Marine Safety Investigation Unit

Transport Malta

MARINE SAFETY INVESTIGATION REPORT

Safety investigation into the serious occupational accident on board the Maltese registered heavy lift /pipelay vessel

PIONEERING SPIRIT

in position 58° 06.2' N 007° 59.9' E

on 27 January 2020

202001/033

MARINE SAFETY INVESTIGATION REPORT NO. 02/2021

FINAL

Investigations into marine casualties are conducted under the provisions of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011 and therefore in accordance with Regulation XI-I/6 of the International Convention for the Safety of Life at Sea (SOLAS), and Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council.

This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 27 January 2020. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

The findings of the safety investigation are not binding on any party and the conclusions reached and recommendations made shall in no case create a presumption of liability (criminal and/or civil) or blame. It should be therefore noted that the content of this safety investigation report does not constitute legal advice in any way and should not be construed as such.

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Harms-Ringdahl, L. (2003). *Investigation of barriers and safety functions related to accidents*. Paper presented at the European Safety and Reliability Conference, 2003, Maastricht, The Netherlands.

Hollnagel, E. (1999). Accidents and barriers. In J-M. Hoc, P. Millot, E. Hollnagel, & P. C. Cacciabue (Eds.), *Cognitive science approaches to process control* (Vol. 28, pp. 175-182). Lez Valenciennes: Presses Universitaires de Valenciennes.

GLOSSARY OF TERMS AND ABBREVIATIONS

DJ welder	Double Joint welder
Dynamic Positioning IMO Class 3	Dynamic positioning is a computer-controlled system that automatically maintains a vessel’s position and heading by using its own propellers and thrusters. IMO Class 3 vessels required a redundancy to be in place so as no single fault in an active system will cause the system to fail. Additionally, the system must withstand fire or flood in any one compartment without compromising system failure.
IP	Injured person
JLS	Jacket lift system
kW	Kilowatts
m	metres
m^3	Cubic metres
nm	Nautical miles
PPE	Personal Protective Equipment
mt	Metric tonnes
WBT	Water Ballast Tank

SUMMARY

A welder helper was tasked to assist in the mounting of two stiffeners as reinforcement to the newly installed jacket lifting system on board, inside a WBT. Upon entering the WBT, the welder helper and the welder walked different routes to reach the work site. Rather than crossing directly from the access ladder and onto the cable trunk, where the welding job was due, he followed the access ladder down to the tween deck level, crossed a guardrail, and walked alongside the cable trunk where unexpectedly, he fell through a large opening in the deck. The welder, who was already on top of the cable trunk preparing for the job, did not see the accident and he was not in contact with the injured welder helper at the time of the occurrence.

After the fall, the injured welder helper was located, and evacuated from the space. A rescue helicopter took the injured crew member to the local hospital.

The injured crew member was unable to assist the Marine safety Investigation Unit to establish the reason for selecting that particular route. However, a number of contributing factors to the accident have been identified by the safety investigation.

1 FACTUAL INFORMATION

1.1 Vessel, Voyage and Marine Casualty Particulars

Name	*Pioneering Spirit*
Flag	Malta
Classification Society	Lloyd's Register of Shipping
IMO Number	9593505
Type	Heavy lift / Pipelay
Registered Owner	Societe d'Exploitation du Pioneering Spirit
Managers	Allseas Engineering BV
Construction	Steel
Length overall	382.00 m
Registered Length	362.07 m
Gross Tonnage	403,342
Minimum Safe Manning	17
Authorised Cargo	Subsea pipes
Port of Departure	Kristainsand, Norway
Port of Arrival	Kristainsand, Norway
Type of Voyage	Coastal
Cargo Information	N/A
Manning	571
Date and Time	27 January 2020 at approximately 13:40 (LT)
Type of Marine Casualty	Serious Marine Casualty
Place on Board	Water ballast tank no. 1006
Injuries/Fatalities	One serious injury
Damage/Environmental Impact	None
Ship Operation	Repair and maintenance
Voyage Segment	At anchor
External & Internal Environment	Daylight, visibility 6 nm, SSW moderate breeze. Slight Southwesterly swell (0.5 m), with a sea temperature of 7 ℃ and an air temperature of 9 ℃
Persons on Board	519

1.2 Description of Vessel

Pioneering Spirit (Figure 1) was built at Daewoo Shipbuilding & Marine Engineering Co. Ltd. in South Korea and delivered in 2014 as a vessel for single-lift installation and removal of large offshore oil and gas platforms, and installation of oil and gas pipelines. She was owned by Societe d'Exploration du Pioneering Spirit of Belgium and managed by Allseas Engineering BV of the Netherlands. The vessel was classed with Lloyd's Register of Shipping.

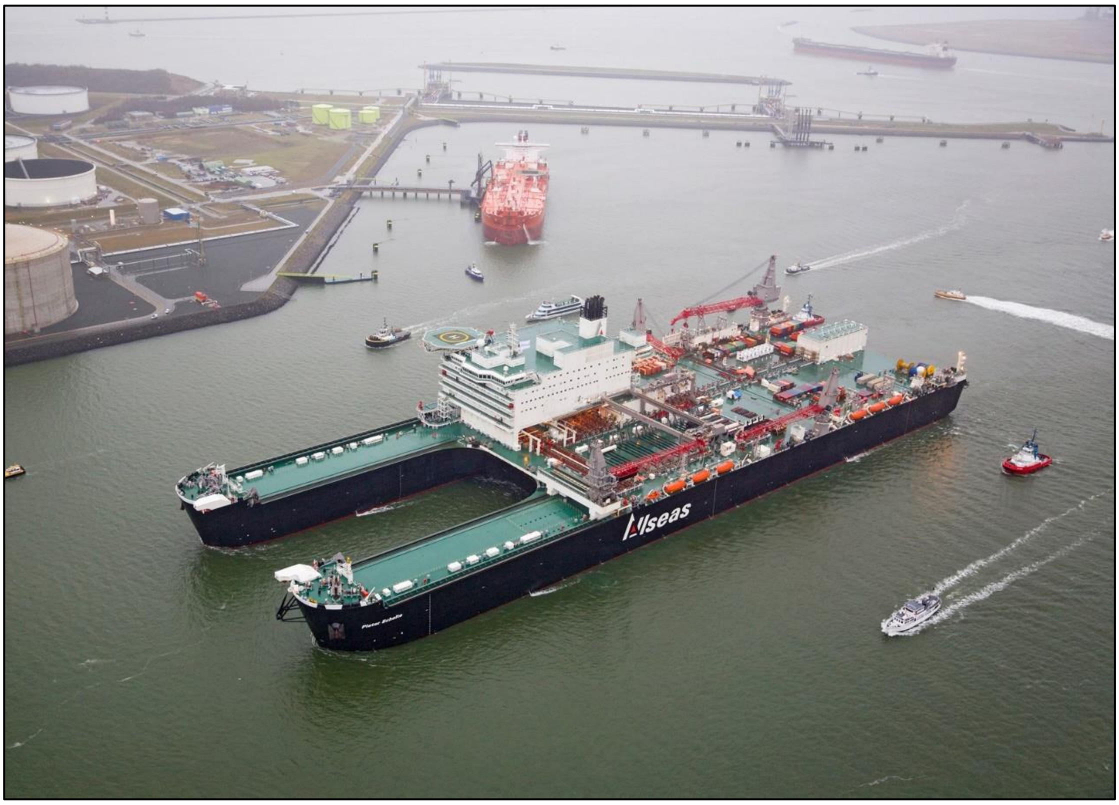

Figure 1: Pioneering Spirit

The vessel had a length overall of 382 m (excluding the stinger and tilting lifting beams), a moulded breadth of 124 m and operating drafts ranging from 10 m to 27 m. Her gross tonnage was 403,342 and had a maximum displacement of 1,000,000 mt.

The vessel's propulsion system consisted of 12 electrically driven Rolls-Royce azimuth thrusters, each providing an output of 5,500 kW and powered by eight diesel-electric engines with a shaft power output of 89,600 kW. The vessel could reach a maximum speed of 14 knots. The vessel was equipped with an IMO Class 3 dynamic positioning system. Her superstructure provided accommodation for 571 persons, in two-berth cabins.

The operator's primary focus area and use of the vessel was for the removal and installation of large platforms in hostile weather areas, including the North Sea (Figure 2). In particular, the operator targeted topsides and jackets that are otherwise difficult to lift in a single section by other crane barges. The vessel was constructed with a `split bow´ that created a 122 m long and 59 m wide slot between the two bow sections, where topsides could be lifted and transported by means of 16 lifting beams.

Figure 2: ***Pioneering Spirit*** **carrying topside**

For the purpose of sub-sea pipe-laying, the vessel had a pipe firing line located along the centreline. The pipe leaves the vessel over a 210 m - long assembly of stinger transition frame and stinger, that is then suspended in the slot between the two bow sections.

1.3 Organization on Board and Key Crew Members

At the time of the accident, *Pioneering Spirit* had a total crew complement of 519, from 23 different nationalities. 59 crew members were engaged on board as sub-contractors. At the time of the accident, the crew complement was in excess of the Minimum Safe Manning Certificate issued by the flag State Administration.

Due to the nature of the specialized work that the vessel was built to perform, the crew consisted not only of conventional seafaring crew; in the technical, nautical and hotel departments, but also in a number of other specialized professions. Among these were four safety officers who reported directly to the master on safety-related aspects on board. Another department on board was that of steel construction, with approximately 300 people engaged.

The management team on board consisted of the master, the chief engineer, and a superintendent. The technical department was supervised by the chief engineer and consisted of about 155 persons, who were assigned to the different technical sections including the engine-room, the deck machinery and the vessel's lifting system for installation and decommissioning. The superintendent was managing the construction department and had a number of technical personnel that reported directly to him, including barge foremen, welding foremen, scaffolding foremen and quality control personnel, amongst others. The catering and hotel department consisted of about 45 crew members that serviced the crew on board under the supervision of the catering manager. The nautical department consisted of six navigational officers and the master. A designated medical physician was also signed on board.

The welding section within the construction department, was assigned a number of different tasks. There were tasks related to construction operations such as pipe laying where the welders would, among other jobs, join pipe sections together. The welders also carried out other tasks related to regular maintenance of the vessel and structural work related to the refitting of the vessel's configuration and equipment to meet project demands. The philosophy behind this was to keep expertise in-house, rather than hire shipyard repair personnel for welding jobs related to maintenance/refitting and potentially having to lay off on board crew members in the off-season periods. The welding crews were under the direct supervision of the welder foremen, who also distributed and organized the welding jobs to be done on board. At the time of the accident a lot of welding tasks were ongoing and scheduled as part of the jacket lift system that was in the process of being installed on board and that had been ongoing since October 2019.

The construction department crew members normally worked in 12-hour shifts. According to the ship´s rest hour registration, the welding team crew members involved at the time of the accident had had sufficient time to rest during the period prior to the accident, and had only been on duty for approximately one and a half hours when the accident occurred.

The master on board, was a national of the Netherlands and was 54 years old at the time. He started working for the vessel's managers in 1991. He had been serving on another vessel managed by the same Company in the capacity of master since 2006, before he assumed command of *Pioneering Spirit* in January 2016. His Certificate of Competence was endorsed by the flag State Administration on 26 September 2016. For the respective duty period, he signed on to *Pioneering Spirit* on 15 January 2020.

The safety officer who had reached the accident site, following the accident, was a 43 years old British national. On the day of occurrence he was on day shift, starting at 1200 and finishing at 2400. He had been working for the operator since November 2016, in the same rank. For the respective duty period, he signed on to *Pioneering Spirit* on 16 January 2020.

The welder foreman who was formally in charge of the welding job that was to be carried out in the tank, at the time of the accident, was 41 years old. He was assigned the day shift, which started at 1200 and ended at 2400. He was a Spanish national and had held the same capacity since January 2014. Previously, he had worked for the operator on other vessels since August 2007. He commenced working on *Pioneering Spirit* in December 2014, shortly after delivery of the vessel. He had held a previous position with the operator as `repair welder´. For the respective duty period, he signed on to *Pioneering Spirit* on 14 January 2020.

The welder who was to carry out the welding job in the ballast tank, at the time of the occurrence, was a 50 year old Spanish national. He was given the position of an advanced structural welder in the beginning of January 2020 and had been assigned the day shift (1200 – 2400). He had been working for the operator since he joined *Pioneering Spirit* in September 2014, previously in the capacity as Double Joint (DJ) welder. For the respective duty period, he signed on to *Pioneering Spirit* on 22 January 2020.

The first welder helper was 26 years old and also from Spain. He was assisting the welder with the welding job in the ballast tank. He had held the position on board as welder helper since 01 January 2020 and was working on day shift (1200 – 2400). He had been working for the operator since February 2018, but had previously joined *Pioneering Spirit* in May 2017 as a subcontractor. For the respective duty period, he had signed on to *Pioneering Spirit* on 10 December 2019.

The second welder helper (IP) who was also assisting the welder with the welding job in the ballast tank, at the time of the accident, was 27 years old. On the day of occurrence, he had started his job at 1200 and was on day shift. He was from Spain and was working as a welder helper since the beginning of July 2017. He started working with the Company since January 2018 on board other ships, and commenced working on board *Pioneering Spirit* in August 2019. For the respective duty period, he signed on to *Pioneering Spirit* on 14 January 2020.

1.4 Environment

At the time of occurrence, the weather was clear with an approximate visibility of six nautical miles. The sea state was calm and a low swell was approaching the vessel from the Southwest. A moderate breeze was blowing from a South Southwesterly direction. The air temperature was recorded to have been 9 °C and the sea temperature at 7 °C.

1.5 Background Information

On the day of the occurrence, *Pioneering Spirit* was at anchor in sheltered waters, off Kristiansand, Norway. The vessel was undergoing maintenance and repair work, and mobilisation in preparation for future contracts. In addition to the vessel's existing capacity to lift oil and gas production unit topsides at the bow end, the vessel was in the process of having a JLS installed at the stern end, not only allowing the installation and removal of the topsides, but also the underwater structure resting on the seabed *i.e.* the jacket. The jacket is the structure upon which the topside is mounted in the offshore oil and gas extraction and production environment. The JLS would, once installed, consist of large lift beams that would be raised from the aft deck and swivel over the vessel's stern (Figure 3). Here, the jacket would come to rest when lifted from the seabed and transferred onto the aft deck.

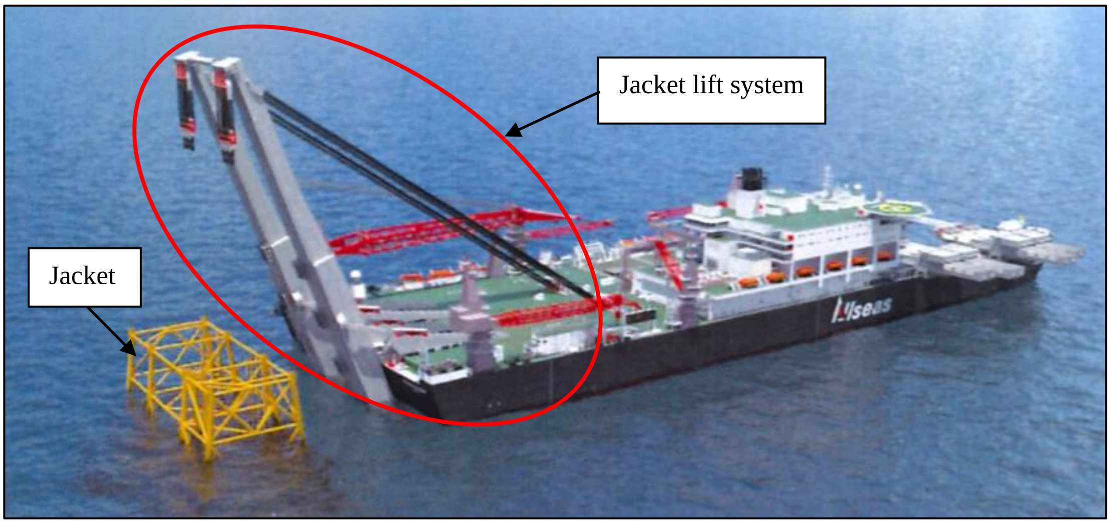

Figure 3: Illustration of Jacket Lift System that was in process of being installed

During a period of seven weeks, between October and November 2019, while the vessel was in Tenerife, Spain, parts of the new JLS installation had been assembled. New winches and electrical cabinets had been mounted below deck in the adjacent WBTs, at each side of the vessel. Forward of the new winch rooms, in the adjacent WBTs nos. 1005 and 1006 (Figure 4), reinforcement for new block-sheave assemblies for wires had been mounted. After completion of the welding of these assemblies in the tanks, the WBTs were sealed off in preparation for the vessel to depart for Northern Europe. The jobs in these WBTs, were at that time, considered to have been completed.

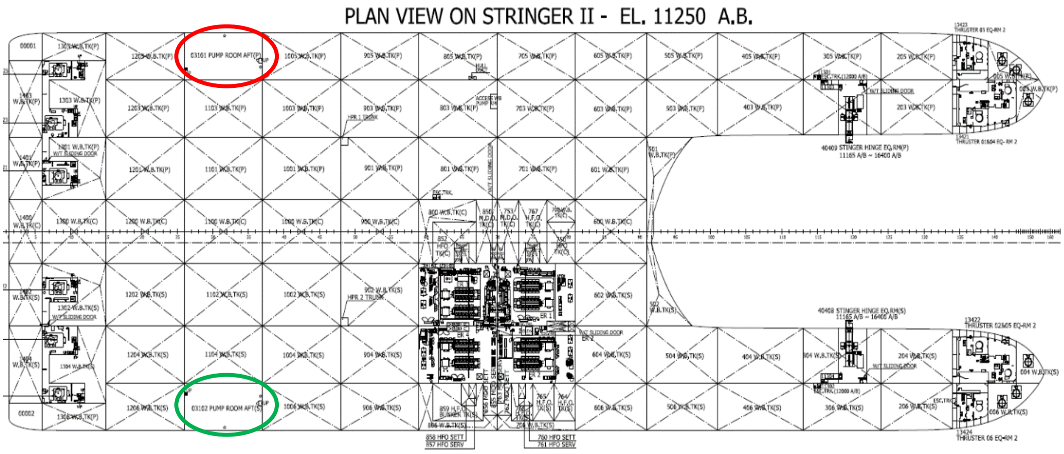

Figure 4: Extract from General Arrangement plan - Position of WBT no. 1006 marked in green and WBT no. 1005 marked in red

After arrival in Norway, the vessel's classification society surveyor came on board to inspect the work done as part of the JLS installation. The survey revealed that the block-sheave assembly installation would need to have two additional stiffeners welded on to the construction for extra strength. Adding the extra stiffeners was considered a minor and non-urgent task that would be fitted into the work schedule, among larger works that were on-going on board in continuation of the installation processes that had started in Tenerife. The task was saved for a day with good time in hand and with manpower resources readily available.

1.5.1 Water ballast tank no. 1006

The accident happened inside WBT no. 1006, which was classified as an enclosed space. The tank, which was fitted on the vessel's starboard side just aft of the accommodation (with one side forming part of the vessel's outer hull), had a capacity of about 10,500 m^3. Access to the WBT was through a manhole on the main deck. On the first platform, lighting had been fitted in preparation for the welding job in the tank, which illuminated the entire upper level of the WBT (Figure 8).

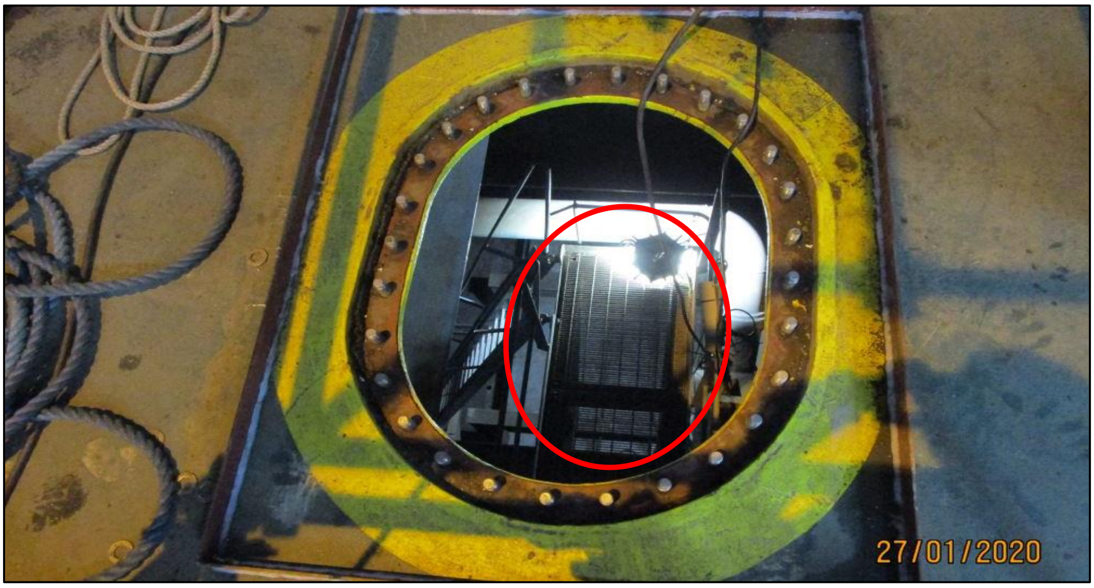

Figure 8: Access to WBT no. 1006 - First level platform with lighting installed marked

There were a lot of large WBTs that formed part of the vessel's structure. The reason for this was that these tanks were a central part of the topside lift system on the foredeck. The tanks would allow the vessel to adjust its draught once the topside lift system is positioned underneath the topside to be lifted. This allowed pre-tensioning to be generated, which is a delicate operation. The ballast water system was further used to compensate for tidal levels during the lifting operations. With the vessel in position, the lift was then conducted as a quick single lift by pumping out ballast water from the tanks. To fill and empty the WBTs, the vessel was equipped with 12 pumps, each with a capacity of 3,600 m^3hr^{-1}, located in pump rooms in various parts of the vessel.

The WBT was divided into two, in the horizontal plane, by a tween deck located approximately in the middle of the tank. A few large openings in the tween deck, including the one through which the IP fell, allowed the ballast water to flow from one level of the tank to the other. Close to the centre of the tween deck, a large cable trunk, situated in the fore and aft direction, formed part of the vessel's structure. The trunk was approximately three metres high from the tween deck and approximately six metres wide. The work site for the welding job was located on top of this trunk, at the aft bulkhead of the tank (Figure 6).

Inside the WBT, from the manhole, a vertical ladder led to the first platform, thence an access ladder with relatively steep steps led to the tween deck (Figure 9). The access ladder passed the trunk with approximately one metre of space in between (Figure 10), just before the ladder reached the tween deck. From the bottom of the stairs there was approximately five metres of passageway to an opening in the deck that led to the lower level of the tank (Figure 11), with another access ladder that led all the way to the bottom which was approximately 16 meters below. The five metres of passageway were bounded by a waist high guard rail.

Figure 9: Access ladder inside water WBT no. 1006

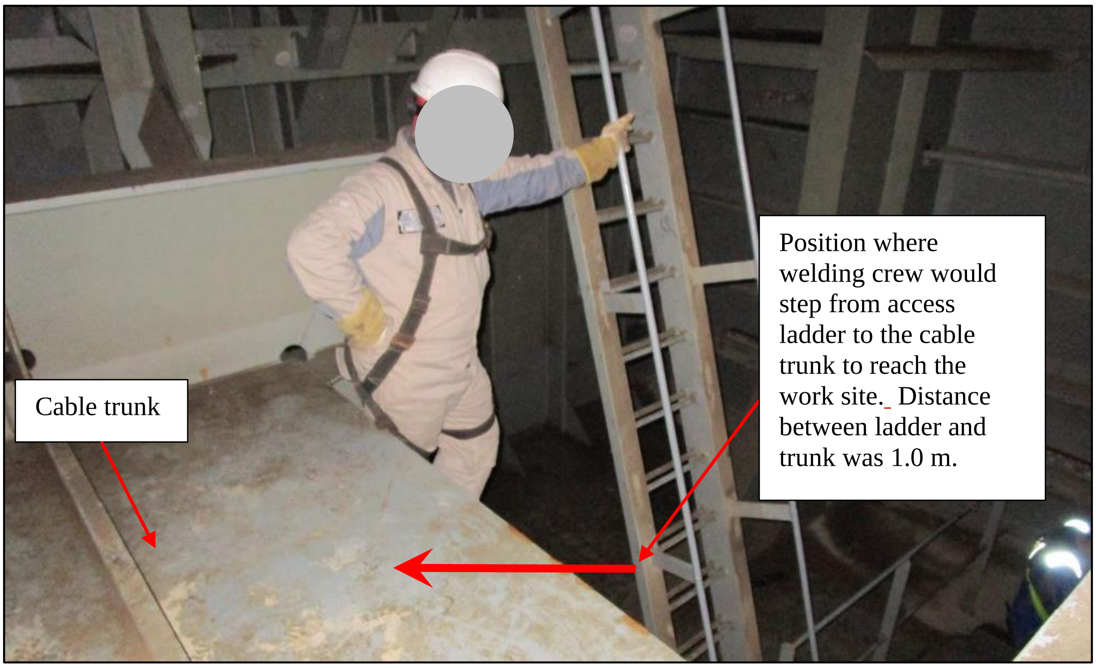

Figure 10: Access ladder passing cable trunk

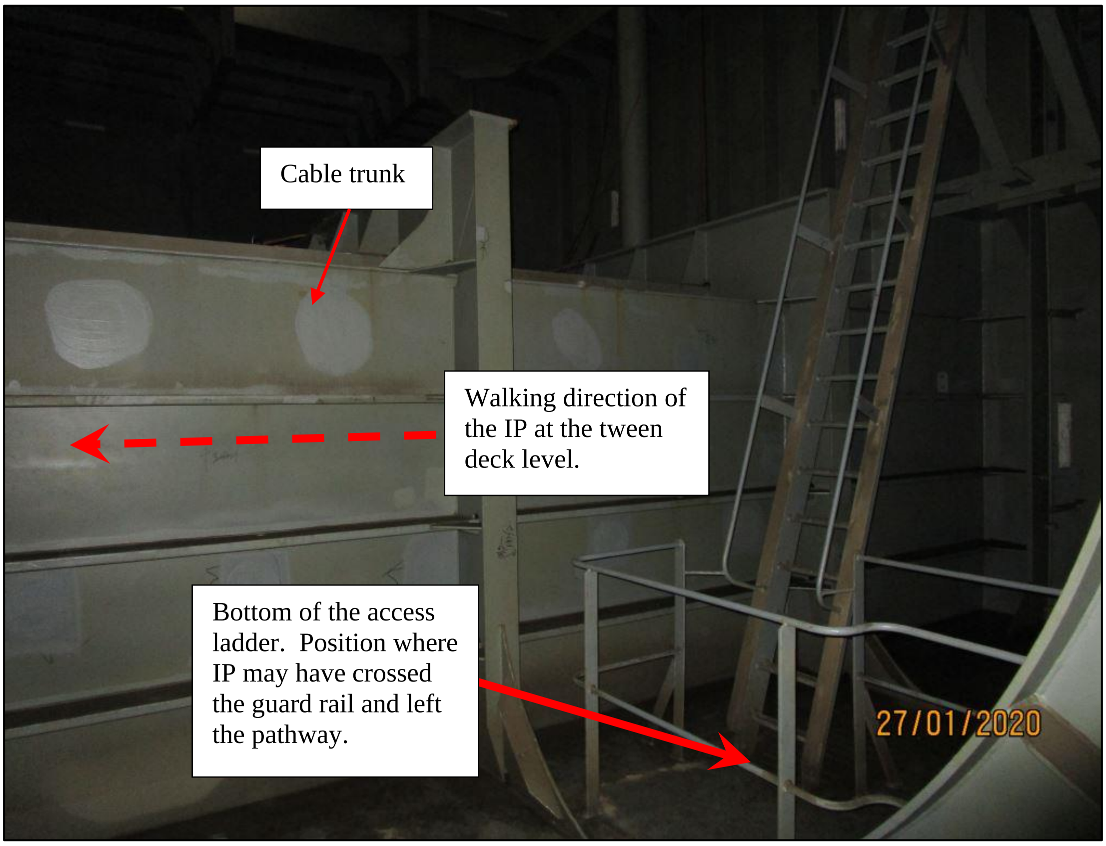

Figure 11: Access ladder ending at the tween deck

The opening in the deck through which the IP fell, was located about halfway from the guard railed passageway to the aft bulk head of the tank (Figure 12). Neither permanent nor temporary barriers had been fitted specifically around the opening in the deck.

Figure 12: Access ladder passing cable trunk. Lighting conditions are similar to those at the time of the accident

The previous work done at the work site, was done in Tenerife, during which a scaffolding was set up to provide access to the work site (Figure 13). A scaffolding was not erected for the welding job at the time of the accident, as this was considered to be a small and quick task.

Figure 13: Scaffolding during initial work in tank in October 2018

1.6 Narrative[1]

1.6.1 Events leading to the accident

On 24 January 2020, at around 2130, the WBT[2] was opened and ventilation was installed in the tank.

During the morning meeting on 26 January 2020, the JLS project co-ordinator requested an entry permit to be prepared for WBT no. 1006 to inspect the tank and subsequently carry out the planned works[3]. An entry permit was completed by the chief mate and first mate, and a hot work permit was completed by the welder foreman.

For works to commence, the safety officer, who was working the night shift, conducted a gas measurement test at the first platform at about 0905. Once cleared, the electricians proceeded to install the lighting at that level. The safety officer carried on performing air quality tests all the way down inside the tank and, at 0925, he recorded the measurements in the designated Confined Space Air Test records as being acceptable.

The preparations for the work were initiated by the night shift welding crew, who entered the WBT in the morning at around 0950. In addition to the night shift welding crew team members, a field engineer[4] involved with the JLS installation entered the tank along with the welders, in order to discuss the construction drawings and to instruct on how the welding of the reinforcement was to be done. Once down in the WBT, the welding crew night shift made an assessment of the work site in order to determine what was needed to carry out the job, such as additional lighting and access platforms. The chief mate was in charge of deeming the tanks safe to work in, and the welder foreman was responsible for giving the clearance to do the specific job inside of the tank. Due to the delegation to the field engineer, the welder foreman was not present in the WBT. The welding team and field engineer considered the

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[1] Unless otherwise specified, all times referred to in this safety investigation report are local time (UTC + 1).

[2] References made to "WBT" in this safety investigation report refer to WBT no.1006.

[3] The extra stiffeners were to be welded onto the sheave-block assembly reinforcement.

[4] In more routine jobs it was usually the welder foreman who would have instructed the welding team, but in this case instructions had been delegated by the foreman to the field engineer.

illumination, access to the work site and the conditions in the tank to be sufficient, as they considered it to be a quick job. A rescue plan had also been prepared as part of the standard procedure for entering into a confined space.

At noon, before the actual welding work had begun, there was a change of shift and the welding team – night shift was relieved by the day shift, consisting of two welders and a welder helper. The standard toolbox talk was conducted among the welding team of the day shift by means of the `Step Back 5x5´scheme, and PPE and safety harnesses were put on, in accordance with the work permit instructions. Risks associated with entry into enclosed spaces were assessed and discussed, and it was deemed safe to carry out the work.

In the meantime, the IP was told to report to the lead welder helper, who, in turn, informed him that he was re-assigned[5] to the job being carried out in the WBT.

At around 1250, the tank watchman requested the day shift safety officer to conduct another gas measurement test of the water ballast tank, prior to entry. This was considered as a standard procedure, to be carried out at the beginning of each shift. When the safety officer arrived at the tank entry point, he found the tank watchman and the welding team waiting. The safety officer carried out the atmosphere tests and recorded his findings as acceptable in the Company's Confined Space Air Test Record, at 1300.

Inside the tank, the safety officer noticed that the access from the ladder to the trunk could be improved and made safer. Once outside, the safety officer contacted the scaffolding supervisor and requested the installation of a bridge between the ladder and the trunk, upon which the crew members had to step off. The scaffolding supervisor advised that his second team would be available to carry out the works after 1330 (after the lunch break).

At 1300, the two welders and one welder helper signed the access register and went inside the water ballast tank to prepare for the job. After delivering several pieces of equipment in the tank and discussing the job with the welders, the welder helper went out of the tank again. Once out of the tank, the welder helper met the IP, who had just

[5] Rotation of personnel across the vessel, was considered as a normal routine.

been assigned to the team as a second welder helper. The first welder helper told the IP to go and get the remote control for the welding machine, while he went to get other supplies needed for the job.

At 1320, the second welder left the tank and, at around the same time, the IP signed the access register and the permit to work for confined space entry, donned a safety harness, and entered the tank. Thereafter, when the first welder helper returned to the WBT manhole, he noticed that the IP had already connected the remote control to the welding machine, which was located on the main deck. Upon looking inside the tank, he saw that the IP had entered the tank and had proceeded down to the first platform below the manhole. He also observed that the hoses that were connected to the welding machine had been lowered down inside the tank.

The welding job was to be carried out at the aft bulkhead on top of a large cable trunk, located on the tween deck of the tank structure (Figure 5), which the welder[6] had stepped on to, from the access ladder. When the IP started lowering the hoses from the welding machine, the welder grabbed and dragged them to the work site. At this time, the two crew members that were inside the tank had visual contact with each other. After that, the welder observed the IP making his way down the second access ladder, and then he turned around, and started to mark where the stiffeners had to be welded on to the sheave-block assembly reinforcement.

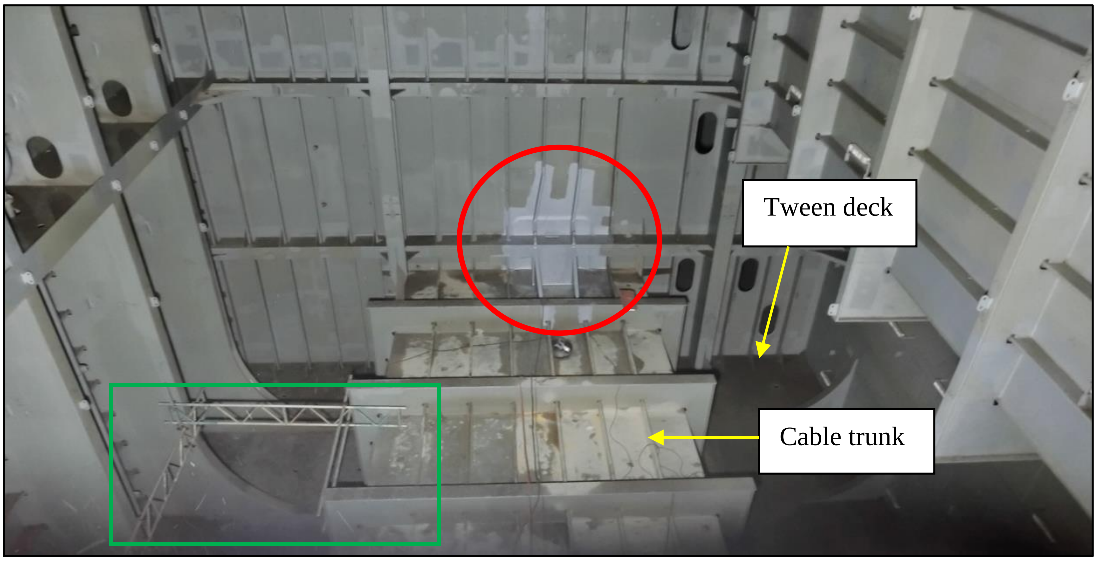

Figure 5: View inside of the WBT. Position where stiffeners were to be welded on, marked in red. Scaffolding (marked in green) was rigged during the recovery of the IP

[6] Hereinafter, the term 'welder' is used to refer to the first welder who had remained in the WBT.

1.6.2 Discovery of the accident

The first welder helper prepared the gas for the welding machine, and not long after he had observed the IP inside the tank, he made his way inside. There, he noticed that everything was ready for the welding job. He saw the welder on top of the trunk on the work site, but he did not see the IP anywhere, even though he had only just observed him inside the tank a few minutes before. The first welder helper stepped off the ladder and onto the trunk, and walked to the work site where he asked the welder for the whereabouts of the IP.

The welder had seen the IP just before, moving down the access ladder, after he had lowered the hoses down. But since he had turned towards the welding site, he did not know where the IP went from there. The first welder helper went back to the access ladder to look for the IP and see whether he had gone further down into the WBT.

At around 1330, on his way down the ladder, the first welder helper shouted for the IP but received no response. He shouted to the welder that the IP was nowhere to be found on the tween deck below the trunk. When the first welder helper made a turn at the bottom of the access ladder, he observed fresh shoe prints on the otherwise untouched sludge coating on the tank tween deck going aft from the tank access pathway, which was bounded by hand railings. The shoe prints led along the side of the trunk in the direction of the work site (Figure 6).

There, the first welder helper discovered a hard hat lying on the deck with the head torch still lit just next to a large opening in the deck leading to the lower level of the WBT (Figure 7).

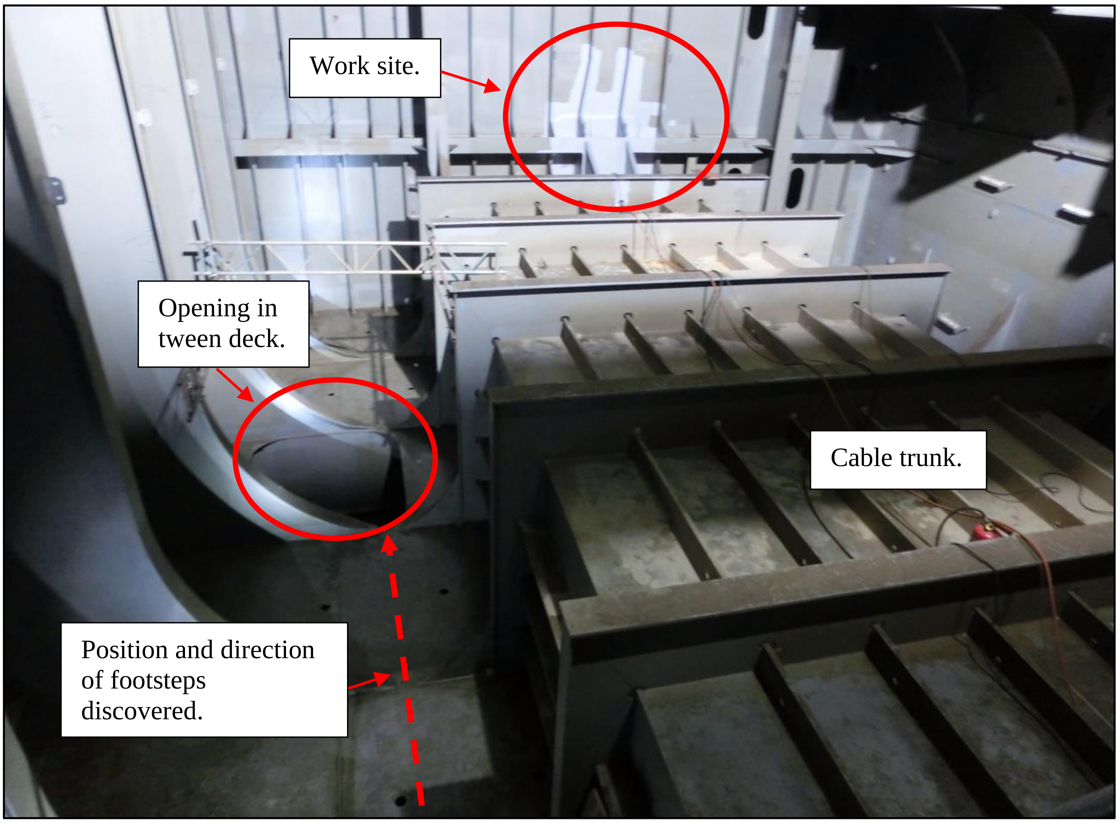

Figure 6: Most probable route taken by the IP

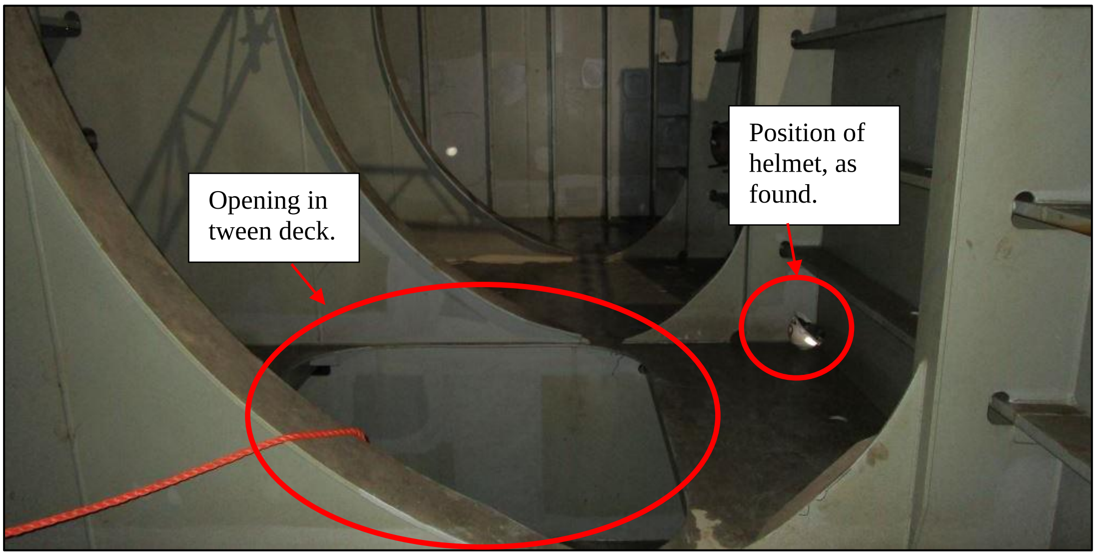

Figure 7: Accident site

The first welder helper rushed towards the opening in the deck to see if he could see the IP there. When he looked down the deck opening, flashing his torch, he saw the reflections from the IP's coverall light up from where he was lying at the bottom of the tank, several metres below. The welder helper started shouting to the IP but he neither got a response nor reaction from the IP. The welder helper immediately instructed the welder to call for help, while he also started to make his way up from the WBT.

Once the welder foreman was notified, he immediately came on site. He then relayed the alarm by means of radio and soon after, the vessel's safety officer and the designated rescue team arrived at the entrance of the tank.

1.6.3 Rescue and evacuation of the IP

At 1348, the rescue team entered the WBT to evacuate the IP from the tank. At 1355, the vessel's medic also entered the WBT and joined the rescue team to examine the condition of the IP. The rescue team members quickly realised that because of the position in which the IP had fallen and landed, at the far end of the tank and at the lowest level, the tripod with the hoist for evacuation installed next to the manhole would not work. For evacuation, they required assistance from the scaffolding department to build a scaffolding structure above the deck opening through which the IP fell from, to support the hoist. The rescue team concluded that it would also need to hoist the injured IP in the same way he had fallen, and then physically carry him from the tween deck, where the deck opening was, and further up the ladders to the manhole entrance.

When the rescue team members reached the IP at the bottom of the tank, they found him conscious but obtund, located in a position at the lower rib of a bottom frame, with severe injuries to both his head and his body. A bag which he had brought with him, containing some welding electrodes and a face shield, was found next to him at the bottom of the tank.

The Neil Robertson stretcher, which the rescue team was carrying, was unsuitable and unable to offer the IP any stability in the position in which he was found. The rescue team decided to have a basket stretcher brought down instead. This took some time because the basket stretcher had to be lowered carefully. At 1420, the IP was finally secured on the basket stretcher. Throughout, the vessel's medic was looking after and monitoring the state of the IP. He had also put a neck brace on the IP's neck for stabilization.

Shoreside authorities and rescue services had also been notified of the accident on *Pioneering Spirit* and shortly after, a boat arrived with paramedics, followed by a rescue helicopter at 1424. Three paramedics from the rescue helicopter entered the tank's manhole at 1432. At the same time, the hoist to lift the IP back up to the level above was ready. The paramedics from the helicopter took charge of the operation and transferred the IP from the vessel's basket stretcher to the one they had brought down with them. At 1511, the IP was lifted and carried on the stretcher out of the tank, by means of a crane with a man-riding basket and elevator, up to the vessel's helideck.

At 1539, approximately two hours after the accident, the rescue helicopter left the vessel's helideck with the IP on board and headed for a hospital in Kristiansand. Later on, the IP was transferred to a hospital in Oslo.

1.7 Work Processes and Procedures

There were formal processes and procedures in place which regulated the entry into confined spaces. A permit to work had to be issued and approved, and a confined space entry checklist had to be completed, before the welding crew could enter the tank. Since the welding job inside the ballast tank was classified as hot work, there was also a hot work checklist that had to be completed before carrying out the work. In addition, another work permit had to be completed for the welding of the two stiffeners.

Before entry, a number of steps had to be observed, to ensure that:

- people performing the job were well trained;
- work risk assessments were carried out;
- work permits have been organised and issued;
- toolbox talks among team members performing the job have been done;
- a confined space rescue plan has been prepared;
- measurement of oxygen levels has been done and the absence of toxic gases has been ascertained before any space ventilation;

- the space has been mechanically ventilated;
- signposting to warn for confined space work has been done;
- any electrical, flow line and other equipment has been isolated and logged according to the lock-out tag-out procedure as necessary;
- unintended start-up of equipment is prevented; and
- crew members intended to perform the work have applied the `Step-Back 5x5´ risk assessment scheme on-site.

Information made available to the safety investigation indicated that all the required steps, outlined by the confined space entry procedure had been followed on the day of occurrence, and associated plans and checklists had been properly prepared and filled, as well as those required by the hot work checklist.

The ‘Step-Back 5x5’ process was a way for the team to perform the job to assess and generate a shared understanding of the risks that they associated with the job, while they were present on site, and to plan any necessary risk mitigation strategies, by means of pocket size cards that would be filled out in situ (Figure 14).

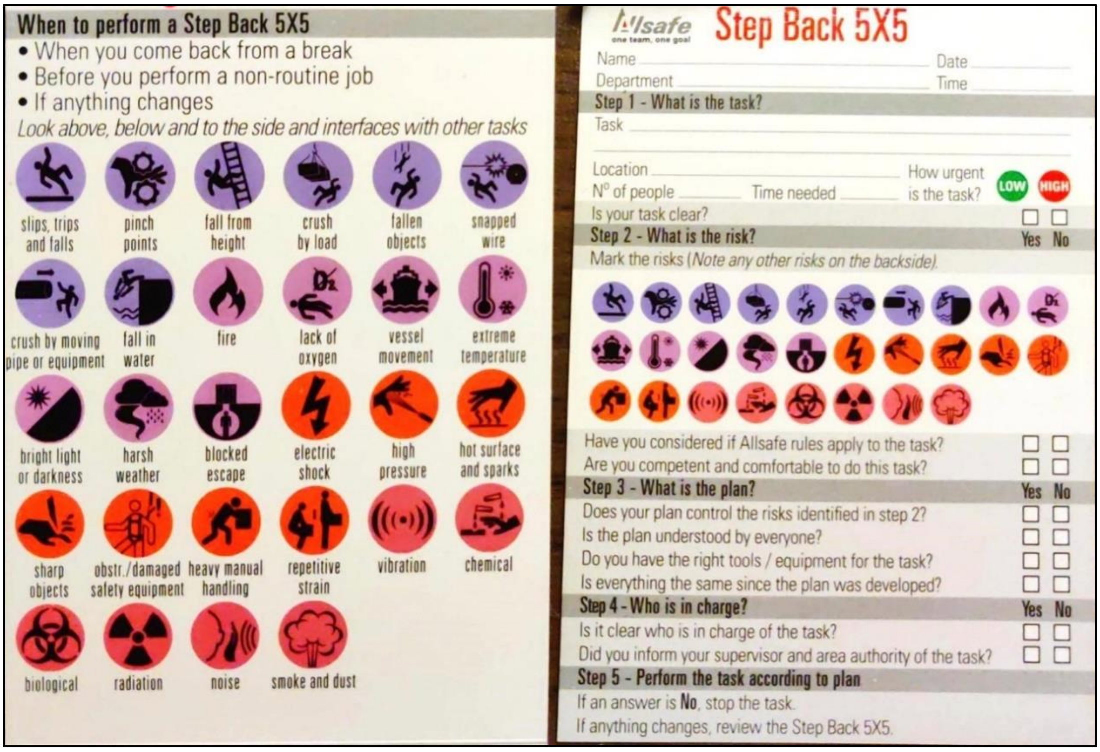

Figure 14: Step-Back 5x5 pocket cards used on board for in-situ risk assessment

1.8 Injuries Suffered by the IP

As a consequence of the fall, the IP sustained severe head injuries and several fractures to his face and pelvis. He remained in hospital for 24 days, during which time, he was assisted in his breathing. He was then discharged and transferred to a hospital in his home country where he underwent further medical treatment. At the time of drafting this safety investigation report, the IP was reportedly still undergoing further medical treatment and was not yet deemed fit to resume work on board.

2 ANALYSIS

2.1 Purpose

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

2.2 Co-operation

Norway and Spain were identified as States with substantial interest in this safety investigation. Cooperation was forthcoming and any information requested during the safety investigation had been provided.

2.3 Fatigue

The crew members that were on duty and involved in this occurrence, had all started their shift at 1200. They had been working for only 1.5 hours before the accident occurred. Day shift workers had a total of 12 hours rest, from 0000 to 1200, before their shift started. This was in line with the requirements of the STCW Code and MLC 2006. The MSIU could not verify the quality of their rest, however, the safety investigation did not find any evidence to indicate that fatigue was contributory to this occurrence.

2.4 Planning of the work in the tank

While the formal work risk assessments that were conducted as part of the planning for the welding job did consider fall from heights, they were restricted to the movement on the tank's access ladders with their equipment – not in relation to risks posed by the structural characteristics of the tank. The access route to the work site was not amongst the items to be discussed in the formal work risk assessments. Neither was the access route discussed as part of the Step-Back 5x5 process done by either the night or day shift welding teams, prior to the entry into the tank and preparation for the job.

When the night and day shifts welding teams entered the tank on several occasions to reach the work site, discuss and plan the job, they all walked directly from the access ladder onto the trunk. It would appear that the repetitive, same route taken by the workers had been accepted as the route to reach the work site. Venturing outside this route had not been considered prior to the accident.

The IP had been assigned to the welding team just before the work was to commence. The welder foreman thought that a change from the previous job would be appropriate. The Company believed that these changes were standard practices to avoid complacency. Because of this last minute decision, the IP had not participated in the Step-Back 5x5 talk, which the other welding team members had been involved in, before he joined at the work site and it was not conducted again after this change, as prescribed by Step 5 in the Step-Back 5x5. When the IP entered the WBT, just prior to the accident, it was the first time that he entered this specific tank. Since he was not part of the preparatory steps for the task in the WBT, it may be hypothesised that the IP may have taken a different route because he did not share a common understanding of this seemingly trivial detail in the job scope, that might have arisen informally during preparations.

In the absence of any witnesses, and due to the IP's memory loss, it may also be suggested that, at the time, he may not have been comfortable to step over the one metre gap from the access ladder to the cable trunk and, therefore, he might have opted for a different route. This is suggested since the IP had directly worked with the welder inside the tank while passing on the relevant hoses to be connected. As mentioned elsewhere in this investigation report, the welder at the time was on the cable trunk and visual contact was made with the IP. At that time, this may have been an indicator to the IP with regards to the whereabouts of the work site location.

During the course of the safety investigation, it was revealed that a discussion was held on whether a scaffolding, similar to the one installed in Tenerife, was needed inside the tank before work could be commenced. However, this was shot down as the task in the WBT was considered to be a minor one and not time consuming. It seems that even though the dayshift safety officer wanted to improve the access in between the access ladder and the trunk, he did not consider it as posing imminent danger, as the works were not stopped. More so, everyone who was involved in the job inside the WBT voiced no concern on the need to step from the access ladder to the cable trunk.

2.5 Accident Dynamics

The IP deviated from the guided access inside the tank by crossing a guardrail which served as a barrier in between the access ladders and pathway, and the rest of the tank (Figure 11).. The IP fell through the opening in the deck on his way to the work site, landing on the bottom of the tank, a drop of about 16 m (Figure 15). The final location of the IP was slightly offset from the deck opening above, in an aft ward direction. This suggested that the IP was in motion and in the direction of the work site, when he fell through.

In the absence of any witnesses and due to the IP's inability to recall the events, the following hypothesis were drawn up to justify the possibilities of why this accident had happened:

- the IP was looking up in the direction of the work site while walking ahead, failing to see the opening;
- the bag he was carrying may have obstructed the opening on the tween deck; or
- the IP noticed the opening ahead of him but, while circumnavigating it, slipped and fell through the opening.

Through these hypothesis, the safety investigation also considered the possibility that the IP was uncomfortable with crossing the one metre gap in between the access ladder and the cable trunk.

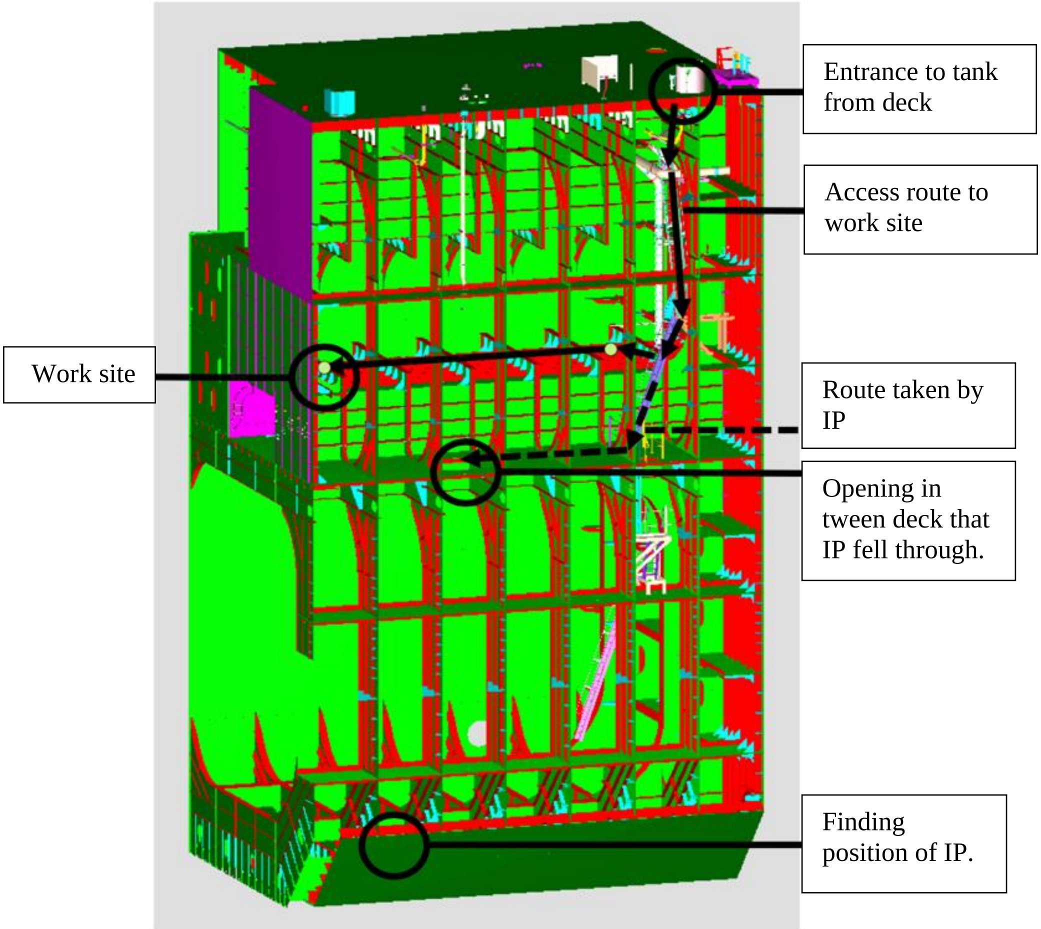

Figure 15: 3D model of water WBT no. 1006, as viewed from starboard side - walking routes marked

2.6 Material Barriers

Material barriers present physical hindrance, which either prevent an action from being carried out (preventive function) or the consequences from spreading (protective function). Therefore, should prevention not be complete, they would minimise the effects of the consequences. A material barrier does not have to be perceived or interpreted by the acting agent for it to serve its purpose.

In the WBT, no barriers were installed immediately around the opening in the deck. The access pathway guardrails acted as a barrier to the entire tank area outside the pathway. However, this barrier was ineffective if work had to be done outside of the pathway. For example, the welding of the additional stiffeners, as part of the jacket lift system installation, were also to be carried out outside the pathway. The passing through the barrier posed a great risk at the time of the accident, but with little or no knowledge of the specific tank architecture it cannot be expected that the IP could have had a focus on the potential dangers associated with this walking route.

It was later revealed that at several locations in the WBTs, bars had been installed across the tween deck openings to prevent personnel from accidentally falling through (Figure 16). These openings were noticed to be of smaller diameters than the one in WBT no. 1006. The openings in WBTs (including no. 1006) were designed to allow large volumes of ballast water to flow through. Additionally, these openings were considered as an access to the large valves, which were installed on the lower part of the tank and, should maintenance be necessary, these openings would be used for the lifting of these valves. Thus, barrier systems such as the bars fitted in other locations of the WBTs were not feasible for such openings.

It was later revealed that some WBTs fitted on board *Pioneering Spirit* had bars across the tween deck openings to prevent someone from going through. These openings were noted to be of smaller diameters than the ones fitted in the WBT (Figure 16). It was not known why these bars had not been installed on all tween deck openings of all tanks present on board.

Figure 16: Protected openings on tween decks of other water ballast tanks

This safety investigation believes that absence of material barriers around the tween deck opening inside of WBT no. 1006, was contributory to this occurrence.

2.7 Personal Protective Equipment (PPE)

Reportedly the IP was wearing a coverall, gloves, safety helmet, safety glasses, and a safety harness. Additionally, work specific PPE, including the face shield, was also meant to be brought to the work site in his bag.

The safety helmet was found at the tween deck level, in a corner next to the opening with its torch switched on. This may suggest that at the time of occurrence, the IP was either holding the helmet in his hand, or the chin strap was not fastened while the helmet was on his head. While taking note that the safety helmet may have reduced the injuries sustained by the IP, it is highly probable that, considering a drop of 16 m, the helmet would not have prevented injuries to the head.

The IP was also wearing a safety harness during the time of occurrence, as was required by the permit to work for confined space entry and the confined space rescue plan. This requirement, however, was placed just in case a rapid extraction would be needed in case of a collapse due to inadequate atmosphere. Due to the injuries suffered by the IP, the harness could not be used to rapidly extract him, since it would most likely have caused his injuries to worsen.

THE FOLLOWING CONCLUSIONS AND SAFETY ACTIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.

3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

3.1 Immediate Safety Factors

.1 It could not be established what caused the fall of the IP through the opening in the deck as he crossed underneath the tank access pathway. Although the lighting in the water ballast tank at the time of the accident was adequate, it was not excluded that:

- the IP was looking up in the direction of the work site while walking ahead, failing to see the opening;
- the bag he was carrying may have obstructed the opening on the tween deck; or
- the IP noticed the opening ahead of him but, while circumnavigating it, slipped and fell through the opening.

.2 There was no immediate barrier system around the opening, which could have prevented the fall.

3.2 Latent Conditions and other Safety Factors

1. There was no determined pathway to the work site, neither by crossing over the trunk nor on the tween deck below, as was the case during previous work at the site.
2. While it could not be established exactly why the IP chose the particular route to the work site, the fact that he was not part of the planning of the work, and had not taken the route to the work site together with his peers during the preparatory work, suggests a potential lack of clarity or alignment with the IP's team mates as to how to best reach the work site once inside the WBT. This may have prompted him to take the different route that he did.
3. All crew members viewed the work in the WBT as a minor task, due to which, a number of safety precautions were deemed unnecessary.

4 ACTIONS TAKEN

During the course of the safety investigation, the managers of *Pioneering Spirit* have carried out the following safety actions:

- The tripod for recovery of persons from a confined space, which was installed by the manhole as a standard procedure for tank entry, was after the accident changed to a scaffolding construction instead. Moreover, it was decided that the scaffolding personnel on board would be included into the rescue team processes;
- The work risk assessment for confined space entry on board was amended to include additional controls which identify the safe route to the work site in large tanks;
- The confined space awareness training was amended to include the specific risks in large tanks. All crew which were required to work in confined spaces had received the updated training;
- Safety session were held with the entire crew of Pioneering Spirit, to explain what had happened and any immediate and preventive actions that will have to be undertaken from that day onwards;
- During the safety session the crew was reminded to redo the Step Back 5x5 when anything changes, including people. The procedure was revised to include the need to review in case of any changes including *persons*.