



Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry
of Transport and Digital Infrastructure

Investigation Report 15/19

Serious Marine Casualty

**Fire in the area of the deck cargo
on board the container ship
YANTIAN EXPRESS
in the Atlantic Ocean
on 3 January 2019**

30 January 2020

This investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Act – SUG). According to said Law, the sole objective of this investigation is to prevent future accidents. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

Issued by:
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1 SUMMARY

A fire broke out on the German-flagged full-container carrier YANTIAN EXPRESS early in the morning of 3 January 2019 in the deck cargo in the area of cargo hold 2. The ship was located in the North Atlantic at this point in time. She was scheduled to reach Halifax on the following day.

The ship's command sounded the general alarm immediately after the fire was discovered. After it was mustered, the crew began to fight the fire in bay 12. Prevailing wind strengths of 8-9 Bft and low temperatures made the conditions for fighting the fire extremely challenging. This and the fact that the supply of compressed air cylinders for the breathing apparatus was almost exhausted resulted in the discontinuation of active firefighting measures in the evening of 3 January 2019. The crew of the YANTIAN EXPRESS continued to fight the fire with passive measures, such as aligning the nozzles so as to cool down the area and for hydro shields, even though the weather conditions deteriorated further on 4 January 2019.

The shipping company contacted the salvage company, SMIT Salvage, early on and consequently the tug SMIT NICOBAR, which was on her way to Mexico, had already been diverted to the YANTIAN EXPRESS on 3 January 2019. The tug arrived at the scene late in the evening of 4 January 2019 and started with fighting the fire with the help of her firefighting monitors.

Despite the work of the SMIT NICOBAR, the fire continued to spread through the deck area of cargo hold 1. After consulting with the shipping company, the master of the YANTIAN EXPRESS gave the crew the opportunity to transfer to the SMIT NICOBAR due to the overall situation, which 11 of the 22 crew members accepted. They were transferred safely with the help of a liferaft.

Since a further deterioration in the weather was predicted, the shipping company decided that all crew members should abandon the YANTIAN EXPRESS. Operating systems were left running wherever possible because a return was planned. The burning ship was abandoned in the afternoon of 6 January 2019.

The MAERSK MOBILISER arrived at the scene on 7 January 2019 and took charge of fighting the fire. Since the situation on board appeared safer than before on 9 January 2019, five crew members transferred to the YANTIAN EXPRESS voluntarily and resumed operations there. The salvage master began his work on the distressed ship along with the crew. The first step was to establish a towing connection with the MAERSK MOBILISER at the stern.

On 10 January 2019, the DALIAN EXPRESS took the other crew members of the YANTIAN EXPRESS on board to take them to Halifax.

When the SOVEREIGN arrived at the location of the tow on 15 January 2019, the SMIT NICOBAR continued her original voyage. Firefighters, salvage experts and additional equipment arrived at the ship, still burning, with the SOVEREIGN. The

firefighters started to fight fires in individual containers. Using the larger pumps now available, it was possible to lower the water level in cargo holds 1 and 2.

SMIT Salvage announced that the containers stowed on the deck of the YANTIAN EXPRESS were extinguished on 21 January 2019. The towing operation to the Bahamas began on 22 January 2019. The YANTIAN EXPRESS continued her voyage unassisted from 1600 on 24 January 2019. She was escorted by the tugs. The last burning containers in cargo hold 1 were also extinguished and all the fire pumps were stopped on 26 January 2019.

The tow arrived at the roadstead of the port of refuge, Freeport (Bahamas), on 30 January 2019. Entry was permitted on 4 February 2019. The unloading operation for the containers in the area of cargo holds 1 and 2 began on 19 February 2019.

On 3 January 2019, the shipping company (Hapag-Lloyd) notified the BSU about the outbreak of the fire. The shipping company co-operated with the investigating agency very closely in the ensuing period.

2 FACTUAL INFORMATION

2.1 Photograph of the ship



Figure 1: Photograph of the YANTIAN EXPRESS

2.2 Ship particulars

Name of ship:	YANTIAN EXPRESS
Type of ship:	Full-container carrier
Flag:	Germany
Port of registry:	Hamburg
IMO number:	9229831
Call sign:	DPCK
Owner:	Hapag-Lloyd AG
Shipping company:	Hapag-Lloyd AG
Year built:	2002
Shipyard:	Hyundai Heavy Industries Co. Ltd. – Ulsan Yard
Classification society:	DNV GL
Length overall:	320.38 m
Breadth overall:	42.88 m
Draught (max.):	14.52 m
Gross tonnage:	88,493
Deadweight:	100,003 t
Engine rating:	49,300 kW
Main engine:	MAN B&W 12K98MC
(Service) Speed:	22.5 kts
Hull material:	Steel
Hull design:	Double bottom
Minimum safe manning:	17

2.3 Voyage particulars

Port of departure:	Colombo, Sri Lanka
Port of call:	Halifax, Canada
Type of voyage:	Merchant shipping/international
Cargo information:	Containers
Manning:	22
Draught at time of accident:	$D_f = 12.9 \text{ m}$, $D_a = 12.9 \text{ m}$
Pilot on board:	No
Number of passengers:	0

2.4 Marine casualty or incident information

Type of marine casualty:	Serious marine casualty, cargo fire
Date, time:	03/01/2019, 0000 ship's time ¹
Location:	North Atlantic
Latitude/Longitude:	φ 37° 37.0'N λ 051° 14.0'W
Voyage segment:	High seas
Place on board:	Hatch cover of cargo hold 2, bay 12
Human factors:	No
Consequences:	Fire and water damage to cargo and ship



Figure 2: Chart showing the position of the accident

2.5 Shore authority involvement and emergency response

Agencies involved:	RCC Boston, later RCC Norfolk, Transport Canada, Federal Bureau of Maritime Casualty Investigation (BSU), Waterway Police (WSP) Hamburg
Resources used:	No resources used by authorities
Actions taken:	No emergency measures by authorities; shipping company concludes salvage contract; several tugs tasked with fighting the fire, transporting equipment and towing the ship during firefighting operation

¹ The clocks were set on the night of 2/3 January 2019. The clock had just been set for the second time when the fire was noticed. Accordingly, ship's time was 0000 = UTC-03:40.

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

The account of the course of the accident is based on interviews with the master, the chief officer, the chief engineer officer, the ship's second engineer officer and the assistant engineer officer (referred to below as 'engineer cadet'). The shipping company provided copies of the deck log book and bell book. A statement of facts and a record of events were also submitted. In addition, a copy of the printout of the alarm event log, which logs special events in the engine room and other technical installations, and the fire alarm system's log data were sent. Moreover, the BSU was provided with daily reports of the salvage master from SMIT Salvage for the period 4 January 2019 to 18 February 2019.

3.1.1 Course of the voyage

The German-flagged full-container carrier YANTIAN EXPRESS was on her way to Halifax, Canada on 3 January 2019. The ship started her westbound voyage in Vŭng Tàu, Vietnam, stopping at ports in Singapore and Colombo, Sri Lanka, during the voyage. She was scheduled to call at several ports on America's east coast after Halifax.

The ports referenced were departed as follows: Vŭng Tàu on 10 December 2018, Singapore on 13 December 2018, Colombo on 17 December 2018. She was scheduled to arrive in Halifax at about 1300 on 4 January 2019.

The voyage had been uneventful up until that point. Due to the worsening sea state, the ship's command prohibited entry to the main deck from 1200 on 2 January 2019. Temperature readings on the refrigerated containers were therefore suspended temporarily. An 8-9 Bft north-west head wind prevailed at this point in time. The sea state stood at force 7. The swell approached from the west at a height of 6 m. The air temperature stood at about 13 °C.

3.1.2 Firefighting operation

3.1.2.1 Events on 3 January 2019

On the night of 2/3 January 2019, the clocks were set to adjust ship's time to local time at the port of destination. The vessel's clocks were changed from UTC-3 to UTC-4 in twenty-minute intervals on each of the night watches. At 0020, the officer in charge of the navigational watch was setting the clock to 0000 and in the process moved on the bridge from the manoeuvring platform at the bridge console to a position, which gave him a view through a gap between the container blocks to well forward on the deck. The width of this gap is about 0.5 m. It emerges at two points on the deck due to the division into three hatch covers per bay and the fact that the containers there are only stowed on the hatch covers. The view of the fore ship was otherwise restricted due to the containers, which were stowed up to a height of six tiers.

While looking through the right-hand gap, the officer in charge of the navigational watch noticed the glow of a fire well forward. He then advised the master of what he had seen immediately and the latter hurried to the bridge. After also confirming this, the master informed the chief engineer officer and the chief officer. The master stated that the flames were already large and clearly visible by this point in time but did not have any unusual colours.

The master used the ship's public announcement system to inform the crew at 0030² and the general alarm was sounded. The crew then went to the mustering point.

The chief officer equipped himself and went forward on the starboard side of the deck with the rating on watch. The fire was visible at the aft edge of bay 12 in the area of the containers in rows 3 and 5 in the first tier³ above the hatch cover at 0034. The fire pump was started shortly after. The power supply in the area of cargo hold 2 was switched off due to the start of the firefighting operation. After equipping, the designated crew members advanced and began to cool down the area surrounding the seat of the fire. Two crew members equipped with self-contained compressed-air-operated breathing apparatus started to fight the fire directly from the front⁴ of the containers. The three water mist lances⁵ on board were also used to fight the fires in the containers.

When the firefighting operation started, the course of the YANTIAN EXPRESS was altered so that the wind now approached from astern. This facilitated the work of the crew on deck and kept the superstructure free of smoke. This course alteration was maintained in the days that followed.

² Ship's time after the 00-04 watch had set the clock. At 0520, the clock on the bridge was put back by 20 minutes to arrive at UTC-4 hours.

³ 120382, 120582. The container slots are identified by a six-digit number. The first two digits indicate the bay, i.e. the row of containers across the breadth of the ship. The following two digits indicate a row of containers. The last two digits indicate the container's tier in the row. See Figures 5 and 6 for more information.

⁴ The front refers to the positioning in the direction of the ship. Normal containers are generally stowed in the direction of the ship with doors facing astern. Refrigerated containers are loaded with the refrigerating unit facing astern.

⁵ Water mist lance in the sense of a fire nail (fog nail) to be driven in.

The alarm event log recorded a smoke alarm detected by the fire alarm system for 3 January 2019 at 003251⁶ (011251-00:40 hours). According to the recording of the actual fire alarm system, the alarm was triggered by smoke detector 62 in cargo hold 2 at 003331⁷ (031331-02:40 hours). The bridge crew muted this alarm 19 seconds later. The alarm was cleared at 102442 on 3 January 2019.

At 0250, the master of the YANTIAN EXPRESS asked a nearby ship for assistance, which was agreed to initially, in case his ship had to be abandoned unexpectedly. The other ship continued her voyage an hour later, however. From 1910 on 3 January 2019, the crew of the HAPPY RANGER provided assistance. This ship remained on scene until the arrival of the first salvage tug and was stood down at 2300 on 4 January 2019.

At 0410 on 3 January 2019, the chief officer, who led the operation at the scene, reported seats of fire in the containers at slots 120382, 120384, 120386, 120582, 120584 and 120784. At 0900, a small amount of smoke was also detected in the container at slot 120184.

		Bay 11 / IMO-HATCH																	
		16	14	12	10	08	06	04	02	00	01	03	05	07	09	11	13	15	
88	111888 HLC F	111488 HLC F	121288 ONE F	121088 YML F	120888 YML F	120688 YML F	120488 ONE F	120288 ONE F	120088 ONE F	120188 ONE F	120388 ONE F	120588 HLC F	120788 ONE F	120988 ONE F	121188 YML F	121388 YML F	121588 YML F		
	SINGSAV1	SINGSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1		
	TRHUJ14032	HLXU340303	TCLL480944	TEMU701500	TCBLU651019	CAUJ790200	TLUJ097281	KKFU787389	NYKJ447113	TCLJ789400	TONJ640094	HLBU201524	FOLJ716400	DRYJ920707	SESSJ517213	WAKJ087547	TONJ1188338		
	2210	2251	4600	4500	4500	4500	45G1	45G0	4500	45G1	45G1	4500	4500	4500	4500	4500	4500		
	3.4	3.2	8.1	6.6	6.4	6.2	10.4	11.7	10.6	12.3	10.8	8.0	8.2	8.1	6.3	6.6	6.1		
86	111888 YML F	111488 ONE F	121288 ONE F	121088 YML F	120888 ONE F	120688 ONE F	120488 ONE F	120288 ONE F	120088 ONE F	120188 ONE F	120388 ONE F	120588 HLC F	120788 HLC F	120988 HLC F	121188 ONE F	121388 ONE F	121588 ONE F		
	SINGSAV1	SINGSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1		
	BEALJ071071	CAUJ270264	SESSJ907940	WAKJ0675493	DRYJ0810271	TLUJ0954207	MOTJ0705100	GLDJ0487111	JACJ0684574	TCLJ0804283	KKFU700200	FOLJ010299	TONJ0828443	TLUJ092290	TLUJ0927444	NYKJ0410529	SESSJ4020711		
	22G1	22G1	4500	4500	4500	4500	4500	45G1	45G1	45G1	4500	4500	4500	4500	4500	4500	4500		
	4.0	4.0	8.1	9.5	10.2	11.0	12.3	12.5	12.7	11.4	12.1	12.2	12.0	10.4	8.8	8.2	10.1		
84	111884 ONE F	111484 ONE F	121284 HLC F	121084 HLC F	120884 HLC F	120684 HLC F	120484 HLC F	120284 ONE F	120084 HLC F	120184 YML F	120384 YML F	120584 HLC F	120784 HLC F	120984 HLC F	121184 HLC F	121384 HLC F	121584 ONE F		
	SINGSAV1	SINGSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1		
	NYKJ0801780	NYKJ0804569	SMOJ4676207	TCLL1882274	HLXU0425718	JACJ08201548	TCLJ0875900	NYKJ407853	JACJ0486743	YMLJ0251034	YMLJ0709553	HLBU1588209	JACJ08143703	MOTJ0703038	SMOJ0253933	JACJ0820986	DRYJ0381250		
	22G1	22G1	4500	4500	4500	4500	45G1	45G1	45G1	4500	45G1	4500	4500	4200	4500	4500	4500		
	13.4	16.8	12.2	12.2	14.7	24.3	14.6	12.7	13.5	12.8	14.2	16.0	24.3	16.8	16.2	13.0	14.2		
82	111882 YML F	111482 YML F	121282 ONE F	121082 ONE F	120882 ONE F	120682 YML F	120482 HLC F	120282 ONE F	120082 ONE F	120182 ONE F	120382 ONE F	120582 HLC F	120782 HLC F	120982 ONE F	121182 ONE F	121382 ONE F	121582 ONE F		
	SINGSAV1	SINGSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1	AUTOSAV1		
	TEMU1907056	TRHUJ247600	TLLJ0691701	TCBLU6182757	TEMUJ230448	SZLJ0883362	CPSJ0402017	TCLJ782083	MOTJ044436	TTNJ0821570	NYKJ0627730	FOLJ0972821	JACJ0822502	ONEJ0036998	TLUJ0584538	FOLJ0306031	FOLJ0201384		
	2200	2200	4500	4500	4500	-21. 4500	4500	4500	4500	2.8 45R1	45G1	4500	4500	4500	4500	4500	4500		
	23.0	23.1	23.3	23.4	23.4	27.8	14.9	18.9	16.5	27.7	16.9	19.6	30.0	23.1	23.2	23.2	23.3		

Figure 3: Bay 11 stowage plan⁸

The red fields indicate burning containers during the first observation at about 0034. The yellow fields indicate additional containers that had caught fire during the observation at 0410. The blue field indicates additional burning container at 0900 on 3 January 2019.

⁶ The investigators corrected the alarm event log times from this point until 090411 on 4 January 2019 by -40 minutes to ship's time. The reason for this is that the alarm event log time is only set once when the time is changed. The recording time (011251) thus referred to UTC-3 at the time of the alarm. The alarm event log clock was not set to 080411 (UTC-4) until 090411 on 4 January 2019.

⁷ According to the alarm log for the fire alarm system, its time refers to UTC. The time difference between the fire alarm system log and the alarm event log is about +02:00:41 hours due to slight deviations in the seconds for the individual data. The BSU therefore assumes that it actually refers to UTC-1. Furthermore, the time is corrected to ship's time.

⁸ The actual position of the containers in bay 12 (bays 11 and 13) is shown in section 3.2.6.1.

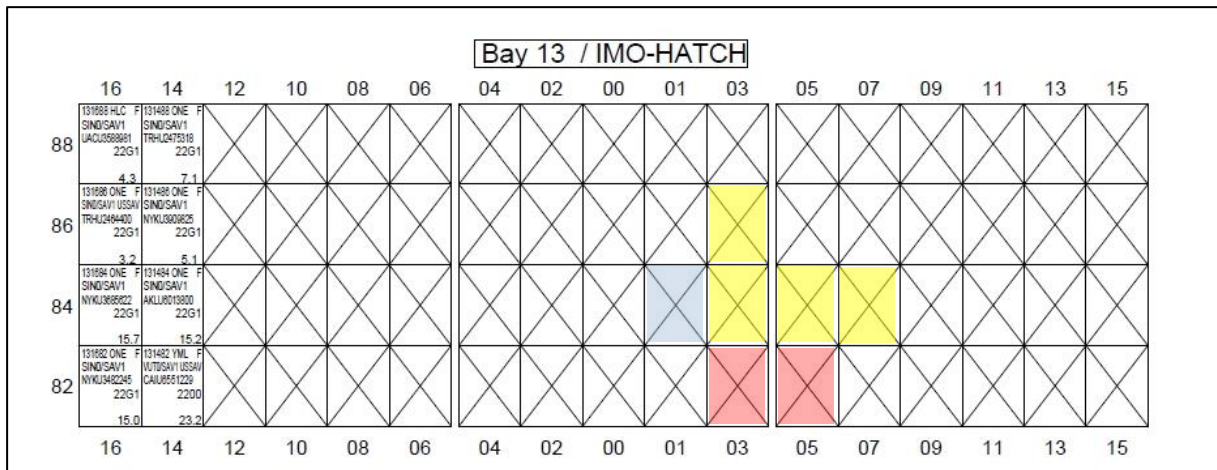


Figure 4: Bay 13 stowage plan

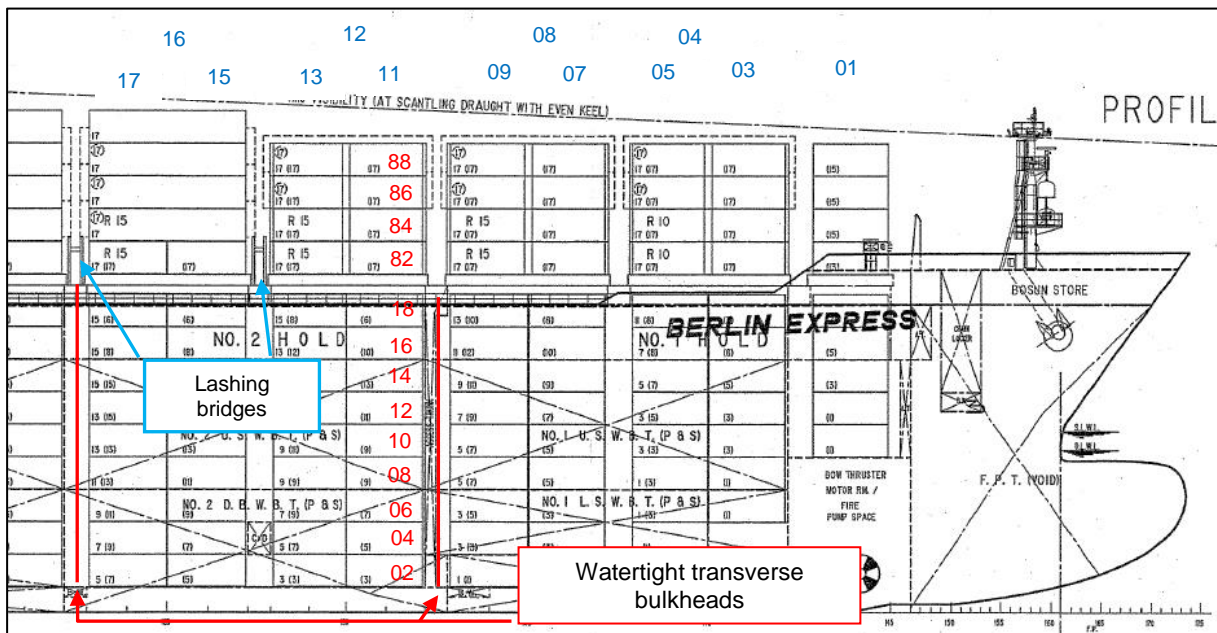


Figure 5: Side view showing bay and tier numbers

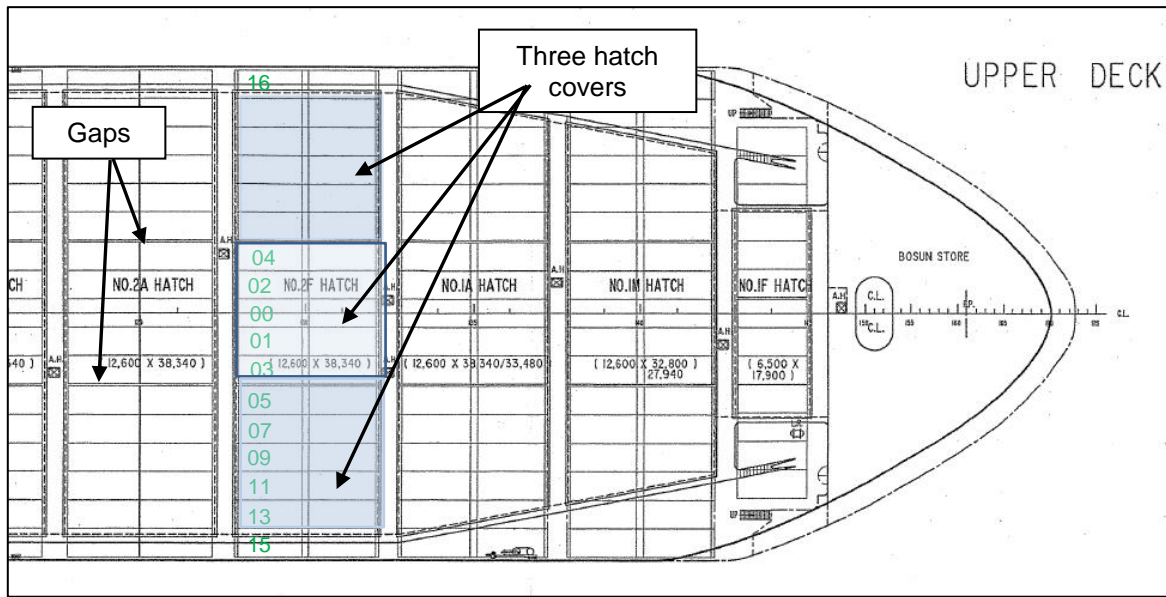


Figure 6: Top view showing row numbers

The two gaps spanning the deck area due to the three pontoon hatch covers per hatch opening and the three hatch covers are also shown here.

At 1005, the chief officer reported to the bridge that he had noticed heat and smoke coming from cargo hold 2. The chief officer and another crew member then descended into the cargo hold at the aft edge with respiratory protection. Only smoke (but no open flames) was seen there, however. This observation was used as an opportunity to spray water into cargo hold 2 via the gaps in the hatch covers. According to the bell book, at 1055 hours the crew began flooding [sic] hold no. 2 through the gaps between the hatch covers.

At 1116, smoke was seen coming out of the containers at slots 120984, 120182, 120184, 120186, as well as from rows 07, 05 and 03 (of bay 12) in their entirety.

		Bay 11 / IMO-HATCH																
		16	14	12	10	08	06	04	02	00	01	03	05	07	09	11	13	15
88	11186 HLC F	11148 HLC F	12128 ONE F	12108 YML F	12088 YML F	12068 YML F	12048 ONE F	12028 ONE F	12008 ONE F	12018 ONE F	12038 ONE F	12058 HLC F	12078 HLC F	12098 HLC F	12118 YML F	12138 YML F	12158 YML F	
	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	
	TGHL014302	HLXJ452337	TCLL490848	TEML0701800	TGBL0518216	CAUL7982560	TLLU0272261	KKFL0783989	NKLU4627113	TCLL7998400	TONL6429314	HLBL0215724	FOUL7194032	DRYL0820707	SEGL0327213	MAGL0575747	TONJ1982338	
	2210	22G1	4500	4500	4500	4500	45G1	45G0	4500	45G1	45G1	4500	4500	4500	4500	4500	4500	
	3.4	3.2	8.1	6.6	6.4	6.2	10.4	11.7	10.8	12.3	10.8	9.0	9.2	8.1	8.3	8.6	6.1	
86	11188 YML F	11148 ONE F	12128 ONE F	12108 YML F	12088 ONE F	12068 ONE F	12048 ONE F	12028 ONE F	12008 HLC F	12018 ONE F	12038 ONE F	12058 HLC F	12078 HLC F	12098 ONE F	12118 YML F	12138 ONE F	12158 ONE F	
	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	SINDSAV1	SINDSAV1	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1		
	BEAL027070	CAUL72264	SESJ0637945	MAGL0574963	DRYL0813271	TLLU0254227	MOTU0781200	SUDL0487711	JACU0584574	TCLL0834263	KKFL0792232	FOUL0122562	TONL0828443	TLLU0222590	TLLU0426744	NKLU4415209	SESJ4232971	
	22G1	22G1	4500	4500	4500	4200	4500	45G1	45G1	45G1	45G1	4500	4500	4500	4500	4500	4500	
	4.0	4.0	8.1	9.5	10.2	11.0	12.3	12.5	12.7	11.4	12.1	12.2	10.4	8.8	8.2	10.1		
84	11184 ONE F	11148 HLC F	12128 HLC F	12108 HLC F	12084 HLC F	12064 HLC F	12044 HLC F	12024 ONE F	12004 HLC F	12014 YML F	12034 YML F	12054 HLC F	12074 HLC F	12094 ONE F	12114 HLC F	12134 HLC F	12154 ONE F	
	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	SINDSAV1	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	
	NYKJ0691750	NKLU0684559	SMOJ497327	TCLL0822724	HLXJ0425718	JACU0391846	TCLL0875580	NYKJ4707853	JACU0426743	VMUK0251034	YMLU0702553	HLBL1526829	JACU043703	MOTU0702033	BMOJ0235333	JACU0382895	DRYL0381250	
	22G1	22G1	4500	4500	4500	4200	45G1	45G1	45G1	4500	45G1	4500	4200	4500	4500	4500	4500	
	13.4	16.8	12.2	12.3	14.7	24.3	14.9	12.7	13.5	12.5	14.2	16.0	24.3	16.8	16.2	13.0	14.2	
82	11182 YML F	11142 YML F	12122 ONE F	12102 ONE F	12082 ONE F	12062 YML F	12042 HLC F	12022 ONE F	12002 ONE F	12012 ONE F	12032 ONE F	12052 HLC F	12072 HLC F	12092 ONE F	12112 ONE F	12132 ONE F	12152 ONE F	
	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	SINDSAV1	SINDSAV1	SINDSAV1	SINDSAV1	SINDSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	VUTOSAV1	
	TEMU1860755	TRHU1247300	TLLU0697701	TGBL0518207	TEML0239446	SZLU083362	OPSL0403217	TCLL7820663	MOTU0644435	TMU0821570	NYKJ0627730	FOUL0672821	JACU0225202	ONEU0039986	TLLU0584438	FOLU0386031	FOLU0201384	
	2200	2200	4500	4500	4500	-21. 4530	4500	45G1	4500	4500	2.8 45R1	4500	4500	4500	4500	4500	4500	
	23.0	23.1	23.3	23.4	23.4	27.8	14.9	18.9	16.5	27.7	16.9	19.6	30.0	23.1	23.2	23.3		

Figure 7: Containers emitting smoke at 1116 on 3 January 2019

At 1140, the chief officer reported that he thought the draught was increasing at the bow. The assumption that water for firefighting had also reached cargo hold 1 was confirmed by a bilge alarm at 031551⁹. An attempt was made to enter cargo hold 1. This was not possible due to dense smoke on the main deck, however.

To suppress a possible fire in cargo hold 2, the sprinkler system installed there was activated at 1140.

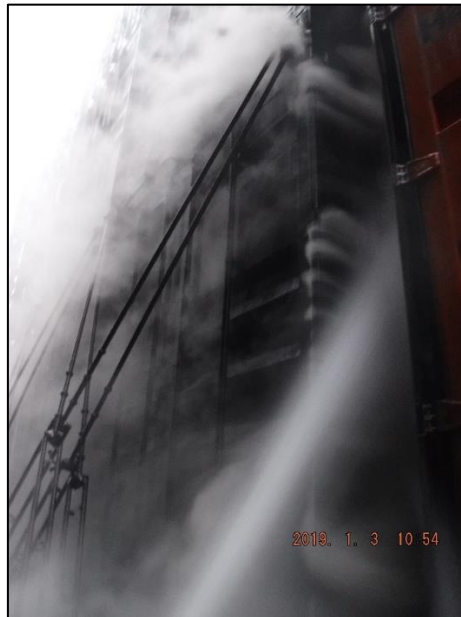


Figure 8: Firefighting at bay 12; row 03 in the middle of the image

At 1151, a report was made from the deck to the bridge that a large amount of white smoke, which may have been steam, was billowing out of cargo hold 2.

No more open flames could be seen coming out of the containers on bay 12 at about 1300. Smoke was still billowing out of most of them, however.

They discontinued the use of the sprinkler system and stopped spraying water into cargo hold 2 at 1355.

To investigate the situation in cargo hold 2, the chief officer and one of the deckhands climbed into it via the middle entrance with respiratory protection. A water level of 2.5 m above the ground, a slight temperature increase and light smoke in the upper area were found.

Consequently, the sprinkler system was put back into operation at 1500.

Flames were seen coming out of some of the containers on bay 12 several times in the afternoon and evening. The bell book indicates that fire was still burning below containers 120382 and 120582 at 1512. At 1625 black smoke was seen from below

⁹ "NO1 C/H BILGE WELL LEVEL (AFT) ALM." The first alarm in cargo hold 2, "NO. 2 C/H BILGE WELL LEVEL (P) ALM" was triggered at 014608 on 3 January 2019.

containers in rows 1203 and 1205. Fire below containers 120582 and 120782 was recorded in the bell book 1640 hours. They were then flooded continuously with the help of the water mist lances. The firefighting operation was also continued from the front of the containers in bay 12.

At 1650, the sprinkler system for cargo hold 2 was stopped again.

To relieve the fore ship, ballast water tanks 2 on the port and starboard side were drained in the double bottom from 1700.

As the day continued, the wind dropped to 3 Bft and veered north.



Figure 9: View of the bow of the YANTIAN EXPRESS¹⁰

The following containers were on fire at 1950: 120182, 120186, 120386, 120382, 120582, 120584, 120782, 120784. Flames were also visible at the front of the underlined containers. Furthermore, a blowout [sic] from an unidentifiable container on the bow occurred in the evening.

The chief officer reported that the crew was exhausted after the firefighting operation had continued for some 15 hours. Due to the firefighting operation and occasional light rain, the fire-protection clothing repeatedly became saturated and had to be changed. The firefighters cooled down quickly because of the strong wind. The clothes donned to protect against the cold were heavy and became even heavier when wet. The crew was therefore assigned to alternating shifts from then on.

Despite all efforts, the fire developed further at about midnight due to the increase in wind, amongst other things. Furthermore, the water jet failed to reach the third tier due

¹⁰ Time taken unknown.

to the strong wind. In addition, the supply of compressed air was almost exhausted after some 24 hours. Fighting the fire under such circumstances was deemed perilous by the Master and the crew was withdrawn for their safety. Nozzles had previously been fixed in such a way that they formed a kind of hydro shield toward the stern but also acted in the direction of the fire.

To keep the crew members together, they were all assembled in the conference room, where everyone was once more accounted for and a summary of the next steps was given. The crew was notified of the presence of the HAPPY RANGER. The ship's command regarded the fire as "out of control" at this point in time.

3.1.2.2 Events on 4 January 2019

The wind increased further in the course of 4 January 2019 with gusts of up to 60 kts measured.

Due to the depth of the firefighting water in cargo hold 2, the electrical bilge well valve controls failed that morning. Since it was no longer possible to open them, no more water could be pumped out.



© Hapag-Lloyd

Figure 10: View of the fore ship of the YANTIAN EXPRESS



Figure 11: Bay 12 on fire

The chief officer and a small group went onto the deck in the morning of 4 January 2019. They checked the position of the nozzles and water lances and collected equipment. A large number of charcoal cubes was found in the transverse corridor between bays 12 and 16. These also glowed beneath the containers on the starboard side of bay 12. No smoke could be seen coming out of the containers in bay 8. The chief officer stated that at that point there were still five full cylinders of compressed air available out of 35 originally.

Preparations for the establishment of a towing connection at the stern were also made in the course of the day.

The YANTIAN EXPRESS and SMIT NICOBAR were in direct contact for the first time on the evening of 4 January 2019. This tug was originally on her way to Veracruz, Mexico. However, the salvage company, which was in contact with Hapag-Lloyd, diverted her at 1200 on the previous day, so as to provide assistance to the YANTIAN EXPRESS (see also Figure 14). The SMIT NICOBAR¹¹ reached the burning ship at 2224¹² and began the firefighting operation at 2300. To this end, the two ships sailed alongside each other at a distance of some 150 m. The SMIT NICOBAR had to stop fighting the fire from time to time because of overheating. This was due to the need for high speed to accompany the YANTIAN EXPRESS and the simultaneous operation of the extinguishing monitors. This issue was resolved by the master of the YANTIAN EXPRESS reducing speed at the request of the master of the SMIT NICOBAR.

3.1.2.3 Events on 5 January 2019

Due to the deteriorating weather on 5 January 2019, the SMIT NICOBAR suspended the firefighting operation at 0340. Similarly, the crew of the YANTIAN EXPRESS only

¹¹ IMO number: 9322592. LOA: 70.9 m. Shipping company: SMIT Singapore.

¹² All times UTC from 4 January 2019 onwards.

checked those nozzles that had already been deployed. The SMIT NICOBAR resumed the firefighting operation at midday.



Figure 12: Fore ship of the YANTIAN EXPRESS on 5 January 2019

The crew of the YANTIAN EXPRESS had investigated the situation in the area of the fire earlier on. Two containers were burning in the fourth tier of bay 12. Containers were also burning in the first and second tiers. It was possible to attribute the black smoke that had previously been clearly visible from the bridge to a container in bay 8. It was also established that the temperature of bay 16's hatch covers stood at 16 °C on the port side. No smoke was seen coming out the containers in bay 16. Moreover, no smoke was seen when the cargo hold entrance was opened at the aft edge of cargo hold 2. No smoke was seen during the inspection inside the cargo hold, either. However, it was established that the water was halfway up the containers in the eighth tier, which corresponds to a water level of about 9 m. The classification society's emergency response team, which had been advised of this fact, then warned of possible stability problems. Consequently, the SMIT NICOBAR switched from direct firefighting to cooling down the area around cargo hold 2 afterwards. In addition, firefighting was continued in bay 8.

The crew at least wanted to attempt to lower the water level in cargo hold 2 with a portable pump powered by compressed air. When the group assembled to operate the pump was already on the move at about 1800, an explosion with heavy smoke and pulsating high flames occurred in the area of the fore ship. The master attributed this to the explosion of the container at slot 080782. This contained nitrocellulose, which is classified as an IMDG Code class 4 dangerous good. After the explosion, the master

issued orders for the plan to be abandoned and the group withdrew to the superstructure. In this context, the superstructure's gastight integrity was also established.

While proceeding toward the fore ship, the chief officer noticed that the bosun's ladder on the starboard side level with bay 4, which was stored under a tarpaulin and used for climbing into the liferaft there, was already on fire.

The crew started to flood cargo hold 1 with CO₂ in the afternoon¹³ after a fire alarm for this hold had triggered. To this end, 158 CO₂ cylinders (out of 440 in total) were activated. However, and even though the crew believed that the CO₂ was deployed, subsequent investigation showed that the designated number of cylinders for cargo hold 1 did not properly discharge (see also chapter 3.2.9).

Around the same time, the engine room's crew started transferring fuel from tanks 3 to tanks 5. Transfer of fuel was executed at the direction of the SMIT Salvage Master to reduce the load on the vessel and to reduce potential risk of explosion.

After consulting with the shipping company, the master decided to ask crew members if anyone wanted to abandon the ship and transfer to the SMIT NICOBAR on the evening of 5 January 2019. 11 of the 22 crew members accepted the offer.

The relevant crew members donned their immersion suits and lifejackets for the transfer. A radiotelephone and a SART buoy were made ready. The SMIT NICOBAR moved to within a close range and a line throwing device was used to establish a line connection. The raft was suspended in the davit and made ready with a line connection to both ships. The raft was then entered and lowered. The lifting hook was released at 2138. The SMIT NICOBAR's crew then pulled the raft toward them. All occupants reached the tug unharmed. The manoeuvre was completed after about 20 minutes. The SMIT NICOBAR then continued to cool down the fore ship of the YANTIAN EXPRESS.

¹³ According to the alarm event log at 1636.



Figure 13: Salvage tug fights the fire

The shipping company concluded the salvage contract with SMIT Salvage on 5 January 2019 (Lloyds Open Form). The salvage company had chartered the tug MAERSK MOBILISER¹⁴, which began her voyage from Newfoundland to the scene early that morning. In New York, the tug ATLANTIC ENTERPRISE¹⁵ was fitted out to carry equipment and several salvage experts to the YANTIAN EXPRESS.

3.1.2.4 Events on 6 January 2019

Extensive fires and black smoke reaching a significant height were visible on the night of 5/6 January 2019. Consequently, it was agreed with the SMIT NICOBAR that a reciprocal course with the YANTIAN EXPRESS should be taken so as to enable extinguishing on the starboard side around bays 1 and 4. Various courses were taken later on to support the SMIT NICOBAR's firefighting activities from various positions. Meanwhile, they continued pumping out the bilges of cargo hold 1. The firefighting activities of the SMIT NICOBAR were later discontinued at the request of the YANTIAN EXPRESS's master, who feared that the increase in water in the two forward cargo holds would have an adverse effect on the ship's stability and structure.

An inspection revealed no smoke in the passageways¹⁶ on that day.

¹⁴ IMO number: 9765471. LOA: 95 m. Shipping company: Maersk Supply Service AS.

¹⁵ IMO number: 7417240. LOA: 42.88 m. Shipping company: Donjon Marine Co. Inc.

¹⁶ In the report, passageway refers to the two passages below deck on the port and starboard side of the ship.

On the morning of 6 January 2019, it was decided in consultation with the shipping company that all remaining crew members should also abandon the YANTIAN EXPRESS. This decision was also influenced by the expected poor weather, as it was assumed this would make abandoning the ship too dangerous if necessary. Plans were made to re-board the ship at a later date, meaning she was not to be abandoned as a dead ship. Various measures were implemented accordingly:

- deployment of a towline marked by a Norwegian buoy;
- deployment of pilot ladders from the pilot gates;
- preparations to maintain the power supply with an auxiliary diesel engine so as to continue operation of the refrigerated containers in cargo holds 3 to 8, as well as to supply the bilge pump for cargo hold 1, the navigation lights and other equipment with power;
- establishment of gastight integrity at the positions still accessible, and
- preparation of the main engine for a quick restart (continued operation of the engine room's ventilation fans, the ventilation fans for the auxiliary diesel and the steering gear, the emergency generator, etc.).

The SMIT NICOBAR's fast rescue boat picked up the 11 remaining crew members in the afternoon of 6 January 2019 and transported them safely to the salvage tug. Due to her size and usual purpose, the SMIT NICOBAR had sufficient accommodation on board for the YANTIAN EXPRESS's entire crew.

At about midnight on 6 January 2019, the ATLANTIC ENTERPRISE sailed from her port of departure. Meanwhile, the SOVEREIGN¹⁷ had been equipped in Rotterdam to support the firefighting measures at the YANTIAN EXPRESS.

3.1.2.5 Events on 7 January 2019

On 7 January 2019, the SMIT NICOBAR cooled down the area of the fire around bay 12 with her firefighting monitors from time to time. The MAERSK MOBILISER arrived at the scene at about midday. The masters of the three ships held a discussion on the way forward. The master of the YANTIAN EXPRESS made it clear that it was not possible for his crew to return to their own ship because they were still exhausted at that point.

¹⁷ IMO number: 9262742, LOA: 67.4 m. Shipping company: Union de Remorquage et de Sauvetage.

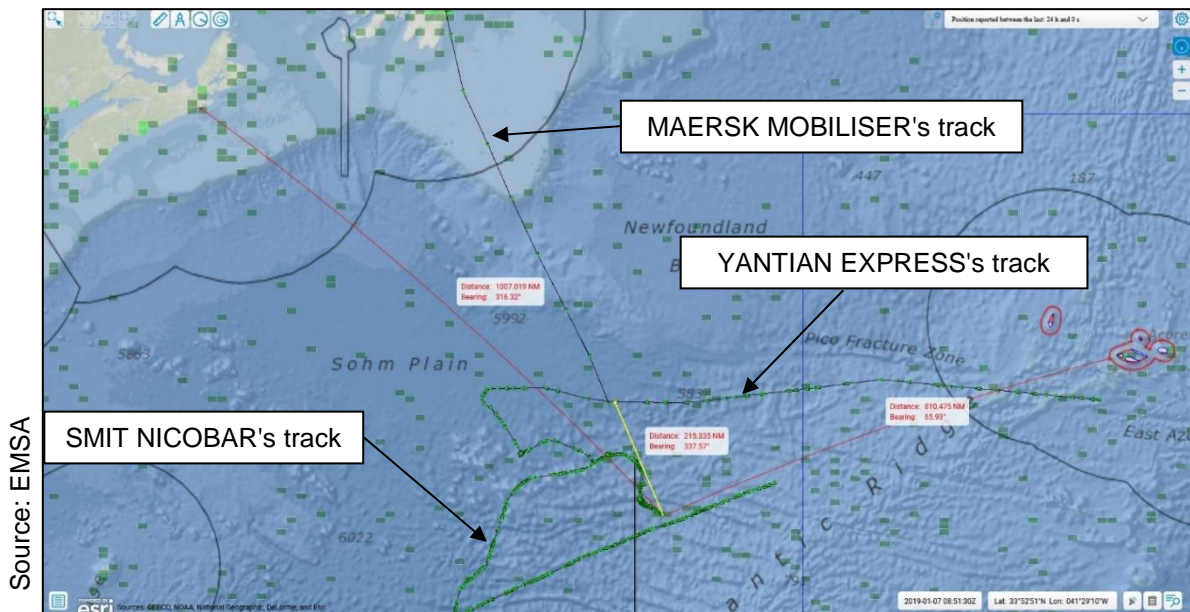


Figure 14: Tracks of the ships involved on 7 January 2019, 0851 UTC¹⁸

The MAERSK MOBILISER took charge of fighting the fire subsequently. A short jet of water was directed only at isolated fires and hotspots. The SMIT NICOBAR remained on standby and followed the drifting YANTIAN EXPRESS. The draught was determined as $D_f=13.6$ m and $D_a=12.9$ m on 7 January 2019.

3.1.2.6 Events on 8 January 2019

Hapag-Lloyd decided on 8 January 2019 that the DALIAN EXPRESS, also on her way to Halifax, should pick up crew members of the YANTIAN EXPRESS who were not needed. To this end, the ship altered course.

The SOVEREIGN left Rotterdam for the burning ship at midday.

The MAERSK MOBILISER continued to fight hotspots and isolated fires.

3.1.2.7 Events on 9 January 2019

The MAERSK MOBILISER was fighting the fire again in the morning of 9 January 2019.

¹⁸ Distance between the MAERSK MOBILISER and YANTIAN EXPRESS displayed incorrectly due to missing position.



Figure 15: The MAERSK MOBILISER at the YANTIAN EXPRESS

The ship's command of the YANTIAN EXPRESS asked her crew for volunteers to return to the ship. Five crew members (master, chief officer, chief engineer officer, second engineer officer and engineer cadet) were prepared to do this.

The MAERSK MOBILISER's fast rescue boat took the above five people back to their ship that afternoon. They were accompanied by the salvage master, who had arrived at the scene with the MAERSK MOBILISER.

The first task after re-boarding the YANTIAN EXPRESS was to establish a towing connection to the MAERSK MOBILISER with a 67 mm towing cable. The ship was then turned so that the wind approached from aft.

The situation on board was investigated with the involvement of the salvage master. It was found that no open flames or smoke were noticeable inside cargo holds 1 to 3. The temperatures in the cargo holds were about 17 °C. Three containers with residual material still on fire were found on deck. The measures necessary in the next few days were discussed after the investigation. The salvage master then returned to the MAERSK MOBILISER, where he also spent the night in the following days.

The plan at this point was to use Halifax as a port of refuge. Accordingly, the ship was slowly towed in this direction stern first.

3.1.2.8 Events on 10 January 2019

The DALIAN EXPRESS reached the tow in the morning and picked up the YANTIAN EXPRESS's remaining crew members on the SMIT NICOBAR without further incident. She then continued her voyage to Halifax.

The ATLANTIC ENTERPRISE sustained weather-related damage while proceeding to the scene, causing her to change course for Halifax during the day.

The SMIT NICOBAR left the YANTIAN EXPRESS to assist the ATLANTIC ENTERPRISE. The tug returned in the evening, however, when the ATLANTIC ENTERPRISE altered course for Halifax.

In the meantime, the MAERSK MOBILISER slacked off the towing connection so as to fight the fire at bay 12 while the other tug was absent. The towing connection was taken in after the return of the SMIT NICOBAR.

3.1.2.9 Events on 11 January 2019

All the empty compressed air cylinders on the YANTIAN EXPRESS were transported to the MAERSK MOBILISER for charging on 11 January 2019.

Since the water level in cargo hold 2 had now risen to 12 m, two pneumatic pumps were installed there. Transferring more fuel made it possible to reduce hogging.

An inspection of cargo hold 1 revealed light black smoke there and that the temperature had risen to 55 °C.¹⁹

Nozzles were installed at the following slots to maintain a kind of water screen and to cool down the containers listed below: 161186, 151288, 151088, 111084, 111182, 100884, 110582, 081582, 071582. The dangerous goods containers at slots 150482, 070782, 011084*, 011286* were thus also protected.²⁰

3.1.2.10 Events on 12 January 2019

A camera drone was launched from the SMIT NICOBAR on 12 January 2019. Its purpose was to monitor the effectiveness of the nozzles installed for cooling down and to check the situation at the fore ship.

¹⁹ According to the salvage company, the ventilations flaps in cargo hold no 1 were found open. All accessible ventilation flaps were closed by the team.

²⁰ The containers marked with an asterisk do not correspond with the dangerous goods stowage plan. This may be an error in the documentation or in the actual stowage.

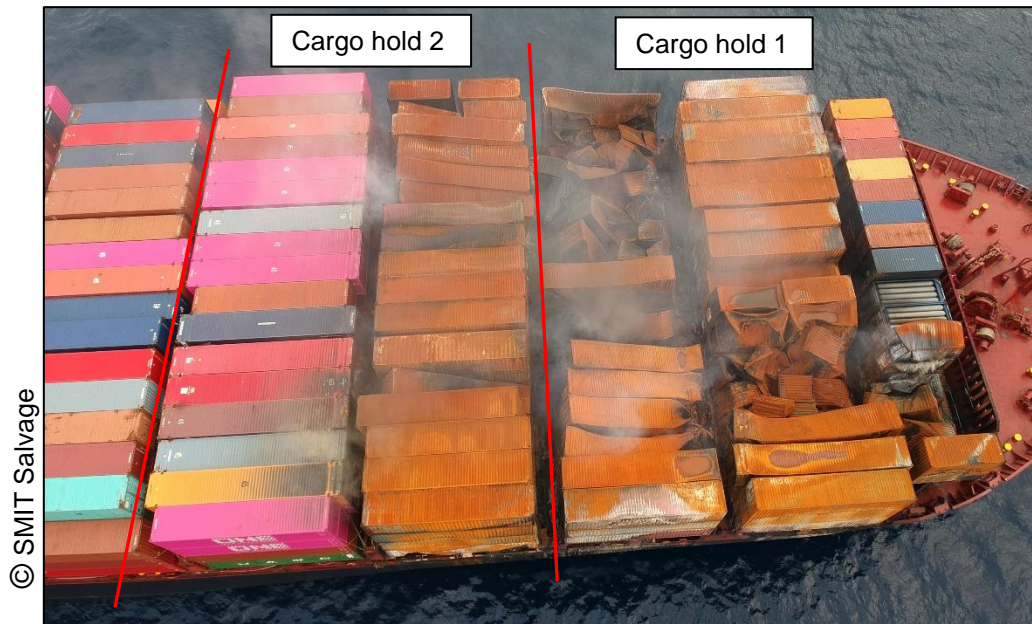


Figure 16: Fore ship of the YANTIAN EXPRESS on 12 January 2019

With regard to the cargo, the shipping company announced that four containers in cargo hold 1 and one container on the deck (161584) supposedly contained 'Titanium Sponge Granules + 10 mesh'²¹. The name in the manifest was 'Granules/Crushed Stone'. Although titanium sponge is not classified as a dangerous good, the data sheet indicates that it has a tendency to explode if it is heated or comes into contact with water. This information was important because a large amount of water had been and was being used to cool down the dangerous goods containers in bay 1. After the announcement, all cooling and firefighting measures around cargo hold 1 were initially stopped.

Given the identified problem, firefighting around cargo hold 2 was also modified, as the use of water there also caused water ingress in cargo hold 1. Therefore, an attempt was made to install a kind of hydro shield between bays 16 and 20 to prevent at least a heat transfer in that direction. Since fire had been seen in the containers at slots 161088, 161288 and 161488, this was also the case.

3.1.2.11 Events on 13 January 2019

The ATLANTIC ENTERPRISE arrived at Halifax on 13 January 2019. In the port they started to take the equipment on board the HORIZON STAR, which was to head for the YANTIAN EXPRESS afterwards.

During her approach, heavy vertical sprinkler systems were manufactured on board the SOVEREIGN, which were to be used on the burning ship.

²¹ Referred to as 'Titanium [sic] Sponge' in the cargo list provided to the BSU. Referred to as 'Titanium [sic] Sponge (non-hazardous)' in the sea waybills provided. 60 metal drums were stowed in each container. The net weight per container was 18 t.

A container on board the YANTIAN EXPRESS carrying matches (160482)²² was flooded, as this cargo posed an increased risk. A container, which evidently contained some kind of charcoal²³ (120782), was opened for inspection. Its cargo was still smouldering. The cooling measures on the dangerous goods containers in bay 1 were continued, as smoke was already rising from one of them. The temperature in cargo hold 1 had risen to 82 °C.

A third portable pump was installed in cargo hold 2 so as to remove the firefighting water there more quickly.

The local weather conditions in Halifax, where the current sub-zero temperatures would have a huge effect on the necessary works at the port, evidently played a role in the salvage company's considerations on the choice of the port of refuge.

3.1.2.12 Events on 14 January 2019

A drone²⁴ was also launched on 14 January 2019 and resulted in changes to the installed nozzles so as to make the cooling measures and the hydro shield more effective. In addition to the container at 011084, smoke could now also be seen rising from the container at 010884.

3.1.2.13 Events on 15 January 2019

After loading was completed, the HORIZON STAR left the port of Halifax. The salvage experts, firefighters and a marine chemist who had transferred from the ATLANTIC ENTERPRISE were also on board.

The SOVEREIGN reached the YANTIAN EXPRESS in the morning. Firefighters and other employees of the salvage company arrived at the scene on her. After the first briefing on the situation, the SOVEREIGN went alongside and her crew began to transfer equipment. Amongst other things, two separate powerpacks were put on the deck of the YANTIAN EXPRESS. The firefighters then started with active firefighting on the deck and in the cargo holds.

Since the water level in cargo hold 2 continued to rise, the cooling measures were initially suspended and a larger pump was installed. The ship's draught was determined as $D_f=14.0$ m and $D_a=12.8$ m on 15 January 2019.

The temperature around the entrance of cargo hold 1 had dropped. However, the firefighters who entered the cargo hold did measure a temperature of 125 °C lower down in the hold. The containers at slots 081118, 080918 and 080718 were responsible for this, in which a smoldering fire had obviously developed. According to the papers, all the containers were carrying tyres. The firefighters also noticed a water level of 1.5 m in this cargo hold.

²² Cargo classified as a class 4 dangerous good.

²³ The cargo documents indicated that this container was carrying coconut pellets.

²⁴ According to SMIT Salvage a drone was used at various stages of the operation on multiple days.

3.1.2.14 Events on 16 January 2019

The SMIT NICOBAR continued her planned voyage to Mexico on 16 January 2019.

The salvage team installed a pump in the bosun's store at the fore ship to remove water there. The high water level there had caused the failure of the electrical connections to the mooring winches at the bow. It was possible to resolve the issue by the end of the voyage, however.

The firefighting measures in the containers at slots 120582 and 120782 were continued. The containers at slots 161688 and 161288 were flooded via punched holes.

The salvage company began preparations for the port of refuge at Freeport in the Bahamas.

3.1.2.15 Events on 17 January 2019

During an inspection of cargo hold 1, it was found that the water level was 8 m. This pointed to a failure of the ship's pumps and/or blocked bilge wells. Consequently, a portable pump was installed there, too.

The container at slot 080718 now also exhibited an increase in temperature. 190 °C was measured at slot 080918. All three containers were further cooled from the outside. To fight the smouldering fires, the containers in positions 080918 and 080718 were opened and nozzles positioned.

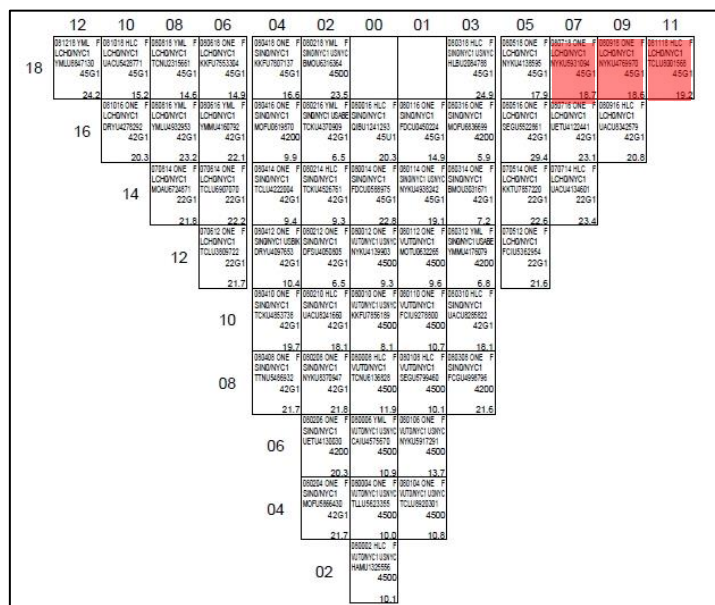


Figure 17: Containers on fire in cargo hold 1, bay 7

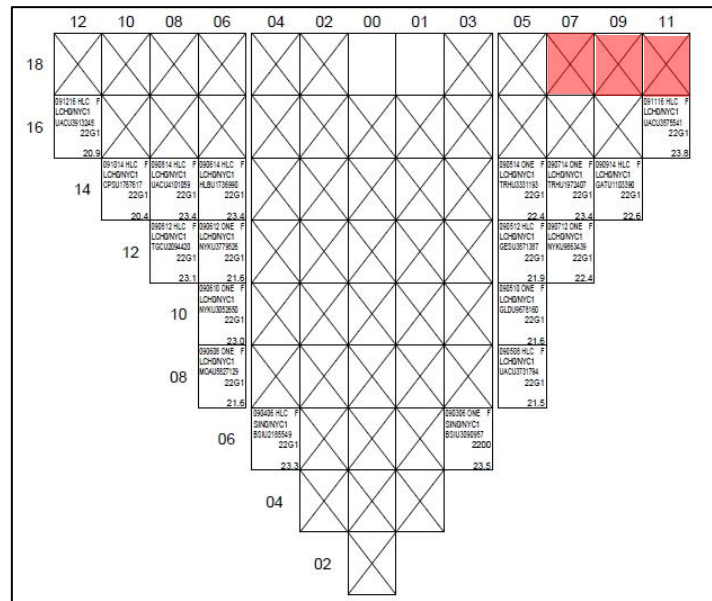


Figure 18: Containers on fire in cargo hold 1, bay 9

3.1.3 Events on 18-26 January 2019

Firefighting was continued at individual fires between 18 and 26 January 2019. Efforts to lower the water level in cargo holds 1 and 2 were also continued. This made it possible to return the ship's draught back to normal.

The HORIZON STAR reached the other ships on 19 January 2019. Additional equipment and the fire experts mentioned thus arrived at the scene. The HORIZON STAR returned to Halifax after the material was transferred.

To make it easier to reach the containers in the cargo hold, the salvagers burnt openings in the hatch covers of cargo hold 1.

SMIT Salvage announced that the containers loaded on the deck of the YANTIAN EXPRESS were extinguished on 21 January 2019, meaning the towing operation to the Bahamas could begin on 22 January 2019. Since the YANTIAN EXPRESS was being towed from the stern, the towing speed was low.

The YANTIAN EXPRESS continued her voyage unassisted from 1600 on 24 January 2019.

The last burning containers in cargo hold 1 were also extinguished and all the fire pumps were stopped on 26 January 2019.

3.1.4 Subsequent events

The YANTIAN EXPRESS reached the roadstead at Freeport on 30 January 2019 escorted by the MAERSK MOBILISER and SOVEREIGN. Permission to enter was granted on 4 February 2019.

The container carrier made fast at an unsurfaced pier with Yokohama fenders ensuring a safe distance to the rocks.

The YANTIAN EXPRESS reached her full manning level again in the days that followed.

The salvage company made preparations to unload the containers at cargo holds 1 and 2 and did so subsequently. To this end, a large crawler crane was erected ashore, the unloading surface was levelled and an area where the containers could initially be stored after unloading was set up and cordoned off. These preparations were completed on 14 February 2019. The unloading of the containers began on 19 February 2019.

On 25 January 2019, Hapag-Lloyd announced the occurrence of a general average in relation to the fire on the YANTIAN EXPRESS.

The YANTIAN EXPRESS left the port of Freeport on 15 May 2019 and reached Halifax on 20 May 2019.

There were no fatalities during the events surrounding the fire on the container carrier. The BSU is not aware of people injured.

3.2 Investigation

The shipping company, Hapag-Lloyd, notified the BSU in the afternoon of 3 January 2019 of the outbreak of fire on its ship. The shipping company co-operated with the investigating agency very closely in the ensuing period.

3.2.1 Crew

The account of the crew members' qualifications is limited to the five people who went back on board.

The 40-year-old German master has worked for the shipping company for many years. He began his assignment on the YANTIAN EXPRESS in November 2018. He has been familiar with the ship for several voyages.

The 29-year-old German chief officer completed his studies at an academic institution specialising in maritime studies²⁵ in 2014. He then served as a watchkeeping officer on ships belonging to Hapag-Lloyd. He was promoted to chief officer in 2017. His assignment on the YANTIAN EXPRESS started in October 2018.

The 63-year-old Polish chief engineer officer went on board on 12 December 2018. He has worked on this ship regularly since 2009.

The 59-year-old Polish second engineer officer also started his assignment on board on 12 December 2018. It was his third voyage on board this ship.

²⁵ University of applied science.

It was the 34-year-old Polish engineer cadet's first voyage on board a ship. After a technical study programme and employment ashore, he went on board in October 2018.

The master and the watchkeeping officers were in possession of a certificate awarded upon completion of training in the carriage of dangerous goods on board ships²⁶.

The shipping company submitted five logs for firefighting exercises on board the YANTIAN EXPRESS from September 2018. One of the training objectives of the exercises on 21 September 2018 and 14 December 2018 was extinguishing fire in containers. During the exercise in December, the use of a water lance was discussed and practised, amongst other things.

3.2.2 YANTIAN EXPRESS

The YANTIAN EXPRESS is a full-container carrier without cargo handling gear. The ship is equipped with seven closed cargo holds forward of the superstructure, as well as one closed (8) and one open cargo hold aft of the superstructure. Cargo holds 1 and 4 can each accommodate two 40' containers and one 20' container one behind the other. Cargo hold 8 can accommodate three 40' containers one behind the other. The remaining closed cargo holds are designed to accommodate two 40' containers one behind the other. The cargo holds mentioned are covered by pontoon hatch covers (three per bay).

The open cargo hold at the stern can accommodate a row of standard 20' containers. When fully loaded, they surround the free-fall lifeboat, which is set up there in the middle of the ship.

The total loading capacity is 7,236 TEU²⁷.

The hatch covers on the YANTIAN EXPRESS only form a partially watertight closure at the top of the cargo hold. This approved design is known as a non-weather-tight type hatch cover. Due to the design, a larger gap remains open between the individual lids.²⁸ The gap on this ship is ≤ 5 cm. A metal strip (gutter bar) welded to the edge of the cover on the side of the gap is intended to prevent rainwater or spray on the surface of the cover from entering the cargo hold as the ship moves (see Figure 19).

The closure of the cargo holds, which is desired for the use of CO₂ as an extinguishing agent in the cargo hold but only feasible to a limited extent due to the gaps, is compensated for by an increase in the amount of CO₂ carried for extinguishing purposes.

²⁶ 'Hapag-Lloyd Training for Masters and Licensed Officers on the Carriage of Dangerous Goods/Hazardous Materials by Ships'.

²⁷ TEU: Twenty-foot equivalent unit.

²⁸ See also MSC/Cir.1087 – Guidelines for partially weather-tight hatchway covers on board containerships.

The ship was not equipped with water based firefighting installations or -systems in the transverse corridors respectively at the lashing bridges that could have been easily activated in the event of a fire on the deck to prevent or delay it spreading to adjacent sections of the deck by means of hydro shields or firefighting monitors.



Figure 19: Cargo hold 1, bay 1, gutter bar and transverse bar

All the transverse corridors have lashing bridges except for the first three between the bays (see also Figure 5). These extend into the second tier of containers, allowing direct access to the second tier for firefighting. The front of the containers in bay 12 and the front and rear of the containers in bays 8, 4 and 1 are therefore only directly accessible in the first tier.

All the cargo holds except for the open one have visible or combined smoke detectors connected to a fire alarm system on the bridge. Fires in the closed cargo holds can be fought with CO₂. A drencher system is available for the open cargo hold. Another drencher system is available on the transverse bulkheads between cargo holds 4 and 3, 3 and 2, and 2 and 1, in each case at the leading edge of the cargo hold. This can greatly increase the fire resistance of the transverse bulkheads in these cargo holds. Accordingly, this sprinkler system is not used to extinguish a cargo hold fire. It should be noted that this sprinkler system is not included in the ship's fire control and safety plan. According to the classification society, this sprinkler system is not required under any regulation. Such 'voluntary' installations would therefore not be included in documents like the fire control and safety plan.

At the time of the accident, all certificates of the ship were valid. The shipping company submitted service reports for the fixed gas fire-extinguishing systems from the years 2017 and 2018, each of which corresponded to the test scope of the two-year

inspection.²⁹ The service also included the CO2 fire-extinguishing systems in the cargo holds. All tests were completed without any complaints.

3.2.3 Cargo

The shipping company submitted the stowage plan for all the dangerous goods carried on the ship and the normal stowage plan for the voyage from Colombo to Halifax. Moreover, the cargo list for the goods carried in bays 1 to 16 and selected sea waybills for them were made available.

The account of the cargo refers to bays 8 (7 and 9) and 12 (11 and 13) in order to give an overview of the bays that were especially affected by fire initially. The documents showed that on the deck bay 8 was fully loaded with 40' containers across three tiers, meaning 51 containers were there. Two 40' slots were not occupied in the cargo hold. Some of the slots were occupied by 20' containers. A total of 61 containers were in the cargo hold in the area of bays 7 and 9.

Bays 11 and 13 were fully loaded across four tiers on the deck. 20' containers could also be found there. A total of 76 containers were thus transported on the deck. A total of 93 containers were transported in the cargo hold at bays 11 and 13.

The distribution of dangerous goods and refrigerated containers in bays 7 to 13 is shown in Figure 20.

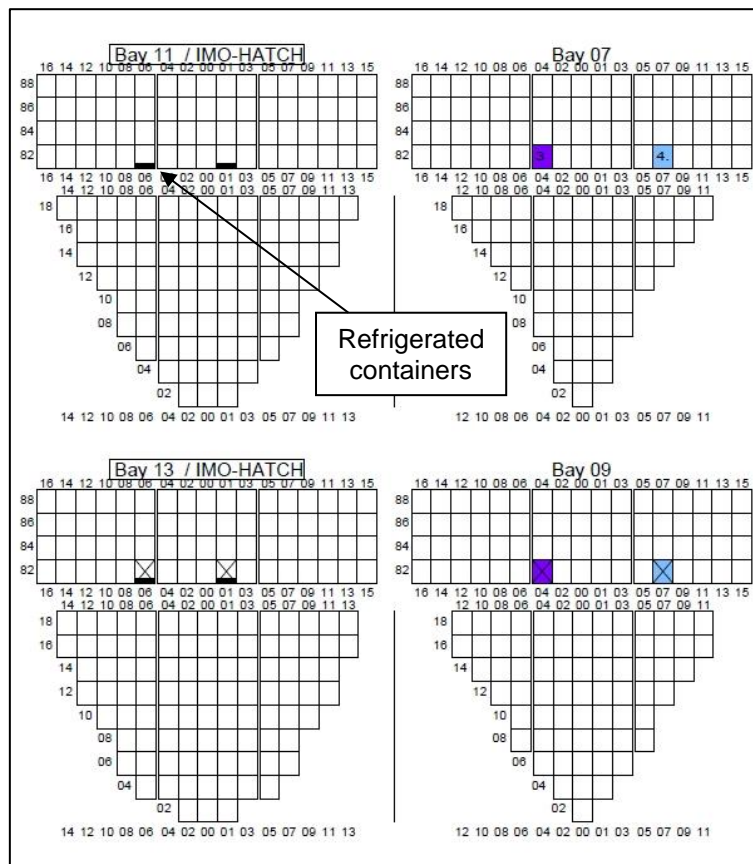


Figure 20: Dangerous goods and refrigerated containers in bays 7 to 13

²⁹ Acc. MSC.1/Circ.1432.

3.2.4 Investigations on board

None of the five crew members who had sailed the ship to Freeport were on board when the first survey was performed. They were relieved and taken home out of concern for their welfare shortly after the ship had arrived at the roadstead.

The shipping company had previously given the BSU an undertaking that these crew members would be available for interview in Hamburg at a later date. The interview was held on 28 February 2019.

In general, it should be noted that the crew had carried out extensive firefighting measures after the fire was detected on 3 January 2019 before abandoning the ship. These were continued after returning on board and intensified further after the arrival of the Falck Nutec firefighters commissioned by SMIT Salvage. Accordingly, it was reasonable to assume during the survey that the condition at the time of the outbreak of the fire no longer existed. This also includes gastight integrity vis-à-vis cargo hold ventilation, the position of fire hoses and whether individual containers were open. To that extent, certain findings are only addressed if related to the outbreak of fire, the first phase of the firefighting operation, specific steps taken during the subsequent firefighting operation or if they constitute an aspect of interest to the investigators.

3.2.5 Findings made with regard to the ship

The investigation on board began on 3 February 2019 at the Freeport roadstead in the Bahamas when, with the involvement of fire investigators from the other parties, the ship was surveyed in those parts of relevance to the outbreak and fighting of the fire, so as to gain an impression of the damage to the ship and cargo. This survey included the bridge, various storage rooms, the CO₂ room, the passageways on the port and starboard sides and the deck around cargo holds 1 and 2.

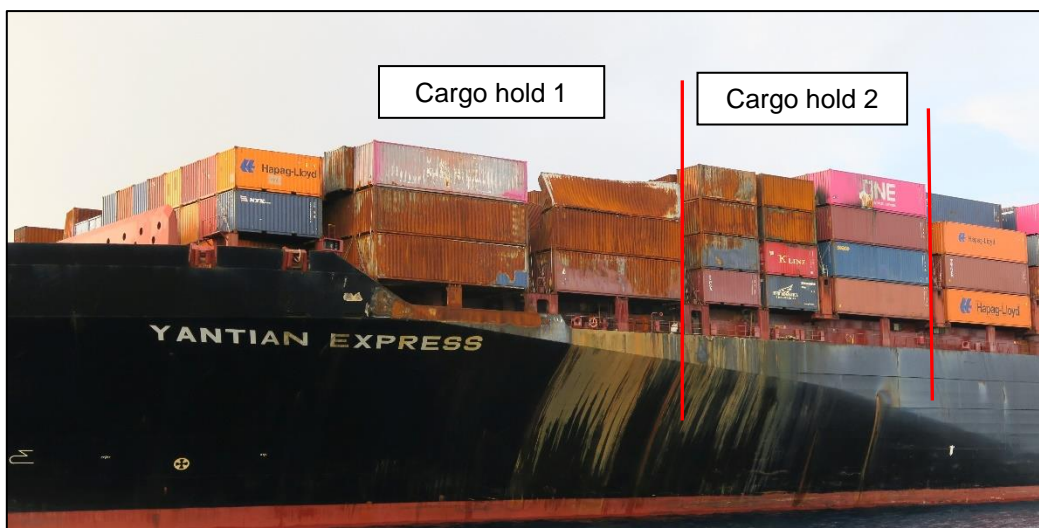


Figure 21: Fore ship on port side



Abbildung 22: Fore ship on starboard side



Abbildung 23: Fore ship on starboard side (cargo hold 1)

The fire alarm system on the bridge of the YANTIAN EXPRESS displayed various alarms on the integrated monitor (see Figure 24). A comprehensive evaluation was later carried out using the system's log data (see subsection 3.2.8)



Figure 24: Fire alarm system display

On the ship's bridge, it was also found that the pilot cylinders for cargo hold 1, which activate the remote-controlled release system, had been opened. The release levers for cargo hold 1 had also been operated. This confirmed the crew's statements on the use of CO₂ in cargo hold 1.

During the inspection of the passageways, major damage to the ceiling of the corridor and to the equipment and cable looms located there could only be identified on the starboard side in the area of cargo hold 1.

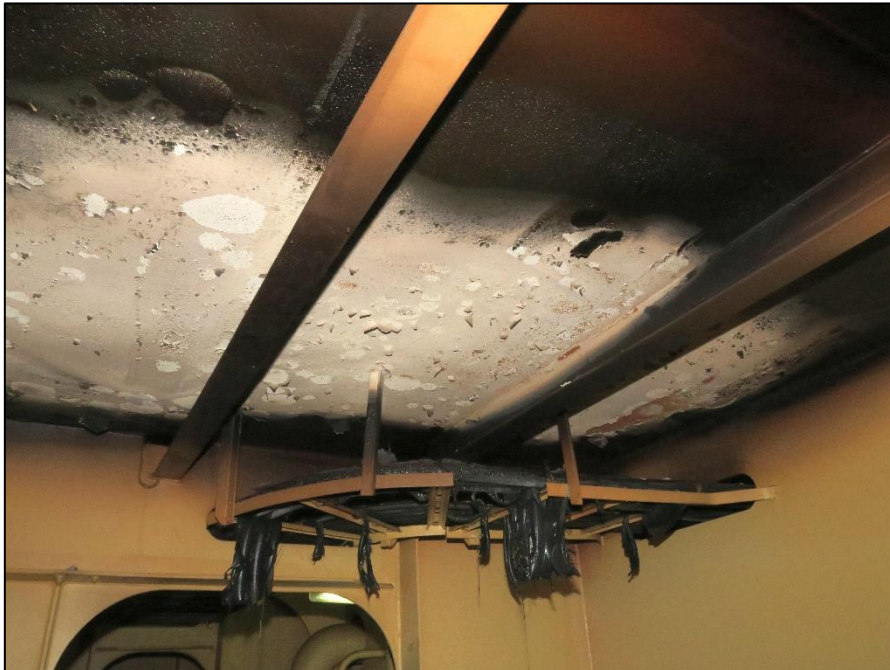


Figure 25: Thermal damage in the starboard passageway adjacent to bay 3

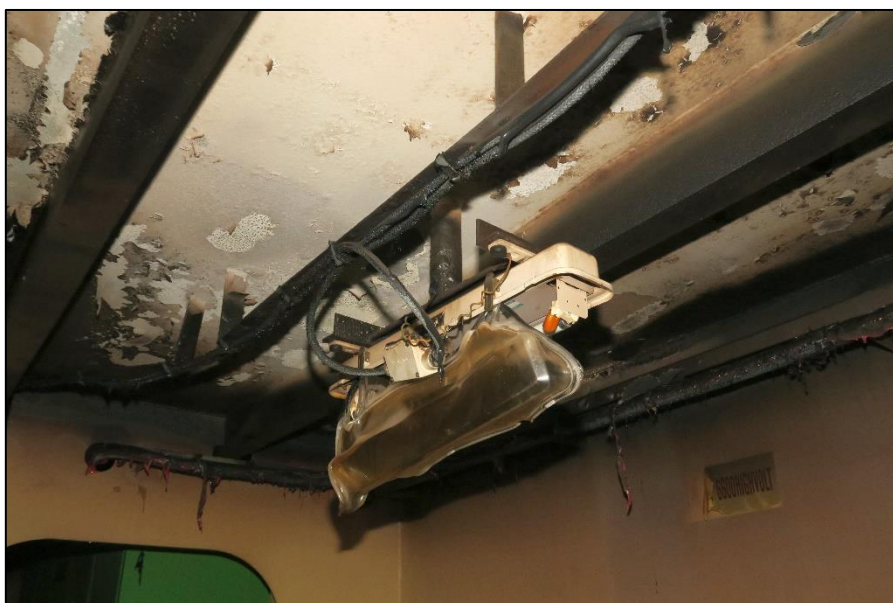


Figure 26: Thermal damage in the starboard passageway adjacent to bay 5

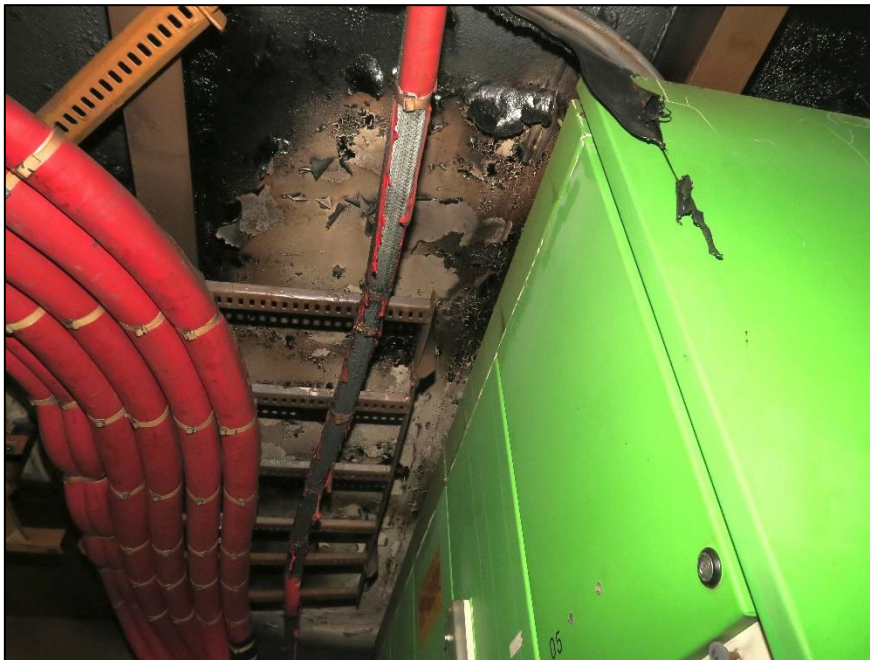


Figure 27: Thermal damage in the starboard passageway adjacent to bay 7

After the arrival of the ship on 4 February 2019, the data record on the voyage data recorder (VDR) belonging to the accident was backed up by BSU that evening. To achieve this, the device's power supply was first restored. The relief crew had disconnected it previously. The VDR in question is a VDR-100 G3 made by Rutter. In the event of an emergency backup, this type of VDR records the 12 hours leading up to the time at which the backup is made. This complied with the regulations at the time the VDR was installed (or when the ship was put into service). Since the master only triggered the emergency backup shortly before abandoning the ship at 0931 UTC on 6 January 2019, no data were available for the period in which the fire broke out. The data recorded were not investigated further.

3.2.6 Findings made with regard to the cargo

3.2.6.1 Cargo in bay 12

The BSU's enquiries into the cause of the fire made during this investigation focused on the containers in the deck area of cargo hold 2 (bay 12, in particular). This was mainly for the following reasons:

- during the first observation of burning containers by the chief officer on 3 January 2019, they were detected at slots 120382 and 120582;
- following that, at 0410 on 3 January 2019, fires were reported in the containers at slots 120382, 120384, 120386, 120582, 120584 and 120784;
- at the beginning, there was no indication of a fire in bays 8 or 16, nor in cargo hold 1;
- smoke was occasionally detected during the inspection rounds in cargo hold 2. No open flames were found during inspection rounds, however;

- firefighting was not carried out at any of the containers in cargo hold 2 subsequently;
- the distance between bays is relatively large due to the wide transverse corridors. According to the chief officer's report, only a low amount of heat was radiated by the containers that caught fire at the beginning. At the beginning, six to eight crew members initially fought the fire both forward and aft of bay 12 without the need for fire suits or breathing apparatus, except in areas of heavy smoke.

On 5 February 2019, the deck in the area of bays 8 and 12 was once more inspected and for the above-mentioned reasons the condition of the containers in the area of bays 11 and 13 was documented.

Only the first and the second tiers were directly accessible from the deck and from the lashing bridge, respectively. The containers were compared on the basis of their numbers and the stowage plan. The stowage plan had to be corrected at some slots. Only three containers were accessible during this inspection, as they had been opened during the firefighting operation. The remaining containers were all locked and could not be opened, not least because of the lashing rods and seals still in place.

120284	120084	120184	120384	120584	120784	120984	121184
120282	120082	120182	120382	120582	120782	120982	121182

Figure 28: Extract from bay 12, first and second tier

The grey background identifies the containers accessible on 5 February 2019.

The following observations were made with regard to stowage during this inspection. The contents of the containers were added based on the cargo list.

- 120282 MOTU0644435 (inconsistent with stowage plan, which indicates 120082)
Polyester
- 120082 TCLU7820653 (inconsistent with stowage plan, which indicates 120282)
Tableware (Stoneware and Porcelainware)
- 120182 TTNU8021570
Refrigerated container: Pizza Cut Pineapple
- 120382 YMLU8706553 (inconsistent with stowage plan, which indicates 120384)
Of Cotton (Baby Garments, knitted or crocheted)
- 120582 FCIU8972821
Polypropylen [sic] Woven Shopping Bag
- 120782 UACU5272502
Coconut Pellets
- 120982 ONEU0039966
Polyester Tyre Cord Greige Fabric
- 121182 TLLU5584536
Polyester Tyre Cord Greige Fabric
- 120284 KKFU7999282 (inconsistent with stowage plan, which indicates 120386)
Tyres

Ref.: 15/19

120084	NYKU4797653 (inconsistent with stowage plan, which indicates 120284) Tyres
120184	YMMU6251084 Of cotton (Men's or boy's shirts, knitted or crocheted)
120384	NYKU5927730 (inconsistent with stowage plan, which indicates 120382) Horn Assy [non-powered horns]
120584	HLBU1599829 Disposable Coverall
120784	TCNU8826843 (inconsistent with stowage plan, which indicates 120786) Wooden Furniture
120984	MOTU6709338 Condensate Pump
121184	BMOU5253533 Wooden Furniture

The following observations were made in the three accessible containers:

- the container at slot 120382, which according to the cargo documents originally contained knitted or crocheted baby garments, was completely burnt out:



Figure 29: View into the container at slot 120382

Only a small amount of fire debris; floor completely burnt.

- the container at slot 120582, loaded with polypropylene woven shopping bags, was also completely burnt out:



Figure 30: View into the container at slot 120582
Small amount of fire debris; floor completely burnt.

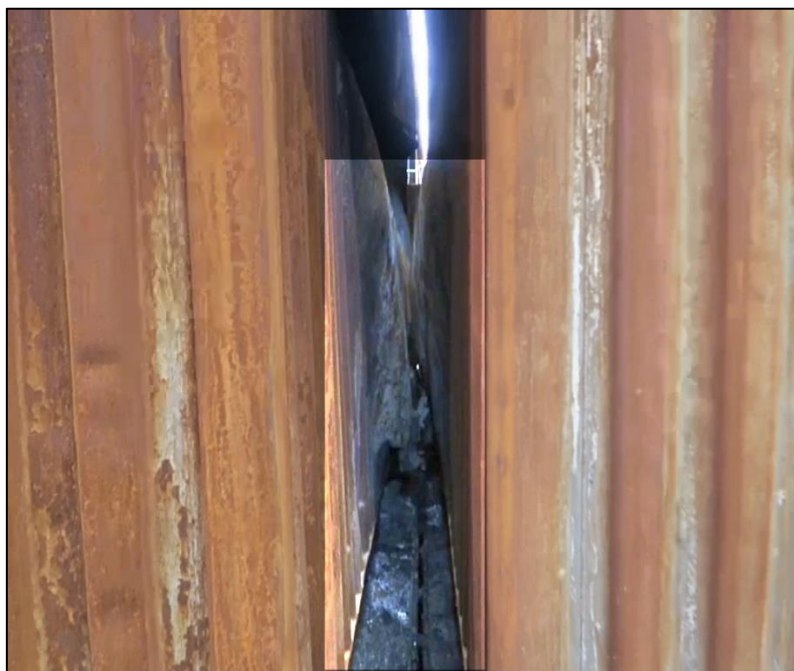


Figure 31: Gap between the containers at slots 120382 and 120582
The two containers are touching due to the effect of the heat. Middle of image brightened.

- the container at slot 120782, which according to the cargo documents was loaded with coconut pellets, still contained the remnants of a coconut pellet load. The pellets, made of a compressed material, were cuboid with an edge length of 2.3 cm x 2.3 cm x 1.5 cm:



Figure 32: View into the container at slot 120782



Figure 33: Close-up of a coconut charcoal cube

During the inspection, the refrigerated container at slot 120182 was also viewed. No effects of fire could be found on the refrigerating unit side located on the aft edge of bay 12 (see also Figure 34).



Figure 34: Undamaged refrigerated container at slot 120182

Work to unload the area affected by the fire began on 19 February 2019 with the containers in bay 1 and then continued in the direction of the stern.

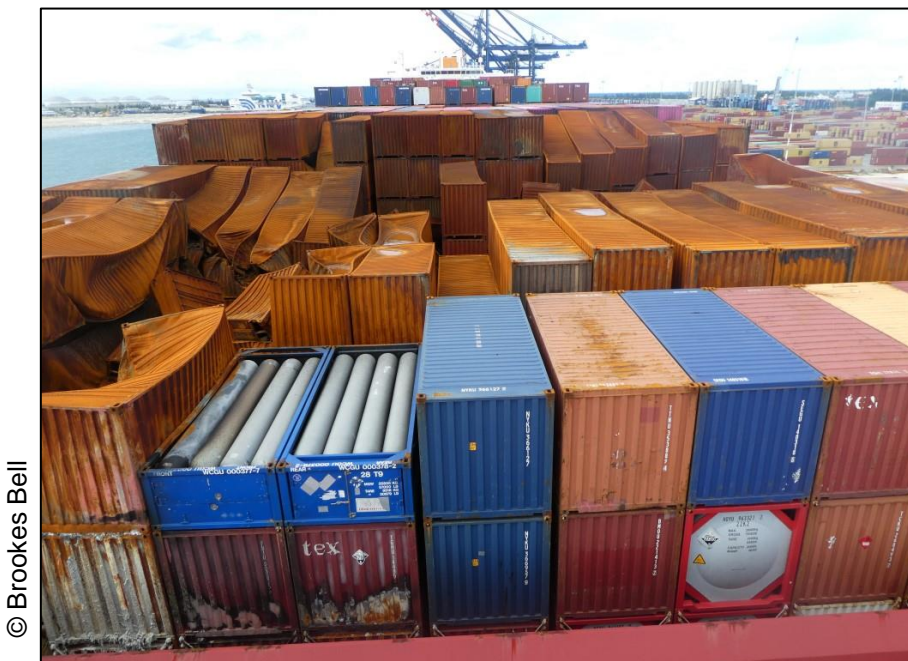


Figure 35: View from bow to stern on 9 February 2019
Bay 1 at the front of the image.

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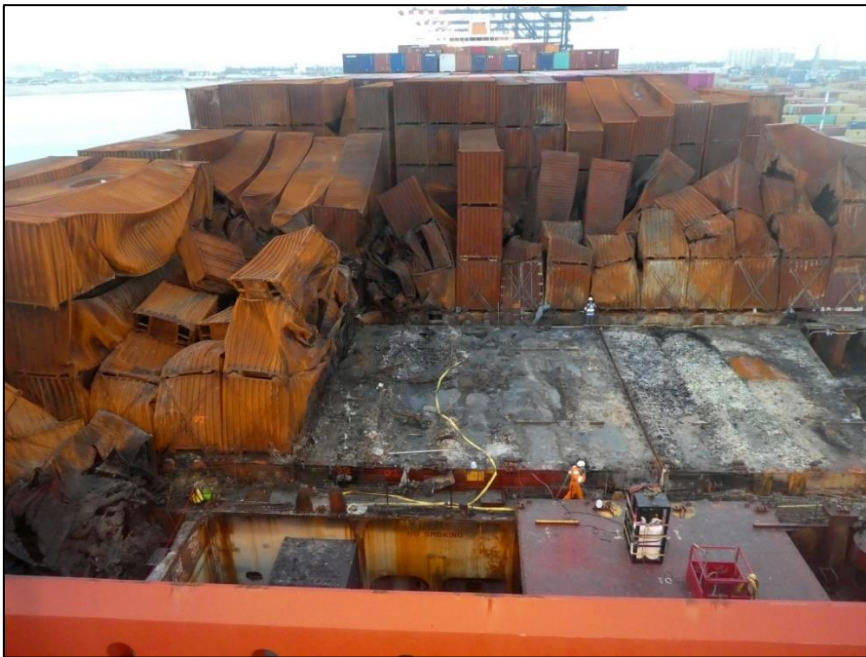


Figure 36: View from bow to stern on 23 February 2019
Bay 1 at the front of the image. More than half of bay 4 unloaded.

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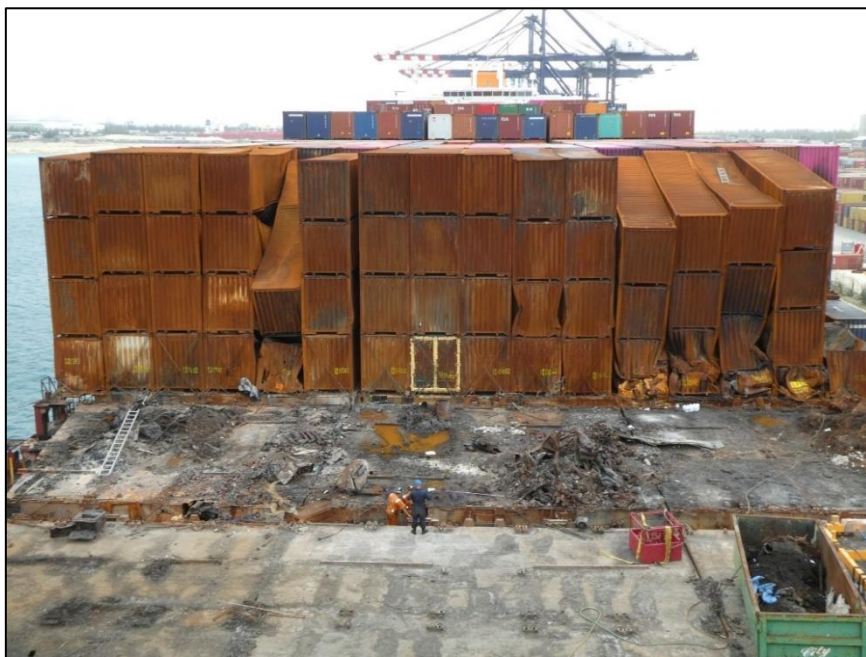


Figure 37: View from bow to stern on 26 February 2019
A view of the forward edge of the containers in bay 12 is shown here.

The BSU continued the examination of the containers on 28 February 2019. Work began to unload the containers from the port side of bay 12, which was of particular interest to the BSU, on the same day. The investigator monitored the unloading operation from a shore-based position. The interior of the previously inaccessible containers was later inspected there in the containers' storage area. No anomalies or inconsistencies with the cargo documents were found. However, actual contents of

containers could only be determined in a few cases due to severe and prolonged fire burned up virtually all combustible materials. Additionally, some of the containers exhibited an extremely high degree of destruction due to the effects of fire, which in some cases caused the overall structure to collapse during unloading. The condition of the cargo inside corresponded with expectations. Cargo was no longer present in some instances because the container floors were burnt and the fire debris fell out when the containers were lifted. Otherwise, the cargo had already mixed with other cargo beforehand.

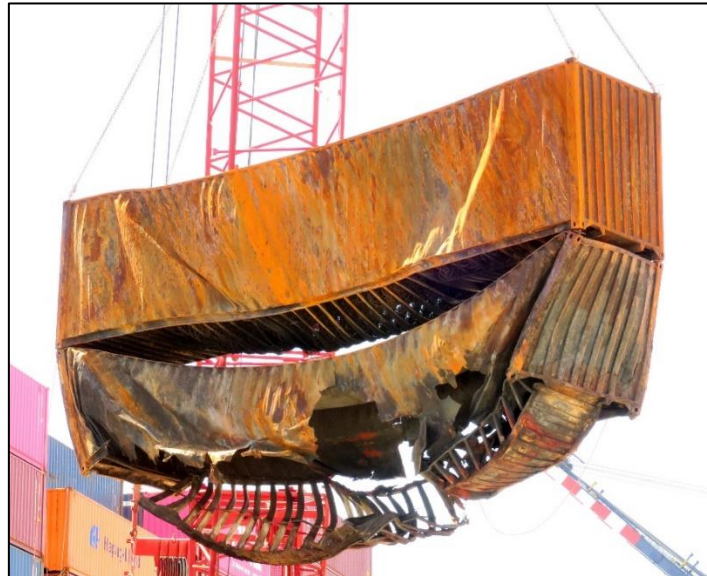


Figure 38: Containers at slots 120788 (top) and 120786

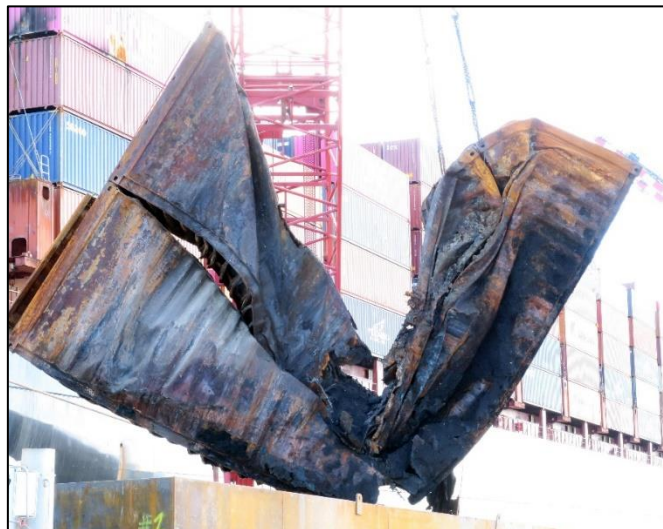


Figure 39: Containers at slots 120784 (top) and 120782

120288	120088	120188	120388	120588	120788	120988	121188
120286	120086	120186	120386	120586	120786	120986	121186

Figure 40: Extract from bay 12, third and fourth tier

120286	GLDU9347711 Tire [sic]
120086	UACU5894574 New Yanmar Engines
120186	TCLU8034263 Tire [sic]
120386	TCLU7966400 (inconsistent with stowage plan, which indicates 120188) Tyres
120586	TLLU6054227 (inconsistent with stowage plan, which indicates 120686) Garment (Ladies Knit Dress, ...)
120786	UACU8143793 (inconsistent with stowage plan, which indicates 120784) Vietnam Black Tea
120986	TLLU5622560 Sport Shoes Pairs
121186	SEGU5317213 (inconsistent with stowage plan, which indicates 121188) Other (Sport Footwear)
120288	KKFU7673969 Respiratory Devices, Accessories and Components
120088	NYKU4427113 Wooden Furniture
120188	MOTU0763120 (inconsistent with stowage plan, which indicates 120486) Tyres
120388	TCNU5403914 Wooden Furniture
120588	TGBU5518019 (inconsistent with stowage plan, which indicates 120888) Other (Sports Footware)
120788	TLLU5672061 (inconsistent with stowage plan, which indicates 120488) Respiratory Devices, Accessories and Components
120988	GESU6937940 Upholstery Sofa Furniture
121188	TLLU4067441 (inconsistent with stowage plan, which indicates 121186) Garment: Ladies Knit Bra

To summarise, it can be stated with regard to the actual container slots that changes were only made in bay 12.

3.2.6.2 Pyrochar

Coconut charcoal rather than the coconut pellets specified in the cargo documents was in container UACU5272502 at slot 120782. The difference between coconut pellets (see Figure 41) and the pyrochar shown in Figure 33 is clear. Coconut pellets are produced by grinding coconut shells and used as fuel for furnaces. In addition, coconut

shells or their fibres are processed into fish feed pellets or into a basic material for plantations. Chemically, coconut pellets are completely different from coconut charcoal.



Figure 41: Coconut pellets³⁰

Pyrochar or vegetable char, produced by means of coconut shell pyrolysis, have properties comparable to wood-based charcoal.

In all likelihood, the cube-shaped pyrochar found here is used as fuel for shishas, i.e. water pipes. This char is sold in various sizes in cardboard containers. This pyrochar can also be used for barbecuing.



Figure 42: Example of cube-shaped shisha charcoal³¹

³⁰ Image retrieved from <https://wood-pellet-line.com/coconut-shell-biomass-pellet-production-line/> on 6 November 2019.

³¹ Image retrieved from <https://www.suedkurier.de/region/hochrhein/kreis-waldshut/Im-Landkreis-Waldshut-gibt-es-immer-mehr-Shisha-Bars> on 12 November 2019.

According to the sea waybill, the total weight of the 40' high-cube container and cargo was 26,150 kg. After deducting the weight of the container, which is estimated at 4,000 kg, 22,150 kg remains. It was indicated that a total of 2,279 packages were in the container. This produces a weight of about 10 kg/package.

The inner volume of a 40' high-cube container is 76.4 m³. The volume of the cargo was specified as 65 m³ in the sea waybill. This means that the container would have been 85% full.

The BSU sent an email to the forwarder and the consignee of the cargo, requesting further information on the cargo but did not receive a reply from either party. Consequently, it was not possible to obtain concrete data on the cargo, the transport route or the transport duration from the place of manufacture or loading to the port of Ho Chi Minh City. According to the sea waybill, the container was put on board the YANTIAN EXPRESS in Vũng Tàu on 10 December 2018. Container UACU5272502 had previously left Ho Chi Minh City on 7 December 2018 and reached Vũng Tàu on 9 December 2018.

After the container had been unloaded from slot 102582, this area was examined. It was found in the process that parts of the charcoal load had also been under this container. Some of the pyrochar (in its cardboard packaging unit) was baked into the fire debris of the polypropylene shopping bags (see Figures 43 to 45).

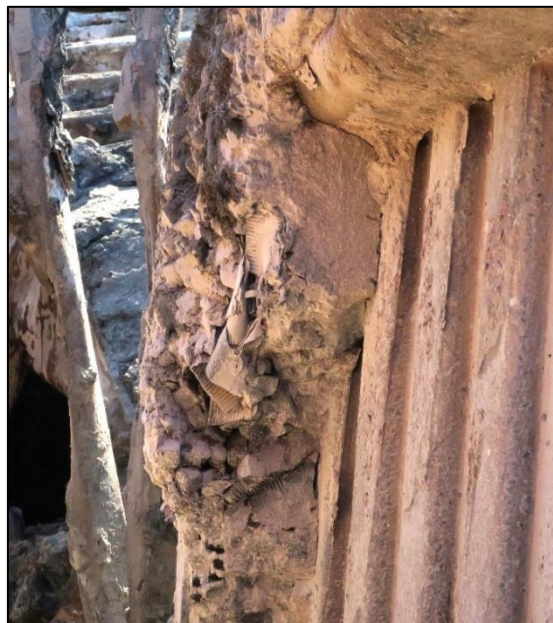


Figure 43: Underside of container from slot 120582



Figure 44: Packed pyrochar at slot 120572



Figure 45: Packed pyrochar at slot 120572

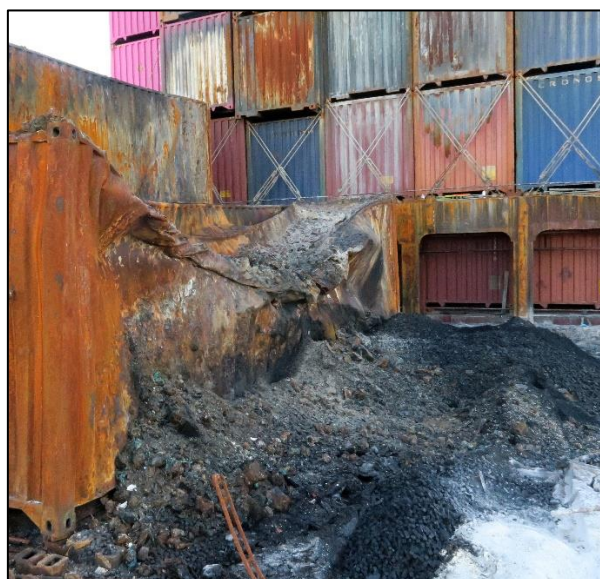


Figure 46: Slot 120782, unburnt pyrochar
The contents spilled out when lifting.

3.2.6.3 Survey of the pyrochar

The investigator secured a smaller sample quantity of the pyrochar locally and sent it to Germany's Federal Institute for Materials Research and Testing (BAM). Since there was no other container with this cargo on board the YANTIAN EXPRESS, no unchanged reference material was available.

The Institute found the following: The sample quantity was sufficient to carry out an adiabatic hot storage test as well as an isoperibol test each with a sample volume of 110 cm³. It was not possible to carry out a test in a 10 cm-cube as intended at the UN N.4 test, since the sample quantity was too small.³²

3.2.6.3.1 Isoperibol hot storage test (prEN 15188:2019)

The isoperibol hot storage tests serve the purpose of experimentally determining the volume independent self-ignition temperatures. The term isoperibol means constant environmental conditions and temperatures, respectively.

For a test, sample containers are filled with a defined bulk density and placed into an oven, which is heated with a constant temperature (storage temperature). A thermal element for measuring the sample temperature is placed in the centre of the sample. Thermal elements to the right and left of the sample serve the purpose of determining the oven temperature. The chronological temperature gradations of the sample- and oven temperatures are recorded.

A test is to be regarded as ignition

- if the temperature gradation in the centre of the sample above the oven temperature has a turning point or
- the temperature in the centre of the sample rises to more than 60 K above the oven temperature

The self-ignition temperature is defined as the highest oven temperature, which does, for a given volume, no longer lead to an ignition. The induction period is defined as temporal distance between reaching the storage temperature (centre of sample) and an ignition.³³

The test with a sample volume of 110 °C showed a self-ignition of 41 K to 224 °C at a storage temperature of 183 °C. Corresponding to prEN15188:2019, the sample did not ignite (See Figure 47).

³² For further explanations of the following tests, see also investigation report 455/15 of the BSU - fire of charcoal cargo - and the corresponding expert opinion (in German language).

³³ See prEN151188:2019.

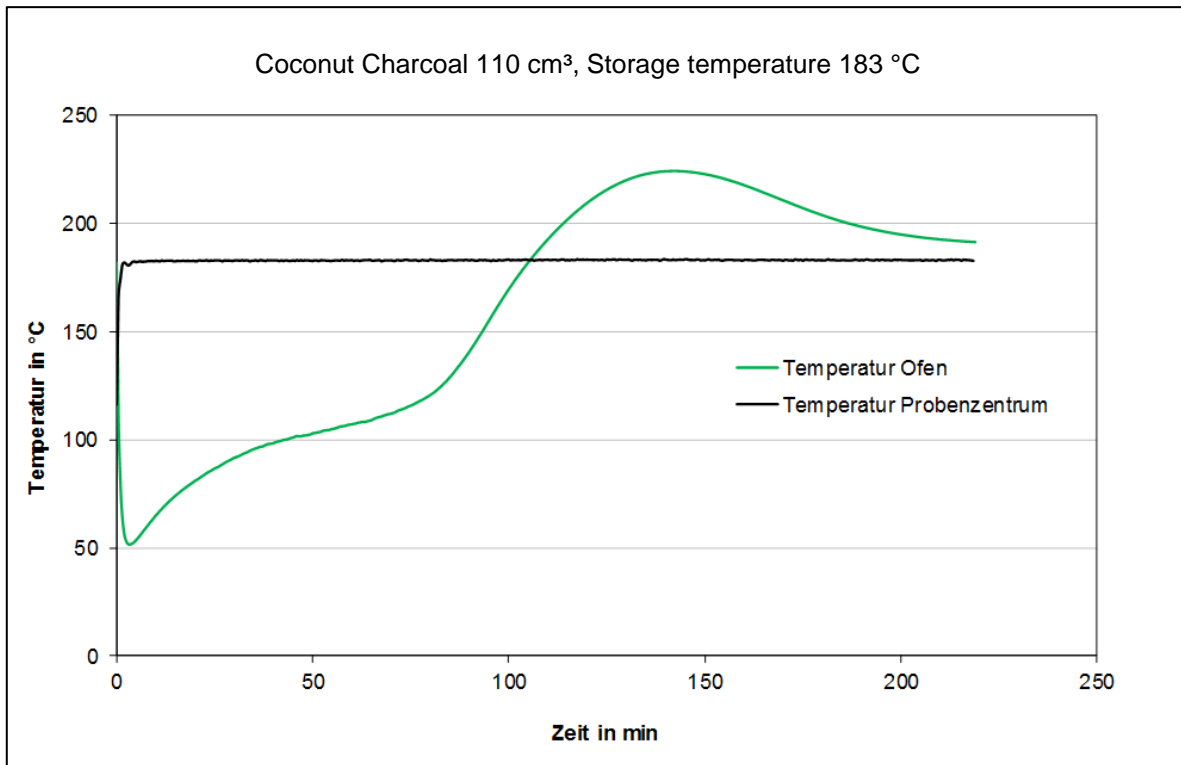


Figure 47: Isoperibol test with cocolut charcoal (110 cm³) at 183 °C

3.2.6.3.2 Adiabatic test

Adiabatic hot storage tests have the advantage that they are volume independent. A test with a small sample quantity is sufficient in order to determine the reaction-kinetic parameters. With knowledge of these parameters, an extrapolation from a small laboratory volume to an actual package/storage is possible. In the adiabatic hot storage test, the oven temperature is at first set to an adequate starting value. If the temperature in the centre of the sample exceeds the oven temperature, this is regulated in such a way that it corresponds to the sample temperature and is kept constant at a low temperature difference, respectively.³⁴

An adiabatic test was carried out with 110 cm³ coconut charcoal (for the temperature profile see Figure 48). The test yielded a comparable low activation energy of 67 kJ/mol. The kinetic of the examined material differs considerably from the kinetic deposited for the N.4 test.

For this reason, a more critical ignition behaviour is to be assumed with coconut charcoal.

³⁴ See draft VDI directive 2263, page 1:2019.

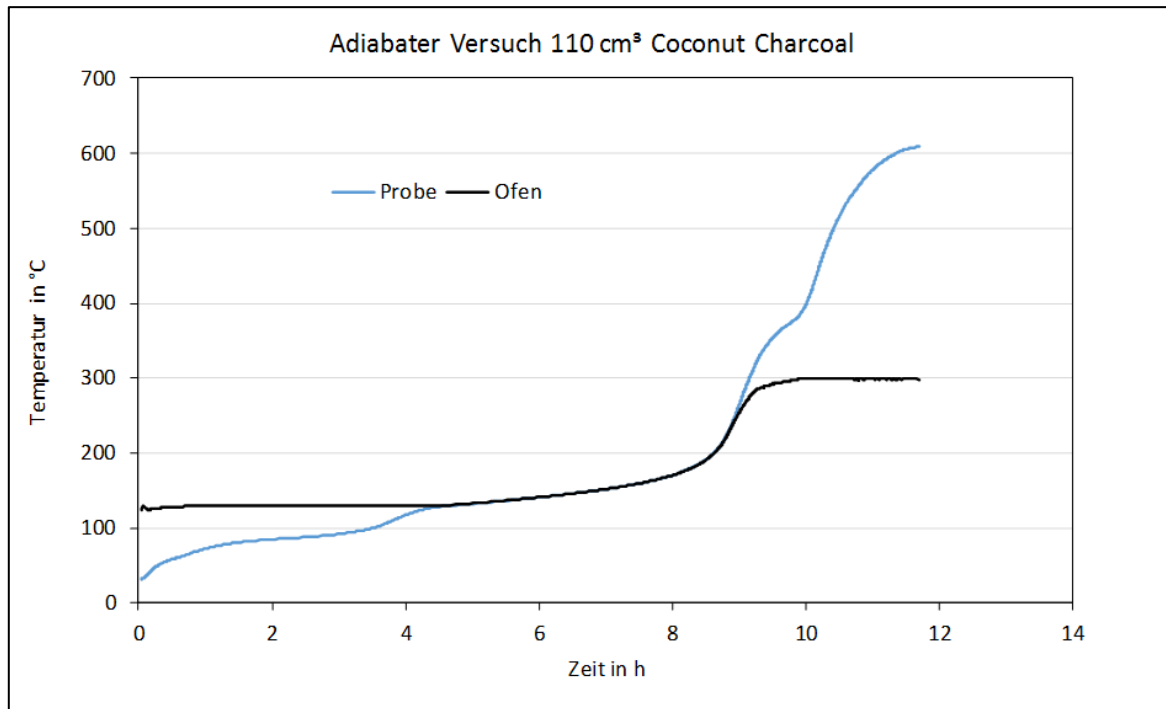


Figure 48: Adiabatic test with coconut charcoal (110 cm³)

3.2.6.3.3 Conclusions

The Federal Institute for Materials Research and Testing made the following conclusions: It can be inferred from the tests that coconut charcoal does not ignite when stored in a 10 cm-cube at 140 °C. Consequently, it would not be classified as self-igniting substance in accordance with the UN test provisions (N.4 Test).

However, an appraisal of the ignition behaviour of large volumes, based on kinetic data from the adiabatic test, yielded that a cubical volume of 27 m³ has a self-igniting temperature lower as 50 °C.³⁵ A self-igniting temperature higher than 50 °C for a cubical volume of 27 m³ justifies a non-classification of a material³⁶ in accordance with the UN-inspection manual. This is not the case for the examined coconut charcoal.

The examinations allow for the conclusion that the fire could have been caused by self-igniting of the coconut charcoal.

3.2.6.4 Dangerous goods cargo

According to the cargo documents, no dangerous goods as defined by the IMDG³⁷ Code were transported in the area of bay 12. During the inspection of the containers stowed in bay 12, no indications of dangerous goods containers, such as dangerous goods labels, could be found.

³⁵ 27 cm³ correspond approximately to the cargo volume of a 20 foot container.

³⁶ See also 33.3.1.3.3 of the recommendation for the carriage of dangerous goods – manual about inspections and criteria.

³⁷ IMDG Code: International Maritime Code for Dangerous Goods.

3.2.6.5 Cargo in other areas

According to the shipping documents, seven 40' containers with titanium sponge were on board the YANTIAN EXPRESS. Four of them were transported in cargo hold 1, bay 8. Another container was in bay 16.

The safety data sheet provided to the BSU by the shipping company contained the following text: "Keep away from heat, sparks, open flames, heated matters and other ignition sources. Keep in a cool place and avoid sunlight. Container may explode on heating. May react drastically or explosively on contact with water. May decompose explosively when heated or involved in a fire." The prohibited firefighting agents indicated included water, CO₂ and foam extinguishing agents.

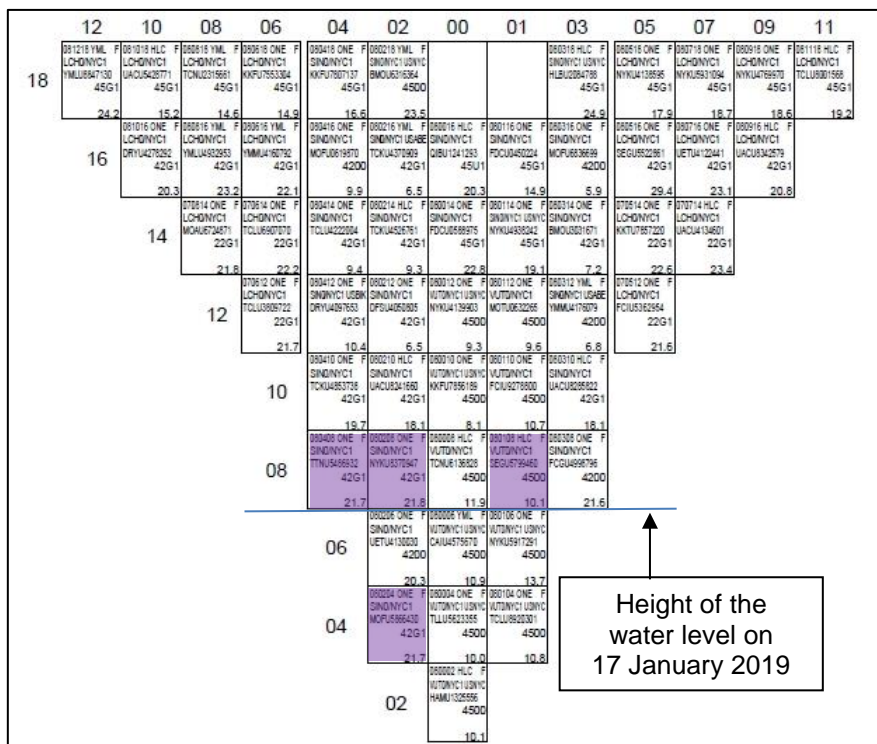


Figure 49: Cargo hold 1, bay 8, 40' container with titanium sponge

In the area of the container loaded with nitrocellulose in slot 080782, a hole was later found in the hatch cover. In the opinion of the firefighters commissioned by the salvage company, it was caused by the combustion of the nitrocellulose. The fire then developed via this hole into hold 1 and led to the ignition of the containers loaded with tires in slots 080718, 080918 and 081118.



Figure 50: Comparable hole on position 080182

3.2.7 Firefighting operation

As already discussed, the crew made extensive use of the three water mist lances on board.³⁸ This had been rehearsed on a barrel during an exercise and appeared simple. The walls of the containers were much thicker, making it far more difficult. Consequently, after the firefighting had begun and the first water lances were punched into place, members of the engine room's crew drilled holes into the containers in the area of the fire in bay 12 as a precautionary measure. The portable drill on board proved less suitable for this. In the end, the mandrel belonging to the water lances was used to create a small starting hole. The hole was then expanded to the diameter of the water lance conventionally using a hammer and chisel. An overview of the holes created in the process can be found in Figure 51.

The three water mist lances were then repositioned from time to time to extinguish all the containers that had caught fire from the inside. Due to the poor accessibility of containers in the second tier, the holes there were halfway up the container.

³⁸ The shipping company pointed out in its statement that there would be no requirement for the vessel to be fitted with such water mist lances.

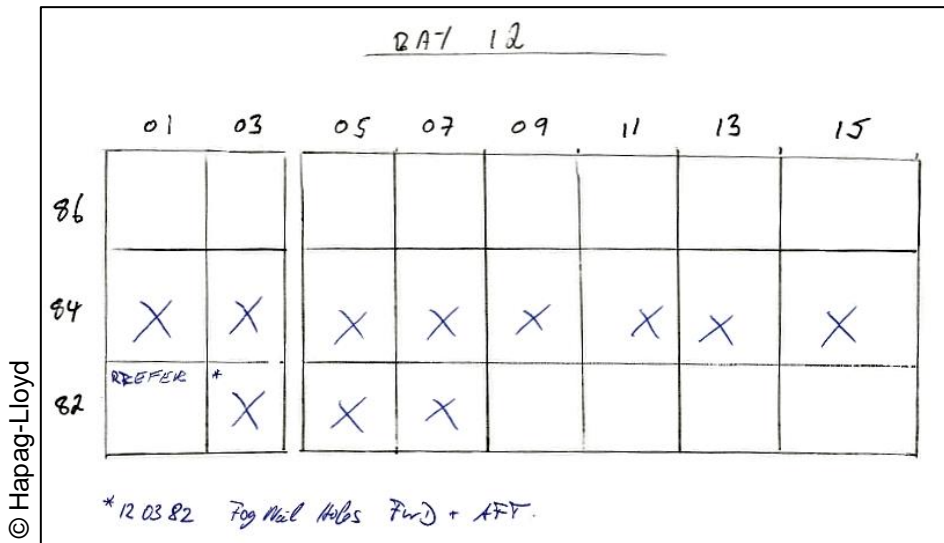


Figure 51: Holes created by the crew for the water lances

A hole for a water lance was punched into the front and back of the container at slot 120382.

During the interview, the chief officer reported that the crew had opened the container filled with shopping bags (120582) during the firefighting operation. It was found that the container was loaded up to the ceiling. Since the cargo had poured out of the container, it was not possible to close the door properly again.

During the interview, sketches relating to the crew's firefighting operation were also handed over (Figures 49 and 50).

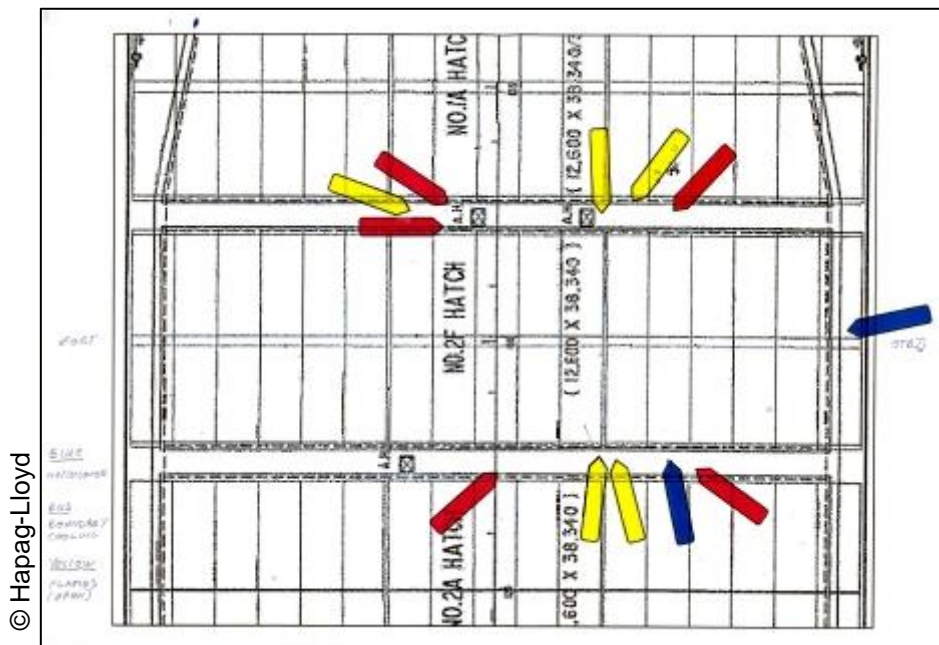


Figure 52: Firefighting by the crew at bay 12

Viewed from the top. The blue arrows indicate the use of water between hatch cover and container floor. The yellow arrows indicate the extinguishing of open flames. The red arrows indicate the cooling down of the environment.

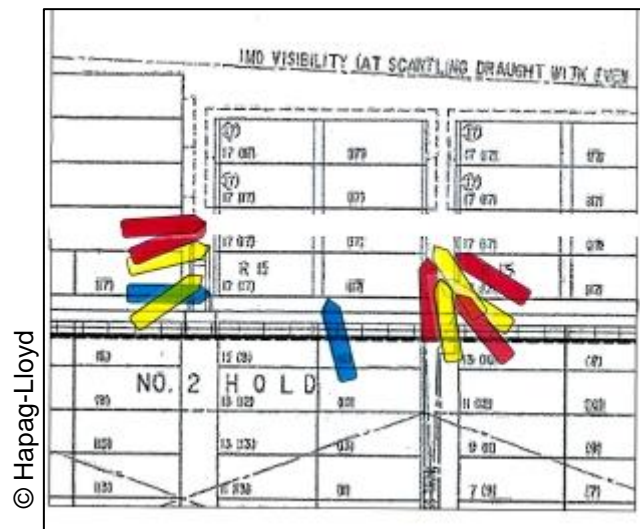


Figure 53: Firefighting by the crew at bay 12

Viewed from the side. The blue arrows indicate the use of water between hatch cover and container floor. The yellow arrows indicate the extinguishing of open flames. The red arrows indicate the cooling down of the environment.

The chief officer also explained that the use of firefighting water beneath the containers was obstructed by the container feet located on the hatch cover and especially by the transverse bars welded onto them (see Figure 19).

During the inspection of the ship on 1 March 2019, the two ventilation openings covered by a grill in the transverse corridor between bays 4 and 8 were to be looked at as well. Since the opening on the starboard side was covered by molten aluminium, it was only possible to view the one on the port side.

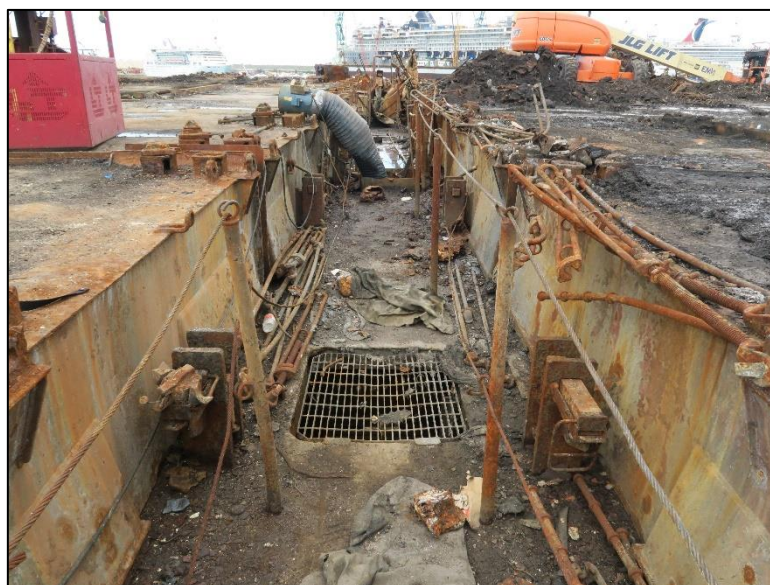


Figure 54: Grill over port ventilation opening in the transverse corridor between bays 4 and 8

It was found here that the flap of the ventilation opening under the grill was not locked. Access to the flap was not possible because the grill was secured by a chain and lock.



Figure 55: Grill over ventilation opening secured by chain and lock

3.2.8 Fire alarm system

The BSU's investigators assume that the activation of a sensor in the fire alarm system does not initially trigger a full fire alarm on the ship automatically. Instead, there is an indication on the bridge that a sensor has detected fire, giving the crew the opportunity to check the actual conditions around the sensor. In addition, the alarm triggered is muted. If the alarm is not acknowledged at the panel within 120 seconds, the general alarm sounds.³⁹ If it turns out to be a false alarm, then the fire alarm system or the sensor or the detection line can be re-activated by clearing the alarm. This is also possible if, in the event of an actual fire, it is necessary to check whether a sensor will detect a fire at a later point in time, e.g. after firefighting measures have been taken.

The fire alarm system's log data are sorted into different lists. These include the history list, which lists all events incl. all faults of the system, and the fire alarm list. The fire alarm list contains those alarms that resulted in a full fire alarm on the entire ship. The first event recorded in the fire alarm list is at 075841 ship's time on 5 January 2019.

There is also a fault list, which logs faulty sensors. The first entry in this list refers to a dirty sensor (68) in cargo hold 1 at 134338 ship's time on 5 January 2019.

Other lists are the pre-alarm list, the warning list and the disablement list. There are no entries in those three lists.

³⁹ If an alarm is activated at a manual call point this starts the general alarm immediately.

The first entries in the **history list** referring to the fire investigated were:

2019-01-03 00:33:31 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 62⁴⁰
2019-01-03 00:33:50 FIRE MUTED
2019-01-03 10:24:42 FIRE REMOVED CENTRAL 1 LMX 14:1 SMOKE 62

The 'SMOKE 62' entry refers to a smoke detector in cargo hold 2.

The next entries also refer to this cargo hold:

2019-01-03 16:34:46 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 62
2019-01-03 16:34:58 FIRE MUTED
2019-01-03 20:01:54 FIRE REMOVED CENTRAL 1 LMX 14:1 SMOKE 62

2019-01-03 20:02:03 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 62
2019-01-03 20:02:10 FIRE MUTED

The next alarm recorded refers to a smoke detector in the forward part of cargo hold 1:

2019-01-04 07:00:46 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 71
2019-01-04 07:01:04 FIRE MUTED

More alarms are then recorded from the various areas of cargo hold 1 and the bosun's store for the following 30 minutes.

The next alarm for cargo hold 2 is not triggered until the evening of 4 January 2019:

2019-01-04 19:07:52 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 61
2019-01-04 19:08:04 FIRE MUTED

2019-01-04 19:16:21 FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 62
2019-01-04 19:16:30 FIRE MUTED

The first entry in the **fire alarm list** is:

2019-01-05 07:58:41 1(14) FIRE ZONE 4 SMOKE 68
NO.1 HOLD(MID)-SMOKE DETECTOR

The following nine alarms in this list refer to sensors in cargo hold 1. The first alarm for cargo hold 2 is:

2019-01-05 14:11:47 12(14) FIRE ZONE 4 SMOKE 61
NO.2 HOLD-SMOKE DETECTOR

3.2.9 Further findings

As part of the comments on the draft, the shipping company informed the BSU that during the service work to restore the operational readiness of the CO₂ system, it was established by the service company that only 8 of the 158 CO₂ cylinders originally intended for hold 1 had actually been triggered by the system. The service company

⁴⁰ The original entry is 2019-01-03 03:13:31 UTC FIRE INSERTED CENTRAL 1 LMX 14:1 SMOKE 62. All times shown in the below information are corrected to the respective ship's time.

attributed this to the non-functional time delay unit. As part of the service work, the time delay units of all cargo holds and the engine room were replaced. In addition, the pilot cylinder system for triggering the corresponding cylinder battery was replaced.

4 ANALYSIS

4.1 Crew

The YANTIAN EXPRESS's crew was experienced and well trained. During the first phase of the firefighting operation, it acted with great commitment prior to abandoning the ship. The investigators were of the opinion that the extinguishing action on the deck containers was carried out in the best possible manner using the resources available on board, such as water mist lances and nozzles.

The return of the five crew members to the YANTIAN EXPRESS on 9 January 2019 cannot be rated highly enough. The maintenance of ship operation together with the salvage master until the arrival of the gross of the salvage experts and firefighters on 15 January 2019 and thereafter laid the groundwork for the success of their firefighting operation.

4.2 Firefighting

Since there were no data from the VDR available for the start of the firefighting operation, most of the details of the sequence of events during the first four days were taken from the entries in the bell book. That material events or actions may not have been entered there due to the overall circumstances cannot be ruled out. Consequently, it was at times difficult during the investigation to find correlations between alarms triggered, especially those of the fire alarm system, and actions taken on board. One reason for this is the fact that alarm logs were not available when the interviews with the crew were carried out. However, it is apparent that the fire was seen by the bridge team before any alarm in the holds triggered.

However, the events and findings did and still show that smoke detector alarms in cargo hold 2 were not triggered by actual fires in this cargo hold. Rather, the fire alarms there were triggered likely by smoke from burning items of cargo that had entered the cargo hold from the deck via the gaps in the hatch covers. It is also possible that smoke was driven into the hold through the gaps in the hatch covers from the fire on deck, and/or due to heat generated by the fire on deck. The extent to which this also applied to cargo hold 1 cannot be determined further, since this cargo hold was no longer accessible to the YANTIAN EXPRESS's crew until the abandoning of the vessel. Inasmuch, the intended discharging CO₂ into cargo hold 1 was at least a preventive measure.

Due to a malfunction of the time delay unit in the line of the fixed CO₂ fire-extinguishing system for hold 1, only the contents of 8 CO₂ cylinders were discharged there. The crew did not notice this malfunction. The BSU investigators assume, however, that this malfunction had no influence on the development of the fire, since in their opinion there was no fire in hold 1 at that time. It was not until the firefighters from Falck Nutec later discovered rising temperatures in the containers in positions 080718, 080918 and 081118.

The gaps in the hatch covers were design-related and approved. However, the gutter bars, which were there for retention, did not prevent burning or glowing objects from entering the cargo holds via the gaps between the hatch covers. Amongst other things, this may have been due to the large amount of water – comprising a lot of firefighting water and sea water washing over the deck – carrying burning objects over the gutter bars. It is also conceivable that burning objects may have been flushed into the gaps due to the active cooling measures beneath the containers.

The crew reported that the transverse bars on the hatch covers (Figure 19) obstructed the active cooling and extinguishing measures underneath the containers. Although the distance between cover and container is relatively large (see Figure 56), the transverse bars reduced the space available.

This posed a particular problem in the case of those containers that could only be reached from the front or back due to their position.



Figure 56: Height of container foot plus twist lock

The active firefighting measures were discontinued on the evening of 3 January 2019. Amongst other things, this was due to the fact that there was no option on board for refilling the compressed air cylinders for the breathing apparatus. As a result, the supply of air cylinders for breathing apparatus sets were almost exhausted at that point in time.

According to the fire and safety plan, there were five sets of breathing apparatus on board. Three belonged to the ship's standard equipment. Two others were available due to the possibility of transporting dangerous goods. The plan indicates that 17,600 l of compressed air (9,600 l for the standard equipment and 8,000 l for the additional equipment) was kept for this purpose.⁴¹ This corresponds to 11 cylinders with a respiratory volume of 1,600 l each. The compressed air cylinders with a volume of 6 l used on board, which were filled at 300 bar, permitted an extinguishing action with respiratory protection for about 30 minutes. Assuming people with respiratory

⁴¹ Assuming two sets of breathing apparatus and the associated (at least two) spare charges were required (regulations 10.2.1 and 10.2.5 SOLAS II-2) and two additional sets of breathing apparatus plus the spare charges had to be on board (regulation 19.3.6.2 SOLAS II-2), the actual quantity of compressed air on board would have had to be 19,200 l if each had been filled with 1,600 l (1,600 l x 12 cylinders).

protection usually work in teams of two, an extinguishing action with respiratory protection would have had to be stopped after less than three hours.

According to the chief officer, there were about 35 air cylinders on board, however. This means that the required amount was well exceeded and would have enabled two people to fight a fire for some nine hours with respiratory protection.

During the firefighting operation on board the YANTIAN EXPRESS, the drencher system for the transverse bulkhead between cargo holds 2 and 1 was also used. The ship's command referred to this installation as a sprinkler system when interviewed. In the view of the BSU, this would mean an installation, which helps to extinguish or suppress fires in the entire cargo hold. The investigators do not rule out the possibility that the crew may have misunderstood the function and attribute this to the fact that the system provided for cargo holds 2, 3 and 4 is not entered in the fire and safety plan.

Gastight integrity would normally have had to be established in cargo hold 1 for the use of CO₂ there. During the inspection of the ship, it was not possible to determine with certainty the extent to which gastight integrity was actually established, as cargo hold 1 was no longer accessible at that point by the crew. On the other hand, the fire service carried out firefighting and ventilation measures later on, which may have resulted in a different condition. However, the salvage company noted that the ventilation flaps in hold 1 were found to be open. It was established during the inspection that the ventilation opening in the transverse corridor between bays 4 and 8 was not closed, at least on the port side. The investigators find it questionable that the lock on the grill, apparently put there to prevent smuggling, was not removed after leaving the last port. Quick access to and closing the ventilation flap was thus prevented.

During the firefighting operation, the YANTIAN EXPRESS's crew opened the container at slot 120582, which was filled with polypropylene shopping bags, and found that the container was completely filled with this cargo. This illustrates that the use of water mist lances in containers is not without problems, as a fire in the middle of the container cannot be reached due to the stowage situation. This is all the more true when, as on the YANTIAN EXPRESS, it is only possible to reach half way up the containers in the second tier due to the structural conditions of the lashing bridge.



Figure 57: Container at slot 120984 with hole for water mist lance

There is no indication that a permanently installed water-based fire control system on deck would have been more effective in containing the fire than the crew's actions in this case. Nevertheless, the BSU believes that such a system can be very helpful, firstly because it does not bind forces and secondly because it is less susceptible to the effects of the fire itself. In addition, the investigators assume that such a system offers great advantages for fires in the upper container tiers.

4.3 Cause of the fire

The fire was detected when two containers were already fully ablaze. Since there are usually no fire detectors installed on the deck and rounds of the large deck area are not continuously made during the night or day, fire detection at this stage of fire development is not unusual, which makes the assumption of earlier fire detection had the refrigerated containers been inspected on the previous day speculative.

It should be noted, in principle, that due to the fire in the deck cargo lasting 19 days and the prolonged influence of firefighting water on the containers and their contents, the remaining cargo or fire debris exhibited a high degree of destruction. In addition, it was almost impossible to reconstruct the course of the fire. For this reason, a process of elimination has been applied when considering the cause of the fire and a comparison between different probabilities made.

As already discussed, the BSU's investigation into the cause of the fire focused on the containers in bay 12. This is because it was established that the first two containers to catch fire were in this bay. The investigators have ruled out the possibility of heat

radiation from a container burning unnoticed in bay 8 or bay 16. Firstly, the crew would very probably have noticed this heat radiation, and secondly, it would have had to cover a relatively large distance from one bay to the other.

The investigators have also ruled out the possibility of fire in a container in cargo hold 2 as being the cause because firefighting measures were not carried out on any of the containers in this cargo hold at any time during the course of the events. The investigators attribute the first smoke detector alarm from cargo hold 2 at 003331 on 3 January 2019 to burning objects entering the cargo hold via the gap between the middle and starboard hatch covers. Another smoke detector alarm was registered at 163446 on 3 January 2019. After that, the next smoke detector alarm for cargo hold 2 did not occur until 190752 on 4 January 2019. Accordingly, these alarms are also an indication that there was no constant smoke development in cargo hold 2 that was typical of a fire.

The cargo in the containers first affected is once more shown below (see also Figure 3 and subsection 3.2.6).

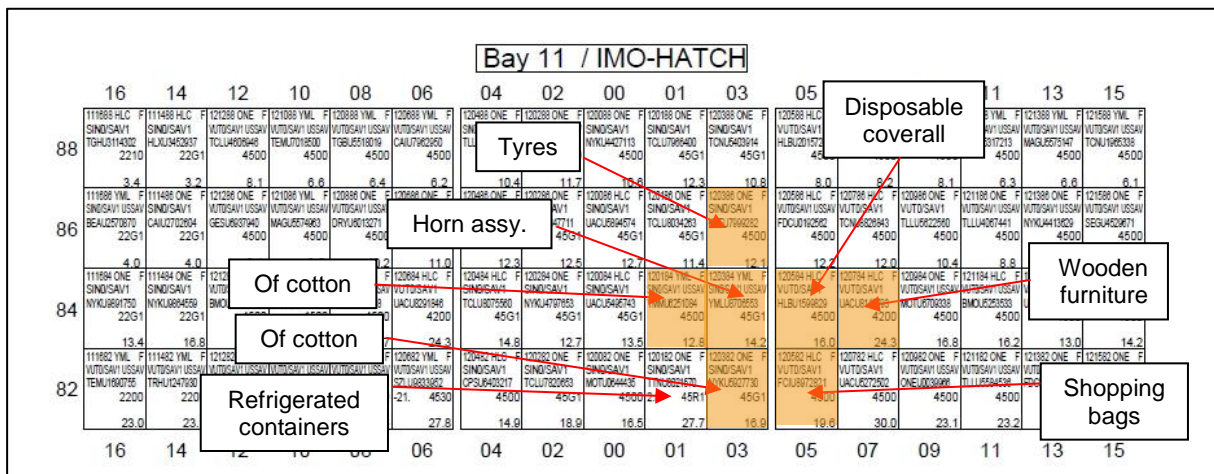


Figure 58: Bay 11 stowage plan

Reference samples of the in figure 58 listed cargoes were not available to determine specific fire hazards, except for the container with “horn assy”. This is because the contents had been essentially consumed by the fire and it was therefore not possible to determine what was in the containers pre fire based upon the remains alone. The investigators do assume that none of these goods posed a particular risk of spontaneous combustion under normal circumstances, however. With that said, however, the investigators cannot rule out any undeclared or misdeclared cargo in these containers.

The containers at slots 120382 and 120582 were identified as being the first containers to catch fire at about 0040 on 3 January 2019. The container at slot 120582 was fully loaded with polypropylene shopping bags (PP Woven Shopping Bag) and put on board the YANTIAN EXPRESS in Vũng Tàu. The investigators found no evidence to suggest

contaminants or the like would lead to spontaneous combustion. The possibility of the container being set on fire by a burning cigarette, for example, cannot be ruled out at this point, either. However, the investigators consider this unlikely due to the length of time between the start of transport and outbreak of fire. A characteristic of polypropylene products is that they produce comparatively high combustion heat when burning. At 46.0 MJ/kg, this is higher than that of heating oil (42.8 MJ/kg) or wood (approx. 18.5 MJ/kg).⁴² The ignition temperature of polypropylene is between 390 °C and 410 °C.

The other one of the first two containers to apparently catch fire (120382) was loaded with 'Of Cotton (Baby Garments, knitted or crocheted)', i.e. cotton garments. The two containers at slots 120382 and 120184 loaded with cotton garments were transported from Djakarta to Singapore from 4 December 2018 and 5 December 2018 respectively, where they were put on board the YANTIAN EXPRESS on 12 December 2018, meaning they were in the transport chain for more than one month before the fire broke out. Cotton garments can catch fire due to self-heating if contaminated with animal or vegetable fats or oils. Such contamination cannot be excluded. The investigators do assume that self-ignition would then have happened much more quickly, however. Moreover, the investigators believe that the assumed highly compressed packaging of the garments was more likely to prevent spontaneous combustion.



Figure 59: Horn from container at slot 120384

The cargo documents indicated that only two loads may have contained a source of ignition. One was the refrigerated container at slot 120182 and the other was the container loaded with horns (Horn Assy) at slot 120384. The investigators consider it unlikely that the refrigerated container was the cause of the fire. Firstly, the container was loaded with pineapples, which do not pose a fire hazard. Secondly, no traces of fire indicating a fire inside the unit could be found on the refrigerating unit (see also Figure 34). The container loaded with horns contained only the horns and no associated power sources. Their packaging was obviously flammable, however.

⁴² Kunststoffe – Eigenschaften, Brandverhalten, Brandgefahren [plastics – properties, fire behaviour, fire hazards]. VdS Verlag, 2516: 2000-12, p. 8 ff.

It is difficult to assess the fire hazard in containers loaded with wooden furniture (120784) and disposable coveralls (120584) without reference samples but the investigators basically assume it was extremely minor. The investigators believe that the containers could only have caught fire if ignition sources such as unextinguished cigarettes were introduced during loading, which is considered unlikely given the fact that the fire broke out after a long period of transport. The two containers were put on board the YANTIAN EXPRESS in Vŭng Tàu, meaning they were in transport for more than 23 days, for example.

In the opinion of the investigators, the container loaded with tyres at slot 120386, which was also put on board a ship in Jakarta, posed no specific danger. Due to the long period of transport, no connection with the outbreak of the fire on 3 January 2019 is seen here, either.

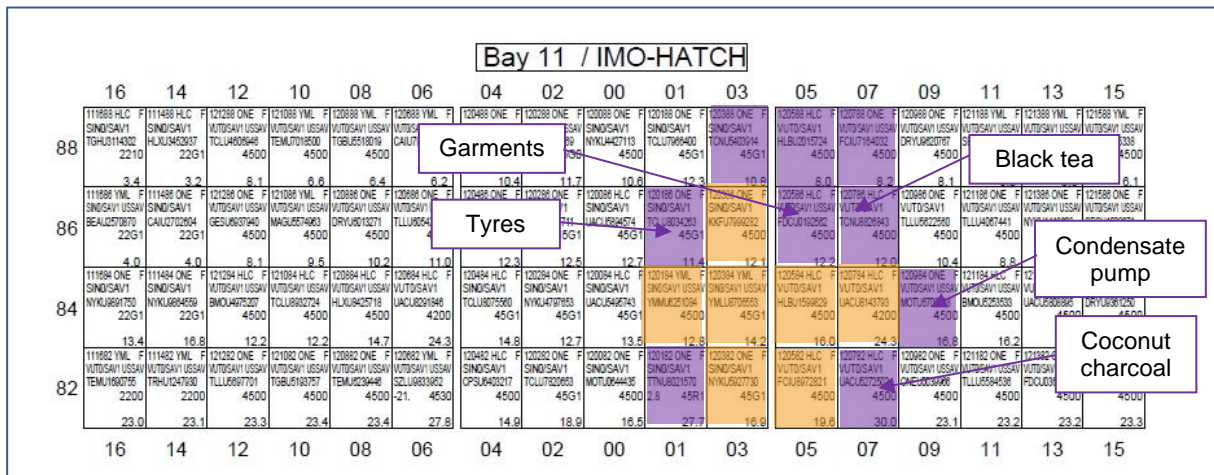


Figure 60: Containers emitting smoke at 1116 on 3 January 2019

The brown fields indicate the burning containers observed at 0410 on 3 January 2019. The purple fields indicate additionally burning containers at 1116 on 3 January 2019.

At 1116 on 3 January 2019, an increase of the containers that had caught fire was reported to the bridge (see also Figure 7). Amongst them was the container at slot 120782. According to the cargo documents, it was loaded with coconut pellets. Both when the container was opened and based on the items of cargo found on the deck and under the container, it became apparent that it was actually pyrochar (coconut charcoal). Coconut-based pyrochar is characterised by the fact that it burns at a high temperature (600 °C to 650 °C) and produces a very low amount of smoke.

Pyrochar offered in the shape of cubes, slices or hexagonal strands, for example, is further processed after the production of raw coal. The raw coal is first ground to a fine powder and then mixed with water and additives to form a paste. This paste is moulded into the desired shape using a kind of extrusion press. Still relatively soft, the strand is

then split. The resulting pieces are then 'baked' in an oven to solidify the mass. This also removes water. Packaging then follows.

Pyrochar is a self-heating substance. This is defined as follows:

"A self-heating substance or mixture is a liquid or solid substance or mixture, other than a pyrophoric⁴³ liquid or solid, which, by reaction with air and without energy supply, is liable to self-heat; this substance or mixture differs from a pyrophoric liquid or solid in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days). Self-heating of substances or mixtures, leading to spontaneous combustion, is caused by reaction of the substance or mixture with oxygen (in the air) and the heat developed not being conducted away rapidly enough to the surroundings.

Spontaneous combustion occurs when the rate of heat production exceeds the rate of heat loss and the auto-ignition temperature is reached."⁴⁴

"The auto-ignition temperature ([...]) is the temperature to which a substance or contact surface must be heated for a combustible (solid, liquid, their vapours or gases) to ignite spontaneously in the presence of air due to its temperature alone, i.e. without a source of ignition, such as a spark. It is different for each substance and pressure-dependent in many cases. Spontaneous combustion is caused by an exothermic oxidation reaction when the rate of heat production exceeds heat dissipation through conduction, radiation or convection. There is no correlation between the auto-ignition temperature and the boiling or flash point temperature of a combustible. Rather, it constitutes a measure for the substance's oxidation sensitivity. The auto-ignition temperature is not a substance parameter in the stricter sense, as it depends particularly on the volume of the substance considered. Larger volumes ignite at lower temperatures."⁴⁵

The transport of animal- or vegetable-based charcoal usually requires a test to prove that the product does not constitute dangerous goods as defined by class 4.2 of the IMDG Code. It must be established that the product's tendency to self-heat is only limited. This test must be carried out by an accredited laboratory. Moreover, the manufacturer must prove by means of a certificate that the product has undergone a longer cooling phase following production to enable safe transportation. In addition, a certificate describing the moisture content, the proportion of bound carbon, the proportion of volatile matter and the ash content must accompany the product. None of the above documents accompanied the pyrochar during transportation.

⁴³ Solid substances and mixtures that ignite even in small quantities at room temperature and in the air after a brief period.

⁴⁴ Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures. Subsection 2.11.1.

⁴⁵ Retrieved from <https://de.wikipedia.org/wiki/Zündtemperatur> on 14 November 2019 [Translated from German source].

The BSU's investigators assume that the declaration of the product as coconut pellets is incorrect. That this was intentional because it made it possible to avoid compliance with the tests and conditions mentioned cannot be ruled out.

With regard to transport, the investigators assume that the pyrochar was stowed in the container and formed a kind of block. This facilitated the self-heating process, as the heat from the block could not dissipate sufficiently. The temperature of the product may have been relatively high at the very beginning of the transport if the material was put into the transport chain immediately after being taken from the oven and packaged.

The transport duration could only be reliably determined for the sea voyage leg based on the cargo documents. The other parties involved in the transport did not respond to a request for comment. However, the transport duration is one of the key variables in the self-heating process. If the transport duration is long enough, a thermal explosion⁴⁶ will occur and the material catches fire. In cases⁴⁷ that are comparable in the view of the BSU, fires broke out after transport for 44 days in a container (MSC KATRINA) or sea transport for 35 days (LUDWIGSHAFEN EXPRESS).

Since no reference material could be obtained for pyrochar, either, the actual properties of the product are unknown. Accordingly, this and the unknown transport duration do not permit any conclusions about the probability or possible course of the self-heating process and thus about the outbreak of a fire in the pyrochar.

Nevertheless, the BSU investigators believe it likely that this is where the fire on the YANTIAN EXPRESS originated. On the one hand, this is supported by the fact that pyrochar burns with almost no smoke development. This means that the crew would not have been able to tell that this container, too, had already caught fire when the fire started. On the other hand, the thermal explosion or outbreak of fire would have occurred in the middle of the pyrochar block, as this is the area most isolated from the environment. This would have meant that the container's door would initially have remained relatively cold. Since the container loaded with pyrochar was stowed directly adjacent to the container with polypropylene bags, the investigators also believe it likely that the fire would spread to this container. The burning temperature of the pyrochar (or heat emitted) was sufficient to ignite the polypropylene.

⁴⁶ Thermal explosions occur when the [energy of a thermodynamic system] cannot dissipate quickly enough, thus causing the temperature of the system to increase. The increase in temperature leads to an increase in the reaction rate, causing even greater heat release and finally an explosion. (Theories of Semenov, Frank-Kamenitzkii and Thomas. <http://www.chemie.de/lexikon/Explosion.html> retrieved on 14 November 2019.)

⁴⁷ BSU: Investigation Report 455/15 and 58/16 – Charcoal cargo fire on the container vessels MSC KATRINA on 20 November 2015 in the Elbe estuary and LUDWIGSHAFEN EXPRESS on 21 February 2016 in the Red Sea.

The spread of fire in this direction and on to the container at slot 120382 is probable for another reason. Due to the gap between the hatch covers, the containers at slots 120382 and 120582 were about 50 cm apart. In the view of the investigators, in contrast to a fire in the cotton textiles, only a fire originating from the polypropylene bags could generate so much combustion heat that the fire had already spread to the container loaded with cotton textiles when it was detected. Due to the resulting temperatures, it is possible that the wall of the container at slot 120582 had already bulged at this point and was in direct contact with the adjacent container at slot 120382 (see Figure 31). This would then have facilitated the ignition of the other container filled with cotton textiles. It is at least conspicuous that the bulge occurred in the middle of the container and thus at the height of an assumed thermal explosion in the container loaded with pyrochar. However, there is no evidence to establish or suggest when the bulge occurred.

5 CONCLUSIONS

5.1 Firefighting

5.1.1 Fire and safety plan

The investigators believe that the YANTIAN EXPRESS's fire and safety plan has a number of inaccuracies. Firstly, the option to use the forward transverse bulkhead drencher system in cargo holds 2, 3 and 4 was not included. Secondly, the volume of compressed air required for the breathing apparatus is incorrectly specified. Neither point influenced the course of this marine casualty. However, it is precisely the option to use the transverse bulkhead drencher system that could be of importance in another case, so crews should be able to identify it clearly in the plan. A corresponding safety recommendation is therefore issued to the shipping company.

5.1.2 Gastight integrity

During the inspection of the YANTIAN EXPRESS, it was found that gastight integrity could not be properly established because a chain and lock prevented access to one of the ventilation openings. The investigators believe that this fact had no impact on the development of the fire in cargo hold 1 or on the effect of the CO₂ allegedly discharged into it.

5.2 Cause of the fire

In conclusion, the BSU's investigators believe it rather unlikely that the fire was caused by an unextinguished cigarette or spontaneous combustion by impurities due to the relatively long (known) transport duration from the ports of loading to the day the fire broke out. On the other hand, an outbreak of fire due to self-heating in a container loaded with pyrochar is considered more likely, as the possibility of a fire breaking out increases with the duration of transport. No actual evidence could be obtained for either cause.

6 Action taken

The shipping company Hapag-Lloyd announced that in the course of its own investigation into the malfunction of the CO₂ fire-extinguishing system on the YANTIAN EXPRESS it was established that the time delay units were not fully functional. Therefore, the shipping company immediately started to initiate an inspection/maintenance on all ships to ensure the correct functioning of this time delay units.

7 SAFETY RECOMMENDATION

The following safety recommendation does not constitute a presumption of blame or liability.

7.1 The shipping company, Hapag-Lloyd

The Federal Bureau of Maritime Casualty Investigation recommends that the shipping company, Hapag-Lloyd, enter the drencher system for the transverse bulkheads in some of the cargo holds on the YANTIAN EXPRESS in the fire and safety plan, even if there is no requirement to enter this part of the equipment. This entry should also be made for other ships belonging to the shipping company with a similar installation.

8 SOURCES

- Written explanations/submissions of the ship's command and the classification society
- Testimony of five crew members
- Explanatory statements of the shipping company on certain aspects