JAPAN P&I CLUB Vol.40 September 2017

P&I Loss Prevention Bulletin

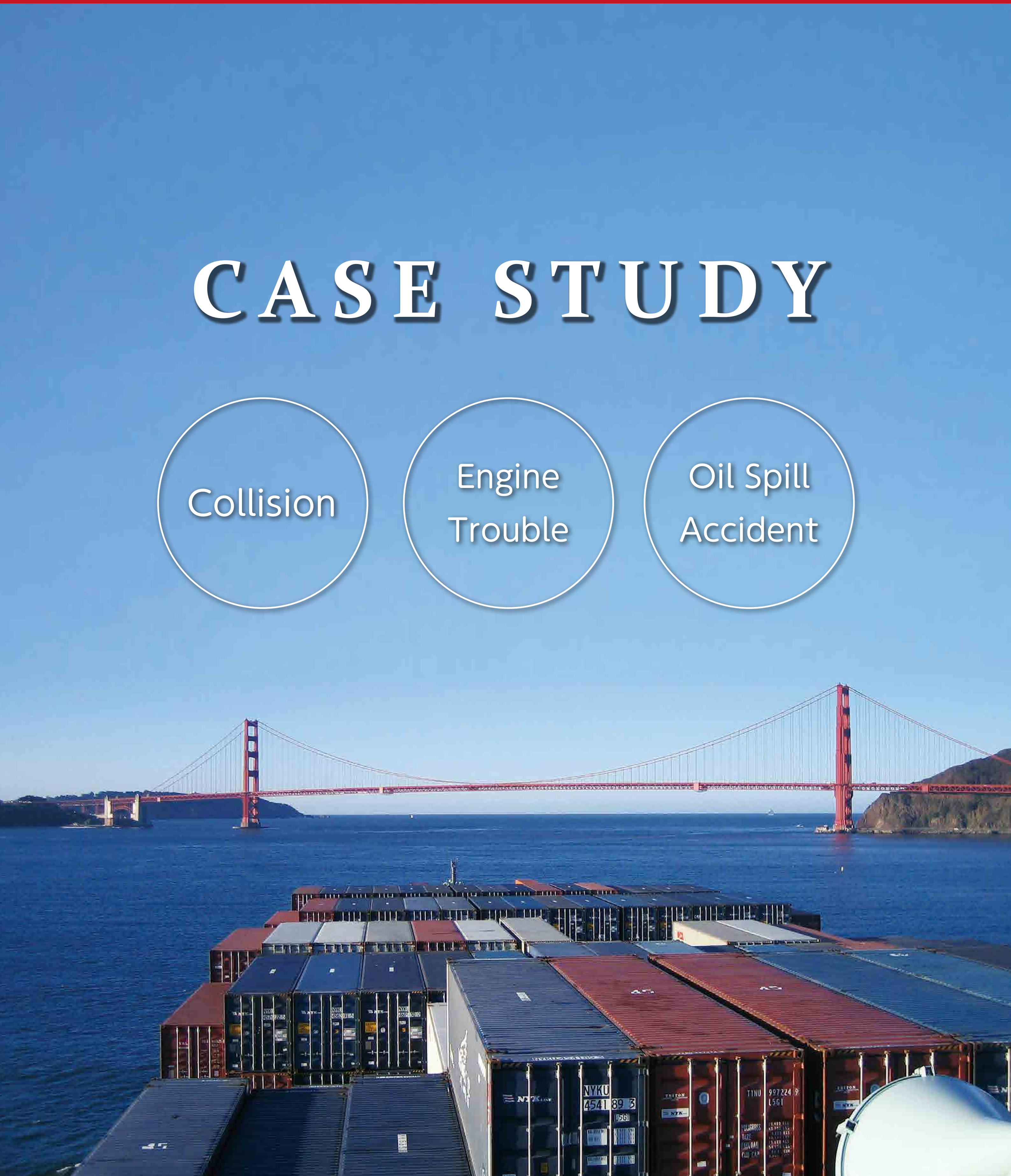
The Japan Ship Owners' Mutual Protection & Indemnity Association Loss Prevention and Ship Inspection Department

CASE STUDY

Collision

Engine Trouble

Oil Spill Accident



Contents

Introduction 1

§1 What is Safety? 1
§1-1 What is Safety? 1
§1-2 Safety and Technicians 2
§1-3 Safety and Culture 3
§1-4 Human Characteristics and BTM (Bridge Team Management) /ETM (Engine-room Team Management) 7
§1-5 BTM・ETM：From Grave-post Type to Preventative Type Analysis/Counter Measure ... 8
§1-6 Training of Inexperienced Officers and Engineers with Low Skill Levels 13

§2 Collision 15
§2-1 Summary of Accident 15
§2-2 Analysis of Accident Cause by Japan Transport Safety Board (Marine Sub-committees) 20
§2-2-1 Applicable Navigation Act 20
§2-2-2 Analysis of Accident by Japan Transport Safety Board 21
§2-2-3 Analysis of Accident Cause by Japan Transport Safety Board (Marine Sub-committees) 22
§2-2-4 Preventive Measures by Japan Transport Safety Board 23
§2-3 Analysis Combining Human Characteristics and Preventive Measures 23
§2-3-1 Analysis of Accident Causes 23
§2-3-2 Analysis of Accident Causes which can be Commonly Seen Regarding the Third Officers of Vessel A and B 27
§2-3-3 Analysis According to Human Characteristics for the Masters of Vessel A and B 32
§2-4 Preventive Measures 33
§2-4-1 The Third Officers of Vessels A and B 33
§2-4-2 The Masters of Vessels A and B 34
§2-4-3 Management on Shore (Ship Management Company) 35

§3 Traffic Systems of the Kii Suido (Strait) and Tokyo Bay 36
§3-1 The Kii Suido (Strait) (See Fig. 30: Attachment ① The Kii Suido (Strait) Traffic System Chart Enlargement) 36
§3-2 Tokyo Bay (See Fig. 31: Attachment ② Tokyo Bay Traffic System Chart Enlargement) ... 38

§4 Engine Trouble and Oil Spill Accidents 40
§4-1 Feature of Trouble and Damages (Attachment ③ See '4 Cycle Diesel Engine of vessel') 40
§4-1-1 Damage that Affects Ship Operation 40
§4-1-2 Damage Characteristics - by Equipment 41
§4-2 Cases 43
§4-2-1 Case ① Piston Seizing and Piston Skirt Broken Damage Accidents 43
§4-2-2 Case ② Crank Pin Bearing Damage Accident ... 46
§4-2-3 Case ③ Oil Spill Accidents 47
§4-3 Accident Analysis in Accordance with Error Chain 53
§4-3-1 Case ① Piston Seizing and Piston Skirt Broken Damage 53
§4-3-2 Case ② Crank Pin Bearing Damage Accident ... 57
§4-3-3 Case ③ Oil Spill Accident 60
§4-4 Analysis with an ETM (Engine-room Team Management) Overview ... 65
§4-5 Preventive Measures 67
§4-5-1 Relationship between Accidents and Causes ... 67
§4-5-2 Preventive Measures 72
§4-6 Proposals for Vessels with a Tight Operation Schedule 73

Conclusion 74
List of References 74
Attachments 75
Attachment ①：The Kii Suido (Strait) Traffic System Chart (Enlarged drawing of Fig. 30) 75
Attachment ②：Tokyo Bay Traffic System Chart (Enlarged drawing of Fig. 31) 76
Attachment ③：4 Cycle Diesel Engine of Vessel 77
Attachment ④：Cases of Additional Engine Troubles (3 Cases) 78

Introduction

There are many kinds of maritime accidents such as collisions, groundings, fires, sinkings, damage to harbour facilities, oil spills and engine troubles. However, about 90% of the causes of these maritime accidents are said to be due to human error. In this bulletin, we will introduce case studies which are based on real incidents that incurred collisions, engine troubles and oil spills. Along with these, 'Preventive Measures' will be analyzed from the viewpoint of human error.

§1 What is Safety?

§1-1 What is Safety?

On May 2015, we held a seminar entitled 'Thinking Safety' which was issued in the P&I Loss Prevention Bulletin Vol.35. Before introducing the actual incident cases, we would first like to review 'what safety is'. (Please refer to the above P&I Loss Prevention Bulletin Vol.35.)

Seafarers are always expected to operate their vessel in a safe condition, which never causes any accidents.
Expressions such as 'Safe Operation' and 'we pray for your safe voyage' are used frequently, however the meaning of 'Safety' is somewhat unclear.

We found an interesting 'definition of Safety', according to the English psychologist Reason:

Fig. 1 San Francisco Golden Gate Bridge

Safety：Having resistance to danger to which an organization is constantly exposed.

More specifically, postulating that this world is exposed to threat, Reason defines `Safety` as the ability of an individual or the capacity of an organization to confront the threat.

> Also Helen Adams Keller said:
>
> Security is mostly a superstition. It does not exist in nature, nor do the children of men as a whole experience it. Avoiding danger is no safer in the long run than outright exposure to danger.

That is to say 'safety' is simply the result of danger avoidance. Therefore, I believe that it is correct to assume that 'there is no such thing as safety' in the world.

§1-2 Safety and Technicians

If we consider safety from the point of view that, not only the captain and chief engineer, but also the entire crew, comprise a collection of technicians, there are many who view safety as being at the leading edge of technology, and an extension of technology itself. In other words, many are of the opinion that as 'vessel technology' and 'skill of the crew members' are improved, it automatically maintains safety'.

It must be simply stated that this way of thinking is incorrect and dangerous. Japanese psychologist Professor Isao Kuroda, Japan Human Factor Institute, emphasized 'Safety must be thought of as being a social value beyond technology, a dimension beyond technology'. On the other hand, from the view point of technology based on moving things, including vessels, it is specific to various fields, for example, technology employed in a vessel, railway and vehicle operation: each is simply a means by which our lives are more enriched.
Thus, it is necessary to consider that, unless the crew at the frontline of safety in operating the vessel separate safety and technology, unless they have a different dimension to safety, safety cannot be maintained.

However, when an accident occurs, the focus is on preventing a reoccurrence, and there is a strong tendency to analyze it from a technical perspective. Thus, measures developed against reoccurrence are taken from a technical perspective.
For example, a Maritime Accident Inquiry is held following a collision accident, and the vessel is found to be in breach of Clause XX of the Maritime Collision Prevention Act. Consequently, the accident is the responsibility of the person in contravention of the legislation, and that person is then subject to suspension of his/her license for a specified number of days. In other words, the focus is commonly on 'who was responsible', and the person in question is punished, and everyone moves on. (The Maritime Accident Inquiry Law was revised in 2008 and the objective of the law is for disciplinary action to be taken against the designated marine officer who caused a maritime accident, whilst Japan Transport Safety Board is in charge of analyzing preventive measures, also.)

However, this approach 'does not investigate and analyze in practical detail', when focusing on 'the cause of the accident'. For example, in the event of a collision caused by crossing vessels, all watch-keepers at brigde, who hold a license and whom do not remember the clause completely, should know that 'the vessel which has the other on her

own starboard side shall keep out of the way'.
However, if we do not investigate and analyze in practical detail as to 'why the marine officers did not or could not take action to avoid the collision despite having knowledge of these regulations', without consideration of the human factors, 'the measures developed to prevent reoccurrence', simply become a patch on the problem, and a similar kind of accident is likely to reoccur as a result.
Professor Kuroda referred to this as the 'grave-post type' of safety measure, i.e. a safety measure which commemorates the accident, calls an end to it, and moves on, without any connection to preventing reoccurrence.

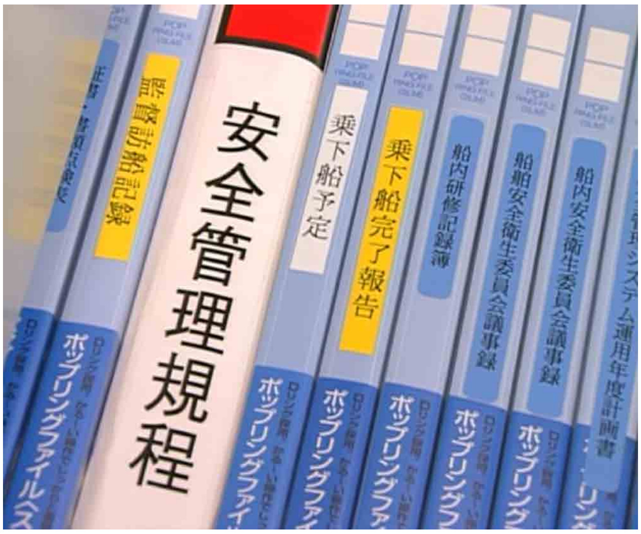


Fig. 2 SMS Manual (Japanese only)

In fact, what we should really consider are social considerations, for example, ensuring that no lives are lost, or that no pollution occurs. It is necessary to consider safety from the point of view of preventative measures to ensure that the accident does not reoccur. Professor Kuroda referred to this as the 'preventative type' of safety measure.

When we consider operation of a vessel, we focus on existing dangers for example, the danger of collision, the danger of a cargo accident, the danger of damage to harbor facilities, and the danger of engine failure. We therefore see 'how to avoid these dangers' as being associated with safety. As human beings, we face these dangers, and engage in activities to avoid them.

According to the above, 'safety' can be defined as:
'a conclusion or evaluation of the results on avoidance of these dangers'.

§1-3 Safety and Culture

Considerable energy is required to activate the system developed within safety management such as SMS manual (Safety Management System manual). This energy must be seen and derived from the safety culture. When we consider this culture, we must see it in terms of the following three components. (See Fig. 3)

1 Science

While this goes without saying, a theoretical knowledge (e.g. physics) is necessary in the world of ships. For example, why does a ship, which is made of iron, float (Archimedes' principle), or when stopping the vessel by astern engine, an understanding of acceleration is necessary to understand how far the vessel will move ahead with a given horsepower applied, and how many minutes it will take. Also, dynamics on how to load cargo through weight distribution, so as not to break the hull, are involved.

2 Skill

Skill is the ability to use scientific theory. Skill differs with the manner in which it is used. Skill is a methodology for effective use for the benefit of society, and a means of taking scientific principles to society. Similar to nuclear power, for instance, the technology we end up utilizing depends on how we utilize the science: it can be an atomic bomb or a nuclear power plant, or a reactor powered vessel, even though the principles are same.

3 Technicians

Technicians are persons making the best use of the skills with a methodology derived from the technology. Persons who operate the safety management system are also considered technicians.

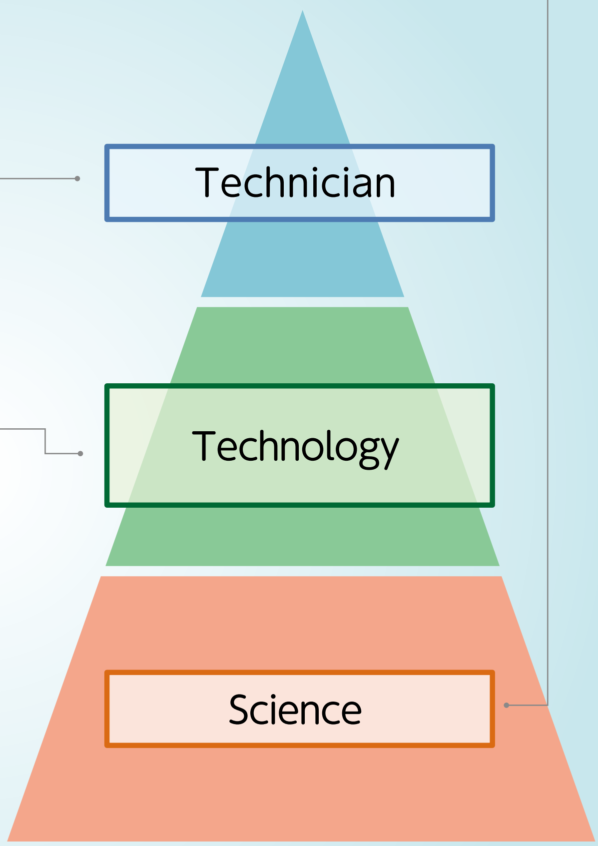


Fig. 3　Pyramid of Science, Technology (Engineering) and Technician (Maritime Officer)

Electronic Chart Display and Information Systems (ECDIS), GPS, AIS, Automatic Radar Plotting Aid (ARPA) and unmanned engine room operation (M0 operation) have been introduced at a rate hitherto unimaginable, and provide a much greater volume of information than in previous visual format. In addition, sounding alarms are also installed in these devices to notify the bridge of vessels which are at risk of collision.

Fig. 4　Integrated Bridge System

At the same time, technicians are responsible for setting the point at which alarms are set, and for the decision as to whether or not to use the various forms of information displayed.These devices do not automatically allow the vessel to avoid dangers in navigation. Until the development or the robotic vessel (unmanned vessel) of the future, the captain and officers as technicians, will conduct an overall evaluation of the provided information and operate the vessel accordingly. In addition, vessels employing M0 operation are increasing in the engine room, and a considerable proportion of operation is now automated. However, even if operation of individual engines can be automated, chief engineer and engineers as technicians view the entire engine room as a plant that operates using the five senses to prevent problems, are still necessary. Also maintaining ‘Safety’ (avoidance of danger) should be done by humans (technicians).

Technicians are therefore required to acquire knowledge and skills for safe operation of the vessel and machinery to ensure safety, and obtain a seamen’s license as evidence of having such knowledge and skills. In other words, because safe operation of the vessel and machinery is extremely complex and difficult, ‘the scope of individual discretion’ naturally becomes wider as a result of carrying out such activities.


一級海技士（航海）
First Grade Maritime Officer (Navigation)
Certificate No. [redacted]
Date of license: 昭和61年8月15日 Aug. 15, 1986
Name (Sex): Okada Takuzo (男) (Male)
Date of birth / Registered Domicile or Nationality / Date of issue / Date of expiry: [redacted]
備考 Note
○更新免許者
甲一航
昭和61年8月15日免許
This holder had been licensed before the STCW Convention entered into force.
(Licensed on Aug. 15, 1986)

JAPAN

CERTIFICATE ISSUED UNDER THE PROVISIONS OF THE INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR SEAFARERS, 1978, AS AMENDED

The Government of Japan certifies that Okada Takuzo has been found duly qualified in accordance with the provisions of regulation II/1, II/2, II/3 of the above Convention, as amended, until Feb. 9, 2021.

The lawful holder of this certificate may serve in the following capacity or capacities specified in the applicable safe manning requirements of the Administration:

Capacity	Limitations applying: Ocean Going Areas	Greater Coasting Area	Coasting Areas
Master	Permitted	Permitted	Permitted
C/O	Permitted	Permitted	Permitted
2/O	Permitted	Permitted	Permitted
3/O	Permitted	Permitted	Permitted
W/O	Permitted	Permitted	Permitted
Other limitation			

Note
This holder had been licensed before the STCW Convention entered into force.

Certificate No. 5100860001006
issued on Apr. 8, 2016

国土交通大臣

The original of this certificate must be kept available in accordance with regulation I/2, paragraph 11 of the Convention while serving on a ship.

Date of birth of the holder of the certificate: Aug. 17, 1956

Signature of the holder of the certificate: OKADA TAKUZO

Fig. 5 Seaman's License (Japanese)

It is, therefore, natural to consider a seaman’s license a qualification that authorizes the holder to carry out the above duties. However, there seem to be many officers and engineers that tend to believe that ‘they are not required to undergo further training, because they graduated’, once they succeeded in passing examinations and obtaining their licenses. But it must be simply stated that this way of thinking is incorrect. As described above, crew having boarded the vessel after obtaining their licenses as first time officers and/or engineers, will have much technical experience to learn, more than what the examination covers and will continue to improve their skills by themselves. Therefore we have to consider them ‘not as graduates but simply as those who just started their seafaring life’.

‘Safe operation of the vessel, machinery and maintenance of the vessel’s schedule’ is the subject of much expectation from the wider society, but once they have trouble and fail to keep the vessel on schedule, there is not only economic loss but credibility lost, also. For example, in the case that a container vessel sailing from Los Angeles, USA, with a large load of grapefruits in the reefer containers, sustained engine trouble en route in the Pacific Ocean and finally could not arrive at Tokyo, Japan on schedule, there would be no grapefruits available at the market place in Tokyo. While this was occurring, consumers that went to a supermarket to buy a grapefruit would discover that the supermarket had sold out. Then the consumer would instead visit a department store to find a grapefruit. However, the price of the grapefruit would be USD 30/pc. Finally the consumer would give up on purchasing one. Then, the consumer will be disappointed because he/she cannot eat a grapefruit. On finding out through the newspapers that the reason why grapefruits are not available in the market was the result of a container vessel’s engine trouble, he/she may lose faith in the shipping company.

This is an extreme example, but we can understand that the ‘safe operation of the ship and its machinery’ is the subject of much expectation from the wider society, and from this point of view, the following are required in Figs. 6 and 7:

Mission of a Technician

- Lifelong Learning
- Calm evaluation of one's own personality

Reform of sense

Fig. 6 Mission of a Technician

Once a technical framework has been established, think about what is most important when it comes to using the framework in practice.

Be conscious about prevention and prediction all of the time in order to not cause an accident.

Concept of "5W1H+2F"

Fig. 7 Prevention and Prediction

In order to be more aware of prevention and prediction, it is required that '5W1H+2F' are considered. 5W1H refers to Fig. 8 below:

5W1H	When ?	Who ?	What ?
	Where ?	Why ?	How ?

Fig. 8 5W1H

Recently, adding 2F (Fig. 9) is favored:

2 F	For Whom ?	For What ?

Fig. 9 +2F

In case of an accident occurring, the person in breach of the legislation is punished and the case is closed. But it is required that 'For Whom' is not only 'for the person in contravention' but also 'for the company' and also 'for society', and 'For What' is 'for no more accidents concerning 5W1H'.

On the other hand, the question arises as to why a technician holding a ship officer's license (Certificate of Competency: COC) causes the same types of accidents. It is because many technicians still believe that improved technology leads to improved safety, that safety is a result of technological advances. As already described before, 'safety must be thought of as a social entity that extends beyond the realm of technology'.

The 'human factor' and 'human error' must be introduced into the counter measure, so as for there 'never to be a reoccurrence of the same type of accident', in the analysis. Rather, preventative type of safety measures are necessary where we ask questions as to why the accident occurred, about the surrounding circumstances of the accident, and consider the best means to prevent reoccurrence.

When formulating a countermeasure to prevent reoccurence, consider

Human Characteristcs

and analyse as to why such an action that led to an accident was taken.

Fig. 10　Human Characteristics

§1-4　Human Characteristics and BTM (Bridge Team Management) /ETM (Engine Room Team Management)

If we assume that 'humans are error-prone, including experts', preventing human error is a matter of BTM and ETM which have been designed to achieve safe vessel operation by raising awareness of bridge and engine room teams. Before an explanation of BTM and ETM, let's consider 'Human Characteristics'.

(Human Characteristics)

The following are the "Human Characteristics" that can hinder appropriate procedures and judgment. (from Nihon VM centte "Anzen no Komado" No.18 30/6/2002)

Twelve human characteristics

1. Human beings sometimes make mistakes
2. Human beings are sometimes careless
3. Human beings sometimes forget
4. Human beings sometimes do not notice
5. Human beings have moments of inattention
6. Human beings are sometimes only able to see or think about one thing at a time
7. Human beings are sometimes in a hurry
8. Human beings sometimes become emotional
9. Human beings sometimes make assumptions
10. Human beings are sometimes lazy
11. Human beings sometimes panic
12. Human beings sometimes transgress when no one is looking

If we consider the above, it appears that human beings are nothing but a collection of defects and shortcomings, and it also even seems that human behaviour is in danger of re-occurrence. However, from another point of view, these defects can be seen as 'wonderful abilities of human beings'. The 'human behaviour characteristic' can consist of advantages and disadvantages, as follows.

1	Attention dispersal model	⇔	Simultaneously perform multiple tasks effectively
2	Evaluate and act on assumptions	⇔	Able to make overall decisions
3	Make decisions on limited information	⇔	Able to make decisions efficiently
4	Haphazard behavior	⇔	Able to make flexible responses to suit the conditions

However, human beings have a wide range of information input systems, along with a single system capable of processing and judging. This system is easily interrupted, and the focus easily switched.

Furthermore, human beings tend to seek the comfortable option, to have real intentions and stated reasons, to be sleepy in time zones, and to find work harder as they become older. These problems are controlled with ‘attentiveness’ and ‘awareness’ as information processing sources, however they are limited and become causes of an inability to avoid errors. For example, an investigation of the time zones in which vessel collisions occur show that they are most common between 2am and 6am, and 2pm and 4pm, which means collisions are likely due to these factors.

§1-5 BTM・ETM : From Grave-post Type to Preventative Type Analysis/Counter Measure

The basic concept of BTM is the same as ETM. This configuration is shown by the M-SHELL Model as follows.
As shown in Fig. 11, the person at the center (**L: person responsible for the accident**) is surrounded by those resources such as: ‘**H: Hardware**’, ‘**S: Software**’, ‘**E: Environment**’, and ‘**L: Persons other than the person responsible for the accident.**’ Each resource is always in a state of change. This situation can be shown in terms of quivering rectangles. Here, if communication and cooperation between the person ‘L’ and those resources are insufficient, ‘L’ is unable to have sufficient contact with others and human error occurs; in consequence, safety is no longer assured. To ensure that an error by a single individual does not create a hazardous situation, it is necessary to spot the error quickly and work as a team to support one another and correct it. This is the basic concept of BTM and ETM.

As described above, all resources are never static. All resources function to ensure good mutual communication, eliminate causes leading to the 12 characteristics of human beings or change point of view to achieve wonderful ability, and suppress the occurrence of errors. Even if L (You) and other resources generate human error, it is possible to manage them in order to prevent errors in the communication gap of the entire team when it is being managed by BTM or ETM.

Fig.11 M-SHELL Model

(Why are BTM and ETM not well-known?)

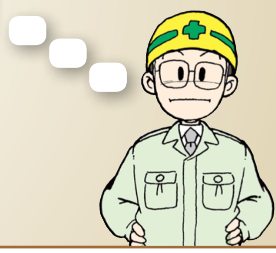
Despite 20 years having elapsed since the introduction of BRM, neither BRM nor ERM have become popular. Possible causes are given below.

Root causes that are not well-known

1) If technical skills are at a high level, it is assumed that 'safety is guaranteed'.

2) Management is not seen as a skill, and the traditional idea of separate deck and engineering sections remains strongly entrenched.

3) Crew training is primarily OJT, where responsibility is left to the site.



A revolution in awareness is required in light of this way of thinking, 'the way of thinking of safety', 'the question of what management is', and 'the reconsideration of OJT'.

The captain, chief engineer, and the company are required to develop ‘an atmosphere in which subordinates (i.e. team members) are able to speak up on matters of safety operation’. This is the foundation of effective use of BTM and ETM.

In comparison with the shipping industry, CRM (Crew Resource Management) appears to be running smoothly in the airline industry. When we compare the two, it appears the difference lies in the level of technology. In an aircraft, the difference in level of skill between the captain and the co-pilot appears to be less than that between a ship’s captain and chief officer, or between a chief engineer and engineer.

For example, if the captain of an aircraft were incapacitated in flight at an altitude 30,000 feet, the co-pilot should be capable of landing.

On the other hand, can a third officer operate his vessel safely to its destination? There is a major difference between ships and aircrafts in terms of the methodology of crew training, including up-skilling. Therefore, we can think that training of inexperienced officers also is an important element when utilizing BTM and ETM.

Furthermore, ‘threats’ are sources of errors. With BRM and ERM, if threats are considered as elements which increase the possibility of errors, the following can be noted.

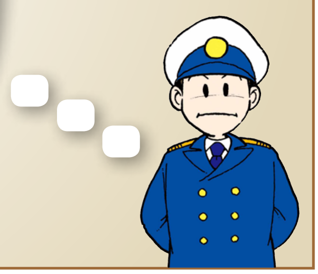
Elements which increase the possibility of human errors

1) A large volume of work (i.e. not enough personnel available to do the work)

2) Time pressure (when the leader is in a rush and this is picked up by team members, it will leave everybody unsettled)

3) Pressure from superior (in particular, regularly shouting at subordinates, scaring them into silence, and inhibiting operation of BRM and ERM)

4) Fatigue and stress (attention is distracted when fatigued, and external stress is a cause of deterioration in abilities)



In other words, unless BRM and ERM can operate properly, not only will errors occur, but stress will develop between the leader and team members, giving rise to a vicious cycle.

Fig. 12 Vicious Cycle

(From Grave-post type to Preventative type analysis/counter measure)

As described before, in case of a risk of collision by a crossing situation, all watch-keepers at brigde, who have a license and who do not remember the COLREGs clause completely, know COLREGs clause 15 ‘the vessel which has the other on her own starboard side shall keep out of the way’, and also knows clause 5 ‘Look-out’ is one of the most important clauses. However, although they know these clauses, sometimes they neglect the Look-out, ‘Why did they not take action to avoid the collision’, and finally why did they cause a collision accident?

By considering ‘Human Characteristics’, it is necessary to analyze as to why they took dangerous action and establish preventative type countermeasures based on the background information of the accident and consider the best means to prevent reoccurrence. Thus it is necessary to change the analysis and countermeasure from the Grave post type to the Preventative type, shown in Figs. 13 and 14;

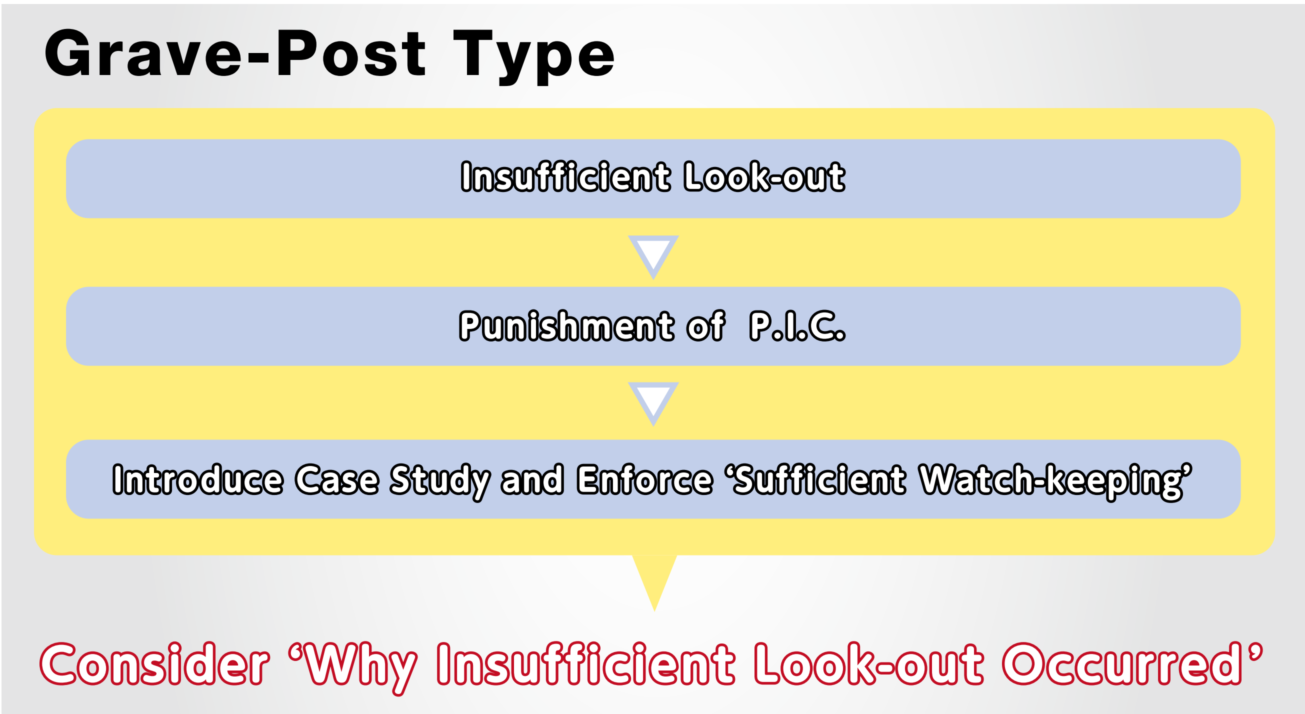


Fig. 13 Grave-Post Type

Preventative Type

Cause of Insufficient Look-out

Paperwork during duty watch Falling asleep	▶	Check necessity of individual documents Check amount of work that triggers falling asleep
Collapse of BTM Non compliance with observance of COLREGs	▶	Although duty officers understand COLREGs and the concept of BTM, analyse as to 'why the duty officers failed to take necessary action'.

Exclusion of Root Cause

Too much paperwork ▷ Review the volume of paperwork ▷ Reduce work load

- Abolish unnecessary and non-urgent documents
- Review SMS Manual
- Prohibit doing of Paper Work during duty watch and control work and rest hours (including falling asleep countermeasures)
- Set priority for various kinds of paperwork

Collapse of BTM
Non compliance with observance of COLREGs ▷ Pertinent: 'Human beings sometimes forget' in Human Characteristics ▷ Remind

- Re-education
- Supervise continuously (Brief before boarding)

Fig. 14 Preventative Type

§1-6 Training of Inexperienced Officers and Engineers with Low Skill Levels

To prevent errors, inexperienced officers and engineers with low skill levels must individually and objectively evaluate and understand the skills with which they are deficient, and endeavor to reach the level of an experienced captain/officer or chief engineer/engineer as soon as possible. OJT and training on shore are methods used in training these officers and engineers. However, the awareness and motivation of the trainee is important. If we consider the level to which skills can be raised with OJT and shore training, Student Oriented (in Fig. 15 below) provides guidelines.

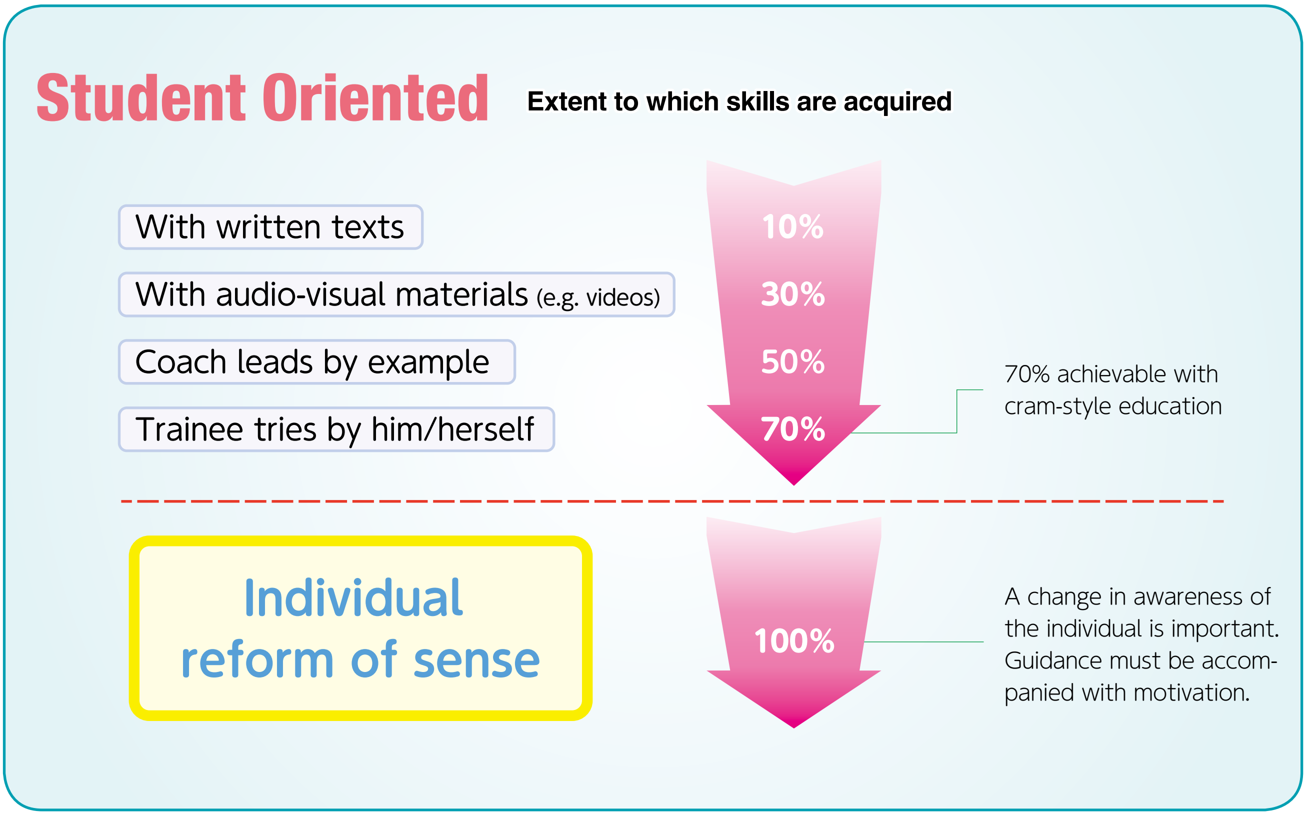


Fig.15 Student Oriented

Approximately 10% of skills are considered to be learned in classroom lessons using written texts. These skills consist primarily of fundamental theory and knowledge.

Use of videos, PCs, and the Internet as ‘audio-visual materials’ are considered to raise the skill level to approximately 30%. Think of a merchant ship school as being the last step before actually doing the real thing on board a vessel.

Subsequent practice and OJT in which the coach demonstrates is considered to increase the skill level to 50%. Further use of simulators and OJT after having entered the company to provide the student with experience is considered to increase the skill level to 70%. In summary, pushing the student is effective to a certain degree, however the attainment of 100% skill is required on-site.

Increasing the remaining 30% skill level is fundamentally a matter of 'individual reform of sense'. Education at this stage is primarily focused on OJT, and coaching is required to raise the motivation of the student. Also, again, it is necessary to understand the fundamental idea behind '5W1H + 2F'. '2F' is especially important in the training field. And, as mentioned above, it is important to be aware of the fact that behavioral characteristics of people deemed to be defects could be turned into wonderful abilities.

For example, the author had the following experience while aboard a vessel as Master. I feel embarrassed just remembering the event.

> On one occasion, the mooring winch on the Forecastle broke down. Immediately, repair work needed to be carried out and I (Master) requested that the chief engineer, the chief officer and the boatswain repair it. I was also required to attend the repair work. In order to repair it, first of all we had to remove the nut that attached the cover, but the chief officer provided only spanners of the wrong sizes .
> I was aware of 'Human Characteristics No. ⑨ Human beings sometimes make assumptions' and smoked down the chief officer 'Why did you not bring various size spanners well in advance?' without realizing 'No. ⑧ Human beings sometimes become emotional' myself.
> Even after completion of the repair work, the chief officer was disappointed for a while. However, if the spanner that he prepared for repairing was of the correct size and he had commenced the work without trouble, it would have been possible to observe that he was able to make overall decisions manifesting wonderful ability, contrary to No. ⑨ Human beings sometimes make assumptions. Remembering this story, I still feel regret towards him, even though more than 10 years had passed.

Considering 'What is safety' and 'Human Characteristics' (described above), let's study the counter measures in order to prevent recurrence through the following three accident case studies.

§2 Collision

§2-1 Summary of Accident

Date and time of occurrence:

On an unspecified day of October 2013, approximately 21: 01 Japan time (JST)

Accident site:

Southwest area of Kii Suido (Strait), north-northeastern area of I-shima

Vessels concerned:

Container Vessel A (50,686 G/T, Loa 292m)

- During navigation from Kobe Port to the Port of Busan in South Korea on the southern routes along Shikoku
- Crew members (21 members on board)

South Africa	×5 (including Master)	India	×2
Ukraine	×3	Romania	×1
U.K.	×1	The Philippines	×8
Russia	×1		

- The third officer keeping watch was present at the collision accident at that time.
  Bridge Watch personnel constituted one A/B and one cadet respectively. The Master was handling paperwork in his cabin.
  The Master, age 52, was assigned to Master in 1994. Following shore duty as marine superintendent and designated person ashore, the Master came aboard the current vessel. The Master had, on four occasions, navigating experience of this area of sea.
  It was the third officer's (Officer of the Watch, age 27, South African) second vessel as navigation officer. As third officer, the officer had, on five occasions, navigating experience in this area of sea.
- Cargo and draft: 2,500 loaded containers with a Draft Even Keel of 11.39m.

Cargo ship B (4,594 G/T, Loa 110m)

- Bound for Mikawa Port from South Korea via Naruto Strait of the Seto Inland Sea

- Crew members (13 members on board)

Korea	×3 (including Master)	Indonesia	×3
The Philippines	×4	China	×1
Burma	×2		

- The third officer and one A/B watch-keeper were present at the collision accident at that time. The Master was taking a rest in his cabin. The Master, age 50, had 10 years of experience as an officer and 5 years of experience as a master. The Master had extensive experience of navigating between China/Korea and Japan. The third officer, (Officer of the Watch, age 24, Filipino) had been on board both a Filipino coaster vessel in Japan and an ocean-going vessel for 16 months. It was his first time to board as third officer. As a cadet, the officer had, on ten occasions, navigating experience in this area of sea.
- Cargo and draft: 5,350 K/T loaded with steel. Draft Fore 5.60m, Aft 6.85m

(Summary of Accident)

The accident occurred at night off the north-northeastern sea coast of I-shima on the Kii Suido (Strait) while Vessel A was sailing southward on a course of <190>, after pilot disembarkation, having just passed Tomogashima Strait, when cargo ship B was navigating southeast on a course of <140> towards Kii Hinomisaki coast having passed the Naruto Strait. In addition, as for the state of the surrounding environment at that time, there were no other ships in the vicinity, which would have affected either vessel's operations, and there was good visibility.

There were no other vessels concerned which may have affected navigation, as long as one could see the information on the AIS and reports from the related party.

Fig. 16 Surrounding Environment

When both vessels approached cutting across each other's courses, the third officer of Vessel A noticed that there was a risk of collision with Vessel B due to the approach alarm sounded by the ARPA and informed that she (Vessel A) would pass the astern of Vessel B via VHF. However, he continued to navigate on the same course and speed, with the exception of altering course to starboard 6 degrees. Also, after the third officer of Vessel B noticed the Closest Point of Approach (CPA) which indicated zero on the ARPA, he altered course to starboard 5 degrees, but still sailed continuing on the same course and speed.

As a result, both vessels kept closing head-on to each other. Although it steered immediately to avoid collision immediately before the collision, the starboard side bow of Vessel A collided with the port side astern of Vessel B.
Both vessels sustained damage to the hull, however, there were personal injuries. Please see Figs. 17, 18 and 19 and Table 20 for collision details and the actions that were taken by both Vessels.

Voyage Route

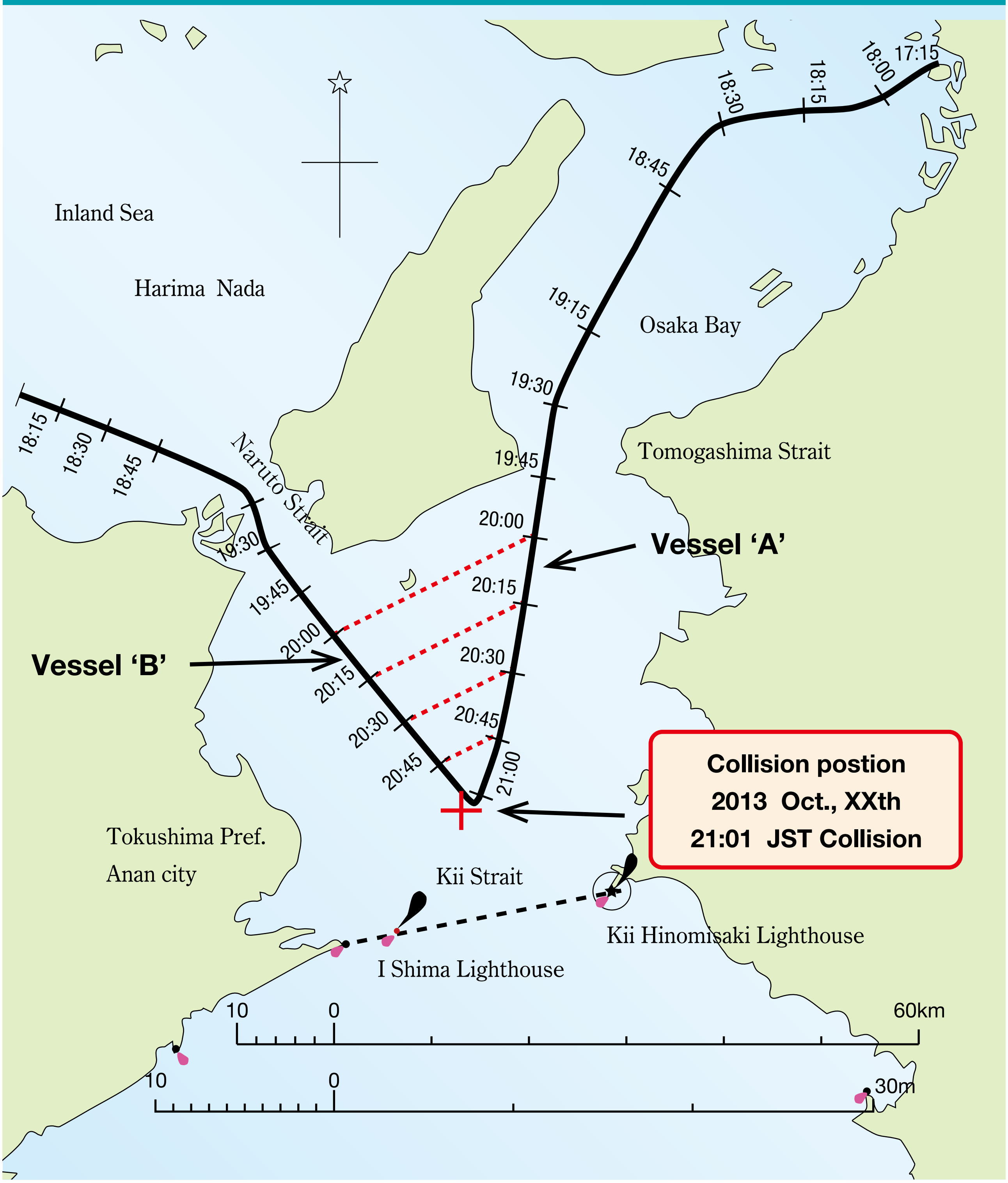


Fig. 17 Voyage Route

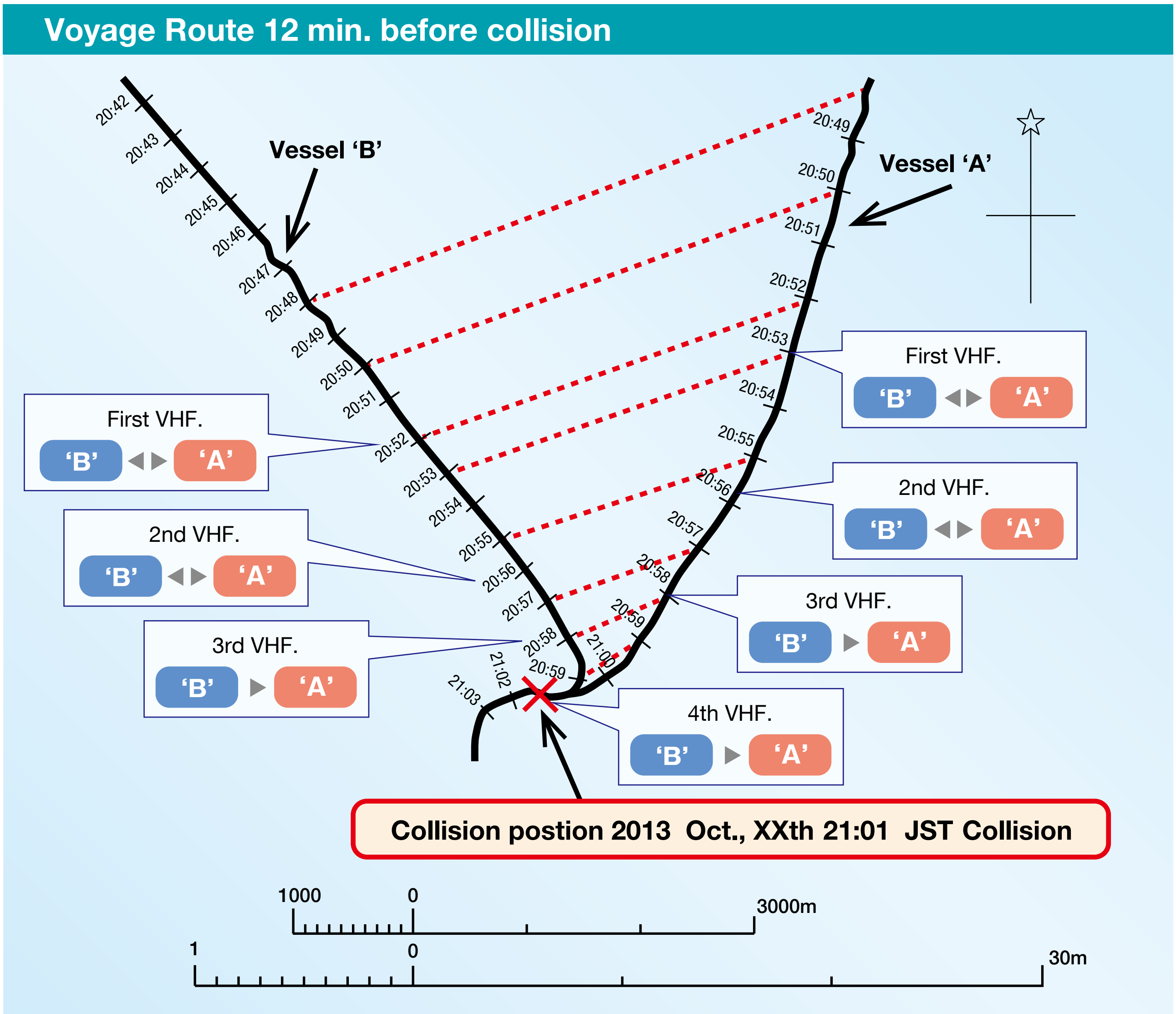


Fig. 18 Details of Voyage Route

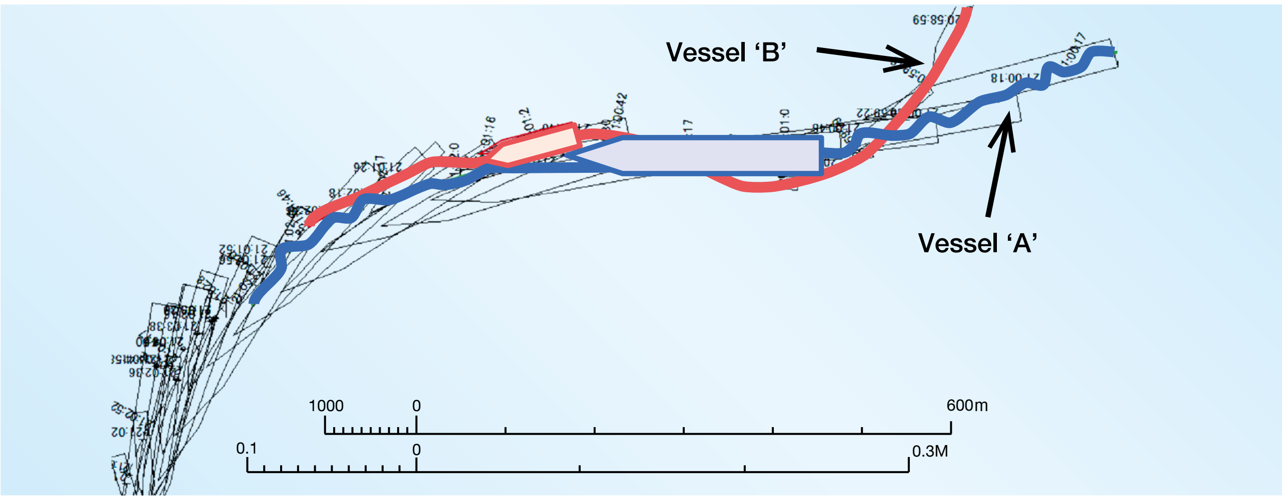


Fig. 19 Details of Voyage Route

Weather and sea conditions Weather : fine, NW wind, wind force 1, visibility: approximately ten(10) nautical miles

	Vessel 'A' (Container vessel)	Vessel 'B' (Cargo ship)
Watch arrangemet at the collision accident at that time	Three in total: the third officer (South African), a Cadet and an AB.	Two in total: the third officer (Filipino) and an AB.
19:54	The Chief Officer took over the watch from the Master.	At around 19:50, the Chief Officer took over the watch from the Master.
	Course <190>, speed 16.0 kts.	Course <140>, speed 12.5 kts.
20:00	The third officer together with other two crew members started watch-keeping.	The third officer together with another crew member started watch-keeping. After verifying the state of the surrounding environment, the Master left the bridge.
20:10	Two radars were in use: Automatic Radar Plotting Aid (ARPA: off-centre) and ECDIS.	Two radars were in use: Automatic Radar Plotting Aid (ARPA: off-centre) and ECDIS.
	One radar used a range of 6 nautical miles and the other a range of 12 nautical miles.	One radar used a range of 6 nautical miles and the other a range of 12 nautical miles.
	The Master left the bridge having commanded his crew to be on alert during the watch.	—
20:25 (approximately)	Vessel B was observed at 7.5 nautical miles. 51 degrees with bearing of <245> off of its starboard bow. Supplemented at 5 nautical miles with ARPA. Verified with the screen that indicated a course of <135> and a speed of 13.0 kts.	—
	At the same time, Vessel B's white, white and red lights were visibly confirmed	—
20:47 (approximately)	CPA alarm sounded at a distance of 3.0 nautical miles (the alarm setting was unknown).	—
20:50 (approximately)	Vessel B was observed at 52 degrees with a bearing of <248> on her starboard bow at 2.3 nautical miles via ARPA.	Vessel A was captured on the monitor at 70 degrees on her port side at approximately 3.0 nautical miles via AIS (superimposed in ECDIS). Visibly confirmed as the CPA indicated it at 0.2 nautical miles. Recognized white, white and green lights of Vessel A.
	Responded to a call from Vessel B via VHF and communicated that Vessel A would pass the stern of Vessel B. Altered course to starboard 6 degrees. Set the new course <196>.	Contacted Vessel A via VHF and confirmed she was going to pass the stern of Vessel B. Vessel B believed Vessel A was heading toward the stern.
20:53 (approximately)	Confirmed Vessel B at 54 degrees with a bearing of <250> on her starboard bow at 1.7 nautical miles via ARPA.	Confirmed Vessel A at 70 degrees with a bearing of <070> on her starboard bow at 1.7 nautical miles via AIS.
	Course <196>, speed 15.0 kts.	Course <140>, speed 12.0 kts.
20:56 (approximately)	Furthermore, officer B requested that Vessel A alter course to starboard via VHF. Gradually started altering course to starboard, the distance was 1 nautical mile.	As the AIS data disappeared, officer B requested that Vessel A alter her course further to starboard side via VHF.
20:57 (approximately)	Confirmed Vessel B at a bearing of <252> at 0.8 nautical miles via ARPA. Steered hard to starboard.	Started altering course steering hard to starboard.
21:01	Collision at 14.6 knots, when bow direction was at <266>.	Collision at 8.6 knots, when bow direction was at <250>.

Table 20 Sequence of Events

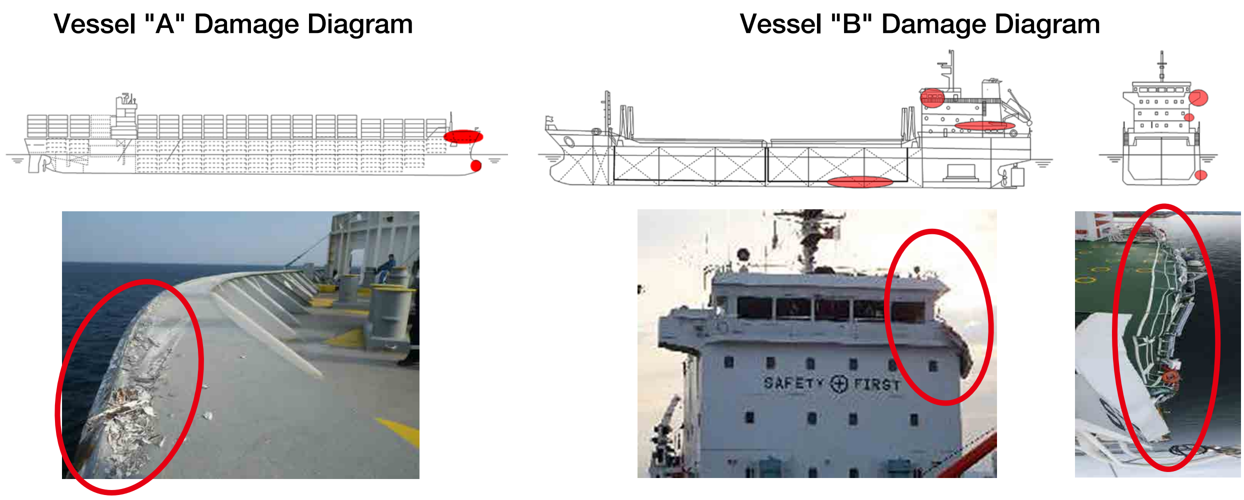


Fig. 21　Damage Diagram

= Communications via VHF =

At around 20:50 (approximately 11 minutes before the collision), the VHF communication (VDR information of Vessel B) transmitted the following (The information of Vessel A was not available from the VDR):

At 20:51:47, Vessel B contacted Vessel A and inquired her intention.
'Vessel A, What is your intention?'

At 20:52:28, After Vessel B confirmed A's intention, Vessel B answered back that she also changed her course to starboard side.
'Vessel A, Pass my stern? OK, Thank you. You are going to my stern.'
'Vessel A, I will going to alter course to starboard side also, Thank you.'

Both sides of the conversation are unknown, because the communication history from Vessel A is not available. Although Vessel A was supposed to have replied that it would change its course to starboard side and navigate in order to pass the astern of Vessel B, the question still remains as to why Vessel B replied that she (Vessel B) also would alter her course to starboard side.

§2-2　Analysis of Accident Cause by Japan Transport Safety Board (Marine Sub-committees)

§ 2-2-1　Applicable Navigation Act

Japan Transport Safety Board determined Rule 15 (Crossing Situation) COLREGs to be the appropriate navigation act.

Rule 15 : Crossing Situation on International Regulations for Preventing Collisions at Sea (COLREGs)

When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

In addition, Rule 16 (Give-way Vessel) of COLREGs was applied to Vessel A and Rule 17 (Stand-on Vessel) was applied to Vessel B.

Rule 16: Action by Give-way Vessel

Every vessel which is directed to keep out of the way of another vessel shall, so far as possible, take early and substantial action to keep well clear.

Rule 17: Action by Stand-on Vessel

(i) Where one of two vessels is to keep out of the way the other shall keep her course and speed.

(ii) The latter vessel may however take action to avoid collision by her manoeuvre alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules. In this case, if the requirements of Rule 15.1 apply to these vessels, the stand-on vessel shall turn to port unless impossible.

(iii) When, from any cause, the vessel required to keep her course and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision.

§ 2-2-2 Analysis of Accident by Japan Transport Safety Board

Japan Transport Safety Board analyses the accident as follows.

(1) Vessel A

Vessel A	
①	(approx.) 20:25 local time on a unspecified day of October. Vessel A was heading southbound on a course of <190>, at a speed of 16.0 kts. In the vicinity of 16.5 nautical miles on a course of <022> from I-shima Lighthouse, a third officer detected Vessel B on radar at a distance of 8 nautical miles, 55.0 degrees with bearing of <245> on her starboard bow. It is probable that the officer visually confirmed each of the two white mast lights and one red light (port side).
②	(approx.) 20:47, the third officer (Vessel A) noticed there was a 'risk of collision' with Vessel B **in response to the ARPA alarm**. 3 minutes after, the third officer responded to a call from Vessel B via VHF. The third officer communicated that Vessel A would pass the astern of Vessel B and hung up the receiver after confirming. The third officer then, set the **new course <196> by altering course starboard to 6 degrees**, and navigated continuing on the same course and speed for approximately 4 minutes. It is probable that despite the change of course, the change of relative bearing to Vessel B was only within 2 degrees turning to starboard side. It is thought that the third officer of Vessel A, according to his understanding of the communication received from Vessel B, assumed that Vessel B was turning to starboard, and therefore kept Vessel A maintaining on the same course and at the same speed. Vessel A steered hard to starboard immediately prior to the collision, however, it was too late.

(2) Vessel B

	Vessel B
③	(approx.) 20:50. Vessel B was navigating on a southeast course of <140> towards the Kii Suido, Kii Hinomisaki western offshore, at a speed of about 12.0 kts. In the vicinity of 8.8 nautical miles on a course of <017> from I-shima Lighthouse, Vessel A was noted to be navigating south on a course of <068> about 3 nautical miles from Vessel B at 70° on her starboard bow, according to the AIS, which was captured on ARPA, the third officer recognized two mast lights and one green (starboard light) of Vessel A. Because the CPA of Vessel A was indicated at 0.2 nautical miles on the ARPA screen, third officer judged that there would be a risk of collision and confirmed the name of Vessel A via the AIS.
④	The third officer contacted Vessel A on VHF and inquired her intention. As Vessel A replied with her intention to 'pass the astern of Vessel B', the third officer repeated the conversation and agreed. Moreover, the third officer finished communication with Vessel A's final confirmation and navigated continuing on the same course and speed.
⑤	Later, the third officer noticed that CPA read zero, which was indicated on the ARPA. He then altered his course to starboard by approximately 5 degrees using auto pilot and set the new course to <145>. Then, he sailed continuing on the same course and speed, however, at about 20:55, thinking that the two vessels were in serious danger of colliding, he communicated via VHF with Vessel A once again. When the third officer requested that Vessel A change course to starboard, Vessel A respond to confirm. However, while waiting for Vessel A to change course to starboard side, the third officer realized that the risk of collision was imminent, and although he steered hard a starboard, it appears that a collision was unavoidable.

§ 2-2-3 Analysis of Accident Cause by Japan Transport Safety Board (Marine Sub-committees)

Japan Transport Safety Board analysed the cause of the accident and issued the following five reasons.

①	Vessel A contacted Vessel B via VHF and informed of her intention to navigate in order to pass the astern of Vessel B. However, **after only altering course to starboard 6 degrees**, the third officer assumed that Vessel B had altered course to starboard side and navigated continuing on the same course and speed.
②	After cadet A of Vessel A listened to the communication via VHF about the change of course to starboard side by both Vessels A and B, he could not see if Vessel B had altered course to starboard side on the ARPA monitor. Also, he considered it not sufficient enough to change heading course, and although he knew that the third officer had altered course to starboard by approximately 6 degrees, he did not advise and report this to the third officer (although, this was not the direct cause of the accident).
③	The reason why Vessel A continued on the same course < 196 > and speed was, presumably, because, through communication with Vessel B via VHF, Vessel A understood that Vessel B was going to alter course to starboard, even if only slightly.
④	After Vessel B discovered that the CPA was zero, indicated on ARPA, she altered course to starboard 5 degrees and set a new course to < 145 > , however, she sailed continuing on the same course and speed. That is to say, it is probable that the third officer may have been waiting for Vessel A to take action by giving way, which meant that Vessel A intended to navigate passing the astern of Vessel B mutually communicating with Vessel A via VHF.
⑤	For both Vessels A and B, they did not adopt either warning signals or manoeuvring signals using whistles or flashing caution signal lights.

§ 2-2-4 Preventive Measures by Japan Transport Safety Board

Japan Transport Safety Board proposed the following preventive measures to avoid a recurrence of the incident.

(1) Vessel A

Vessel A	
①	After the other vessel is first detected, in the event that both vessels approach cutting across each other's courses,/or in the event that both vessels are on a course to cross each other, regardless of whether communication via VHF is maintained, /or regardless of whether VHF communication takes place, at first, it is naturally expected that quick recognition of the possibility of a collision with the other vessel is ascertained. Then, according to the Rule of the Maritime Collisions Prevention Act (COLREGs), avoidance action should be taken in ample time and, at the same time, dynamically so as to be easily recognised by the other vessel.
②	In the case of noticing that there is a risk of collision, in accordance with the Rule of Maritime Collisions Prevention Act (COLREGs), the necessary action is to be taken immediately and recognition that it is not necessary to communicate mutually by VHF.
③	The watch-keeper who felt uneasy and warned about the movement of the other vessel is obliged to immediately report it to the Officer of the Watch (OOW).

(2) Vessel B

Vessel B	
④	Look-out is to be adequately performed and in the event of the other vessel being detected, the course of the other vessel is to be accurately determined.
⑤	In the event that the stand-on vessel, which is vessel B in this case, does not understand the give-way vessel's intention or action, warning signals are to be sent without hesitation. And, in the case of feeling uneasy about the movement of the other vessel, the Master is to be immediately requested to come up to the bridge.
⑥	In the case that it is obvious that the give-way vessel is not following appropriate actions in accordance with the Rules of Maritime Collisions Prevention Act (COLREGs), action to avoid a collision is to be immediately taken and recognition that it is unnecessary to communicate via VHF accordingly.
⑦	In the case of observing the give-way vessel's course and accurately determining whether it is possible to avoid a collision with the give-way vessel on her present course, and in the event that it is recognised that a collision is unavoidable, take the best course of action to avoid a collision

§2-3 Analysis Combining Human Characteristics and Preventive Measures

§ 2-3-1 Analysis of Accident Causes

As explained in §1-5, similar accidents are likely to reoccur without the 'establishment of preventative safety measures' according to an analysis of the accident causes that include Human Characteristics, focusing on the aspects of 'why the accident occurred' and 'why the person involved took such unsafe measures'.

In other words, it is necessary to consider safety from a 'preventative type' perspective in order to safeguard society against the occurrence of an accident. In this section, we are going to determine the measures necessary in order to prevent recurrence, from the viewpoint of preventive measures, of this kind of collision accident.

Firstly, let's apply the behaviour that the third officer of Vessel A took according Human Characteristics respectively. Table 22 shows a summary of this. We are indicating ○ for applicable and × for not applicable.

Vessel 'A' 3rd Officer				
Human Characteristics			Behaviour	Reason
①	Human beings sometimes make mistakes	×	–	Detected Vessel B via radar at a distance of 8 nautical miles.
②	Human beings are sometimes careless	×	–	Same as above
③	Human beings sometimes forget	○	give-way vessel's heading course change was six (6) degrees.	Forgot Rule 16 (give-way vessel) of Maritime Collisions Prevention Act (COLREGs).
④	Human beings sometimes do not notice	×	–	Paid attention to the other vessel's movement.
⑤	Human beings have moments of inattention	○	Carried out inadequate look out.	Relied solely on ARPA information.
⑥	Human beings sometimes are only able to see or think about one thing at a time	○	Relied solely on ARPA information.	Negligent with verifying visually.
⑦	Human beings are sometimes in a hurry	×	–	There was no testimony attaining to anything be conducted in haste.
⑧	Human beings sometimes become emotional	×	–	Was not particularly emotional
⑨	Human beings sometimes make assumptions	○	Thought that all was normal, because avoidance action was taken. Assumed that Vessel "B" would also alter its course starboard side.	Cadet considered that the change of heading course degrees were not sufficient enough. (Collapse of BTM)
⑩	Human beings are sometimes lazy	○	Not verified visually.	Did not verify the other vessel's constant watchkeep and confirmation of change relative bearing.
⑪	Human beings sometimes panic	○	Continued altering course between starboard and port sides immediately before the collision.	Even forgot about maneuvering characteristics.
⑫	Human beings sometimes transgress when no one is looking	○	Did not carry out Master's standing order (sharp look-out).	Neglected in spite of having been directed to be cautious of crossing vessel.

Table 22　Vessel 'A' 3rd Officer Human Characteristics

Similarly, we are going to analyse the third officer of vessel B as well.

Vessel 'B' 3rd Officer				
Human Characteristics			Behaviour	Reason
①	Human beings sometimes make mistakes	×	–	There was a delay in visually verifying the other vessel, but it was verified.
②	Human beings are sometimes careless	×	–	Same as above
③	Human beings sometimes forget	O	No joint action in accordance with Maritime Collisions Prevention Act (COLREGs) (Rule 17: Action taken by Stand-on Vessel)	Regarding the relationship between large vessels, when they are approaching at 3 nautical miles, they are to take joint action.
④	Human beings sometimes do not notice	O	Did not notice until Vessel A was 3 nautical miles away.	Negligent with look-out.
⑤	Human beings have moments of inattention	O	Was negligent during look-out.	Relied solely on ARPA information.
⑥	Human beings sometimes are only able to see or think about one thing at a time	O	Relied solely on ARPA information.	Negligent with verifying visually.
⑦	Human beings are sometimes in a hurry	×	–	There was no description applicable.
⑧	Human beings sometimes become emotional	×	–	Same as above
⑨	Human beings sometimes make assumptions	O	Thought that Vessel A was going to give-way because she changed her heading course to 20-30 degrees.	Assumed Vessel A would pass the stern via VHF.
⑩	Human beings are sometimes lazy	O	Neglected to keep watching the other vessel's movement constantly. Not verified visually.	Did not verify the other vessel's constant look-out or confirm change of relative bearing.
⑪	Human beings sometimes panic	O	Contacted unilaterally via VHF. Did not confirm the other vessel's reply.	Only contacted unilaterally via VHF.
⑫	Human beings sometimes transgress when no one is looking	O	Transgression of master's standing order (not reported).	Master's standing order: to report when a dangerous ship is visually confirmed.

Table 23 Vessel 'B' 3rd Officer Human Characteristics

For the third officer of Vessel A, seven (7) out of the twelve (12) Human Characteristics items are applicable, whereas, eight (8) of the Human Characteristics are applicable to the third officer of Vessel B. An analysis using the M-SHELL model as to why such behaviour was taken in relation to these characteristics is shown in Fig. 24.
To begin with, we consider the root cause to be 'Exclusive Node'. In spite of insufficient avoidance action (third officer communicated that Vessel A would pass the astern of Vessel B), however in reality, Vessel A altered course to starboard 6 degrees only (in general, Vessel A should alter her heading course to starboard 60 degrees).
Meanwhile, vessel B did not notice vessel A until she approached at a distance of 3.0 nautical miles.

If you were to take a snapshot of each manoeuvre and lay them all out on a table in card form, it would be possible to trace as to why such action was taken and find out what caused the accident.

On analysing as to why the third officer of Vessel A caused the accident, firstly we can say that there was a lack ability in recognizing the importance of look-out. Further, this was not only down to the fact that work was not prioritised appropriately, but that there was also an insufficient understanding of the Maritime Collisions Prevention Act (COLREGs). In addition, it is clear that there were other causes, such as impatience, a lack of caution and non compliance with the Master's standing order.

On the other hand, when analysing the third officer of Vessel B similarly, we can conclude that the accident causes are the same for the third officer of Vessel A. We understand that the cause was not only down to the fact that there was a lack ability in recognizing the importance of look-out, but in addition, work was not prioritised appropriately. Moreover there was insufficient understanding regarding the Maritime Collisions Prevention Act (COLREGs). It is also clear that there were other causes, such as impatience, a lack of caution and non compliance with the Master's standing order.

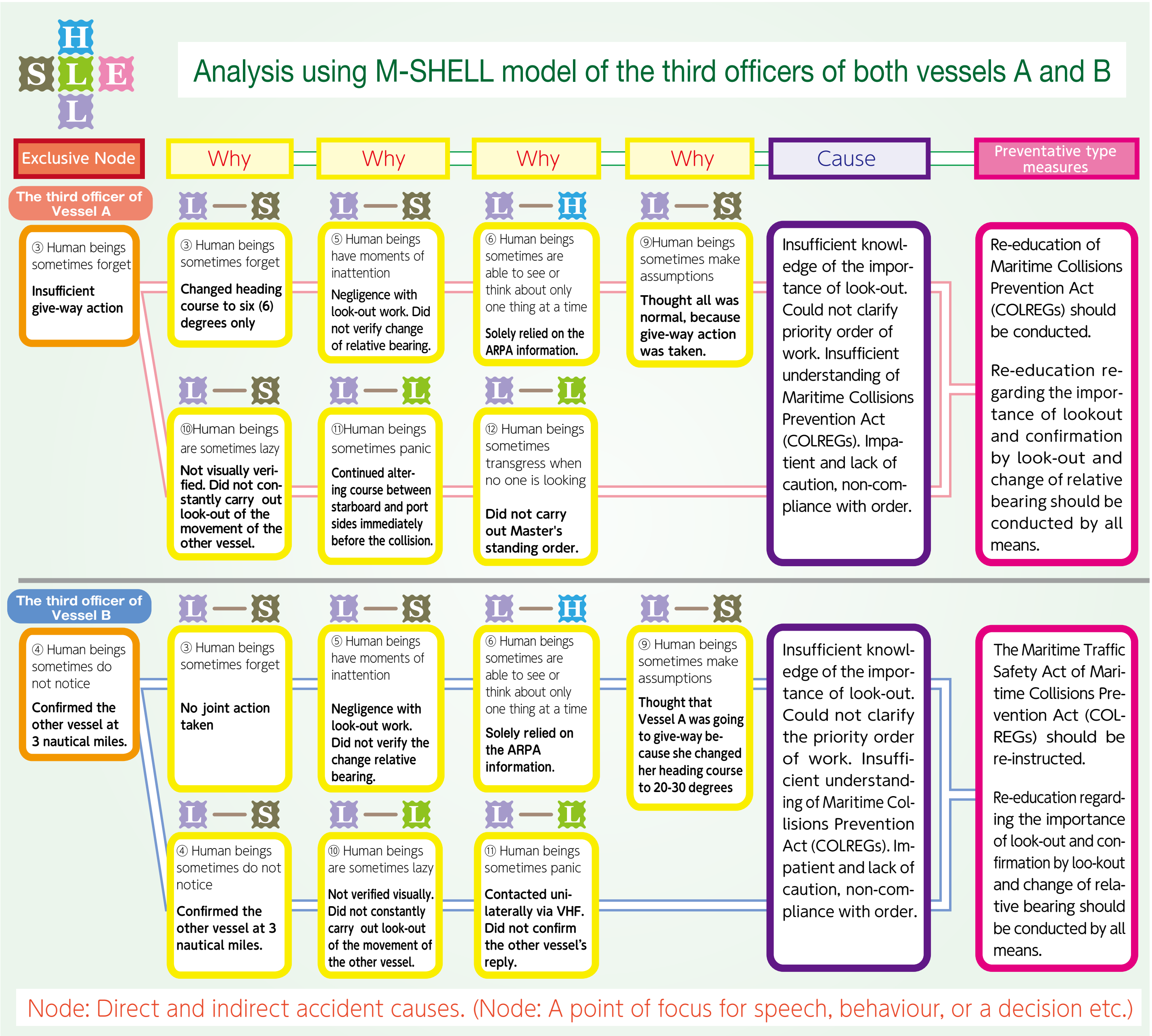


Fig. 24 Why-why? Model

§ 2-3-2 Analysis of Accident Causes which can be Commonly Seen Regarding the Third Officers of Vessel A and B

There are several common points regarding the accident causes of the third officers of vessels A and B. We are going to analyse this focusing on the 'Why?' of Human Characteristics. A summary of the common points regarding the third officers of both vessels is as follows:

(1) They relied solely on ARPA information regarding the risk of collision, and did not verify the changes in compass bearing that the other vessel continued on (③ , ⑤ and ⑥).

Human Characteristics :

- ❸ Human beings sometimes forget
- ❺ Human beings have moments of inattention
- ❻ Human beings sometimes are only able to see or think about one thing at a time

The testimony of the third officer of Vessel A is as follows:

> 'At approximately 20:25 (approx.36 minutes before the collsion), along with detecting Vessel B's starboard bow at a distance of 8 nautical miles on radar, I visually confirmed her two white mast lights for the first time. Then I also visually confirmed one red light, and recognized that Vessel B was navigating on a course of approximately <135> at a speed of about 13.0 kts. I continued to look out visually using the radar, while assigning a cadet to watch the radar and the Able Seaman to look out visually. (Approx.) 20:47, which was approximately 14 minutes before the collision, the third officer of Vessel A noticed that there was a risk of collision with Vessel B following the ARPA alert'.

The testimony given by the third officer of Vessel B is as follows:

> 'At Approximately 20:50 (approx. 11 minutes before the collision), I caught Vessel A on the AIS and recognized two white lights and one green light. Vessel A, which was heading southbound was overtaking our vessel, at approx. 25° on her port side abeam aft, about 3 nautical miles away from our vessel. Then, I thought there was a risk of collision, because the CPA was indicated at 0.2 nautical miles via ARPA. I obtained the information that Vessel A was navigating to pass the stern of Vessel B via VHF, and confirmed the vessel name via AIS'.

The course, speed and approaching information of both vessels according to the AIS data analysis are shown in Table 25.

Time (about)	Distance bewtween vessels (Nautical Miles)	Vessel 'A' Heading	Vessel 'A' Speed	Vessel 'A' Bearing Vsl. 'B'	Vessel 'A' Relative Bearing to Vsl. 'B'	Vessel 'B' Heading	Vessel 'B' Speed	Vessel 'B' Bearing Vsl. 'A'	Vessel 'B' Relative Bearing to Vsl. 'A'
20:25:00	7.5 nm	<190>	16.0kts	<245>	Starb. 55Deg.	<139>	12.4kts	<065>	Port 74Deg.
		Noticed Vessel 'B' by ARPA and Radar							
20:30:00	6.5 nm	<190>	16.0kts	<245>	Starb. 55Deg.	<139>	12.3kts	<065>	Port 74Deg.
20:34:59	5.5 nm	<190>	15.8kts	<245>	Starb. 55Deg.	<140>	12.4kts	<065>	Port 75Deg.
20:40:00	4.5 nm	<190>	15.9kts	<246>	Starb. 56Deg.	<140>	12.2kts	<066>	Port 74Deg.
		ARPA Alarm. Changed Co. 6 deg. To Starb'd							
20:45:00	3.4 nm	<196>	16.1kts	<248>	Starb. 52Deg.	<140>	12.1kts	<068>	Port 72Deg.
						Noticed Vessel 'A' by AIS and ARPA			
20:50:00	2.3 nm	<196>	16.1kts	<248>	Starb. 52Deg.	<139>	12.0kts	<068>	Port 71Deg.
20:52:00	2.0 nm	<196>	16.2kts	<250>	Starb. 54Deg.	<140>	12.2kts	<070>	Port 70Deg.
20:53:00	1.7 nm	<196>	16.2kts	<250>	Starb. 54Deg.	<139>	12.4kts	<070>	Port 69Deg.
						Steered Hard Starb'd			
20:55:00	1.3 nm	<208>	16.2kts	<251>	Starb. 43Deg.	<145>	12.5kts	<071>	Port 74Deg.
20:57:00	0.8 nm	<212>	16.0kts	<252>	Starb. 40Deg.	<151>	11.9kts	<072>	Port 79Deg.
		One shot to steered port and then Hard Starb'd							
20:58:00	0.5 nm	<210>	15.8kts	<250>	Starb. 40Deg.	<151>	11.8kts	<070>	Port 81Deg.
20:59:00	0.4 nm	<223>	15.9kts	<247>	Starb. 24Deg.	<206>	10.1kts	<067>	Port 139Deg.
21:00:00	0.3 nm	<248>	15.2kts	<239>	Port 9Deg.	<273>	8.4kts	<059>	Port 214Deg.
21:00:30	0.2 nm	<257>	14.7kts	<245>	Port 12Deg.	<278>	8.1kts	<065>	Port 213Deg.
21:01:00	0.2 nm	<266>	14.6kts	<270>	Starb. 4Deg.	<250>	8.6kts	<090>	Port 160Deg.
		Collision!							

Table 25 AIS Information

There was almost no change in relative bearing from approximately 20:25, when the third officer of Vessel A noted the other vessel, until to approximately 20:40, when the approach alarm of ARPA sounded. Although Vessel A altered course to starboard at around 20:40 when the distance from Vessel B was 4.5 nautical miles, she (Vessel A) set a new course to 〈196〉 and altered course to starboard 6 degrees only. In addition, the change of relative bearing after change of heading course was slightly astern (starboard), which shows there was no effect on the give-way vessel at this point.

Thus, we can ascertain that the behaviour of third officer of Vessel A led to the following errors:

(1)	Relied solely on ARPA infromation.	Human Characteristics ⑤ Human beings have moments of inattention
(2)	There was a change in heading course to give-way, but the change in bearing was not verified. (The effectiveness of the give-way action was not confirmed)	Human Characteristics ⑥ Human beings sometimes are only able to see or think about one thing at a time

(3)	Although the vessel confirmed that it was navigating to pass the stern of the other vessel via VHF, the other vessel felt uneasy due to such a slight veering, Under normal circumstances, the appropriate give-way vessel is to widely change heading course to <248> to the astern of the other vessel	Human Characteristics ③ Human beings sometimes forget

This is in violation of Rule 16 of the Maritime Collisions Prevention Act (COLREGs) (Action by Give-way Vessel) that defines: Every vessel which is directed to keep out of the way of another vessel shall, so far as possible, take early and substantial action to keep well clear. (See §2-2-1 Applicable Navigation Act)

Also, the following are behaviour errors regarding the third officer of vessel B.

(1)	He first only recognized vessel A on the radar when it was at a distance of 3 nautical miles away	Human Characteristics ⑤ Human beings have moments of inattention
(2)	Relied solely on the ARPA information	Human Characteristics ⑤ Human beings have moments of inattention
(3)	He over relied on the VHF information of the other vessel.	Human Characteristics ⑥ Human beings sometimes are only able to see or think about one thing at a time
(4)	If there is a distance of 3.0 nautical miles between large vessels and TCPA is estimated at 12-13 minutes, it is reasonable timing to start joint action.	Human Characteristics ③ Human beings sometimes forget

'The most appropriate joint action should be taken to avoid collision with another power-driven vessel' which is in accordance with the Maritime Collisions Prevention Act Rule 5 (Look-out) and Rule 17 (Action by Stand-on Vessel). (Regarding Rule 17, please see §2-2-1 Navigation Act)

(Maritime Collisions Prevention Act (COLREGs) Rule 5: Look-out)

Rule 5 requires that every vessel shall at all times maintain a proper look-out both visually and aurally as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

(2) Inhibited communication because of assumptions

Human Characteristics: ⑨ Human beings sometimes make assumptions

Miscommunication via VHF can be one of the reasons for a collision. On account of a breakdown in 'communication with external information' (one of the principles of BTM), there was information breakdown between the officers (both third officers) on both vessels, thus it is thought that human error (making an assumption) was at fault. Namely, we can determine that both third officers of Vessel A and B made the following assumptions.

The third officer of Vessel A: The third officer of Vessel A: Thought that all was well, because avoidance action was taken. He assumed that Vessel B would also alter her course to starboard side by VHF communication.

The third officer of Vessel B: The third officer of Vessel B: Assumed that Vessel A had changed her course to starboard side to navigate in order to pass the stern of Vessel B because he confirmed it via VHF.

The dangers of collision avoidance using VHF, have been pointed out in 'CAUTION ON THE USE OF VHF RADIO IN COLLISION AVOIDANCE' issued by The Maritime and Port Authority of Singapore (MPA) dated the 4th of July 2005.

'CAUTION ON THE USE OF VHF RADIO IN COLLISION AVOIDANCE'

①	Many investigations worldwide have revealed that VHF communication is one of the contributing factors in collisions at sea. In many of the so called 'VHF assisted' collisions, the 'VHF communication' between the bridges had created misunderstanding among the officers which led to close quarter situations and collisions. We are of the view that compliance with the International Regulations for Preventing Collisions at Sea will be more effective in averting a collision rather than the use of VHF communications (based on scanty and unclear information), to avoid a close quarter situation. A recently concluded investigation showed that both vessels were using VHF communication to agree on action to be taken in order to avoid collision, however, many collisions occurred.
②	'VHF assisted' collisions, contacts or near misses are not uncommon occurrences at sea. The IMO has taken a serious view of this trend.'
③	Based on our findings and experience in similar occurrences, we believe that such incidents are avoidable. We wish to reinforce this learning among all the masters and navigators serving on Singaporean ships through this circular. We wish to take this opportunity to reiterate the following possible dangers involved in the use of VHF communication as a means of avoiding a collision. Factors to be considered are as follows: a. (omitted) b. Uncertainty over the interpretation of messages received due to language difficulties and an imprecise or ambiguously expressed message; c. Loss of valuable time in trying to establish contact on VHF radio instead of taking concrete action in accordance with the Collision Regulations; and d. The danger of agreeing to a course of action that does not comply with the Collision Regulations resulting in a situation which the action intended avoidance of.
④ and ⑤	(omitted)

Since implementation of the AIS, it is now easier to call on the other vessel via VHF. However, critical time was

wasted when using it take avoidance action, after both vessels approached one another at a distance of 3 nautical miles.
If using VHF, it is necessary to start communicating from a much earlier stage and only use it for reference. Thereafter, it is necessary to observe the other vessel's action utilizing the look-out strictly in accordance with Maritime Collisions Prevention Act (COLREGs). In addition, extra time for it shall be needed.

(3) Both Vessels A and B were in breach of the Masters' standing order.

Human Characteristics: ⑫ Human beings sometimes transgress when no one is looking

The procedures of the SMS Manual for Vessel A and the Masters' standing order for both vessels are as follows. The fact that both of the third officers of each vessel did not fulfil this criteria can be regarded as one of the causes of the collision. (The parts in red are considered a violation)

Vessel A: SMS Manual and Master's standing order

= SMS Manual =

- Watch-keeper shall pay attention to any other vessel in sight. Please pay extra attention if there is a sudden change in circumstances while navigating.
- To keep an appropriate distance from the other vessel as always. Not to sail across the path of another vessel within one (1) nautical mile, except when necessary.

= Master's standing order =

- The Officer of the Watch shall proceed with the procedures described in the SMS manual.
- Do not hesitate to call the Master up to the bridge, if in doubt. Even if it is too late to call the Master up to the bridge or it is no deemed longer necessary, by all means be sure to call to the Master to the bridge as soon as possible.
- Before calling the Master up to the bridge as early as possible, for safety reasons change the heading course or stop the engine without hesitation, remembering that it will enable the Master to have extra time for situation assessment.

= Specific orders for the Master to come up to the bridge =

- When in doubt about an action being taken by the approaching vessel
- When recognizing something unusual as a duty officer
- When either of the duty officer or watch person of the bridge has a doubt for whatever reason. Use the public-address system, in the case that you cannot make a telephone call to the Master.

Vessel B: Master's standing order

- The Officer of the Watch is naturally expected to take action to avoid collision promptly if there is a risk of a dangerous situation during navigation. Do not be too cautious when using whistle signals.
- Keep appropriate look-out of the surroundings and immediately report the spotting of dangerous meeting ships.
- Do not think too much when taking actions to a avoid collision.

§ 2-3-3 Analysis According to Human Characteristics for the Masters of Vessel A and B

The Master of Vessel A was handling e-mails in his cabin at the time of the collision accident. Meanwhile, The Master of Vessel B was taking a rest in his cabin.

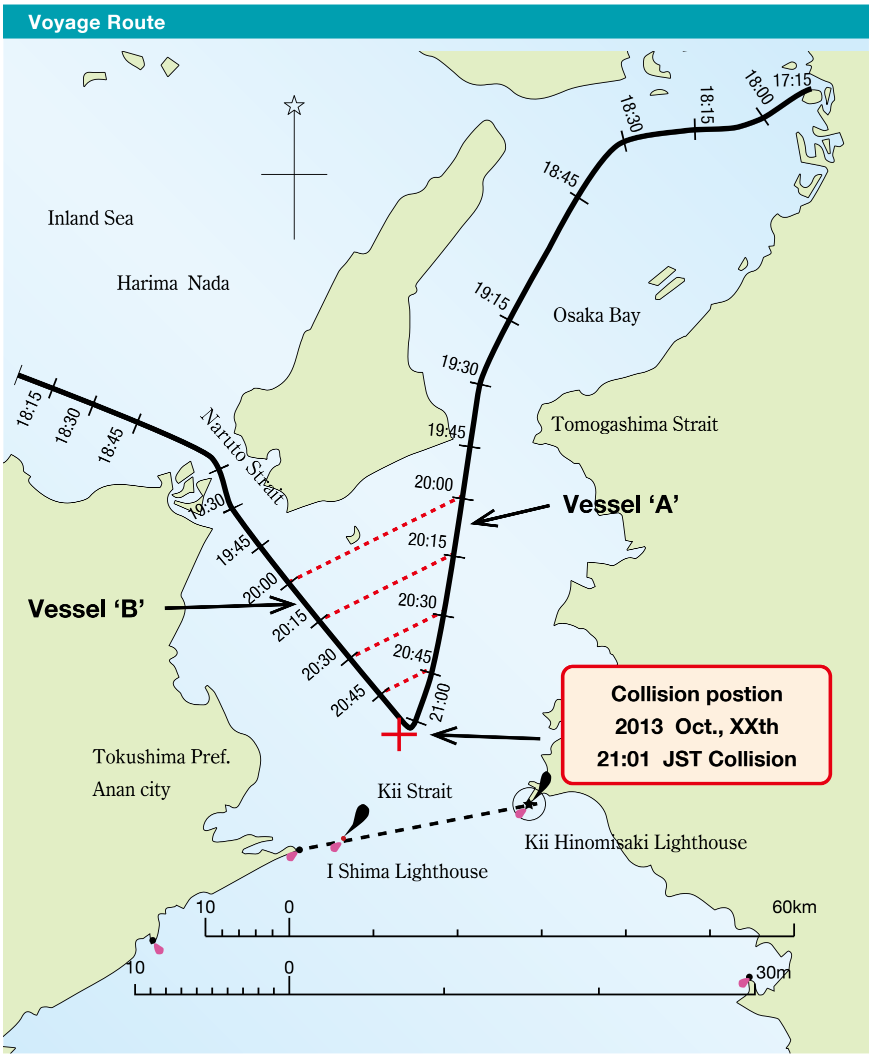


Fig.26 Voyage Route (same as Fig17)

As can be seen in Fig. 26, the traffic system of the Kii Suido (Strait) is a sea area which easily causes a crossing situation because it has a narrow angle for approaching 'vessels between the Naruto Strait and Hinomisaki' and 'those navigating north to south between the Tomogashima Strait and the Kii Hinomisaki coast of I-shima Island'. Also, there are a large number of fishing vessels operating, along with a high volume of marine traffic. Although it depends on the individual circumstances, if the waters are congested and there is a narrow channel, the Master is expected to command by himself in a large ocean-going vessel.

Why did both Masters of the vessels stay in each of their cabins? We are going to analyse the Masters of both vessels, according to the Human Characteristics.

(1) The Master of vessel A was checking his e-mail in his cabin after disembarkation of the pilot.

When analysed according to Human Characteristics, the following two apply:

6 Human beings sometimes are only able to see or think about one thing at a time
7 Human beings are sometimes in a hurry

It is understandable that contact with related parties needs to be made and that incoming information must be checked without delay, having sailed out from Kobe port. However, it should be obvious that safe navigation be top priority, when comparing the processing of e-mails with that of steering a ship through a narrow channel.

(2) The Master of vessel B was taking a rest in his cabin after having passed the Naruto Strait.

Human Characteristics: ⑩ Human beings are sometimes lazy is applicable here.

It is true that the Master would be quite fatigued, because it is easy to imagine that the Master had continuously been in command at the bridge all the way from South Korea via the Naruto Strait of the Seto Inland Sea to Mikawa Port. However, in navigating the approximately 25 nautical mile passage of the Kii Suido Strait (almost two hours at a speed of 12.0 kts.) from Naruto Strait to Hinomisaki, why was the Master not in command of operation on the bridge?

§2-4 Preventive Measures

These preventive measures were formulated from the point of view of preventing a similar accident through drawing up countermeasures applicable to the third officers and Masters of the ships involved, Vessel A and Vessel B, and the managing companies of the respective ships.

§ 2-4-1 The Third Officers of Vessels A and B

There were similarities in the specific behaviours of the Human Characteristics involved that led to the accident. If these specific behaviours can be eliminated, preventive measures can be formulated. These are summarized as illustrated in Fig. 27 below:

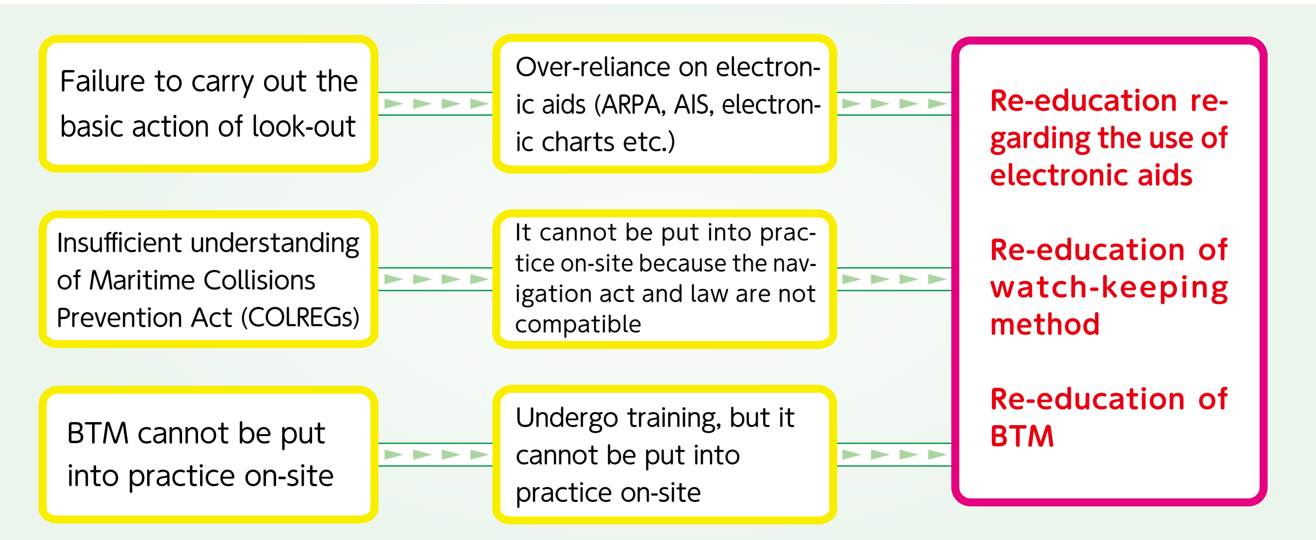


Fig. 27 Preventive Measures for the Third Officers of Vessels A and B

As the analysis in §2-3 shows, the conclusion is that the following are the root causes of the accident.

①	A failure to carry out the basic action of a look-out.
②	A tendency to rely too heavily on ARPA, AIS, electronic charts and other electrical equipment.
③	Although the Maritime Collisions Prevention Act (COLREGs) is understood, it could not be put into practice on-site.
④	There was failure in implementing the BTM despite the presence of the A/B (able seaman) and a cadet on the bridge.

In order to achieve improvements in the above, retraining in all of these areas is necessary. As obvious as it may appear, this is an important measure in order to prevent similar accidents occurring again.

§ 2-4-2　The Masters of Vessels A and B

Despite the fact that the Kii Strait is congested with a narrow channel, the fact that the Masters were not on their respective bridges is one of the reasons for the collision. This is summarized as illustrated in Fig. 28 below.

The reasons behind the fact that the respective Masters left their bridges are as follows: the Master of Vessel A was concerned about dealing with e-mails and other paperwork, and put priority on this rather than steering the ship through the narrow channel.
In addition, it is also a fact that the Master of Vessel B did not give priority to manoeuvring the ship through the narrow channel over taking a break. Therefore, the root cause for the accident can be taken as a lack of awareness regarding the safe operation of the ships.

In the case of both Masters, there were no problems regarding the level of their technical skills or their ability to operate in these waters. Both Masters presumably would have felt enough regret regarding their actions, but they clearly both need retraining in maintaining priorities concerning the safe operation of a ship.

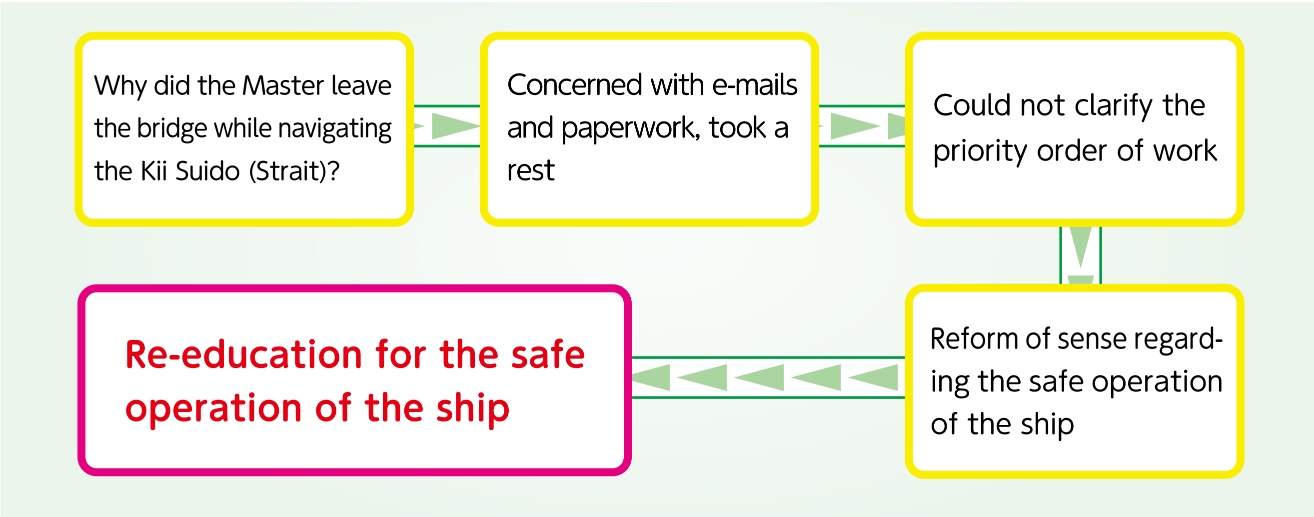


Fig. 28　Preventive Measures for the Masters of Vessels A and B

§ 2-4-3 Management on Shore (Ship Management Company)

The author also understands that the Master of Vessel A went back to his cabin, because he was concerned about e-mail checking and paperwork. However, as a fundamental measure to improve this situation it is important to set up a system where this kind of pressure is avoided.

Because the implementation of the ISM code, SMS, and the use of e-mails have led to advances in communication technology, the amount of paperwork a Master has to deal with has increased enormously. Moreover, there is now great pressure from the organisation for the strict adherence to deadlines for the submission of various reports.

However, in considering priorities of 'what is the most important right now', it is clear that the most important duty of the Master is to command the ship safely through a narrow channel. Therefore, it is of importance that the organisation implements improvement measures in order to reduce pressure on the Master, and does not just leave the situation in the hands of those on the ship.

Moreover, in the case of the Master of Vessel B, he was suffering from accumulated fatigue because he had to command the ship for a long time going from the Kanmon Strait to the Naruto Strait. The summary of this is shown in Fig. 29. There is therefore also a need to implement safety measures, such as the efficient use of inland sea pilots, in order to reduce the amount of time the Master has to spend commanding the ship.

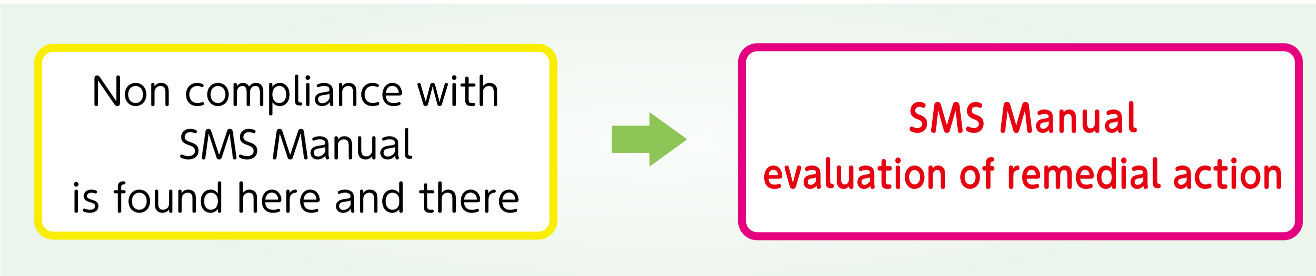


Fig. 29 Preventive Measures for Management on Shore (Ship Management Company) of Vessels A and B

Since the introduction of the ISM code and SMS, although there have been reviews regarding ways of effective implementation, the results of these reviews show that the contents of the SMS manuals have actually increased enormously. The situation would therefore seem to have become one whereby people have to operate within the framework of the SMS, and the basic procedures for the safe operation of the ship are being neglected in the process.

Against this backdrop, and in order to return to the original way of thinking, it should be identified as to what is actually necessary to allow the carrying out of basic operations, and the safe operation of the ship. The time has now come to consider taking the corrective action of simplifying the SMS manuals.

§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).

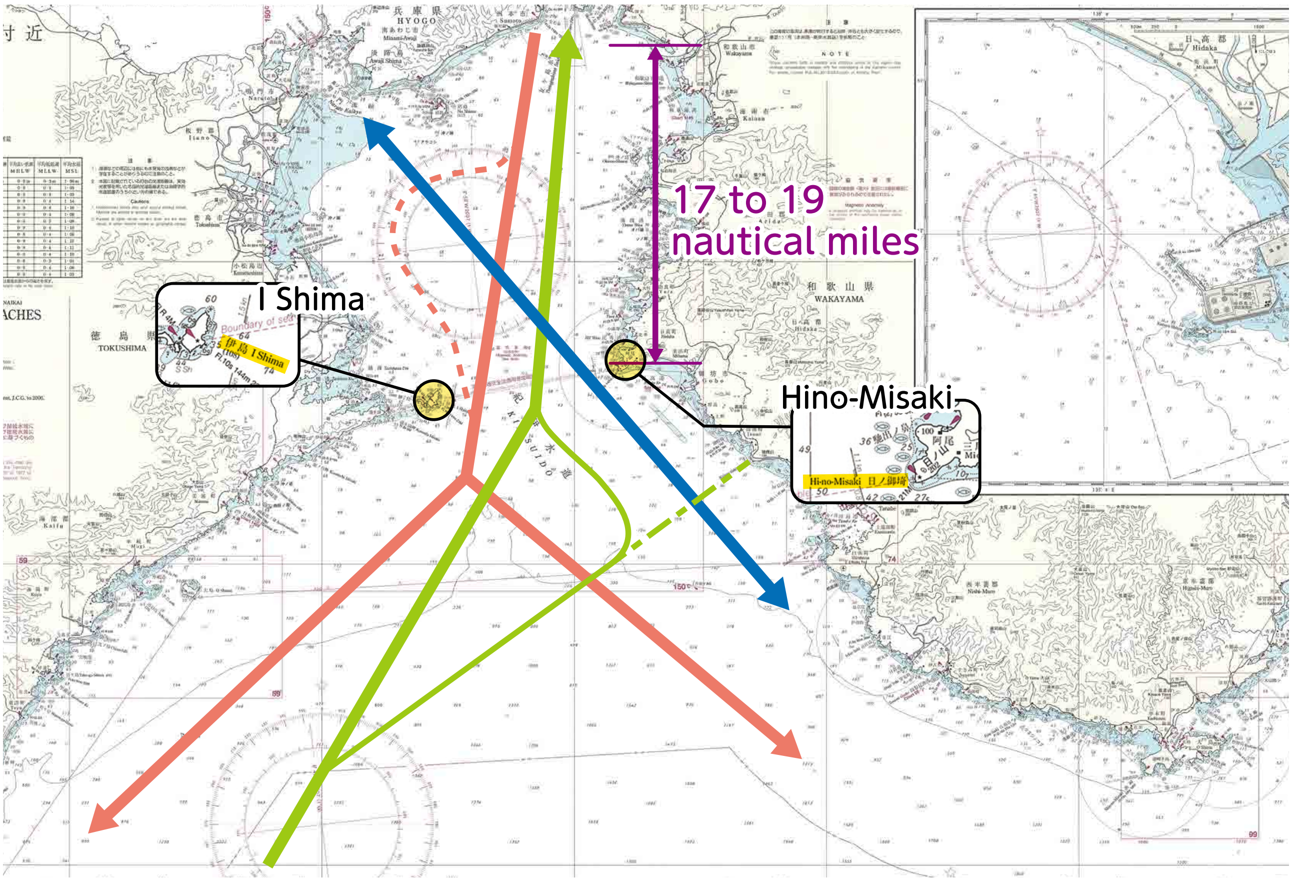


Fig. 30 The Kii Suido (Strait) Traffic System Chart

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.

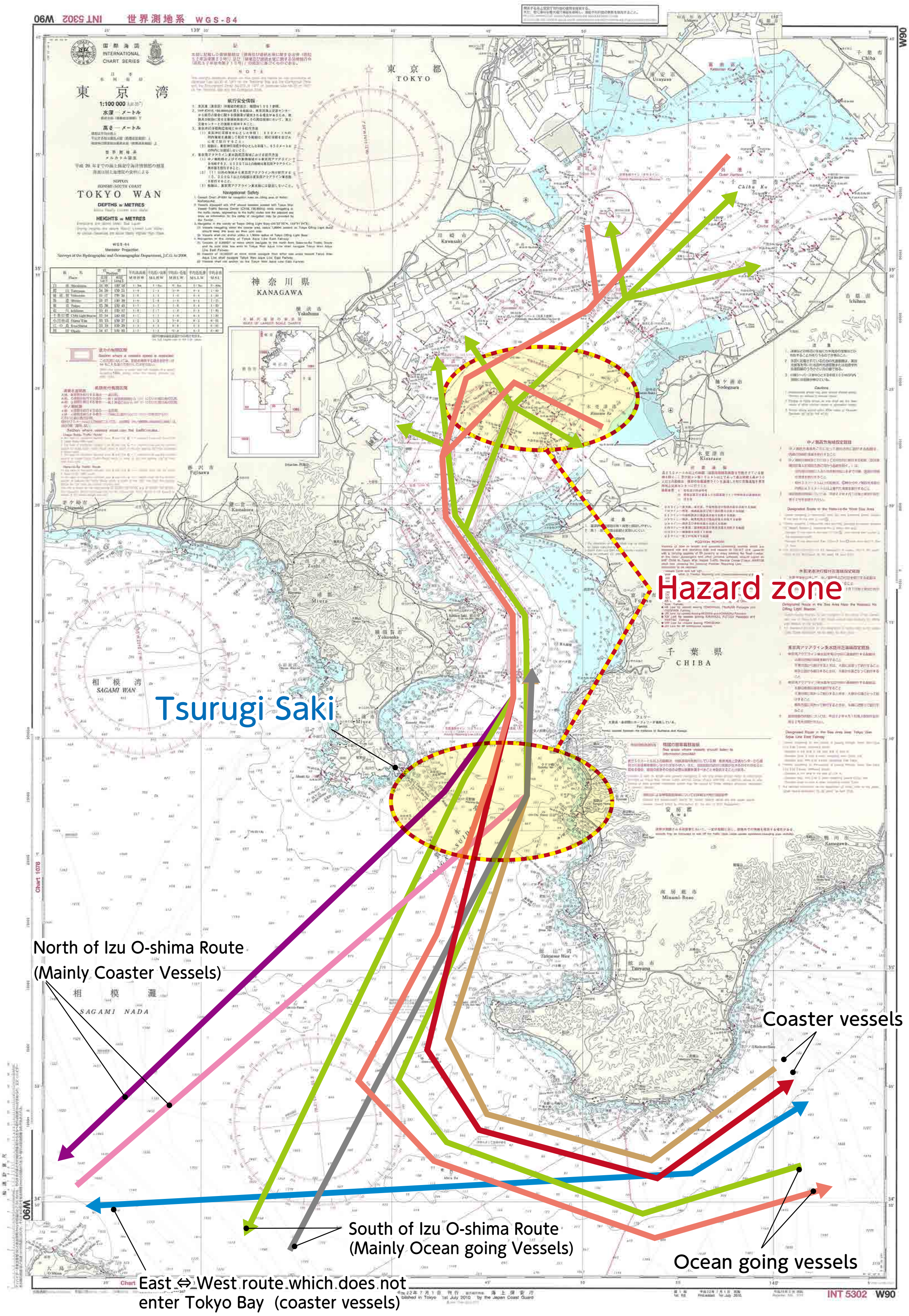


Fig. 31 Tokyo Bay Traffic System Chart

§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')

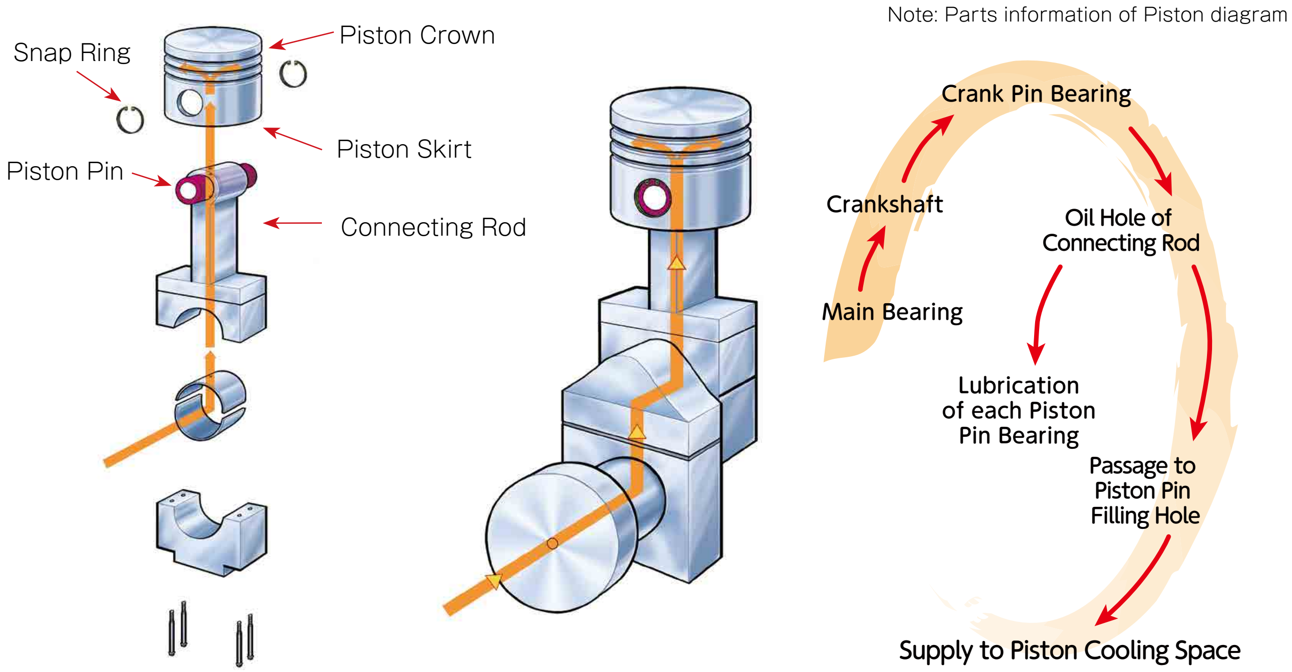


Fig. 32 Piston diagram and Cooling oil supply route

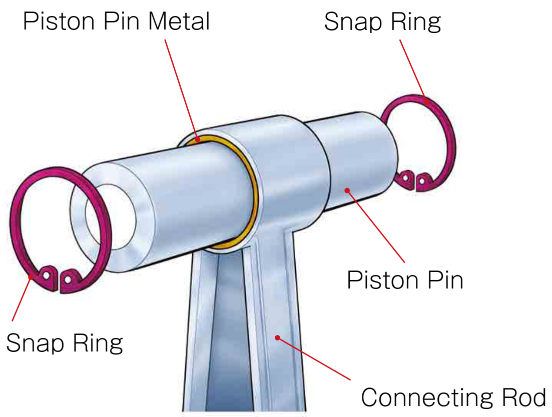


Fig. 33-1 Piston Pin Diagram

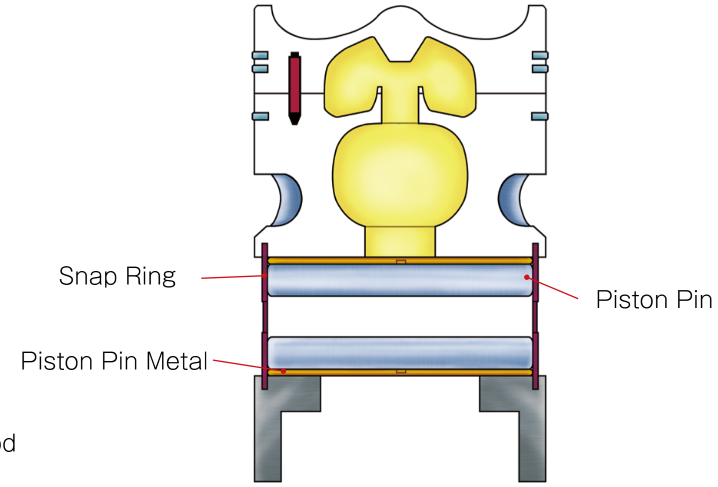


Fig. 33-2 Piston Pin Diagram

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).

⑤	When the accident occurred in March 2013, a description of the condition of No.4 cylinder is as below:	
	(a) Piston skirt	● The lower part of the oil ring of the port side piston skirt was severely seized and sustain broken damaged ● The broken damage part dropped down
	(b) Piston pin boss	● The bottom part of the piston pin boss was broken ● 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.
	(c) Snap ring	● The snap ring of the bow side piston pin was broken in the centre and had dropped down ● Had the snap ring been appropriately inserted into the snap ring gutter, a contact mark would naturally not have appeared.
	(d) Cylinder liner	● A vertical scratch approximately 5mm in depth sustained on the bow side to cylinder liner
⑥	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.	

(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)

ⓐ 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.

ⓑ 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.

ⓒ 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.

ⓐ 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.

ⓑ 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.

ⓒ 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.

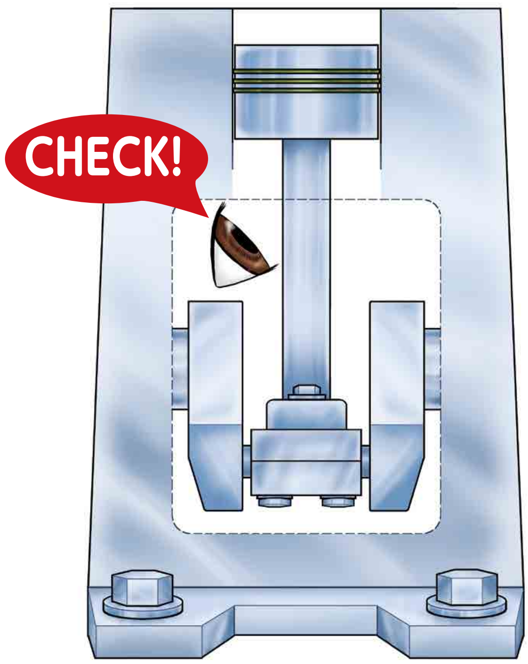


Fig. 42 Appearance of Crankcase

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 >> 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'.	Crew training
<< Thorough guideline creation >> 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'	Thorough ship management and supervision

(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.

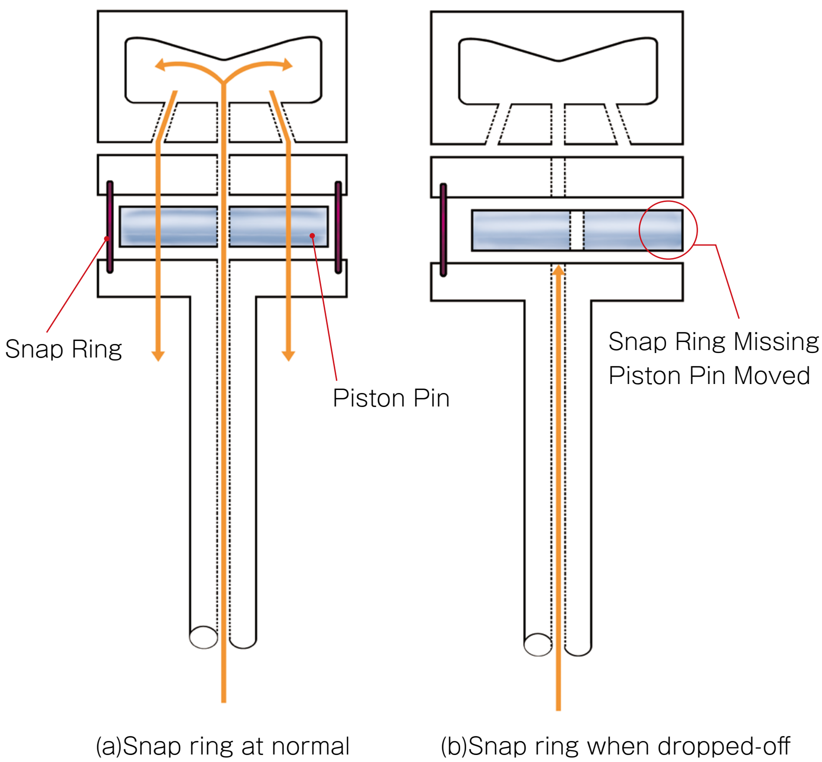


Fig. 43 Prevention of LO Flow which Aids Piston Pin Movement

§ 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(㎥/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
❸ 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.
❺ 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?
❻ 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
❸ 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.
❺ 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?
❻ 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.

Conclusion

Safety is only a result that avoids all dangers. Thus, it is natural to think 'safety does not exist' in the world. If the precision of planning to avoid danger becomes greater, it will be closer to realizing safety. Because of that, it cannot disregard the PDCA method.

Therefore, the method for measuring the Safety Management System and the SMS manual is very rational. However, in order to organize this system which is embedded within safety management performance, it requires a tremendous amount human energy. It is essential that we think of this energy as safety culture. While thinking of this culture, it needs to consider the pyramid consisting of three items of 'Science', 'Technology/Skill' and 'Technician' which support safety.

Keeping that in mind, in analysing these cases, if it does not analyse by stepping into the issue of 'why such risky action was taken?' with the Human Characteristics and, further, by taking a preventive measure, questioning 'what it should do in order not to be involved', a similar accident could reoccur.

It is important to precisely analyse the individual sequence of events before an accident occurs, to extract and examine the insufficient management which lays hidden in the background and to lead effective preventive measures in order to exclude those factors. The author hopes you now recognize the importance of 'preventative type' safety measures.
Last but not least, for safe navigation, the importance of condition monitoring such as basic watch 'lookout' and 'round watch' should always be at the forefront of ones mind.

List of References

(1) Marine Accident and Incident Reports by Japan Transport Safety Board of Ministry of Land, Infrastructure, Transport and Tourism
Report search site：http://jtsb.mlit.go.jp/jtsb/ship/index.php

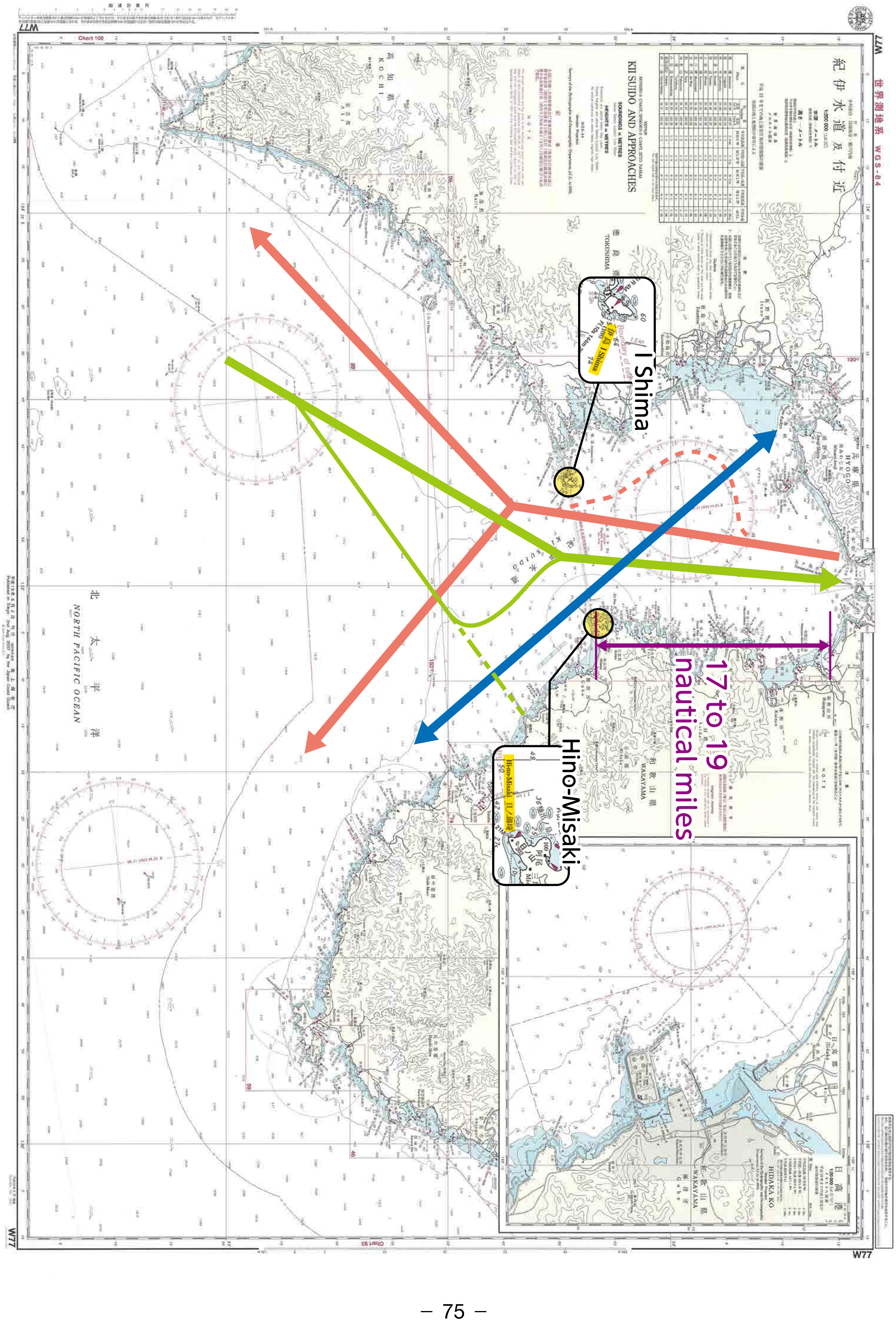
(2) Class NK
・Class NK bulletin 'Summary of damage' from fiscal year 2009 to 2014
・No. 292, 296, 301, 304, 309 and 312

(3) Nautical Charts published by the Japan Coast Guard and the Japan Hydrographic Association
・Fig. 30 The Kii Suido (Strait)
・Fig. 31 Tokyo Bay

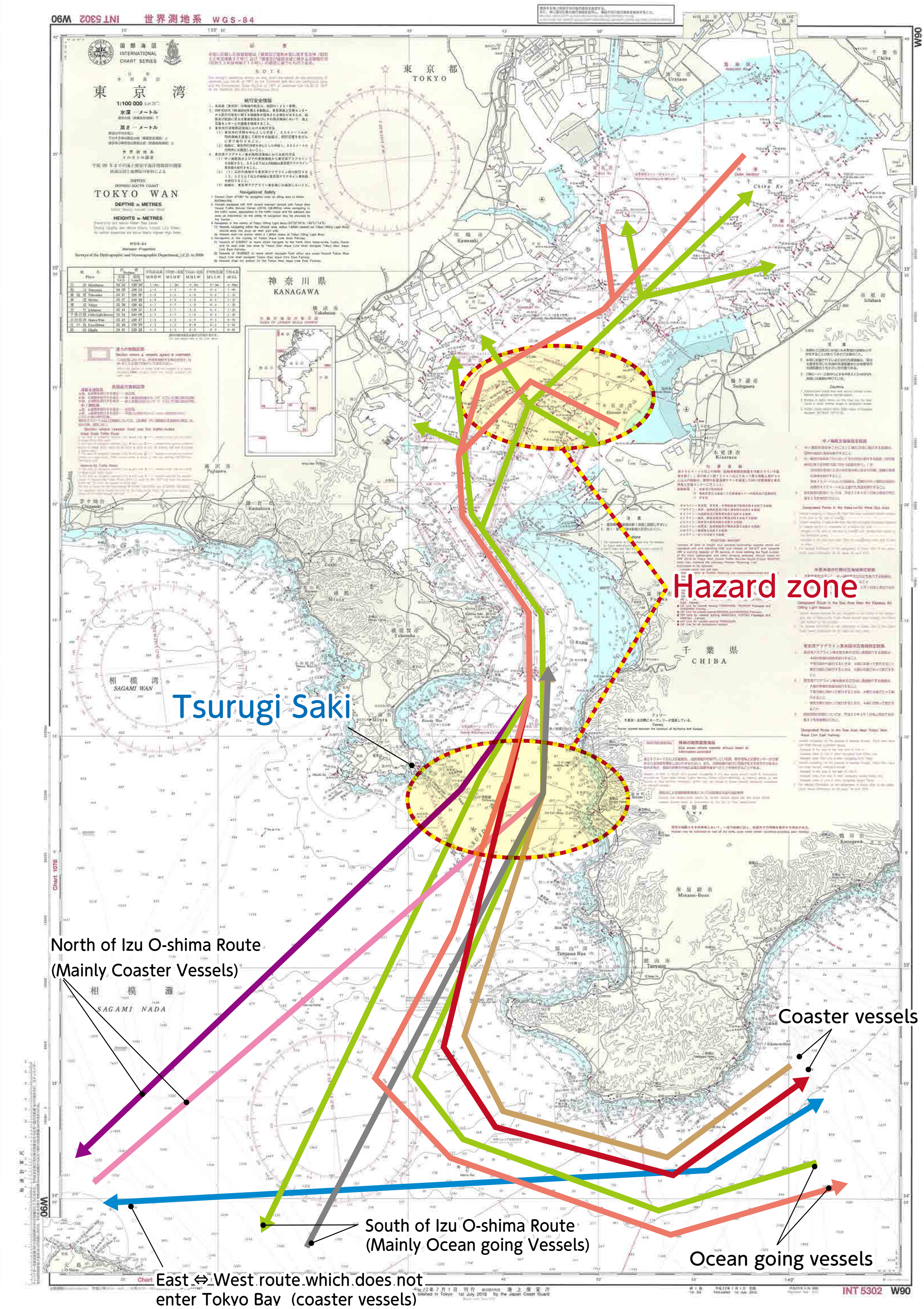
List of Attachments
Attachment ①：The Kii Suido (Strait)　Traffic System Chart (Enlarged Drawing of Fig. 30)
Attachment ②：Tokyo Bay　Traffic System Chart (Enlarged Drawing of Fig. 31)
Attachment ③：4 Cycle Diesel Engine of Vessel
Attachment ④：Additional Engine Trouble (3 Cases)

Attachments

Attachment ①：The Kii Suido (Strait)　Traffic System Chart (Enlarged Drawing of Fig. 30)



Attachment ②：Tokyo Bay Traffic System Chart (Enlarged Drawing of Fig. 31)



Attachment ③ : 4 Cycle Diesel Engine of Vessel

The basic structure of a ship's 4 cycle diesel engine is identical to that of a car engine. As shown in Fig. 50, it constitutes a power output section (upper part) and driving mechanism (lower part). The power output section is comprised of a cylinder liner and piston. This section is where the supplied fuel combusts. The piston slides up and down within the cylinder, which has a combustion chamber located at the top. Fuel is supplied to the combustion chamber, where power is generated via the combustion of fuel. The driving mechanism constitutes a connecting rod and a crankshaft. This section generates propulsion powered by the engine. The 'power' which the piston obtains in the combustion chamber is transmitted to the crankshaft via the connecting rod. The reciprocating motion of the piston is transferred into rotary motion via the crankshaft. This then becomes the vessel's propulsion power, which is the driving power. If the power output section or driving mechanism is damaged, propulsion power cannot be obtained. Therefore, this affects the ship's navigation.

The characteristics of a crankcase will be described. The crankcase can be defined as a box-shaped housing where the crankshaft is stored. Because the housing has a door, it is possible to conduct internal inspection. The door is small, however, crew can monitor the state of the engine's internal structure sufficiently by using a hand mirror and adjusting the position of the crankshaft.

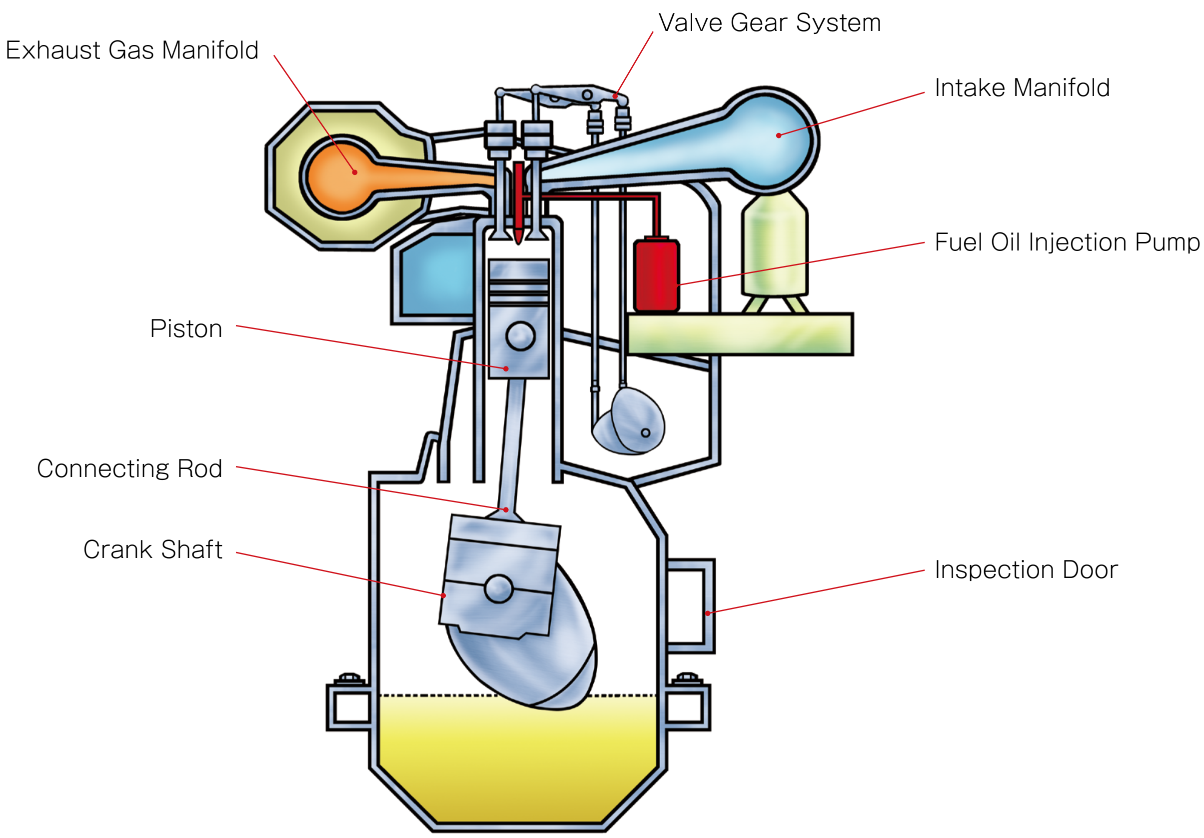


Fig. 50　4 Cycle Diesel Engine of Vessel

Attachment ④ : Cases of Additional Engine Troubles (3 Cases)

【Reference Information】

According to Marine Accident and Incident Reports by the Japan Transport Safety Board, three cases of operation disability due to engine trouble, together with our accident analysis will be introduced.

【Case ④　Accident summary】

On starting up the main engine in preparation for entering port following anchorage, there was an abnormal noise.
As a result of the inspection of each of the parts carried out by the crew, it was acknowledged that water was gushing out from the No.6 cylinder indicator valve.
Due to the leakage of cooling water into the cylinder, caused by a broken hole in the turbo charger casing, following main engine start-up, this led to the bending and consequent damage of the connecting rod.

Analysis by Japan Transport Safety Board		Analysis by our Club		
Items	Details	Items	Details	Remarks
Cause Analysis	<Relationship with hull, engine, etc.> Yes <Analysis of detected items> ● Regarding the vessel, which was anchoring, due to a hole that appeared in the turbo charger casing of the main engine, cooling water leaked into the cylinder, she heaved up anchor and tried starting the main engine in preparation work for entering port, the connecting rod had sustained bending damage and the main engine could not operate, which presumably led to service incapacity. ● When measuring the thickness of the turbo charger casing, which was carried out approximately two months prior to this incident, it was detected there was a thin part. If the use limit value and past history were confirmed and the casing had been replaced on this occasion, the occurrence of such an incident may have been prevented. ● It is presumable that the trouble can be prevented, if the blowing air operation is carried out by opening the indicator valve before staring the main engine.	Direct cause	Due to a hole that appeared in the turbo charger casing of the main engine, cooling water leaked into the cylinder. When starting main engine operation, the main engine could not operate because the connecting rod sustained bending damage.	(Report)
		Indirect cause	Although the following instruction existed, it was not strictly adhered to. ● Instruction for maintenance of turbo charger ● Main engine operation instruction There was no recognition as per below: ● Recognition 'of development to engine trouble, when using a casing that is beyond the its usage thickness limit' ● The recognition of 'why does the thickness wear and tear of the casing progress?' ● The recognition of 'whether bending damage of the connecting rod will be sustained by liquid compression when the main engine is suddenly started' ● Could not recognise the signs of an accident by round inspection?	(Report) (Report) (Assumption) (Assumption) (Assumption)
		Root cause	There were no guidelines as per below: ● 'Cooling water treatment guidance that may affect the thickness reduction of the turbo charger'	(Assumption)

Analysis by Japan Transport Safety Board		Analysis by our Club		
Items	**Details**	**Items**	**Details**	**Remarks**
Preventive measures	The following are considered to be useful items for prevention of similar trouble in the future. ● Measure the thickness of the turbo charger casing and replace with a new one in the event that a thin part beyond use limit is detected. ● Before starting and after stopping the main engine, carry out air blowing operation by opening the indicator valve to check if there is no contamination inside the cylinder. ● Appropriate water quality treatment of cooling water by injecting anti corrosive agent	Preventive measures	(1)A superintendent of the vessel is to issue a safety notice as follows and calls for attention to compliance of work instructions regarding maintenance and engine operation.	
			● ‘Strictly utilize maintenance instructions of the ship, in accordance with the maintenance instructions of the turbo charger manufacturer instruction manual’.	Engine Management
			● ‘Operate strictly based on operation instructions of the vessel which were created in accordance with the main engine manufacturer instruction manual.’	Engine Management
			(2)A superintendent of the vessel must call for attention of the following. A safety poster is available.	
			● ‘Importance of round inspection utilizing the five human senses’	Monitoring the situations
			(3)A superintendent of the vessel is to create the guideline and establish a system of corrosion inhibition.	
			● ‘Cooling water treatment guidance that may affect the thickness reduction of the turbo charger’	Engine Management
			(4)A superintendent of the vessel is to train crew thoroughly as per follows:	
			● ‘Helping them understand the structure of a turbo charger, and ask what kind of accident could be predicted in the case of using it beyond the thickness use limit’	Education
			● ‘Why does the thickness of the casing deteriorate through wear and tear? What kind of attention and management is necessary in order to restrain it?’	Education
			● ‘Help them understand the structure of the main engine and ask as to what kind of accident could occur in the case of suddenly starting the main engine when liquid enters the cylinder.’	Education
			● ‘Round inspection utilizing the five human senses’	Education

Table 51 Engine Trouble Case ④

《Point of cause》 **Breach of maintenance instructions, breach of procedure, lack of education and training, insufficient round inspection, etc.**

【Case ⑤　Accident summary】

During navigation, the lubricant oil low pressure alarm for the main engine reverse and reduction gear was activated. Although the electric lubricating oil pump for back-up automatically started, the lubricating oil pressure indicated 0kg/cm2. Once the pump was stopped and re-started, the pressure increased once again, however, it went down immediately following that. Following the result of the overhaul inspection of the LO strainer for reverse and reduction gear by the crew, they abandoned main engine operation, because traces of metallic powder were detected.
Also, as a result of the inspection of the reverse and reduction gear conducted by the engine manufacturer, damage to the needle bearing of the directly-connected LO pump drive gear shaft and in the inner race, in the bush of forward and reverse clutch shaft and bearing metal was discovered.

Analysis by Japan Transport Safety Board		Analysis by our Club		
Items	Details	Items	Details	Remarks
Cause Analysis	<Relationship with crew, etc.> Yes <Relationship with hull, engine, etc.> Yes <Analysis of detected items> ● During its navigation, damage to needle bearing of LO pump of reverse and reduction gear caused the decrease in oil pressure. Due to the shortage of LO supply quantity, the main engine could not operate and it seemed that her service became unavailable. ● The needle bearing of the LO pump in the main engine had been used since her first voyage, and there would be a possibility that the bearing caused the damage because of ageing.	Direct cause	Damage to needle bearing of LO pump of reverse and reduction gear caused the decrease in oil pressure. Then, because of the lack of LO supply quantity, the main engine could not operate.	(Report)
		Indirect cause	(1)Although instructions existed for maintenance of LO pump directly connected to driving shaft of reverse and reduction gear of main engine, there were not strictly adhered to. (2)There was no recognition as per below: ● Recognition 'of development to engine trouble, when using a needle bearing of LO pump that is beyond the time by when it should be replaced.' ● Could not recognise the signs of an accident by round inspection?	(Report) (Assumption) (Assumption)
		Root cause	The following instructions for maintenance were not established. ● 'Check operation details such as check valve in LO system'	(Assumption)

Analysis by Japan Transport Safety Board		Analysis by our Club		
Items	Details	Items	Details	Remarks
Preventive measures	The following are considered to be useful items for prevention of similar trouble in the future. ● To inspect the needle bearing by overhauling the LO pump of reverse and reduction gear regularly and to exchange the bearing within the time described in the instruction manual.	Preventive measures	(1)A superintendent of the vessels creates the following guideline of maintenance and instructs those on the whole of the vessel thoroughly. ● 'Regarding the confirmation of small-part operations such as check valve, specifically what and how should it be carried out?'	Understanding of structure
			(2)A superintendent of the vessel is to issue a safety notice as follows. ● 'Strictly utilize maintenance instructions of the ship, in accordance with the maintenance instructions of the LO pump manufacturer instruction manual.'	Engine Management
			(3)A superintendent of the vessel must call for attention of the following: ● 'Importance of round inspection utilizing the five human senses'	Monitoring the situations
			(4)A superintendent of the vessel is to train crew thoroughly as per follows: ● 'Help them understand the structure of the LO pump, and ascertain as to whether they know what kind of accident could occur in the event of using it beyond its replacement hours.'	Education
			● 'Round inspection utilizing the five human senses'	Education

Table 52 Examples of Engine Trouble ⑤

《Point of cause》 **Breach of maintenance instruction, poor control of check valve (backflow prevention) in LO system, lack of education and training, insufficient round inspection, etc.**

【Case ⑥ Accident summary】

During navigation, there was an abnormal noise from the engine room, and the crew discovered the leakage of LO in the vicinity of main engine No.3 cylinder. When the crew overhauled the cylinder head cover of No.3 cylinder, following the main engine manufacturer's instruction, the crew discovered one of two missing intake valves.
As a result of overhauled work on the cylinder head conducted by the main engine manufacturer, it was detected that one intake valve cotter passed through the top part of the piston by dropping into the cylinder, after the cotter became disengaged from the mounting part due to wear and tear of a piece of cotter of the intake valve (two-piece fittings which are fixed in order not to drop the valve by being settled in the artificial groove portion on the valve shaft part of the intake/exhaust valve). In addition, through further detailed inspection, damage to the turbine nozzle ring and rotor of the turbo charger was discovered.

Analysis by Japan Transport Safety Board		Analysis by our Club		
Items	Details	Items	Details	Remarks
Cause Analysis	< Relationship with hull, engine, etc. > Yes < Analysis of detected items > ● During navigation, a piece of cotter which was used in the intake valve of main engine No.3 cylinder dropped off through wear and tear and the intake valve fell into the cylinder. Then, damage to the piston and so forth was caused by it being sandwiched by both flanks of the cylinder head and top part of the piston, which, presumably, meant that the main engine could not operate properly and hence the termination of the shipping service on that occasion.	Direct cause	● A piece of cotter which was used in the intake valve of main engine No.3 cylinder dropped off through the wear and tear and the intake valve fell into the cylinder.	(Report)
		Indirect cause	● No recognition of 'when the cotter and cotter contact surface of the intake and exhaust valve will chafe leading to engine failure' ● Could not recognise the signs of an accident by round inspection?	(Assumption) (Assumption)
		Root cause	The following guideline was not established. ● Guidelines for maintenance regarding 'overhauling, measurement and recording of each part, from the important equipment, should start after vessel purchase' ● Guidance of maintenance 'what we do with which parts specifically, regarding the detailed maintenance of accessories and related parts'. ● Guideline of maintenance of 'measurement inspection in order to grasp wear and tear at the part of the cotter, when carrying out overhaul maintenance'.	(Assumption) (Report) (Assumption)

<table>
<tr><th colspan="2">Analysis by Japan Transport Safety Board</th><th colspan="3">Analysis by our Club</th></tr>
<tr><th>Items</th><th>Details</th><th>Items</th><th>Details</th><th>Remarks</th></tr>
<tr><td>Preventive measures</td><td>The following are considered to be useful items for prevention of similar trouble in the future.

● When maintaining by opening and closing cylinder head of main engine, thoroughly inspect the cotter and cotter contact surface of the intake and exhaust valves.</td><td>Preventive measures</td><td>(1)A superintendent of the vessel is to create the guideline and establish a system of detailed inspection maintenance.
● Guidelines for maintenance regarding 'overhauling, measurement and recording of each part, from the important equipment, should start after vessel purchase'
● Guidance of maintenance 'what we do with which parts specifically, regarding the detailed maintenance of accessories and related parts'.
● Guideline of maintenance of 'measurement inspection in order to grasp wear and tear at the part of cotter, when carrying out open maintenance'.

(2)A superintendent of the vessel must call for attention of the following: A safety poster is available.
● 'Importance of round inspection utilizing the five human senses'

(3)A superintendent of the vessel is to train crew thoroughly as per follows:
● 'Allow the crew to learn about the structure around the cylinder cover and educate them as to what kind of trouble may occur in the event of maintenance failure'
● 'Round inspection utilizing the five human senses'</td><td>

Engine Management

Engine Management

Understanding of structure

Monitoring the situations

Education

Education</td></tr>
</table>

Table 53　Examples of Engine Trouble ⑥

《Point of cause》 **No overhaul of important equipment, insufficient time management for maintenance, under-management of parts regarding accessories of important equipment, lack of education and training, insufficient round inspection, etc.**

MEMO

The author

Capt. Takuzo Okada
Master Mariner
General Manager
Loss Prevention and Ship Inspection Dept.
The Japan Ship Owners' Mutual Protection & Indemnity Association

JAPAN P&I CLUB
日本船主責任相互保険組合

Website http://www.piclub.or.jp

● Principal Office（Tokyo） 2-15-14, Nihonbashi-Ningyocho Chuoh-ku, Tokyo 103-0013, Japan
Tel：03-3662-7229 Fax：03-3662-7107

● Kobe Branch 6th Floor Shosen-Mitsui Bldg. 5, Kaigandori Chuoh-ku, Kobe, Hyogo 650-0024, Japan
Tel：078-321-6886 Fax：078-332-6519

● Fukuoka Branch 6th Floor Meiji-Dori Business Center 1-1, Shimokawabata-machi, Hakata-ku, Fukuoka 812-0027, Japan
Tel：092-272-1215 Fax：092-281-3317

● Imabari Branch 2-2-1, Kitahorai-cho, Imabari, Ehime 794-0028, Japan
Tel：0898-33-1117 Fax：0898-33-1251

● Singapore Branch 80 Robinson Road #14-01B SINGAPORE 068898
Tel：65-6224-6451 Fax：65-6224-1476

● Japan P&I Club (UK) Services Ltd 38 Lombard Street, London EC3V 9BS U.K.
Tel：44-20-7929-3633 Fax：44-20-7929-7557

Translated by: YUZEN Translation LLC **Illustrator:** Ms. Makoto Kiryu