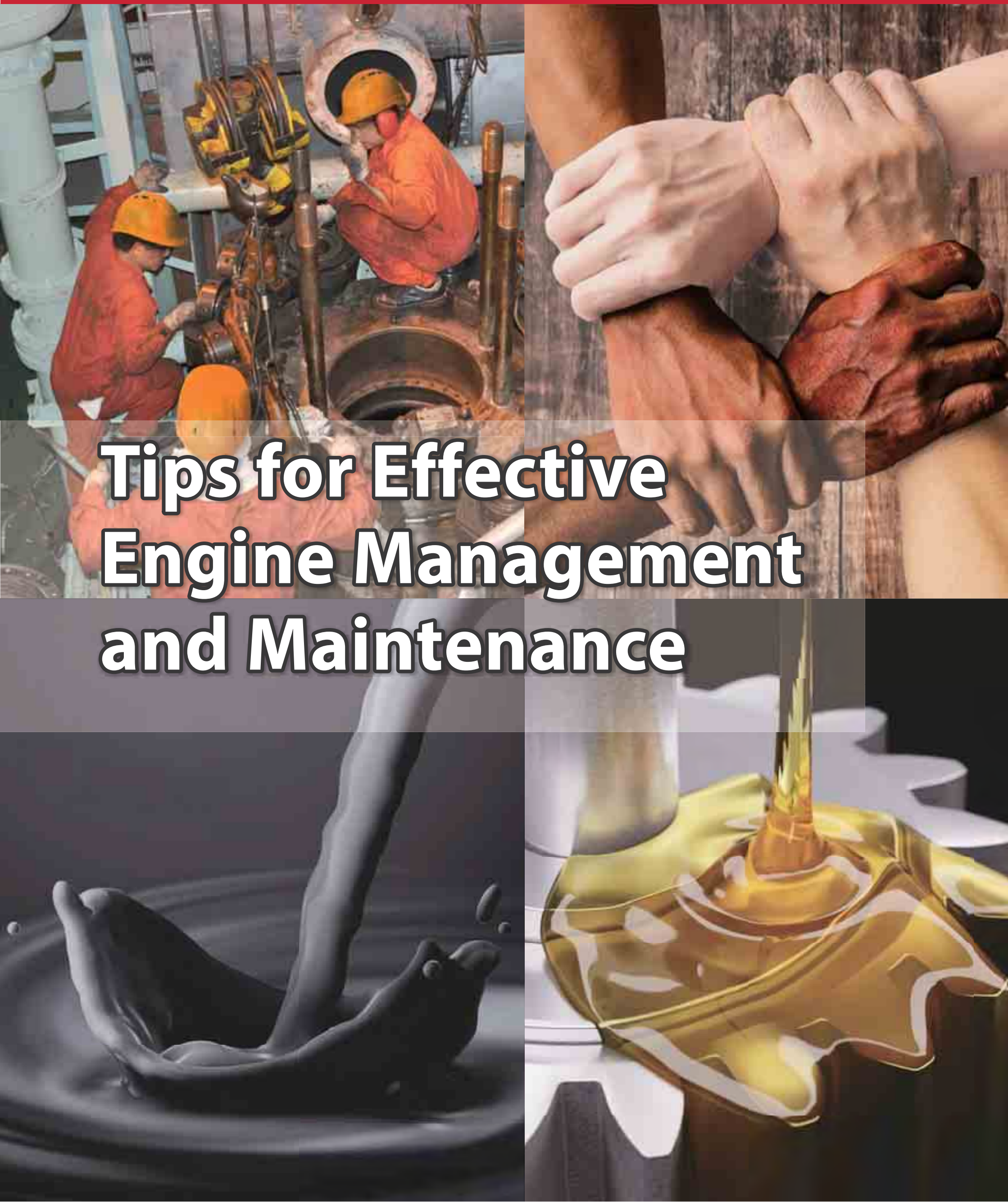
JAPAN P&I CLUB Vol.49 December 2020

P&I Loss Prevention Bulletin

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

Tips for Effective Engine Management and Maintenance



Contents

Chapter 1 Introduction

In previous seminars and loss prevention bulletins, we introduced the following themes:

- the causes of marine casualties/incidents,
- the reasons why similar types of marine accidents continue, and
- the recommended measures needed to prevent a reoccurrence.

A brief outline of each is given below.

The root cause of marine casualties/incidents:

A Chain of Human Errors.

The reasons why similar types of marine casualties/incidents continue:

While it is impossible to prevent human errors completely, in the past, those involved in safety management and many shipowners/management companies have taken measures to prevent recurrence from a technical perspective because they assumed that the cause of casualties/incidents was mainly due to the chain of errors that surfaced as a result of technical issues. Previously, the parties who were directly related to the casualties/incidents were punished and the case was closed.

However, with this method, the possibility of the same kind of accident reoccurring is apparent, since we have not analyzed the root cause as to why experienced crewmembers and marine engineers generated human errors that could lead to casualties/incidents.

Recommended measures to prevent a reoccurrence:

We need to analyze the human behavior characteristics of the person who caused such errors: the root cause, the psychological factors, and human capability/limitation, to establish an environment that eliminates them.

When focusing on the root causes of a ship's machinery failure and incidents, it appears that most cases are the result of management problems regarding oils (fuel oil and lubricating oil) and inspection/repair/maintenance work that was not properly performed. However, the engineers and their crewmembers in the engine department tend to pursue the cause as to whether there is any abnormality regarding mechanical/electrical engineering integrity and soundness in design/manufacturing, such as whether the engine machinery/equipment itself is working and running normally or not. Regrettably, it is often the case that reoccurrence preventive measures, such as those mentioned above, tend to get neglected or forgotten.

In this guide "Tips for Effective Engine Management and Maintenance" we have included all of the key elements taken from our open seminars that were held in Japan in 2019.

We recommend that ship owners/ship management companies, in particular, recognize human behavioral characteristics as a threat. We wish to emphasize the importance of ① "**supporting human resources**" and ② "**being prepared for panic**". By cooperating with the vessels and those who man them more effectively will lead to successful teamwork. It is hoped that the key points raised in this bulletin will assist and promote prevention and the reoccurrence of casualties/accidents.

Please refer to the following loss prevention bulletin on human behavioral characteristics, psychological factors, and human capability/limitation that contribute to the root causes.

Vol.35

Thinking Safety – Bridge Resource Management and Engine Room Resource Management

(Issued in July 2015)

Chapter 2 The importance of repair/ inspection/maintenance

The following are the fundamentals of repair/inspection/maintenance and are empirically said to be the lifelines of the engine department.

- The management of Oils (fuel oil and lubricating oil)
- The grasping of machinery working status/appropriate maintenance (especially the fuel supply system)

ERM (Engine Room Resource Management) was stipulated as a requirement following the revision of the STCW Convention (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) in 2010. The requirement specifies the standards of navigational watchkeeping needed in accordance with the Mariners Act in Japan. The standard goes on to explain that crewmembers must surely implement what has been traditionally important/necessary regarding technical knowledge and maintenance methods that are the fundamentals of engine management. To reliably realize this, crew members must utilize all of the engine department's resources and cooperate with one another, communicate with the engine team effectively, and make sure that work on planned maintenance is carried out along with continuous condition monitoring while keeping up to date with training. Therefore, repair/inspection/maintenance is closely linked to ERM.

It is also recommended that not only the crewmembers on-board, but also that the shipowner/ship management company consider the following to achieve effective engine management in addition to mechanical/electrical engineering technical theory:

It is essential to respect the “positiveness and faithfulness” of humans.

It is necessary to be mindful of “supporting human resources” paying particular attention to the fact that “people have limitations”.

2-1 Building up a trustful relationship among engine team members

Figure 2-1 is one of the posters that we issued in early 2019 to promote safety. There may be a gap between what the “boss” expects (conceit and the preconception) and what the “younger crewmember” may understand (a lack of information).

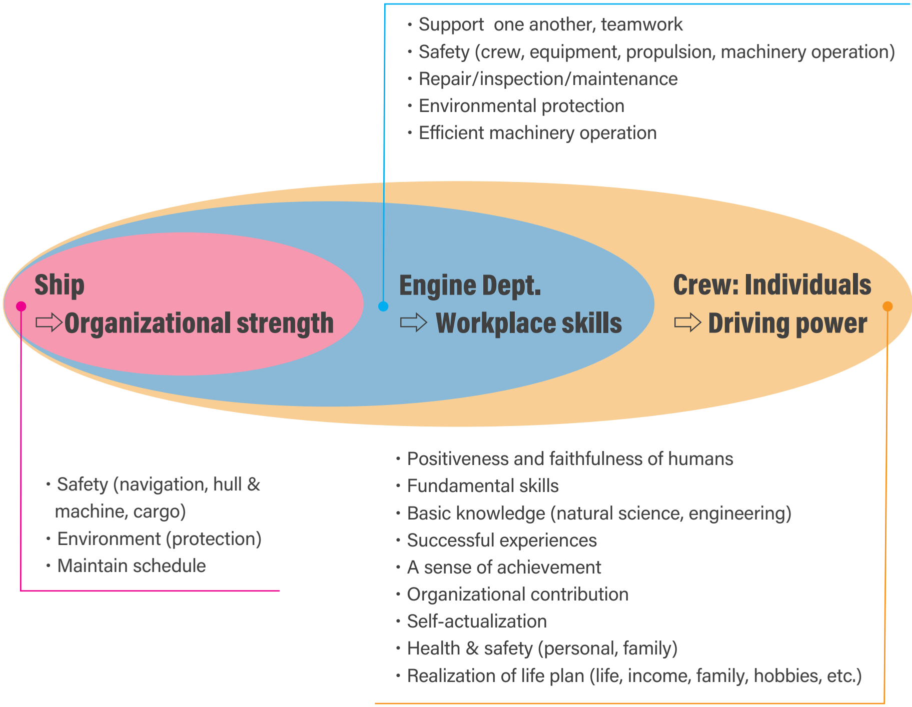
Figure 2-1 4th Engineer gets lost and struggles

Life onboard a ship is sometimes considered backward with a system that remains straitjacketed and hierarchical. If experienced crewmembers teach younger crewmembers in an old-fashioned manner with conceit and preconception, it may scar them mentally and take some time for them to recover. Therefore, to create a sustainable workplace, experienced crewmembers should be aware of the fact that younger crewmembers are more vulnerable to a stressful environment, particularly when under the supervision of experienced crewmembers. Given these circumstances, experienced crewmembers also need to acknowledge this and take a more flexible approach, for example:

① To compliment younger crewmembers whenever possible
② To not give ambiguous instructions to younger crewmembers
③ To create a safe space and environment where younger crewmembers can concentrate
④ In order to support younger crewmembers, experienced crewmembers need to be aware of what they need to know, and not pressure them

It is recommended that the senior engineers conduct an extensive and comprehensive diagnosis of each crewmember in the engine department as early as possible, so as to be able to approach younger crewmembers appropriately. Please refer to “Reference material 01: Ability diagnosis of onboard work performance” (Page 106).

It is difficult to build up a trustful relationship in the engine team under vague circumstances, i.e. an attitude of conceit, preconceptions, and a lack of information will hinder a trustful relationship. To prevent this, as shown in Figure 2-2, experienced crewmembers and younger crewmembers should establish a sense of unity.



Establish a sense of unity	Root causes behind individual action: Respect/trust/peace of mind (mentally)
	Control & manage attitude and emotions (envy)
	Knowledge/ability/skill related to emotional regulation: Trustworthiness, principles, ability to evaluate, ability to communicate, achievement, autonomy
	"Do not lie, do not make excuses, & do not betray colleagues: to save face

Figure 2-2 On building a better team

Therefore, the experienced crewmembers need to utilize 6 capabilities effectively to build a trustful relationship with younger crewmembers who have a diverse way of thinking, especially when they work on onboard operations that require organizational control and discipline.

The 6 capabilities are “trustworthiness, principles, ability to evaluate, ability to communicate, achievement, and autonomy”.

6 Capabilities

- Trustworthiness
- Principles
- Ability to evaluate
- Ability to communicate
- Achievement
- Autonomy

Trustworthiness : **Self-protection makes for a weak leader.**

Don’t be dismissive.
Support those under your leadership.
Be true to your word.

Principles : **Rules that follow a vision are strong.**

Have a clear vision.
Decide how the team should be.
Breaking the rules is a joint responsibility.
Create rules to prevent mistakes and gaps.
Eliminate the contradiction between words and actions.

Ability to evaluate : An absolute appreciation of roles is motivating.

It is not necessary to be biased (unfairly kind).
It is important that everyone develop strong resilience.
It is necessary that everyone be aware of their role.
Investing in the education of younger personnel under your leadership is ideal.

Ability to communicate : Was the information "understood" rather than simply "transmitted"?

Always encourage them to leave their comfort zone and make sure that everything is absorbed.
Use repetition if you want to be understood.
Don't communicate with uncertainness.
Share the best and ultimate achievements.

Achievement : A mechanism that allows a team to exert its greatest performance.

Leaders must work harder than anyone else.
Keep going no matter the outcome.
Consider the result an "opportunity to learn" that will strengthen younger personnel under your charge.
Face and respect your younger personnel as individuals.
Create an updatable and readily accessible manual.

Autonomy : Create an environment that encourages those under your charge to act of their own accord.

Create a safe work environment.
Encourage younger personnel to emulate others.
Real leaders win over both superiors and those under their charge.
Endurance is key to success.

If you try to control your those under your charge by downplaying them, you will likely be repulsed and may face difficulties in building a strong team. In other words, if you do not respect those working for you, they may never listen to you and may never cooperate.
In short, it is important that "one does not lie, does not make excuses, and does not betray their team". Namely, "do not betray others to save face".
Based on this, if the mutual understanding of values between the two parties creates cooperation and empathy, the engine department can build the most robust teamwork and obtain high-quality work results.

Shipowners and ship management companies tend to tighten the SMS (Safety Management System) as a countermeasure for casualties/accidents. However, it should not interfere with the teamwork of the crewmembers.

2-2 Why is repair / inspection / maintenance necessary ?

The author attended a seminar on the human factors surrounding aeronautical engineers, which included many hints that could be considered applicable for onboard work in a ship's engine department.

Tips that can be applied to a ship's engine department

The aviation field considered human characteristics and capabilities carefully in aircraft design to effectively improve manoeuvring operations. This is where an understanding of human factors first began. Besides, even in recent years, even though aircraft technology has advanced to a high degree, it is dependent on humans to a large extent, so it is extremely important to understand human behavior characteristics and to align them with machines to improve overall system safety. The author would like to focus on the background of a more profound recognition of human factors.
Figure 2-3 shows the "biggest threat" to aircraft and ships, two main forms of transportation.

On an aircraft, if the aircraft gets damaged or there is engine failure due to "human" error with repair/inspection/maintenance or if it is manoeuvred incorrectly, "gravity" will cause it to crash.

On a ship, if a ship sustains damage to the hull or the main engine stops because of "human" error similar to the above, a marine casualty/accident occurs because the "water (sea)" causes instability, inconvenience, and isolation.

Therefore, both forms of transportation have the same phenomena in common, that is, the biggest threat is "human beings".

Aircraft and ships are inspected before commencement of operation to ensure that they have been designed and built in accordance with the rules and regulations and that they are operated correctly. On passing, a certificate is issued. This is then proof that an aircraft is airworthy or that a ship is seaworthy.

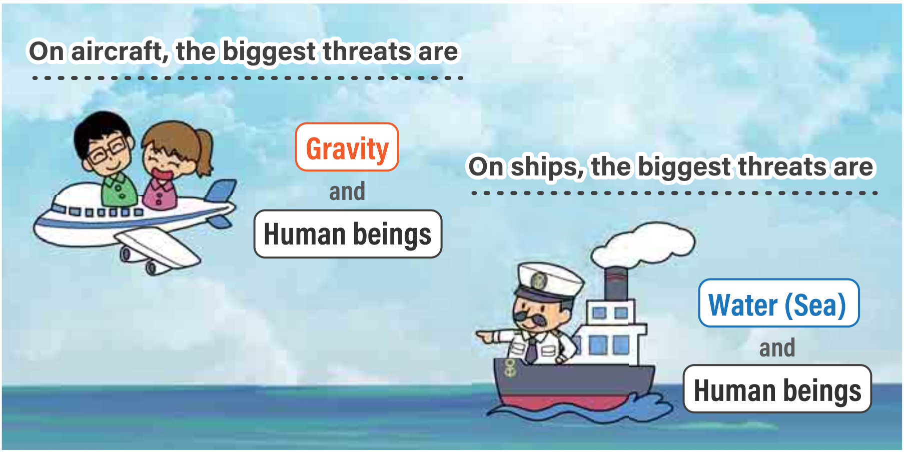


Figure 2-3 What is the biggest threat?

The carrying out of repair/inspection/maintenance is to "maintain the inherent airworthiness and seaworthiness" of an aircraft or ship. Besides, it is just this "essential positive action" that enables "humans" to discover defects or problems within machinery. However, because "humans" work on this machinery directly, and let us remember that "humans" pose the greatest threat, it is recommended that experienced crewmembers always reconfirm just what "repair/inspection/maintenance" is and make sure that younger crewmembers understand, putting themselves in the shoes of the younger crewmembers.

2-3 Harmony between technology and human beings: 4M management

In the aircraft field it is said that 4M management, as shown in Figure 2-4, is indispensable as a guiding principle to properly manage the repair/inspection/maintenance necessary to ensure that the aircraft remains "airworthy".

Man who acquires the Method (necessary knowledge) and who uses the Material, the Machine & the Facility can carry out repair/inspection/maintenance. Those 4 initials are M. 4M management is the same as ERM (Engine Resource Management), and it is essential for the **implementation of quality control**.

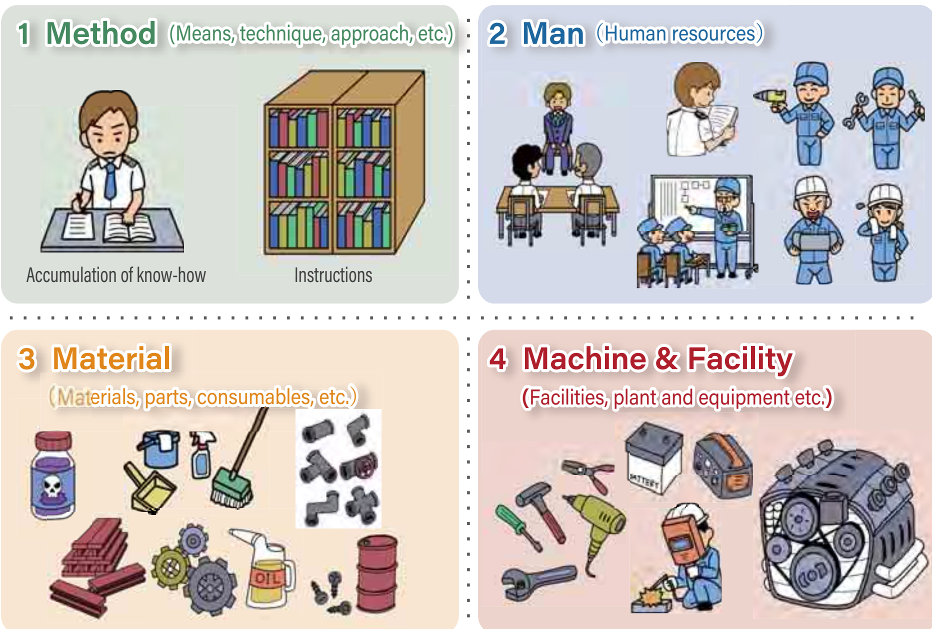


Figure 2-4 Management of 4M

4M is compromised when the following examples occur:

(1) Machine&Facility: the maintenance personnel judges the deterioration of parts by measuring with a “faulty measuring scale”.

(2) Machine&Facility: the maintenance personnel tightens bolts using an “uncalibrated torque wrench that has a deteriorated spring”.

(3) Material: the maintenance personnel installs non-genuine parts.

In Table 2-5, aircraft and ships can be compared using 4M.

It is clear to see that 4M can be applied to ships also, therefore, please take some time to review this and use it onboard whenever possible.

Industry		Aircraft	Ship
Important points		Gravity Human beings	Water (Sea) Human beings
4M	Method	Knowledge, Repair/ Inspection/Maintenance, Instruction Manual, Procedure, Training, Education	Knowledge, Operation, Repair/ Inspection/Maintenance, Instruction Manual, Procedure, Training, Education
	Man	Airline Mechanic (Supervisor, Subordinate, Senior, Junior)	Engine Department Crew (Supervisor, Subordinate, Senior, Junior)
	Material (Materials, Parts, Consumables, etc.)	Repair/Maintenance Parts, Fittings, Lubricating Oil	Repair/Maintenance parts, Ship Supplies, Chemicals, Lubricating Oil
	Machine & facility (Facilities, Plant and Equipment etc.)	Facility, Equipment, Measure Tools, Maintenance Hangar	Facilities, Equipment, Measure, Tools, Dry Dock

Table 2-5 Comparison of 4M

2-4 Limitation of human capacity

Factors that cause human error include the following recognition processes.

Error when registering information

Example: Crewmembers sometimes overlook parameter information of engine room machinery dials etc. (change of pressure, temperature, vibration, and so on) during engine room rounds, etc.

Errors in the memory process (errors due to limitations of short-term memory, long-term memory) (lapse)

Example: The technical personnel forgot what he planned to do.
The technical personnel believed that he completed his work even though he did not finish it.

Error in the judgment process (mistake)

Example: The technical personnel believed the action was correct without any doubt.
The technical personnel worked according to procedures that do not apply.

Temptation to deviate (violation)

Examples: The technical personnel unavoidably used a tool not specified for the task.
The technical personnel believed it was safe and didn't wear the prescribed protective goggles.

Error in the output process (slip)

Example: The technical personnel hit the wrong key on the keyboard for operating the remote monitoring system;
the technical personnel skipped the items on the check sheet and proceeded; Captain inadvertently pressed the main engine “manual emergency stop button,” which was identically shaped and located immediately adjacent to the “program by-pass button,” and the main engine stopped in an emergency in the center of the canal (Please refer to “3-2-1 Incident case of loss of propulsion in the US: Incorrect operation of the main engine in the wheelhouse”) , etc.

Among the above factors, let’s look at errors that occur when registering information.

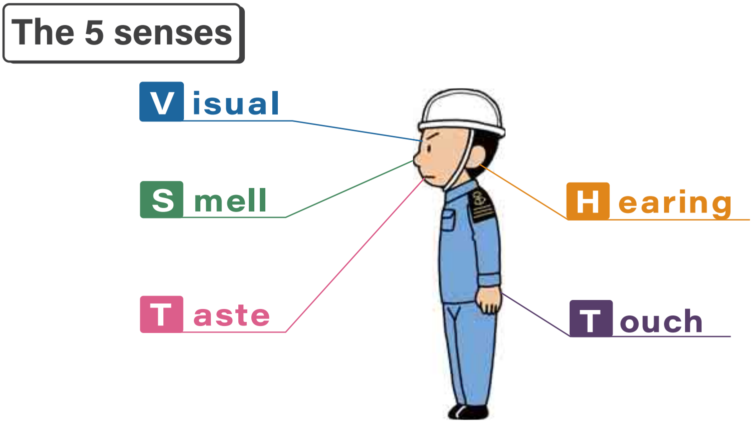
Errors when registering information

Table 2-6 shows, “Errors when registering information”. Let us imagine your vision during taking a round in the engine room when “Focusing on one thing,” “Checking aimlessly,” “Thinking about something different,” or “Jumping to the wrong conclusion,” and so on. The information around you that you recognize with your eyes such as “color, numerical values, indication on a measuring gauge, quantity, and open/closed state of switches and valves,” and so on can be perceived as only an image like some ordinary scenery or landscape. As a result, it cannot enter into your selection/judgment/decision process accurately and cannot be transmitted to the brain, which then leads to an incorrect output (action). Factors such as similar notation, a confusing display, busyness, fatigue, lack of sleep, aging, your physical condition, and so on also influence the background processes behind your actions, and if they overlap, the risk of error increases. Please be aware that a lack of sleep can lead to the same decline in brain function as when drinking alcohol. Please refer to the errors of each process in “Reference Material 02: Under what circumstances does an error occur?” (Page108).

Errors when registering information	
Information is not registered.	**Focusing on one thing** ・Vision/hearing is limited. ・Field of view is limited. ・Visible range is limited.
Information is registered, but not processed.	**Checking aimlessly** ・A lack of interest. **Thinking about something different**
Information registered, but was illuded.	**Jumping to wrong conclusion** ・The information is of interest but misinterpreted. (Hasty judgments, misunderstanding, assumptions).

Table 2-6 Errors when registering information

Humans collect information by taking advantage of their five senses when making decisions and acting on them. Figure 2-7 shows the ratio of the five senses affecting information collection in general.



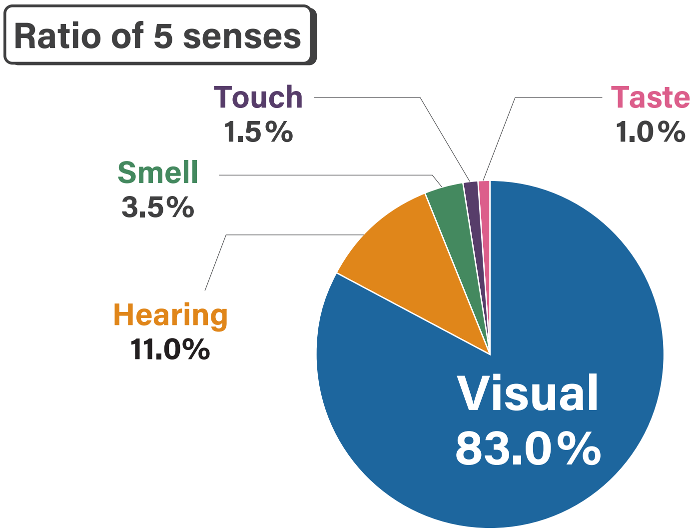


Figure 2-7 Ratio of 5 senses

Surprisingly, sight accounts for 83%, and hearing 11%. However, since the brain cannot process all the information it perceives, it can only see and hear according to the information that the brain imagined in advance. That is, since humans' subjectivity interposes, you will only see what you want to see and will hear only the sounds you want to hear. Furthermore, these abilities greatly influence the decision of engine operation and repair/inspection/maintenance.

Humans have the wonderful capability to "see, hear, judge, act," but these limitations can cause human error. Therefore, it is necessary to harmonize between the goals to be achieved and machinery/equipment function. If it is impossible to do so, it will result in incorrect operation or faulty engine room machinery maintenance.
For the aviation industry, "human capability and its limitations" are shown in Table 2-8, and are essential items for qualification requirements, maintenance programs, maintenance training, and so on. Thus, these are incorporated into the basic education program, and national examinations require proficiency in this area. It is highly likely that the shipping industry can learn something from these important points that originated in the aviation industry.

POINT

(1) Understand human capabilities and their limitations.

(2) Based on these capabilities, we need harmony amongst humans, machinery systems and the environment.

Table 2-8 Human capabilities and limitations

2-5 Error chain: example of an engine accident

Most engine accidents are the result of a chain of small errors.

Engine accident error chain example

Figure 2-9 shows an example of an engine accident error chain. The following human errors (in red) form the chain.

1. The engine department started an additional generator during the voyage. It is because the ship demanded extra power supply for machinery operation.

2. The Third Engineer did not notice any abnormalities when conducting the rounds of the engine-room using the MO checklist. He forgot the indicated reading of the gauge that was relayed to him by his colleague verbally (Error in memory (Lapse)).

3. The differential pressure alarm for the DG inlet fuel strainer was activated.

4. The Chief Engineer instructed the person in charge to take appropriate remedial action such as checking the actual condition and cleaning the strainer but did not confirm this himself (insufficient consideration, speculation, wishful thinking: Error in judgment process (mistake)).

5. The person in charge ignored the alarm because he had a preconceived image that it was a false alarm as usual (assumptions): Error when registering information).

6. **This time, the strainer actually clogged entirely, and the generators stopped. Finally, the ship lost power completely (blackout).**

Figure 2-9 Error chain: example of an engine incident

As a countermeasure, according to the principles of ERM and BRM, if one person's mistake occurs during teamwork, somebody must notice this as early as possible and "advise, warn, or help out".
The following situations illustrate this:

- A Third Engineer, boarded a ship for the first time after being promoted. It was his 3rd day onboard. Because he was unfamiliar with the engine-room MO check list system, he had difficulties completing the checks.
- The Chief Engineer boarded after returning from shore service. It had been a long time.
- The Second Engineer was in charge of the generator. He had been on board for 5 consecutive years and he had the longest ship boarding experience among the engine crew members. Furthermore, he believed that he had the best understanding of the engine room.

When the strainer differential pressure alarm activates, if the crewmembers can distinguish between physical abnormalities (strainer blockage) and electrical abnormalities (signals, wiring, and so on) based on the logic tree shown in Figure 2-10, they can refer to the 8 inspection items and grasp the whole picture.
As a result, the person in charge can establish a mutual understanding with the Chief Engineer regarding the 8 inspection items and be on the same page.
Therefore, they could have broken the chain of errors through referring to the 8 items related to engine operation management, repair/inspection/maintenance work, and troubleshooting.

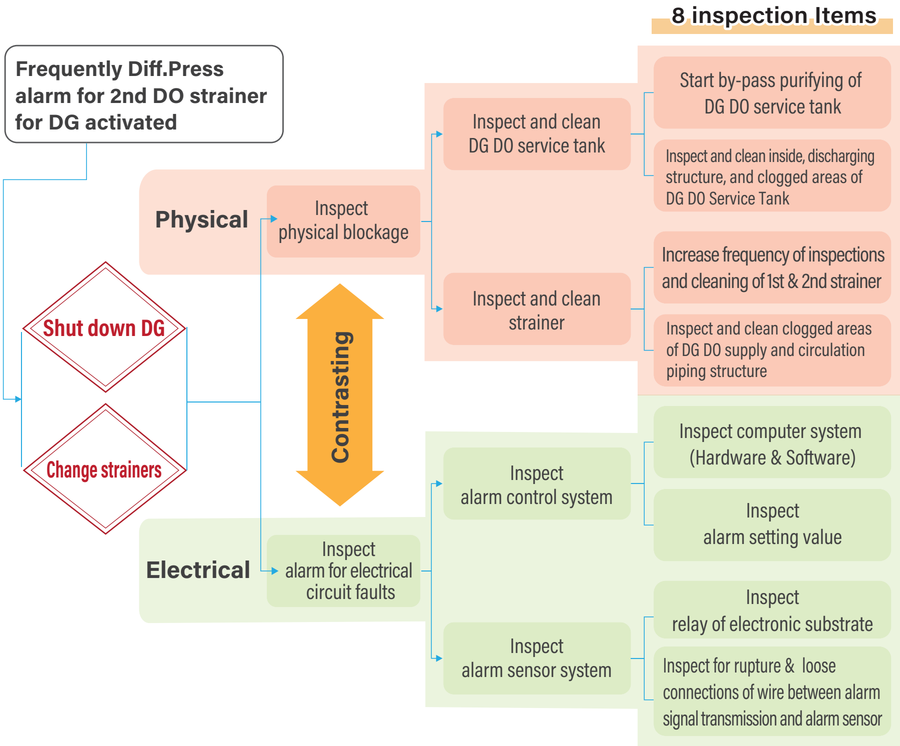


Figure 2-10 Logic Tree: in event of strainer differential pressure alarm

In various jobs other than this example, it is recommended that the person in charge of each piece of machinery/equipment prepares such a technical basic chart in cooperation with the engine department. It helps crewmembers to resolve engine difficulties. And then, when they build the troubleshooting procedure, it is good to add weak points peculiar to the ship by taking advantage of the advice of experienced experts. As a result, it becomes a more persuasive weapon in the fight to resolve trouble.
Therefore, it is recommended that the chief engineer make an effort to establish the above system that enables the engine department to work as one team in cooperation.

In addition to a logic tree analysis, there is also a “fishbone” analysis method that can be used for problem-solving. Please refer to “Reference Material 03: Problem Solving Method” (Page 111).

2-6 What to be careful of with repair/inspection/maintenance

Even if the ship management company or the ship prepares an absolutely perfect procedure/instruction manual in theory, we cannot eliminate human error because humans apply their five senses, as mentioned above. James Reason said maintenance accidents of aircraft occur in an environment as shown in Table 2-11, according to his book “Managing Maintenance Error”. He is a British psychologist famous for his “Swiss cheese” model of accident causation. He worked in the aviation field with the Royal Air Force Institute of Aviation Medicine and the U.S. Naval Aerospace Medical Institute.

Errors in repair/inspection/maintenance

(1) Humans directly implement and rely on their hands for repair/inspection/maintenance work.

(2) The level of wear and deterioration of each item to be maintained will vary, making it difficult to formulate routine procedures. Therefore, the organization, management and awareness all directly influence this.

(3) Reassembly work is more vulnerable to human error than that of disassembly, because reassembly imposes a much greater burden upon limited mental resources (memory and attention), thus greatly increasing the probability of error.

(4) Many accident causes are as follows: incorrect parts, incorrect installation of components, fitting of wrong parts, electrical wiring discrepancies, foreign objects (tools, rags, personal items) left behind in the reassembly of machinery, and so on.

(5) There are several assembly procedures, hence the margin for error is increased.

(6) When there is a simple and quick work procedure, which violates the approved procedure. (Black book)

(7) Overfatigue, etc.

Table 2-11 Errors in repair/inspection/maintenance

The ship's crewmembers and the manager/supervisor of the ship management companies might realize that the same things are happening onboard. Repair/inspection/maintenance errors always occur when maintenance personnel "(1) do not perform the work that must be done at a determined time/timing, or (2) perform work that does not need to be done", as shown in Table 2-12.

Example: The crewmembers did not replenish lubricating oil in the generators with the manufacturer's recommended amount (Please refer to "3-2-2 Incident case of loss of power in Norway: Inadequate replenishing of system lubricating oil to diesel generators on electric propulsion vessel").

When there are errors in repair/inspection/maintenance
(1) When maintenance personnel do not perform necessary work required during operating conditions or repair/inspection/maintenance recommended in the instruction manual at the appropriate time.
(2) When maintenance personnel perform repair/inspection/maintenance work that is not required or is prohibited.

Table 2-12 When there are errors in repair/inspection/maintenance

The managers/supervisors of shipowners or ship management companies must repeatedly remind crewmembers about "errors that occur during inspection/repairs/maintenance" as shown in Table 2-12 and Table 2-13, also mentioned above in "2-4 Limitation of human capacity".

On the other hand, there are times when crewmembers cannot always perform the important repair/inspection/maintenance.

There might be several possible reasons behind this:

- **The ship management company does not supply sufficient quality and quantity of spare parts to the ship due to cost-saving.**
- **Because of the tight schedule, it will not secure the time for repair/inspection/ maintenance.**
- **As a result, the crewmembers onboard lose motivation to carry out repair/ inspection/maintenance, and in the worst case, they deteriorate and lose the ability to perform repair/inspection/maintenance work onboard.**

That is, it is the “collapse” of 4M and ERM. When repair/inspection/maintenance progress falls behind schedule, instead of leaving everything entirely up to crew members on board, the ship management company must analyze what is happening between those onboard and the management system on the company side. It is indispensable for the company to establish a system that supports the seafarers onboard the ship to achieve a higher safety level.

2-7 When and what should crewmembers evaluate and judge on board?

The basis of engine room watchkeeping is to monitor the condition of the equipment (recognizing and grasping the current situation).

When monitoring engine operation condition, the crewmembers must always consider “when, where, and what they need to pay attention to on board”. Table 2-13 and Table 2-14 show the basic check items needed during engine operation and repair/inspection/ maintenance.

Basic items to check during engine operation

Category	Status of Device or Machine	What to Judge/Evaluate? **Please increase awareness of the problems, and listen to the noises coming from the machinery.**
Machine Operation Management	**Prior to starting of equipment**	• Are the pressure gauge, thermometer, and rotating gauges accurate? • Is the glass of instruments and sight glass broken or dirty? • Is the scale easy to read? • Is the lighting around the engine machinery & equipment sufficient? • Is a pipeline system for lubricating oil, cooling water, fuel oil, etc. in place? • Are the control switches or control valves set to the correct positions?
	Starting of equipment	• Is continuous operation possible? • Is it normal? • Will it be necessary to stop the machinery & equipment manually all of a sudden? • Is it abnormal?
	During operation (unusual, abnormal, leakage, alarm sounds, vibration, noise, smell, etc.)	• Is continuous operation possible? • Is it normal? • Will it be necessary to stop the equipment manually all of a sudden? • Is it abnormal?
	Emergency manual stop	• Can it be repaired? • Do you have to leave it? • Will it be necessary to carry out any additional inspections/confirmation, including that of related systems and equipment?

Table 2-13 Basic items to check during engine operation

Basic items to check during repair/inspection/maintenance

Category	Status of Device or Machine	What to Judge/Evaluate? Please increase awareness of the problems, and check attentively.
Repair / Inspection / Maintenance Management	Prior to repair/ inspection/ maintenance	• Did you prepare 4M (Method, Man, Materials, Machine & Facility), and do you have a risk assessment protocol in place?
	During maintenance	• Must any parts that you removed due to overhauling be replaced or renewed? • Are there any abnormalities? • Is it possible to reuse or refit any of the parts during overhaul on the machinery?
	Regular maintenance	• Will the maintenance be implemented as scheduled (as planned)? • Or will the schedule be brought forward? • Will the time of maintenance be extended (postponed)? • Is the maintenance schedule recommended by the manufacturer appropriate considering the actual operation and running of the equipment? • Is it earlier or later?
	Repair	• Can own crew on board manage repair, inspection, and overhaul by themselves? • Will it be necessary to arrange for the repair company from shore to attend during an emergency? • Will repair and overhaul need to be carried out at a dry dock urgently? • At present, is it possible to carry out emergency repair work by the own crew on board and to postpone full-scale repairs until the next regular dry dock?

Table 2-14 Basic items to check during repair/inspection/maintenance

As mentioned above in "2-4 Limitation of human capacity," if crewmembers "check aimlessly," or "think about something different" during engine room rounds, this is likely to cause an error.

It is important for younger crewmembers to consciously monitor conditions and predict changes that may occur during inspection and to keep up to date regarding each piece of machinery where attention should be paid. When monitoring and inspecting, they must also remember the voice of experience from experienced crewmembers/colleagues and information about trouble that occurred on other ships.

In other words:

(1) When crewmembers check the engine, they must pay full attention and listen carefully for abnormal noises coming from the machinery during its operation.

(2) When crewmembers carry out repair/inspection/maintenance, they must observe and evaluate the wear, deterioration, and aging of the machinery carefully comparing this with the information from each manufacturer and drawing reference to past similar vessel accidents.

Therefore, crewmembers need to increase their awareness of potential problems, and look out for and listen carefully with close attention.

2-8 Summary

Engineers must understand science principles (chemistry and physics) and apply these to engine room engineering and technology (technical skills). Marine engineers who have to operate ships with limited technical personnel need to pay attention to this and consider the psychology (law of behavioral characteristics: human limitations). From now on, they need to think about how to utilise psychology and ergonomics in order to mitigate the risk caused by humans.

When planning work instructions for operating machinery, crewmembers should place human beings at the center of the equation rather than machinery by incorporating team members' wisdom and experience and considering the human capabilities and limitations (weak points & threats) due to human behavioral characteristics.

Ultimately, they need to raise the standard of work by applying the above.

It is also true that experienced crewmembers such as the Chief Engineer and the First Engineer have high hurdles to negotiate as they support their team in successful engine room management. However, to achieve safe operation without engine trouble, experienced crewmembers need to devise ways to bring out the best performance in younger crewmembers under their care. This will mean changing their approach to younger crewmembers. Furthermore, the younger crewmembers will also need to have a flexible mindset.

However, changing the attitudes of others can be challenging, so experienced crewmembers need to step outside of their comfort zones if they are to improve the whole team to create a sustainable workplace.

Then, it is recommended that experienced crewmembers do the following:

(1) Prepare an adequate working environment, such as a safe space to work.

(2) Train and mentor next generation younger crewmembers in basic skills.

(3) Offer ample support (non-technical skills) to help younger crew members develop.

By doing this, younger crewmembers will develop the tools needed to be independent. Experienced crewmembers and younger crew members need to establish a sense of unity. We would like to ask the experienced crewmembers to simply demonstrate to younger crew members the fundamentals, such as to not lie, to not make excuses, and to not betray their team. Through the mutual understanding of both parties, a truly robust team can be realized.

As mentioned above in “2-5 Error chain: example of an engine accident”, the following error chain causes engine trouble:

(1) When the engine department crew not only lack knowledge and experience in technical skills, but also make errors when registering information, memory, judgment, deviation, output, etc., they begin to overlook small abnormalities in engine operation and repair/inspection/maintenance.

(2) If crew members continue to deviate from the original reasons or purpose of engine operation and repair/inspection/maintenance due to “conceit, preconceptions, or a lack of information,” the ship cannot achieve maintenance as planned in accordance with the SMS (Safety Management System).

The engine department crew tends to focus on the completeness of their mechanical/electrical technical knowledge and tend to focus mainly on dealing with engine equipment. However, since humans have limitations, it is necessary to consider how this will play out in the future as humans remain central to engine room operation. Thus, when planning work instructions for operating machinery, consideration must be given to improving work methods with people at the heart of the operation.

Furthermore, the shipowner and the ship management company need to include awareness building, which harmonizes and aligns technical safety with such limitations, that reinforce repair/inspection/maintenance, as shown in Figure 2-15.

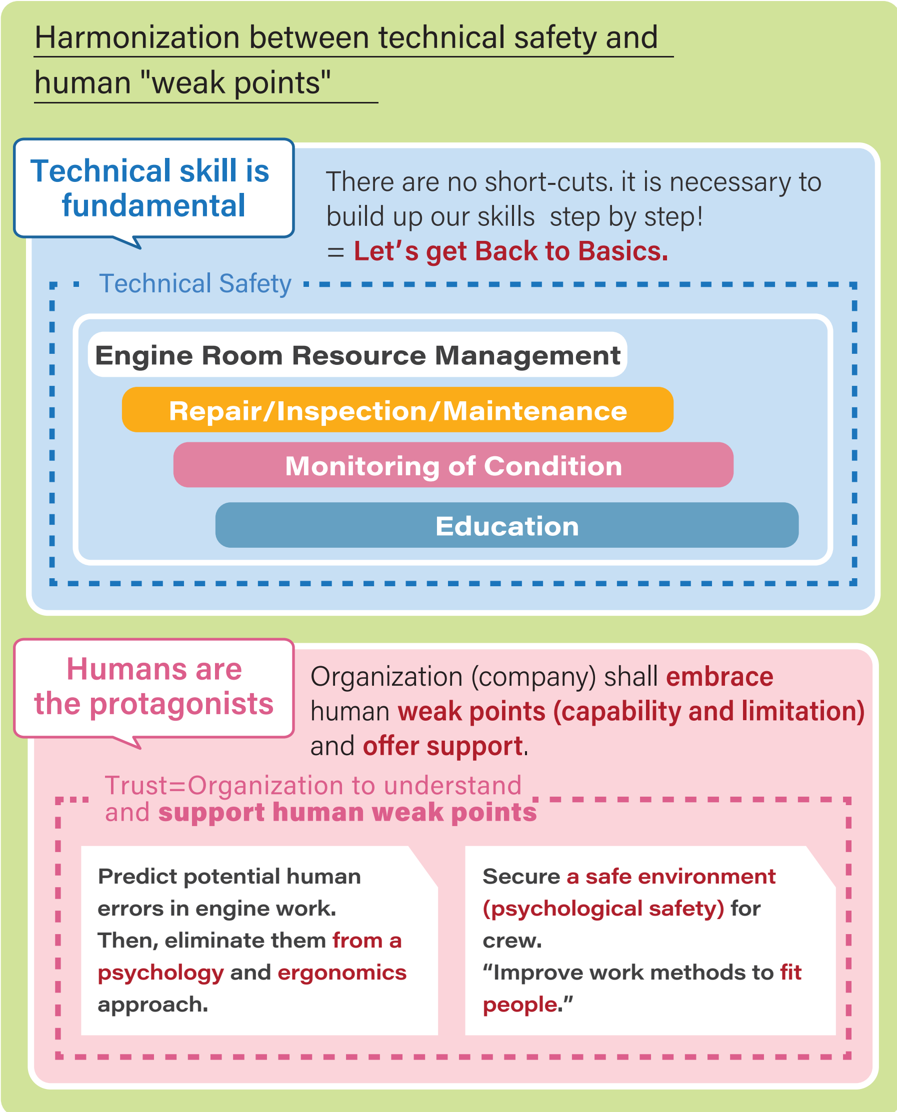


Figure 2-15 Harmonization between technical safety an human “weak points"

Chapter 3 Preparing for an emergency situation

The engine department's mission is to "maintain stable ship's propulsion and secure a source of electrical power". However, there is a risk of an accident occurring if these cannot be secured.

Loss of propulsion or loss of power can have both primary and secondary impacts on marine casualties.

1 Primary (direct) impact

The following are primary impacts shown in Figure 3-1.

① Collision with other vessels

② Damage to port facilities

③ Stranding

④ Cargo claim, etc.

Figure 3-1 P&I accidents that seriously impact the operation

2 Secondary impact

The following are secondary impacts.

① Personal matter (sickness, injury, and loss of life)

② Consequential environmental influence (pollution, destruction, so on)

③ Claims for damage to property and cargo

④ Economic loss caused by "off-hire"

⑤ Reputational damage caused by media reports

Experienced crewmembers and younger crewmembers are engaged in various operations in accordance with the SMS（Safety Management System) of each company. So, if they routinely make risk assessments related to the operations concerned with understanding the impact of such casualties as mentioned above, it will be possible to take the level of safety up a notch.

3-1 Common recognition of the state of loss of propulsion and loss of power

There are various causes of loss of propulsion and loss of power, but those states can be defined into two damaged states; partially and completely. If the bridge team on board and the shore team don't understand those states accurately, they cannot establish a system organization structure for recovery. After receiving the first report from the engine department, it is important for both the officer on watch on the bridge and the superintendent on shore to confirm the situation simply and accurately. As shown in Table 3-2, the loss of propulsion power and loss of power can be precisely grasped by distinguishing between complete losses, such as loss of self-propelling and deadship, and other partial losses.

Partial and complete loss

(1) Loss of propulsion:

① Partially damaged state: reduction of main engine output which inevitably leads to reduced speed operation (damage that lead to speed reduction).

- During speed deceleration of the main engine.
- When a main engine cylinder is cut off.
- When cutting a main engine turbocharger.

② Completely damaged state: loss of self-propelling ability (damage requiring towing).

- When it is impossible to operate the main engine.
- When it is impossible to achieve propulsion supply and control of hull stability and manoeuvring due to weather and sea state conditions, because the main engine is partially damaged.
- Operating conditions of the main propulsion plant are not satisfactory. When the boiler and auxiliary machinery cannot operate due to lack of power.

(2) Loss of power (blackout):

① Partially damaged state: When some power supply units can supply a limited amount of power.

- It is impossible to use/start diesel generator or main switchboard system.
- It is possible to use/start emergency generator (diesel generator cannot supply power).
- It is possible to use battery system (neither emergency generator and diesel generator can supply power).

② Completely damaged state: Dead Ship.

- None of the power supply units can supply any power.
- It is impossible to use stored energy such as starting air to start the prime mover, battery, hydraulic pressure, and so on.

Table 3-2 Partial and complete loss

3-2 Cases of loss of propulsion and loss of power

The following cases are examples of loss of propulsion and loss of power in the USA, Norway, and Japan.

3-2-1 Incident case of loss of propulsion in the US: Incorrect operation of the main engine in the wheelhouse

In Texas, USA, a tankship lost its propulsion completely while navigating in a canal (artificial waterway) which resulted in a collision and a cargo (crude oil) spill.

Accident summary

The tankship carrying most of its cargo capacity was behind the scheduled time while navigating the canal, so the captain decided to rapidly raise the main engine speed according to the pilot's instructions. He tried to increase the speed of the vessel by pushing the "program by-pass button". However, he inadvertently pressed the main engine "manual emergency stop button", which was identically shaped and located immediately adjacent to the "program by-pass button", resulting in a complete loss of propulsion.

Figure 3-3 Maps where the canal accident occurred

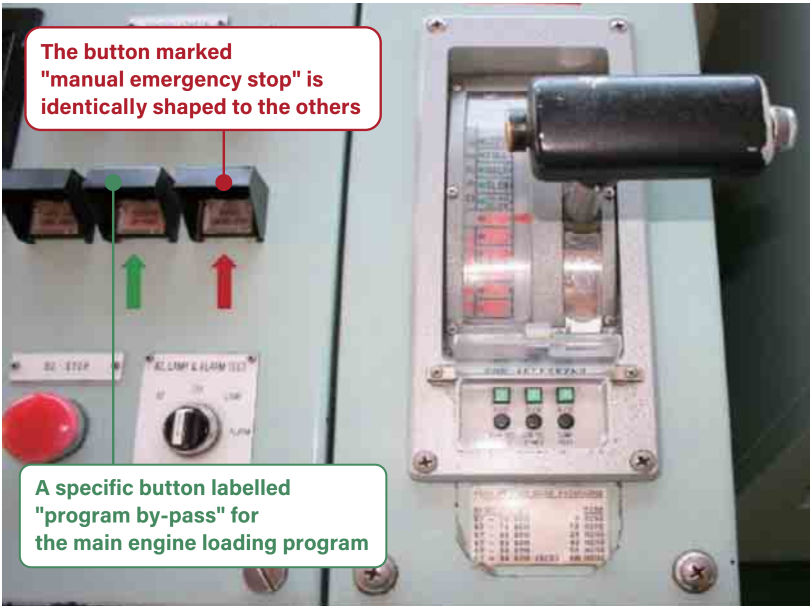


Photo 3-4 Buttons for “manual emergency stop” and “program by-pass”

The ship dropped an emergency anchor using the starboard anchor because of an emergency stop to the main engine and loss of ship’s manoeuvrability. However, the ship’s heading bearing became uncontrollable, and the port bow collided with another ship at berth. After that, the starboard bow collided with another barge that approached from the front. As a result, the starboard ballast tank and No. 1 center cargo tank were breached. An estimated 462,000 gallons of crude oil spilled into the water.

3-2-2 Incident case of loss of power in Norway: Inadequate replenishing of system lubricating oil to diesel generators on an electric propulsion vessel

This is an accident in which an electric propulsion ship lost its power completely while cruising in stormy weather causing it to drop an emergency anchor.

Accident summary

At 13:50 on March 23, 2019, an electric propulsion passenger ship carrying a total of 1,373 (915 passengers and 458 crew) left Tromsø for Stavanger, southwest, in Norway running on 3 generators.

One week before the accident, on March 16th, No.3 diesel generator (hereinafter DG3, Units 1, 2, and 4 being DG1, DG2, and DG4, respectively) was inoperable due to a turbocharger failure. As a result, the manufacturer engineer worked on disassembling DG3's turbocharger on board.

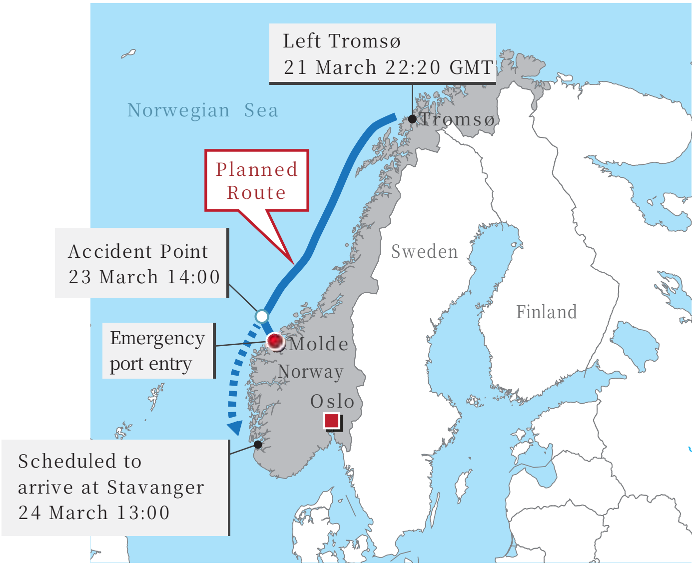


Figure 3-5 Maps of navigation route

The weather at that time was strong winds and rough waves (Beaufort wind power 9-10 from the southwest, significant wave height 9-10 meters), and the ship was in rough weather. During operation, DG1, DG2, and DG4 had frequent lubricating oil low level warnings and low lubricating oil pressure warnings for several hours from the early morning of the same day.

At 13:37 pm, the diesel generators all stopped in succession, so the crew responded by trying to restart the stopped diesel generators, but at 13:58 pm all 3 diesel generators stopped completely, and the ship resulted in a loss of propulsion. 2 minutes later, since the ship started drifting in the direction of the coast (shallows and southeast), a distress signal “Mayday” was broadcasted. From 8 to 22 minutes later, emergency anchoring (starboard 1st and port 2nd, dropping in that order) was conducted, however the anchors did not hold, and the ship continued to drift towards the shore. DG1, DG2, and DG4 were replenished with enough lubricating oil, and from 24 to 36 minutes later, the crew manually restarted DG2 and turned on the main power supply. Then, the electric propulsion devices on both sides were started, so the ship was able to secure minimum ship’s propulsion. One hour and 9 minutes later, a passenger rescue by helicopter began. From 1 hour 26 minutes to 1 hour 48 minutes later, the other two DGs restarted which secured half ahead speed. Finally, 26 hours and 29 minutes later, the ship was able to arrive at the nearest port of Molde.

For details, please refer to “Reference Material 04: Accident details of loss of power in Norway” (Page 116).

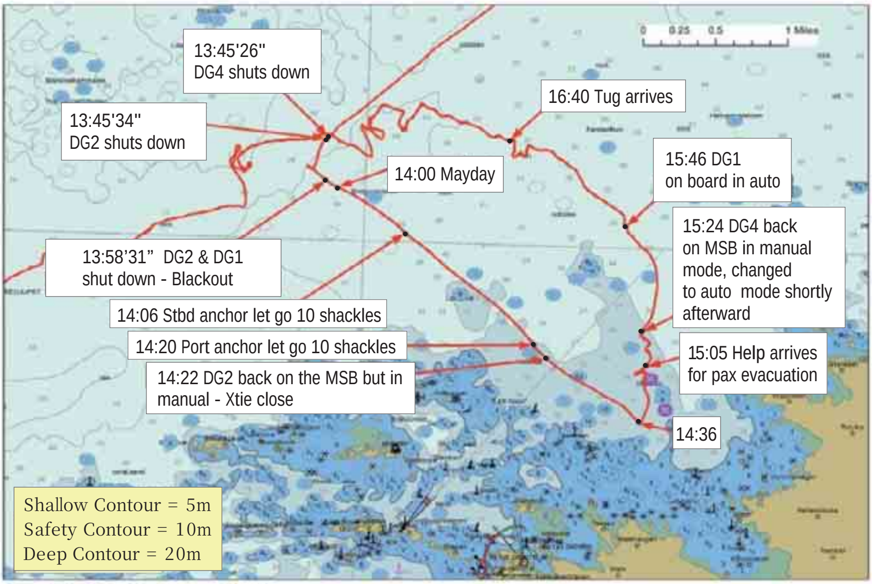


Figure 3-6 Map with sequence of events

Cause

(1) The engine manufacturer's recommendation for the amount of system lubricating oil for the ship's diesel generator is to remain between 68 to 75% of tank capacity. However, the amount of lubricating oil at the time of the incident was 28-40%. As a result of pitching and rolling caused by stormy weather, the liquid level of the system lubricating oil was further lowered, and the suction capability of the lubricating oil supply pump was lost. As a result, each generator's lubricating oil pressure dropped, the safety device was activated automatically, and the generators stopped.

(2) Regarding preparation for heavy weather voyages, there was a lack of risk assessment based on the safe return to port defined in the SOLAS Convention on the following points.

- **There was no standby generator**
- **Amount of lubricating oil was insufficient**

3-2-3 Transport Safety Board investigation reports for Japan: Cases of loss of power

According to the Japan Transport Safety Board's accident safety database, between 2011 and 2018, there were 8 vessels (5 cases occurred in port areas) that were identified as "vessel not under command" due to loss of power or loss of control power source onboard during navigation (excluding pleasure boats, personal water craft, mini boats, recreational fishing vessels, fishing vessels, tug boats, and push boats, etc.)

Accident 1: Navigating in stormy weather

Accident 2: Activation of over-speed protection device for diesel generator

Accident 3: Loss of control power source DC24V

Accident 4: Cooling fan control circuit failure

Accident 5: During port entry standby, crewmembers set the start switch for standby diesel generators from "automatic" to "manual" to clean the lubricating oil strainers of the diesel generators. After a while, one of two diesel generators in operation stopped suddenly due to an oil leakage from its load management governor. As a result, the automatic power backup sequence could not be engaged.

Accident 6: Activation of ACB safety protection devices of the diesel generator during operation

Accident 7: Activation of safety protection device for the boiler and stopping the main engine suddenly due to sensor failure

Accident 8: After switching the valve to the middle position to receive marine diesel oil and heavy fuel oil, this caused heavy fuel oil of higher hydraulic head pressure to flow into the marine diesel oil tank. As a result, this caused the diesel generators (supplied by the marine diesel oil tank) to stop.

For more details, please refer to "Reference Material 05: Details of The investigation reports of the Japan Transport Safety Board; cases of loss of power" (Page 119).

3-3 Response to be taken by a ship in the event of an emergency

3-3-1 Diesel Engine Plant System

Before going on to talk about how a ship should respond in the case of an emergency, we will first look at the layout of the engine room's machinery and how each piece of equipment is related. The purpose of each piece of machinery in the engine room is as follows. Below is a Diesel Engine Plant System. Please see Figure 3-7.

(1) Main engine & shaft system: Generating propulsion
(2) Generator: Generating electric power
(3) Boiler: Generating the heating source mainly for fuel oil or cargo
(4) Emergency generator: Generating emergency electric power supply to the minimum critically important backup machinery when the generators cannot supply electric power.
(5) Emergency battery: Supplying power to the control system and some lighting when power cannot be supplied from an emergency generator.

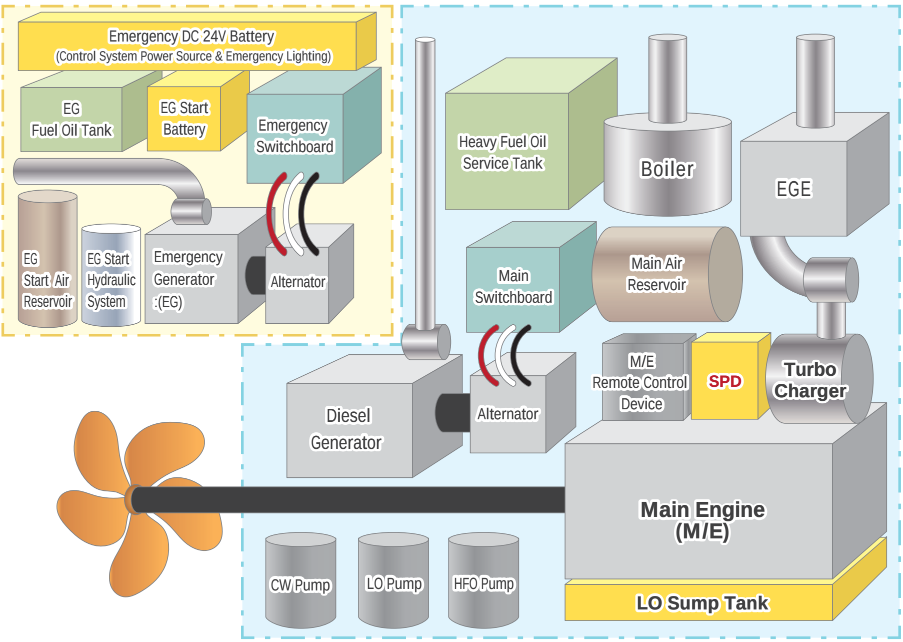


Figure 3-7 Machinery layout in engine room (Diesel engine plant system)