oil leakage caused by abrasive powder from the abnormal wear of piston ring/cylinder liner.

④ Surface wear and burn-out of exhaust valve.

⑤ Exhaust valve sticking due to accumulation of unburnt deposits in the exhaust valve guide aperture.

⑥ Blow-by and high-temperature corrosion, due to poor sealing of exhaust valve seat.

⑦ Surface wear and burn-out of piston crown.

⑧ Turbocharger problems due to accumulated unburnt deposits (e.g., explosion overrun).

2 Medium/high speed 4-stroke diesel engine problems

The higher the engine speed, the greater are the chances of adverse ignition delay. In particular, when the temperature and pressure inside the cylinder are low and the load is also low, diesel knocking may lead to unstable combustion. This will also increase PM and black smoke emissions. Such situations can be alleviated by increasing the load to improve ignition condition. Bear in mind that the same problems related to the low speed 2-stroke engine mentioned above, can also occur in the medium/high speed 4-stroke engine.

Table 5-30 Ignition and combustibility issues

## Detection of and countermeasures for issues arising from oil with poor ignition and combustibility

Table 5-31 shows a summary of diagnostic issues regarding the detection of ignition and combustion problems.

| Diagnosis of potential issues | Countermeasures |
|---|---|
| It is essential that crew members carefully monitor the following engine conditions and make a correct diagnosis: | In the event of any abnormal combustion, crew members must take immediate onboard action and follow the appropriate measures outlined below: |

| Diagnosis of potential issues | Countermeasures |
| --- | --- |
| **1 2-stroke engine**<br>① Ensure proper maintenance of the fuel injection valve and secure the valve opening pressure in order to atomize fuel oil properly and produce a good spray.<br>② Enhance engine monitoring (e.g. monitoring of exhaust gas temperature, rpm of the turbocharger (surging), specific fuel consumption, concentration of iron in drain oil sampled from the bottom of the cylinder liner).<br>③ For engines equipped with temperature sensors, continuously monitor the cylinder liner temperature.<br>④ For engines equipped with cylinder pressure sensors, crewmembers must evaluate the state of combustion by reading the cylinder pressure. Where sensors are not equipped, measure and evaluate in-cylinder pressure with a mechanical indicator. | **1 2-stroke engine**<br>① **Reduce engine load.**<br>Reducing engine load will help to reduce thermal and mechanical loads at relevant locations. This is effective in preventing any further deterioration.<br>② **If mechanically possible, crewmembers should adjust and advance fuel injection timing.**<br>Be aware though that by advancing fuel injection timing, Pmax (maximum in-cylinder pressure) and Nox (nitrogen oxide) values will also rise. Crewmembers must ensure that Pmax limits are within a range which does not exceed the upper limit outlined in the Nox technical file. |
| **2 4-stroke engine**<br>① Ensure proper maintenance of the fuel injection valve and secure the valve opening pressure in order to atomize fuel oil properly and produce a good spray.<br>② Enhance engine monitoring (e.g. monitoring of exhaust gas temperature, rpm of the turbocharger (surging), specific fuel consumption).<br>③ In order to improve startability, cylinder cooling water in the engines should be preheated, if possible. | **2 4-stroke engine**<br>① If possible, adjust and increase the engine output to a medium load. However, for the generators, consideration must be given to the balance between onboard power demand and the number of operating engines.<br>② Crewmembers should add a combustion improver to the fuel (in case of emergency, it is advisable to keep a reserve stock of combustion improver onboard). |

Table 5-31 Detection of and countermeasures for ignition and combustibility issues

## 5-3 Countermeasures for the safe use of cylinder oil

The following is a summary of recommended precautions for the selection of cylinder oil when using low-sulphur compliant fuel oil.

In a two-stroke engine, cylinder oil, which has a close relationship with combustion, serves the following functions:

① **Prevention of corrosion of the cylinder liner and other combustion chamber components by neutralizing acids formed from the by-products of the fuel oil combustion process.**

② **During Hydrodynamic Lubrication, it spreads uniformly over the cylinder liner surface forming a stable oil film between the piston rings and the cylinder liner to ensure smooth lubrication.**

③ **Provision of a gas seal between the piston rings and the cylinder liner to prevent blowing out of combustion gas and compressed air.**

④ **Prevention of build-up of deposits in the piston rings, piston ring grooves and cylinder liner which could otherwise lead to ring sticking or breakage.**

Engine crew members should therefore ensure proper management and control of the cylinder oil which is designed to suppress deterioration of the fuel oil. Care must be taken to maintain both oil viscosity and the proper functioning of any additives to the cylinder oil. These additives help to disperse any sludge generated by the products of combustion and prevent agglomeration and adhesion to machine parts, whilst also reducing the formation of deposits. Compliant fuel oil (VLSFO sulphur content 0.50% or less) has a lower sulphur content than conventional fuel oil (HSHFO sulphur content 3.50% or less). When selecting a lubricating oil, careful consideration must be given to the ability of that oil's alkalinity to neutralize acid (refer to the above mentioned point ① ).

The main component of additives is an alkaline earth metal (mainly Ca). The alkaline ability to neutralize is expressed as the base number (BN).

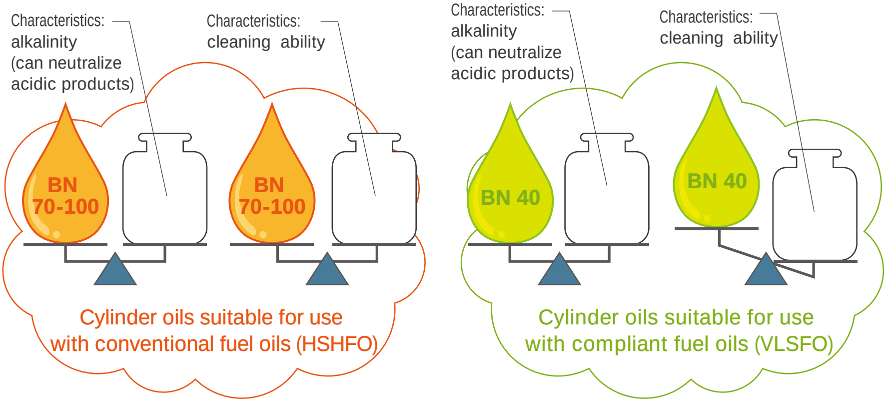



Figure 5-32 BN selection considerations based on degree of pollution by sludge, deposits etc.

If cylinder oil previously used in the conventional fuel oil HSHFO is used in the compliance fuel oil VLSFO, the alkalinity will be excessive, and carbonate deposits will form around the piston and on the piston crown.

In two-stroke engines prior to 2020, ships used a cylinder oil of about 70 to 100 BN for the high sulphur content of the conventional fuel oil HSHFO in open sea areas outside of ECAs.

However, from 2020, ships need to use a cylinder oil of 40 BN which corresponds to fuel oil with a sulphur content of 0.50% or less.

As shown in Figure 5-32, cylinder oil with a high BN has a high ability to disperse incomplete combustion products, such as soot and other substances inside the cylinder oil film. Careful consideration should be given to this dispersing ability when the piston ring/cylinder liner are in poor condition, and when using fuel oil with poor combustion quality. It is therefore recommended that the company consult with the engine manufacturer before selecting and using cylinder oil for a two-stroke engine. Pay careful attention to the matching of compatible fuel oil VLSFO and cylinder oil.

Similarly, consultation is also recommended when selecting lubricating oil for a four-stroke trunk piston type engine.

# 5-4 Onboard check

Regarding the five properties of compliant fuel oil as previously described, there is a short and simple method to diagnose the compatibility, cold flow properties, and ignition and combustion quality, which can be done in about 30 minutes whilst bunkering.

Photograph 5-33(a) Ship bunker manifold

Photograph 5-33(b) Sampling of fuel oil

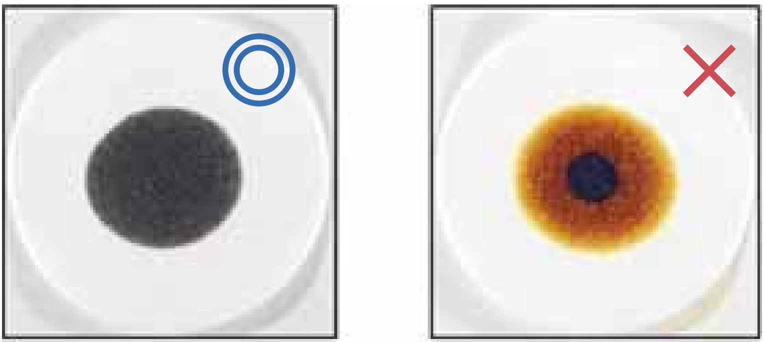
## =Simple diagnostic test=

### 5-4-1 Diagnosis of Compatibility

As described in "5-2-1 ① Compatibility", asphaltene can begin to aggregate when different fuels are mixed, and/or when undergoing thermal shock or when the fuel is oxidized. These particles will grow from fine to coarse, and will finally deposit as asphaltene sludge.

Compatibility can be checked by a fuel oil spot test (ASTM D4740) using a portable test kit as shown in Photograph 5-34. Assessment is made by the circular patterns that appear after the heated sample oil is dropped onto the test paper and dried. Particles that cannot smoothly pass through the test paper are deposited in a circular shape (inner ring), making it easy to judge by their appearance. As shown in Photograph 5-35, when a more distinctive spot can be seen in the center of the filter paper, this implies that the fuel is unstable. If we think of the filter paper as a strainer, it can be seen that the strainer would immediately become clogged if the oil did not spread evenly and appears thick around the center.

Photograph 5-34 Spot test kit for FO compatibility and stability



Left : Evaluation 1 Good compatibility Right : Evaluation 5 Very Poor compatibility

Photograph 5-35 Example of test result (compatibility of FO)

## 5-4-2 Diagnosis of cold flow properties

As described in “5-2-3 ③ Cold flow properties”, these properties indicate the ability of a fluid to flow at low temperatures. Since the average temperature of most domestic refrigerators is around 5°C, crew members can simply evaluate the cold flow properties of fuel oil by leaving a cup of bunker sample oil in a refrigerator for about 30 minutes with a thermometer.

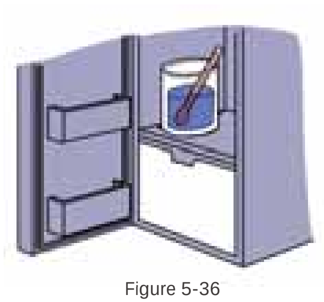
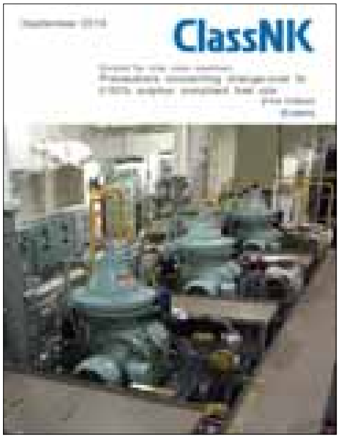


Figure 5-36
Simplified test methods
for Pour point in refrigerator

Any low viscosity or loss of cold flow properties should be reported to the charterer and the ship operator and a request made to implement the countermeasures shown in 5-2-3 above.

For issues regarding “Cold flow properties” and “Compatibility”, please refer to Japan P&I News No. 1044 “THE 2020 GLOBAL SULPHUR CAP — Precaution of “Compatibility” and “Cold flow properties” for compliant fuel oils” published by this club on 11 November 2019. Please also refer to the TEC-1190 “Booklet for ship crew members Precautions concerning change-over to 0.50% sulphur compliant fuel oils [First Edition]” published by ClassNK on 30 September of the same year. This is a particularly practical booklet containing details about additive manufacturers.



## 5-4-3 Assessment of ignition quality

As described in “5-2-5 ⑤ Ignition and combustion quality”, CCAI has until now been the main indicator of ignitability. CCAI can be calculated by referring to the density and kinematic viscosity described in the Bunker Delivery Note (BDN). Depending on the oil quality grade, the international standard “ISO 8217:2017 Petroleum products — Fuels (class F) — Specifications of marine fuels” states that a CCAI value of 860 or 870 or less is required for the operation of marine engines. This should be compared to the estimated value calculated by the crew and used as a guide to the ignitability index. If CCAI exceeds the upper value limits, the ship should report this to the charterer and the ship operator, and make a request to implement the countermeasures shown in Table 5-31 above.

# 5－5 Summary

For safe usage of compliant fuel oil, it is recommended that the shipowner, ship management company, and crew members adopt the following onboard measures:

1 **With the manufacturer's cooperation, review the operation manual for proper fuel oil management (engine, purifier, fuel oil, lubricating oil, additives, etc.) and draw up a revised set of operation procedures.**

2 **Verify previous cases of fuel oil problems.**

3 **Establish a system for the monitoring of the operational status of machinery, and countermeasures to deal with any abnormalities.**

4 **Organize regular inspections to ensure the proper working of machinery in accordance with the manufacturer's instruction manual.**

5 **Ensure a sufficient store of spare parts and fuel oil additives onboard.**

6 **Make sure that crew members are fully versant with various work procedures, previous cases of trouble, and appropriate emergency responses, and provide emergency onboard training drills based on set contingency plans.**

# Chapter 6 Conclusion

In the current climate, in Japan's domestic shipping industry, the securing of younger crewmembers is becoming a challenge, and the current personnel is aging, thus the shortage of human resources is becoming more serious. On the other hand, in Japan, the international shipping industry tends to rely heavily on foreign crew because of intense international competition, meaning that more Japanese crewmembers are engaged in land-based activity. As a result, on the rare occasion that they board a ship, they tend to have mostly theoretical knowledge. In the past, the environment was conducive to fostering skills whereby it was natural to hand over maritime ship skills (operation, repair/inspection/maintenance, and management, and so on) to the succeeding generations: ① On oceangoing vessels all of the crew members were Japanese, and ② on coastal vessels, there was a seamless transition between ages of the personnel on board. However, under the current circumstances, it is difficult for the shipping industry to realize this. Furthermore, the STCW Convention and the Mariners Act in Japan require that crewmembers of the engine department acquire ERM ability to function more organically with resources such as information, human resources, and equipment.

As mentioned in the conclusion of Chapter 2, how to create a sustainable workplace is key. Experienced crewmembers are required to take the following actions (non-technical skills):

(1) To move out of their comfort zone.

(2) To aid the development of younger crewmembers who will lead the next generation.

(3) To create and secure a Psychologically Safe Space where experienced crewmembers can fully support their younger counterparts.

This will lead to a mutual understanding of the entire team and encourage cooperation and empathy. It will also build robust teamwork.
On the other hand, it is impossible to prevent human error that may cause a marine accident. And, in order to break the chain of human errors, it is also necessary to foster harmony amongst people, systems, and the environment. Shipowners, ship management companies, and even the ship may realize a reduction in engine accidents by including awareness, that harmonizes and aligns the gap between technical safety and human weak points, to form a firm understanding of (must-do) maintenance.

For "effective engine management and maintenance", the engine department's crew members should build the strongest "One Team" relationship through mutual understanding. They must then continually be aware that human beings are to be at the center daily jobs being performed, such as lubricating oil management, fuel oil management, and inspection/repair/maintenance of the engine. Furthermore, through regular drills/training, shipowners, ship management companies, and even the ship need to prepare measures that incorporate both soft aspects and hard aspects, so that human beings do not panic in an emergency and can respond calmly without making errors.

# Reference Materials

**Reference Material 01:**
Ability diagnosis of onboard work performance: Main Text P. 7

To achieve the purpose and mission on board, the Chief Engineer conducts the engine department's ability diagnosis within one week after boarding.

- **There are 3 scores (A: Merit, B: Pass, C: Needs to improve) allocated for all aspects of the engine department that make up a comprehensive evaluation. If ability or knowledge is not satisfactory (less than 60%), an "F" will be given.**

- **Chief Engineers and First Engineers will work together with experienced crewmembers in order to further strengthen management of the engine department.**
  **They are to support younger crewmembers and develop countermeasures that will work on improving their weak points.**

- **If anyone remains below average for 3 months, it is considered dangerous, so it will be necessary to consult with the captain and discuss the reassignment of crew with the Human Resources Department.**

| Rank | Behavioural characteristics | Each person's fundamental capability | Total Score | Average score | Emergency response | Blackout recovery | Alarm Response | SMS | Communication | Routine Work | Engine & Equipment operation | Periodical maintenance | No. of ships experienced |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C/E | Hurries (impatient) | 75 | A | 80.9 | 81 | 81 | 78 | 86 | 76 | 86 | 76 | 83 | 15 |
| 1/E | Lazy | 80 | A | 84.9 | 85 | 85 | 82 | 90 | 80 | 90 | 80 | 87 | 13 |
| 2/E | Emotional | 65 | B | 74.9 | 75 | 75 | 72 | 80 | 70 | 80 | 70 | 77 | 9 |
| 3/E | Assumptions (preconceptions) | 55 | C | 69.9 | 70 | 70 | 67 | 75 | 65 | 75 | 65 | 72 | 4 |
| G/E | Does not notice | 75 | B | 79.9 | 80 | 80 | 77 | 85 | 75 | 85 | 75 | 82 | 13 |
| Engineer /Other | Transgression (violation) | 30 | F | 59.9 | 60 | 60 | 57 | 65 | 55 | 65 | 55 | 62 | 2 |
| Fitter | Hurries (impatient) | 50 | B | 74.9 | 75 | 75 | 72 | 80 | 70 | 80 | 70 | 77 | 20 |
| Oiler/A | Only able to see one thing | 45 | C | 64.9 | 65 | 65 | 62 | 70 | 60 | 70 | 60 | 67 | 15 |
| Oiler/B | Transgression (violation) | 55 | C | 69.9 | 70 | 70 | 67 | 75 | 65 | 75 | 65 | 72 | 10 |
| Oiler/C | Moments of inattention | 60 | C | 64.9 | 65 | 65 | 62 | 70 | 60 | 70 | 60 | 67 | 10 |
| Oiler/D | Careless | 45 | F | 54.9 | 55 | 55 | 52 | 60 | 50 | 60 | 50 | 57 | 5 |
| Wiper | Forgets | 35 | F | 39.9 | 40 | 40 | 37 | 45 | 35 | 45 | 35 | 42 | 4 |
| Oiler/Other | Panics | 30 | F | 34.9 | 35 | 35 | 32 | 40 | 30 | 40 | 30 | 37 | 2 |
| Total evaluation score of Engine Dept. | — | 54 | F | 65.7 | 65.8 | 65.8 | 62.8 | 70.8 | 60.8 | 70.8 | 60.8 | 67.8 | — |

Table: Reference 1 Example of ability diagnosis

## Reference Material 02:
## Under what circumstances does an error occur?: Main Text P. 16

The following tables are from a seminar on human factors of the Japan Aeronautical Engineers' Association, and is used by the shipowner/ship management company or the ship to analyze fault weaknesses. If it is known how such errors occur, it will help develop efficient responses to human factors that may have caused the fault.

### (1) Error when registering information

| Error when registering information | |
|---|---|
| **Information is not registered.** | ・Vision/hearing is limited.<br>・Field of view is limited.<br>・Visible range is limited. |
| **Information is registered, but not processed.** | ・A lack of interest. |
| **Information registered, but was illuded.** | ・The information is of interest but misinterpreted. (Hasty judgments, misunderstanding, assumptions) |

Table: Reference 2 Error when registering information

### (2) Error in the memory process (lapse)

To prevent errors in the memory process (Lapse), there must be opportunity for crew members review everything repeatedly. For example, in the engine department, "In the meeting before work starts, the person in charge explains the specific notes of important work from the viewpoints of 4 M." Moreover, "Engine crewmembers check the emergency response procedures, including the low probability of accidents, one theme each day."

| Error in the memory process (Lapse) | |
|---|---|
| **Limitation of Short-term memory** | ・Memory is limited. Most of the information kept in short-term memory will be stored for approximately 20 seconds. The memory can be improved using visuals and rehearsal.<br>・Normal person, 7 items (5-9) Example: Colours of the rainbow, musical scales (c d e f g a b), main characters of a drama (The Magnificent Seven)<br>・It is easy to remember telephone numbers, because they are grouped. |

| | |
|---|---|
| **Limitation of Long-term memory** | Please imagine the folowing situations.<br>・When you know something, but cannot recollect it when you need to.<br>・When you lose your memory.<br>・When your memory gets distorted.<br>・Semantic memory: letters, symbols, numbers, etc.<br>・Episodic memory: personal memories such as joining a company or wedding.<br>・Procedural memory: procedural (how to ride a bicycle, how to use chopsticks, etc.) |

Table: Reference 3 Error in the memory process (Lapse)

## (3) Error in the judgment process (mistake)

| Error in the judgment process (mistake) | | |
|---|---|---|
| Making misjudgements such as: | | |
| ・Insufficient consideration | ・Prospect | ・Short cut reaction |
| ・Mechanical reaction | ・Hopeful observation | ・Speculation |
| ・Reckless/indiscreet | | |

Table: Reference 4 Error in the judgment process (mistake)

## (4) Temptation to deviate (violation)

| Temptation to deviate (violation) |
|---|
| May deviate from the rules because of:<br>・Time pressure<br>・Too much work<br>・Respect for speed (even if the outcome of work is not perfect, it is fast anyway)<br>・Rules that are unclear or unfit for the situation.<br>・Situations where it is permissible not to follow the rules<br>・Inappropriate deployment of appropriate facilities and materials (resources)<br>・Supervisor is too tolerant or lacks ability to manage<br>・A climate that overvalues boldness<br>・A climate that places less emphasis on safety (aloft work/high places of work (2m or more) but no safety belt is worn) |
| Countermeasure: We must not make excuses. |

Table: Reference 5 Temptation to deviate (Violation)

## (5) Error in the output process (slip)

| Error in the output process (slip) |
|---|
| Errors in output (behaviour) ⇒ Subconsciously unwillingly.<br>In spite of the correct judgment result, if the action (output) is different from the decision result at the action stage, an error may be caused by any of the following.<br>・Limitation of movement capability (force, dimensions).<br>・Limitation of operating time.<br>・Confused by surrounding events.<br>・Subconsciousness. |
| **Example: He meant to address the audience with "an opening address" but instead used "a closing address".** |

Table: Reference 6 Error in the output process (Slip)

## Reference Material 03

Problem Solving Method: Main text P. 21, P. 41

Even if younger crewmembers have little experience, they can analyze accidents in a logical way, and can plan countermeasures by utilizing solution methodology.

**MUST POINT**

- **Build up a stock of solutions.**
- **Finally, establish a successful formula.**

We have provided the following with reference to “Jyohowo shunjini seirishi Aidhiawo Umidasu! Noto・Memo Furukatsuyo Jyutsu.” (provisional translation) by Nagaoka Shoten.

### 1. Logic tree: We would like to analyze problems and plan solutions!

#### 1. Introduction

“How to analyze problems & come up with a solution!” (Provisional translation.)

A logic tree is a useful thinking tool for logically analyzing work problems and formulating solutions.

First, break down a problem or solution into elements to be considered and then analyze them **further into a lower hierarchy**.

As a result, the logical reason is shown in the form of a tree diagram (tree)

#### 2. Advantage

① It is possible to grasp the whole picture of the task.

② It is possible to avoid oversight/omission of problems, and it is possible to find solutions easily.

③ It is possible to correct gaps in the discussion easily, because it is clear which hierarchy the discussion belongs to.

### 3. How to draw a logic tree (Refer to Figure Reference 7)

① At the starting point, write down the problem you want to solve and start thinking about how you may solve it, e.g. reducing work stress.

② Break down the starting point task into 2 to 4 components (up to 5). (The first layer in Figure: Reference 7)

At this time, it is important to be aware that there should be "no overlap, mutually exclusive and collectively exhaustive" information (called "MECE"). Also, depending on the task, the method of disassembling will be "Result⇒Cause" (Why), "Purpose-Means" (How), "Whole-Part" (What), etc.

③ Disassemble the disassembled components into 2 to 4 elements.We will extend it to lower layers to make it more specific. (The second layer in Figure: Reference 7)

④ Similarly, disassemble the components disassembled in the first layer to appear in the second layer. Do this until you reach the fifth layer.

⑤ Objectively compare and examine ways to solve problems by referring to the completed logic tree.

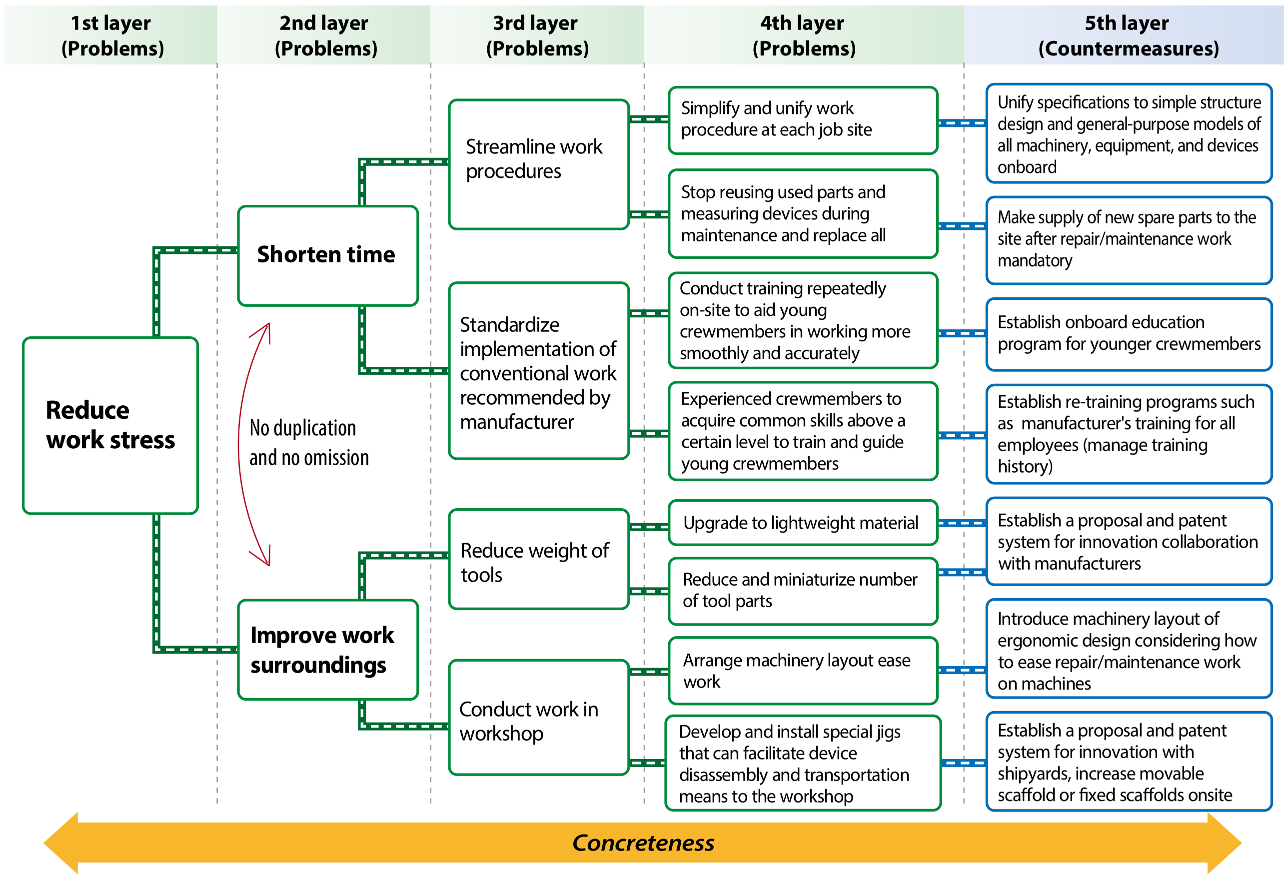



Figure: Reference 7 How to consider reducing work stress

## 2. Fishbone: Illustrate issues and their causes in the form of a fish skeleton!

### 1. Overview

・Fishbone is an idea generation method that looks at "Cause and effect".

・Originally it was a classic tool for analyzing factors that affect quality characteristics in the quality control of products.

・Business analysis often uses this method. This is similar to a logic tree.

・It is not exhaustive. This method's characteristics are such that we can understand the causal relationship between issues and factors **more intuitively**.

### 2. Advantages

① It is easy to visualize causal relationships and find solutions.

② It is possible to grasp issues and factors intuitively.

③ It is easy to summarize important points and organize discussions. We can also apply ideas to develop a special tool for maintenance.

### 3. How to draw a Fishbone diagram (Refer to Figure Reference 8)

① We draw an arrow shape with a triangle and a horizontal bar and write our theme (issue or situation) in the triangle. This corresponds to the fish head and bones.

② We focus on 3 to 8 important factors when thinking about the theme. We draw large bones coming out of both sides of the spine in a well-balanced manner and write each factor at the end of each large bone.

③ We further break down the factors written at the end of the large bones and consider 3 to 6 elements. We draw medium-sized bones on either side of the large bones and write down considered elements.

④ We then break down these elements further and consider causes and solutions. Similarly, stretch small bones from the medium-sized bones and write down considered elements.

⑤ After you have completed your Fishbone diagram, you can develop ideas and further ideas based on this. It is similar to a logic tree, but it is not a bird's-eye view, yet it allows you to intuitively understand causal relationships.

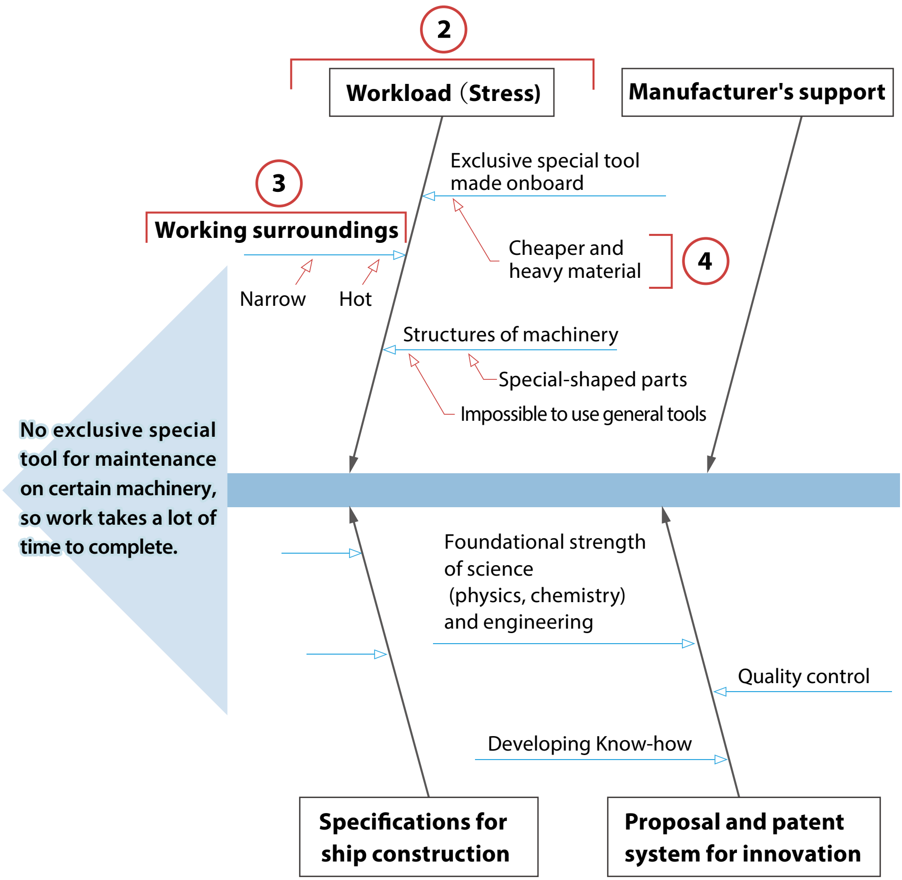



Figure: Reference 8 How to develop a special tool for maintenance

## **Reference Material 04:**
## Details of Power Loss Accident in Norway: Main Text P. 35

Chapter 3 introduces an accident in which an electric propulsion ship lost its power completely while cruising in stormy weather and where it was forced to urgently drop anchor.

The details of the accident are as shown in Table: Reference 9 below.

| Accident details | |
|---|---|
| (1) | At 13:50 on March 23, 2019, an electric propulsion passenger vessel was sailing southwest from Tromsø in Norway to Stavanger with three generators operating. |
| (2) | The weather at that time is as follows. Strong gale to storm winds: from the southwest (Beaufort 9-10 or 22-25 m/s).<br>Very high waves: Total Significant Wave Height from the west over deep water of 9-10 meters (with a mean wave period of 12-13 seconds). |
| (3) | The total number of people was 1373 people. (915 passengers on board and 458 crew members.) |
| (4) | The following abnormalities in the generator had occurred by the time the accident occurred on the afternoon of March 23.<br>(a) On March 16, the turbocharger on No. 3 generator (hereinafter referred to as DG3. In the same manner No. 1, No. 2, and No. 4 generator are referred to as DG1, DG2, and DG4 respectively) failed rendering the turbocharger inoperable. On the day of the blackout, a maker's technician was on board to dismantle the damaged turbocharger to prepare for a replacement to be fitted at the next port.<br>(b) The ship was equipped with 4 generators, but since DG3 was inoperable, generators DG1, DG2, and DG4 continued to operate. 3 generator engines could manage to supply electric power for the propulsion machinery and ship services without the use of a standby generator engine.<br>(c) Between 05:00 and 09:04, on March 23, before the accident occurred, the operational DGs registered alarms of "Lubricating oil low level and low volume" 18 times.<br>The Engineers on watch accepted them, but each alarm was cleared within a few seconds.<br>After that, the alarms did not occur until 13:37. |

| Accident details | |
|---|---|
| | (d) 13:37 When DG4 registered an alarm indicating that the DG was shedding load due to low lubricating oil pressure. A few seconds later, it registered a low lubricating oil pressure alarm.<br>(e) 13:39 DG1 registered a low lubricating oil sump level alarm.<br>(f) 13:45 DG4 shut down, and then eight seconds later, DG2 shut down.<br>(g) 13:56 DG2 was restarted.<br>13:58 DG1 and DG2 shut down.<br>It caused a complete blackout and loss of propulsion, and then the ship began drifting toward the bank (shoal).<br>(h) Within 30 seconds of the blackout: The emergency diesel generator started and powered the emergency switchboard. |
| (5) | 14:00 Master broadcasted a "mayday". |
| (6) | 14:06 ～ 14:20 Master instructed the crew to drop both anchors. However, the anchors did not hold, and the ship continued to drift astern towards the shore at a speed of 6–7 knots. |
| (7) | 14:22 The engineers transferred a total of 10.8 m3 of lubricating oil to the lubricating oil sump tanks of DG1, DG2, and DG4. DG2 started. DG2 restored power to the main switchboard, in manual load-sharing mode. |
| (8) | 14:29 ～ 14:34 hours: Both propulsion motors started, providing sufficient propulsive power to maintain slow speed ahead. |
| (9) | 15:05 The first helicopter hoisting operation took place. The evacuation of passengers continued until the next morning. |
| (10) | 15:24 ～ 15:46 DG1 and DG4 were restarted in automatic load-sharing mode, and the starboard propulsion motor was restarted to enable the propulsion motors' output to maintain a speed between slow ahead and half ahead. Although DG1, DG2, and DG4 had been restarted, the engineers had to continuously balance the electrical load manually. The Navigation Officers manoeuvred towards open waters, still with both anchors lowered. |
| (11) | 16:40 The first tugboat arrived. However, the weather conditions were too severe to secure a towline. |

| Accident details | |
|---|---|
| (12) | Until the morning of March 24, the helicopter rescue of passengers continued. |
| (13) | 06:30 On 24 March: Weather conditions had improved sufficiently to enable tugs to be made fast, and towlines were secured fore and aft, although the vessel maintained its propulsion. |
| (14) | 09:15 The master decided that the vessel was out of danger and that it was safe to stop the passengers' evacuation. The local Police reported that 479 passengers had been evacuated safely and received at the emergency centre ashore. |
| (15) | Around 16:25 The ship was moored alongside in Molde. |

Table: Reference 9 Details of power loss accidents on electric propulsion ships

## Reference Material 05:

The investigation reports of the Japan Transport Safety Board: cases of loss of power: Main Text P. 39

Probable causes and countermeasures for the eight accidents in "3-2-3 Transport Safety Board investigation reports for Japan: Cases of loss of power" are summarized in Table: Reference 10 and Table: Reference 11.

**List of probable causes of loss of power in Japan**

| Accident No. | Location | Vessel type, Accident type | Probable causes | If emergency anchored |
|---|---|---|---|---|
| 1 | Coastal Northern Japan | Cargo ship (Blackout) | In stormy weather following a wind, snow and wave warning, during coastal navigation, the ship became unable to run the main engine due to loss of power (blackout). The coast guard patrol boat tried in vain to tow the ship but was forced to give up due to the stormy weather. After anchoring and repairing by the crew, the ship restored power, and she resumed sailing after anchoring. There was no announcement as to the cause. | Dropped emergency anchoring |
| 2 | Inside harbour<br><br>Central Japan | Car carrier (Blackout) | While departing port, the "crimp type terminal connecting the electric wires of electric motor for the stern thruster " broke due to hull vibration, resulting in a single-phase operation. An overcurrent flowed, the overload protection device of the stern thruster was activated, and the generator was unable to accept the load fluctuation which resulted in over-speed. Since the over-speed protection device activated, the ship lost electric power and could not run the main engine. | — |
| 3 | Coastal Central Japan | Cargo ship (Loss of control power) | While the ship supplied power onboard using a shaft generator during coastal navigation, the fuse holder of the DC24V power on charge and discharge board caused contact failure, and the ship lost control power. Finally, the ship could not run the main engine. | — |

| Accident No. | Location | Vessel type, Accident type | Probable causes | If emergency anchored |
|---|---|---|---|---|
| 4 | Coastal Central Japan | Cargo ship (Loss of control power) | During coastal navigation, the cooling fan of the "converter that converts AC current to DC current" broke down, which caused the converter to overheat, and the ship became unable to supply DC 24V as control power. Finally, the ship could not control both the main engine and the changeable pitch propeller. After emergency towing, the ship dropped emergency anchoring. | After emergency towing, dropped emergency anchoring. |
| 5 | In the bay<br><br>Central Japan | Cargo ship (Blackout) | The ship operated two generators in parallel while manoeuvring for entering port operation. However, emergency stop was activated due to a lubricating oil leakage of the governor.<br>The ship equipped with four generators driven by a diesel engine, two of which were operated in parallel normally while passing the narrow channel, and the ship used the other two as standby generators. However, when the accident occurred, the crew cleaned the engine's lubricating oil strainers, and set the automatic start switch to manual so as not to start the standby generator. Therefore, the backup standby generator could not automatically backup. | — |
| 6 | Inside harbour<br><br>Western Japan | Passenger ferry (Blackout) | While departing port, a phase-to-phase short circuit occurred in the wiring of A and B circuits in the junction box, resulting in a short-circuit current flow between circuits A and B. Then, the safety protection device of the main switchboard A-MCCB (Moulded Case Circuit Breaker) was activated. The function worked and turned off (disconnected). At that time, the two branch lines connected to the A-MCCB were damaged and bounced off, resulting in an interphase short circuit caused by contact with the C-MCCB branch line. The ground fault generated by contact with the wall surface of the main switchboard caused an excessive current to flow to the main switchboard's busbar. As a result, the ACB (Air Circuit Breaker) safety protection function was activated and opened. The ship stopped the main engine due to loss of power, and the generator was still running, and crewmembers tried to reconnect the ACB, but it was impossible. | Dropped emergency anchoring |

| Accident No. | Location | Vessel type, Accident type | Probable causes | If emergency anchored |
|---|---|---|---|---|
| 7 | Inside harbour<br><br>Central Japan | Cargo ship (Blackout) | While entering the port at the harbour, the safety protection device functioned incorrectly due to a defective sensor board of the boiler. This resulted in the main boiler misfiring. Therefore, in order to reduce steam consumption, crewmembers transferred electric load from one of the two turbine generators (2,500 kW) to the diesel generator. However, after crewmembers opened the ACB of one turbine generator, the operation condition of the manually started diesel generator (1,500kW) became unstable. As a result, the ACBs of both generators tripped, and the ship lost power. | After the emergency towing, dropped emergency anchoring. |
| 8 | In the bay<br><br>Southern Japan | Cargo ship | The Chief Engineer stopped using the heavy fuel oil shortly after leaving the port in the bay. In order to improve the combustion condition of the main engine, the switching valve was opened halfway in an attempt to mix marine gas oil with heavy fuel oil. He had "confirmation bias" regarding the check valve, and he assumed that heavy fuel oil would never flow to the marine gas oil side. Since the heavy fuel oil service tank's oil level was higher than that of the marine gas oil service tank, the switching valve opened at the same time, so the heavy fuel oil flowed back into the marine gas oil service tank. In the generator engine, heavy fuel oil flowed to the marine gas oil service tank. As a result, the running generator received Fuel oil with increased viscosity, and the atomization of the fuel injection valve became defective and the generator engines stopped, resulting in the ship losing power. As a result, the main engine also stopped suddenly (emergency procedure). After the accident, crewmembers discovered that the valve was not a switching valve. | Dropped emergency anchoring |

Table: Reference 10 List of probable causes of loss of power in Japan

## List of countermeasures of loss of power in Japan

| Accident No. | Countermeasures: Safety Action: |
|---|---|
| 1 | (1) The ship must review measures for stormy weather. The ship is to implement additional remedial measures if necessary. |
| 2 | (1) The ship must make an inspection plan for the crimp type terminals that connect the electric wires of the thruster motor. This is to be carried out regularly. |
| 3 | (1) The ship is to establish an inspection plan for the fuse holder of the DC 24V power supply charge/discharge board. To be carried out regularly.<br><br>(2) Since the managers/supervisors of the ship management companies had discovered that the fuse holders had deteriorated after the accident, fuse holders on all ships have been replaced. |
| 4 | (1) The ship must develop an inspection plan for the cooling fan and regularly carry it out. This is to be replaced if necessary.<br><br>(2) The ship must install a failure alarm device for the cooling fan. |
| 5 | (1) When carrying out maintenance and inspection work on generators, and so on, the ship must consider the navigation area. When passing a narrow channel traffic route such as the Uraga Channel and Kanmon Straits, the ship must maintain an engine plant system so that it can automatically start the standby generator in case of an emergency. The crewmembers must refrain from cleaning the strainer. |

| Accident No. | Countermeasures: Safety Action: |
| --- | --- |
| 6 | As a safety measure for the entire company, the management company held a Masters/Chief Engineers meeting to disseminate information among the ship and other managed ships within the company.<br>The ship must do the following:<br>(1) Secure the wiring to the junction box.<br>(2) Replace any damaged MCCB (Moulded Case Circuit Breaker).<br>(3) Correct final drawings and important documents for newly installed electric equipment for appropriate inspection/repair/maintenance. Carry out an occasional survey by a Recognized Organization after the repair.<br>(4) Measure and record insulation resistance of electric equipment and devices for refrigerated vehicles with an insulation resistance tester, every month: ① insulation resistance between the electric circuit and the hull and ② interphase insulation resistance.<br>(5) Regularly vacuum-clean the interior of electrical equipment and devices and remove soot and dust.<br>(6) ① Inform and remind crewmembers of the danger of short circuits related to electrical equipment and devices, and ② conduct re-training regarding safety such as inspection, cleaning, and electric shock.<br>(7) Crewmembers must use and operate the public address system onboard effectively based on the procedure "Information for passengers in an emergency" to provide the correct information to passengers.<br><br>**Other recommended measures**<br>(1) The ship must consult with manufacturing companies, and so on, regarding the main switchboard and MCCB, and establish regular maintenance plans for all equipment and devices, including equipment and devices that were not part of the accident.<br>The company must continuously confirm and evaluate the record of insulation resistance measurement of electric equipment and devices for refrigeration vehicles with the managing ship and their crewmembers of their ship. |

| Accident No. | Countermeasures: Safety Action: |
| --- | --- |
| 7 | The management company must instruct on the following safety measures to both the ship and other ships.<br>(1) A major casualty may occur during manoeuvring standby, berthing, and passing congested or high traffic routes if the main boiler misfires.<br>A ship must not operate the main boiler in combustion mode if it is difficult to handle load fluctuations well.<br>(2) The ship must regularly hold tests to confirm the starting and running of diesel generators, with it operating in normal load. The generators are also to be regularly overhauled.<br>A ship must carry out the following maintenance: Renewing air cooler, and repair/inspect/maintain/overhaul the turbocharger and cooling freshwater system, and so on.<br>(3) A ship must hold tests to confirm the starting and running of the emergency diesel generator using a load applicable the machinery in accordance with the manual.<br>A ship must carry out the following maintenance: Inspect the switchboard, and replace ACB.<br>(4) A ship must increase the frequency of operation tests for the boiler safety protection device. A ship must carry out the following maintenance: Renew damaged sensors. |
| 8 | (1) The ship must evaluate risk and check for any adverse influences on the system using piping diagrams before opening and closing the valves.<br>(2) The ship must mix marine gas oil and heavy fuel oil using a dedicated device and not mix them directly by operating several switching valves simultaneously. |

Table: Reference 11 List of countermeasures of loss of power in Japan

Please refer to the URL in a list of references at the end of this bulletin regarding details of the above tables.

**Reference Material 06:**
Emergency response checklist immediately after loss of propulsion and loss of power: Main Text P. 45

The following is a checklist for emergency response on board.

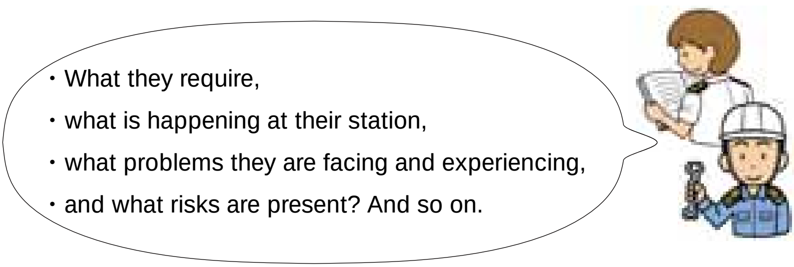
## CHECK LIST

- ☐ Master must follow the company SMS procedures for loss of propulsion and blackout, which is described in the "Emergency Procedures Manual" as a contingency plan.

- ☐ Crewmembers must record the position of the vessel and time accurately in the deck logbook and in the engine logbook.

- ☐ Master may have to drop anchors to reduce the ship's speed. When manoeuvring in confined waters, the anchors should be 'cleared' for immediate use.

- ☐ Master and Chief Engineer must "keep good" and efficient communication between the bridge and the engine room. The bridge and engine room should exchange critical information so that key personnel can fully understand the situation and make informed decisions. Each department on board must quickly inform other departments as follows:




If bridge and engine room crewmembers do not exchange critical information during an emergency, we must know that there is a risk that key personnel will not be fully aware of the situation and may make ineffective decisions.

## ☑ CHECK LIST

- ☐ Master and Chief Engineer must instruct some of the crewmembers to go to the emergency generator room to try and start the generator when it does not automatically start.

- ☐ Master and Chief Engineer must instruct some of the crewmembers to go to the steering room to attempt emergency steering.
  However, the master and deck officers must predict and recognize that this becomes less effective when the engine has stopped and when the ship's speed is reduced to below steerage along with the vessel's forward movement cutting through the water.

- ☐ When engineers find that the machinery driven by steam turbine devices has stopped after a blackout or boiler emergency trip, they must carry out turning the rotor shaft by any means possible to prevent the rotor shaft from bending.

- ☐ Engineers must operate the feedback system from ESB to the main switchboard (MSB) if possible.
  Some ships are equipped with an electric feedback system. On such a ship, the electric power source from the emergency generator via the ESB can feedback to the main switchboard, so that the ship recovers power to the main switchboard (MSB) during a blackout. (Please refer to "3-3-3(2) 2) Precautions for recovery work"). Engineers must understand and be familiar with how to operate and control it practically.

- ☐ When engineers find an overload of current on the electrical devices, they must operate (push) the reset button to reset and recover the electrical breaker function after it has tripped.

- ☐ It will probably be necessary to bring the engine to a STOP to enable the restart. The engine control room should take control until power has been fully restored.

## Reference Material 07:
How to prevent panic: Main text P. 55

### (1) Inability to move or think

Ms. Amanda Ripley investigated and wrote about some of the most harrowing catastrophes in history in order to piece together exactly how humans react in a crisis such as survivors from the September 11 attacks and Hurricane Katrina, in her book “The Unthinkable: Who Survives When Disaster Strikes - and Why”, Random House Audio (Translated into Japanese by Machiko Oka, Kobunsha Co., Ltd.). According to the book, in moments of total disaster, the first phase of human reaction is “denial”, the next phase moves into “deliberation” that considers the actions to be taken, and as a result, humans take “action”. However, in many cases, after “awareness of the situation”, most people tend to shut down their mind entirely in the disaster and seem to lose all strategic awareness. On the other hand, those who have been selected for special missions have the common features of being able to react more effectively under stress, which is probably due to the environment and background in which they developed.

In other words, when humans are exposed to hazards, they experience what is known as normalcy bias in which they consider themselves to be indifferent or minimally affected by threat warnings, “It is okay” and “That can’t be true.” when faced with a situation. However, in the event of an emergency, ship crewmembers are required to do the following:

① to train themselves to deal with stress effectively,

② to react calmly, and

③ to respond immediately to critical situations without panic, in the same way as those who are selected for special missions.

## (2) Preventive measures against panic

As mentioned above, when humans encounter an emergency, they fall into a state of "Inability to move or think". To prevent this, it is essential to plan controllable measures for emergencies and implement such manageable measures during normal conditions as well. (Please always be ready for what you have planned).

① **Reduce the anxiety factor (discomfort) in an emergency**

② **Foster a flexible mentality that can cope with anything on site**

According to the book "Behavioral Science of Natural Disasters, (preliminary translation)" in order to prevent panic, it is possible to divide panic into soft aspects and hard aspects for both during normal times and in emergencies:

**Soft aspect measures**

(measures that include information and social psychological elements) :

・・・Information transmission, trouble recovery procedures, training for situation judgment, and so on.

**Hard aspect measures**

(measures that mobilize both physical and human resources) :

・・・The reviewing and improvement of machinery, securing of personnel, emergency machinery operation, emergency repair, and so on.

The table "Panic prevention measures during disaster evacuation (preliminary translation)" from the book is divided into 2 classifications of which 4 categories can serve as countermeasures. Following the same structure, we have applied this to the case of loss of power, as can be seen in Table: Reference 12 below.

For example, regarding soft aspect measures during ordinary times, "emergency response training, including low probability accidents" should be carried out repeatedly.

Regarding hard aspect measures, "modifying wiring to important machinery such as cooling water pumps and air compressors from an emergency generator" and "changing specifications of the speed control scheme of the induction motor using the pole change method, so that these motors will be able to run using the power supply from an emergency generator" should be prepared.

It is recommended that the ship management company and the ship take account of these tips when considering a further framework for emergency response.

**Preparation for panic prevention measures for loss of power**

| | 1. Soft measures | 2. Hard measures |
|---|---|---|
| A. Ordinary | (1) Clarify and establish information transmitting organization / role allotment.<br>(2) Produce manuals for:<br>・normal recovery procedures,<br>・feedback method from the emergency generator via emergency the switchboard to the main switchboard,<br>・the switching method receiving power from the main switchboard to emergency switchboard for the Diesel generator air compressor in an emergency.<br>・the special recovery procedures to plant-up the engine system by the emergency generator.<br>(3) Regularly conduct recovery training for loss of power, including low probability situations (Normal start-up, air circuit breaker failure, emergency generator start fail, regular use generator start fail, emergency anchoring, etc.)<br>(4) Conduct simulations (to strengthen the mind) assuming that the worst-case scenario occurs based on past accident cases. | (1) Reconfirm fuel supply pipeline of the regular generator and the emergency generator.<br>(2) Carry out regular inspections of the following batteries:<br>・for starting the emergency generator.<br>・for the control system power source.<br>(3) Improve regular repair and maintenance methods for defective piping, structure, wiring, machinery, and equipment.<br>(4) Re-inspect machinery/equipment that can be operated from the emergency generator and switchboard.<br>(5) Modify the power supply wiring that can start the regular generator start air compressor from the emergency switchboard. Modify auxiliary machinery required for plant-up to low power variable specifications.<br>(Please consult this with the classification society, manufacturer, and shipyard beforehand.)<br>(6) Test run emergency generator and backup alternative power supply.<br>(7) Secure and store parts for important machinery.<br>(8) Secure space for temporary evacuation space when engine room overheats. |

| | 1. Soft measures | 2. Hard measures |
|---|---|---|
| B. In time of emergency | (1) Report and share accurate information related to trouble.<br><br>(2) Establish a common understanding and recognition of the situation. Promptly instruct regarding recovery work procedures.<br><br>(3) Status report on recovery prospects.<br><br>(4) Cooperate with other departments. Propose a special system for emergency anchor and cargo management.<br><br>(5) Provide any other information to reassure everyone. | (1) Mobilize personnel from other departments in time of emergency.<br><br>(2) Operation of emergency generator and backup alternative power supply.<br><br>(3) Prevent engine room from overheating. Repair defective machinery. Rescue and nurse injured persons.<br><br>(4) Secure a means of contact with the head office. |

Table: Reference 12 Preparation for panic prevention measures for loss of power

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