at which a wave moves a floating object), the anchor chain tension reaches approximately 50 tons at a wind speed of 10m/s and exceeds its holding power at 6 shackles at this point in time. Also, it was revealed that the anchor drags at 8 shackles at a wind speed of 15 m/s and at 12 shackles at a wind speed of 25m/s.

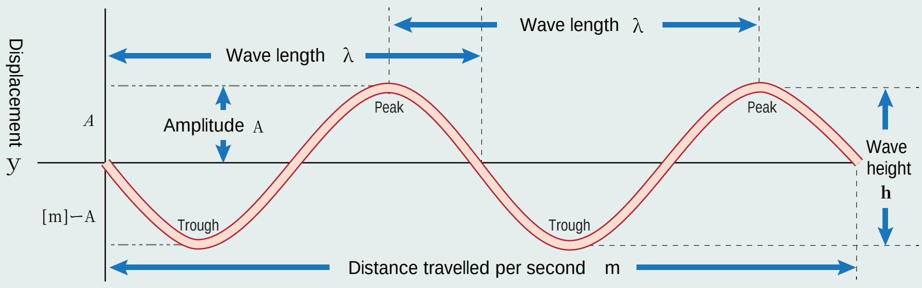
Don' t underestimate "swell" and "wave height" which may cause ship motion during anchoring.

Watch out for wind and for waves ! !

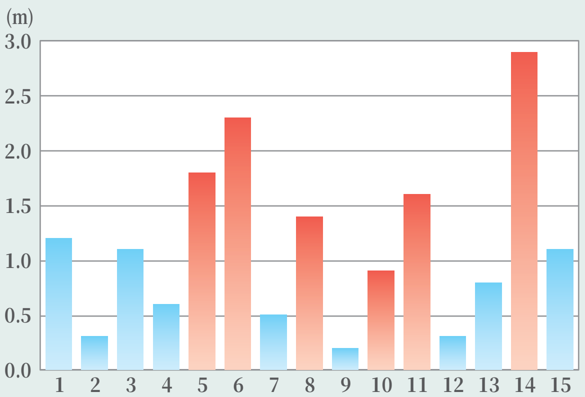
- Be careful regarding changes in wind direction, when a typhoon or windy atmospheric depression approaches.
- At sea, where there are few structures against wind, it is estimated that the maximum wind speed will be be1.5-2 times stronger than the average wind speed.
- The higher the swell becomes, the greater the danger of dragging anchor will be, remarkably. Anchor at a position where the encroachment of a swell is expected is to be avoided. Occasionally, the maximum wave height may be 1.5-2 times of that of the significant wave height (*1).

*1) Significant wave height (from the Japan Meteorological Agency website)

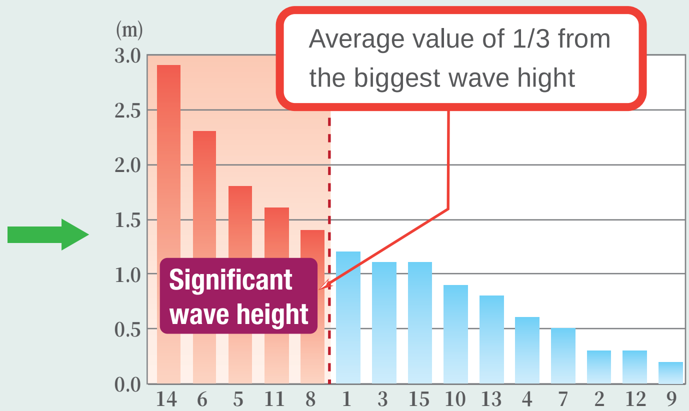
Choose 1/3 of the wave observations (within a timeframe of 20 mins.) in descending order from the top. Of those, the average wave height and period becomes the significant wave. According to this definition, this is also referred to as the "1/3 maximum wave".



Graph expressing waves: in the event that two waves are generated per second



Wave hight detected at a point
(Irregularly changing)



Sort in descending order of wave height

4—3　Detection of dragging anchor

There are conventional methods to check for anchor dragging:

①

Check the ship’s position, to confirm whether it is located outside of a turning circle (see Fig. 61).

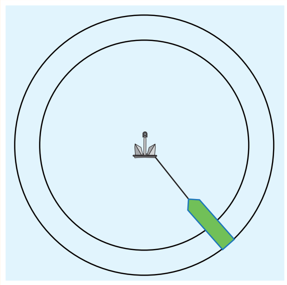


Fig. 61　Turning Circle

②

The bow cannot stand against the wind.

③

The ship's side against the wind has not changed.

④

Check to see that there is no slacking of chains, just before a ship’s side is about to turn against the wind.

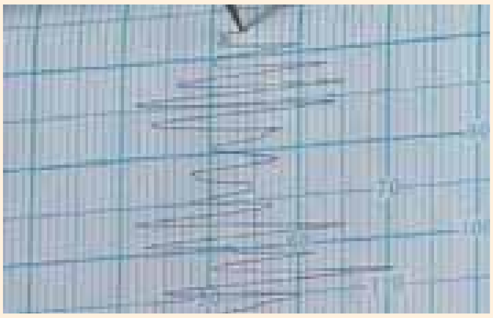
⑤

Check as to whether there are extraordinarily large vibrations coming from the anchor chains.

⑥

In the event that the course recorder does not show a sine curve movement.

Photograph 62 shows the course record when being anchored while being exposed to wind at a wind speed of 8 m/s, when the author was on board a Pure Car Carrier (PCC). It is difficult to tell if it is a sine curve movement or not.



Photograph 62

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.

= Actual ship movement at the time of anchor dragging =

With GPS now being commonplace, a recent study analysis shows that anchor dragging is a phenomenon that consists of two different stages. This study points out that anchor dragging started before it was detectable, prior to conventional methods of dragging anchor detection today (the first stage: dragging anchor with yaw and sway). (Note: this is not applicable when the anchored point is precisely written down, whereby even a slight change in the ship's position can be grasped.)

The first stage: dragging anchor with yaw and sway

The yaw and sway motion of a ship during anchoring is often compared to a "figure-of-eight" pattern. (Part "A" in the diagram to the right shows that the anchor is not dragging.) It has been found that as wind pressure force begins to exceed the anchor's holding power, the ship yaws and is pressed transversely, as shown in area "B" in the diagram. Also, it should be relatively easy to control the manoeuvrability of a ship and weigh the anchor).

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 transversely at a certain speed, as shown in area "C" in the diagram. The conventional method of detecting anchor dragging takes place at this stage. At this stage, it is getting difficult (more time is needed) to weigh the anchor and if weighing the anchor cannot be accomplished, it is almost impossible to start manoeuvring.

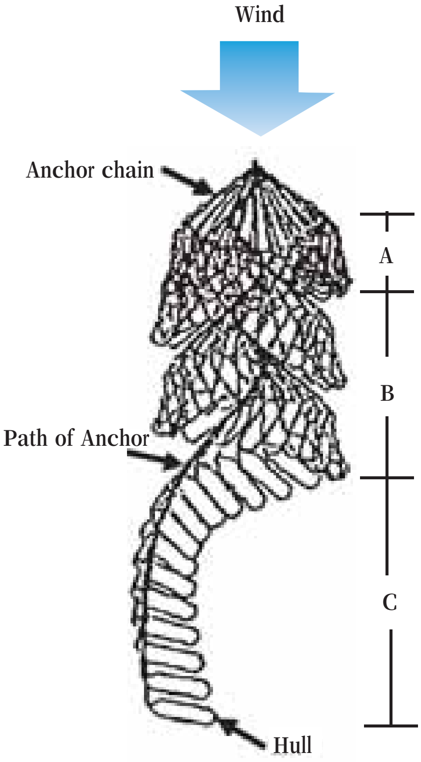
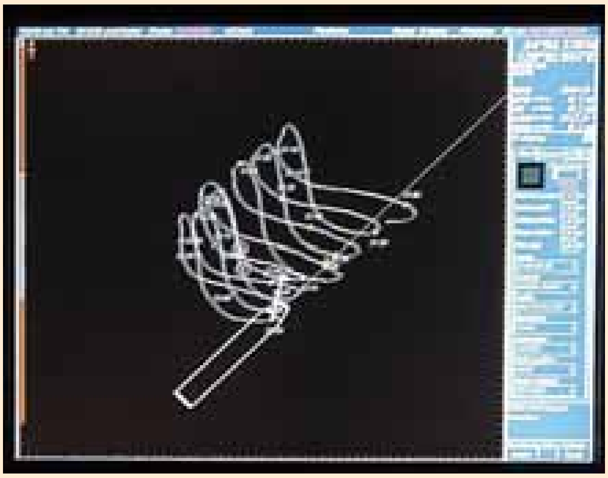


Fig. 63

Using tracking devices that display location information such as GPS, ECDIS and RADAR, it is now easy to detect anchor dragging during the first stage. When an anchor does drag now, in addition to the usual methods of detection concerning dragging anchor, it is desirable that "early prediction" and "early detection" of a dragging anchor be the norm and that "safety countermeasures are taken as early as possible".

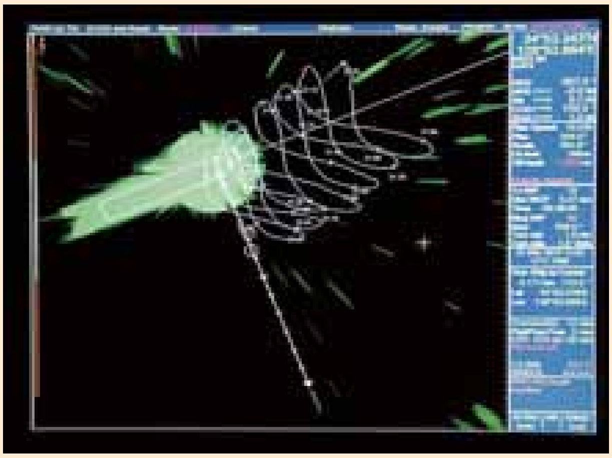
Photographs 64, 65 and 66 are actual displays of the ECDIS and RADAR when the author was on board the Pure Car Carrier (PCC). It was possible to grasp the actual ship's movement using the ship's position record and the electronic displays.

Display of ECDIS and RADAR



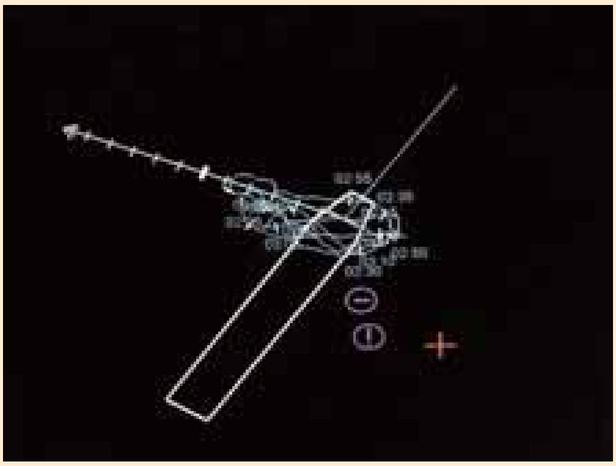
Photograph 64

Using the ECDIS display, it is possible to view the full size of the hull by narrowing in on the display range. Also, GPS tracks are shown for approximately 60 minutes.
This helps us understand the first stage in more detail: Dragging Anchor with Yaw and Sway.



Photograph 65

Similarly, the RADAR range was set to 0.75 nautical miles and the track of the GPS was set for 60 minutes.
This helps to solidify understanding of the first stage: Dragging Anchor with Yaw and Sway.



Photograph 66

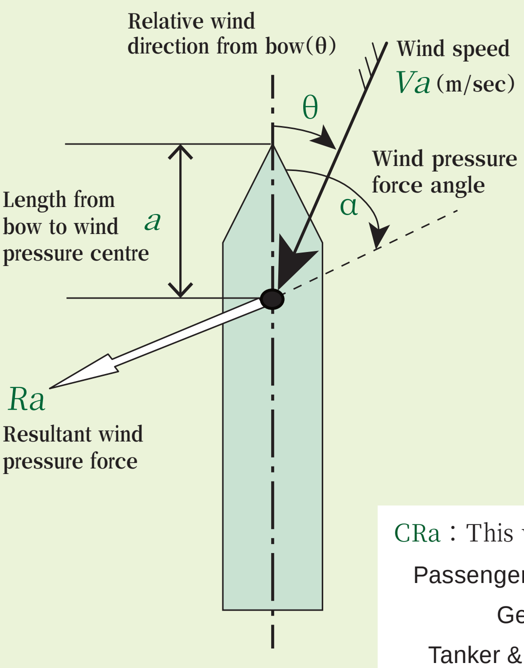
Because there were no other vessels at anchorage, an anchor dragging wind pressure experiment was conducted. The hull faced sideways to the wind direction instantly and was pressed at a speed of 3 to 4 knots, thus more time was required for weighing the anchor.

4—4　Wind pressure force

In order to have a grasp of the external forces that cause anchor dragging, we must have an understanding of the wind pressure force. Wind pressure force can be calculated with the following “Hughes Formula”.

Hughes Formula

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



- θ ：Wind direction from bow [degree] (Relative Wind Direction)
- Va ：Headwind speed [m/sec]
- ρ ：Air density [0.125 kg · sec /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)
- CRa ：Wind pressure force coefficient (this can be calculated by the following formula)

CRa：This varies for different ship types, as follows.

Passenger, PCC, Ctnr	：1.142−0.142cos2θ−0.367cos4θ−0.133cos6θ
General cargo	：1.325−0.050cos2θ−0.350cos4θ−0.175cos6θ
Tanker & bulk carrier	：1.200−0.083cos2θ−0.250cos4θ−0.117cos6θ

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

It is difficult to calculate for wind pressure force at a specific time instantly when manually calculating. However, it is easy to calculate the wind pressure force once the formula has been input into a PC. Examples for reference using Excel are shown in Table 67.

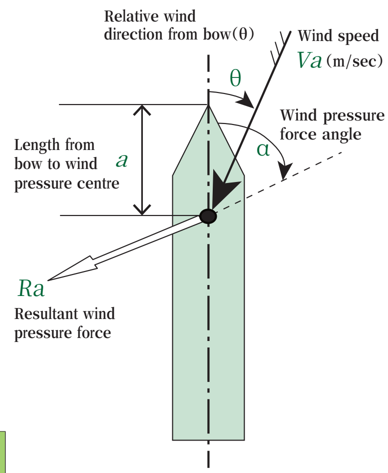
Wind Pressure Force Cal.：Just Reference

1　This formula calculates the wind force of your vessel at the wind speed.
2　The wind force coefficient in each kind of ship is calculated automatically.
3　Input the following data

Loa (m)	200
(Projected area (Front)) (m2) (A)	800
(Projected area (Side)) (m2) (B)	5,800
(Wind Speed) (m/s)	19.5 (Ave.Wind Speed × 1.25 or 1.50)
(Kind of ship) (Passenger, PCC, Ctnr:1 General Cargo : 2 Tanker, Bulker: 3)	1

＊ Input Wind Speed by below ref. data

Less than 8 m/s	: Ave. Wind Speed
Strong Wind : 8 ～ 13m/sec	: Ave. Wind Speed × 1.25
Storm Wind : More than 13m/sec	: Ave. Wind Speed × 1.50



RESULTS

(θ) Wind direction from bow (deg)	(*Ra*) Total wind force (t)	(*RL*) Longitudinal(t)	(*RT*) Transverse(t)	(*a*) Point of action(m)	(*α*) Angle of action(deg)	(CRa) Factor
0	14.26	14.26	0.00	58.20	0.00	0.75
10	20.84	18.50	9.60	62.80	27.43	0.92
20	43.23	30.23	30.90	67.40	45.62	1.31
30	80.39	40.60	69.38	72.00	59.67	1.65
40	118.01	40.06	111.01	76.60	70.15	1.73
50	139.78	29.83	136.56	81.20	77.68	1.58
60	145.98	18.21	144.84	85.80	82.83	1.35
70	150.59	9.95	150.26	90.40	86.21	1.22
80	159.95	4.46	159.89	95.00	88.40	1.19
90	165.41	0.00	165.41	99.60	90.00	1.20
(Impact)	85.56	Wind Force on Front（θ＝0）× 6，Tanker/Bulker × 4)				

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

Impact Force :
Wind Force on Front × 5 ～ 6 for PCC/CTNR/Passenger ship, × 3 ～ 4 for Tanker/Bulker

Table 67

Regarding the calculating formula in the table, the following were used.

Calculation Formula in Above table

Total Wind Force

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

Longitudinal Force

$$RL = Ra \times \cos\alpha$$

Transverse Force

$$RT = Ra \times \sin\alpha$$

a　Point of Action

$$a = (0.291 + 0.0023 \times \theta) \times Loa$$

α　Angle of Action

$$\alpha = \left\{1 - 0.15 \times (1 - \theta/90) - 0.8 \times (1 - \theta/90)^3\right\} \times 90$$

Wind Pressure Co-efficiency (CRa)

1　$1.142 - 0.142\cos 2\theta - 0.367\cos 4\theta - 0.133\cos 6\theta$　(Passenger Ship / PCC / Container)
2　$1.325 - 0.050\cos 2\theta - 0.350\cos 4\theta - 0.175\cos 6\theta$　(General Cargo)
3　$1.200 - 0.083\cos 2\theta - 0.250\cos 4\theta - 0.117\cos 6\theta$　(Tanker / Bulker)

Impact Force

PCC/CTNR/Passenger Ship	Wind Pressure on Front × 6
Bulker	Wind Pressure on Front × 4

4—5 Holding power created by anchor and anchor cable

Holding power created by anchor and anchor cable

$$H \text{ (Holding power created by anchor and anchor cable)} = Ha + Hc = \lambda a \times Wa' + \lambda c \times Wc' \times \ell$$

H	: Holding Power Created by Anchor and Anchor cable (kgs)
Ha	: Holding Power Created by Anchor (kgs)
Hc	: Holding Power Created by Anchor cable (kgs)
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 cable (m)
λa	: Anchor Holding Factor
λc	: Anchor Holding Factor

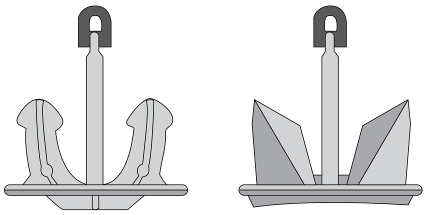
Anchor holding power during anchoring is the sum of "holding power by anchor" and "frictional force of anchor cable lying on the sea bottom".

The holding factor of an anchor or anchor cable (λ a and λ c) is different depending on the type of anchor or type of sea bottom. The anchor holding factor (λ a) and anchor cable holding factor (λ c) of a JIS type or AC14 type are shown in Tables 68 and 69 respectively.

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**

Table 68



λ c : Anchor Chain Holding Factor

	Holding	Dragging	
λ c		Sand	Mud
	0.75 ～ 1.0	**0.75**	**0.60**

Table 69