Final Report

FATALITY OF CREW ONBOARD CHEMICAL TANKER CONCERTO AT SEA ON 1 JUNE 2022

TIB/MAI/CAS.126

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

9 June 2023

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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SYNOPSIS

On 1 June 2022, the Singapore registered oil and chemical tanker, MT Concerto, while enroute between ports in China, was carrying out gas-freeing operation upon completion of tank cleaning operation of cargo tanks (COTs).

An Able Seafarer Deck (ASD), who was on look-out duty on the bridge, was tasked by the watchkeeping officer at the instructions of the Chief Officer to perform change-over of the portable air chute on the main deck for the ongoing gas-freeing operation of the COTs. The ASD was later discovered lying unconscious on the main deck. Efforts to revive the ASD were unsuccessful and the ASD was declared dead.

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

In the absence of the autopsy report, the investigation opined that the ASD had likely inhaled N_2 and some toxic vapours from the cargo tanks while in the process of conducting the change-over of portable air chute from COT 8P to 8S. The investigation further revealed that the established venting procedures for carrying out the gas-freeing operation were not used onboard and the crew did not check the gas concentration of the COTs prior to its commencement.

In addition, there was no risk assessment and toolbox talk carried out for the personnel involved in the gas-freeing operation. There was also a lack of effective implementation of the SMS requirements onboard Concerto, such as allowing gas-freeing operation (change-over of portable air chute) to continue during still weather and the look-out being sent down from the bridge during the hours of darkness while the vessel was under way at sea.

DETAILS OF VESSEL

Name	Concerto
IMO number	9743837
Flag registry	Singapore
Classification society	Nippon Kaiji Kyokai (ClassNK)[1]
Ship type	Oil and chemical tanker
Hull	Steel
Delivery	31 July 2017
Owner/ ISM Manager[2]	Diana Navigation Pte Ltd / TM Shipmanagement Co. Ltd
Gross tonnage	22987
Length overall	180.15m
Moulded breadth	28.20m
Moulded depth	16.30m
Summer draft	11.37m
Service speed	About 14 knots

Concerto
(*Source:* the Company)

[1] As per the international management code for the safe operation of ships and for pollution prevention – ISM Code, ClassNK was the Recognised Organisation (RO) for carrying out ISM audit and issuance of ISM related certificates, as well as for survey and issuance of other statutory certificates.
[2] The "ISM Manager" is referred to as the Company in this investigation report.

1 FACTUAL INFORMATION

All times used in this report are ship's mean time of Concerto which was eight hours ahead of the UTC (UTC+8), unless otherwise stated.

1.1 Sequence of events

1.1.1 On 30 May 2022, at 1236H, after discharging its cargo, Concerto departed the Port of Dongguan, China, and was bound for another port, Nantong, China.

1.1.2 At about 0600H on 31 May 2022, while the vessel was at sea, the ship's crew commenced cleaning operation for cargo tanks (COTs) of 2P, 4P, 6S, 8P, 8S and 13S[3] using hot sea water and freshwater for rinsing, in preparation for a docking survey in China.

1.1.3 At about 1800H, the tank cleaning operation of the six COTs was completed. The Chief Officer (CO) then commenced lining up all these tanks for gas-freeing operation[4] with the assistance of deck crew. Three COTs (2P, 4P and 8P) were planned to be connected to a common pipeline using a portable air chute, taking fresh air from the fixed gas-freeing air fan located inside the ballast pump room.

1.1.4 At about 1830H, the line-up[5] of the three COTs was completed and gas-freeing operation commenced. All deck crew then stood down and returned to the accommodation. The CO went to the bridge and provided the Junior Third Officer (Jr 3O), who was the Officer of Watch (OOW) with some instructions for gas-freeing the COTs, and for these instructions to be handed over to the next duty officer. The CO stood down and went to his cabin for rest.

1.1.5 At about 2350H, an Able Seafarer Deck (ASD1), who was the in-coming watchkeeper[6] met up with the out-going watchkeeper[7], another Able Seafarer Deck (ASD2) on the bridge. Both went on deck to change-over the portable air chute from 2P to 13S (see **figure 1**) as tasked by the Jr 3O.

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[3] P represents port side and S represents starboard side.
[4] The gas-freeing operation is required for the preparation of man entry into the tank for various purposes, such as inspection and survey, maintenance work, or manual cleaning to load another type or different grade of cargo or washing for clean ballast tank.
[5] Setting up of cargo tanks, pipelines etc. for an operation.
[6] Keeping sea watches with the Second Officer for the periods of 0001-0400H and 1200H-1600H.
[7] Keeping sea watches with the Jr 3/O for the periods of 0800-1200H and 2000H-2400H.

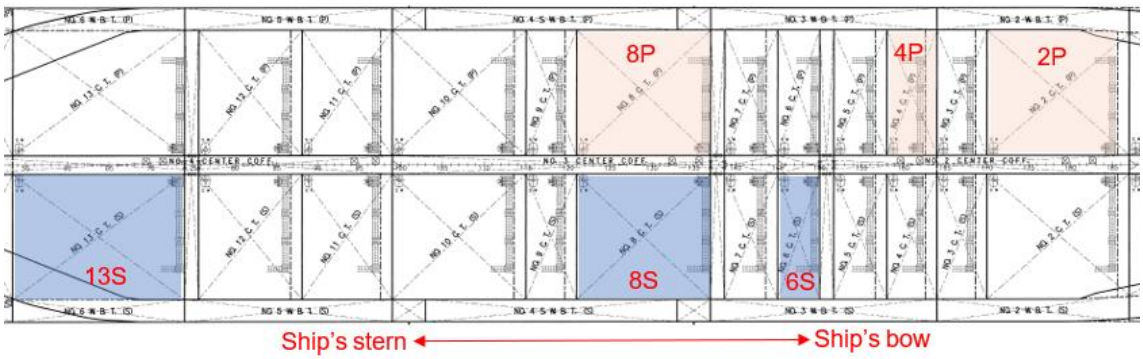


Figure 1 – Gas-freeing of six COTs
indicated on ship's General Arrangement plan
(*Source*: the Company, annotated by the TSIB)

1.1.6 After completing the task, the ASD2 stood down from his duty and the ASD1 returned to the bridge at about 0012H, on 1 June 2022. By this time, the Second Officer (2O) had taken over the navigational watch as the OOW from the Jr 3O.

1.1.7 At about 0208H, the ASD1 left the bridge as instructed by the 2O, to change over the portable air chute for other COTs (4P to 6S and 8P to 8S) according to the instruction given by the CO. At about 0215H, the ASD1 performed a radio check using a walkie-talkie with the 2O on the bridge when leaving the accommodation from the port side and informed that he was proceeding to the deck for the task. The 2O acknowledged the ASD1's reporting. There was a torch light beam captured by ship's CCTV[8] and it is deemed from the torch light carried by the ASD1.

1.1.8 At about 0235H (20 minutes past since the last reporting), the 2O called the ASD1 on the radio to check the status of the task but did not receive any response. The 2O tried a few more calls to no avail. The 2O then called other common spaces[9] inside the accommodation using the ship's internal telephone but could not locate the ASD1.

1.1.9 The 2O then called the duty engineer in the engine room and requested for his assistance to send the Oiler, who was on duty together with the duty engineer, to look for the ASD1 in the accommodation, including the ASD1's cabin. The 2O continued calling the ASD1 by radio.

1.1.10 At about 0242H, after passing several vessels in the vicinity, the 2O switched

[8] CCTV was installed at forward mast facing aft and captured the entire deck area.
[9] Cargo control room, crew and officer mess rooms.

on the bridge wing cluster lights[10] located at the port and starboard sides to illuminate the deck to look for the ASD1 and subsequently switched them off.

1.1.11 By about 0245H, having searched all the common spaces in the accommodation and the ASD1's cabin, the Oiler reported that the ASD1 could not be found. The 2O immediately informed the CO that the ASD1 was uncontactable after going on deck.

1.1.12 The CO went on deck and noticed that ambient air on deck was still and instructed the 2O to alter the ship's heading towards the wind in view of the on-going gas-freeing operation. The CO walked towards forward from the port side and around 0256H found the ASD1 lying unconscious on the starboard side main deck. There were no signs of injury on the ASD1's body, the CO informed the 2O on the bridge, who then informed the Master accordingly.

1.1.13 The Master immediately went up to the bridge and instructed the 2O to raise the ship's general emergency alarm. The Master made an announcement on the public address system calling all crew to muster for an emergency. He also took over ship's conn and further altered the ship's heading to the starboard side to gain some natural air flow on deck.

1.1.14 By about 0300H, all crew had mustered and proceeded to assist the CO in recovering the ASD1 while the gas-freeing operation continued[11]. The CO checked on the ASD1's condition again and confirmed there were no signs of breathing, no pulse was detected, and his body temperature was measured to be about 34 degrees Celsius. The CO and Bosun took turns to provide artificial respiration and CPR[12] to the ASD1.

1.1.15 The Master handed over the conn of the vessel to the Jr 3O and went to the deck to check the condition of the ASD1. Thereafter the Master reported this incident to the Company.

1.1.16 By about 0325H, the ship's crew shifted the ASD1 to A-deck alleyway inside the accommodation. CPR and artificial respiration were continued but the ASD1 remained unconscious without any signs of breathing or pulse. Blood pressure was unmeasurable, and the body temperature remained at about 34

[10] The 2O didn't switch on the bridge wing cluster lights earlier as this would affect the safe navigation of Concerto and of the passing vessels in the vicinity.
[11] The gas-freeing fan was still running when the ASD1 was discovered.
[12] Cardiopulmonary resuscitation. The Resuscitator was also used to provide medical oxygen.

degrees Celsius.

1.1.17 At about 0350H, the Master updated the condition of the ASD1 to the Company and diverted the ship to the nearest port (Taichung, Taiwan) which was about 40 nm away, with the concurrence of the Company. By this time, the body temperature of the ASD1 had dropped to about 33.4 degrees Celsius.

1.1.18 At about 0600H, the condition of the ASD1 did not improve and the body temperature further dropped to about 23 degrees Celsius. In consultation with the Company, the Master stopped the vessel [13] and waited for further instructions regarding the next destination. The investigation team gathered that Radio Medical Advice was not sought considering the body temperature and no response of the ASD1.

1.1.19 At about 1100H, with no change in the ASD1's condition over the last five hours, in consultation with the Company, the Master declared the death of the ASD1. The ASD1's body was then shifted to the ship's provision storeroom [14] for preservation. On 2 June 2023, at about 1000H, the Company instructed the vessel to proceed to the port of Yeosu, South Korea for offloading of the body.

1.1.20 On 5 June 2022, at about 1248H (local time in South Korea, UTC+9), Concerto anchored at the port of Yeosu. At about 1600H on 6 June 2022, after the necessary port formalities, the body of ASD1 was transferred ashore and at about 2218H, Concerto resumed her voyage to the next port of call.

1.2 The ship

1.2.1 Concerto is an oil and chemical tanker having a total of 28 COTs located at the port and starboard side allowing her to carry different types of chemicals segregated. At the time of the incident, she was chartered for the carriage of MARPOL Annex II[15] cargoes, loaded mainly at ports in the Middle East for discharging at ports in Asia.

1.2.2 At the time of occurrence, of the 28 COTs, five were in laden condition and Concerto was drawing a draught of 5.7m forward and 7.8m aft.

[13] The vessel was drifting at a location of Latitude 24 34.2N and Longitude 120 11.2E (about 24nm away from Taichung port) while waiting for further instruction from the Company.
[14] Ship's vegetable room where the temperature was kept at 4 degrees Celsius.
[15] The International Convention for the Prevention of Marine Pollution from ships, as modified by the Protocol of 1978. The Annex II regulates the Control of Pollution by Noxious Liquid Substances in Bulk.

1.2.3 Concerto, a typical chemical tanker of a similar design like others, has external raised deck frames of about 1.3m high all along the deck above the cargo tanks (see **figure 2**). These deck frames extend on deck athwartships from one side to the other.

Figure 2 – View of the deck and raised deck frames
(*Source*: the Company)

1.3 The crew

1.3.1 There were 24 crew of single nationality (Bangladeshi) onboard, and one Korean technical superintendent from the Company was following the vessel for preparation of the scheduled docking repair in China. All crew held valid STCW [16] competency certificates required for their respective positions onboard, and the working language was English.

1.3.2 The qualification and experience of the Master, relevant officers and crew are tabulated in table 1 below.

Designation onboard	Age	Qualification	Duration onboard (month)	In rank service (Year)	Service in Company (Year)	Working schedule onboard
Master	46	COC – Master / STCW II/2, IV/2	1.5	7.58	5.33	N/A
Chief Officer	44	COC – Chief Officer / STCW II/2, IV/2	1.5	0.17	7.5	0800-1700 (Day worker)

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

Second Officer	36	COC – Officer of the watch (deck) / STCW II/1, IV/2	7.8	2.08	5.42	1200-1600 0000 – 0400
Jr Third Officer[17]	26	COC – Officer of the watch (deck) / STCW II/1, IV/2	0.9	0.25	1.83	0800-1200 2000 – 0000
ASD1	**26**	Deck Rating as per STCW II/5	**7.8**	**0.92**	**2.92**	**1200-1600 0000 – 0400**
ASD2	39		7.8	6.5	1.5	0800-1200 2000 – 0000

Table 1

1.3.3 The CO had been newly promoted from 2O and had undergone a structured computer-based training developed by the Company, in preparation for his promotion. Since joining, he was under the supervision of his predecessor as trainee since 17 April 2022.

1.3.4 During the training period which lasted about a month, the CO had performed a full tank cleaning and gas-freeing operation under observation, from Singapore to Batangas and Batangas to Ulsan respectively. The CO took over duties from his predecessor who signed off Concerto at Ulsan on 22 May 2022. The CO then performed one tank cleaning and gas-freeing operation on the voyage of Ulsan and Dongguan, which was followed by another one from Dongguan to Nantong, during which the occurrence took place.

1.3.5 All persons listed in Table 1 had undergone an Advanced Tanker Operations training for serving onboard oil and chemical tankers. The course covered areas of cargo loading, discharging and care in transit or handling of cargo which was based on the guidelines of the IMO Model course 1.02 and 1.03[18], in accordance with standard industry requirements.

1.3.6 The ASD1 had started sailing on the Company's vessels since 2017 and was promoted from an ordinary seaman to an ASD in 2020. Prior to joining Concerto, he had served on four chemical tankers. He had experience in tank cleaning and gas-freeing operations onboard Concerto in April and May 2022, prior to this occurrence.

1.3.7 According to a Medical Examination Certificate issued to the ASD1 on 19

[17] The Jr 3O was on his first ship as a deck officer.
[18] 1.02 - Advanced Training for oil Tanker Cargo Operations. 1.03 - Advanced Training for Chemical Tanker Cargo Operations.

September 2021 by a medical institution approved by the DG Shipping Bangladesh for seafarers' medical check-up, the ASD1 was certified medically fit for duty onboard ship. The certificate issued was valid for two years, without any limitations or restrictions on fitness in accordance with the STCW Code[19]. The section of self-declaration in the certificate did not indicate any pre-existing health issues.

1.3.8 Prior to the incident, the ASD1 supported the CO for the tank cleaning operation during his afternoon watch period (1200H-1600H) on 31 May 2022. According to Concerto's work/rest hour records, in the past 24-hour prior to the occurrence, the ASD1 had 16 hours of rest and in the last 7-day period, he had 112 hours of rest, indicating compliance with the STCW and MLC Convention's requirements concerning the hours of work and rest[20].

1.4 The last cargo discharged and other relevant information

1.4.1 Details (relevant information and associated hazards) of the last cargo discharged from the five COTs (2P, 6S, 8P, 8S and 13S) and one used as pre-wash solvent loaded in COT 4P are listed in the table 2.

	2P	**6S**	**8P**	**8S**	**13S**	**4P**
Last cargo	Diethanolamine (DEA)	Toluene diisocyanate (TDI)	Polymethylene polyphnyl isocyanate (PAPI)	Polymethylene polyphnyl isocyanate (PAPI)	Butyl Cellosolve[21]	Methylene Chloride[22] (MEC, as cargo tank pre-wash solvent)
Quantity[23] discharged	423MT	828MT	812MT	812MT	202MT	40m^3
Identified and potential hazards extracted	• Harmful if swallowed • Irritating to skin, risk of serious	• Causes skin irritation • Causes serious eye	• Causes skin and eye irritation • Harmful if	• Causes skin and eye irritation • Harmful if	• Combustible liquid • Harmful if swallowed, in	• Causes eye irritation • Harmful if inhaled • Aspiration hazard

[19] STCW Code, A-1/9 which defines the standards of medical fitness for seafarers.
[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] The product name refers to Ethylene Glycol Monoalkyl Ethers, which is listed in the table of Chapter 17 of the IBC Code.
[22] The product name refers to Dichloromethane, which is listed in the table of Chapter 17 of the IBC Code.
[23] Figures in metric tonnes as per ship's records are rounded off the decimals.

from MSDS	damage to eyes • Danger of serious damage to health by prolonged exposure if swallowed	irritation • Fatal if inhaled • May cause respiratory irritation	inhaled • May cause respiration irritation • etc	inhaled • May cause respiration irritation • etc	contact with skin or if inhaled • Causes skin irritation • Causes serious eye irritation	• Can enter lungs and cause damage to body systems • In poorly ventilated areas, vapor can readily accumulate and can cause unconsciousness and death
TLV-TWA[24] from MSDS	1mg/m^3 =0.23ppm	0.005ppm	0.005ppm	0.005ppm	200ppm	200mg/m^3 =50ppm
IBC[25] Code – hazards[26]	Safety and pollution hazards	Safety and pollution hazards	Safety and pollution hazards	Safety and pollution hazards	Safety and pollution hazards	Safety and pollution hazards
IBC Code – Vapour detection[27]	Toxic vapours	Toxic vapours	Toxic[28] vapours	Toxic vapours	Flammable and toxic vapours	Flammable and toxic[29] vapours
IBC Code – Chapter 15[30]	• The ventilation system exhaust ducts shall discharge at least 10m away from openings into accommodation spaces, work areas or other similar spaces, and intakes to ventilation	• Same as column 2 • In addition, this type of cargo may react to water in a dangerous manner	• Same as column 2 • In addition, this type of cargo may react to water in a dangerous manner	• Same as column 2 • In addition, this type of cargo may react to water in a dangerous manner	Overflow control for safe loading and others	• Same as column 2

[24] Threshold Limit Value (TLV) and Time Weighted Average (TWA) is the airborne concentration of a toxic substance averaged over an 8-hour period, usually expressed in parts per million (ppm).
[25] International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk.
[26] "S/P" in column "d" listed in the table of Chapter 17 of the IBC Code indicating both its safety and pollution hazards.
[27] Carbon or other flammable vapours content to less than 2% by volume which the combustion cannot be supported if air is subsequently introduced into the tank.
[28] The MSDS of the PAPI indicates that the acute inhalation toxicity is LC50, Rat, 4h, 0.49mg/l.
[29] The MSDS of the MEC indicates that the acute inhalation toxicity is LC50, 7h, Rat > 10000ppm (10000mg/l).
[30] Special requirements in Chapter 15 are applicable where specific reference is made in column "o" in the table of Chapter 17. These requirements are additional to the general requirements of the Code.

	systems, and at least 4m above the tank deck.					

Table 2 – List of cargo and pre-wash solvent carried in the five COTs and its associated hazards

1.4.2 According to the Company, the MEC was regularly carried in the Company's fleet of ships either as cargo or cleaning solvent for several decades, and the crew onboard ships were familiar with the handling of this product.

1.4.3 According to the Company, the personal protective equipment (PPE) required after full tank cleaning (including hot water washing and freshwater rinsing) for changing-over of the portable air chutes for the six COTs listed in table 2, was to be considered as level C.

1.4.4 At level C, respiratory protection (SCBA) was not needed, but skin and eye protection were required. The SCBA only needed to be worn under level A and B. The PPE required for different level of protection[31] is indicated in tables 3a,3b and 3c.

Protection	Safety helmet	Safety shoes	Boilersuit	Safety glasses	Chemical splash goggles	Chemical splash suit	Chemical gloves	Chemical boots	Gas tight suit	SCBA	Personal gas meter
Level A	●		●						●	●	
Level B	●		●			●	●	●		●	●
Level C	●	●	●		●	●	●	●			●
Level D	●	●	●		●	◊	●	◊			●
Level E	●	●	●	●	◊	◊	◊	◊			●

● As essential equipment must wear
◊ Consider wearing depending upon circumstances/risk assessment

Table 3a – PPE required for different levels of protection

[31] Level A has the highest level of skin, respiratory and eye protection; level B has the highest level of respiratory and eye protection but with low level of skin protection; the cargo being handled are less hazardous, respiratory and skin protection are not an issue, but eye protection is still required for level C.

Hazard level	Inhalation	Ingestion	Eyes	Skin Absorption
Level A	High	High	High	High
Level B	High	High	High	Medium
Level C	Low	Low / Medium	Medium	Medium
Level D	Low	Low / Medium	Medium	Low
Level E	Low	Low	Low	Low

Table 3b – Level of PPE protection based on the types of exposure

Type of operation	Toxic	Corrosive	Flammable	None of the three
Cargo watch	D	D	D	E
Sampling	A or B or C	A or B or C	C	D
Tank cleaning with fixed machines	C	C	E	E
Tank cleaning with portable machines	A or B or C	A or B or C	C	D
Sweeping inside COTs	Not applicable	Not applicable	Not applicable	D
Emergency spill response	A or B or C	A or B or C	D	D
Any other task where risk of exposure may exist	A or B or C	A or B or C	D	D

Table 3c – PPE matrix for different types of operations and different types of hazards

1.5 The tank cleaning process

1.5.1 After all cargo were discharged from the five COTs at the port of Dongguan, a pre-wash was planned for three COTs (6S, 8P and 8S) by using MEC, which was loaded in the COT 4P (about 40m³), to achieve the ideal results of cleanliness. MEC was used for flushing pipelines and cargo tank bottom first and then recycled for tank cleaning.

1.5.2 The introduction of MEC into the three COTs[32] was staggered into two batches – firstly, to COT 6S followed by both 8P and 8S. At the end of pre-washing each of these three COTs, MEC was discharged to shore at the same port. The breakdown of the approximate amount of MEC used in each tank is indicated in table 4 below.

		COT		
		6S	8P	8S
Approximate amount used	Pipeline and bottom flushing	4m³	5m³	5m³
	Recirculation during pre-wash	6m³	10m³	10m³

Table 4 – The approximate amount of MEC used for each COT

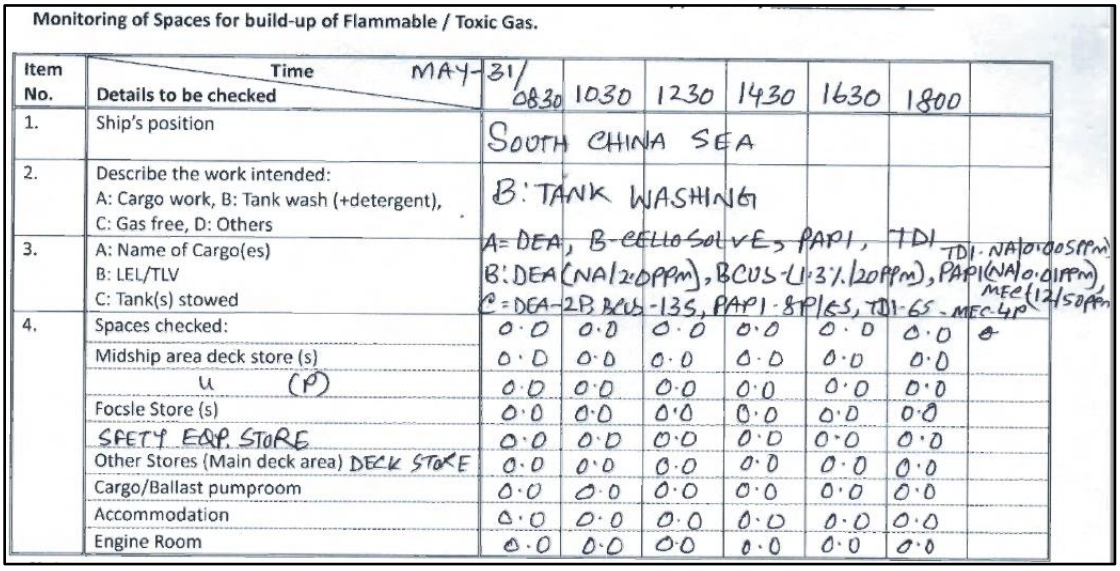
1.5.3 After the pre-wash of the three COTs was completed, a full tank cleaning for all the six COTs, including COT 4P, was performed when the vessel departed the port. Full tank cleaning was carried out in a sequence of three hours with hot sea water Butterworth[33] washing, followed by a fresh water rinsing of about 15 minutes for each COT.

1.5.4 During the tank cleaning, an atmosphere check and monitoring of various spaces were carried out as per the Company's established procedures, such as forecastle store, deck store at midship, safety equipment store, deck store, accommodation, cargo/ballast pumproom and engine room. The readings[34] were all measured to be zero by ship's crew on 31 May 2022 (see table 5).

[32] The pre-wash with MEC was needed for COT 6S, 8P & 8S due to the probability of the chemical carried previously may react to water in a dangerous manner.

[33] The washing machines on Concerto are fixed type which consist of revolving nozzles, driven by liquid to create a spherical wash pattern or cycle inside a cargo tank.

[34] Abbreviations of cargo names written in the records for Lower Explosive Limit (LEL) and Threshold Limit Value (TLV) are referred as, DEA - Diethanolamine; B CELLOSOLVE - Butyl Cellosolve; PAPI - Polymethylene polyphnyl isocyanate; TDI - Toluene diisocyanate.



Monitoring of Spaces for build-up of Flammable / Toxic Gas.

Item No.	Details to be checked \ Time MAY-31/	0830	1030	1230	1430	1630	1800	
1.	Ship's position	SOUTH CHINA SEA						
2.	Describe the work intended: A: Cargo work, B: Tank wash (+detergent), C: Gas free, D: Others	B: TANK WASHING						
3.	A: Name of Cargo(es) B: LEL/TLV C: Tank(s) stowed	A= DEA, B-CELLOSOLVE, PAPI, TDI TDI-NA/0.005PPM B: DEA(NA/20PPM), BCUS-L/3%/20PPM), PAPI(NA)0.01PPM) C=DEA-2P BCUS-13S, PAPI-8P/6S, TDI-6S - MEC-4P MEC(12/50PPM						
4.	Spaces checked:	0.0	0.0	0.0	0.0	0.0	0.0	0
	Midship area deck store (s)	0.0	0.0	0.0	0.0	0.0	0.0	
	U (P)	0.0	0.0	0.0	0.0	0.0	0.0	
	Focsle Store (s)	0.0	0.0	0.0	0.0	0.0	0.0	
	SFETY EQP. STORE	0.0	0.0	0.0	0.0	0.0	0.0	
	Other Stores (Main deck area) DECK STORE	0.0	0.0	0.0	0.0	0.0	0.0	
	Cargo/Ballast pumproom	0.0	0.0	0.0	0.0	0.0	0.0	
	Accommodation	0.0	0.0	0.0	0.0	0.0	0.0	
	Engine Room	0.0	0.0	0.0	0.0	0.0	0.0	

Table 5 – Readings of flammable/toxic gas taken on 31 May 2022 (*Source*: the Company)

1.5.5 According to ship's records, the five COTs (2P, 6S, 8P, 8S and 13S) were maintained in an inert[35] condition with nitrogen during the voyage and a vapour return line was used while discharging at the port of Dongguan. COT 4P was also inert with nitrogen before loading with MEC.

1.5.6 During the tank cleaning, as there was no measurement of the tank atmosphere carried out, the gas concentration of all the six COTs was unknown.

1.6 Inert gas and tank venting system

1.6.1 Onboard Concerto, Nitrogen (N_2) used as an inert gas was generated using the ship's membrane separation nitrogen generator and having 95%-99.999% purity with oxygen content of less than 5%. N_2 was supplied to the COTs using a fixed piping system, as and when required.

1.6.2 Concerto had open[36] and closed (controlled) tank venting system to cater for the types of cargo[37] carried onboard. Each COT is installed with a set of high

[35] Introducing inert gas into cargo tanks is to eliminate the risk of fire and explosion by keeping the oxygen content below 5% by volume and supress the combustion of flammable hydrocarbon gases inside tanks.

[36] A standard term used in the IBC Code, the term 'Open' refers to the tank venting system has no restriction and cargo vapour, which is not harmful or flammable, can flow out from the tank during normal cargo operation. If the cargo carried is harmful or flammable, then the controlled tank venting system (like the PV valves) should be used.

[37] Presenting flammable and/or toxic hazards.

velocity pressure and vacuum (PV) valve[38]. This set of valves is fitted at about seven metres above the main deck, serves as a safety device for preventing over and under pressure in the COT and dispels gases away from the main deck in case of over-pressurisation.

1.6.3 On the same structure of the PV valve, a gas-freeing flap (see **figure 3**) is designed to be used during purging and gas-freeing operations. It consists of a cover which is manually open/shut using a wingnut. At the time of the occurrence, the gas-freeing flaps for the six COTs were kept open.

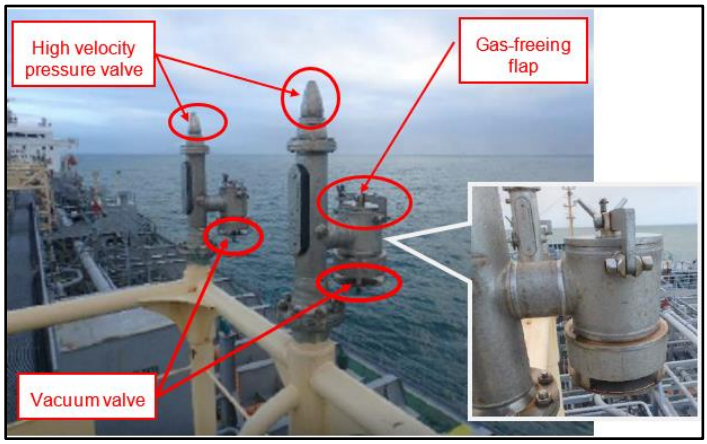


Figure 3 – PV valve with gas-freeing flap
(*Source*: the Company, annotated by TSIB)

1.7 The gas-freeing operation

1.7.1 As per the instructions of the CO, this operation was to be carried out in two batches with each batch involving three COTs. The first batch included COTs 2P, 4P and 8P and the remaining three COTs were for the second batch.

1.7.2 Prior to commencing the gas-freeing operation, the line-up of six COTs was completed at about 1830H on 31 May 2022 (see **figure 4a**), where the respective COT gas-freeing flap and tank cleaning hatch (TCH) were kept open. The oil tight hatch (OTH) of each COT was also cracked open by loosening four bolts and nuts (see **figure 4b**). According to the Company, gas-freeing operation of a COT can be safely performed with the PV valve and the gas-freeing flap open and there is no need to open the OTH or the TCH, in the initial stage of gas-freeing operation.

[38] Pressure (+20KPa) | Vacuum (-3.5KPa).

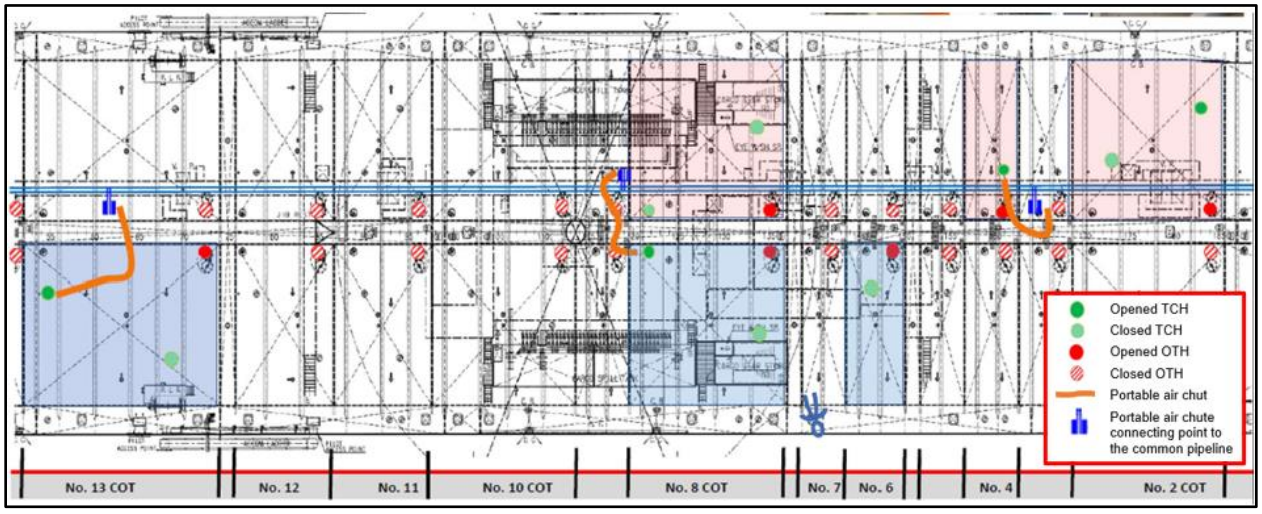


Figure 4a – Status after line-up of six COTs indicated on the General Arrangement Plan (*Source*: the Company)

Figure 4b – Portable air chute connected the TCH and OTH cracked open (*Source*: the Company)

1.7.3 The fixed gas-freeing fan (see **figure 5**) used onboard Concerto is a centrifugal type and solely for gas-freeing purpose with a working capacity of 400m³ per minute. It is directly connected to a common pipeline longitudinally at the center of deck to supply fresh air to the port and starboard sides COTs through portable air chutes connected to the respective COT.

1.7.4 In its interaction with the CO, the investigation team gathered that starting of the fixed gas-freeing fan requires notice to be given to the duty engineer to prepare an additional generator to cope with the increase in electrical load. The CO further explained that once the operation of the fixed gas-freeing fan has stabilised, the duty engineer would stop the additional generator. At the time of occurrence, the engine room was manned by the duty engineer and assisted by an Oiler.

1.7.5 The gas-freeing operation was carried out using the dilution[39] method.

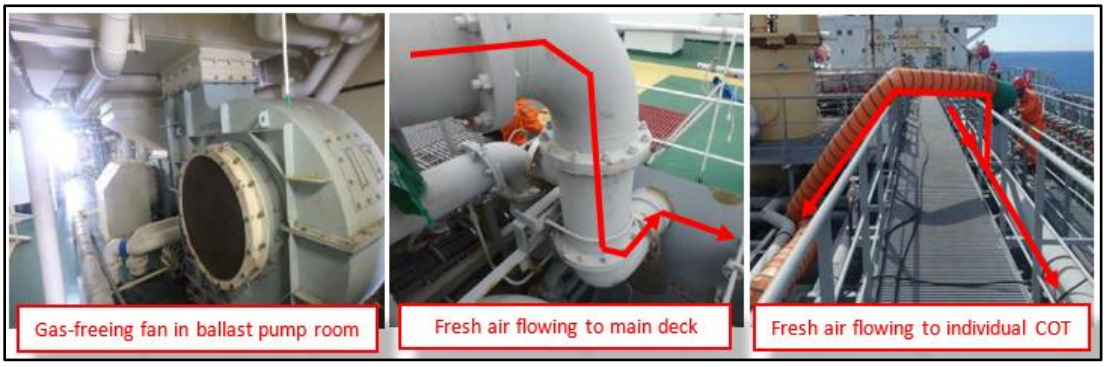


Figure 5 – Flow of fresh air driven into the individual COT from the fixed gas-freeing fan (red annotated by the TSIB; *Source*: the Company)

1.7.6 The CO also added that for operational convenience, when changing over the portable air chute from one COT to another, the fixed gas-freeing fan would not be stopped.

1.7.7 At the time of occurrence, the gas-freeing operation for two COTs (2P and 8P from the first batch) had ended. Gas-freeing operation for one COT from the first batch and two COTs (8S and 13S) from the second batch were still on-going, and gas-freeing for COT 6S, the last COT of the second batch, was yet to commence. The portable air chute had been changed from 2P to 13S by the ASD1 and ASD2 at midnight. The status of the gas-freeing operation is indicated in the table 6 below.

1st batch			2nd batch			Performed by
COTs	**Time started**	**Status**	**COTs**	**Time started**	**Status**	
2P	31 May 2022 / 1830H	Ended at about midnight, 1 June 2022	**13S**	At about midnight, 1 June 2022	Gas-freeing on-going	ASD1 & ASD2
8P	31 May 2022 / 1830H	Ended just prior to the occurrence	**8S**	Started just prior to the occurrence	Gas-freeing on-going	ASD1
4P	31 May 2022 / 1830H	Gas-freeing on-going	**6S**	Pending to start gas freeing	-	-

Table 6 – Status of gas-freeing operation for the six COTs documented by the TSIB

[39] Introducing fresh air into cargo tanks at a high velocity to form a homogeneous mixture throughout the tanks, as a result, the concentration of the original gas decreases progressively.

1.8 The safety management system

1.8.1 The Company managed oil and chemical tankers of type II and type III[40]. A full-term Document of Compliance certificate was issued to the Company by ClassNK on 1 April 2021 based on an audit completed on the same date and valid until 24 April 2026. The last verification audit for this issuance was carried out on 14 July 2022.

1.8.2 A full-term Safety Management certificate was issued by ClassNK to Concerto on 13 December 2017, based on an audit completed on the same date and valid until 12 December 2022. The last intermediate verification was conducted on 28 August 2020.

1.8.3 The last Flag State Control and Port State Control inspections were conducted on 21 November 2019 and on 13 May 2022 respectively, neither of these documented any deficiencies[41].

1.8.4 The Company's Safety Management System (SMS) procedures written in English had a section of gas-freeing operation, which requires the gas-freeing operation to be carefully planned, considering expected vapours that may be flammable, toxic, or corrosive. The procedures noted that a large volume of gas would be expected to dissipate from COTs when using the fixed gas-freeing fan.

1.8.5 The same section provided some guidance on the effectiveness and safe of gas-freeing operation which included the following:

- The end of portable air chutes should be kept at about 3-4 feet height from cargo tank bottom;
- Cargo line valves other than required for ventilation should be closed and secured;
- No gas-freeing is to be carried out in still air condition. Ship's heading to bow/side wind may be necessary while gas-freeing to ensure relative wind of 5m/s (about 10 knots);
- The toxicity hazard shall be adequately briefed to the crew prior to the gas-

[40] According to the International Bulk Chemical Code (IBC Code), type II ships subject to the Code shall be designed to meet the standards of transporting products (listed in Chapter 17 of this Code) with appreciably severe environmental and safety hazards which require significant preventive measures to preclude an escape of such cargo, and type III ships shall be designed to meet the standards of transporting products with sufficiently severe environmental and safety hazards which require a moderate degree of containment to increase survival capability in a damaged condition for type III ships.

[41] Such inspections like audits, are based on a sampling process.

freeing operation and additional precautions taken as per the risk assessment conducted; and

- Ensure cargo lines, manifold common lines and crossovers are well drained and blown through before venting through them. All other non-essential valves in the manifold and cargo piping system shall be closed and secured prior to the gas-freeing operation.

1.8.6 The gas-freeing operation section also highlighted venting of flammable and/or toxic gases from the COTs shall be carried out only through the approved tank venting system. All openings (such as TCH and OTH) at the deck level should be kept closed until the gas concentration within the COT was below 30% low explosive limit (LEL)[42] and the toxic vapour was below TLV-TWA limit (the safe limits). The Company was not aware of the practice (see paragraph 1.7.2) on Concerto to keep the TCH open and OTH cracked open when lining-up COTs.

1.8.7 The Company had established procedures for risk assessment (RA) applicable to all tasks onboard which could cause harm to people, damage to environment and property. Its objectives were to assess all identified risks and to implement safe control measures to keep these risks within a tolerable[43] level. The ship's Master was required to ensure procedures for RA are to be complied with, including effective and efficient control measures are in place and implemented. The Chief Engineer (CE) and the CO were to carry out RA and monitor for their respective area of tasks under their supervision. In doing so, the detailed RA explained in the COSWP[44] could be referred to.

1.8.8 A template in the SMS titled "Risk Assessment Form" had been categorised into different type of tasks, such as deck and engine routine, non-routine operations, maintenance main and auxiliary engines, boiler, navigational equipment, cargo and mooring operations, etc. Tank cleaning was listed as one of the categories. There was no mention of gas-freeing operation in the RA category.

1.8.9 Based on the ship's records, the RA and toolbox talk for tank cleaning operation

[42] The lowest concentration by volume of a gas or vapour that burn in air. It varies from gas to gas.

[43] Defined as a reasonable acceptable level, which no additional controls are required. Arrangements should be made to ensure that controls are maintained. Have a responsible officer supervising the work.

[44] 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 onboard ships. A copy of COSWP was onboard at the time of the accident.

were carried out on 31 May 2022 by the CO with the deck crew and the CE. This RA Form, which was acknowledged by the Master, identified several risks for the preparation, during and after completion of the tank cleaning operation. There was no RA carried out for the gas-freeing operation.

1.8.10 In addition to the established RA procedures, the Company had also created a "Quick Hazard Identification Guide" as a tool, encouraging all seafarers onboard their ship to practice it by asking simple questions. If the answer to any question was a "Yes", the individual was required to discuss it with supervisor and to take preventive measures before starting the job. Some examples of such questions are:

- Is there a risk of slipping, tripping, falling from height or falling overboard?
- Is there any risk of lack of oxygen, or exposure to toxic gases or hazardous substances?
- Is there a risk due to poor lighting?

1.8.11 The Company also had a written policy of "Stop Work Authority", which empowered all staff including seafarers in the Company and contractors engaged to provide services onboard ships, to exercise a "Stop Work" intervention without any fear of punishment, whenever there was a risk or perceived risk to the vessel, life, local environment, or safety of the individual within the working environment including an unsafe condition or an unsafe act observed. The work would be suspended till issues or concerns had been adequately addressed.

1.8.12 The Company also recognised that unsafe acts and unsafe conditions are often an early warning indicator for accidents and considered as risk behaviours. To change these risk behaviours, a Behaviour Based Safety Program had been implemented onboard to train the seafarers on how to observe and identify unsafe acts and unsafe conditions, intervene, and inform the individual, get the individual agreed not to continue the same unsafe acts and to report the observation by recording the details on the SPIRIT Card[45] for trending and rewarding to the individual by the Company. For the past one year, there was no SPIRIT card reported relating to tank cleaning and gas-freeing operation onboard Concerto.

1.8.13 The Company had designated the CE as the Safety and Quality Officer (SQO)

[45] An acronym for Safety Performance Improvement by Respectful Intervention and Training, which is a no-blame initiative for improving the safe operation onboard ships.

onboard each ship to assist the Master, as the chairman of Safety and Quality Committee, by performing certain duties, among others. Of these was to identify hazards to health, safety and environment, to make rounds of vessel daily to check, inspect and monitor and supervise working practices done by seafarers.

1.8.14 The SQO has the authority to instruct any crew directly to correct or improve any non-conformity such as sub-standard condition or improper practice in immediate danger and to recommend the head[46] of concerned departments to correct or improve it. There was no evidence to suggest if the SQO had identified any lapses in the working practices onboard the vessel.

1.8.15 For the safety of navigation, the Company's SMS procedures under the section of "Sole Lookout" stated that an OOW would not be a sole lookout during the hour of darkness[47] and required a duty rating for performing such duty to support the OOW. This requirement had also written in the Master's Standing Orders and acknowledged by the CO, 2O and Jr 3O.

1.8.16 In response to the investigation team's query, the Company clarified that the crew on daywork (Bosun and Ordinary Seaman) had participated in the tank cleaning during the day and thus were not deployed for the gas-freeing operations anticipated for the night.

1.8.17 All officers and crew had, according to the Company, a proper understanding of its SMS requirements.

1.9 Relevant gas-freeing guidelines

1.9.1 The IBC Code requires that the gas-freeing of COTs used for cargo shall be through the vent outlets which shall be at least 2m above the cargo tank deck level, to minimise the hazards due to the dispersal of flammable or toxic vapours in the atmosphere. When the flammable vapour concentration at the outlets has been reduced to 30% of the lower flammable limit and, in the case of a toxic product, the vapour concentration does not present a significant

[46] Referred to the CO, Second Engineer and Chief Steward for the deck, engine and catering departments, respectively.
[47] During the period between sunset and sunrise.

health hazard[48], gas-freeing may thereafter be continued at cargo tank deck level.

1.9.2 The Tanker Safety Guide (Chemicals)[49] also provides guidance on the safe procedures for gas-freeing after tank cleaning and cleaning by ventilation. It highlights that the gas-freeing operation need to be carefully planned, considering the expected flammable, toxic or corrosive vapours. Relevant guidelines listed for the gas-freeing operation are extracted as follows:

- Venting toxic and flammable gas during gas-freeing should be through the ship's approved gas-freeing outlets, which may use high-velocity vent valves sufficient to carry the vapours clear of the deck; and
- In the case of a toxic product, the vapour concentration does not present a significant health hazard, should gas-freeing be continued at the cargo tank deck level.

1.9.3 The Guide highlights the dangers of N_2 which is a colourless and odourless gas that will cause oxygen deficiency in confined spaces and at exhaust openings on deck, during the purging of tanks and void spaces. Exposure to high concentration of N_2 is usually fatal.

1.9.4 The Guide further highlights that exposure to N_2 reduces the O_2 in the body and is also results in a drop in CO_2 levels in the blood. As a result, the lungs are not stimulated to work harder to compensate for the lack of O_2. The person is not aware of any danger and may even feel a state of euphoria before the stimulus to breathe is removed completely and the person is asphyxiated. Crew members with duties associated with operations involving N_2 should be fully briefed on these risks during the toolbox talk.

1.10 Additional information

1.10.1 According to the Company, based on the capacity of the fixed gas-freeing fan, the first batch of COTs would take about seven to eight hours to be thoroughly ventilated with fresh air with only the gas-freeing flap open. According to the records on Concerto, gas-freeing of the first batch of COTs was commenced

[48] Health hazard, defined in the IBC Code as - corrosive effects on the skin in the liquid state or acute toxic effect taking into account values of, LD50 (oral) - a dose, which is lethal to 50% of the test subjects when administered orally; LD50 (dermal) - a dose, which is lethal to 50% of the test subjects when administered to the skin; LC50 (inhalation) - the concentration which is lethal by inhalation to 50% of the test subjects; or other health effects such as carcinogenicity and sensitisation.

[49] Published by the International Chamber of Shipping, a reference book for operations on chemical tankers.

at about 1830H on 31 May 2022, and accordingly the second batch would be expected to start at between 0130H and 0230H on 1 June 2022 which would be during the 2O's watchkeeping hours.

1.10.2 In response to the investigation team's query on using the approved tank venting system before achieving the safe limits (paragraph 1.8.6), the Company clarified that a closed setup for gas-freeing operation without opening the TCH and OTH of the respective COT is possible[50]. This is done by joining a portable air chute[51] to the manifold connection (for the respective COT) from the fixed gas-freeing pipeline on deck, and to release the tank vapours from the PV valve and gas-freeing flap (see **figure 6**).

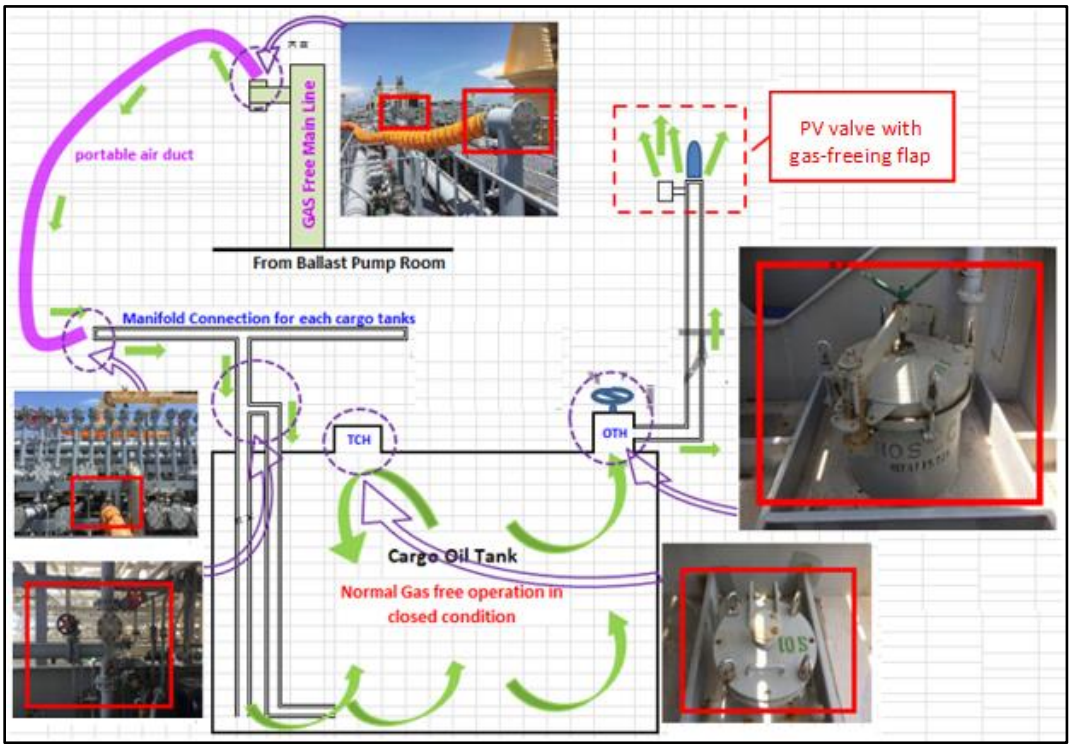


Figure 6 – Illustration of a closed setup of gas-freeing operation of a COT without the need to open the TCH and OTH
(*Source*: the Company)

1.10.3 The investigation team noted that the illustrated closed setup for gas-freeing operation was not specifically mentioned in the gas-freeing operation section

[50] The Company superintendents visited their fleet of ships to verify compliance with this setup after the occurrence.
[51] Total five pieces (2 pcs x 23m, 1 pc x 13m, 1 pc x 18m and 1 pc x 20m) were available onboard Concerto which would allow gas-freeing of four COTs to be carried out simultaneously.

of the Company's SMS. The Company was expecting its crew to follow this setup based on the safe limits of toxic gas as prescribed in the SMS.

1.10.4 When asked, the CO confirmed that he was aware of the closed setup for gas-freeing operation which was possible to be carried out on Concerto. The CO further added that –

- Using the closed setup for gas-freeing operation would take a longer time (average about 20 hours for each COT) to complete the gas-freeing operation;
- He had observed that portable air chute being connected directly to the TCH of COT (that is, not closed setup for gas-freeing operation) when he was undergoing his training with his predecessor, as well as on some of the ships managed by the same Company that he had served; and
- The Bosun of Concerto had raised concerns to him about the inconvenience and the longer time in connecting the portable air chute for the closed setup for gas-freeing operation.

1.10.5 The CO also mentioned that he did not understand the meaning of achieving the safe limits as stated in the Company's SMS and did not seek any clarifications from the Master[52] of Concerto.

1.10.6 The investigation team noted the following steps were reportedly performed for the change-over of the portable air chute by the ASD1 and ASD2 prior to midnight on 31 May 2022:

- Stopped the fixed gas-freeing fan;
- Removed the portable air chute from COT 2P, tightened all bolts of the COT 2P TCH by hand[53], OTH remained crack open;
- Removed the bolts of COT 13S;
- Inserted the portable air chute into COT 13S TCH; and
- Re-started the fixed gas-freeing fan.

1.10.7 The investigation team gathered that both the ASDs did not bring any gas detector[54] for the change-over and had not worn any breathing apparatus for

[52] In the CO's opinion, the Master was approachable and willing to guide him if needed.

[53] As tank mopping, drying, inspection, etc. would be carried out inside the COT during daytime on 1 June 2022, hence the bolts were only hand-tightened for ease of facilitating the daytime activities.

[54] The vessel had five sets of portable multi-gas detector (GX-2009) capable of detecting concentration of O_2, H_2S, CO and LEL by displaying LED warning lights and beeping sounds. The detector had a clip allowing it to be affixed for a hands-free use. All the five sets portable multi-gas detector were reportedly in good working condition at the time of the occurrence.

the task. The ASD2 recalled that there was head wind at the time and there was no abnormality or gas smell noted at that time.

1.10.8 The investigation team also gathered that there were no atmospheric checks done for any of the six COTs at the time of commencement of gas-freeing operation till the occurrence.

1.10.9 From the footage recovered from the CCTV, it was observed that the torch light beam shone by the ASD1 at about 0217H was seen moving forward from the port side main deck and then turning to the centreline near COT 8. The timing taken for ASD1 to change-over the portable air chute from COT 8P to 8S was three minutes and 22 seconds. The distance between the two TCHs of COT 8P and 8S was about 4-5 metres. Thereafter, the torch light beam was seen moving further to the starboard side main deck and moved forward at a total of 23 meters distance. At about 0224H, the torch light beam was last seen at a location between COTs 7S and 8S at the starboard side main deck (where the ASD1 was discovered by the CO).

1.10.10 When the ASD1 was found by the CO, he was wearing his casual clothes (polo-T and trousers), safety shoes and a helmet. There was no gas detector found on him or any other PPE.

1.10.11 During the inventory of personal belongings, there was no prescribed or privately owned medication found in the ASD1's cabin.

1.11 Cause of death

1.11.1 COVID-19 Polymerase Chain Reaction (PCR) test was carried out for the body of ASD1 at Yeosu Hospital and was indicated as negative result. The body of the diseased had been conveyed back to his home country and an autopsy examination was carried out. At the time of finalising this report, the result of the autopsy examination was not available to the investigation team and hence the cause of death of death is not known.

1.12 Environmental condition

1.12.1 At the time of occurrence, Concerto was sailing on a gyro heading of 053°[55].

[55] Direct reading from gyro compass, which is between NE and ENE.

The ship's logbook indicated that there was southerly[56] gentle breeze of about 4-6 knots (Beaufort wind force 2), the sea condition was slight about half to one metre. The sky was cloudy but with good visibility. The ambient air temperature was at about 26 degrees Celsius.

1.12.2 The ship's heading was maintained at 053º since 1730H on 31 May 2022 without alteration. During this period, the wind direction had changed from a direction of SSE to southerly at about 0200H on 1 June 2022.

1.12.3 The ship's VDR records of the wind direction and speed at 0200H (about the time that the ASD1 went on deck) on 1 June 2022, which corresponds to the ship's logbook records, is indicated in **figure 7**.

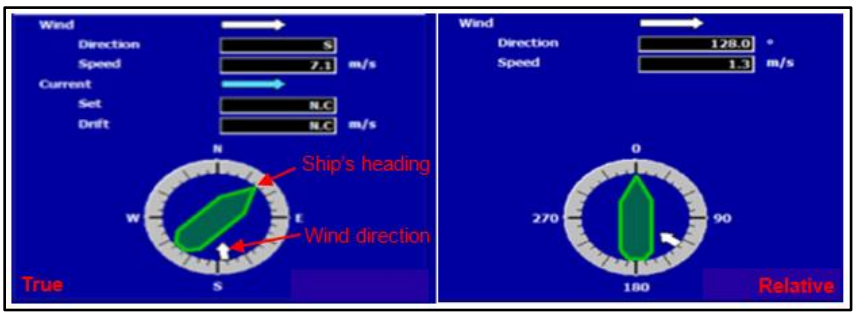


Figure 7 – The true and relative wind direction from ship's heading at 0200H, 1 June 2022 (*Source:* the Company, annotated in red by TSIB)

1.12.4 At about 0400H on 1 June 2022, the ship resumed back to the original course (053°), the wind direction was from starboard side about 115º relative to the ship's heading and speed was about 4 knots as per wind indicator on the bridge (see **figure 8**).

Figure 8 – Wind direction & speed shown on the wind indicator at 0400H, 1 June 2022 (*Source:* the Company, annotated in white by the TSIB)

[56] The gentle breeze was relatively from the ship's starboard quarter.

2 ANALYSIS

2.1 The likely cause of death

2.1.1 The available evidence indicated that the ASD1 was medically fit for duty onboard ship without limitations or restrictions and had 16 hours of rest in the past 24-hours. In the absence of bodily injuries and an autopsy report on the cause of death, the investigation team considered the possibility that the ASD1 may have been overcome by vapours from the COT's while in the process of carrying out the change-over of portable air chute used for gas-freeing.

2.1.2 The investigation team reckoned that there is a possibility of presence and accumulation of toxic vapours and/or N_2 when the ASD1 was on deck, based on the following:

(a) Both COTs 8P and 8S had been washed with cold and hot water in an inert condition (containing N_2). During tank cleaning, O_2 levels may increase in a COT and reducing the N_2. There was no measurement of the tank atmosphere carried out to check the gas concentration prior to commencement of gas-freeing operation and the amount of residual N_2 inside these tanks after tank cleaning was not known. Nevertheless, the possibility of the COT remaining in inert condition could not be ruled out.

(b) The likelihood of remnant toxic vapours (MEC[57] used as a pre-wash) inside the COT 8P also existed.

(c) The OTH of COTs had been cracked open at the time of setting up for the gas-freeing on the previous day. The deck frames of about 1.3m height extending athwartships could have caused the formation of pockets of vapours (like a temporary confined space due to the still air condition), to accumulate around the deck area between the COTs.

2.1.3 There is thus a possibility that the toxic vapours from COT 8P and N_2 from COT 8S in their respective concentration may have been present at the deck area before the ASD1 went on deck.

2.1.4 When the ASD1 went on deck for the second time during his watch to change

[57] MEC has an aspiration hazard, can enter lungs and cause damage to body systems, and in poorly ventilated areas, vapor can readily accumulate and can cause unconsciousness and death. In this case MEC would likely be the known vapour instead of PAPI, considering that COTs 8P and 8S had been cleaned and pre-wash with MEC.

over the portable air chute to the remaining COTs, the fixed gas-freeing fan was not stopped as it was during the first time the ASD1 went on deck with the ASD2. The portable air chute was removed from COT 8P and carried over to the starboard side. It is likely that during this attempt and working in an area where vapours from the COTs had likely emanated, when the ASD1 attempted to connect the portable chute to the TCH of COT 8S, the high-capacity fan would have blown the tank contents out of the TCH, on to the deck.

2.1.5 The investigation team opines that it is likely due to operational convenience that the ASD1 did not switch off the fixed gas-freeing fan even though the procedure requires the fixed gas-freeing fan to be stopped during the change-over. By having the fixed gas-freeing fan running during the change-over, there is a likelihood of toxic vapours emanating from COT 8S.

2.1.6 In the absence of any respiratory protection equipment and without a gas detector to warn the ASD1 of the possibility of low O_2 level or toxic vapours in the area, the ASD1 inhaled remnant N_2 (which is colourless and odourless) and other toxic vapours from COT 8S in still air condition on deck. The inhalation of remnant N_2 and toxic vapours from COT 8S had likely resulted in ASD1 to collapse on deck after walking at a distance about 23 meters.

2.2 Deviation from the gas-freeing procedure

2.2.1 According to the Company's SMS procedures on gas-freeing operation, venting of flammable and/or toxic gases from the tank was only permitted through the approved tank venting system, i.e. the PV valves and gas-freeing flap. However, at the time of line-up for preparation of gas-freeing operation, the OTH had been cracked open, presumably to expedite the gas-freeing process.

2.2.2 The vessel's design allowed closed setup for gas-freeing operation without the need to open the TCH and OTH of the COTs on deck. Though the Company's SMS did not specifically mention to start the gas-freeing operation with closed gas-freeing setup, the SMS did not allow the opening of the TCH and OTH for gas-freeing operation until the gas concentration within the COT was measured to be within limits (LEL below 30% and the toxic vapour below TLV-TWA limit).

2.2.3 It was evident that the gas concentration within the COTs was not measured to ensure it was within the safe limits before opening the TCH and OTH and the

TCH had also been kept open at the time of line-up for connecting the portable air chute to conduct the gas-freeing.

2.2.4 As per the CO's account, the crew deemed the closed setup for gas-freeing operation to be cumbersome and taking a longer period to achieve a gas-free COT. The investigation team noted that after the occurrence, the Company's verification of the closed setup confirmed compliance with its SMS procedures. However, as there was no such verification done prior to the occurrence, the investigation team opines that the crew onboard Concerto, had normalised and deviated from the Company's established procedures and IBC Code and Tanker Safety Guide on the need to ensure that the gas concentration of the COT is within the safe limits before opening the TCH and OTH.

2.2.5 This deviation had possibly extended to other vessels managed by the Company prior to the occurrence.

2.3 Risk assessment and Company's control measures

2.3.1 The practice onboard Concerto of opening the TCH and OTH for gas-freeing operation without measuring the LEL and TLV-TWA limit and on other ships managed by the Company (as experienced by the CO) was apparently not known to the Company.

2.3.2 The RA and toolbox talk were duly carried out for the tank cleaning operation as per the Company's SMS procedures. However, there was no RA conducted for the gas-freeing operation, likely because gas-freeing operation was not listed as a RA category in the RA Form. In the absence of a RA and a toolbox talk, the execution of the gas-freeing operation would be left to the individuals, and reliant on their respective experience.

2.3.3 The Company's procedures only required atmosphere checks to be done at different spaces (deck stores etc.) where the crew would typically access, which were carried out as per Table 5 during tank cleaning. There were no requirements to check for toxic vapours within the COTs prior to the commencement of gas-freeing operation. This increased the risk of the crew involved in gas-freeing operation to be exposed to remnant toxic vapour dispersed from the COTs especially in the early stages of gas-freeing operation.

2.3.4 The Company accorded the hazard level of gas-freeing operation as level C which did not necessitate the use of the SCBA. It is likely that the Company had assumed a cargo tank would be clean after tank cleaning. While such assumption is not unreasonable, the level of cleanliness is dependent on the effectiveness of the cleaning operation. The investigation team held the view that checking the COTs for remnant toxic vapours is an important step even after a complete cleaning of the COTs has been done. It would thus be important to conduct a check on the COTs to ensure that toxic vapours are below the hazardous level for other operations to be conducted safety, such as gas-freeing operation.

2.3.5 It is further recognised as vapour pockets could exist at the main deck level in still air condition, aggregated with the structure of deck frames, it is important for the crew working on deck to carry a gas detector when gas-freeing operation is on-going, so that the presence of toxic vapours and lack of oxygen can be detected early.

2.3.6 Considering the uncertainties on the condition of the COTs after tank cleaning and the possibilities of vapour pockets, it is deemed necessary for a RA to be conducted prior to carrying out gas-freeing operation.

2.4 Effectiveness of implementing SMS

2.4.1 All officers were reportedly familiar with the SMS requirements. However, according to the CO, he did not have a comprehensive understanding of the intent to ensure that the gas concentration within the COT is within the safe limits, and he followed the practice that he had observed during his training period.

2.4.2 The investigation team’s understanding of the Company’s prohibition of gas-freeing in still weather is to minimise the exposure of crew to toxic vapours when performing change-over of COTs. It is likely that the still weather had not been noticed by the 2O when the ASD1 was sent on deck.

2.4.3 Prior to the commencement of the gas-freeing operation, there was no toolbox meeting conducted involving officers and crew onboard Concerto, including highlighting the prohibition of the conducting gas-freeing in still weather. Only the Jr 3O was verbally briefed about the plan to change-over of the COTs by the CO. It was evident that the gas-freeing operation was not carefully planned

and did not consider the hazards associated with the activities such as presence of the dangers of toxic vapours and N_2.

2.4.4 The Company had guidelines on the different level of PPE required for the hazards identified in different operations onboard. Level C PPE protection was recommended by the Company for the task of changing-over the portable air chute during the gas-freeing operation. Except for safety shoes and safety helmet, the other PPE listed in Table 3a, including personal gas detector, had not been worn by the ASD1 and ASD2.

2.4.5 The OOW being responsible for the safety of navigation, turned himself to be the sole lookout during the hour of darkness by sending away the ASD1 to the deck which was not in line with the Company's SMS requirements (see paragraph 1.8.15).

2.4.6 The occurrence demonstrated the importance of adhering to the established procedures in the SMS and for the crew to seek clarification if the SMS is unclear instead of performing a task which could pose a risk to the safety of persons or the ship.

2.5 Activities on deck during the hours of darkness

2.5.1 Performing activities on deck during the hours of darkness poses a significant risk to the crew involved as the lighting on deck cannot be readily switched on for the safety of navigation of the vessel. This is more so for activities involving certain level of risk, such as gas-freeing of COTs. In conducting gas-freeing at night, the crew would be reliant on portable torch lights while performing various checks and tasks such as changing over portable air chutes for COTs which pose tripping hazards. In addition, it is challenging for the crew to perform cargo vapour concentration checks at night.

2.5.2 The investigation team opined that sending one crew alone to work on deck during the hours of darkness hours is not recommended for routine shipboard activities. Doing so may have unintended consequences, such as in this case - the ASD1 was discovered unconscious on deck about 30 minutes of him being on deck. Similarly, crew could find themselves in other situations such as man-overboard or suffer an injury that goes undetected and could be fatal. If such a need is urgent and is unavoidable, then a detailed RA should be conducted so that risk control measures are implemented before commencement of the work.

2.6 Incidental observations

2.6.1 According to the Company, seven to eight hours were needed for thorough ventilation with fresh air for each batch of COTs. However, COT 2P's ventilation was ended an hour earlier based on the records obtained by the investigation team.

2.6.2 Although this early suspension of COT 2P's gas-freeing did not contribute to the occurrence, it indicated that the gas-freeing operation had been hastened.

2.6.3 The investigation team noted that all dayworkers were involved in tank cleaning in the day. Using them during the hours of darkness could compromise their rest hours. Nevertheless, with careful planning, dayworkers could be adjusted to perform the gas-freeing operations in the hours of darkness and making use of the lookout at the hours of darkness for switching of portable air chute could be avoided. The investigation team thus deemed that the planning of the tank cleaning and gas-freeing operations on Concerto was inadequate.

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 ASD1, while performing the duty as a lookout, was sent to work on deck alone during the hours of darkness to change-over the portable air chute for the gas-freeing operation. The ASD1 had likely inhaled remnant of N_2 and toxic vapours when he was performing the change-over of the portable chute from COT 8P to COT 8S.

3.2 Prior to carrying out the change-over, the ASD1 did not stop the fixed gas-freeing fan and was not carrying a portable gas detector which could have alerted him of the low oxygen level or presence of toxic vapours in the area on deck.

3.3 Gas-freeing operation was not listed as an RA category in the SMS and hence there was no RA and toolbox carried out for the gas-freeing operation.

3.4 After tank cleaning, the TCH had been kept open and the OTH was cracked open during the line-up of COTs for the preparation of gas-freeing operation which was deviated from the Company's SMS requirement that venting of flammable and/or toxic gases from COT was only permitted through the approved tank venting system.

3.5 The gas-freeing operation was conducted by a practice of directly connecting the portable air chutes to the TCHs of COTs and did not check if the gas concentration of the COTs was within the safe limits prior to doing so.

3.6 The CO followed the practice observed during his training period as he was not clear of the meaning of achieving safe limits for the gas concentration of the COTs, as prescribed in the Company's SMS.

3.7 The Company's SMS was not effectively implemented onboard Concerto as the gas-freeing operation was not done in accordance with the established procedures in the SMS as well as the safe navigation of the ship in the hours of darkness was not ensured:

(a) the change-over of the portable air chute was done in still air condition; and appropriate PPE for the task was not donned,

(b) the OOW sent his assistant (ASD1) away to perform the change-over of the portable air chute for the gas-freeing operation and left himself as the sole lookout during the hour of darkness at sea, compromising navigational safety.

3.8 All dayworkers were deployed in tank cleaning during the day. No consideration was given to deploy dayworkers for the change-over of portable air chute during the hours of darkness and instead the lookout was used for the change-over of the portable air chute. The planning of the tank cleaning and gas-freeing operations was inadequate.

4 SAFETY ACTIONS

During the course of the investigation and through discussions with the investigation team, the following safety actions were initiated by the relevant stakeholders.

4.1 Actions taken by the Company

4.1.1 Immediately after the occurrence, the Company sent out a circular to its fleet of tankers, informing them of the loss of life accident, raising awareness and reminding the danger associated with gas-freeing operation for toxic cargo tanks. The Designated Person Ashore and the Management of the Company had informed all masters of its fleet to emphasise on the need to ensure strict compliance to the Company's established SMS procedures, hazards identification, supervision and monitoring of the task carrying out onboard vessels.

4.1.2 After its internal investigation, the Company disseminated a circular to its fleet sharing additional details of the occurrence, learning points and measures for preventing similar occurrence. The findings and lessons learnt from the accident are included in the senior officers' pre-joining briefing as well as the webinars for ship's officers and crew.

4.1.3 The Company has planned an annual training for its fleet of vessels on the safety aspect of cargo operation, tank cleaning, gas-freeing operation.

4.1.4 During the submission of weekly operational and maintenance plans to the Company, the respective superintendents in-charge will provide advice and recommendations to guide the vessels to follow the Company's procedures on the good practices stated in its SMS in relation to the tank cleaning, gas-freeing such as:

- Allow frequent breaks for crew;
- Senior deck officer may relief CO;
- Master may support CO to take the navigational watch on the bridge;
- 4-on and 8-off duty roster may be used for deck crew, instead of 6-on and 6-off throughout the respective operations;
- To adjust work routine depending on weather condition (hot or cold climates);
- Master to review and amend tank readiness time as the situation demands;
- Keep few hours in hand for crew recovery after hectic tank cleaning

operation.

4.1.5 The Company reviewed its SMS procedures on the section of gas-freeing operation as following:

- Included the use of closed setup method for the gas-freeing operation at initial stage, and to monitor the vapour concentrations and oxygen contents of COTs and various spaces before and during the gas-freeing operation.

- A list of items to be carried out before the gas-freeing operation had been established which included the risk assessment and gas-freeing operation checklist to be checked by COs and verified by Masters. The gas-freeing operation should be carefully planned, communicated to the crew involved and monitored the progress and to ensure personnel are not exposed to any health hazards posed by cargo vapours. A responsible officer should supervise all gas-freeing operation onboard. Personnel involved must wear proper PPE as per the Company PPE procedural requirements.

- A list of safety precautions for the gas-freeing operation also included in the procedures which highlighted adequate briefing of flammability and toxicity hazards of last cargo carried on board to crewmembers is required. Any crew working on deck during the hours of darkness should communicate with the OOW on walkie-talkie in every 5-10 minutes intervals and sending crew alone on deck is not allowed.

- The safety precautions for the gas-freeing operation had been amended to clearly indicate that the venting of flammable and/or toxic gases from the tank shall be carried out only through the approved tank venting system. In addition to indicating all opening at deck level should be kept closed until the concentration of the gas is below 30% LEL, the SMS added that the toxic gas concentration shall also not pose any significant health hazard (which is a value below TLV/TWA).

5 SAFETY RECOMMENDATION

In view of the safety actions taken by the Company, no safety recommendation is made.