§3 Traffic Systems of the Kii Suido (Strait) and Tokyo Bay

We referred to the traffic system in §2-3-3, and the author conducted BTM briefings for navigation officers when they are operating in the sea area. We are pleased to introduce these to you for your reference.

§3-1 The Kii Suido (Strait)

(See Fig. 30: Attachment ① The Kii Suido (Strait) Traffic System Chart Enlargement)

This sea area can be roughly divided into the following two sea routes:

① The route that goes to and from Osaka Bay via the Tomogashima Strait (indicated by the red ➡ and green ➡ lines on the map).

② The area off the Kii Peninsula – Naruto Strait route (➡ only suitable for small vessels under 5,000 GT)

When going to and from the Seto Inland Sea, these voyage routes are measurably shorter than going through the Akashi Strait (which takes an indirect route around Awaji Island).

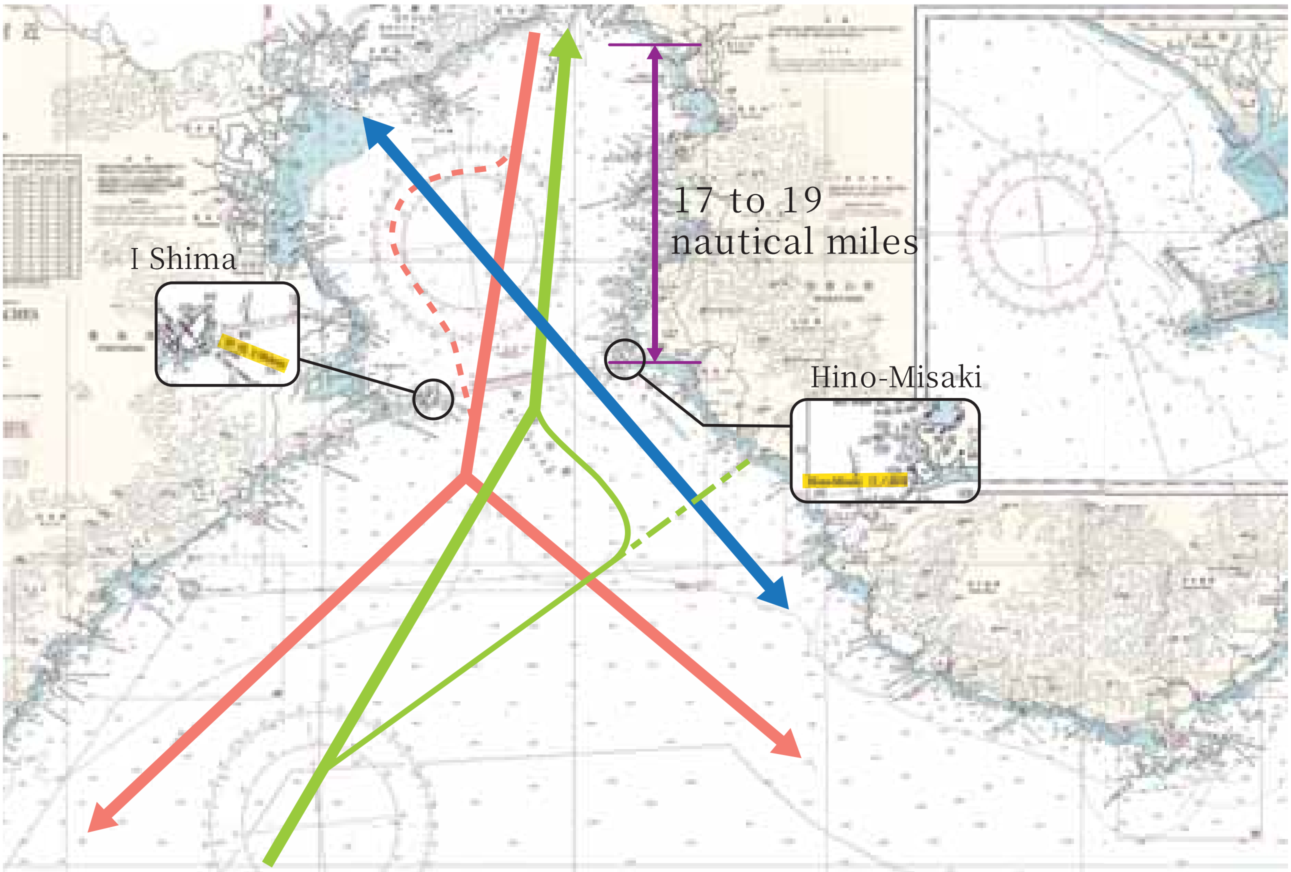


Fig. 30 The Kii Suido (Strait) Traffic System Chart

Because these two traffic systems are crossing in the Kii Suido (Strait), this means that this is an area in which it is necessary to be on the alert at all times. Article 15 of COLREGs (Crossing Situation) was most generally applied in this area. However, as can be seen on the map, the crossing of vessels in this area takes place at an angle close to overtaking, and if the give-way vessel uses a change of course in order to avoid collision, she is forced to use a large angle to change course.
In the case explained in this report, if Vessel A used a momentary heading manoeuvre in the direction of the astern of Vessel B in order to avoid collision, she would have to change course from 190 to 248 degrees.

When a large angle to change course of this type is performed in these waters, as in the case of Vessel A, the bow of the give-away vessel ended up pointing in the direction of Tokushima. Naturally, even if she turns towards the astern of the other vessel, the give-way vessel can be manoeuvred in such a way as to follow the astern, making it possible to return reasonably quickly to her original course. Therefore, the deviation of the give-way vessel from the original course is not that great. However, psychologically, this means heading the vessel straight towards the coast, navigation officers without much experience and whose technical skills are not sufficient can hesitate to carry out such an avoidance action. In view of this, and as seen in the accident presented in this report, this allows some understanding of the fact that the third officer of Vessel A in question only changed heading course by 6 degrees.

If the vessel in question is heading towards Osaka Bay, she can navigate following the traffic system leading towards the Naruto Strait. The vessel can successfully fade out from the sea off Hinomisaki and head towards Tomogashima Island. This is not a particularly difficult manoeuvre.
A vessel heading towards Osaka Bay from the sea off Muroto and navigating along the coast of the Kii Peninsula in a north-easterly direction can see another vessel heading towards the Naruto Strait (north-west operation vessel indicated by the blue line on the map) on her starboard side. This makes the vessel heading towards Osaka the give-way vessel.
Especially in the area between Shionomi and the Naruto Strait, the many coaster vessels navigate in a line, so the crews of these vessels must experience difficulties in trying to avoid collisions with other vessels.

If a vessel trying to push across from I-shima Island to Hinomisaki is in danger of being hit in the sea off Hinomisaki by a crossing vessel heading towards the Naruto Strait, the said vessel will have to make a wide turn to starboard at the mouth of the Kii Suido (Strait). However, as the coast is visibly very close, it is difficult to find a stretch of water that will allow her to alter her course to starboard side in order take avoidance action.

Therefore, one suggestion when navigating in the wide sea area heading from the sea off Cape Muroto to Osaka Bay, would be to follow the traffic system from Shionomi to the Naruto Strait, and to position the vessel in the wide waters to the south of Hinomisaki, and to then take a course allowing a successful fade out in the sea area off Hinomisaki.
It is true that the vessels heading towards the Naruto Strait navigate in a line, but as in the same way as a car trying to get on to an express way, it is possible to find gaps in the traffic.

An additional fact is that there are many fishing vessels in the waters in this sea area. Vessels also come and go from the ports of Wakayama and Komatsushima, meaning that this sea area can be described as being congested. The point where pilots who navigate Osaka Bay are taken on board is about 1.5 nautical miles from the Tomogashima Strait. In order to board the pilots who will navigate the Osaka Bay, many vessels have to slow down and prepare the engines (S/B Eng.). It may be because of this that, vessels in the area have to change heading course broadly in order to avoid collision in these, as mentioned above, congested sea areas. This causes a disruption to the whole sea traffic system (as the same would happen in the case of a motor vehicle changing lanes suddenly).

Therefore, when preparing to enter the Osaka Bay, at a point of 5 nautical miles from Hinomisaki, it is important to have the engines on standby ready to use at any time and to reduce speed in order to be able to carry out avoidance action at any time.
Moreover, when leaving Osaka Bay and heading southbound, until the vessel is clear of the traffic system between the Naruto Strait and Shionomisaki, the engines should be in S/B mode. It goes without saying that the Master should be in command of operations, and depending on the circumstances, it will be necessary to utilise sub-officer of the watch and additional lookouts as reinforcements.

§3-2　Tokyo Bay
(See Fig. 31: Attachment ②　Tokyo Bay　Traffic System Chart Enlargement)

This sea area has a higher volume of marine traffic than Osaka Bay. Also, there are several complicated traffic routes such as a vessel heading towards Tohoku along Chiba Prefecture at the entrance of Tokyo Bay, a vessel crossing the Pacific Ocean from the sea off Nojima-Saki, and a ship navigating the O-Shima northern route and another ship sailing the O-Shima southern route. And these vessels concentrate in the sea off the coast of Tsurugi-Saki in the southeast of the Miura Peninsula.

There is more complicated movement of vessels found at the point of embarkation or disembarkation for pilots in Tokyo Bay: because this point is approximately 1.0 to 1.5 nautical miles south of the Uraga Suido Traffic Route No.1 buoy. Oceangoing vessels have no choice but to decrease speed drastically in order to let the pilot embarkation or disembarkation in such a congested traffic system. Furthermore, in this sea area where vessels concentrate, an unavoidable more complicated give-way takes place, as vessels are crossing and overtaking other vessels.

Generally, there are many coaster vessels that operate the O-Shima northern route. Vessels from Tohoku to Ise Bay, Kansai are (or vice versa) are crossing over the exit of Tokyo Bay off the coasts of Nojima-Saki and O-Shima in the sea area. (course shown in blue line on the chart)

Safe navigation in this sea area is to operate at S/B speed, while keeping the engine on standby all of the time because the traffic in the sea area is congested. Many large ocean-going vessels have no choice but to make plans to slow down towards the pilot's embarkation point, or to start accelerating (R/Up Eng.) immediately after having let the pilot disembark. However, in congested sea areas like these, avoidance action should be taken by reducing speed without hesitation, just the same as with cars, and not only through taking avoidance action by changing to a wide heading course by force. When the Author was a new Master himself, such unreasonable operations to attempt (S/B Eng.) (enter the bay) around the point of embarkation or disembarkation for pilots and to accelerate (R/UP Eng.,) immediately after the pilot disembarked were enforced. However, as a Master and having gained experience of such an operation, the author became more cautious and exercised safe navigation (S/B or R/UP Eng.) off Su-no-Saki.

It is necessary to fully understand these traffic systems in the Kii Suido (Strait) and Tokyo Bay, which were discussed above. It is also necessary for managers on shore to explain sufficiently to the Masters of ocean-going vessels, who do not have enough navigation experience in these sea areas.

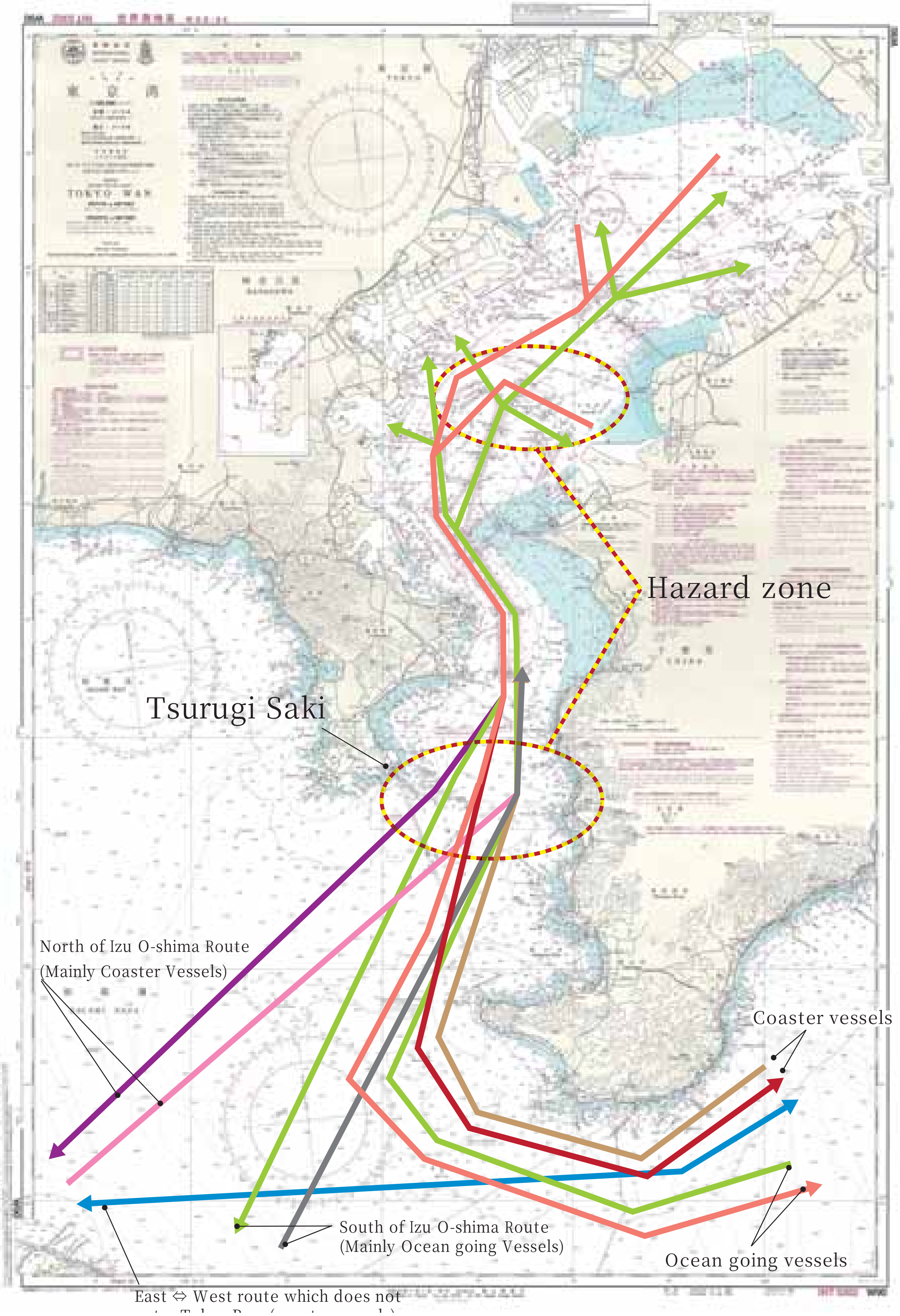


Fig. 31 Tokyo Bay Traffic System Chart

§4 Engine Trouble and Oil Spill Accidents

§4-1 Feature of Trouble and Damages
(Attachment ③ See‘ 4 Cycle Diesel Engine of vessel ’)

Firstly, an explanation about engine trouble in general. Please also refer to the P&I Loss Prevention Bulletin ‘Thinking Prevention of Engine Trouble’ (Vol.38).

§4-1-1 Damage that Affects Ship Operation

The following main parts among the components of a main engine are large, both in size and weight.

(1)	Power output section:‘ Piston/Cylinder liner ’
(2)	Driving mechanism:‘ Connecting rod/Crankshaft ’

In the event that these parts are damaged, the repair is generally large-scale. At the same time, damage to such parts will also affect ship operation. In addition, because the repair itself is difficult, it requires experience and a high level of skill. As a result, owing to either of the following reasons, it takes time for the vessel to be made serviceable again. Therefore, it is necessary to lay out a framework in order to prevent accidents.

(1) If it is beyond the capacity of the crew, it will be necessary to arrange for the manufacturer or a repair worker to intervene.

(2) Even if the crew were to attempt a repair, they would not be so accustomed to it.

On this occasion, in order to study the accident cases, we referred to the Marine Accident and Incident Reports regarding engine trouble and vessel damage available from Japan Transport Safety Board of Ministry of Land, Infrastructure, Transport and Tourism homepage. According to the Reports, there were 138 accounts of engine trouble and damage over a period of eight years from January 2008 through to June 2016; these breakdowns and damage accounts occur mainly in the following part of the main engine (except for pleasure craft and fishing boats).

Piston/Cylinder liner/Cylinder head | Crankshaft bearing/Crank pin bearing

Turbo charger | Reverse and reduction gear | Air intake & exhaust valve

Coastal vessels were mainly referred to in this report. Coastal vessels have smaller engine rooms and operate at a lower output, compared with ocean going vessels. Also, most of them have 4 cycle diesel engines, not 2 cycle diesel engines that are found on many ocean going vessels. However, the Report focuses on many themes regarding trouble and damage to owners and ship managers of both coastal vessels and ocean going vessels.

§ 4-1-2 Damage Characteristics - by Equipment

Each characteristic will be described below, according to the frequency of the equipment that tends to be damaged.

(1) Piston, Cylinder Liner and Cylinder Head

(except for chain accident related with Air Intake & Exhaust Valve)

Approximately half of the damage to pistons, cylinder liners and cylinder heads were due to burnout. Most piston structures comprise of a cooling system using lubricating oil (hereinafter LO), but burnout is caused by a short supply of cooling oil. This shortage is also caused by a shortage of LO pressure and a blockage in the cooling oil supply route.

Moreover, there are cases of bending damage to the push-rods because of damage sustained to the exhaust valve caused by a strike from the piston crown due to the looseness of the fixing bolt between the piston crown and the piston skirt. The following measures are taken:

- Crew are to understand the risk of damage to an engine when disassembling and assembling it.
- When disassembling and carrying out maintenance, crew should confirm and inspect the parts carefully again before assembling, in order to avoid assembly mistakes regarding important parts such as the LO channels and tightening of parts.

(2) Crankshaft bearing/Crank pin bearing

Most damaged sustained by crankshaft bearings is due to a lack of LO.

This is because the sludge in the LO builds up in the strainer and filling pipe due to neglect of maintenance and inspection. In addition, most causes of damage to the crank pin bearing (large end of the connecting rod) come from over-tightening, insufficient tightening or uneven tightening of the connecting rod bolt (hereinafter referred to as crank pin bolt). The following measures are taken:

- To comply with and carry out the tightening method and force necessary based on the manufacturer's instruction manual.
- In every maintenance carried out, it is important to check for any cracks (dye penetration inspection), the bolt length (dimension measurement), length-of-use of components (compared with maximum hours of use) and to exchange the parts, if necessary.

(3) Turbo charger (except for air intake & exhaust valve chain accidents)

Damage to the turbo charger is related to damage sustained by the shaft (burnout of rotor shaft bearing, bending of rotor shaft, breakage, etc.) and hole in the casing. The main cause of a hole appearing in the casing is due to thickness depletion and corrosion sustained by long-term use. The following measures are taken:

- Measures taken against thickness depletion

  To conduct a thickness measurement regularly and to exchange the casing based on the manufacturer's standard.

- Prevention of corrosion

  Carry out the quality check of cooling water (property analysis, chemical treatment, etc.) and appropriate temperature control.

(4) Main Engine Reverse and Reduction Gear

- There are many cases where damage to the main engine reverse and reduction gear is caused by a problem concerning the hydraulic system. The preventive measures ensure that the maintenance and inspection of the hydraulic pump are carried out.

(5) Air Intake & Exhaust Valve

The following are main damage accounts regarding air intake & exhaust valves:

- Breakage of valve seat
- A valve detaches from its valve shaft and falls into the cylinder. As a result, the cylinder head, piston and cylinder liner will be damaged.
- Furthermore, the fragments of damaged parts enter the turbo charger and cause damage to it.

Approximately half of the damage accounts of the air intake & exhaust valves cause damage to the turbo charger. Even when maintenance is implemented regularly, damage can still occur. Preventive measures are to ensure that the crew confirms and inspects the following states described in the manufacturer’s instruction manual, when disassembling and maintaining.

- To check and measure the cracks in the valve shaft and the valve seat (in order to verify the wear and tear and deterioration state)
- To confirm the length-of-use of component parts (compare with maximum hours of use)

(6) Summary

Summing up each aforementioned measure, it is important that confirmation with regards to the state of the engine and inspection are thoroughly carried out, based on the manufacturer’s instruction manual during disassembly and maintenance work. Namely, it is as follows:

- Evaluate and replace the component parts based on the standard. (Deterioration, cracks, dimension measurement, wear and tear, maximum hours of use, etc.)
- During the assembly process, reconfirm and inspect repeatedly the same parts in order to prevent mistakes during the assembly of critical parts.

§ 4-2　Cases

The following cases will be introduced: ① a damaged piston and crank pin bolt, which may greatly affect navigation when damaged, ② crank pin bearing damage, and ③ oil spill accidents that cause great harm to the environment.

§ 4-2-1　Case ①　Piston Seizing and Piston Skirt Broken Damage Accidents

(1) Outline of accident

< Vessel's particular >

Tanker Main engine output 2,942kw, built in 2001

< Summary of accident >

On March 2013, a broken hole appeared in the crankcase door of the main engine No.4 cylinder during operation, which caused LO to gush out. Immediately, the watch engineer stopped the main engine. Then, as the result of inspection that both the chief engineer and the engine officer carried out, the following accounts of damage were detected.

①	Broken damage to piston skirt
②	The broken damage part dropped down

Following consultation between the Master and the chief engineer, the Master deemed that the vessel was disabled for navigation and the vessel was towed to the nearest port.

Before analysing the causes of the accident, piston structure and the flow of LO will be explained. (Please see Figs. 32, 33-1, 33-2 and end of booklet: Reference Attachment ③ : '4 Cycle Diesel Engine of vessel')

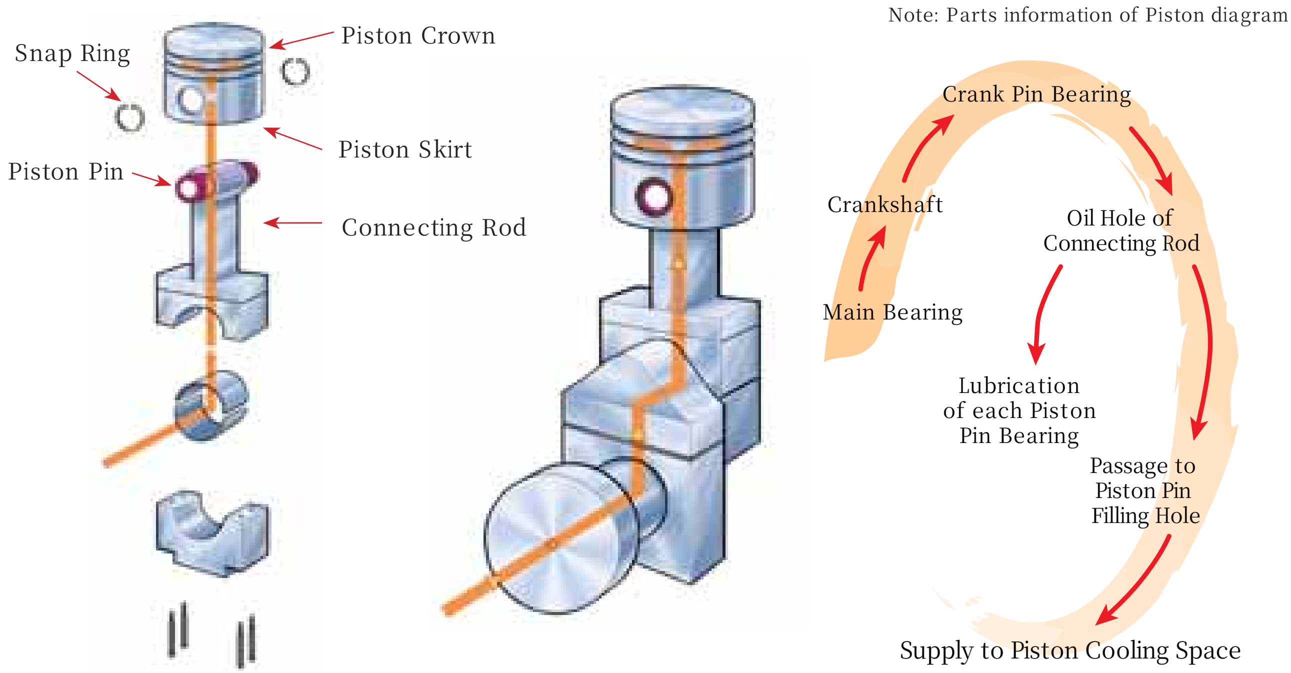


Fig. 32　Piston diagram and Cooling oil supply route

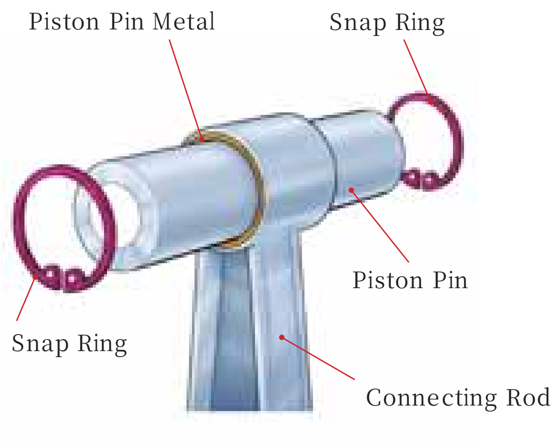


Fig. 33-1　Piston Pin Diagram

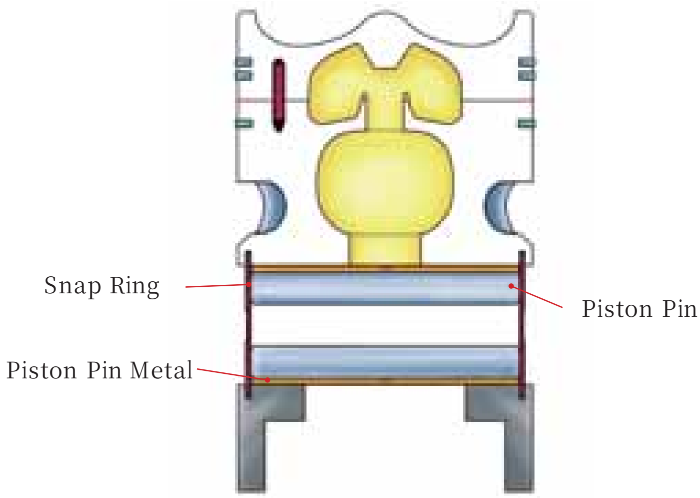


Fig. 33-2　Piston Pin Diagram

The piston structure consists of two parts: an upper part and a lower part. The upper part has a special alloy piston crown and the lower has a cast iron piston skirt. The piston is of the assembly-type. The upper and lower parts are connected by tightening bolts. The yellow line in Fig.32 shows the route of the cooling and lubricating oil that is supplied from the main bearing.

The piston pin is a metallic hollow-shaped cylinder. The piston and connecting rod are connected via the boss (borehole) in the piston skirt and a piston pin in the small end bearing of the connecting rod. Also, the piston pin (full floating type) has clearance between the small end bearing of the connecting rod and the piston pin boss. Both ends of the piston pin boss have a gutter.

As can be seen in Figs. 32, 33-1 and 33-2, the piston pin is prevented from coming adrift from the bearing by metal C-shaped retaining rings (hereinafter, snap rings) affixed in these gutter areas. In addition, there is a hole that allows for LO (as cooling oil) to flow to the piston pin. This cooling oil is supplied from the oil hole in the connecting rod up to the piston.

(2) The events that occurred

The sequence of the events that occurred is summarised as follows:

①	Broken damage in the piston skirt of No.4 cylinder also occurred previously. Repair including the replacement of new and remodeled parts carried out by an engine manufacturer was conducted in October 2010.
②	Main engine LO consumption increased from around June, 2012. There is a possibility of abnormalities at this point. Just before the accident, consumption increased by approximately three times to that of normal.
③	This is why the chief engineer and engineer conducted the inspection of the crankcase, however, an abnormality was not detected.
④	Up until the trouble occurred, the chief engineer and engineer assumed that the cause of increased LO consumption was down to abnormal wear of the piston rings. In fact, overhaul and maintenance was reviewed during dock repair work that was scheduled on June 2013 (3 months later following the accident).

<table>
<tr><td rowspan="9">⑤</td><td colspan="2">When the accident occurred in March 2013, a description of the condition of No.4 cylinder is as below:</td></tr>
<tr><td rowspan="2">(a) Piston skirt</td><td>● The lower part of the oil ring of the port side piston skirt was severely seized and sustain broken damaged</td></tr>
<tr><td>● The broken damage part dropped down</td></tr>
<tr><td rowspan="2">(b) Piston pin boss</td><td>● The bottom part of the piston pin boss was broken</td></tr>
<tr><td>● There was a contact mark on the bow side of the piston pin boss on the far outer side of the gutter, where the snap rings are inserted, that was caused by surface contact from the piston pin.</td></tr>
<tr><td rowspan="2">(c) Snap ring</td><td>● The snap ring of the bow side piston pin was broken in the centre and had dropped down</td></tr>
<tr><td>● Had the snap ring been appropriately inserted into the snap ring gutter, a contact mark would naturally not have appeared.</td></tr>
<tr><td>(d) Cylinder liner</td><td>● A vertical scratch approximately 5mm in depth sustained on the bow side to cylinder liner</td></tr>
<tr><td>⑥</td><td colspan="2">During navigation, a broken hole appeared in the crankcase door of No.4 cylinder, which caused LO to gush out. The watch engineer stopped the main engine immediately.</td></tr>
</table>

(3) Analysis by Japan Transport Safety Board

Japan Transport Safety Board analysed the cause and recommended preventive measures as follows.

① Cause Analysis (Please see Figs. 32, 33-1, 33-2 and 43 on page 77 regarding diagrams)

a Although the manufacturer carried out a repair in October 2010, the snap ring of the piston pin boss was not fully inserted into the snap ring gutter during the assembly process. Due to this, the ring broke and dropped down during operation.

b Thereby, the route for supplying LO was blocked because the piston pin moved to the axial direction retarding the supply of LO. As a result, the piston was deprived of coolant, which caused it to seize and subsequently sustain broken damage to the piston skirt.

c On the other hand, as for the time of the snap ring dropping down, it is pressumed to have occurred around June 2012, when LO consumption had increased. Inferred grounds are as follows:

- Piston pin moved to the axial direction due to it dropping off the snap ring.
- Consequently, the following events occurred and LO consumption increased.
- The piston pin made contact with the cylinder liner and vertical scratch damage was sustained. Through the vertical scratch damage, cooling oil leaked into the combustion chamber and combusted.
- Because the passage to the supply of LO became blocked and the piston was in need of coolant, the heated piston evaporated the LO nearby.

② Preventive measures by Japan Transport Safety Board

Based on the above analysis, the following are recommended as preventive measures that can be applied to similar accidents in future.

a The strengthening of supervision during assembly

While assembling the important parts of an engine, technicians are to carry out assembly correctly while under the supervision of a supervisor who is familiar with the work.

b To make inquiries to the manufacturer, when an abnormality has been discovered, and investigate its cause.

In the case of an extraordinary increase in LO consumption, the crew are firmly requested to make inquiries to the manufacturer regarding the following:

- To check as to whether the increase of LO consumption is within the acceptable range.
- If further necessary, investigate the cause at an early stage by disassembling each part.

c Review of inspection methods by crew

- Crew should keep in mind the following, when inspecting the crankcase.
  - To observe carefully the state of the cylinder liner.
  - To try changing the piston position through turning for easier observation.

§ 4-2-2 Case ② Crank Pin Bearing Damage Accident

(1) Outline of Trouble

＜ Vessel's particulars ＞

Cargo ship Main engine output 1,080kW Built in 2004

＜ Summary of accident ＞

On October 2011, because the main engine automatically stopped with a loud sound during navigation, she dropped anchor in an emergency at the end of the traffic lane nearby. On inspection during anchorage, the large end of the connecting rod of No.7 cylinder passed through the crankcase door. After draw out of the No.7 piston, she shifted to anchorage by cutting operation of No. 7 cylinder. After that she was towed to port for repairing.

According to the investigation by Japan Transport Safety Board, the following accounts of damage were detected.

①	The state of the four crank pin bolts at the large end of the connecting rod of No.7 cylinder are described as follows: (See Reference Picture 34)	
	(a)	Two bolts were cut at the stud bolt end
	(b)	The other two bolts sustained bending damage in the middle section
②	Broken damage of piston and cylinder liner (See Reference Pictures 35 and 36)	
③	Burnout of the crank pin bearing metal	

Reference Picture 34
Bending loss of connecting rod


Reference Picture 35
Broken damaged cylinder liner


Reference Picture 36
Broken damaged piston

(2) The events that occurred

The sequence of the events that occurred is summarised as follows:

①	On the 4th of October in 2010 (approximately one year before the accident occurred), the crew carried out piston) draw-out of the No.7 cylinder during regular inspection. During the assembling work, they used a torque wrench to tightening in the crank pin bolts.	
②	When the accident occurred, the cylinder was found to be in the following state:	
	(a)	Two of the bolts at the big end of the connecting rod had snapped and the other two bolts sustained bending damage.
	(b)	The connecting rod itself sustained bending damage
③	When the accident occurred, the main engine automatically stopped with a loud noise. Then, the following parts had been damaged.	
	(a)	Broken damage: piston and cylinder liner
	(b)	Burnout: crank pin bearing metal

(3) Analysis by Japan Transport Safety Board

Japan Transport Safety Board analysed the cause as follows and recommended preventive measures.

① Cause Analysis

The cause was that the crank pin bolt of main engine No.7 cylinder had snapped, which led to the freeing of the large end and the consequent disconnection of the connecting rod from the crankshaft.

② Preventive measures

Based on the above mentioned analyses, the following was recommended as a preventive measure that can be applied to a similar accident in the future.

- In the event of piston draw-out work, based on the guideline for maintenance work and standard (instruction manual), maintenance of the crank pin bolt (replacement, dye penetration inspection, cleaning, tightening force and so on) is to be carried out appropriately.

§ 4-2-3 Case ③ Oil Spill Accidents

On examination of oil spill accidents that our Club deals with, most accidents of this type which occur, excluding collisions and those that run aground, are not cargo oil spill accident related but occur at the time of bunkering of fuel oil (hereinafter FO).

(1) General Bunkering Procedure

First, an explanation of the general bunkering procedure. The vessel has FO bunkering work instructions from an environmental protection standpoint in accordance with the safety management system and manuals (hereinafter referred to as SMS). The work instructions generally consist of making a bunkering plan, a bunkering work plan, preparation for bunkering, work before oil receiving, receiving oil work, and work after bunkering. As can be seen in Table 37, the steps of the procedure from the making of a bunkering plan to work before oil receiving are as follows.

①【Before bunkering】

Operating situation			Procedure	Remarks
A. Previous port -During navigation -Entry into port				
	a.		Making of bunkering plan	
		I	Confirmation of necessary bunkering amount	
			· Decided actual measurement of each tank, calculation of estimated consumption amount and provisional amount for bunkering	
		II	Confirmation of receivable quantity	
			Make a plan that does not exceed 90% of the capacity of each tank	
		III	How much bunker oil is needed in each tank?	
		IV	Bunkering order	
			· Set in order of MDO (marine diesel oil) then HFO (heavy fuel oil) and plan the refilling from a far-off tank procedure.	
		V	Valve operation order	
			· Carry out valve opening/closing test beforehand.	
		VI	Bunkering work task assignment	
			· Task assignment and personnel arrangements	
	b.		Bunkering work arrangement	
		I	Pre-meeting among all members of engine department regarding bunkering work arrangement	
			· Role allotment (personnel arrangements): where, how much and into which tank the FO is to be refilled.	
			· Countermeasure in state of emergency	
		II	All attendants sign their names after a meeting	
		III	Keep all crew thoroughly informed regarding the importance of the bunkering work arrangement.	
	c.		Prepare for bunkering (the following work should be carried out, before and after port entry)	
		I	Final confirmation of the actual level and remaining quantity of all FO tanks.	
			· The person responsible on scene must recalculate the plan, based on the actual fuel property and actual remaining quantity in the tank	
			· Transport necessary fuel to FO settling tank.	
			· Lock the FO transfer pump in order for it not to start automatically	
		II	Prepare tools	
			· Sounding table, specific gravity & volume conversion table, calculator, watch, stationary, transceiver, etc.	
			· Piping diagram, fire extinguisher, oil removal material, sounding tape, thermometer, pressure guage, tool, etc.	
		III	Line-up	
			· Entirely close unnecessary valves	
		IV	Set scupper plugs on deck	
		V	Precision check of remote level gauge and operation check of each alarm on valve remote control panel, indicating light, etc.	
		VI	Pressure test for bunker line during a dock or navigation before bunkering, if necessary	
B Following port entry				
	a.		Hoisting B flag after entering port (Red light all-round at night)	
C. Bunker barge alongside				
	a.		Work before oil transfer	
		I	Check the bunker oil volume on barge	
			· Confirmation using sounding table of barge	
		II	Oil transfer volume	
			· Oil transfer capacity of barge and receivable quantity of vessel	

	a.	Ⅲ	Means of communication (transceiver etc.)	
		Ⅳ	Countermeasure in state of emergency	
		Ⅴ	After final check, a signature is required from both the barge side and vessel side	
		Ⅵ	Hose connection	
		Ⅶ	Contents confirmation of Bunker Delivery Note(hereinafter, BDN)	
			・Oil type/oil quantity/oil property of fuel oil	
		Ⅷ	Preparation for sample oil at collecting point	

Table 37 Example of Bunkering Procedure

① Making a bunkering plan

The bunkering plan is to be made by the filing in of the requirements in the list stipulated in the SMS, etc. At this stage, in the same plan, the results of supposition calculation using figures based on previous bunkering oil temperatures, seawater temperatures, and fuel properties, etc., are filled in.

② A bunkering work plan

A person responsible on scene (generally a first engineer, described below as or hereinafter 1/E) makes a bunkering work plan following the bunkering plan and explains it to each crew member following approval of the plan by the chief engineer. The 1/E explains the steps involved in bunkering work such as personnel arrangement, individuals work responsibility, each work procedure, work method, countermeasure in state of emergency and so on.

③ Preparation for bunkering

In the preparation for bunkering stage, the person responsible on scene re-calculates the bunkering plan, based on the actual amount of fuel remaining in the tank and the actual fuel property just prior to bunkering. In other words, the practice of PDCA concerning the bunkering work plan is essential

④ Work prior to oil receiving

A third engineer (hereinafter 3/E) attends tank measurement on the bunker barge side or joins for reading aloud the information from the flow meter, and keeps a record to report to the person responsible on scene. The person responsible on scene re-calculates the requirement and completes the final bunkering plan. A point to confirm here is whether the bunker barge retains the necessary amount and specification of fuel in accordance with the ordered amount or not. Then, once the chief engineer approves the calculation result, the oil receiving begins.

⑤ Receiving oil work

During oil receiving acceptance, the crew of the engine department must pay attention to the following two duties.

1) To monitor oil leakage and tank liquid level

- To verify any abnormality such as leakage
- To carry out tank measurement regularly (Needless to say, but trim and heel correction is required when verifying the oil amount.)
- A responsible person on scene is to calculate the rate of oil receiving flow. He also must know when it is time to change tanks.

2) Appropriate action to be taken when there is an oil leakage

- When an oil leakage is found, the person responsible on scene should immediately announce the order to stop pumping, and in the event of an overboard oil spill, the crew of the engine department must report it to the C/E and duty officer immediately.
- All crew onboard must handle this in accordance with the oil spill control station and shipboard oil pollution emergency plan.

⑥ Work after bunkering

Having completed receiving work, the engine department not only submits the bunkering tank record to the deck department, but also restores it to the normal fuel transfer line and fuel supply line promptly. Table 38 shows an example of work instructions for both completed oil receiving work and post bunkering work.

②【During bunkering work】				
Procedure				Remarks
Operating situation			D. Commencement of bunkering	
	a.		Oil receiving work	
		I	After having started oil transfer and confirmation of any leakages of oil, gradually increase the oil transfer volume up to the planned quota.	
		II	Check the receiving tank liquid level at regular intervals (actual measurement by sounding scale).	
			• Non-receivable tank: if `no inflow (no change of liquid level)' after a certain interval since starting, continuous monitoring is not necessary	
		III	Watch system, three persons at least	
			• One each for manifold and sounding, and a chief engineer (high command)	
		IV	When receiving to more than two tanks, pay attention to manifold pressure at the time of switching tanks.	
			(Adjust the oil transfer volume, if needed)	
		V	Collecting sample oil	
		VI	After transferring oil, carry out air blowing.	
		VII	Confirmation of completion having received the arranged quantity (both for vessel and barge)	
			• Carry out tank measurement after bubbles have subsided.	
			• When there is no difference between receivable quantity and ordered quantity (OK), receivable quantity will be written down on BDN and the chief engineer will sign the document.	
			• Issue Letter of Protest in case of shortage.	
		VIII	When something unusual happens, the person responsible on scene must stop the oil transfer immediately.	
			• After confirming the cause of the abnormality and measurement carried out, oil transfer can be re-started.	
			Permission for restart of oil transfer by chief engineer is required.	
			• In the case of an oil spill into the sea, report it to both the chief engineer and to the duty officer immediately.	
			Handle in accordance with oil spill control station and shipboard oil pollution emergency plan	
			E. Secure bunkering	
	a.		Work following oil transfer	
		I	Receiving oil sample for custody	
		II	Removal of hose	
		III	Secure each tool and B flag (red light)	
		IV	At appropriate time, restore the fuel line and bunkering line of vessel side to normal	
		V	Submit the record, i.e. final bunkering quantity, tank condition, etc. to the deck department.	
		VI	Secure the sealed deck scupper	

Table 38 Example of Bunkering Procedure

(2) Outline of accident

FO bunkering work was carried out on the vessel (approximately 8,000 GT) while it moored for cargo discharging work. However, just at that time, the following accident occurred in the No.3 FO tank which was the last to top-up tank.

①	FO overflows from the air vent (See Reference picture 39)
②	The crew could not contain the fuel on the deck and approximately 100 litters spilt into the sea (See Reference Pictures 40 and 41).

After the spill, the Japan Coast Guard and the vessel and shipowner arranged for seven work boats and cleaning experts. The cleaning work was completed in one day. As a result, a sum total of approximately JPY 27,000,000 in expenses was paid in insurance money for the investigation and cleaning up of the spilt FO.

Reference Picture 39
No.3 Fuel oil tank air vent (after overflow)

Reference Picture 40
Port side of upper deck

Reference Picture 41
State of oil spill overboarding

(3) The events that occurred

According to the surveyor's report, which was arranged after the accident, it was confirmed that the following events led to the FO spill.

①	In the work carried out at a previous port, the second engineer, (hereinafter referred to as the 2/E) was planning to carry out sounding of No.3 FO tank, which was set to finalize top-up tank. However, he failed to carry this out.
②	Without confirming the actual measurement in ①, the 1/E: the person responsible on scene, made the bunkering plan, assuming that the tank had ' no remaining oil'. The plan for receiving oil was scheduled to be carried out using four fuel tanks, in the following order: No.4 (port side and starboard side), No.5 (central) and No.3 (central).
③	In addition, calculation details of the bunkering plan were not specified. The surveyor that our Club arranged for accident investigation presumed that approximately 62KL, which is equivalent to 66% of the No.3 FO tank capacity on the bunkering plan (amount required for tank top-up), according to the investigation.
④	Although the 3/E and two oilers carried out tank measurement of the No.3 FO tank before starting oil transfer, they did not realize how much remaining oil was left in the tank.
⑤	Also, even during receiving oil work, the 3/E and the oilers continued to measure the tank liquid level. In spite of the fact that receivable quantity was beyond the amount of the bunkering plan, which was indicated above in ③, they did not request that the oil transfer be stopped. Consequently, because the receivable quantity was in excess of tank capacity, FO overflowed from the air vent.
⑥	During tank overflow, the No.3 FO tank was filled with approximately 91KL of FO, which is equivalent to 96% of tank capacity. However, the oil transfer amount from the barge was as instructed.
⑦	Therefore, though the stripping work was cancelled, the 1/E, who was the person responsible on scene during bunkering work and in charge of maintaining contact between the barge and the vessel, was delayed in taking measures to initiate an emergency stop when it stated to overflow.

§4-3　Accident Analysis in Accordance with Error Chain

Not limited to marine accidents only, it is almost impossible for an accident to occur from a single error. A series of errors cause an accident in the end. Regarding the three cases which were introduced in §4-2, we are going to analyse each event from the perspective of error chains.

§4-3-1 Case ① Piston Seizing and Piston Skirt Broken Damage

The error chain of piston seizing and piston skirt broken damage accidents (Case ①) was analysed according to time-sequence.

Time-sequence ① Trusted entirely to the manufacturers

Time -sequence ①	In October 2010, main engine No.4 cylinder piston skirt sustained broken damage and repair was carried out by the engine manufacturer.	
Errors		Related problems
1	The crew, ship owner and ship management company did not understand why it was replaced with remodeled parts.	Insufficient ship management
2	Relied on the manufacturer because it was a replaced with a remodeled one (over-trusted)	Assumptions
Measures		Methods
<< Establish guidelines and ensure compliance with crew on ship >>		Thorough instruction
In the case of discovering something unusual, make an inquiry to the manufacturer for advice promptly and take emergency measures.		Thorough ship management and supervision

Regarding repair by engine manufacturer, in spite of having exchanged the part with a remodelled one, crew, owner and ship management company were not aware of the reason why.

Time-sequence ②
Investigation as to the cause was insufficient, despite the fact that LO consumption had increased

Increase of LO consumption as the sign of an accident cause was a phenomenal fact. Although the crew realized the abnormality, both the crew and the ship management company neglected to take the appropriate action.

Time-sequence ②	Trunk piston type lubricating oil is consumed mainly for lubrication between cylinder and bearing and cooling the piston. Since around June, 2012, the lubricating oil in the main engine had been excessively consumed and - it increased to approximately three times the normal amount just prior to the accident.	
Errors		Related problems
1	The Vessel noticed the unusual increase of consumption, however, it did not make inquiry to the manufacturer for further information.	Insufficient daily duty management
2	There was no guideline for lubricating oil management.	Insufficient ship management

Measures	Methods
<< Establish guidelines and ensure compliance with crew on ship >>	Thorough instruction
Prior to the manufacturer's repair, 'confirmation and request for important repair procedures, timing of watch on the ship's work site, the necessity of any assistance, etc.' should be sought.	Thorough ship management and supervision

Time-sequence ③ Could not discover abnormal state when inspecting the crankcase

Time -sequence ③	There was no abnormality discovered when inspecting inside the crankcase.	
Errors		Related problems
1	At the time of inspecting inside the crankcase, why was 'the observance of the parts consisting of the piston, cylinder liner, etc.' not carried out?	Insufficient daily duty management
2	In the event of inspecting the cylinder liner, it is necessary 'to adjust the piston location'.	Crew's insufficiency of working skills
3	There was no observation guideline	Insufficient ship management

Measures	Methods
<< Establish guidelines and ensure compliance with crew on ship >>	Thorough instruction
In the event of inspecting the crankcase, it is also necessary 'to observe not only for foreign substances (such as metalic pieces of bearings, combustion residue, etc.) at the bottom of crankcase, but also inside of the piston skirt, the appearance of the connecting rod, the state of the cylinder liner and so on'. When inspecting the cylinder liner, it is necessary 'to adjust the piston location'.	Thorough ship management and supervision

A crankcase is, as shown in Fig. 42, a box shape room which houses the crankshaft. As there is a door attached, it is possible to inspect the inside. However, this door is too small and it is not possible to observe the internal structure without using a hand mirror or adjusting the position of the crankshaft (See Fig. 42). There are three errors that occurred in the chain, when analysing as to why the abnormality was not detected at the time of inspecting the crankcase.

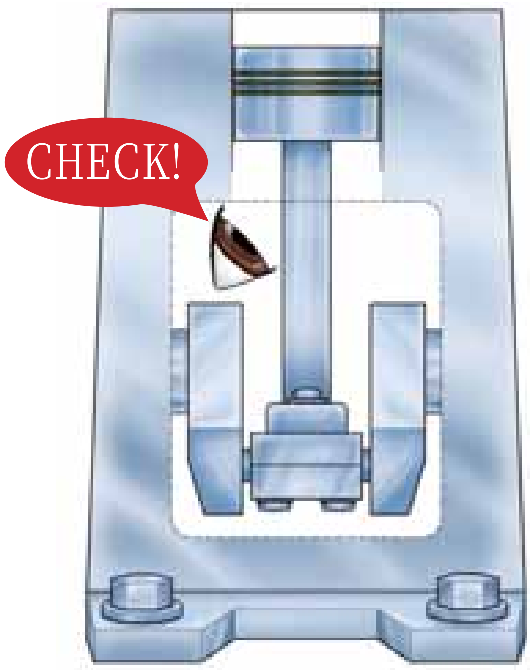


Fig. 42 Appearance of Crankcase

Time-sequence ④ Insufficient response to abnormal wear of piston rings

The crew presumed that the cause of unusual LO consumption (Time-sequence ②) was a result of abnormal wear of the piston rings, however, they did not report or making an inquiry to the ship manager or manufacturer.

Time -sequence ④	Until the accident occurred, abnormal wear of the piston rings was assumed to be the cause (all of the cylinders were planned to be opened up and examined during the next dock repair work scheduled in June 2013).	
Errors		Related problems
1	Despite the fact that abnormal wear of the piston rings was assumed, why was an overhaul of the pistons not carried out immediately?	Insufficient ship management
2	There was no guideline.	Insufficient ship management
Measures		Methods
<< Establish guidelines and ensure compliance with crew on ship >>		Thorough instruction
When it is deemed necessary to carry out an overhaul because of an abnormality, make a request to the administrator immediately.		Thorough ship management and supervision

Time-sequence ⑤ Not realizing abnormality within the engine

The main reason for burnout was a lack of LO, but it was in fact caused by the dropping-off of a snap ring. A description of the mechanism that controls LO and how this causes the oil to not flow smoothly, as a result of a snap ring dropping off, is as follows. (See Fig. 43)

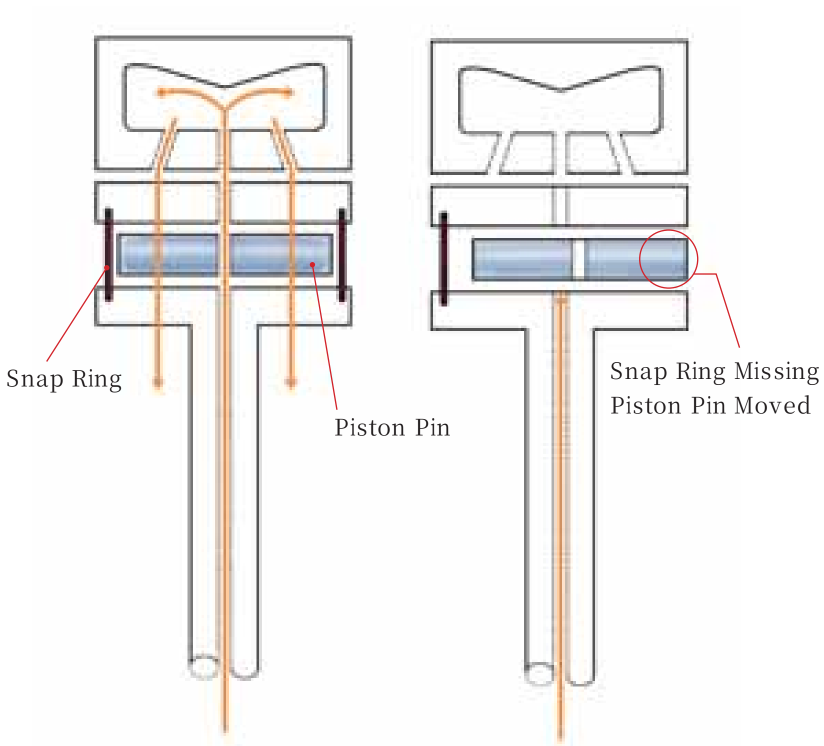
Time -sequence ⑤	The main engine No.4 cylinder on the 28th of March, 2013 was as follows.
	(1) Piston Skirt : severe seizing and broken damage at the bottom of oil ring (2) Piston Pin Boss : broken damage at the bottom in entire circumference. There was a contact mark from the piston pin on the fore side. (3) Snap Ring : breakage to the centre and dropped off. There was no contact mark in the gutter insert. (4) Cylinder liner : existence of vertical scratch damage (two lines).
The causes are presumed as follows.	
	(1) The cause of burnout was down to a lack of cooling oil in the piston. (2) Strength deterioration by piston skirt overheat. (3) The snap ring on the bow side was not set correctly. (4) The snap ring had dropped-off and the piston pin moved to the same direction. (5) Both left and right sides of the piston pin made contact with the liner on the bow side and caused vertical scratch damage.
As a result, the following were caused.	
	Due to the dropping-off of a snap ring, there was a shortage of piston pin cooling oil. Furthermore, as a result of the shortage of piston pin cooling oil, it caused overheat, strength reduction and broken damage to the liner.

Errors		Related problems
1	The insufficient awareness of the inportance of piston assembly by the engineer in charge.	Insufficient ship management
2	Lack of risk prediction of 'engine trouble may be caused if snap ring is not correctly inserted'.	Crew's insufficiency of working skills
3	Regarding assembling equipment which may lead to an accident, why did he not instruct the manufacturer to pay attention to assembly work or inspect the work that was being carried on board at that time?	Insufficient ship management
4	There were no opportunity for training and on-ship guidance.	Insufficient ship management
Measures		Methods
<< Thorough crew training >>		Crew training
The essence of the accident is 'how to understand the basic structure of a piston and what kind of accident can be predicted in the case of insufficient maintenance'.		
<< Thorough guideline creation >>		Thorough ship management and supervision
Regarding the parts which may lead to an accident occuring because of failure of maintenance inspection/assembly, and 'working instructions to the shore worker or watch on the ship's work site'		

(a) As described earlier, the piston pin (full floating type) is inserted into the piston pin boss. The snap ring is inserted into the gutter of both ends of the boss.

(b) Therefore, if the ring gets separated, the pin will move toward the axial direction. Thus, the passage of LO gets blocked by the shifting of the positions between the oil hole of the connecting rod and the filling hole of the piston pin.

(c) As a result, the filling oil to the upper part of the piston pin boss and piston cooling space will be stopped.



(a)Snap ring at normal (b)Snap ring when dropped-off

Fig. 43 Prevention of LO Flow which Aids Piston Pin Movement

§ 4-3-2 Case ② Crank Pin Bearing Damage Accident

The error chain of Case ② 'crank pin bearing damage accident' was analysed according to time-sequence.

Time-sequence ① Crew's lack of awareness regarding the important points of piston assembly.

Time-sequence ①	On the 4th of October, 2010 Main engine No.7 Cylinder piston) draw-out by the crew	
	Errors	Related problems
1	The insufficient awareness of the inportance of piston assembly by the engineer in charge.	Crew's insufficiency of working skills
2	Lack of risk prediction which 'may develop to engine trouble, if connecting rod was tightened incorrectly'.	Crew's lack of knowledge
3	Why was there no opportunity to take internal training?	Insufficient crew training
	Measures	Methods
	<< Reinforcement of crew training >>	Crew training
	'Allow the crew to learn about the basic structure of the connecting rod and educate them as to what kind of trouble may occur in the event of maintenance failure', which is at the root of the trouble.	Thorough ship management and supervision

All error chains derive from the crew's insufficiency of knowledge and operational skills required for important maintenance.

Time-sequence ② Lack of knowledge regarding how to tighten bolts

Time-sequence ②	When the accident occurred on 28th October in 2011, the condition of main engine No.7 cylinder was as follows: ● Two connecting rod bolts broke at the large end of the stud bolt. ● The other two bolts were bent in the middle	
	Errors	Related problems
1	The crew was not familiar with both the tightening technique and the inspection method. ● Technique of tightening based on the manufacturer's instruction manual (torque, angle, hydraulics) ● Handling a torque wrench (precision, setting and correction) ● Carry out correct assembly of each part, inspect nut and bolt surfaces and penetration test of crank pin bolt before tightening.	Crew's insufficiency of working skills
2	No maintenance guideline	Insufficient ship management

3	Why was the senior engineer negligent to confirm the important points regarding connecting rod assembly?	Insufficient work instructions, etc.
Measures		Methods
<< Thorough guideline creation >>		Thorough instruction
●	Regarding connecting rod assembly, 'tightening technique, handling of a torque wrench, parts assembly and cleaning the surfaces of nuts, and penetration test of tightening bolts etc.'	Thorough ship management and supervision
●	'Items that the senior engineer must confirm' when maintaining a vessel.	

Although crew should have been familiar with the 'technique of tightening and the inspection method of the crank pin bolt, which were referred to in the manufacturer's instruction manual'. But they could not have done this.
The crew must assemble each part so as for them not to come loose with centrifugal force and vibration during engine operation. That is why it is important to understand the following regarding the technique of tightening and the inspection of bolts.

(a) Technique of tightening based on manufacturer's instruction manual (torque, angle and hydraulic jack)

Technique and force of tightening are stipulated in the manufacturer's instruction manual. The crew must tighten the blots evenly based on the instructions. At that time, it is necessary to pay attention to each tightening unit.

< Remarks on bolt tightening method >

- Not to make a mistake in the technique of tightening using several different methods.
- Torque method (N・m or kgf・m), angle method(°), torque ＋ angle method (tightening in two stages), hydraulic jack method (MPa or kg/cm^2), etc.,

< Having disassembled the connecting rod and having newly replaced crank pin bolt remarks >

- Carry out re-marking of the Set Mark when assembling.
- Check for bolts and nuts that may have worked loose following a certain operation hours after the assembly. (For example: inspect the position of the Set Mark and re-tighten to the specified torque)

(b) How to handle a torque wrench (precision, setting and calibration)

In torque method, a torque wrench is used for tightening bolts. The wrench has the following features. Crew must understand how the wrench works and handle it appropriately.

- Set the control value correctly for the wrench.
  The unit should be noted: （[N・m] value ＝ [kgf・m] value × 9.8, [kgf・m] value = [N・m] value × 0.102,
  For example, 49N・m = 5kgf・m）
- Crew must treat the wrench carefully as a precision-tool in order to maintain precision.

Also, the following are required for safekeeping of the wrench.

- The wrench is to be stored separately from other general tools.
- The setting point should be set to the minimum level.
- The wrench should be calibrated regularly or replaced with a new one.

(c) Assemble correct parts, clean and inspect nut and bolt surfaces before tightening

Before tightening, it is a must that the surfaces of nuts and bolts are thoroughly inspected and cleaned, together with correct assembly. For example, crew must tighten after inspecting and cleaning of the seat surface of the large end and the bolt head and nut. If crew neglect to clean, dust will gather. This will cause the nut to end up in a 'loosened state', because such dust stuck in a specific area deteriorates the tightening force of the nut and bolt then exposed to centrifugal force and vibration due to the rotational motion of the crankshaft during engine operation.
As a result, the large end will detach from the crankshaft which has a danger working free. In addition, roughness and scratches on the seat surface of the bearing will reduce bearing contact surface area. If nuts and bolts are unevenly tightened, a similar problem will occur. Therefore, the inspection of the seat surface is also important.

(d) Dye penetration inspection of the bolt (non-destructive inspection), etc.

As the bolt receives repeated stress during engine operation, the strength is reduced each year. Then, at the time of disassembly and maintenance, crew must inspect to see if there is any damage on the metallic surface by Dye Penetration Inspection. If any damage is found on the bolt, it has a danger of breaking.

Note: Dye Penetration Inspection is also referred to as colour check. This is a non-destructive inspection method which detects cracks that appear on the surface of the material, by using a red or fluorescent coloured penetrant; with the usage of the capillary action principle.

(e) Handling precautions regarding the bolt

In this case, the bolt itself was broken. Thus, in addition to the tightening method, durability management requires special care. The points are: dye penetration inspection (non-destructive inspection described above in (d)), dimension measurement (evaluation of bolt extension), maximum hours of use (bolt life management), etc. The necessity of dye penetration inspection is mentioned above. Moreover, crew must be able to recognise the extent to which the bolt extended by measuring and recording the length of the bolt. In this case, compare it with a spare new one. Also, maximum hours of use of the bolt is described in the manufacturer's instruction manual. It must be replaced based on this. For example, 20,000 hours of maximum use, is roughly equivalent to 3 years when annual operation rate is approximately 80% (equal to around 7,000 hours per year). Therefore, the bolt must be included in maintenance schedule as an essential spare part.

<< Reference Information >>

Nippon Kaiji Kyokai ' Summary of Damage ' Generator Engine's Connecting Rod Accident.

The previously mentioned 'accident' occurred in the main engine of a 4 cycle diesel engine. Class NK shows a 'Summary of damage' in their bulletin annually. In their bulletin, Class NK issued a detailed warning notice regarding the above accidents which occurred in the generator of the same type of engine (4 cycle diesel engine). (They posted in the bulletins No. 292, 296, 301, 304, 309 and 312 from fiscal year 2009 to 2014) . The points of the above accident are summarized below, with reference to their bulletin. The number of annual average for accidents that were clearly caused by crank pin bolt breakage (including looseness and dropping-off) accounted for more than 60%.
Crank pin bolt breakage is mainly caused by incorrect tightening during assembly of piston by crew. The mechanism is as below:

When the engine is in operation, inertia force of the piston interacts with the large end of the connecting rod. At that time, if the bolt is insufficiently tightened, it will work loose. As a result, the bolt will break and the nut will drop off respectively.
The causes of insufficient tightening of bolts are mainly as follows:

①	It was tightened with an insufficient torque.	
②	Although the bolt was tightened by a prescribed torque, this was insufficient for the following reasons:	
	(a)	Failure to notice a rough seat surface. However, it was tightened as it was.
	(b)	Failure to notice cracking at the part of the serration on the large end of the connecting rod. However, it was tightened as it was.

'Angle tightening' as opposed to 'torque tightening' is indicated by the engine manufacturer. The reason is because it can be tightened with greater precision.
Moreover, there is another large reason for breakage of the crank pin bolt. It is deterioration in strength of the bolt itself. It is caused by the continued excessive hours of use of a bolt beyond the limit recommended by the engine manufacturer. A measure is to carry out maintenance based on the instruction manual and service news updates.

§ 4-3-3 Case ③ Oil Spill Accident

The error chain of an 'Oil Spills Accident' (Case ③) was analysed by time-sequence. Error chains were caused by both breach of work in accordance with work instructions and crew's lack of operational skills and knowledge.

Time-sequence ① Failed to check for remaining oil of final top-up tank

Time-sequence ①	At previous port, 2/E was allocated to measuring work of the remaining oil in the topping up tank (No.3 FO tank), but he did not do it.	
Errors		Related problems
1	Did the 1/E accurately explain to the 2/E the work plan timetable, work allotment, procedure and the importance of the task at the meeting before duty? Could the 2/E grasp it?	Daily duty management
2	Did the 1/E not confirm with the 2/E in the meeting that the work had been completed? Was there not bad communication between the 1/E and 2/E?	Daily duty management
3	Did not the 2/E have more important work which was a priority? If he had, why did not the 2/E ask the 1/E for a change of assignment? Did not the 1/E grasp the 2/E's work responsibilities? Could not the 1/E rearrange the 2/E's work with other personnel?	Daily duty management

4	Were not remarks regarding the danger, when there was an error of measuring remaining oil, described in the work instructions? Could the 2/E grasp it?	Work instruction related
5	Could not the 2/E predict the risk of trouble through failing to measure the remaining quantity?	Recognition of danger

Measures	Methods
<< Reinforcement of crew training >>	Crew training
Daily duty management (planning, assignment, communication regarding actual duties, and inappropriate responses towards more important work to be prioritized)	Crew training
Work instruction related (remarks missing regarding the danger of making a mistake when measuring remaining oil)	Crew training
Recognition of danger (insufficiency of risk prediction towards the trouble which may be caused by failure in measuring the remaining oil in the tank)	

Time-sequence ② Breach of procedure

Because items to be checked was not conducted, breach of procedure was raised as a problem.

Time-sequence ②	Made a plan assuming that there was no remaining oil in the topping up tank, despite not having carried out measuring of the actual remaining oil amount.	
Errors		**Related problems**
1	Did the 1/E accurately explain to the 2/E the work plan timetable, work allotment, procedure and the importance of the task at the meeting before duty? Did the 2/E understand it?	Daily duty management
2	The 2/E did not carry out remaining oil measurement. However the 1/E made the bunkering arrangement plan document, assuming no oil remained. What is the reason for this?	Fig. 37 Work instructions Lack of information of A-a
3	Was the 1/E competent for the duty allocated in the assignment of roles?	Fig. 37 Work instructions Lack of information of A-a

Measures	Methods
<< Thorough guideline creation >>	Thorough instruction
● Daily duty management (confirmation)	Thorough ship management and supervision
● Work instruction related (making a bunkering arrangement plan document and an allotted list for bunkering arrangement work sharing)	

Time-sequence ③ Breach of plan

Work instructions were not considered during making the plan.

Time-sequence ③	Make a plan at a target level which is equivalent to 66% of the tank capacity (approximately 62KL) (this is related to Time-sequence ⑤)	
Errors		Related problems
1	How reliable was the remote level gauge for the topping up tank? (Did the 1/E confirm if it may be useful to grasp the liquid level by checking normal operation and indicator prior to bunkering?	Table 37 Work instructions A-c
2	Were the crew able to acquire the method and an understanding of the state of the topping up tank through measuring the tank regularly during bunkering? Did the 1/E understand the various calculation methods (inflow quantity(m^3/h), estimated completion time, etc.)	Table 38 Work instructions D-a
3	Could the 1/E obtain the calculation method for predictive adjustment of the final liquid level of the topping up tank, having measured the liquid level of the tank which completed receiving oil.	Table 38 Work instructions D-a
4	Did the 1/E make plans to double-check the system for measuring the liquid level of all tanks? (Appropriate personnel arrangements)	Table 38 Work instructions D-a
Measures		Methods
<< Thorough guideline creation >>		Thorough instruction
● Work instruction related (grasp of bunkering progress and regular tank level measurement: remote level gauge, actual measurement (sounding scale) ● Work instruction related (appropriate bunkering work sharing and list of work allotment)		Thorough ship management and supervision

Time-sequence ④ The remaining oil measured was not precise.

Time-sequence ④	Although the 3/E and two oilers measured the actual remaining oil quantity in the tank just before the start of bunkering, they did not realize the quantity.	
Errors		Related problems
1	Why did the 3/E not notice the remaining oil before the commencement of bunkering?	Table 38 Work instructions D-a
2	Who was the person responsible for calculating the remaining oil quantity? The chief engineer or the 1/E? Did the engineer in charge of calculation of remaining oil quantity understand the calculation method?	Fig. 37 Work instructions A-a, b, c

3	Did they correctly obtain the necessary environmental information (temperature, trim, etc.,) for calculating remaining oil quantity and data (specific gravity & volume conversion factor, etc.)?	Table 37 and 38 Work instructions A-c, C-a, D-a
4	Did the chief engineer check the statement of re-calculated planning immediately before bunkering that was formulated by the 1/E? Was a final meeting immediately before the start of bunkering held?	Table 37 Work instructions A-a, b
Measures		Methods
<< Thorough guideline creation >>		Thorough instruction
● Work instruction related (measurement of all tanks, work sharing, calculating the remaining oil and supervision by superintendent)		Thorough ship management and supervision

Time-sequence ⑤ Did not stop oil transfer despite the occurrence of an overflow

Time-sequence ⑤	The 3/E and two oilers (who measured the liquid level continuously) did not stop oil transfer even when it exceeded the planned top-up level during bunkering, which caused overflow from the air vent.	
Errors		Related problems
1	Why did the 1/E not stop even when it was beyond the top-up liquid level of the plan? ● Did the 3/E and two oilers actually measure the tank regularly during bunkering and report to the 1/E? ● Did the 1/E check the difference with the liquid level, by confirming the tank during bunkering by remote level gauge regularly? ● Did the chief engineer have a grasp of the final situation just before completion of topping up?	Table 37 Work instructions C-a, D-a
2	Did the 1/E correctly calculate the top-up liquid level of all receiving tanks in advance? ● Safe work and action cannot be ensured, if top-up liquid level of each tank is fixed at the time of making a plan. ● If the liquid level of the tank after bunkering is different to the plan, the finalized liquid level of the topping up tank must be adjusted. Did the 1/E conduct the correction calculation method? (PDCA) ● If the liquid level of the previously completed tank is less than that of the plan, the liquid level of the topping up tank will be high. Did they not consider this to be dangerous?	Table 37 Work instructions A-a
3	Did all workers understand the final liquid level to be topped up? ● Anyone could notice something unusual and offer an opinion.	Table 38 Work instructions D-a
Measures		Methods
<< Thorough guideline creation >>		Thorough instruction
● Work instruction related (bunkering arrangement, estimate the liquid level of the receiving tank, inform those around and monitor the situation)		Through ship management and supervision

Time-sequence ⑥
Both chief engineer and the 1/E did not have a firm grasp of the amount of oil in the final topping up tank.

Time-sequence ⑥	Overflow: When the accident occurred, 96% of tank capacity (approximately 91KL) had been pumped into the topping up tank. There was no problem regarding bunkering work on the barge side (agendas in the pre-meeting, oil transfer quantity, total amount of oil transfer, etc.)	
Errors		Related problems
1	Did the chief engineer and the 1/E recognize that the topping up tank had been filled to 96% when it began to overflow.	Table 38 Work instructions D-a
2	As to what percentage did the chief engineer and the 1/E recognize the liquid level of the topping up tank to be at that time?	Table 37 and 38 Work instructions A-a, b, D-a
Measures		Methods
<< Thorough crew training >>		Crew training
● Work instruction related (grasp of the bunkering quantity before topping up, tank liquid level and quantity adjustment before completion of transfer)		Thorough ship management and supervision

Time-sequence ⑦ Delayed emergency stop

Time-sequence ⑦	The 1/E (who is responsible for bunkering work and contact liaison with the barge) delayed in emergency stop measures, following overflow.	
Errors		Related problems
1	Is there an emergency procedure instruction manual on board? Handling of it ? Recognition of it ? ● Fundamental code of conduct that the vessel is to maintain under SMS and safety management manual	Table 37 and 38 Work instructions A-b, C-a, D-a
2	Did all crew recognise 'accident impact in the case of neglecting emergency actions'?	Recognition of danger
3	Did all crew attend an emergency procedure instructions workshop in advance?	Safety training
4	Had all crew conducted emergency drills at the time of overspillage?	Safety management code and training in the case of an emergency

Measures	Methods
<< Thorough guideline creation >>	Thorough instruction
● Work instruction related (emergency procedure instructions)	Thorough instruction
<< Reinforcement of crew training >>	Crew training
● Recognition of danger (Accidents that escalate when emergency response is inappropriate)	Crew training
● Safety training (enthusiasm towards emergency procedure instructions)	
● Safety management code (Making a plan and implementation of emergency drills)	

§4-4 Analysis with an ETM (Engine-room Team Management) Overview

Just as with Bridge Team Management (BTM), Engine-room Team Management (ETM) is a functional organized system that utilises mutual communication between not only those such as chief engineer, engineer and engine department crew, but also between software (SMS manual and safety management code, etc.), hardware (equipment) and environment (external information).

As indicated in each table under '§4-3 Accident analysis along with the error chain', the problem is 'Why was something unusual ('foresight'), which caused trouble from daily monitoring situations of equipment allocated in the engine room, not discovered?' Or, 'Why was there not the effective function of the 'human five senses' in order to shed light on the problem?'
The cause was down to a lack of basics regarding engine watch. As was introduced in the 'collision accident' cases, the most important aspect of operation in navigational watch is 'look-out'. Although it is emphasized that it is important to taking a quick and dynamic approach towards a dangerous situation at sea, the same applies to engine watch.
In other words, the fundamentals of engine watch is for the crew to collect and analyse difficult to detect information via remote monitoring sensors, and by 'utilizing the superior human senses during engine room round watch'. Furthermore, crew is required to take the necessary actions.

Engine-room Team Management (ETM) Analysis

Compliance Rules		Problems
Piston seizing, Piston skirt broken damage		
Constant operation information and adjustment of main engine and auxiliary machinery and equipment (temperature, pressure, consumption and those changes)	①	Main engine LO consumption increased from around June, 2012. Although consumption increased by approximately three times to that of normal condition just before the accident, there were neither inquires made to the manufacturer nor particular actions taken, regarding the abnormal consumption of LO.
	②	Were signs of abnormality not noted until the day prior to when the trouble occurred? How had the temperature of LO and the pressure changed? Was there an abnormal noise, or an overheated casing?

Appropriate Planned Maintenance System: maintaining the state of equipment that performs to the design specification.		①	Was the piston maintained in a planned manner?
		②	Because the item was replaced with a remodeled part, they trusted the overhauling and assembly entirely to the manufacturer. Assembling work was not confirmed on the vessel side.
Education on the ship: establishment of common recognition regarding the engine system.			
①	Regular study session workshops about engine operation and its procedure with the operation management system.	①	As LO consumption increased by approximately three times to that of normal, the inside of the crankcase was inspected. However, there was no abnormality found and it was thought that the piston rings were worn.
②	Information sharing of trouble cases and experiences	①	Risk prediction was not recognized. What kind of accident was expected, in the event of insufficient maintenance of the basic structure of the piston?
③	Workshop based on the maintenance procedure and its risk assessment	①	There was no guideline for points to be checked ‘ such as important procedure for assembling, timing regarding watch on the ship's work site and the necessity of asking for assistance from the vessel' for manufacturer's repair work.
		②	There was no guideline ‘ for inquiring after the manufacturer for advice and emergency measures to take ’ in the case of discovering an abnormality on the ship.
		③	Because some parts such as a snap ring may cause an accident due to damage, a guideline and a checklist ‘ on issuing an instruction to manufacturer worker or watching out for abnormalities in the ship's working areas ’ for inspection maintenance and assembly are required.
		④	There was no guideline‘ on making a request to the ship superintendent immediately, if overhaul due to abnormal prediction was found to be necessary'.
		⑤	Did they share information in more casual circumstances (i.e. during recess)?
Crank pin bearing damage accident			
Constant operation information of main engine and auxiliary machinery and equipment (temperature, pressure, consumption and those changes)		①	Were signs of abnormality not noted until the day prior to when the trouble occurred? Was there abnormal noise, or an overheated casing?
Appropriate Planned Maintenance System: maintaining the state of equipment that performs to the design specification.		①	Carry out overhaul inspection based on the planned maintenance schedule.
		②	There must have been a description regarding the technique of tightening in their instruction manual.

Education on the ship: establishment of common recognition regarding the engine system			
①	Information sharing of trouble cases and experiences	①	There was no recognition of 'if the connecting rod is tightened incorrectly, that it may develop to engine trouble'.
②	Workshop based on the maintenance procedure and its risk assessment	①	There is no maintenance guideline regarding 'tightening techniques, handling of a torque wrench, parts assembly and nut surface cleaning, penetration test when tightening bolts, etc.'
		②	There was no safety guideline for 'items that the senior engineer must confirm' when maintaining a vessel.
③	To utilize five senses	①	Was the utilization of the five senses to detect something amiss at the time of round inspection understood?
		②	Did they share information in more casual circumstances (i.e. during recess)?
Oil Spills Accident			
Education on the ship: establishment of common recognition regarding bunkering		①	Breach of procedure
		②	Insufficient communication
		③	Lack of risk prediction

Table 44 ETM Analysis

§ 4-5 Preventive Measures

§ 4-5-1 Relationship between Accidents and Causes

In the above described cause analysis, the common causes are emergent in ‘ETM’ respectively. Firstly, the relationship between cause and accident, though basic, is the main focus.

In Table 45, ❶ cause investigation flow, tracking back from the accident result, is shown. The accident causes can be roughly divided into ❸ a direct cause, which is directly connected with the accident and ❹ indirect cause, which is the surrounding circumstances behind it. And, the causes in the background can consist of ❺ human indirect causes and ❻ root causes led by insufficient control of the organization. It will be difficult to prevent a similar accident, until the indirect causes related to human error, which are shown in flowchart ❺ and ❻ , including root causes hidden in ❻ , are eliminated.

1 Consequences : Impact caused by an accident

Number of concerned people (injury or death), compensation for property damage, spilt quantity, damaged areas, black-out hours, business disruption, loss amount, etc.

▼

2 Accident/Trouble

Equipment damage, black-outs, oil (bilge) spillage, air pollution, falls, etc.

▼

3 Direct Cause : Clear reasons

Dangerous action (Disregard for safe working practices, not wearing safety equipment), dangerous situations (dark, noisy and harmful or explosive situations)

▼

4 Indirect Cause : Reasons underlying background influences of direct cause

It may be the case that this cannot be proved, even if it was investigated.

▼

5 Human Indirect Cause :

Human error : Human factor (lack of experience, etc.) and
Work factor (i.e., sleep deprivation and fatigue)

▼

6 Root Cause : Insufficient management

Lack of planning, insufficient procedure, standard and guideline, lack of compliance, etc., even equipment design error.

Fig. 45 “Relationship between Trouble and Cause, and Cause Investigation Flow”

Each of those accidents that apply to this flowchart will be shown in Tables 46, 47 and 48.

Case ① Piston burnout and piston skirt broken damage accident

Items		Details
③ Direct cause		The route for supplying lubricating oil was blocked and the piston overheated. Subsequently, the piston skirt sustained broken damaged due to the piston seizing in the cylinder liner. As a result, the cylinder liner and crankcase door was damaged.
⑤ Indirect cause	①	There was no recognition of risk prediction, for example, that 'engine trouble may have developed if the snap ring had not been correctly inserted'.
	②	At the time of inspecting the inside of the crankcase 'not only should contaminants at the bottom (metal pieces of bearings, combustion residue, etc.) be observed, but also the state of the piston and liner'.
	③	Could not recognise the signs of an accident by round inspection?
⑥ Root cause		The following guideline was not established.
	①	Guideline of points to be checked 'such as important procedure for assembling, timing regarding watch on the ship's work site and the necessity of asking for assistance from the vessel for manufacturer's repair work.
	②	Guideline 'for inquiring after the manufacturer for advice and emergency measures to take' in the case of discovering an abnormality on the ship. In the guideline, the necessity of being able to adjust the piston location in the event of inspecting the liner should be added.
	③	Because some parts such as a snap ring may cause an accident due to damage, a guideline and a checklist of 'working instructions to the shore worker or watch on the ship's work site' for inspection maintenance and assembly are also required.

Table 46 Cause Analysis (Piston Seizing, Broken Damage in Piston Skirt Cases)

Case ② Crank pin bearing damage accident

Items		Details
③ Direct cause		Due to breakage of the connecting rod bolt, the large end of the connecting rod was released and the connecting rod passed through the crankcase door, which disabled the main engine operation.
⑤ Indirect cause	①	There was no recognition of risk prediction that 'if the connecting rod was tightened incorrectly, that it would develop to engine trouble'.
	②	Could not recognise the signs of an accident by round inspection?
⑥ Root cause		The following guideline was not established.
	①	Regarding the assembly of the connecting rod, guideline for maintenance of 'technique of tightening, handling of torque wrench, parts assembly and cleaning the surfaces of nuts, penetration test of the bolts, etc.'
	②	Safety guideline of 'items that the chief engineer and the 1/E must confirm' when maintaining a vessel

Table 47 Cause Analysis (Cause Analysis Cases)

Case ③ Oil Spills Accident

Items		Details
❸ Direct cause		Delay in emergency stop measures by the 1/E following overflow. The 1/E is responsible for bunkering work and contact liaison with the barge.
❺ Indirect cause	①	Technical knowledge insufficiency
		● Method of measuring the tank liquid level
		● Calculation method of remaining oil in tank (bunkering quantity) (Implementation of trim heel correction by tank table)
	②	Lack of safety and environment awareness
		● Superintendent's awareness of safety and environment
		● 1/E, 2/E and 3/E's recognition of danger (risk prediction)
		● An accident that is expected to occur when tank measurement is not sufficient
		● Accidents that are expected to escalate when emergency response is inappropriate
		● Safety training related: enthusiasm about emergency procedure instructions.
		● Safety management code related: Making a plan and implementation of emergency drills
❻ Root cause	①	The following were insufficient regarding work instructions for bunkering.
		● Remarks before bunkering plan: measurement of remaining oil
		● Remarks when making bunkering plan: (a) Bunkering plan (ensure more than 10% of tank space for topping up = plan not to fill more than 90% of tank capacity) (b) Work sharing (personnel arrangements) and estimation of receivable tank level (c) Supervise by superintendent and double-check
		● Remarks before bunkering work: (a) Meeting for information sharing on bunkering plan (b) Reconfirmation of countermeasure in state of emergency
		● Remarks before receiving: measurement of all tanks, work sharing, calculation of remaining oil and supervision by superintendent
		● Remarks during bunkering: regular measurement of tank level (remote level gauge, actual measurement (sounding scale))
		● Remarks at the time of topping up the tank: grasp of receivable quantity and tank level
		● Emergency procedure instructions (There is a high possibility that spillage into the sea could have been suppressed, had the 1/E taken action immediately at the time of the overflow.)
	②	Insufficient routine work
		● Failure of, inadequacy and/or lack of information sharing regarding reporting and confirming of plan, manning and practice, and plan changes (if applicable).

Table 48 Cause Analysis (Oil Spills during Bunkering Cases)

Considering the analysis of events with a viewpoint from the PDCA cycle (Plan, Do, Check and Action), the key point is that ‘Safety can be defined as the result that avoids risks’ as explained in Chapter 2. In the case of engine related trouble, Plan is associated with work instructions and guidelines which were created based on the manufacturer’s instruction manual, work analysis, experimental rule, past lessons, principles of natural science and various kinds of technological information, etc. This technology is not simply summarised into work instructions. Extracting the fundamental risks assumed in each duty in advance, manageable measures will be introduced following analysis in order to reduce the risk level. In addition, the risk level will be reduced, if everyone clearly understands work instructions and guidelines of risk management (human factors) and practices it accordingly. However, if there is a lack of human experience and fatigue, the risk cannot be reduced because it is not possible to ‘Do’ (or) follow work instructions or guidelines accurately. No matter how bad the outcome, risk cannot be avoided. Elements of human behaviour stand between the fundamental plan and the end result. Therefore, when thinking about cause categories, it is an indirect cause that a human cannot execute.

Let’s compare daily duties or services on the ship to a drama. We exemplified daily duties on a ship using role play (drama). Work instructions and guidelines can be replaced with scenario (Plan) and the crews’ behaviours with the actors’ performances on the stage respectively. Even if the scenario is poor, once splendid actors perform (Do) and overcome the poor situation, it in turns into a masterpiece. However, it is hard for the ship owner and ship manager to allocate a superstar (a noted member of crew) to always perform. In order to encourage the actors to perform better than a certain level, it is important to prepare a wonderful (attractive) scenario to support them.

Meanwhile, accident analysis is Check (evaluation) and preventive measures are Action (improvement). Moreover, it will be ideal, if the Plan can be improved so as to better verify as to whether the preventive measures are functioning effectively.

However, following accident occurrence, the person involved tends to focus on the direct cause, which is easy to actualize generally. Because of this, symptomatic measures are often taken. This can be applied to the ‘grave-post type’ of safety measure which was explained in the ‘Loss Prevention Bulletin: Thinking Safety (Vol.35)’; and that this kind of symptomatic measure can cause another similar accident.
It should be emphasized that preventive measures should be introduced following the digging up of the root cause (‘preventative type’ of safety measure). Therefore, first of all, events prior to the accident should be specified and, then, the cause can be extracted by analysing as to why each time-sequenced event occurred. And, finally, preventive measures will be led by examining ways to eliminate the cause.

In ISM Code 2010 amendment, the following is specified: 1.2.2. It should assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards; and 9.2 The Company should establish procedures for the implementation of corrective action, including measures intended to prevent recurrence. Because of this, it is presumable that both risk evaluation and the scheme for preventive measures are established in the SMS manual at the respective companies. Please take a look at it.

§ 4-5-2 Preventive Measures

Summarizing the root causes of Cases ①, ② and ③, an accident could be caused, because the following items were insufficient. In all stages, it is required that work instructions and guidelines be equipped, to perform thorough crew training and to observe the prepared guidelines and work instructions strictly.

① **Conduct the maintenance and inspection based on the manufacturer's instruction manual**

② **Replace parts in accordance with the standard**

③ **Confirmation of critical points regarding the process of maintenance and repair assembly**

④ **Watch-keeping that utilizes the human five senses**

⑤ **Understand the relationship between the basic structure of equipment and trouble**

⑥ **Maintenance of work instructions and guidelines**

⑦ **Thorough crew training**

Regarding prevention for accidents related to the engine including Oil Spill Accidents, the following items are especially important.

Maintenance	The systems and equipment on the vessel must operate normally as designed based on the principles. Therefore, the crew is expected to maintain and inspect the above in a planned manner everyday. The measure is for the ship manager to establish 'a system that has guidelines and a thorough method of instruction' as a Plan. For example, the guideline requires PMS (Planned Maintenance System), work instructions, guidelines for maintenance and a work check list.
Monitoring of the condition	The system and equipment on the ship is operated under a variety of conditions. Thus, the crew must clearly understand those different operating states on a daily basis. If they can recognize an abnormality at an early stage, appropriate measures can be timely taken. Therefore, the measure is for the ship manager to establish the 'basics of engine watch' in order for the crew to be able to Do (practice). For example, enforcement of daily inspection and safety education.
Education system	The crew are expected to understand trouble related to the basic structure of the above. Thus, in order for the crew to practice (Do) it, it is important for the ship manager to establish a 'maintain and improvement system of knowledge level = the education system'. For instance, regarding the system and equipment, it is to re-educate the fundamental items and structure and hold a case workshop. These were summarised in the Table 49.

No	Insufficient items	Measures	Key points of `ETM'
①	Performance of maintenance and inspection based on manufacturer's instruction manual	`Planned Maintenance System (PMS) /Work instructions/ Maintenance guideline /Work checklist'	Maintenance
②	Part replacement in accordance with the standard		
③	Confirmation of important phase in the process of maintenance, recovery and assembly		
④	Round inspection utilizing five human senses	Daily inspection and safety training	Monitoring the situations
⑤	Understanding the relationship between basic structure of appliance and trouble	Re-education of basic items and structure	Education system

Table 49　Summary

§4-6　Proposals for Vessels with a Tight Operation Schedule

It is also essential to try to ensure the quality maintenance of vessels with tight operation schedules such as coastal vessels, ocean going container vessels and PCCs. In other words, operation management is the main issue here due to the influence of operating time schedules for these vessels. In these circumstances, the crew can only carry out small-scale maintenance during the short staying hours. For example, replacing fuel injection valves on an engine. However, it is impossible to carry out medium scale maintenance in a short and limited time frame. Therefore, there will inevitably be more cases of medium scale maintenance by engine manufacturers or ship repairing companies during berthing. Regarding large-scale maintenance, it is to be carried out by the above mentioned agents during the docking period. As a result, crews are facing the reality that they cannot be expected to improve their technical skill levels for these middle and large scale operations, because they have less opportunity and experience of maintenance and also get less opportunity to earn practical experience.

Therefore, ship managers should pay attention to the above mentioned maintenance background/circumstances and crew's technical skill levels. In order to compensate for this, a checklist that includes a summary of remarks for maintenance, inspection and assembly points for each maintenance site will be useful. It is important to make a checklist like this and perform thorough instruction on the vessel. It is most effective for the crew to make this kind of checklist, however, it would be an option to outsource this to an engine manufacturer or technical consultant.