FINAL REPORT

FATAL INJURY ON BOARD MATHU BHUM AT GULF OF MARTABAN ON 3 DECEMBER 2016

MIB/MAI/CAS.005

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

13 February 2018

The Transport Safety Investigation Bureau

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SYNOPSIS

On 3 December 2016, the Singapore registered Mathu Bhum was enroute from Singapore to Yangon, Myanmar. The engine room crew were dismantling the Fire, Bilge and Ballast (FBB) pump with a view to taking some photographs of its condition for submission to the Class surveyor.

The engine room crew assigned by the Second Engineer to work on the FBB pump comprised the Fourth Engineer (the engineer-in-charge), the Oiler, the Wireman and the Engine Cadet. Pre-job briefing and risk assessments were carried out before the start of the dismantling work.

By 1200H the crew managed to remove a number of bolts using appropriate spanners and wrenches. Some of the bolts however were badly seized and could not be removed. To remove the seized bolts, the crew decided to fabricate a tool by welding a metal wedge piece onto the seized bolt, in order to loosen the seized bolt by knocking on the welded metal piece with a hammer. Hot work permits were issued for the dismantling work.

At about 1400H, the Fourth Engineer while standing on the engine room tank top attempted to weld the wedge. He instructed the Engine Cadet to switch on the power for the welding machine which was located in the engine room workshop two decks above. At the engine room workshop the Engine Cadet noticed that the fitter was doing some other welding work and his welding cable was connected to the welding machine. Upon being informed by the Engine Cadet of the Fourth Engineer's instruction, the fitter removed his welding cable and connected the Fourth Engineer's welding cable to the welding machine. This resulted in the fatal electrocution of the Fourth Engineer.

The TSIB classified the occurrence as a Very Serious Marine Casualty and launched an investigation.

The investigation identified that the welding task was being performed by an untrained person in a hazardous environment, unsupervised and without adequate protection measures in place to prevent an electric shock. Other factors included insufficient recognition of hazards and risk mitigation, inadequate communications for the dismantling job and steep authority gradient between crew and the officers.

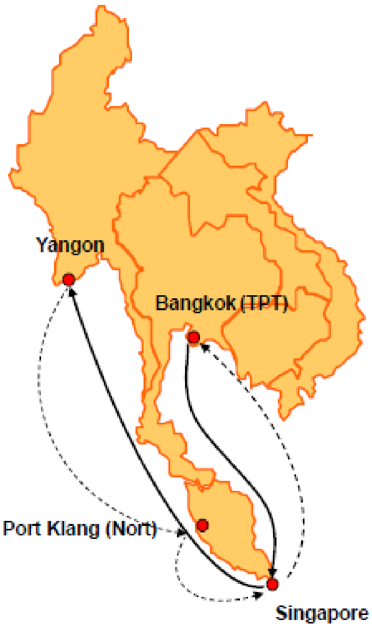
VIEW OF VESSEL

DETAILS OF VESSEL

Name	Mathu Bhum
IMO Number	8813647
Call Sign:	9VCS2
Flag:	Singapore
Classification society	DNV GL
ISM Recognised Organisation	ClassNK
Ship type	Cargo ship (Feeder container)
Builder	Hanjin Shipbuilding, Korea
Year Built	1990
Owner/Company	Regional Container Lines Pte Ltd
Manager	RCL Shipmanagement Pte Ltd
Gross tonnage	11,079
Length overall	145.65m
Beam	25.00m
Moulded depth	11.50m
Summer Draught	8.11m
Main engine(s)	HYUNDAI MAN B&W 6L60MC
Total power	10,440Kw (14160BHP)
Remarks	Accommodation (Infirmary) – located Forward Engine room – located Aft

SERVICE RUN OF VESSEL

RTY : RCL THAILAND YANGON SERVICE



Origin				Destination/Transit Time				
POL	Terminal Name	ETA	ETD	SIN	RGN	PKG (N)	SIN	TPT
Bangkok/TPT	Thai Prosperity Tml	Sat	Sun	4	8	15	-	-
Singapore	Keppel Terminal	Wed	Thu	-	4	11	-	-
Yangon	Myanmr Industrual Port (MIP)	Sun	Wed	-	-	4	7	11
Port Klang	Northport (Malaysia) Bhd	Sun	Mon	-	-	-	2	6
Singapore	Keppel Terminal	Tue	Wed	-	-	-	-	4
Bangkok/TPT	Thai Prosperity Tml	Sat	Sun	4	8	15	-	-

RCL Group's service pattern for Mathu Bhum as obtained from RCL

1 FACTUAL INFORMATION

All times used in this report are Ship's Mean Time (UTC + 6.5H).

1.1 Sequence of events

1.1.1 On the morning of 3 December 2016, Mathu Bhum, which had departed Singapore on 30 November 2016, was sailing on a north-westerly course in the Gulf of Martaban towards her next port of call in Myanmar.

1.1.2 At about 0800H, the Second Engineer (2E) instructed the Fourth Engineer (4E) to open up the Fire, Bilge and Ballast (FBB) pump (see **Figure 1**), located at the bottom platform of the engine room[1], to take some photographs of the pump's condition for submission to the vessel's Class society for assessment under the Continuous Survey of Machinery (CSM) programme[2]. A crew member, an Oiler[3] (OL), was assigned to assist 4E.

[1] The FBB pump, as well as a Fire and General Service (GS) which is also shown in Figure 1, were two similar pumps in the engine room and were used to provide water for general services, firefighting, ballasting, etc.

[2] The aim of the CSM programme is to assess the general condition of the whole machinery and equipment by opening up a part of the machinery and equipment through reasonable procedures in a continuously and systematically planned manner.

[3] Oiler - Trained and certified as a Rating forming a part of an engineering watch.

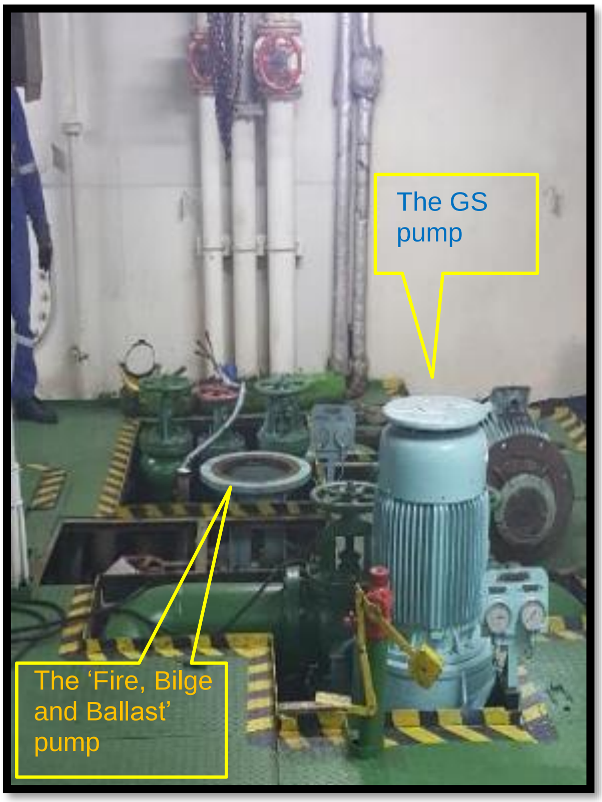


Fig.1 – FBB pump at engine room bottom platform

1.1.3 At about 0830H, 4E and OL began removing the bolts and nuts of the pump. A pre-job briefing for 4E and OL was conducted by 2E as per the company's requirements.

1.1.4 At about 1000H, 4E reported to 2E that he had managed to remove some bolts using appropriate spanners and wrenches. He also reported that some bolts were seized and he had difficulties in removing them. 2E assigned a Wireman (WM) and an Engine Cadet (EC) to assist 4E. 4E remained the overall person-in-charge.

1.1.5 2E suggested that the team make use of the oxy-acetylene gas cutting equipment and welding machine for the removal of the seized bolts. As WM was a trained welder, he was asked to prepare the gas cutting and welding equipment. The welding machine was in the engine room workshop (located two decks above the FBB pump) and the welding cable needed to be run from the welding machine to the FBB pump.

1.1.6 At about 1015H, a risk assessment team (comprising 2E, 4E, OL, WM and EC) prepared a risk[4] assessment[5] of the gas cutting/welding job. The Master and Chief Engineer approved the results of the risk assessment. The Master issued a hot work permit[6] for the job. 2E was the safety officer for ensuring the implementation of risk control measures and also required to be the responsible person in attendance.

1.1.7 At about 1040H, 4E, OL, WM and EC resumed their FBB pump bolts removal work. For the time being, acetylene gas cutting and welding were not needed as the team managed to remove some more bolts using appropriate spanners and wrenches.

1.1.8 At about 1215H, WM informed 4E that he would not be joining the team after the lunch break, as he was required to check the working condition of the deck cranes which would be needed for the arrival port preparations. Subsequently, 4E updated 2E of the work progress and that WM would be away after lunch and he would continue working with OL and EC.

1.1.9 After lunch, at about 1330H and without WM, 4E took upon himself to try to remove the seized bolts using the oxy-acetylene gas cutting equipment (i.e. by heating the bolt heads and then cutting the bolt heads by hammering a wedge through the "soften" bolt heads). He was not successful. He then informed OL and EC that he intended to use the welding machine to weld a metal wedge piece onto bolt heads (see **Figure 2**) with a view to hammering at the end of the metal wedge piece in order to loosen the bolts (i.e. by way of increasing the leverage for turning the bolt heads). He immediately began preparation for the welding. By this time, the boiler suit that he was wearing had become wet owing to his sweating in the engine room's hot environment.

[4] Risk is "a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence." (ISO 8402:1995/BS 4778). Risk in occupational safety and health when referred to, are most commonly defined as 'risk is the likelihood that a person may be harmed or suffers adverse health effects if exposed to a hazard.'

[5] Assessment of risk is the determination of quantitative or qualitative estimate of risk related to a well-defined situation and a recognized threat (also called hazard). Quantitative risk assessment requires calculations of two components of risk (R): the magnitude of the potential loss (L), and the probability (P) that the loss will occur.

[6] Required by the company's Safety Management System when performing any hot work outside the engine room workshop. Hot work permit is typically required for work accompanying high temperatures which can ignite a flame ambient combustible material and flammable gas mixture in a work space and hot work accompanying a naked flame, electric welding, electric cutting, gas welding and gas cutting. (RCL Ship Management SMS, RSM-S-034 Rev.2/02-11-15).

Fig. 2 – Illustration of a metal piece welded to a bolt head

1.1.10 At about 1400H, with OL holding the metal piece with a leather glove, 4E began to weld the metal piece on to the bolt. Noting that there was no power to the electrode, 4E instructed EC to go to the engine room workshop to switch on the welding machine.

1.1.11 According to OL, while waiting for EC to turn on the welding machine, 4E was standing in the engine room tank top and holding the electrode holder in his right hand, with his back leaning against the engine room floor plate (see **Figure 3**). His left hand was resting on the adjacent floor plate. While OL was aware that insulated gloves should be used welding, he did not raise his concern to 4E, as he assumed that 4E, as an officer, knew what he was doing

Fig. 3 – Illustration of 4E's approximate position at the start of welding work

1.1.12 At about 1403H when EC arrived at the engine room workshop, he saw the fitter[7] using the welding machine. The fitter's welding job cable was connected to the welding machine. EC then told the fitter that 4E had instructed him to switch on the welding machine for welding work at FBB. Considering instructions from an engineer officer, the fitter promptly disconnected his welding cable, connected the off-site welding job cable and switched on the power.

[7] Fitter - Trained and certified as a Rating forming a part of an Engineering watch.

1.1.13 At the FBB pump, OL heard 4E shouted suddenly that he was being electrocuted. At that time the 4E's hand was on the non-insulated part of the electrode holder (see **Figure 4**).

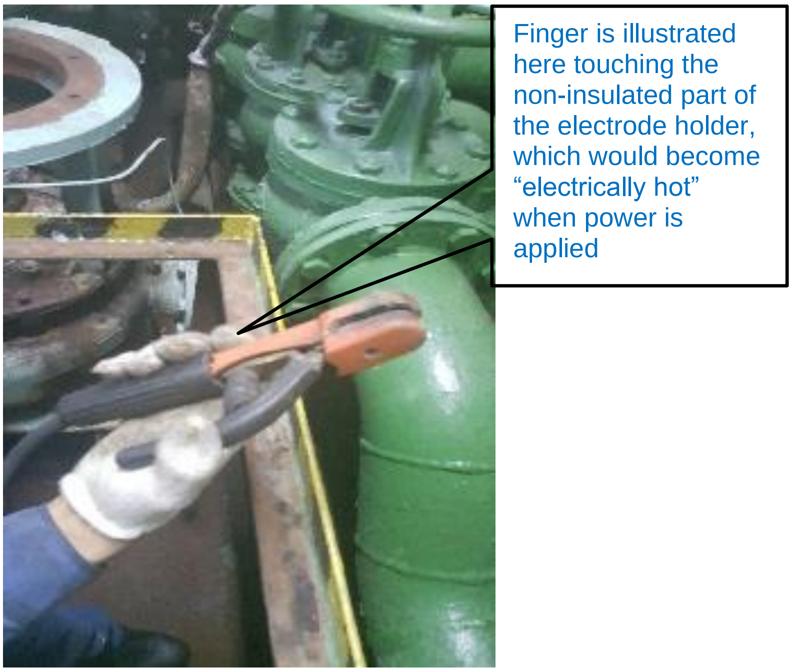


Fig. 4 – Illustration of how 4E was holding the electrode holder

1.1.14 OL immediately pulled the welding cable away from 4E's hand and started to lift 4E off the tank top to the bottom floor plate. EC, unaware of what had happened, had meanwhile came back from the engine room workshop. EC immediately assisted OL in pulling 4E from the tank top. 4E was lifted out and placed on the engine room floor plate. EC immediately informed 2E who was checking the operational readiness of the Oily Water Separator located about 15 metres away and had no line of sight to the FBB pump.

1.1.15 At about 1404H, 2E, after seeing that 4E was unconscious, went to the engine room workshop to inform the other engine crew members about the accident. The fitter also rushed down from the engine room workshop to help.

1.1.16 Engineers started to administer cardiopulmonary resuscitation (CPR) to 4E at about 1405H and 2E informed the duty officer on the bridge, the Master and the Chief Engineer of the accident. By 1408H, the Second Officer (2O), who was the medical officer, and other crew members had arrived with the medical kit and bag, to assist with administering CPR to 4E. The Master reported the accident to the Designated Person Ashore[8] (DPA) who sought medical advice from Kluaynamthai Hospital in Bangkok, Thailand.

1.1.17 CPR was continued till about 1445H when 4E was moved to the engine control room (ECR). At about 1455H, 2O administered 0.4ml adrenaline injection as per medical advice instructions from Kluaynamthai Hospital. By about 1530H, 4E was moved to the ship's infirmary which was located in the accommodation block.

1.1.18 CPR was continued at the infirmary. 4E's vital signs were not detected and he was declared dead in consultation with International Radio Medical Centre (C.I.R.M.)[9]. At about 2000H, 4E's body was moved to the cold room for preservation for offloading at Yangon, Myanmar, the next port. The Master said he noticed, when 4E's body was being prepared for preservation and transfer to the freezer, some burn marks on 4E's shoulder back and left leg near the shin.

1.1.19 On 4 December 2016 at about 0930H, Mathu Bhum was moored at Myanmar International Port (MIP) Berth 1. Officers from Myanmar Police, Myanmar Port Authority and the company's locally appointed agent boarded the vessel. After establishing the circumstances and cause of death, the Myanmar Police and Myanmar Port Authority permitted the vessel to release 4E's body to the mortuary of a local hospital.

1.1.20 4E's body was subsequently handed over to the company's local agent at about 1040H, to facilitate its repatriation to his home.

1.2 Fire, Bilge and Ballast pump

1.2.1 The FBB pump was amongst the machinery items in the engine room that were were subject to the CSM programme. The CSM was to be carried out whilst the vessel was en-route to the next port and photographs of the machinery were to be sent back to the attending Class surveyor for his assessment.

1.2.2 The FBB pump was an electric motor driven centrifugal pump. It was divided into three sections (see **Figure 5**), viz. the motor, the shaft and

[8] A Designated Person Ashore (DPA) serves as the link between the ships and shore management.

[9] The medical assistance (free of charge) of the C.I.R.M. is assured by doctors on call 24 hours. The Ships in navigation with sick or injured person on board can contact the C.I.R.M. by phone or email.

coupling, and the impeller casing. For a comprehensive inspection, these three sections are to be seperated from each other, hence the need for removal of the bolts and nuts.

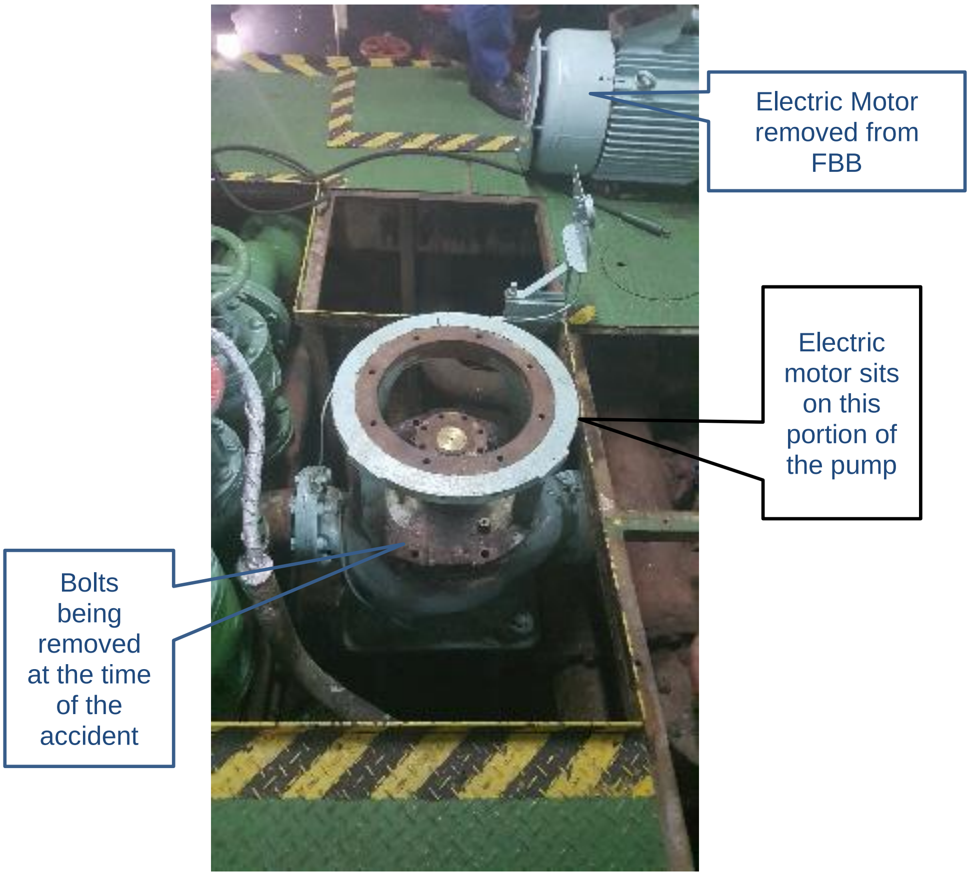


Fig.5 – Sections of the FBB pump

1.2.3 As the pump base foundation sat on the engine room tank top, access for maintenance work was limited (see **Figure 6**).

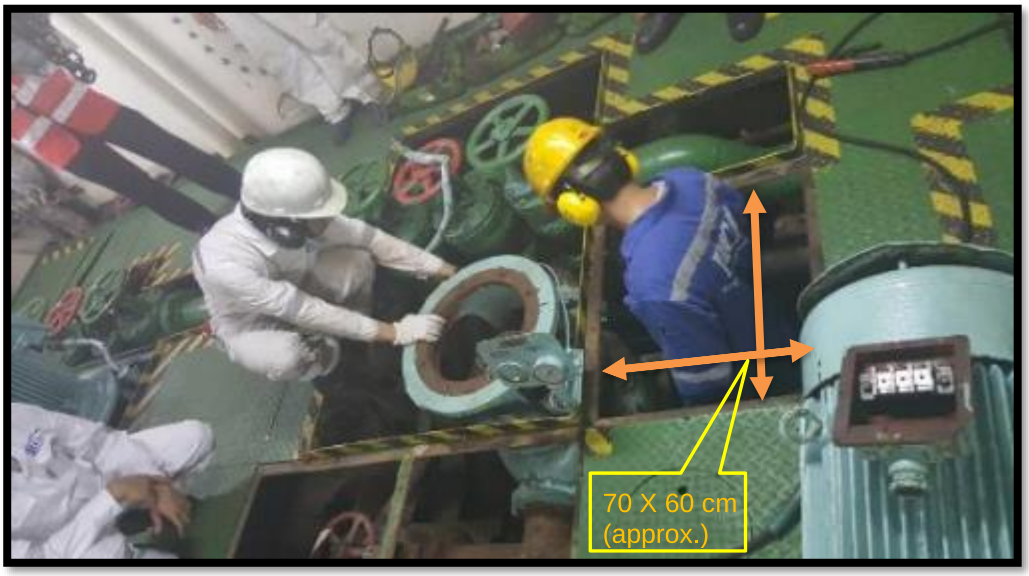


Fig. 6 – Illustration of the workspace around the FBB pump

1.3 Welding machine

1.3.1 The alternating current (AC) arc welding machine on board Mathu Bhum was made by Osaka Transformer Co. Ltd. in 1974. It had been on board since the delivery of the vessel.

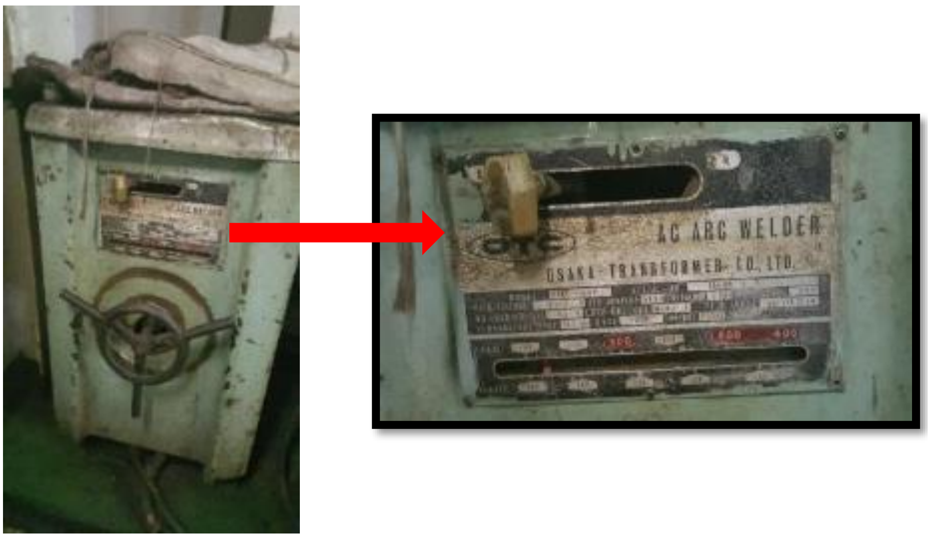


Fig. 7 – (Left) Welding machine on board Mathu Bhum
(Right) Welding machine name plate

1.3.2 A typical welding machine set-up is shown in **Figure 8**.

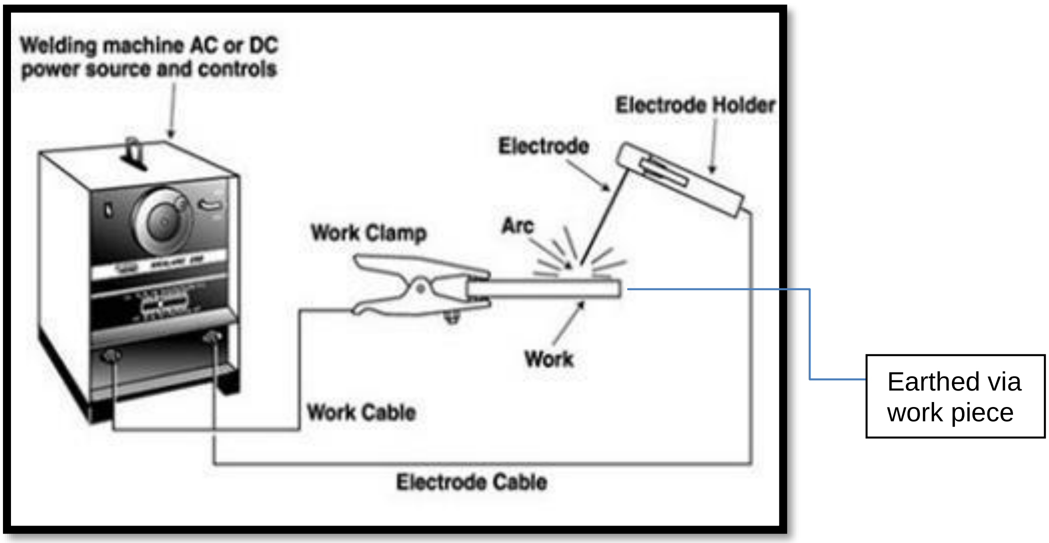


Fig. 8 – A typical welding machine set-up

1.3.3 However, the welding machine set-up on board Mathu Bhum was different from a typical welding machine set-up in that the machine was earthed directly to the ship's hull (see **Figure 9**), thus dispensing with the need of using a welding clamp to clamp the workpiece and then earthing the work piece.

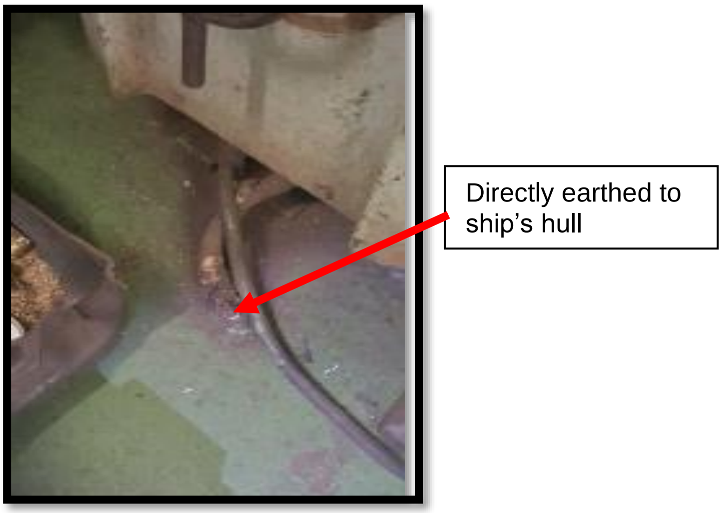


Fig.9 – Earthing of welding machine

1.3.4 The welding machine itself did not have an ON/OFF switch. It had three cables with connectors. One cable was connected to a power source in the engine room workshop (see **Figure 10**) and the other two welding job cables could be connected to the welding electrode holder.

Fig. 10 - Power source in the engine room workshop

1.3.5 The AC supply to the welding machine was stepped down to a lower voltage through a transformer. It had a Non Load Voltage[10] of 80 volts as indicated on the welding machine name plate.

1.3.6 A monthly inspection record of the welding machine was kept on board by WM. The machine was last inspected by WM on 19 November 2016. The result was noted as Satisfactory.

1.3.7 The company's Planned Maintenance System history records showed an entry on 15 November 2016 by 2E that stated – *Checked was condition and operation test machine tool, cutting and welding equipment found satisfactory – Good Condition.*

1.3.8 Inspection of the machine post-accident showed that while the welding electrode holder's insulated handle was intact, certain parts of the holder were not well maintained - a couple of screws were not recessed or missing, and the sheath was cracked in some areas (See **Figure 11**).

[10] Non Load Voltage is when the welding machine's power is switched on but the welding has not commenced, i.e. the electrode has not touched the welding piece to close the electrical circuit.

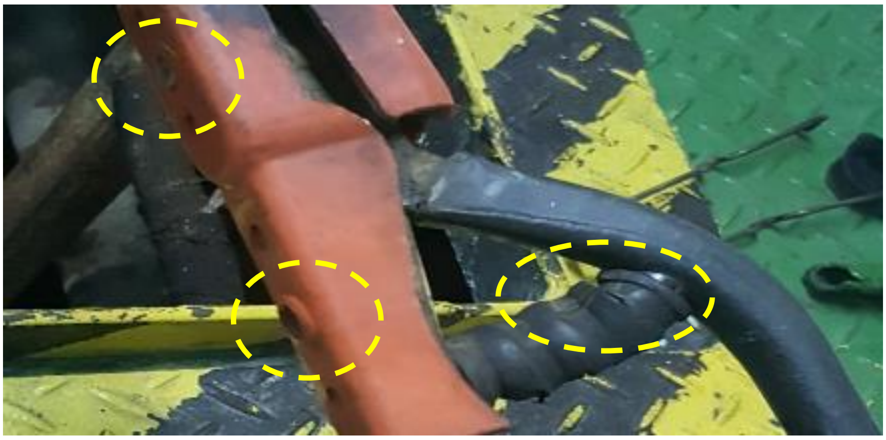


Fig. 11 – Welding electrode holder

1.4 Safety Management System (SMS)

1.4.1 The vessel held the relevant certificates to indicate compliance with the International Safety Management Code and a functional Safety Management System (SMS). The other documents on board the vessel included organisational policies, procedures, manuals, checklists, etc. and reference to industry common publications such as the Code of Safe Working Practices.

1.4.2 The company's SMS[11] stated –

The risks of electric shock are much greater on board a ship than they are normally ashore because of wetness, high humidity and high temperature including sweating reduce the contact resistance of the body. In those conditions severe and even fatal shocks may be caused at voltages as low as 60V. A notice of instructions on the treatment of electric shock should be posted in every place containing electric equipment and switchgear. Immediate on the spot treatment of an unconscious patient is essential.

1.4.3 For this non-routine work activity of removal of bolts from the body of the FBB pump, a risk assessment (RA), as required per the company's SMS (RSM-S-RA 03 Form Rev.2/16-05-16), was duly carried out by the team of 2E, 4E, OL, WM and EC on 3 December 2016. The results of the RA were approved by the Master and Chief Engineer.

[11] All officers and crew had acknowledged their familiarisation with the company's SMS.

1.4.4 One of the hazards[12] identified in the RA assessment was "electric shock while welding at work site". The hazard as per the risk matrix was assigned a "High Risk[13]" factor. The existing control measures were:

- To have all equipment checked and tested checked by Electrician (Wireman) before use and ensure they are in good order
- To follow the instructions in the hot work permit
- To keep the work site dry and clear from any liquid and water

1.4.5 To further reduce this risk, additional control measures were introduced and documented (see **Figure 13**), viz.:

- To have an additional person to be standing by for cutting off the power
- To frequently check engine room tank-top floor for any presence of water

The incorporation of these additional control measures would reduce the hazard to a "low risk[14]" factor. 2E was the safety officer for ensuring the implementation of risk control measures.

1.4.6 The Master then issued a hot work permit[15] valid from 1040H to 1600H for the use of welding and gas cutting equipment, in accordance with the company's SMS, for the work[16] to commence. The permit also required 2E to be the responsible person and be in attendance. The permit implied that WM, being a part of the team was to perform the welding task but did not clearly specify this role.

1.4.7 The company's SMS required Shipboard Safety Committee meetings be conducted monthly and the outcome reported to the company. The outcomes of the three monthly meetings prior to the accident (on 29 September, 31 October and 29 November 2016) included the following:

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[12] A hazard is something that can cause harm, e.g. working with welding machine with a possibility of electrocution. A risk is the chance, high or low, that the person will get electrocuted.

[13] High risk (from risk matrix) identified the consequence as extreme and the probability of occurrence as unlikely.

[14] Low risk (from risk matrix) identified the consequence as moderate and the probability of occurrence as unlikely.

[15] As per company's SMS – Relating to any work involving temperature conditions which are likely to be of sufficient intensity to cause ignition of combustible gases, vapours or liquids in or adjacent to the area involved.

[16] Welding bolts for the removal of FBB

- *Only crew who had received appropriate training and demonstrated adequate skill shall be allowed to operate cranes, welding equipment, anchor winches or other potentially dangerous heavy machinery or power tools.*
- *Head of department should emphasise the safety working on board to all crew; some of the training crew to be guided and observed for the job, sometime need to brief job description before commencement of work.*
- *Senior officers are requested to closely monitor and instruct the crew to wear safety gears while working on deck, in engine room, in enclosed space on hot work job.*
- *Senior officers are reminded to observe closely and ensure that the Safe Working Practices are adopted and followed by the crew in order to protect the ship's crew from any risk of accidents.*

1.4.8 The company's SMS had a safe working requirement poster, stipulating various types of Personal Protective Equipment (PPE) to be worn when performing different types of work.

One of these safety requirements was:

Hands-Arms protection	**Hazards** – abrasion, temperature extremes, cuts and punctures, impact, chemicals, **electric shock**, skin infection, disease or contamination
	Options – wear gloves, insulation gloves, gauntlets, mitts, wrist cuffs, armlets

1.4.9 WM and 2E were not with the 4E, OL and EC at the time of the accident. 2E was checking the operational readiness of the Oily Water Separator located about 15 metres away.

1.5 Regulatory requirements

1.5.1 Regulation 54 "*Electrical welding equipment*" of Singapore's Workplace Safety and Health (Shipbuilding and Ship Repairing) Regulations 2008[17] requires the following:

[17] WSH Act under Ministry of Manpower (MOM) – Key legislation to effect the principles of Occupational Safety and Health framework.

(1) It shall be the duty of any person who provides any alternating current (AC) electric arc welding equipment for use in a shipyard or on board a ship in a harbour to comply with paragraphs (2) and (3).

(2) All alternating current (AC) electric arc welding equipment for use in a shipyard or on board a ship in a harbour shall be fitted with an effective low voltage shock preventer which reduces the open-circuit secondary[18] *voltage to not exceeding 25 volts.*

(3) The low voltage shock preventer referred to in paragraph (2) shall be —

(a) fitted in accordance with the manufacturer's instructions; and
(b) inspected and tested by a competent person once every 6 months.

1.5.2 MOM's regulation applies to ships in harbour and does not apply when ships are outside the harbour.

1.5.3 Singapore's Merchant Shipping Act and related Regulations which applies to Singapore registered ships do not have a similar regulatory requirement for e.g. *requiring the person providing an AC electric arc welding equipment on a Singapore ship to be fitted with an effective low-voltage shock preventer which reduces the open circuit secondary voltage to not exceeding 25 volts*.

1.5.4 There are also no Classification rules and requirements under hull and machinery for welding equipment on board a vessel.

1.5.5 Safety practices for welding issued by many government agencies also highlighted that, if welding was to be performed under electrically hazardous conditions (damp or while wearing wet clothing, on metal structures such as gratings, floors or scaffolds when there is a high risk of unavoidable or accidental contact with the work piece or ground), the use of the following equipment was advised:

- Semiautomatic DC constant Voltage welder
- DC Manual (Stick) welder
- AC Welder with reduced voltage control

[18] Literature on Electric shock by welding – Primary Shock Voltage (230, 460 volts) and Secondary shock voltage (20-100 volts).

1.5.6 The Code of Safe Working Practices for Merchant Seafarers[19] (COSWP) published by the Maritime and Coastguard Agency (MCA) of the United Kingdom provides best practice guidance for improving health and safety on board ships. COSWP recommends that AC electric arc welding equipment on board ships –

> *"may be used provided they have an integral voltage-limiting device to ensure that the idling voltage (voltage between electrode and work-piece before an arc is struck between them) does not exceed 25 V rms".*

1.5.7 A copy of the 2015 Edition of COSWP had been on board the Mathu Bhum since June 2016. None of the officers and crew interviewed by the investigation team were aware of the information contained in COSWP on performing welding work with an AC electric arc welding equipment.

1.6 Vessel's manning

1.6.1 The vessel's complement comprised 23 Thai nationals including the Master. All officers held valid STCW[20] certificates of competency and appropriate endorsements from the Flag Administration, and all crew members held valid training certificates for their position on board and had undergone training for medical first aid and care on board a ship.

1.6.2 4E, the deceased, a 26-year old Thai national, had been with the company for 38 months since his cadetship, serving on similar type of ships. He had been on board the vessel in the current contract for about 4 months, having joined the vessel on 28 July 2016.

1.6.3 4E had 9 months in rank experience. He had undergone some welding related training, as part of this his competency examinations.

[19] Although COSWP carriage on board Singapore registered ships is non-mandatory, the publication is widely known in the industry for good recommendations on safe working practices on board ships.

[20] The International Convention on Standards of Training, Certification and Watch keeping for Seafarers (or STCW), 1978 sets qualification standards for masters, officers and watch personnel on seagoing merchant ships.

1.6.4 The daily watch-keeping schedule for 4E was as follows:

Schedule daily work hours at sea (watch-keeping)	Schedule daily work hours at port (watch-keeping)	Remarks
0800-1200 2000-2400	0600-1200 1800-2400	Overtime at sea 1300-1500

1.6.5 4E was certified medically fit for sea service on 1 June 2016 without any conditions by a maritime medical clinic approved by the competent authority in Thailand. He had 14 hours of rest in the last 24 hours prior to the accident, of which 8 hours were continuous. This was in compliance with requirements of the STCW 95 Convention and Maritime Labour Convention.

1.6.6 2E was 29 years old, and had been with the company since 2010, starting off as a cadet. He was promoted to the rank of a second engineer in 2013. He sailed in that rank for about 5 months. Thereafter he sailed as a third engineer for 9 months, before taking up the role of a second engineer on Mathu Bhum in 2015 for 5 months.

1.6.7 He left the company for 2 years, before returning and joining Mathu Bhum as second engineer in November 2016, i.e. a month before the accident. He had a combined sea-service of about 4 years, including his cadet days. He had about 11 months of in-rank experience with the company.

1.6.8 In addition to STCW certificates, WM held a (non-mandatory) Welder Approval Test Certificate for Manual Metal Arc Welding Level 1 issued in 2011 from a training institute in Songkhla, Thailand.

1.6.9 4E, OL and the fitter were not in possession of any welding certificates or qualifications. There were no training records to show that they had undergone any training for welding.

1.6.10 Rest hour records were kept. Rest taken by all officers and crew complied with rest hour requirements under the STCW 95 Convention and Maritime Labour Convention.

1.6.11 Alcohol test conducted by the Master post-accident showed that none of the officers and crew members were under the influence of alcohol.

1.7 Weather conditions

1.7.1 The weather at the time of the accident was cloudy with North-easterly wind at about 10 knots with good visibility. The state of the sea was large wavelets with scattered whitecaps (crests). There were no reported unusual rolling of the vessel.

1.7.2 Air and Sea temperatures were reported to be about 29° and 30° Celsius respectively. Ambient temperatures inside the engine room was recorded as 45° Celsius.

1.8 Autopsy report

1.8.1 An autopsy conducted by the Department of Medical Care, Yangon General Hospital, Office of Police Surgeon indicated - an acute circulatory collapse[21] (pending the results of Histopathology and Chemical examination, which were not yet available at the time of the completion of this investigation report).

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[21] A circulatory collapse is defined as a general or specific failure of the circulation, either cardiac or peripheral in nature. Although the mechanisms, causes and clinical syndromes are different the pathogenesis is the same, the circulatory system fails to maintain the supply of oxygen and other nutrients to the tissues and to remove the carbon dioxide and other metabolites from them. The failure may be hypovolemic, distributive. A common cause of this could be shock or trauma from injury or surgery – Open source

2 ANALYSIS

2.1 The occurrence

2.1.1 4E was electrocuted when his welding cable was connected to the power. The electrocution was most likely as a result of secondary voltage when 4E's body completed an electrical circuit with the welding equipment as follows:

- 4E's wet right hand's contact with the "electrically hot" part of the electrode holder (see Fig. 3 in paragraph 1.1.13); and
- 4E's left leg's contact with the foundation of the FBB pump's base[22].

Thus, the AC current flowed through 4E's body between the wet right hand and the left leg[23].

2.1.2 The following unsafe conditions were present in this accident:

- 4E was using cotton gloves[24] to handle the non-insulated portion of the electrode holder;
- The tank-top had some puddles of water where he was standing;
- The working environment of a typical engine room had caused his boiler suit to be wet due to sweating (thus reducing his body's electrical resistance);
- The limited workspace around the FBB pump (see Figure 5 in paragraph 1.3.4); and
- Absence of a low voltage shock preventer that could reduce the welding machine's No-Load Voltage of 80 volts to not more than 25 volts.

[22] Although this was not witnessed by OL, it was very likely that 4E's left leg was pressed against the foundation of the pump's base. This was corroborated by the burn marks on 4E's left leg.

[23] In an electrocution, an AC current will flow through the human body, potentially causing seizures which can result in cardiac arrest, whereas a DC current will flow on the surface of the human body. (See Electric Arc Welding On board: Essential Safety Checks and Precautions – Source - Wilhelmsen).

[24] 4E did not wear any leather gloves. A pair of leather gloves prepared by WM before lunch were in the vicinity of the FBB pump.

2.2 Welding machine

2.2.1 The power source cable coming from the welding machine can be connected to either the short welding job cable for welding works inside the workshop, or to the longer welding job cable for welding works outside the workshop. Only one welding job cable can be connected to the power source cable at one time.

2.2.2 The fitter, on being asked by EC to switch the cables for 4E, did as he was told, and switched on the power to the welding machine without checking the situation at the FBB pump. There seem to be no clear responsibility as to who was to perform the connector change-over and whether this change-over required communication between the personnel involved in the current job and the new job.

2.2.3 The electrocution was unlikely to be a result of a defect of the welding machine. The welding machine had been in use by the fitter before the accident, and there was no defect reported about the welding machine by any users (including WM and the fitter).

2.2.4 The electrode holder was not very well maintained. While this condition did not affect its operational capability, the "electrically hot" parts of the holder contributed to the occurrence, when 4E inappropriately held the holder with wet cotton gloves.

2.2.5 The welding machine on board the vessel did not have a voltage limiting device to prevent risk of secondary voltage shock.

2.2.6 The company's SMS had not taken into account the provisions of COSWP, despite it being referenced as a part of the company's SMS in assessing risks associated with working with AC welding equipment on board.

2.3 Voltage limiting device

2.3.1 A low voltage shock preventer (voltage limiting device) is required under Regulation 54 "*Electrical welding equipment*" of Singapore's Workplace Safety and Health (Shipbuilding and Ship Repairing) Regulations, to prevent the risk of secondary voltage shock for users when ships are in harbour.

2.3.2 It is desirable for Flag Administrations to ensure such a device is fitted whenever an AC Arc Welding equipment is in use, regardless of the location of the ship, i.e. within harbour or outside of it.

2.4 Human element

2.4.1 4E had a combined sea service of about 3 years, including his cadet days. He had only about 9 months in rank experience on similar type of vessels. His experience on welding and related knowledge would be expected to be limited to what he was taught during his training at his maritime college. There were no records of him being specifically trained to perform any welding work on board the vessel. 2E had assigned him a welding related job despite knowing that safety committee meetings had stressed that untrained personnel were not to perform tasks such as welding.

2.4.2 2E was the assigned safety officer to supervise the work for which a hot work permit and RA was issued. However, he was not on-site to supervise.

2.4.3 When WM (a certified welder) went to perform another task of checking the cranes prior to the vessel's arrival at the next port, 2E did not re-assess[25] the existing control measures and potential risks of the work being performed by a non-qualified person.

2.4.4 OL did not raise his concern to 4E when he observed an unsafe practice by the latter of holding the electrode holder, due to the authority gradient, i.e. afraid to speak up because the other party is perceived to be more senior (and thus higher authority).

2.4.5 Likewise, when EC informed the fitter to changeover the welding cable power to 4E's cable, the fitter did not raise any concern due to the authority gradient.

[25] This could be due to a combination of his lack of experience with welding related tasks and his being focused on another non-priority job.

2.5 Safety Management System (SMS)

2.5.1 The company's SMS catered for RA and permits to work, including hot work permit.

2.5.2 Although the RA conducted on the day of the operation identified specific hazards with risk of electric shock, its likelihood of harm was assessed as "Unlikely". The company's SMS did not provide for an oversight mechanism to ensure RA's when conducted, are in line with industry practice or norm[26]. The risks of work involving an AC electric arc welding equipment without a voltage limiter had also not been addressed in the risk control measures.

2.5.3 The process of RA and hot work permit should take into consideration changes in circumstances and situations which would require the identification of additional hazards that were not present earlier. The RA was aimed to fulfil SMS requirements. It however did not achieve the intended purpose, i.e. reduction of risk factors by implementing effective risk control measures.

2.5.4 The SMS did not clearly identify the person or persons suitably qualified and competent to handle the welding equipment and to perform welding work on board.

2.5.5 There was no specific requirement in the company's SMS for training of personnel, on non-mandatory technical skills, such as welding, despite the monthly meetings stressing that work should only be performed by properly trained personnel.

2.5.6 The SMS did not cater for addressing the authority-gradient to give the seafarer confidence to stop work if they feel work was unsafe[27].

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[26] Typically, a High Risk activity is associated with a "likely occurrence" rather than as an "Unlikely occurrence". Even more so in this case, where the likelihood of electric shock was "Unlikely" for an activity involving electric welding equipment.

[27] COSWP – Chapter 2.8.3 – Personnel who find a condition that they believe to be hazardous or unsafe, should immediately report it to a responsible person who should take appropriate action.

3 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 cause of factor of this occurrence was the unsafe handling of the electrode holder of an AC electric arc welding equipment with no voltage limiting device, while working in a hazardous (damp) environment.

3.2 Other safety factors involved in this accident included the following:

- The welding machine related tasks were not performed or supervised by a trained and experienced person.
- The risk assessment as required by SMS did not achieve the intended purpose, i.e. reduction of risk factors by implementing effective risk control measures.
- Clear responsibilities of operation of the welding equipment were not established.
- Perception of officer-crew relationship and authority gradient in the OL's mind resulted in him not raising his concern to the 4E when he observed an unsafe practice by the latter of holding the electrode holder.

4 SAFETY ACTIONS

During the course of the investigation and through discussions with the investigation team, the following safety action was initiated by the shipping company.

4.1 Following the accident, the Company implemented the following additional preventive measures and issued instructions to their fleet, related to welding:

- Personnel performing welding work should don dry boiler suit and only use dry insulating gloves
- Conduct safety precaution briefing and establish communication system before starting and during the work;
- Post established risk assessment and hot work permit at the site visible to all crew working at the site;
- Ensure proper procedures in place for welding work such as to disconnect input power before changing connections and not conduct welding when standing on wet surface or while standing in water;
- Attendance by head of department or assign a supervisor to monitor the welding work onsite; and
- Implemented a STOP Work Authority procedure vide a revision to their SMS, RSM-S-091, to inculcate a safety culture on board the vessel in general, especially when unsafe practices are observed, so that any authority gradient is managed effectively.

5 SAFETY RECOMMENDATION

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

5.1 To the company – To revise the company's SMS by documenting welding related work responsibilities, to ensure that personnel involved in performing welding works are appropriately trained and qualified. **[TSIB-RM-2018-002]**

5.2 To the company – To revise the SMS in order to take into account safe working practices for welding. **[TSIB-RM-2018-003]**

5.3 To the company – To review its SMS to ensure the effectiveness and oversight of the conduct of effective risk assessments and permits to work. **[TSIB-RM-2018-004]**

5.4 To the Flag Administration – Recognising that there may be no statutory requirement for ships to be installed with a voltage limiting device on AC electric arc welding equipment, to recommend to the owners and operators of Singapore registered ships for the installation and use of voltage limiting device to be included in the company's SMS, by issuing an appropriate Shipping Circular. **[TSIB-RM-2018-005]**

End of Report