

Final Report

FATAL INCIDENT OF THIRD ENGINEER ON BOARD YUAN SUI HAI AT SEA 25 SEPTEMBER 2020

TIB/MAI/CAS.092

**Transport Safety Investigation Bureau
Ministry of Transport
Singapore**

14 SEPTEMBER 2021

The Transport Safety Investigation Bureau of Singapore

The Transport Safety Investigation Bureau (TSIB) is the air, marine and rail accidents and incidents investigation authority in Singapore. Its mission is to promote transport safety through the conduct of independent investigations into air, marine and rail accidents and incidents.

TSIB conducts marine safety investigations in accordance with the Casualty Investigation Code under SOLAS Regulation XI-1/6 adopted by the International Maritime Organization (IMO) Resolution MSC 255(84).

The sole objective of TSIB's marine safety investigations is the prevention of marine accidents and incidents. The safety investigations do not seek to apportion blame or liability. Accordingly, TSIB reports should not be used to assign blame or determine liability.

Table of Contents

SYNOPSIS	1
VIEW OF VESSEL	2
1 Factual information	3
1.1 Sequence of events	3
1.2 Crew Experience, work schedule and rest hours	8
1.3 Additional information from interviews	10
1.4 Main engine and FOIV	13
1.5 Safety precautions and training on the main engine	14
1.6 Engine data extracted and other information	19
1.7 The SMS of YSH	23
1.8 Additional information from the Company	24
2 Analysis	25
2.1 The occurrence	25
2.2 Deviation from established safety procedures	26
2.3 Permit to work system	27
2.4 Training enhancements	28
3 Conclusions	29
4 Safety actions	30
5 Safety recommendations	31
5.1 For the Company of YSH	31

SYNOPSIS

In the early hours on the 25 September 2020, while transiting south-westerly in the Indian Ocean for a Brazilian port, the Singapore registered bulk carrier, MV Yuan Sui Hai (YSH), experienced an exhaust temperature anomaly from the main engine. The engine crew subsequently assembled in the engine room and emergency replacement of a fuel oil injector valve (FOIV) was initiated.

After the fuel oil high-pressure pipe had been removed from the engine cylinder cover, the Fourth Engineer and supervising engineer (Second Engineer) left the main engine to the spare parts room, while the Third Engineer (3E) was alone on the cylinder head platform. Shortly after, a loud bang was heard and the 3E collapsed on the platform with the FOIV and its securing nuts nearby. The 3E was bleeding from the right-side of his face with fainting pulses. Immediate first aid was given on board and YSH deviated to the nearest port for shore medical assistance, but the 3E succumbed to the injuries before medical treatment could be provided.

The Transport Safety Investigation Bureau classified the occurrence as a very serious marine casualty.

The investigation revealed that the securing nuts of the FOIV were removed by the 3E while the engine RPM had not attained zero. The FOIV expelled from the cylinder cover with substantial force on to the 3E's face. While the investigation team could not establish the reasons for the 3E's removal of the FOIV without waiting for the RPM to be zero, the investigation revealed that the engine crew relied on memory and observations on how the FOIVs were removed previously and with varied interpretations of the safety precautions stipulated in the engine manual. There was also an absence of supervision in terms of task assignment(s) to the engine crew. The engine's data records retrieved from the main engine revealed that certain safety precautions were not carried out.

This incident iterates the importance of compliance to safety precautions, especially for ship engine where the omission of any steps can result in undesired outcome for both the engine and personnel. The purpose of each safety precaution should be well comprehended and verification processes be established to ensure that work is safe to commence. These can be achieved through appropriate checklist(s) as part of a permit-to-work system with enhance scope in training encompassing these safety precautions.

VIEW OF VESSEL



DETAILS OF VESSEL

Name	Yuan Sui Hai (YSH)
IMO Number	9806938
International Call Sign	9V5560
Flag Registry	Singapore
Classification society/ ISM ¹ Recognised Organisation	Lloyd's Register/ China Classification Society
Ship type	Cargo ship - Bulk (Ore) Carrier
Year Built	2019
Owner	Yuan Shou Hai Pte. Ltd. (Singapore)
Company ² / Operator	COSCO Shipping Bulk Co., Ltd. (Guangzhou, China)
Gross tonnage	203322
Length Overall (LOA) / Breadth	361.90m / 64.99m
Draught	10.5m (Fwd) / 13.10m (Aft)
Main engine ³	MAN-B&W 7G80ME-C9.5

¹ In accordance with ISM Code – SOLAS Chapter IX, IMO Res.A.741(18) as amended thereof.

² Responsible for the safe management of the ship under the ISM Code.

³ MAN Energy Solutions (MAN ES) is the engine designer (as the licensor) and CSSC Marine Service Co. Ltd. (CMD) in China (as the licensee) built and delivered the engine for the vessel. MAN ES is referred to as the ED hereinafter.

1 FACTUAL INFORMATION

All times used in this report are Ship's Mean Time (SMT). At the time of the incident, SMT⁴ was seven hours ahead of Coordinated Universal Time (UTC) unless otherwise stated.

1.1 Sequence of events

- 1.1.1 YSH departed Singapore on a ballast voyage on 21 September 2020 after bunkering operation, bound for Ponta Da Madeira, Brazil, with an estimated time of arrival (ETA) on 18 October 2020.
- 1.1.2 About three days later, on 24 September 2020, YSH was heading south-westerly in the Indian Ocean, with the Third Officer (3O) as the officer of the watch (OOW). The 3O was assisted by an Able-Seafarer (Deck) (ASD-1) performing the role of a lookout and the Master was in the cabin, having retired for the night. The vessel was on an Unattended Machinery Space (UMS)⁵ status.
- 1.1.3 YSH was making a SOG (speed-over-ground) of about 13kts with its engine telegraph on Full-Ahead⁶. The sea was calm with a westerly wind of force 4-5 on the Beaufort Scale (Bf 4-5) with light traffic⁷ (about two to three vessels) within a 24Nm⁸ range. The 3O subsequently handed the navigation watch to the Second Officer (2O) at around 0001H (UTC +7) on 25 September 2020. The bridge was now manned by the 2O (as the OOW) and ASD-2. The Fitter⁹ was in the engine room carrying out a fire safety round, a normal practice on UMS ships.
- 1.1.4 At about 0125H, the main engine's exhaust gas recorded an abnormal temperature difference and triggered an alarm for the no.4 cylinder¹⁰. The alarm sounded in the duty engineer's cabin (Second Engineer – 2E). Concurrently the

⁴ The ship's position at the time of occurrence was in the meridian of UTC+7. The ship was in the midst of crossing to meridian of UTC+6 when the occurrence happened. The SMT was retarded to UTC +6 on 25 September 2020 at 0200H. The investigation team noted that some of the shipboard logbooks and records indicated that the SMT as UTC+6 at around the same time as the occurrence. Separately, some of the reports from YSH to the Company referenced the time of occurrence as UTC+8. For consistency, the time used for this investigation report shall be UTC+7, which is the time referenced in the engine digital record that was extracted for the purpose of this investigation.

⁵ SOLAS II-1/46 as amended, allows for the machinery spaces (engine room) to be unattended with critical alarms and functionality of main engine to be transferred to the bridge. As per typical routines at sea, the engine room is unmanned around 1700H and manned again the next morning (usually around 0700H). During this period the engineer(s) on duty carry out fire safety watch before retiring for the night.

⁶ 53 revolutions per minute (RPM).

⁷ Information retrieved from the voyage data recorder (VDR).

⁸ Nautical mile. 1Nm = 1852m.

⁹ An engine rating holding relevant certificates to perform support roles for keeping an engineering watch.

¹⁰ YSH's main engine was a seven-cylinder engine.

Fitter informed the 2E by telephone. At around 0135H, the 2E went into the engine room and informed the OOW via the telephone that he needed to check on the main engine with the Fitter.

- 1.1.5 At around 0150H, the Chief Engineer (CE) who was also informed by the 2E via the telephone arrived in the engine room. Thereafter, the OOW was advised through two separate calls between 0155H and 0200H to briefly reduce the engine RPM¹¹ and increased it again. The Fourth Engineer (4E), who was incidentally awake in his cabin, felt the changes of the main engine's revolutions, went down to the engine room thinking that the Fitter was alone in the engine control room (ECR).
- 1.1.6 In the 4E's presence, the CE and 2E determined that the fuel oil injection valve (FOIV) of the no.4 cylinder needed replacement. The 4E and Fitter called the rest of the engine crew (Third Engineer – 3E, ETO¹² and two Motormen) to the engine room for the replacement job. Separately, the CE went to the Master's cabin and briefed him on the urgent work, which the CE estimated could take between 1-2 hours. The Master asked the CE to inform the bridge and that the Master would join the OOW on the bridge shortly.
- 1.1.7 The CE informed the OOW of the Master's verbal approval for the urgent repairs and the controls for the main engine were transferred to the ECR¹³ at about 0205H. The nearest vessel at this time was about 9Nm to the east of YSH. At about the same time, the 2E briefed the engine crew¹⁴ (less the ETO) at the middle level of the main engine (refer to **figure 1**), regarding the plan for the replacement of the FOIV. Shortly after, some of the engine crew began to prepare the necessary tools.
- 1.1.8 At about 0210H, the CE informed the OOW on the bridge that the main engine would need to be stopped. The OOW informed the Master via telephone accordingly. According to the 2E, the crew were instructed by him to remove the fuel oil high-pressure (FOHP) pipe of the no. 4 cylinder, after closing¹⁵ the main start air valve (refer to **figure 2**). The CE recalled walking to the main engine

¹¹ RPM was reduced to 23 RPM before being increased to 47 RPM.

¹² Electro-Technical Officer, an engineer performing maintenance and repair on board ships with an electronic element.

¹³ The audio recordings of the VDR confirmed the OOW informing the Master on the phone prior to transferring the controls to the ECR as requested by the CE.

¹⁴ The engine crew informed the investigation team that the 2E briefly instructed them to start preparing for the replacement of the FOIV and to prepare the required tools. The engine crew could not confidently recall if the 2E briefed them about any safety precautions to be taken.

¹⁵ The 2E informed the investigation team that the closing of the main start air valve was done by himself.

from the ECR (leaving the ETO alone in the ECR) specifically reminding the engine crew to only remove the FOHP pipe.

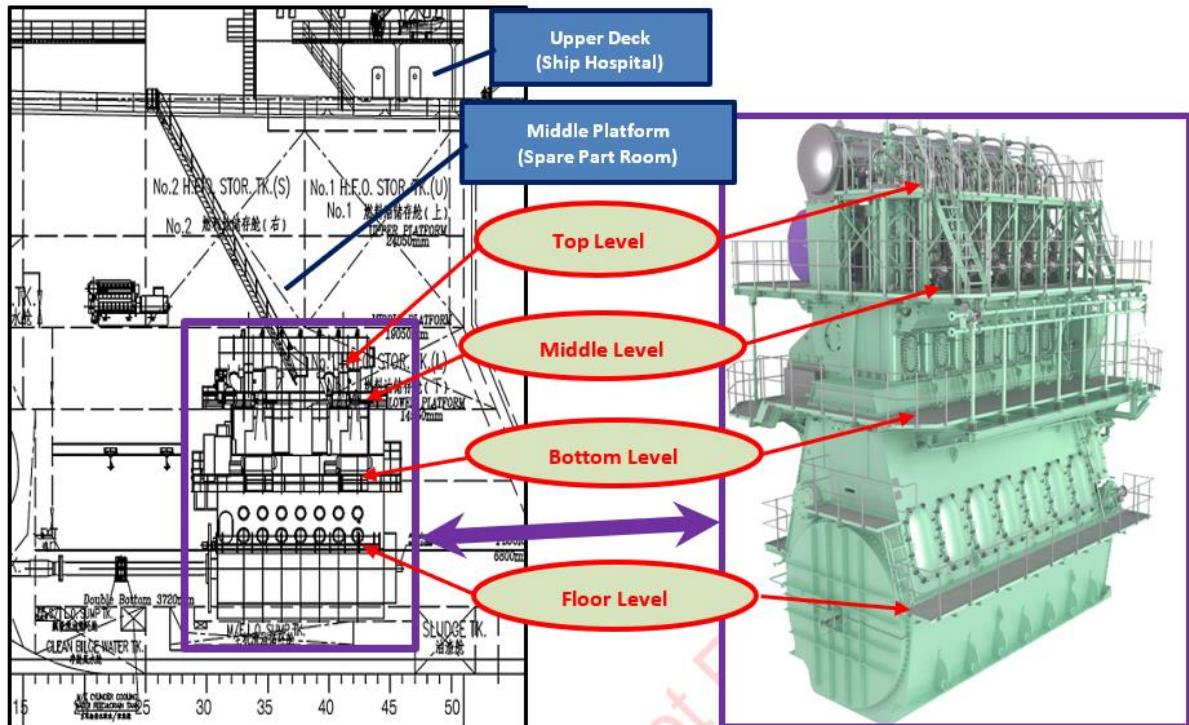


Figure 1: Illustration of the layout together with the upper deck, engine room and associated levels¹⁶ of the main engine—*not to scale*. (annotated by TSIB)

Source: General Arrangement plan of YSH and ED

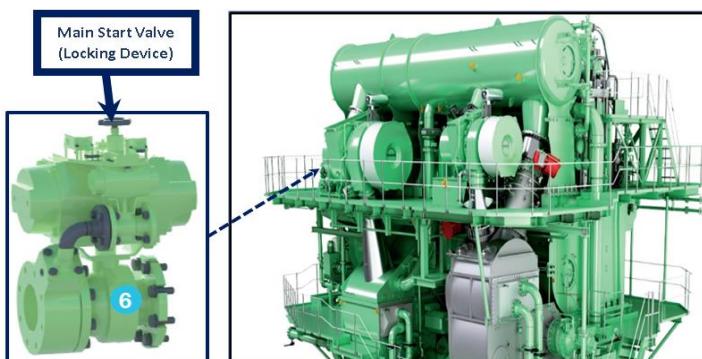


Figure 2: The main start air valve and its locking device, located at the starboard aft of the main engine (middle level) indicated by the dotted blue arrow. (annotated by TSIB)

Source: Engine Manual

¹⁶ The top level is commonly known as the Cylinder Head Platform and the middle level is commonly known as the Fuel Pump Platform.

- 1.1.9 Between 0215H and 0220H, while the 3E, 4E, Fitter and two Motormen were removing the FOHP pipe at the top level of the main engine, the 2E went to the spare part room (at the middle platform, accessed by a stairway from the middle level of the main engine) to take a new FOIV. Concurrently, the engine RPM was in the process of being reduced sequentially (i.e. in steps according to the engine order telegraph¹⁷ (EOT)).
- 1.1.10 By about 0223H, the FOHP pipe had been removed. The Fitter¹⁸ and 4E both separately recalled that the 3E and 4E remained at the top level, with the 3E covering the outlet of the FOHP pipe to the engine with rags and carrying out general cleaning of the area, while standing on the pedestal. At around the same time, before going towards the no.6 cylinder, the CE walked towards both the 3E and 4E on the top level and instructed them not to remove any other parts until the engine RPM had come to zero.
- 1.1.11 The 2E returned with a box containing a FOIV at about 0225H. Realising that the FOIV brought by the 2E was an old and defective one¹⁹, the 4E informed the 2E and accompanied the latter back to the spare part room to get the correct FOIV. By then the EOT had been rung to stop at 0226H, and the nearest vessel was 14Nm to the east of YSH.
- 1.1.12 Around 0227H²⁰, a loud bang was heard. The CE and the remaining engine crew who were near the main engine saw that the 3E had fallen from the pedestal and lay unconscious on the floor of the top level.
- 1.1.13 The CE rushed over to the 3E and held his head in his arms and noted that the 3E's face was badly injured near the right temple (above the ear and to the right of the eye) and was bleeding profusely with faint breathing. The FOIV from the no.4 cylinder was by the side²¹ of the 3E. The CE assessed that the head of the FOIV (marked in red arrow in **figure 3**) had likely hit the 3E on the face.

¹⁷ The sequence recorded in the log provided by the ED was Half-Ahead to Slow Ahead (0223H) to Dead Slow Ahead (0225H) to Stop (0226H).

¹⁸ At this time the Fitter and both the Motormen had wiped and the area near the top level and cleared the tools before going to the middle level of the main engine.

¹⁹ The 4E had been on board YSH for a longer period and knew the ship well.

²⁰ The SOG was 8.1kts as recorded in the VDR.

²¹ The two securing nuts of the FOIV were later discovered by the engine crew to have been removed.



Figure 3: The FOIV from the no.4 cylinder of the main engine.
(annotated by TSIB) Source: Engine crew of YSH.

- 1.1.14 The rest of the engine crew rushed to assist the CE, subsequently carrying the 3E to the ship's hospital (infirmary) on the upper deck.
- 1.1.15 The OOW on the bridge was notified of the occurrence, who then informed the Master. The Master informed the Chief Officer and the 3O and the three of them soon arrived at the infirmary.
- 1.1.16 Thereafter, between 0245H to 0325H, several calls were made (via Satcom) by the Master and Chief Officer to the Company's DPA and the Guangzhou Xinhai Hospital²², seeking medical advice and assessing options to deviate YSH for immediate medical treatment for the 3E. The engineering crew meanwhile continued the FOIV replacement²³ work, which was completed by about 0328H.
- 1.1.17 Thereafter, by about 0340H, YSH's speed was increased gradually and the vessel headed towards Sri Lanka for medical evacuation of the 3E ashore, with the earliest estimated time of arrival as 28 September 2020 while concurrently seeking coordination instructions from the Sri Lankan MRCC. The 3E's vital signs were being monitored by the ship's crew. At about 0545H, YSH reported to the Sri Lankan MRCC that 3E had lost his vital signs.
- 1.1.18 YSH subsequently anchored at the Port of Hambantota, Sri Lanka on 28 September 2020, and the body of 3E was transferred to the hospital ashore. YSH then departed Sri Lanka on 2 October 2020 and continued its voyage, after being released by the local authorities. The death certificate for the 3E, issued

²² The Guangzhou Xinhai Hospital was contracted with the Company to provide telemedicine consultation services including medical emergencies to their fleet.

²³ The log records of the main engine extracted by the ED indicated that at about 0242H, the main engine reached zero RPM and the SOG was about 3.1kts.

by the Sri Lankan authority dated 7 October 2020, stated the cause of death as *cranio-cerebral injuries blunt trauma to head*.

1.2 Crew Experience, work schedule and rest hours

1.2.1 YSH was manned by 21 officers and ratings from the People's Republic of China (P.R.C). The official and working language on board was the Chinese language. The engine department comprised eight personnel (CE, 2E, 3E, 4E, ETO, Fitter and two Motormen). The crew experience matrix of those involved is shown in the table.

Designation	Master	Chief Engineer	Second Engineer
Qualification	Deck Officer Class 1 STCW II/2, IV/2 Revalidated Oct 2017	Chief Engineering Officer STCW III/2 Revalidated Feb 2020	Chief Engineering Officer STCW III/2 Revalidated Apr 2018
Certification Authority	MSA - China	MSA - China	MSA - China
Nationality	P.R.C	P.R.C	P.R.C
Age	55	47	47
Experience in Rank	18 years	9 years	6 years
Period with Company	(as Master) 12 years	(as Chief Engineer) 4 years	(as Second Engineer) 3.5 years
Period on board	2 weeks	2 weeks	2 weeks
Duty Schedule	N/A	N/A	Day Work (on UMS duty)

Designation	Fourth Engineer	Fitter	Motorman 1
Qualification	Third Engineering Officer STCW II/1 Issued Apr 2019	Able Seafarer Engine STCW III/5 Revalidated Jan 2015	Able Seafarer Engine STCW III/5 Issued Jul 2014
Certification Authority	MSA - China	MSA – China	MSA - China
Nationality	P.R.C	P.R.C	P.R.C
Age	29	50	43
Experience in Rank	2.5 years	10 months	7 years
Period with Company	(as Fourth Engineer) 2.5 years	(as Fitter) 10 months	(as Motorman) 7 years
Period on board	10 months	2 weeks	2 weeks
Duty Schedule	Day Worker	Day Worker	Day Worker
Designation	Motorman 2	Third Engineer	
Qualification	Motorman STCW II/4 Issued Dec 2018	Second Engineering Officer STCW III/2 Issued 2016	
Certification Authority	MSA - China	MSA - China	
Nationality	P.R.C	P.R.C	
Age	29	32	
Experience in Rank	9 months	2 years	
Period with Company	(as Motorman) 9 months	(as Third Engineer) 2 years	
Period on board	2 weeks	2 weeks	
Duty Schedule	Day Worker	Day Worker	

- 1.2.2 As with most ships, the scope of responsibilities²⁴ for the 3E on board YSH were the maintenance of generators, air compressors, compressed air bottles, boilers, fuel condensate and feed systems, as well as lighting and power grid for all decks and living spaces.

²⁴ According to the SMS.

- 1.2.3 Prior to the incident, the 3E had on 24 September 2020, conducted routine checks and maintenance work from about 0800H to 1100H. After an hour of training from 1800H to 1900H, the 3E took rest. The investigation team gathered that when the engine crew called the 3E for assisting with the urgent work on 25 September 2020, the 3E was asleep in the cabin.
 - 1.2.4 In the last 24-hour period, the 3E had 19 hours of rest and in the last 7-day period, the 3E had 113 hours of rest, both indicative of compliance with MLC/STCW's hours of rest and work requirements. These records were reflected accordingly in the documentation gathered by the investigation team.
 - 1.2.5 There were no other specific activities like shipboard drills on the day of 24 September 2020 and the work/rest records of the crew (including the engine crew) were reflected according to their routine work schedule.
 - 1.2.6 According to the Company, all YSH's engine crew (except the ETO) had been on board other ships of its fleet with the same engine type. The crew had also undergone in-house training for this specific engine type²⁵, facilitated by the Company's trainers who had attended a course (ME-C control system and operation course) by the ED. Both the CE and 2E had also attended separate courses for this engine type by other course providers in 2016 and 2018 respectively.
 - 1.2.7 According to the Company's records, the 3E had worked on one of the other Company's ship (with the same type of main engine) as a Fourth Engineer, which underwent a similar FOIV replacement about 2.5 years ago. However, the confirmation on whether the 3E had participated in the work itself at that time, could not be obtained.
- 1.3 Additional information from interviews
 - 1.3.1 The investigation team sought clarification from the Master on the discussion with the CE at the time the approval was given for the replacement to commence. The Master confirmed that the work was to take one to two hours according to the CE, and that there was no time pressure to resume the voyage immediately as YSH had a two-day buffer on the ETA to the next port, which was about a month away.

²⁵ The Company shared that this was a 3-day compulsory course which included sharing of incident cases and pre-boarding safety training. The investigation team gathered that such training did not specifically cover replacement of a FOIV, as this topic was deemed as common engineering knowledge under STCW qualification.

- 1.3.2 According to the CE, he had agreed for the removal of the FOHP pipe as this removal would not cause any safety issues despite the engine being on Slow Ahead. The CE recalled seeing the 2E closing the main start valve and isolate the fuel inlet valves²⁶ but the CE did not confirm their status via the Local Operating Pane (LOP, see 1.5.5). The CE also added that he did not see the need to engage the turning gear (see 1.5.7) for the replacement of the FOIV.
- 1.3.3 The CE had served with the 3E on another ship (while holding the same appointment respectively) for about 10 months before joining YSH. The CE confirmed that this type of work had not been done on that ship during that period. The CE opined that the 3E could have felt pressured to have this replacement done to shorten the main engine's service downtime. The CE further added that the 3E could have mistaken that the main engine RPM was zero after the EOT had been rung to stop. Recalling in hindsight, the CE felt that that the 2E and himself should have intensified the supervision of the task to be done, by ensuring that the engine crew understood the instructions and to cross check their actions.
- 1.3.4 The 2E recalled that the main start valve and the fuel inlet valves were shut personally by himself. On asking of the specific jobs for each of the engine crew, the 2E added that a general safety brief on the procedure (which included the main engine RPM to be zero) and tools to be used, was conducted. The 2E further confirmed that he had forgotten to open the indicator (cock) valve as required. The 2E informed the investigation team that he did not think it was necessary to engage the turning gear as required by the manual. The 2E added from his assessment that there was an urgency to get the main engine back running but could not elaborate on how and when this urgency was communicated from.
- 1.3.5 The 2E also informed the investigation team that there was no other major work during the day prior to the incident and no major work planned for the next day either, especially for the 3E. The 2E also shared that the engineer officers were expected to have an adequate understanding of the main engine and the 2E did not personally ensure that they understood his instructions.
- 1.3.6 From the conversations with the investigation team, the 4E recalled that when he arrived at the ECR, both the CE and 2E were discussing the reason for the exhaust gas temperature to be high. After monitoring the main engine

²⁶ Closing of the fuel inlet valves is a work procedure stated in the job card for the removal of the FOHP/FOIV.

parameters, the decision to replace the FOIV was made. The 4E also mentioned that the 2E had briefed the engine crew on steps to be taken and the tools to be prepared for the FOIV replacement. From his knowledge and understanding of the main engine, the 4E too added that there were no safety issues to remove the FOHP pipe while waiting for the RPM to attain zero.

- 1.3.7 The 4E also confirmed that the CE had instructed the 3E and himself not to remove any other parts until the RPM is zero. According to the 4E, the 2E too instructed both to wait for further instructions after the FOHP pipe was removed, before the 2E went to the spare parts room.
- 1.3.8 Describing from his experience, the 4E shared that he had conducted the replacement of FOIV on at least two occasions in the past two years including once on YSH²⁷. The 4E assessed in hindsight that the 3E could have mistaken the sound of the EOT being rung to Stop, as the main engine attaining zero RPM.
- 1.3.9 The 4E shared that from the past two experiences, the turning gear was engaged only once, and added that engaging the turning gear may not be necessary, as long as the RPM was confirmed zero, the main start air valve and the starting air distributor blocked with the indicator (cock) valve opened.
- 1.3.10 In his interaction with the investigation team, the 4E also felt that the work was being performed in a haste, possibly to get the main engine back into operation quickly for fear of delays. When asked why he didn't intervene to stop the 3E from removing the FOIV, the 4E added that he did not witness the removal of FOIV by the 3E, and the 3E could have commenced doing so only after the 4E left the area with the 2E to the spare parts room.
- 1.3.11 The Fitter had conducted the same work on the same engine type, the last being less than a year ago, while this was the first time with this team of engine crew. The Fitter shared that he vaguely recalled that the 2E mentioned about the need to wait for the main engine RPM to reach zero, when being briefed at the middle level.
- 1.3.12 The Fitter shared that specific tasks were not assigned to individuals but were assigned as a group (i.e. the 3E, 4E, two Motormen and Fitter were assigned to take the tools and then assist with the removal of the FOHP pipe). He could not

²⁷ For another cylinder.

confirm if the main start valve was closed but expressed the possibility that the 2E had done so. The Fitter responded that he was aware that the indicator (cock) valve must be opened when the main engine has attained zero RPM as a part of the procedure but could not recall if this was done on that day.

- 1.3.13 When asked about the procedures to be carried out for the FOIV replacement, the Fitter was able to narrate each separate step. The Fitter asserted that he would act according to the instructions given by the engineer officers and for this case, the CE or the 2E before carrying out the work. The Fitter was confident that without the two securing nuts loosened intentionally, there was no possibility that the nuts would be dislodged, expelling the FOIV.
- 1.3.14 On being asked, the Fitter confirmed that the turning gear was not engaged. From his understanding and experience, the turning gear is engaged only when the main engine is completely stopped, typically when the ship is berthed in ports.
- 1.3.15 The investigation team also became aware from its interaction with the engine crew, that the Company viewed machinery downtime negatively, which affected the crew's performance grades. There was a general understanding on board that the Company might penalise the ship's crew for undue delays or taking too much time in repair work.

1.4 Main engine and FOIV

- 1.4.1 The 7G80ME-C9.5 engine is an electronically controlled engine and is commonly fitted on board the fleet of bulk carriers under the same Company of YSH.
- 1.4.2 This is a two-stroke diesel engine which has seven cylinders with each having an 80cm (cylinder) bore diameter. The engine data is recorded and stored in a non-erasable digital record which can be extracted for analysis.
- 1.4.3 Each cylinder cover is equipped with three FOIVs, an (cylinder) air starting valve and an indicator (cock) valve. The FOIVs are connected with the FOHP pipes, each FOIV being about 0.65m long and weighing about 15kg. It consists of a valve head and a valve housing. The FOIV is fitted to the cylinder cover by two securing nuts with a spring housing for each nut (see **figure 4**). The securing nuts were found to have been removed at the time of the occurrence.

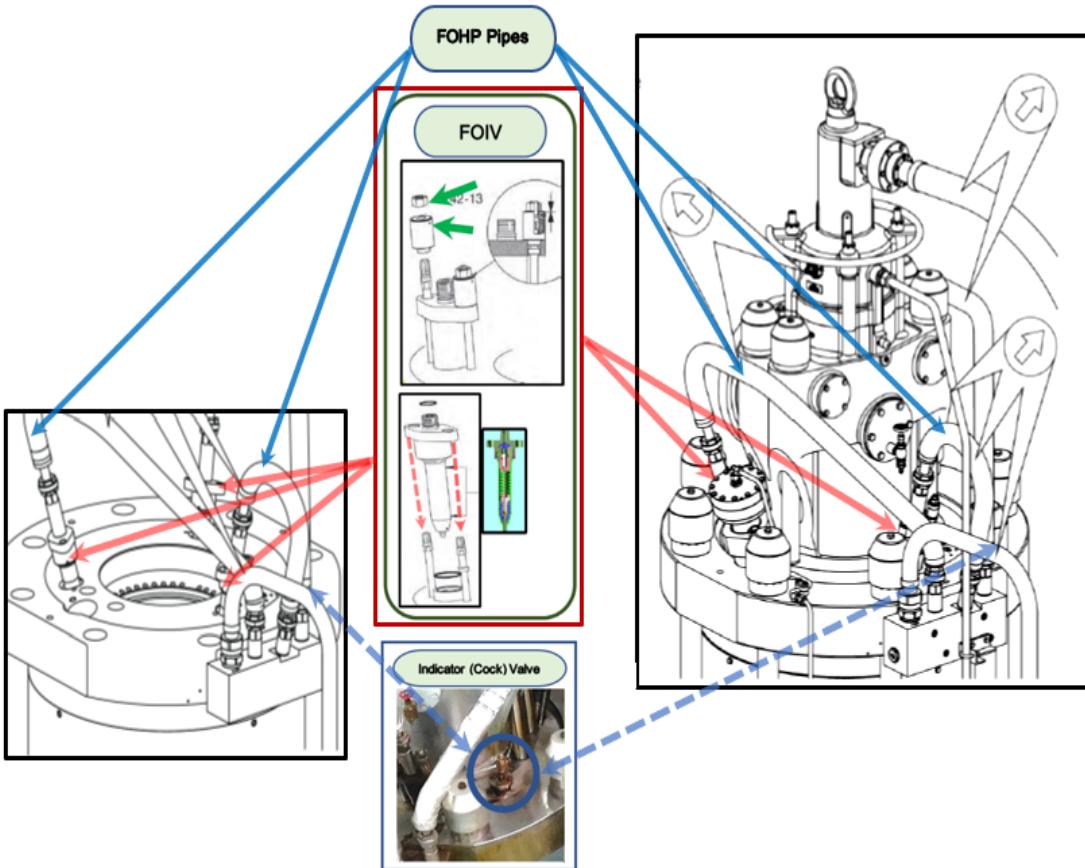


Figure 4: The cylinder cover with the FOIVs, FOHPs and indicator (cock) valve (blue-circled). For the FOIV, the green arrows show the components (spring housing and nut) of the securing arrangements and the dotted red arrows indicate the direction in which the FOIV is fitted to the cylinder cover (annotated by TSIB)

Source: Engine Manual

1.5 Safety precautions and training on the main engine

- 1.5.1 The engine manual (technical documentation in English) carried on board YSH was divided into several chapters. This included a chapter on general safety precautions, as well as chapters on ‘maintenance work cards’ specific to individual parts, mechanisms and system – together with those for the FOHP pipe and the FOIV, *inter alia*.
- 1.5.2 In the chapter on general safety precautions, the requirement of reading and following all instructions given in the work cards is stated. Table 1 shows the general safety precautions applicable before carrying out specific works on the main engine.

<input type="radio"/>	Stop the Engine
<input type="radio"/>	Shut off starting air supply - At starting air receiver
<input type="radio"/>	Block the main starting valve
<input type="radio"/>	Shut off starting air distributor/distributing system supply
<input type="radio"/>	Shut off safety air supply - Not ME Engines
<input type="radio"/>	Shut off control air supply
<input type="radio"/>	Shut off air supply to exhaust valve - Only with stopped lub. oil pumps
<input type="radio"/>	Engage turning gear
<input type="radio"/>	Shut off cooling water
<input type="radio"/>	Shut off fuel oil
<input type="radio"/>	Stop lubricating oil supply
<input type="radio"/>	Shut down hydraulic power supply
<input type="radio"/>	Shut off and block the auxiliary blowers

Table 1 – General precautions for work on the main engine

- 1.5.3 The work cards for both the FOHP pipe and the FOIV also include similar tabulated safety precautions shown in Table 2. The precautions required for the engine to be stopped²⁸, the starting air supply to be shut off, main starting valve to be blocked, starting air distributor (and system supply) to be shut off and the turning gear to be engaged, *inter alia*.

<input type="radio"/>	Stop the Engine
<input type="radio"/>	Shut off starting air supply - At starting air receiver
<input type="radio"/>	Block the main starting valve
<input type="radio"/>	Shut off starting air distributor/distributing system supply
<input type="radio"/>	Shut off control air supply
<input type="radio"/>	Engage turning gear
<input type="radio"/>	Shut off fuel oil
<input type="radio"/>	Stop lubricating oil supply
<input type="radio"/>	Shut down hydraulic power supply

Table 2 – Safety precautions for work on FOIV

- 1.5.4 The investigation team gathered that the replacement of FOIV is a common, routine maintenance work for similar ship engines of YSH, which normally takes about 1.5-2 hours. The investigation team further gathered that the procedures associated with the safety precautions for the replacement of FOIV are similar to those captured in Table 2.

²⁸ In the engine manual, stopping the engine is referred to zero RPM of the engine.

1.5.5 There are two types of operating panels for the main engine, fitted at the designated control stations separately –

- I. the Main Operating Panel (MOP) at the ECR²⁹, which is the main information interface for the engineer to operate some components. In addition, the MOP displays (see **figure 5**) the status of some of the valves and components (as input by the engineer), i.e. allows the crew to monitor the status of the main engine, including the turning gear.
- II. the LOP at the aft end of the main engine, where the basic functions are available, such as main engine starting, engine speed, control, stopping, reversing, and relevant engine data is displayed.

²⁹ A duplicate panel was also on the bridge.

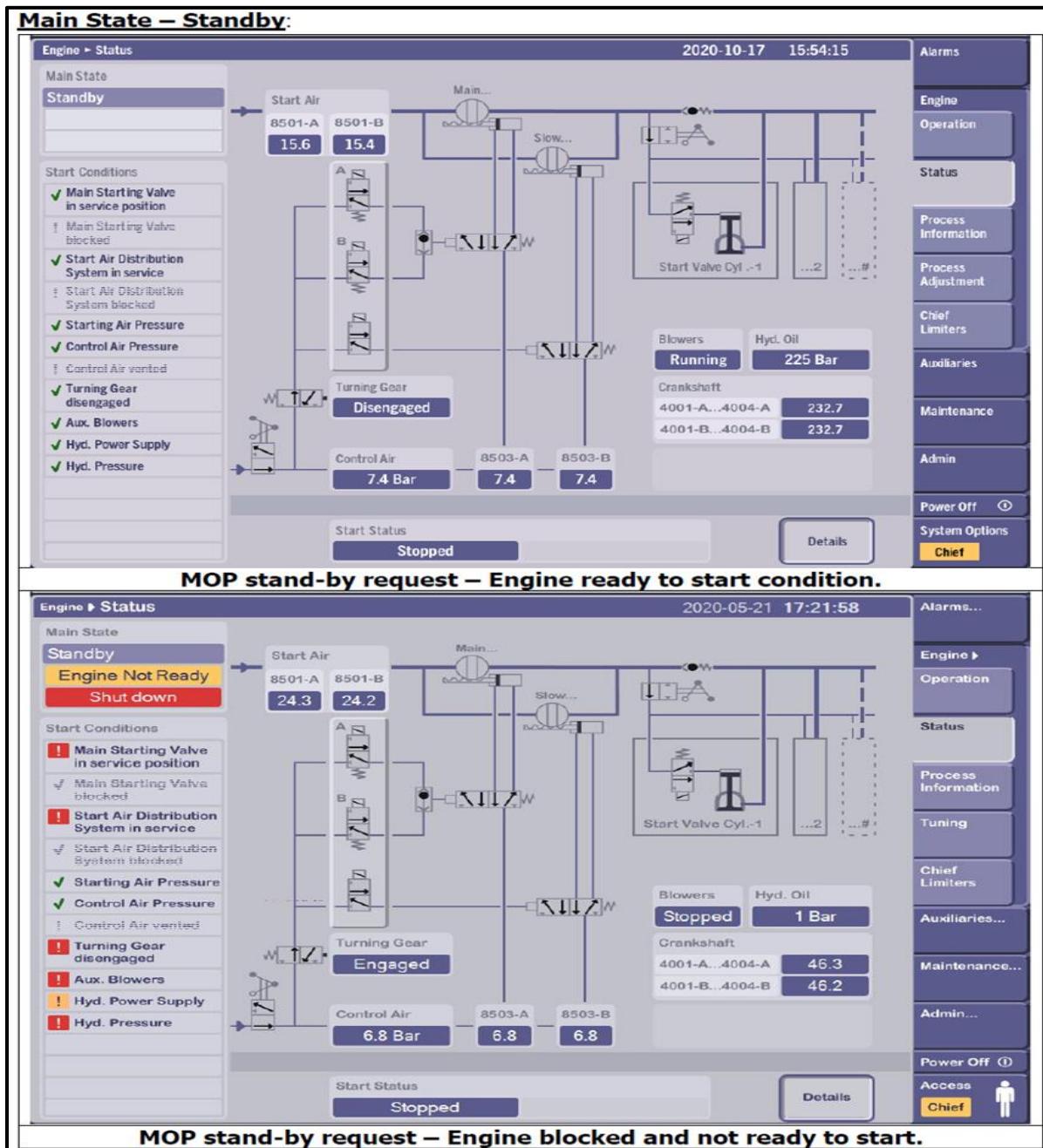


Figure 5: Illustration of the MOP displays - when the “Standby”³⁰ mode for the main engine is selected (Top) and when “Standby – Engine Not Ready” mode is selected (Bottom). Source: The ED.

³⁰ Compared to the status of ‘Finished with engine’ or ‘Engine not ready’, which are generally known to be selected for repairs (i.e. after all moving parts of the main engine are confirmed isolated or secured), the ‘Standby’ status would mean that the main engine is ready to be started anytime.

1.5.6 According to the ED the detailed steps stated in the engine manual, for the dismantling of the FOIV are –

- Stop the engine, revert the engine readiness to inactive mode³¹, and ascertain that the engine RPM is zero;
- Close the starting air supply (at the air receiver), block the main start valve, isolate the starting air distributor and control air supply;
- Open indicator (cock) valve³²;
- Engage the turning gear;
- Turn the engine for one complete cycle³³;
- Isolate the fuel oil inlet supply and hydraulic supply;
- Dismantle the high-pressure fuel pipe;
- Dismantle the fuel oil injection valve³⁴.

1.5.7 The turning gear is a reversible electric motor which, through a system of gears, can be used to turn a large diesel engine (or steam turbine) and the gear assembly, slowly and enable positioning for overhaul or inspection. The common safe preparatory works before engaging the turning gear are –

- Ensure that the starting air supply is shut off, the main start and slow turning valves are blocked, and that the cylinder indicator (cocks) valves are open;
- Ensure that the engine RPM is zero;
- Ensure that the engine mode is in Finished With Engine (FWE);

When the turning gear is engaged³⁵, check that the MOP/LOP indicates so. Thereafter, the engine is turned for one full cycle (revolution) to check for fluid flowing out of indicator (cocks) valves.

1.5.8 Both the MOP in the ECR and LOP (local), display the main engine RPM and

³¹ The Finished-With-Engine (FWE) mode is the safest, and preferred mode. At the time of the occurrence the FWE was not applied.

³² To relieve residual pressure in the cylinder combustion chamber.

³³ To distribute the heat and allow remaining gas pressure in the cylinder combustion chamber to escape via the scavenge ports.

³⁴ According to the ED, an extraction tool (which carried on board YSH) could be used to aid the removal of the FOIV when it is sticking (hard to remove) to the cylinder cover during the dismantling activity. There was no evidence to suggest that the FOIV was hard to remove in this case.

³⁵ With the turning gear engaged, a control valve (i.e. turning gear interlock) will not allow starting air to admit and operate the engine cylinders.

can be used to verify if the engine RPM has attained zero. The alternative to verify whether the actual engine RPM has become zero is to visually check that the intermediate shaft (connected between the main engine and the propeller shaft) has stopped (from either the lower or floor level). On the day of the incident, none of the crew verified whether the RPM was zero prior to commencement of the removal of FOHP pipe.

- 1.5.9 The investigation team further gathered that it is possible for most engineers to ascertain whether the RPM has reduced, by listening to the change in the sound of the engine.
- 1.5.10 The safety chapter in the engine manual stipulates the prerequisite, where the operation and maintenance of the engine is to be carried out exclusively by qualified professional personnel. The ED further clarified that holders of engineering qualifications under the STCW convention are deemed qualified to carry out this FOIV replacement work.
- 1.5.11 On training requirements, the ED shared that with the purchase of the main engine, complimentary training is provided to the clients. The investigation team noted that the Company was given five course placements for imparting technical knowledge for this type (ME-C) of engine, conducted in Shanghai (MAN PrimeServ Academy), China, in addition to being conducted at the academy in Copenhagen. The account maintained by the ED for the Company of YSH showed that these training slots had not been utilised³⁶.

1.6 Engine data extracted and other information

- 1.6.1 At the request of the investigation team, the ED's representative in China extracted the engine data record during YSH's call at the shipyard in Dalian on 18 November 2020 and the data was sent to the ED for analysis. The investigation team was then provided a copy of the analysed engine data and annotated as appropriate (see **figures 6a-6b**). The ED also provided extracted data showing the EOT positions with respect to the RPM and the estimated pressure in the no.4 cylinder (see **figure 6c**).

³⁶This is not a mandatory course for the engine crew (or engine department officers) to handle this type of ship engine and it does not deem these engineers as unqualified.

<i>Time</i>	<i>EDS Outvar – Data ID</i>	<i>EDS Outvar – Data Status</i>	<i>Comments</i>
00:40	Crankshaft speed (rpm)	53 rpm	First data available
01:23	Pi (PMI) – Cylinder #4	14 bar → 9 bar	Failure of fuel equipment
01:57	Speed set-point (rpm)	53 rpm → 23 rpm	On Bridge Control
01:59	Speed set-point (rpm)	23 rpm → 44 rpm	On Bridge Control
02:05	Control Station - Selection	6 → 5	Change to ECR Control
02:23	Speed set-point (rpm)	44 rpm → 36 rpm	On ECR Control
02:23	Auxiliary Blowers	0 → 2	Aux blowers started (2x)
02:24	Speed set-point (rpm)	36 rpm → 23 rpm	On ECR Control
02:25	Speed set-point (rpm)	23 rpm → 20 rpm	On ECR Control
02:26	Speed set-point (rpm)	20 rpm → 0 rpm	ECR Telegraph stop position
02:26	Fuel Plunger Stroke (mA)	6 mA → 0 mA	Fuel injection stopped
02:28	Crankshaft speed (rpm)	19 rpm	Crankshaft wind-milling
02:30	Crankshaft speed (rpm)	17 rpm	Crankshaft wind-milling
02:32	Crankshaft speed (rpm)	14 rpm	Crankshaft wind-milling
02:34	Crankshaft speed (rpm)	12 rpm	Crankshaft wind-milling
02:36	Crankshaft speed (rpm)	9 rpm	Crankshaft wind-milling
02:38	Crankshaft speed (rpm)	7 rpm	Crankshaft wind-milling
02:40	Crankshaft speed (rpm)	5 rpm	Crankshaft wind-milling
02:41	Crankshaft speed (rpm)	2 rpm	Crankshaft wind-milling
02:42	Crankshaft speed (rpm)	0 rpm	Engine rotation stopped

Figure 6a: Tabulation of relevant extracted data with timelines – annotated by ED
(Source: The ED)

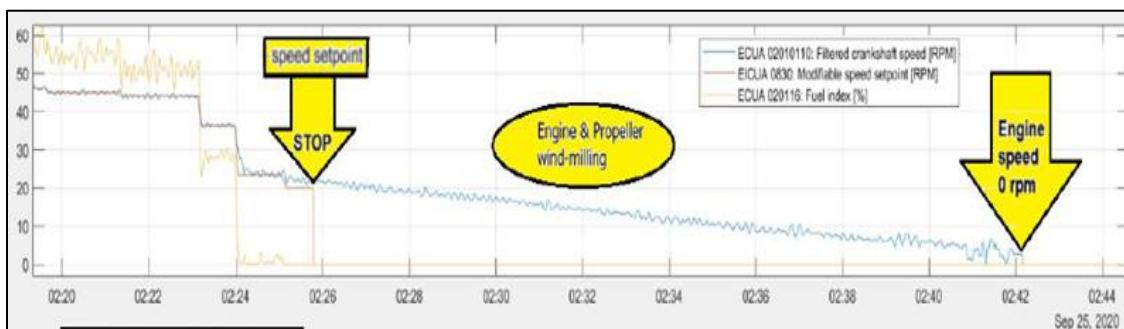


Figure 6b: Graphical representation of Line recorder extract showing speed setpoint stopped, engine & propeller wind-milling³⁷ until 0243H (i.e. when engine RPM comes down to Zero) - (Source: The ED)

³⁷ The free rotation of internal compressor unit when the engine is inoperative, but not seized.

Local time 25 Sep 2020	Telegraph set-point	RPM actual speed	Fuel Index	Exhaust valve timing	Pscav pressure	Pcylinder pressure	Comments
00:40	53 rpm	53 rpm	75%	-80 Deg	1,95 Bar	175 Bar	First data
02:05	47 rpm	47 rpm	65%	-90 Deg	1,20 Bar	135 Bar	
02:23	44 rpm	44 rpm	50%	-90 Deg	0,70 Bar	120 Bar	
02:24	36 rpm	36 rpm	25%	-90 Deg	0,35 Bar	100 Bar	Aux blower starting
02:25	24 rpm	24 rpm	0%	-90 Deg	0,12 Bar	50 Bar	Fuel Index to 0%
02:26	0 rpm	21 rpm	0%	-66 Deg	0,100 Bar	48 Bar	Telegraph STOP
02:27	0 rpm	20 rpm	0%	-66 Deg	0,095 Bar	31 Bar	Pcylinder measured
02:28	0 rpm	19 rpm	0%	-66 Deg	0,090 Bar	30 Bar	Pcylinder measured
02:29	0 rpm	18 rpm	0%	-66 Deg	0,085 Bar	30 Bar	Pcylinder measured
02:30	0 rpm	17 rpm	0%	-66 Deg	0,085 Bar	29 Bar	Pcylinder measured

Figure 6c – Tabulated representation of EOT positions with respect to RPM and the estimated pressure in no.4 cylinder – annotated by ED
(Source: The ED)

- 1.6.2 A discussion was held remotely between the investigation team and the ED to understand the key findings from these records, which are summarised below –
- From figure 6a, at 0123H, the alarm for no.4 cylinder's exhaust gas high temperature was activated (i.e. temperature different from the rest of the cylinders);
 - From figure 6b, after the STOP (engine) was selected on the EOT at 0226H, the engine and propeller shaft were wind-milling until 0243H, i.e. it took about 17 minutes (from about 0226H to 0243H) for the RPM to reach zero.
 - From figure 6c, the main engine RPM at this time corresponded with the RPM between Full-Ahead and Half-Ahead;
 - The ED summarised for the investigation team that, from the time period the main engine was on ECR control (for carrying out the FOIV replacement), until the main engine was restarted at about 0340H (after the replacement), the status of the main start valve remained “on”, the starting air distributor was not blocked, the turning gear was not engaged, and the main engine was on ‘standby’.

- The ED further analysed (see figure 6c) that the pressure in no. 4 cylinder's combustion chamber at the time of the incident (at about 0227H), was estimated to be between 30 and 48 Bar.
- The extracted engine data also revealed that most of the required actions³⁸ of the listed safety precautions from the engine manual (specifically from the specific job card for the replacement of FOHP and FOIV) had not been followed (see **Figure 7**).

~0340	Main start valve	Status 1 → In service	Status never changed
~0340	Start air distributor	Status 0 → Not blocked	Status never changed
~0340	Turning gear	Status 1 → Dis-engaged	Status never changed
~0340	Engine not ready	Status 0 → Off	Status never changed

Figure 7 – Tabulated statuses from the analysed engine data
(Source: The ED)

- 1.6.3 On being asked whether there are any other safety features built in the main engine to prevent accidental turning of the engine, the ED reiterated the significance of the main engine to be at least on '*standby engine not ready*' if FWE was not chosen. The reason is that the main engine does not know what the engineer's intention is, unless the related components like closing the main start valve, blocking the starting air distributor, engaging the turning gear, *inter alia*; were done for each stage. The ED also opined that the engine crew should be aware of the risk of having the main engine started accidentally and thus should have selected FWE before commencing any work on the main engine.
- 1.6.4 The ED further added that the audibility of the engine rotation (of all seven cylinders) when the RPM has not reached zero is distinguishable and can be heard from any platform of the main engine by any person even when ear plugs, or earmuffs are worn.
- 1.6.5 Responding to the investigation team's query on whether a verbal feedback from an engine crew (for e.g. the ETO) on the status of the related mechanisms (such as the main start valve, starting air distributor and turning gear) from the MOP or LOP, would be useful to prompt the engine crew working on the main engine for an additional verification. The ED responded that such a process is dependent on the Company. The ED does not provide such level of detailed guidance on how to manage the work or repair process, noting that it may not

³⁸ The main start valve was not blocked, the starting air distributor and control air supply were not isolated, the indicator (cock) valve was not opened and the turning gear was not engaged.

be practical³⁹ to have someone stationed in the ECR to monitor the MOP or at the local site (LOP) to check the status.

- 1.6.6 On being queried further, the ED added they were not aware of similar incident in the past with their engines or those by other engine manufacturers. In conclusion, from the data readout (event and timing), the ED commented that the information extracted suggests a series of missteps on the safety precautions required to be followed as per the main engine manual and a rushed job.

1.7 The SMS of YSH

- 1.7.1 The SMS and related risk assessments, permit-to-work system etc. were in the Chinese language.
- 1.7.2 According to the SMS the CE holds the leadership role for the engineering department and the associated responsibilities, while the 2E holds the role responsible for all matters relating to the main engine, *inter alia*.
- 1.7.3 According to the job scope, the CE is to ensure that the engine room machinery and equipment are to be repaired at the earliest and the defect reported to the Company ashore thereafter, with appropriate documentation. This responsibility includes ensuring and supervising the preparatory work, ensuring proper tools are used in accordance with the requirements of the associated machinery or engine manuals, assigning the jobs and role to each engine crew and to safeguard the safety of the engine crew.
- 1.7.4 The 2E too holds the responsibility of the overall safety for the engine crew and for the engine room, including adhering to the procedures stipulated in the engine manual, guiding and supervising the engine crew during repairs. The 2E's job scope required him to seek the guidance of the CE accordingly.
- 1.7.5 According to the SMS, for emergency repairs of the main engine, the safety guidelines mentioned in the maintenance section referred to the ED's instructions (refer to Table 1). In addition, the following step as a safety precaution was also mentioned – The turning gear is to be engaged after the main engine RPM is zero, the engine must be turned by the turning gear.

³⁹ In terms of manpower or the supervision arrangements for different companies with different type of ships and the specific repair/ part replacement work.

- 1.7.6 The SMS has a section on Risk Assessments where a risk assessment matrix with regards to work related to the main engine, stipulated the requirements to adhere to the SMS sections on the role of each engine crew, emergency repairs and general safety requirements for (maintenance) work in the engine room.
- 1.7.7 There is no permit-to-work requirement in the SMS for emergency repairs in the engine room. There is a checklist for daily maintenance work required under the SMS section on general safety requirement, to be checked by the 2E and signed off by the CE.
- 1.8 Additional information from the Company
- 1.8.1 The Company's view on this incident was that, there was a lack of supervision vis-à-vis adherence to SMS, the main engine manual and related work cards. These included the lack of a specific division of labour, starting the work without confirming that the main engine had stopped turning and certain assumptions on the overall safety requirements for each step of the safety precautions (including the use of the turning gear).
- 1.8.2 According to the Company, the compiled records on the performance grading of this team of engine crew on YSH, revealed that the 3E was graded as an excellent crew member. The performance grading criteria listed were generally - sense of responsibility, knowledge and skillset on the machinery, equipment or area of responsibility, leadership ability, supervision ability and adaptability to changes of situations encountered regarding the work involved. There was no mention of downtime period for machinery being used as a grading criterion in the SMS.
- 1.8.3 When asked, the Company shared that for the recent four FOIV replacement works on other ships prior to this occurrence (including one during daytime while the ship was underway) for this engine type, the average time taken was between one hour and one hour fifteen minutes. No difficulties had been reported during these FOIV replacement works and the time taken for each of the main engine RPM to come down zero, took about a quarter of the total time for the job⁴⁰.

⁴⁰ According to the Company, this was based on the estimated timings of the engine RPM taken from the engine order printer unit after the EOT (from the ECR control) selected Stop Engine, to the time recorded for the main engine to achieve zero RPM.

2 ANALYSIS

2.1 The occurrence

2.1.1 There was no eyewitness account to the actual occurrence of the FOIV expelling from the cylinder cover and hitting the face of 3E. The investigation team analysed how the accident might have occurred based on the information gathered, such as the extracted (pre-and-post incident) engine data, observations of the engine crew, their training and past experience, the engine manual and the SMS of YSH. The ED provided a visualisation of the probable position of the 3E just prior to the accident, based on the information available.

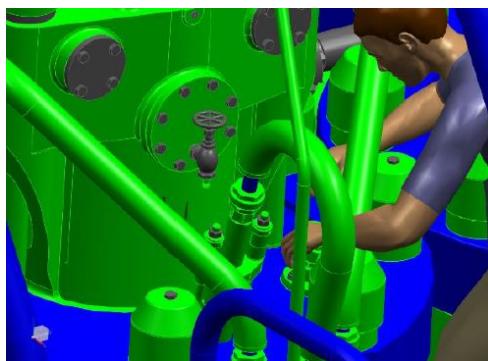


Figure 8: Visualisation of the 3E's probable position just prior to the accident – not to scale.

Source: ED

- 2.1.2 The main engine had been rung stopped at 0226H, i.e. about one minute prior to the loud bang heard by the engine crew. Corroborating this information with the injuries sustained, it is evident that the FOIV had ejected out of the cylinder cover by the pressure within the cylinder with substantial force⁴¹ onto the face⁴² of 3E, resulting in the fatal injuries while the engine was still rotating, and the propeller was still wind-milling.
- 2.1.3 Noting that the securing nuts of the FOIV to the cylinder cover had been found removed, it is plausible to deduce that the work to remove the FOIV had commenced before the engine RPM had come down to zero, which was a deviation from the established procedures in the engine manual and the SMS of YSH.

⁴¹ The 30 to 48 Bar of pressure thrusting a 15kg object, explains the loud “bang” heard by the engine crew.

⁴² The 3E was standing on the pedestal which was below the right-side of the cylinder cover while working on the FOHP and FOIV that were on the left of 3E. This had likely resulted in the injury sustained only on the right of 3E’s face while he was looking and at the same time, loosening or removing the securing nuts before the FOIV expelled.

- 2.1.4 Since most of the engine crew were involved in various other tasks, the probability of the securing nuts to have been removed by the 3E were high, without the knowledge of the other engine crew, including the 2E and CE.
- 2.1.5 Reasons for the 3E to proceed with the early removal of the securing nuts of the FOIV could not be established with certainty. The investigation team hypothesised the following possibilities –
- The 3E may have perceived (auditory) that the main engine had achieved zero RPM once the EOT was rung to stop; or
 - The 3E was not aware of the need to wait for the engine RPM to come down to zero; or
 - There were no specific instructions given regarding when to remove the FOIV, contrary to what was claimed by the engine crew; or
 - The job had implied urgency to restore the engine's serviceability, leading him to hasten the process.

2.2 Deviation from established safety procedures

- 2.2.1 Noting the missing steps for the extraction of the FOIV (see footnote 37), the investigation team attempted to understand reasons for the 3E to hasten the process of the removal of the FOIV. An experienced engineer like the 3E, is expected to know that even after the EOT is rung to stop, it takes a while for the engine RPM to attain zero.
- 2.2.2 The 2E was certain that he had closed the start air valve (i.e. the locking device) and the CE also told the investigation team that he remembered the 2E doing so. The engine data retrieved post incident suggests otherwise. The incident shows the importance of having a verification process⁴³ to ascertain that the necessary safety precautions have been done prior to commencing the task. This is more so when there is an urgency, real or perceived, to hasten the completion of the task.
- 2.2.3 Correlating the safety precautions to be taken (such as the turning gear to be engaged and the indicator (cock) valve to be opened) prior to the removal of the FOIV and the opinion of the engine crew, the engine crew of YSH had varying

⁴³Utilising the MOP or LOP to validate that each step under para 1.5.6 is fulfilled before proceeding to the next step.

interpretations on the relevance of these steps (see section 1.3). It is also likely that the engine crew did not refer to the steps in the engine manual and relied on their working style and memory on typical steps to be performed.

- 2.2.4 The investigation team deemed probable that the implied pressures to complete repair work expeditiously to avoid being penalised and affecting the performance grades of the engine crew may have had bearing on deviation from established procedures. A strict compliance with the procedures, could have prevented this occurrence.
 - 2.2.5 Therefore, it is important that the crew refer to the relevant manual and observe the safety precautions strictly before commencing any repair work. In addition, effectual job delegation and supervision vis-à-vis a checklist would provide visibility of the tasks performed by the assigned crew.
- 2.3 Permit to work system
- 2.3.1 The key emphasis before carrying out any work on any ship, especially on the main engine should be in full compliance with relevant physical prevention systems established, such as those in the engine manual – i.e. the isolation and restraining of hazardous energy sources, before the work commences.
 - 2.3.2 In this case, for the FOIV replacement work to commence, the main engine had to be stopped and the engine RPM had to attain zero. These could have been validated by an engineer officer from the MOP or LOP.
 - 2.3.3 The MOP or LOP, could also have been used to verify that both the starting air supply and control air supply are isolated, to prevent event where the start valve is not fully closed or any incidental starting of the main engine. Thereafter, the indicator (cock) valve should have been opened⁴⁴ to relieve residual pressure in the cylinder's combustion chamber.
 - 2.3.4 The engineer officer would then ensure and verify that the FWE status is selected on the MOP at the ECR before engaging the turning gear and thereafter, turning the engine for a complete cycle. Lastly, ensuring that the fuel oil inlet supply and hydraulic supply are isolated, before the removal of the FOHP and thereafter, the FOIV for replacement.
 - 2.3.5 Though the engine manual contained the broad steps to be done from a

⁴⁴This is also to vent the exhaust gases and to expel the residual hot gases when the engine is turned after the turning gear is engaged.

guidance point of view, which were expected to be known and understood by a certificated engineer, listing these actions as a checklist or a process within the SMS which forms a part of emergency repairs in the engine room would have been desirable. In turn, a permit-to-work (PTW) system for such work should have been implemented⁴⁵, so that these processes conform to the job cards in the engine manual and allow a step-by-step action.

- 2.3.6 PTW is intended to be safety focused and to break error-chains, especially when such work is required to be done during the crew's hours of rest or when there is an actual or implied urgency to resume serviceability of essential machinery or equipment, where the crew may take short cuts at the expense of safety. Having a detailed PTW can ensure that the necessary safety precautions are taken and reduce ambiguity with proper delegation of tasks being discussed and recorded. This in turn would ensure closed-loop procedural supervision for each required action.
 - 2.3.7 Similarly, it may be desirable for a reasonable timeline to be established in the SMS, based on historical data of other similar engine and machinery tasks, to reduce the probability of implied time pressures.
- 2.4 Training enhancements
- 2.4.1 The Company had provided training and briefing for the engine crew prior to joining the ships, where all the Chief Engineers and Second Engineers were certificated with additional course on specific engine types.
 - 2.4.2 Although the lack of training for a specific engine type was not deemed as a contributing factor, it is evident that the engine crew did not wait for the engine RPM to attain zero and had differing views on the safety precautions to be taken. This suggests that there is room for improvement in training to enhance the knowledge of the engine crew.
 - 2.4.3 Regardless of the engineering knowledge expected to be garnered in the course of obtaining a certificate of competency, enhancement of such knowledge can be achieved at various levels, i.e. prior to embarkation, especially if the crew has not worked on the particular engine in the past and on board familiarisation sessions by more experienced engineers so as to increase awareness on safe practices as provided for in the engine manuals.

⁴⁵ A good practice would be for the CE to discuss with the Master and the engine crew, before the PTW is approved.

CONCLUSIONS

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- 3.1 The securing nuts for the FOIV to the engine cylinder cover were found removed after the 3E was hit by the expelled FOIV from the cylinder cover, while the engine RPM was in the process of being reduced but had not reached zero.
- 3.2 There was no eyewitness when the securing nuts were removed after the 3E was left alone at the affected engine cylinder. The FOIV had likely been expelled out from the cylinder cover by the pressure in the cylinder after the securing nuts were removed while the engine was winding down after the EOT was rung to stop.
- 3.3 The 3E had either mistaken the auditory sound of the engine when rung to stop via the EOT for the RPM achieving zero; or he was unaware on the need to wait for the RPM to be zero before commencing the removal of the FOIV. There was also the possibility of implied urgency which could led to him hastening the FOIV removal process.
- 3.4 From the engine digital (data) record and interviews with the engine crew, there were missing safety precautions which were stipulated in the engine manual prior to the replacement of the FOIV work to be carried out. Although the 2E recalled that the start air valve had been closed prior to the commencement of the work, the engine data retrieved after the occurrence shown otherwise.
- 3.5 There was also reliance on working memory from the engine crew, with varying interpretation of the safety precautions. No verification processes were in place to ascertain the status of each required system or component of the main engine with a seemingly indiscernible supervision. There was also no delegation of tasks prior to commencing the removal of the FOIV which resulted in the engine crew in performing the tasks themselves as they deemed appropriate.
- 3.6 There was no checklist nor a permit-to-work system in place to ensure that all the safety precautions stipulated in the engine manual had been performed prior to the commencement of the replacement of the FOIV.
- 3.7 Knowledge enhancement and retraining, especially on familiarisation of the purpose of the safety precautions for the main engine should be expanded. It

would also be ideal to engage the engine maker (designer) on how the scope of pre-joining and recurrent training should cover vis-à-vis the engine manual.

4 SAFETY ACTIONS

During the course of the investigation and through discussions with the investigation team, the following preventive / corrective action(s) were taken by the Company of YSH.

- 4.1.1 Included in the SMS under emergency repairs in the engine room, a new “permit-to-work” cum checklist system. The checklist is to be completed by the supervising engineer officer for the repair work, verified by the Chief Engineer and work will commence only after approval from the Master. The Master will only allow work to commence after both the checklist is verified and the Company ashore (specifically the engineering superintendent) is notified.
- 4.1.2 This checklist entails requirements for job assignments to each engine crew, adherence to the engine manual’s safety precautions according to the specific work required to be performed (on the main engine) and supervision from assigned engineer officer.
- 4.1.3 New requirement is added to the engine room’s “Pre-work Meeting Record Book” for situations requiring emergency repair(s) on the main engine, where a risk assessment must be conducted together with the engine crew involved in the repair work(s), after the approval to commence is granted by the Master.

5 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

5.1 For the Company of YSH

- 5.1.1 To review the SMS for the inclusion of a step-by-step checklist, in accordance with the safety precautions stipulated in the engine-manual, with guidelines on the verification of each step, for the supervising engineer to carry out and the Chief Engineer to verify, prior to the approval of the permit-to-work for the required work to be carried out. **[TSIB-RM-2021-30]**
- 5.1.2 To engage the engine designer or maker to review the scope of pre-joining briefings and on-board training to enhance the understanding of the safety precautions stipulated in the engine manual. **[TSIB-RM-2021-31]**

-End of Report-