Final Report

ELECTROCUTION OF WELDER ON BOARD THE CONTAINER SHIP SOUTHERN LILY AT SEA ON 23 JULY 2018

TIB/MAI/CAS.084

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

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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.

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Table of Contents

SYNOPSIS

On 23 July 2018[1], at about 1055H, the Singapore registered container ship, Southern Lily was underway at sea, bound for the Port of Apia, Samoa.

The Welder was carrying out repair of the ship's safety railings on deck alone, without any assistant or supervision. The Welder suffered cardiac arrest and burn injuries after an electrocution and succumbed to the injuries before reaching the hospital.

The Transport Safety Investigation Bureau of Singapore classified the occurrence as Very Serious Marine Casualty and launched a marine safety investigation.

The investigation revealed that, it was probable that rainwater got onto the deck when the Welder was in the process of welding and had resulted in the electrocution. The assistant assigned to the Welder for the hot work deviated from the role and went to perform another task.

The investigation also revealed that the welding machine installed on board was an alternating current output type without voltage limiting device fitted which exposed user to higher risk of electrocution. In addition, the person responsible to conduct safety checks for the welding task did not possess the relevant knowledge and the terms used in the safety checklist pertaining to the hot work procedure were not clear.

[1] TSIB came to know about this occurrence on 6 July 2020.

VIEW OF VESSEL

Southern Lily
(*Source*: ShipSpotting.com)

DETAILS OF VESSEL

Name	Southern Lily
IMO Number	9296339
Flag	Singapore
Classification society	Nippon Kaiji Kyokai (ClassNK) / Lloyd's Register (LR)[2]
Ship type	Container ship
Hull	Steel
Delivery	11 January 2006
Owner / Operators / ISM[3] Managers	Pacific International Lines (Private) Limited
Gross tonnage	9725
Length overall	145.93m
Moulded breadth	22.60m
Moulded depth	10.80m
Summer draft	8.12m
Max cargo capacity	907 TEU[4]

[2] ClassNK was for conducting survey and issuance of other statutory certificates. LR was for carrying out ISM audit and issuance of ISM related certificates.
[3] International management code for the safe operation of ships and for pollution prevention.
[4] Twenty-foot equivalent unit.

1 FACTUAL INFORMATION

All times used in this report are ship's mean time of Southern Lily, which was thirteen hours ahead the UTC (UTC + 13H), unless otherwise stated.

1.1 Sequence of events

1.1.1 On 23 July 2018, the Singapore registered container ship, Southern Lily (SL) was underway at sea, at a speed of about 13 knots (kt), bound for the Port of Apia, Samoa.

1.1.2 At about 0730H, the Welder[5], together with the Bosun, met the Chief Officer[6] on the bridge for a briefing on the jobs for the day as this was the standard practice on board SL. The Welder and the Bosun were given different jobs.

1.1.3 The Welder was assigned a job of repairing a damaged[7] ship side safety railings on the starboard side main deck near bay 27. An Able Seafarer Deck (ASD) who was on the same navigational watch as the Chief Officer was also at the briefing, had been assigned to assist the Welder. A hot work permit was prepared by the Chief Officer after completing a risk assessment (RA), contents of which were communicated during the briefing to the attendees.

1.1.4 At about 0800H, the Welder prepared[8] for hot work at the site and the ASD performed a radio check with the bridge duty officer (the Third Officer) with a portable radio. Thereafter the duo started straightening the dented railings using a hydraulic jack.

1.1.5 By about 0900H, the Chief Officer came on the main deck for a safety round[9] and joined the duo briefly in straightening the dented railings.

1.1.6 The straightening of the railings completed before the morning tea break (at about 1000H) and the Chief Officer returned to the ship office. The Welder and the ASD too went to the mess room for tea break.

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[5] A dayworker who was having routine working hours between 0800H and 1700H at sea, was told to take deck repair job order from the Chief Officer for the day as instructed by his superior, the Chief Engineer.

[6] Kept navigational watches for the periods of 0400H-0800H and 1600H-2000H at sea.

[7] In dented and broken condition arising from previous cargo operations. Number of damaged safety railings to be repaired were not recorded.

[8] The preparation work included running of the welding cable from the forecastle store and getting ready the welding kit comprising the welding gloves, shield, electrodes and holder.

[9] A practice carried out by the Chief Officer in the morning to ensure all was in good order including safety of crew working on deck when at sea.

1.1.7 At about 1030H, the Welder returned to the work site, preparing to start the welding work. After donning the life vest brought by the ASD, the Welder told the ASD to carry on with the painting work[10] of the crane housing fenders at the aft of the lifeboat deck. The ASD left for the painting work and the Welder commenced the welding work alone.

1.1.8 At about 1055H, the Master came on deck for a round[11] and saw the Welder lying on the floor unconscious with face down near bay 27. The welding cable and electrode holder were found about half a meter away from the Welder.

1.1.9 The Master turned the Welder over and noted that the Welder had a weak pulse. The Master went into the accommodation to alert the Chief Officer and subsequently informed the Third Officer on the bridge to sound the general alarm and make an announcement for mustering all the crew for the emergency. The Master then returned to the location and started to provide CPR[12] to the Welder.

1.1.10 At about 1100H, the ASD heard the alarm and returned to the main deck and saw the Master providing CPR to the Welder.

1.1.11 At about same time, the Bosun too arrived at the main deck, and the Master instructed the Bosun to switch off the power source of the welding machine. A short while later, the Chief Officer came to the site and took over from the Master to continue administering CPR. The Welder remained unconscious with weak pulse.

1.1.12 By about 1115H, the Welder was transferred to the infirmary, where CPR was continued and vital signs measured, which appeared very weak.

1.1.13 The Master subsequently sought radio medical advice[13] and was advised to arrange for the Welder to receive shore medical treatment as soon as possible.

1.1.14 At about 1158H, the Master called the Company (the ISM Manager) informing

[10] According to the ASD. Painting was the second job assigned to the ASD by the Chief Officer for the day.
[11] Similar practice as the Chief Officer's, to carry out daily deck round to see if all was in order.
[12] Cardiopulmonary resuscitation, a lifesaving technique used in many emergencies including heart attack. The STCW (The International Convention on Standards of Training, Certification and Watch keeping for Seafarers), Convention, A-VI/4 mandatorily requires seafarers to have minimum standards of competence related to medical first aid and medical onboard ship, this includes providing immediate first aid in the event of accident or illness.
[13] CIRM (Centro Internazionale Radio Medico), a medical centre in Rome, Italy that provides radio medical advice by doctors to ships of any nationality navigating at sea. The Master sought advice from another service provider SEABIRD, a medical care centre in India, contracted by the Company to provide for pre-employment medical check-up for the ship's crew.

them of the occurrence and conveyed the intention of diverting the ship to the nearest port for the Welder to receive proper medical treatment.

1.1.15 The Master diverted SL to Nukualofa, Tonga and made the necessary arrangements with the Company's local agent. By about 1801H, SL had arrived at the Port of Nukualofa and the Welder was transferred to a launch boat for subsequent travel to a hospital.

1.1.16 On the morning of 24 July 2018, the Master received information from the agent that the Welder had passed away[14] before reaching the hospital.

1.2 The ship

1.2.1 SL was a feeder container ship, constructed with four cargo holds and two cargo cranes installed along the ship's centre line.

1.2.2 The main deck was one level lower than the poop deck outside the accommodation and connected by an inclined staircase on both sides.

1.2.3 At the time of occurrence, the location where the Welder was working was sheltered by 40-foot containers loaded above. The ASD was working at A-deck (lifeboat deck) which was one deck above the poop deck (see **figure 1**). Bay 27 was located at the last cargo hold in front of the accommodation. The locations between the ASD and the Welder were blocked by the 40-foot containers at that bay.

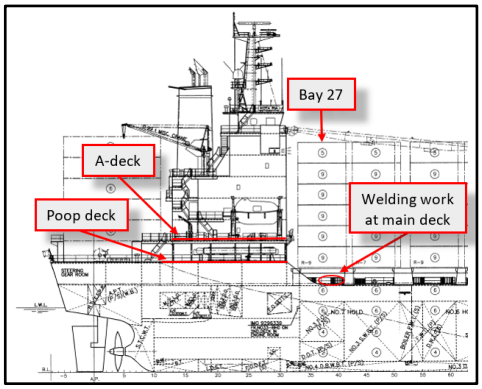

Figure 1 – SL's General Arrangement Plan annotated by TSIB with the two locations (*Source*: The Company).

[14] According to a letter issued by a Medical Officer from the local hospital, the Welder had no signs of life upon arrival at the hospital at 1830H on 23 July 2018.

1.3 The crew

1.3.1 At the time of the occurrence, 22 crew (including the Master) of six nationalities were on board SL. All the crew held valid STCW[15] competency certificates required for their respective positions on board. The working language on board was English.

1.3.2 The Chinese Master joined the Company as Deck Cadet in 2002 and had risen progressively to the rank of Master in about 12 years. The Master had signed off from SL in January 2018 and re-joined SL again in March 2018.

1.3.3 The Chinese Chief Officer joined the Company as Second Officer in 2009, after serving three ships was promoted to the rank of Chief Officer in 2011. He held a Certificate of Competency qualified to be a Master in 2015 and had undergone a Senior Officer Leadership Assessment training programme in 2017. The Chief Officer had served on more than five container ships with this Company.

1.3.4 The Fijian ASD joined the Company in December 2017 and SL was the first contract with the Company. The ASD had served on various types of ship and this was the ASD's second container ship.

1.3.5 The Indian Welder had been on board for about eight months, having joined SL also in December 2017, this being the first time with the Company. Prior to joining this Company, the Welder had worked as a Fitter[16] for about 10 years with another shipping company and had served on container ships. He held a Welder Performance Qualification Certificate[17] dated 14 June 2016.

1.3.6 The ship's records indicated that the Welder and the ASD had attended several types of training during their tenure on board SL, including risk assessment (generic), personal safety on operating power and high pressure tools, hot work procedures (including permit to work and checklists to follow), and occupational health and safety, etc.

1.3.7 According to the STCW Convention, a minimum competency of the electrical

[15] STCW, Manila Amendments sets qualification standards for masters, officers and watch personnel on seagoing merchant ships.

[16] Part of the Fitter's responsibilities was to carry out ship repair on board, including cutting and welding tasks.

[17] There is no statutory qualification under STCW for being engaged as a welder on board a ship. Most companies engage persons who hold some certification for welding in the marine industry as welders. The Performance Qualification Certificate indicated that a certain quality standard on welding had been obtained by a person.

and control engineering knowledge at the management level[18] would be required to be held by the Chief Engineer Officer and Second Engineer Officer. Both the Chief Engineer and Second Engineer possessed appropriate qualifications under the STCW Convention.

1.3.8 A check on the repair jobs carried out in the past indicated that the Welder had carried out welding of the ship side safety railings at the occurrence site two days before the occurrence. The Welder had also performed welding works on many other occasions in the month of July, such as cargo hold air vent pipes, container sockets on hatch covers, lashing platforms, ballast tank air pipe on main deck and mooring roller fairlead.

1.3.9 According to the work/rest hour records, maintained electronically, the Welder had 13.5 hours of rest[19] on the previous day (22 July 2018), and had 94.5 hours of rest in the last 7-day period (16 to 22 July 2018), indicating compliance (as documented) with the STCW and MLC Convention's requirements concerning the hours of work and rest[20].

1.4 The welding machine

1.4.1 The alternating current (AC) arc[21] welding machine was manufactured in 2004 and was installed inside the forecastle store (see **figure 2**). The welding machine was of a transformer type, which stepped down 440V AC from the ship's main power source to 80V AC (maximum no-load voltage[22]). There was no voltage-limiting device (VLD)[23] fitted to the welding machine.

[18] STCW, Chapter III, Section A-III/2. The competence includes operate, test, detect faults, maintain and restore electrical and electronic control equipment to the operating condition on board.
[19] 22 July 2018 was a weekend (Sunday), the Welder was permitted five hours overtime in the morning.
[20] STCW, Chapter VIII and MLC, Reg 2.3 with regards to rest hour - Minimum hours of rest shall not be less than i) ten hours in any 24-hour period; and ii) 77 hours in any seven-day period. Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours.
[21] A type of fusion welding process using an electric arc to create an intense heat to melt and join metals, this electric arc is created between a consumable or non-consumable electrode and the base material using alternating currents (AC) from a power supply.
[22] The maximum working voltage of a welding machine which is switched on, but not in use.
[23] Also refers to low voltage shock preventer, it reduces the voltage at the output terminals of the welding equipment to a safe voltage to protect the operator against electric shock.

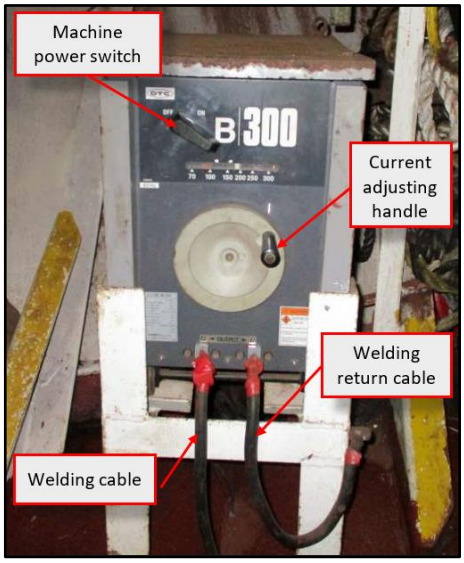

Figure 2 – The welding machine inside forecastle store used at the time of the occurrence - annotated by TSIB
(*Source*: The Company)

1.4.2 According to the maker's user manual, the welding machine met the ANSI Standard Z49.1[24] and CGA Standard W117.2[25]. The main specifications are tabulated in table-1.

Type	Bz-300F-4
Rated output current	300 A
Rated input voltage	440 V
Rated frequency	60 Hz
Rated output	25kVA. 13.8kW
Output current range	70 – 300A
Max. no-load voltage	80 V
Rated load voltage	35 V
Temperature rise	160 °C
Weight	63kg

Table-1 – Welding machine main specifications

[24] Safety in Welding and Cutting from American Welding Society.
[25] Code for Safety Welding and Cutting from Canadian Standards Association.

1.4.3 The user manual provided some safe welding precautions as follows:

a) Read and understand the safety information given in the manual;
b) Have only trained and experienced persons perform installation, operation, and maintenance of this equipment;
c) Use only well-maintained equipment, repair or repair damaged parts at once;
d) Do not touch live electrical parts;
e) Wear dry, hole free insulating gloves and body protection;
f) Insulate yourself from work and ground using dry insulating mats or covers;
g) Properly install and ground this equipment according to its User Manual;
h) Ground the workplace;
i) Do not use worn, damaged, undersized or poorly spliced cables;
j) Do not touch electrode and any metal object if power switch is on;
k) Do not wrap weld cables around your body; and
l) Turn off power switch when not in use.

1.4.4 Additionally, there was a safety warning sign cautioned “Electric shock can kill” which was pasted on the welding machine (see **Figure 3**), and another warning which stated not to touch live electrical parts.

Figure 3 – Warning sign - annotated by TSIB in red
(*Source*: The Company)

1.4.5 The welding cable (electrode lead cable) connected to the welding machine, when not in use, were normally coiled up and hung on a fixed hook inside the store. According to the crew on board SL, when welding was needed, the welding cable (and extension cables with connector) would be pulled to the work site. An earthing cable (at the back of the welding machine) was secured

to ship's structure when the machine was installed. The welding return cable[26] was permanently connected to the storage rack (see **figure 4**) and appeared to have been in place since installation.

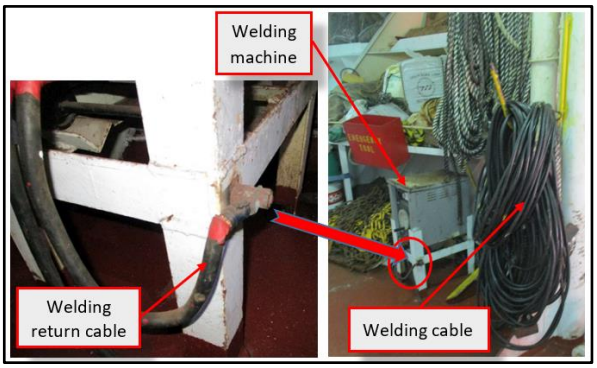

Figure 4 – View of welding return cable and welding cables - annotated by TSIB
(*Source*: The Company)

1.4.6 Apart from the welding cable, a typical set-up (see **figure 5**) would require bringing the welding return cable (workpiece lead cable) to the work site and be clamped to a workpiece. This was to limit the hazard of exposing to electric current to a smaller area. The setup on board SL was not like this according to the Company.

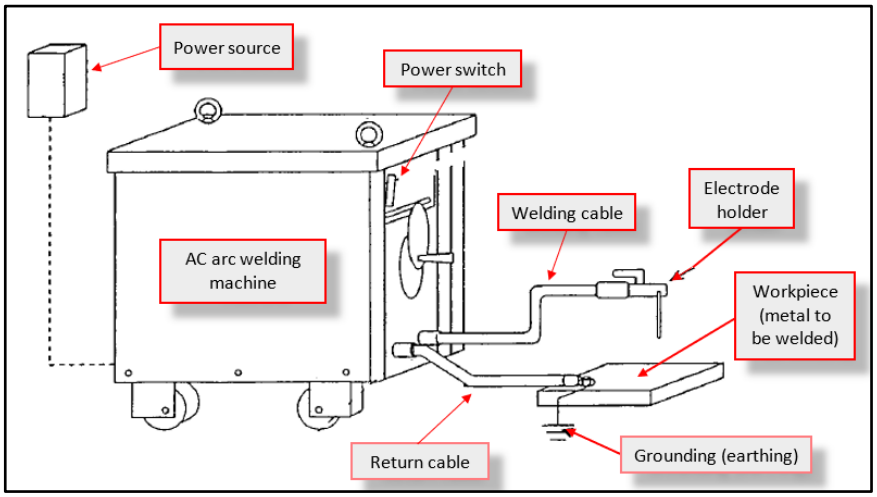

Figure 5 - Illustration of a typical welding set-up contained in the user manual - annotated by TSIB
(*Source*: The Company)

[26] The welding return cable carries as much current as the welding cable itself, both the welding and return cables are part of the electric circuit. For safe welding, the welder should use a return cable clamped as near to the welding place as possible.

1.5 Additional information

1.5.1 SL left the Port of Auckland on 20 July 2018 and was scheduled to arrive at the Port of Apia on 25 July 2018. At the time of occurrence, the Port of Nukualofa was considered the nearest port in the Master's assessment for medical assistance which was about six hours sea passage.

1.5.2 The Welder was alone and hence no one witnessed how the occurrence happened. When the Master discovered the unconscious Welder, (see **figure 6**), the overall which the Welder was wearing were found to be damp. The electrode lead cable holder was about half a metre away from his body. The welding cable was seen laid along the main deck passageway from the forecastle store, and there was no welding return cable seen at the work site.

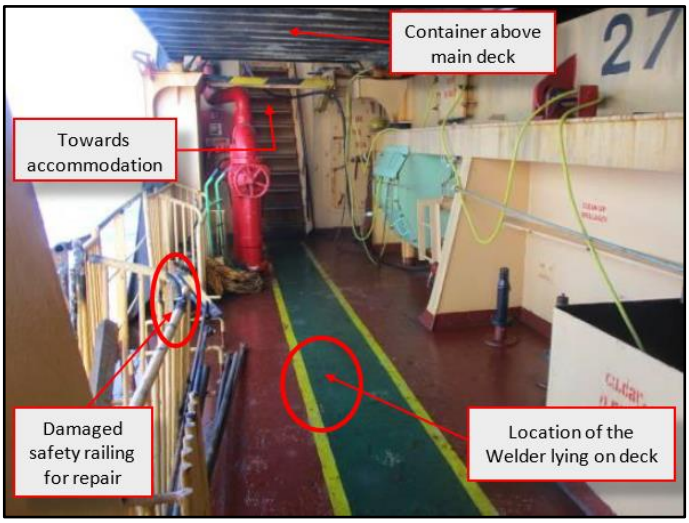

Figure 6 – View of the work site (taken after few hours of the occurrence) – annotated by TSIB
(*Source*: The Company)

1.5.3 The working gears used by the Welder were not noted to be defective or broken. The insultation of the electrode holder and welding extension cables were found intact. The personal protective equipment (PPE) used by the Welder, such as gloves and safety shoes too were intact and not broken (see **figure 7**).

1	Welding cable and electrode holder	3	Gloves	5	Welding extension cables
2	Safety shoes	4	Welding visor		

Figure 7 – Welding cables and PPE reportedly used by the Welder
(*Source*: The Company)

1.5.4 According to the Chief Officer, before the navigational watch was handed over to the Third Officer, the Third Officer had been briefed on the work planned on the main deck including the welding task. According to the Third Officer, at about 1045H a sudden passing rain shower was experienced that lasted for about three to four minutes. The Master also recalled that there were intermittent passing rain showers during the morning tea break, prior to the occurrence.

1.6 The Safety Management System (SMS)

1.6.1 The Company managed a fleet of container, bulk carriers and general cargo ships.

1.6.2 A full term of Document of Compliance certificate was issued to the Company by ClassNK on 29 August 2016[27] and it was valid until 18 May 2019. The last annual (third) verification was carried out on 31 July 2017.

1.6.3 A full term of Safety Management certificate was issued by Lloyd's Register to SL on 8 May 2017 based on the verification audit completed on the same date and was valid until 7 May 2022. There were three observations[28] raised during the verification audit and were subsequently closed accordingly.

1.6.4 The last Flag State Control inspection was carried out on 23 December 2014 with no deficiencies raised. The last Port State Control inspection was carried

[27] This certificate was rewritten due to amendments to the Company's particulars.

[28] Observations raised at the time of audit, i) equipment to be used was indicated in good condition for a past working aloft work permit, but two samples of the safety harness were inspected and found no tag attached covering periodical inspection by a designated person to ensure it met safety standard; ii) the examination frequency was not tally with the planned maintenance schedule (PMS) programme in the ship's computer and the Company's SMS procedures; and iii) discarded lashing gears in the forecastle store were not clearly tagged or labelled indicating not to be used.

out on 25 May 2018 without any deficiency.

1.7 The SMS procedures

1.7.1 The Company's SMS procedures had a strict drug and alcohol policy on its fleet of ships. At the time of accident, there was no evidence to suggest that any crew members consumed alcohol prior to their duties.

1.7.2 The SMS had a specific section on hot work procedure, providing guidelines on type of work to be classified as hot work[29], any work associated with a naked flame such as electric welding fell into hot work category. There were additional requirements such as risk assessment to be conducted and a permit to work to be issued before commencement of hot work task.

1.7.3 In the same procedure, the Chief Officer (for deck related work) was required to conduct safety checks (relevant items stated in the checklist cited in paragraph 1.7.4) to ensure safety requirements were met. Thereafter, a duly completed hot work checklist (part of the permit to work) was required to be submitted to the Master for approval. The Master would review it and ensure all conditions of the permit to work were met before issuing the permit.

1.7.4 The copy of the hot work checklist provided to the investigation team contained the names and ranks of persons (the Welder and the ASD) involved at the work site and was signed by the Chief Officer. The permit was granted by the Master and it was valid from 0800H to 1600H on 23 July 2018. The following items had been ticked on the checklist by the Chief Officer except for the item d) which was ticked off as "NO[30]" (not applicable):

a) If a risk assessment had been carried out;
b) If a toolbox meeting led by the officer in-charge and involving all individuals with a role in the hot work operation had been held before the work commencement;
c) If an assistant had been provided;
d) If there was any danger of personnel engaged in the hot work getting wet;
e) Is working equipment (welding machine, cables, electrode holder, etc) in good order;

[29] Defined in the Company's SMS as any work involving welding, burning, producing high temperatures which can ignite on ambient combustible material and flammable gas mixture in a workspace.

[30] The Chief Officer's rationale to tick off as "NO" could not be established by the investigation team. The Company's interpretation was that this likely meant work was not allowed to be continued if there was a danger to personnel engaged in the hot work getting wet.

f) If the welding machine was earthed;
g) If the operator had worn proper personal protective equipment (eye protection, footwear, etc);
h) If the duty officer (bridge watchkeeper) had been informed.

1.7.5 The risk assessment report generated[31] from the Company's computer system for the hot work indicated that various hazards had been identified with control measures indicated. The existing control measure for the hazard of 'bad weather - rain', to mitigate the risk of electrocution, was to stop work during rain or sea spray and to monitor[32] the weather. The likelihood of this hazard occurring was documented as low[33]. Another relevant hazard identified was 'lack of clarity/not understood on the roles and responsibility' and 'complacency (lack of perception)' which were both documented to have low likelihood and a low risk.

1.7.6 The Chief Officer was required to ensure and monitor the safety requirements to be followed when the hot work was performed, and to report to the Master when the job was done.

1.8 Relevant safe working practice

1.8.1 The COSWP[34] was incorporated into the Company's SMS procedures and to be carried on board its fleet of ships.

1.8.2 Chapter 24.2 of the COSWP provides guidance that hot work in places other than the workshop should be the subject of a permit to work system. Operators should be suitably trained in the process, familiar with the equipment to be used and instructed where special precautions need to be taken.

1.8.3 Chapter 24.6 highlights that electric welding power sources for shipboard use should have a direct current (DC) output not exceeding 70V with a minimum ripple to minimise personal harm from electric shock. However, if DC

[31] Generated on 22 July 2018.
[32] The investigation team was not aware of whether a person had been identified for this task, i.e. the assistant or the officer keeping the navigational watch on the bridge.
[33] The investigation team could not establish why this was deemed as low, but the Company's clarification on the low likelihood was probably due to the ship's trading locations (in South Pacific Islands) and the seasons in which SL was trading.
[34] Though not a mandatory publication for carriage on Singapore registered ships, the Company's SMS had incorporated the Code of Safe Working Practices for Merchant Seafarers (COSWP) as the part of procedures for reference. The COSWP, edition 2015, published by the UK Maritime and Coastguard Agency (MCA), provides best practice guidance for improving health and safety on board ships. A copy of COSWP was incorporated into the Company's SMS procedures and kept on board at the time of the accident.

equipment is not available, AC output power sources may be used provided they have an integral voltage-limiting device[35] (VLD) to ensure that the idling voltage[36] does not exceed 25V rms[37].

1.8.4 In 2018, following a recommendation by TSIB[38], the Maritime and Port Authority of Singapore (MPA, the flag Administration of SL) issued a Shipping Circular (no.5 of 2018) recommending that a VLD for AC electric arc welding equipment to be fitted. At the time of occurrence, there was no VLD fitted on the welding equipment on board SL.

1.8.5 The COSWP recommended that a go-and-return system using two cables from the welding set should be adopted. The welding return cable should be firmly clamped to the workplace (workpiece). The return cable of the welding set and each workpiece should be separately earthed to ship's structure. The use of a single cable with hull return as onboard SL is not a recommended practice (see paragraph 1.4.5).

1.8.6 The COSWP further recommended that an assistant should be in continuous attendance during welding operations and the assistant should be alert to the risk of accident shock to the welder and ready to cut off power instantly, raise the alarm and provide artificial respiration without delay. During the occurrence on board SL, the assistant (the ASD) was not with the Welder.

1.8.7 The COSWP also highlighted that there are increased risks of electric shock to the operator if welding is done in hot or humid conditions. Body sweat and damp clothing greatly reduce body resistance. Under such conditions, the operation should be deferred until such time that an adequate level of safety can be achieved. In no circumstances should a welder work while standing in water or with any part of their body immersed.

1.9 Cause of death

1.9.1 A letter was issued by the local hospital in Nukualofa, confirming that the Welder was found dead with no signs of life on arrival.

[35] Regulation 54 (Electrical welding equipment) of Singapore's Workplace Safety and Health (Shipbuilding and Ship Repairing) Regulations requires this device to be fitted on board a ship in a harbour with an effective low voltage shock preventor which reduces the open-circuit secondary voltage to not exceeding 25V. This preventor shall be fitted in accordance with the maker's instructions and to be inspected and tested by a competent person once every six months.

[36] The voltage between electrode and workpiece before an arc is struck between them.

[37] Root-mean-square, used to define the current of an AC wave.

[38] TSIB's Safety Investigation Report MIB/MAI/CAS.005

1.9.2 A death certificate issued by the Ministry of Health, Tonga on 26 July 2018, indicated that the cause of death was due to cardiac arrest caused by electrocution.

1.9.3 A post-mortem examination on the body was carried out in India on 12 August 2018, the examination revealed that several injuries and burns appeared on the body

a) Multiple contused abrasions on the areas of forehead, outer end of eyebrow, above the root of nose, front of chin and chest, etc;
b) Superficial to deep burns over an area extending from the back of right chest outer to midline to the back of right armpit fold and back of upper arm, elbow and forearm, outer aspects of right and left thigh above the knee, the back of hip, left leg below the knee, etc;
c) Joule burn with firm, pale and ashen grey base showing charring of the cuticle towards centre, on palmar aspect of lower end of right index finger, front of left forearm below the elbow, front of left upper arm above elbow.

1.9.4 The cause of death to the Welder opined due to electrocution indicated on the post-mortem certificate.

1.10 Environmental condition

1.10.1 At the time of occurrence, the ship's logs indicated that there was north-easterly gentle breeze at the speed of about 7-10kts (Beaufort scale, force 3), and light sea condition with less than one and half meter. Overcast sky with occasional rain during the period between 0800H and 1200H on 23 July 2018, the visibility was good approximate at about 6-12 nautical miles.

1.10.2 SL was moving in a direction against the wind, but there was no sea spray encountered on the main deck.

2 ANALYSIS

2.1 The electrocution

2.1.1 The Welder was assigned to repair the safety railings at bay 27 on the main deck. Although the Welder was to be assisted by an ASD, at the time of the incident the Welder was alone. In the absence of a witness account to the occurrence, the investigation team looked into the factors and evidence obtained post-accident.

2.1.2 The insulation of the electrode holder and welding extension cables were found intact and the Welder had reportedly worn proper PPE like gloves. It is likely that the electrocution had resulted from external factors.

2.1.3 From the time that the ASD was reportedly asked by the Welder to carry on with the painting work at the lifeboat deck till the Master saw the Welder lying on the main deck, about 25 minutes had elapsed.

2.1.4 Based on the accounts of the Master and the Third Officer, the vessel experienced intermittent rain showers during the morning tea break period and at about 1045H. Correlating the damp overalls of the Welder and the position where the Welder was discovered, it was probable that rainwater got onto the deck when the Welder was in the process of welding, resulting in the electrocution.

2.1.5 The information obtained from the post-mortem report (see paragraph 1.9.3 b) suggested that the initial bodily contact with the live electric current was through the Welder's right index finger and/or left forearm[39]. The multiple contused abrasions over the face areas suggested that the Welder had likely fallen face down on deck after the electrocution.

2.2 Safety feature of the welding machine on SL

2.2.1 There are no statutory requirements governing the installation of welding machines on board ships. Many ships come with welding machines fitted at the time of delivery of the ship. The welding machine on board SL was manufactured in 2004 and met certain standards (see Paragraph 1.4.2).

[39] In the absence of a witness account, the investigation team could not ascertain how these signs appeared, but could not rule out the possibility that the welding electrode holder was held by the Welder in the right hand, the left arm was holding the railing to be welded, and the forearm came in contact with the railing.

2.2.2 According to COSWP a welding machine installed on board a ship should ideally have a DC output not exceeding 70V with a minimum ripple to minimise personal harm from electric shock. If a machine with an AC output is provided then a safety device (the VLD) should have been fitted as recommended by the flag Administration of SL as well as mentioned in the COSWP (a copy of which was referenced in the Company's SMS) and cited in Singapore's regulations under the Ministry of Manpower.

2.2.3 The welding machine was an AC output type with a maximum no-load voltage of 80V which was more than three times higher than the recommendation by COSWP (at 25V). The Company could not provide an explanation why the recommendations by the flag Administration and the COSWP had not been taken into consideration. Had a VLD been fitted, the outcome of this occurrence may have been different.

2.2.4 Thus, it is desirable that the welding machine should have either a DC output of not exceeding 70V or VLD fitted for AC out type to ensure the safety of the welder.

2.3 Safety checks for hot work

2.3.1 Before the hot work was submitted to the Master for approval, a list of safety checks was required to be carried out by the Chief Officer as per the Company's SMS procedures. The rationale of ticking off the item d) as "NO" in the hot work checklist could not be established. However, the investigation team assessed that "NO" could suggest that there was no anticipation of danger of the personnel engaged in the hot work to get wet. Despite this, the RA contained risk mitigating measures such as monitoring the weather and stopping the work.

2.3.2 In such a situation, there is likelihood that the crew would not anticipate any dangers associated with getting wet, as happened in this case. If the item had been ticked off as a "YES", the crew would have treated with caution after the tea-break, especially during which the intermittent rain showers happened.

2.3.3 Another item in the hot work checklist required the Chief Officer to check if the working equipment (welding machine, cables, electrode holder, etc.) were in good order. This was duly ticked off by the Chief Officer. The words "in good order" appeared subjective and did not indicate what was deemed as good. Noting that there were no damages to the equipment (insulation was intact),

the investigation team viewed that this check did not include checking the setup of the welding machine.

2.3.4 The same welding setup had been used for the past welding works on board SL, but the welding return cable was not set up as per the user manual, and the ship's hull was used as a default forming an electric circuit. The Chief Officer may not have the relevant knowledge to assess the proper setup of the welding machine, cables, electrode holder and thus only focused on general equipment conditions, such as visual check for any wear and tear of the insulation condition of the welding cable and electrode holder. The investigation team however held the view that it would have been desirable for the Chief Engineer or the Second Engineer to be consulted on this matter before approving the task as they possessed the relevant STCW Convention qualifications.

2.4 Deviation from the established hot work procedures

2.4.1 Welding is a high-risk task involving high voltage. During the process of welding, the Welder would focus on the area to be welded. Thus, the Company's hot work procedures required an assistant to be assigned to the Welder. The role of this assistant was to help to look for any danger or hazards which could affect the Welder. In this case, the assigned assistant (the ASD) left the Welder alone to carry out another task (painting).

2.4.2 Had the ASD stayed on, the working environment could have been monitored better, such as alerting the Welder of the possibility of rain due to passing rain clouds as well as allowed for early intervention to request medical attention.

2.4.3 Although the Third Officer (as the Officer of the watch) was briefed by the Chief Officer regarding the welding task on deck, the Third Officer was not aware of the contents of the Risk Assessments or when the hot work had commenced. The investigation team held the view that the risk assessment should have been discussed in detail with the Welder, the ASD, and the Third Officer, so that, the control measures for monitoring the bad weather (rain) could be highlighted with the intention to stop the welding work. Had this been done, the Third Officer could have communicated the information about the passing rain to the Welder and the ASD on the main deck.

2.4.4 The hot work procedures also required the Chief Officer to ensure and monitor the safety requirements to be followed when the hot work was performed and

to report to the Master when the job was done. Though the Chief Officer joined the duo to help in straightening the dented safety railings, the Chief Officer was not present when the hot work commenced to ensure that the work had been performed safely, as intended by the SMS. Had the supervision been carried out by the Chief Officer, it is unlikely that the ASD would leave the Welder alone doing the welding work.

2.4.5 The above indicated that there were deviations from the Company's established SMS procedures. As SMS procedures are to ensure the safety of the crew and to achieve a safe operation, they should be adhered strictly. If there is a need to deviate from the established procedures, then the relevant risk assessment should be performed accordingly.

2.5 Incidental findings

2.5.1 The go-and-return system using two cables (welding and return cables) for welding tasks is a good safe working practice as recommended by COSWP. It is noted that the ship's hull was used by default to form the electric circuit for carrying out welding works on board SL. This arrangement exposed the person performing welding to electric current to a larger area, as opposed to the go-and-return system which limits the exposure to electric current to a smaller area (see **figure 8**).

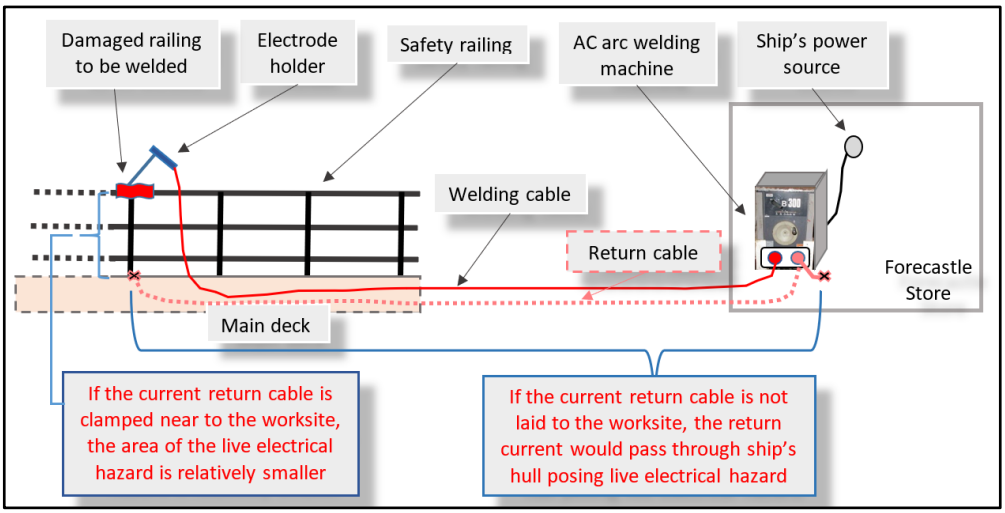

Figure 8 – Illustration on the scenarios of laying and not laying the welding return cable to the worksite.

2.5.2 As the welding return cable was permanently connected to the storage rack, the Welder had likely continued with the same setup after joining the ship.

Though this unsafe practice did not directly contribute to the occurrence, the investigation team views this to be an important point so that the hazards associated with this setup are understood by the ship’s crew.

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 Welder was carrying out welding of the ship's safety railings on the main deck alone, without any assistant or supervision as required by the permit to work.

3.2 As the vessel had experienced intermittent rain showers before and during the hot work, it was probable that rainwater got onto the deck when the Welder was in the process of welding resulting in the electrocution.

3.3 The welding machine installed on the vessel was of an AC output type with a voltage three times more than the recommended. There was no safety device fitted to the welding machine to protect the user from electrocution.

3.4 It is probable that there was no anticipation of the Welder getting wet while performing the welding work. Although there were risk mitigating measures like monitoring weather and stopping the work in the RA, no one was monitoring the weather and the welding did not stop amid the intermittent rain showers.

3.5 The term "in good order" for the working equipment in the Company's hot work checklist was subjective and did not specify clearly what to look out for. In addition, being a deck officer, the Chief Officer may not have the relevant knowledge to assess the proper setup of the welding machine and the associated equipment.

3.6 There were deviations from the established hot work procedures, the Chief Officer did not ensure that the welding was performed safely, the ASD assigned to assist the Welder went away for another task and the weather condition was not monitored.

3.7 The go-and-return system using two cables was not practised on board SL exposing the person performing welding to electric current to a larger area.

4 SAFETY ACTIONS

Arising from discussions with the investigation team, the Company has taken the following safety action.

4.1 After the occurrence, the Company circulated a safety bulletin to the ships of its fleet to ensure that the SMS on hot work procedure is to be strictly followed by crew.

4.2 The Company required all the ship's Masters to provide training to all crew on the permit to work (PTW) system and to ensure all works requiring the PTW to be monitored and supervised by senior officers.

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.

It is recommended for the Company (the ISM Managers):

5.1 To ensure the types of welding machine installed on board in its fleet of ships are of DC output type approved by the competent authority or having safety features such as voltage limiting device. **[TSIB-RM-2021-013]**

5.2 To review the safety checklist in the Company's SMS on hot work procedures to ensure that all items are clear and achievable by the person performing the checks. **[TSIB-RM-2021-014]**

- End of Report -