



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

Investigation Report 198/15

Serious Marine Casualty

**Chemical reaction within the fertilizer load on
board the PURPLE BEACH in the
deep water roadstead on the German Bight
on 25 May 2015**

The 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 Act, 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

The PURPLE BEACH, flying the flag of the Republic of the Marshall Islands, was proceeding to Brake on 25 May 2015. Loads of various types of fertilizer were on board the multi-purpose carrier in the lower holds of cargo holds 2 to 5, which were loaded in Antwerp. In addition, various types of general cargo were stowed in cargo hold 1 and in the tween decks of cargo holds 3 and 4.

Since the River Weser was closed due to a separate incident, the ship's command opted for an anchorage in the deep water roadstead on the German Bight. During the anchor manoeuvre, the master noticed smoke in the area of cargo hold 3 from his position on the bridge. An initial survey of the scene was carried out during the anchor manoeuvre. Some time later, an individual wearing breathing apparatus attempted to investigate cargo hold 3. This attempt was aborted due to the dense smoke rising from the cargo hold entrance hatch (booby hatch). The ships command had realised, that the smoke generation was possibly connected with the cargo of fertilizer in the lower hold of cargo hold 3

After consultation with the ship's management, the ship's command decided to use CO₂ as an extinguishing agent. The Weser pilots were notified of the events on board as the first contact point ashore 2.5 hours after the CO₂ was discharged. Later on, Vessel Traffic Service (VTS) Bremerhaven issued a prohibition on entry, which was to be maintained until the situation on board was clarified. Since a fact-finding team (FFT) from the fire service was required for the inspection on board, VTS Wilhelmshaven contacted the German Central Command for Maritime Emergencies (CCME) with a request that it assume overall command of the operation, which happened at 0259 on 26 May 2015¹. The first team from Cuxhaven Fire Service reached the PURPLE BEACH on a federal police helicopter at about 0500. The firefighters established that the ammonium nitrate-containing fertilizer on board decomposed. With regard to an assessment about the development of the reaction rate, the fire department could only make an approximation. Therefore, the vessel was not considered a safe platform anymore. This led to the decision to evacuate the vessel. When the firefighters left the vessel a massive outbreak of smoke developed, which – together with the readings made – was indicative of an imminent explosion. All the firefighters left the ship as the situation unfolded. The ship's command of the PURPLE BEACH was advised to abandon the ship as well. The crew complied with this and abandoned the ship on a free-fall lifeboat. The nearby MELLUM took the crew of the PURPLE BEACH on board. Due to the exposure of the crew of the PURPLE BEACH, the firefighters, and some of the MELLUM's crew members, these individuals were all decontaminated, examined, and later flown to various hospitals as a precaution.

¹ All times shown in this report are Central European Summer Time (CEST) = UTC + 2 hours.

The ships MELLUM, NEUWERK und NORDIC were ordered to the scene and were later tasked with cooling the distressed vessel and suppressing the cloud of smoke. The assumption at this point was that an exothermal self-sustaining decomposition of ammonium nitrate based fertilizer had occurred in hold 3 and was ongoing. The deployed units managed to flood cargo hold 3 of the ship with water over the next few days, thus stopping the reaction. The ship was then towed to a place of refuge in Wilhelmshaven, which is also where the BSU began its investigations on board the ship.

For the actual unloading operations and the disposal of discharged water, the PURPLE BEACH later shifted to another berth in Wilhelmshaven, where the unloading of the ship was completed in July 2016. The towing operation to Turkey, where the ship was destined for scrapping, began in March 2017.

The marine casualty did not give rise to any fatalities or serious injuries. The BSU was not made aware of any water pollution.

2 FACTUAL INFORMATION

2.1 Photo of ship



Figure 1: Photo of the PURPLE BEACH

2.2 Ship particulars

Name of ship:	PURPLE BEACH
Type of ship:	Multi-purpose carrier
Nationality/Flag:	Republic of the Marshall Islands
Port of registry:	Majuro
IMO number:	9138135
Call sign:	V7FK3
Owner:	PURPLE BEACH Shipping GmbH
Charterer:	MACS Maritime Carrier Shipping GmbH & Co.
Manager:	VINETA Bereederungsgesellschaft mbH
Year built:	1998
Shipyard/Yard number:	Shanghai Shipyard/168
Classification society:	DNV GL
Length overall:	192.37 m
Breadth overall:	26.70 m
Gross tonnage:	23,401
Deadweight:	33,720 t
Draught (max.):	11.4 m
Engine rating:	12,480 kW
Main engine:	Sulzer 8RTA52U
(Service) Speed:	16 kts
Hull material:	Steel
Hull design:	Double bottom, double sides in the area of the cargo holds
Minimum safe manning:	16

2.3 Voyage particulars

Port of departure:	Antwerp, Belgium
Port of call:	Brake, Germany
Type of voyage:	Merchant shipping, international
Cargo information:	Fertilizer and general cargo
Manning:	23
Draught at time of accident:	Df = 9.5 m, Da = 11.0 m
Pilot on board:	No
Canal helmsman:	No
Number of passengers:	1

2.4 Marine casualty or incident information

Type of marine casualty:	Serious marine casualty; chemical reaction with strong heat and smoke development
Date, time:	25/05/2015, 1720
Location:	Deep water roadstead on the German Bight
Latitude/Longitude:	ϕ 54°03.77'N, λ 007°28.00'E
Ship operation and voyage segment:	At anchor
Place on board:	Cargo hold 3's lower hold
Human factors:	Unknown
Consequences:	Short-term medical complaints due to combustion gases among the crew members and passenger from the PURPLE BEACH, four crew members from the MELLUM and 11 firefighters. Cargo hold 3 flooded as part of the firefighting operation, causing water ingress in cargo hold 2 with ensuing damage to the fertilizer loads in both cargo holds. Destruction of the cargo on the tween deck in cargo hold 3 due to strong heat, water and acidic gases. Damage to parts of the ship and her equipment due to acidic gases. No water pollution

Extract from Navigational Chart 49,
Federal Maritime and Hydrographic Agency (BSH)

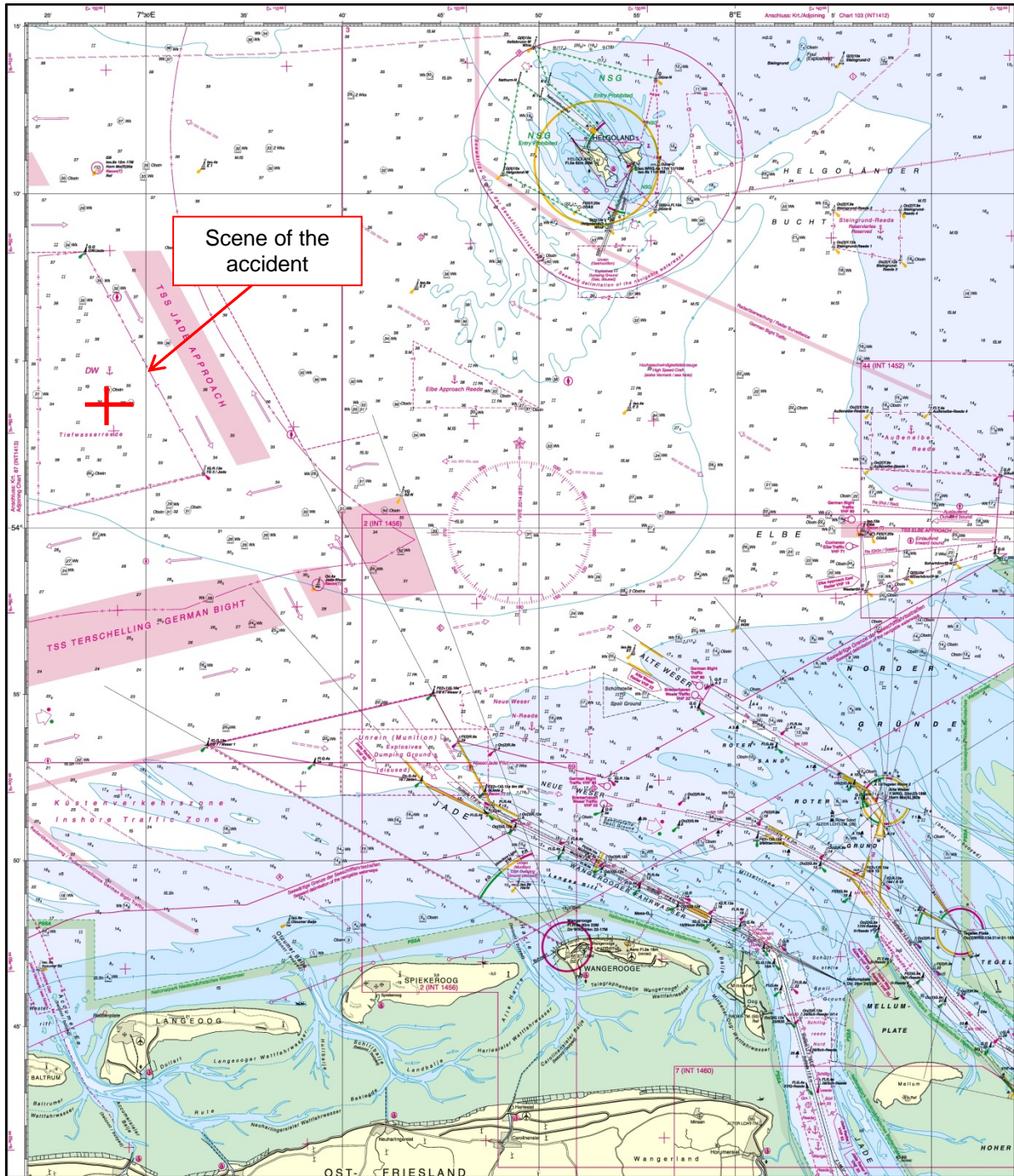


Figure 2: Navigational chart showing the scene of the accident

2.5 Shore authority involvement and emergency response

Agencies involved:	CCME, VTS German Bight, VTS Bremerhaven, firefighting units (FFUs) from the Cuxhaven, Bremerhaven and Hamburg fire services, casualty care teams (CCTs), units from various fire services for pollution measurement ashore and at sea, WSA Cuxhaven, WSA Wilhelmshaven, WSA Emden
Resources used:	Multi-purpose ships ² NEUWERK and MELLUM, emergency tug NORDIC, buoy tenders NORDERGRÜNDE and GUSTAV MEYER, various helicopters from the federal police and other agencies, boats from the waterway police (WSP) and the German Maritime Search and Rescue Association, pollution control plane from the German Navy
Actions taken:	Assumption of overall command of the operation by the CCME, deployment of a FFT on board the PURPLE BEACH, deployment of firefighters on board the PURPLE BEACH for various tasks, deployment of the analytical task force (ATF) from Hamburg Fire Service and their sensor technology for determination of the gas concentrations and temperatures on the PURPLE BEACH, employment of external laboratory services for determination of pollutants, cooling of the ship's shell plating and washing of the deck areas with the assistance of the multi-purpose ships, flooding of cargo hold 3 with the assistance of the NEUWERK's pumps, suppression of the gas clouds by the multi-purpose ships and the NORDIC, ship's towing operation to a safe berth planned with the involvement of a towing company and provision of support. Hotline set up and public information about the impact of the events on the PURPLE BEACH
Results achieved:	Chemical reaction within the fertilizer load stopped. Measurements showed that no health hazards existed ashore, apart from an odour nuisance. The ship was towed to a port after the chemical reaction was stopped and then unloaded subject to the conditions imposed by various administrative bodies

² Also called water pollution control vessels.

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

3.1.1 The marine casualty

The account of the course of the accident is based on the information in the PURPLE BEACH's deck log book, the statements of various crew members, the recordings of VTSs Wilhelmshaven and Bremerhaven, the CCME's accident log, the logs and recordings of the ships NEUWERK, MELLUM and NORDIC, and the mission reports of the Cuxhaven and Bremerhaven fire services.

The PURPLE BEACH, flying the flag of the Marshall Islands, sailed out of Antwerp at 1412 on 24 May 2015. Brake was her next port of destination. 23 crew members and one passenger were on board.³ Due to a temporary closure of the River Weser's fairway in the area of the Stromkaje at Bremerhaven on 25 May 2015 and the draught-induced dependence on the tide, the PURPLE BEACH anchored in the deep water roadstead on the German Bight at 1712. The ship's command opted for this anchorage due to the small number of vessels using it after consulting with German Bight Traffic⁴ and the Weser pilots. The ship anchored with the port anchor with eight chain lengths immersed. Plans had been made to be at the pilot transfer position for the Weser pilot at about 0500 on 26 May 2015.

The master was controlling the anchor manoeuvre from the bridge and noticed a small amount of white smoke rising at the aft edge of cargo hold 3 on the port side at 1720. Shortly afterwards, he also noticed a small amount of smoke rising on the starboard side. At this point, the fifth shackle was on deck.

The master informed the chief officer, who was supervising the anchor manoeuvre on the forecastle, of the observations and asked him to check the situation at this cargo hold. The chief officer then sent crew members to this cargo hold and went there himself. It was established at the scene that smoke was escaping from the fan cowls. The smoke had a chemical odour, was white in colour and not hot. The ventilation flaps were closed and a check was made to establish whether all the electrical power consumers in this area were disconnected from the grid, which was the case. One of the able-bodied seamen was instructed to don his fire-protection clothing, self-contained breathing apparatus and the associated full-face mask. The booby hatch on the aft edge of the cargo hold was then opened on the starboard side. Due to the fact that there was no visibility in the cargo hold because of the dense smoke and that the able-bodied seaman believed to sense the smoke under his mask, the attempt to enter the hold was aborted. An increase in temperature could not be detected by hand in the area of the cargo hold.

³ In the interest of improving legibility, the passenger is not shown separately below.

⁴ Call sign of the VTS responsible for the German Bight.

After that, a fire hose was positioned at each of the four corners of the cargo hold in preparation for the cooling measures.

The anchor manoeuvre had been completed in the meantime and the ship was moored with port anchor and eight chain lengths immersed.

The ship's command referred to the cargo documents to identify the cargo in hold 3. Ammonium nitrate based fertilizer was stowed in this cargo hold's lower hold. Various metal structures and machinery parts packaged in wooden crates were loaded in the tween deck, which were stowed as well on board in Antwerp. The decision to discharge CO₂ in cargo hold 3 was taken by the ships command at 1815 after consulting with the management's DPA⁵. To this end, the hatch covers of cargo hold 3 were fully locked and all other openings of this cargo hold were closed as well. The chief engineer officer and second engineer officer went to the CO₂ room to make the necessary preparations. After this was completed, the master sounded the general alarm and instructed the other part of the crew to assemble on the bridge at 1820. After the headcount was confirmed twice, CO₂ was activated for cargo hold 3 at 1831. In accordance with the instructions from the manufacturer of the extinguishing system, the content of 48 cylinders was discharged to begin with. A further eight cylinders⁶ were activated after an interval of 30 minutes. The CO₂ discharge was completed at 2000.

A reduction in the smoke rising was observed after about 50% of the amount planned had been discharged. The smoke reduced to a minimum after the total amount was discharged. Consequently, the crew was permitted to go inside the superstructure. Openings in the hatch where smoke continued to rise were sealed further later on and the crew believed the situation was stable.

The first shore-based agency the ship's command notified about the events on board the PURPLE BEACH via email was the Jade-Weser Pilot Station at 2103. The latter forwarded this information by telephone at 2120 to VTS Bremerhaven, which then contacted the ship's agency for Brake to obtain information on the cargo. Shortly afterwards, a prohibition on entering the River Weser was imposed on the PURPLE BEACH, which was to be maintained until the situation on board was clarified. At 2148, the pilots informed VTS Wilhelmshaven, responsible for the German Bight, that a prohibition on entry had been issued. Following that, the VTS contacted the ship on VHF with a request for details. The Maritime Security Centre in Cuxhaven and other agencies were informed of this. Contact was also made with a representative of the management, who asked for assistance at 2307.

⁵ DPA: Designated Person Ashore – person tasked with liaising between ship and ship's management in accordance with the ISM Code.

⁶ There were 140 cylinders of CO₂ on board in total.

As the situation unfolded, the various administrative bodies discussed the deployment of a boarding team to gain a picture of the situation on board. This was also against the backdrop of the crew not wanting to open the hatch to investigate the scene unaided and of VTS Bremerhaven insisting on reliable information on the situation in the cargo hold. Ultimately, VTS Wilhelmshaven requested that the CCME assume overall command of the operation at 0222 on 26 May 2015. Declaration of assumption was made at 0259. Prior to that, the CCME had already alerted a unit trained in fighting ship fires from the Cuxhaven Fire Service (FFU Cuxhaven⁷) at 0211, which was to take on the role of FFT and be flown by federal police helicopter to the PURPLE BEACH.

The ship's command of the PURPLE BEACH received notice of the prohibition on entry on 26 May 2015 at 0143 when it asked the Weser pilots about the ensuing schedule on VHF. At 0314, the ship was informed by a member of the CCME via telephone that a team from the fire service would soon be lowered onto her to make an on-scene investigation.

Multi-purpose ship MELLUM was instructed to proceed to the PURPLE BEACH at 0350 on 26 May 2015. The MELLUM was instructed to move to a standby position at the scene initially. The helicopter set down the six-member FFT on the PURPLE BEACH at 0451. After a briefing on the situation and the action taken so far by the ship's command, the first FFU response team began its own investigation. After taking a gas concentration reading on the deck, cargo hold 4 was first entered with respiratory protection to measure the temperature there on the bulkhead in the tween deck to cargo hold 3. It was 36-38 °C above the cargo stowed there. Following that, the temperature of the tween deck was measured from cargo hold 2 and the temperatures found were identical. A measurement in the lower holds was not possible because they were also filled with fertilizer in the two cargo holds referred to, which obstructed entry. During the mission in cargo hold 2, the team noticed yellow smoke rising from an construction-conditioned existent opening of about 0.4 m x 0.5 m in the watertight transverse bulkhead on the port side. The team also noticed a light burning in the access trunk for cargo hold 2, even though the operational commander of the fire service had been assured earlier that the cargo holds reportedly were disconnected from the grid. After the information given by the fire service, the light was switched off.

After the initial on-scene investigation and the forwarding of information to the CCME at 0609, the second response team started another investigation. Preparations were also made to close the opening found in cargo hold 2 with wooden plates and PU-foam to prevent the spread of heat and smoke. The investigation revealed a temperature increase of 6 °C within 45 minutes at each bulkhead of cargo hold 3. A 54 °C hotspot was found on the starboard side of the bulkhead of cargo hold 4.

⁷ FFU: Firefighting Unit

In cargo hold 2, a yellow liquid mass was now emerging from the opening found there instead of smoke. The firefighters believed they could hear something boiling behind the wall. In addition, they noticed smoke emission on the deck in the area of cargo hold 2. The response teams were withdrawn due to the temperature increase and discharging liquid. Significant yellowish discolouration was visible on the clothing of the second response team after deployment.

By this time, the CCME had alerted the ATF from the Hamburg Fire Service and a CCT. Moreover, the master of the MELLUM, which reached the PURPLE BEACH at 0530, was designated on-scene coordinator (OSC). The multi-purpose ship NEUWERK was also ordered to proceed to the PURPLE BEACH. Due to the gas concentration readings, it was initially assumed that an explosive atmosphere prevailed in cargo hold 3. This gave rise to the opinion that opening the hatches, which was suggested by the FFT, was initially regarded too dangerous in the view of CCME. Based on the above assumption, all ships not involved in the operation were ordered to sail clear of the deep water roadstead at 0900 and that the airspace was closed for a radius of 5,000 m around the PURPLE BEACH.

The fire service's operational commander, who had boarded at 0755 with the second FFU from Cuxhaven, made contact with the management of the ship via the PURPLE BEACH's master at 0837. At this time, the management assumed that the fertilizer cannot decompose itself. After the fire department had explained the situation, the management's representative basically agreed with the flooding of the cargo hold.⁸ T

At about 0820, neither an increase in the ship's temperature in the area of the cargo holds nor water pollution was found during the surveillance flight of the German Navy's pollution control plane requested by the CCME.

The circumstances found on board the PURPLE BEACH suggested that a chemical reaction had started in the fertilizer load, as this fertilizer was prone to decomposition under certain circumstances, releasing toxic gases and significant heat. It was also still assumed that an explosive gas concentration prevailed in cargo hold 3. In the opinion of the firefighters, the assumption that an explosion could reportedly not be ruled out resulted from the detected decomposition of the fertilizer, the already existing watertight integrity together with the discharging of CO₂ and the relatively unknown cargo in the tween deck. To halt the chemical reaction, a decision to open the hatch cover of and discharge water into cargo hold 3 using the MELLUM's water cannons was taken at about 0930 in consultation with the ship's command. Only a minimum crew was supposed to be on the PURPLE BEACH during this operation. Prior to that, any individual who was surplus to requirements was to be evacuated to the MELLUM on her workboat via the pilot ladder on the starboard side level with cargo hold 3.

⁸ The BSU is not aware of the scope of the arrangement made later on between the vessels owner and the Central Command for Maritime Emergencies.

The ship's command gathered the crew members in the mess and informed them of the situation and the potential hazards. At about 0945, while preparing for the evacuation, a massive outbreak of dense yellow smoke emerged from cargo hold 3. This surrounded the firefighters on board the workboat, which had removed their breathing apparatus for the evacuation, and the crew of the boat from the MELLUM. Two more firefighters could not board the boat and fled to the aft part of the vessel. This was assessed as very dangerous and gave rise to the assumption of an imminent explosion. The leader of the FFT, his deputy and the other two remaining firefighters withdrew to the port side of the aft deck, where they were also affected by the fumes, however. Since the cloud of smoke was spreading mainly on the starboard side, the ship had to be evacuated on the, because of the sea state, far more turbulent port side. To this end, the boat from the MELLUM was used again. His crew wore now breathing apparatuses. The four firefighters boarded the boat via the gangway deployed for this purpose. Due to the hazardous situation caused by the prevailing swell, the ship's command was advised to use the free-fall lifeboat for the crew, which the ship's command complied with. The PURPLE BEACH's crew boarded and released the free-fall lifeboat at 1005.

Since transferring from the lifeboat to the MELLUM also proved too hazardous for the crew of the PURPLE BEACH due to the swell, the entire lifeboat was lifted onto the MELLUM using the shipboard crane. To prevent a lasting health hazard due to substances deposited on the clothing or skin, all the crew members of the PURPLE BEACH, all the firefighters, and the crew of the boat from the MELLUM were decontaminated on board the MELLUM and their clothes withheld. The group (36 people) was then examined, provided with makeshift clothing and flown to various hospitals ashore, as this was the only way to guarantee that the examination and monitoring would be appropriate after contact with the fumes. This task was completed at about 1300. The PURPLE BEACH's master and chief engineer officer remained on board the MELLUM to assist the OSC.

Additional firefighters and the CCT were taken to the MELLUM by helicopter in the morning at the request of the CCME. The NEUWERK arrived at her position in the vicinity of the distressed freighter at 1336. The smoke emission, which in the meantime had decreased considerably, increased again (see Figures 3 and 4) in the afternoon. Consequently, the safety distance for other shipping was temporarily extended to 5,000 m. The superstructure of the ship, which was in the wind at that point, was completely surrounded by the rising smoke. As the day continued, the CCME sought information about hazards associated with the fertilizer during the chemical reaction and the options for slowing down or stopping this reaction from the various points of contact for chemical accidents and the manufacturer of the fertilizer. The surveillance flight was made by the pollution control plane over the ship and one of the ships deployed circled her to determine the temperatures on board. No significantly elevated temperatures were found.

In the final hours of 26 May 2015, the NEUWERK took the ATF from the Hamburg Fire Service and a SIGIS-2⁹ on board and returned to the deep water roadstead to take the first readings there at about 0130 on 27 May 2015.



Figure 3: Aerial view of the PURPLE BEACH at 1426 on 26 May 2015



Figure 4: Spread of the smoke at 1428 on 26 May 2015

⁹ Scanning Infrared Gas Imaging System.

The first calls from the general public concerning a chemical odour nuisance were received in the early hours of the morning of 27 May 2015. Therefore, the NORDIC, which was now at the scene, and the NEUWERK started an attempt at suppressing the smoke using their water cannons that morning. This was possible because of the ability of the ships to operate with gas protection because it allowed them to move extremely close to the PURPLE BEACH (see Figure 5). The fire service also set up and continuously monitored 25 measuring points on the coast to assess the risk to the general public. In addition, the CCME set up a hotline at 1300, which continued to provide the information available until 0900 on 30 May 2015.

Since the experts consulted had ruled out a risk of explosion, the CCME started to prepare for the flooding of cargo hold 3 in consultation with the fire service, the ship's management and the emergency response service (ERS) of the classification society, DNV GL. It was assumed that the PURPLE BEACH did not have any energy available to open the cargo hold hatch covers. Consequently, the decision was made to discharge water via the booby hatches. The NEUWERK went alongside the PURPLE BEACH for the laying of the necessary B hoses. This made it easy for the firefighters deployed to reach the distressed vessel fully protected. Pumping started at 1721 on 27 May 2015. To begin with, 100 m³ of water was to be discharged using three B hoses. The crisis management team later issued instructions for 2,000 m³ of water to be discharged. Since the NEUWERK's gas protection filter was depleted after about four hours, pumping was discontinued at 2145 and the NEUWERK cast off. Some 500 m³ of water had been discharged at this point in time.

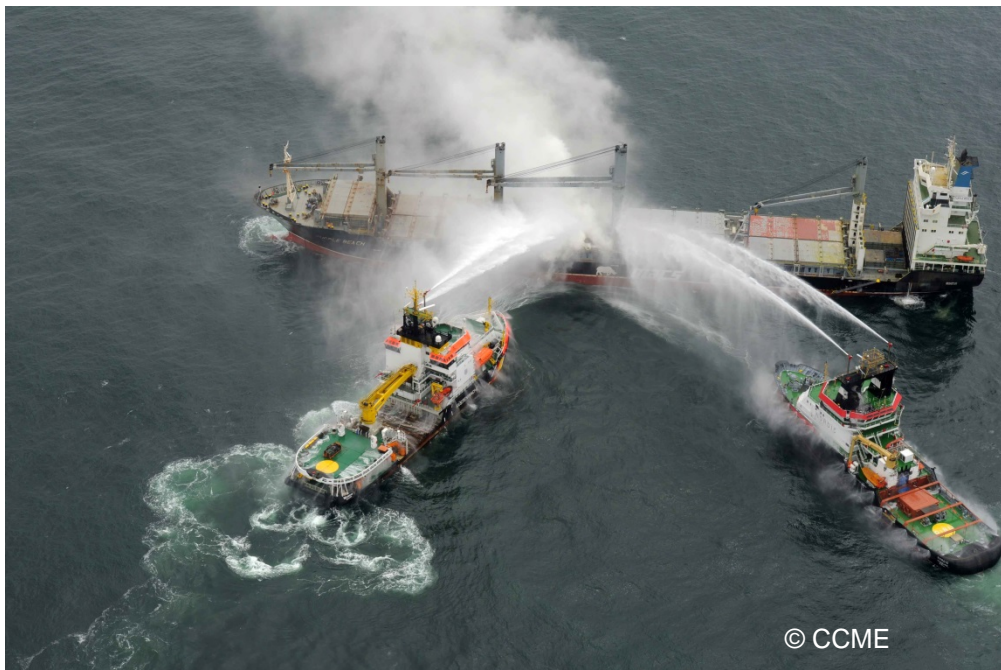


Figure 5: NEUWERK and NORDIC in operation

Each vessel operating with gas protection and activated sprinkler system while suppressing the smoke

All the crew members of the PURPLE BEACH previously admitted to hospitals were discharged on 27 May 2015. They were initially accommodated in the seamen's mission in Bremerhaven at the management's request.

Measurement at the land-stations was discontinued in the course of the morning of 28 May 2015, as the wind had turned to a south-westerly direction and the coast of Lower Saxony was thus no longer affected. Due to the weather conditions – winds of 6-7 Bft and swell of 2.5-3 m, it was not possible to transfer personnel with the necessary protection. The situation on the PURPLE BEACH was still continuously monitored, however. Attempts were also made to establish whether the auxiliary diesel engines or boiler installation on board were still serviceable. It was not possible to obtain reliable information on this.

Since calm weather prevailed on 29 May 2015, the NEUWERK went alongside the PURPLE BEACH again late in the morning to prepare for another discharge of water. Water was then discharged via four B hoses from 1206 onwards. Two additional B hoses were later connected. In addition, firefighters were sent into the PURPLE BEACH's superstructure to gather information and it was found in the process that at least one auxiliary diesel engine was still in operation. Accordingly, it was possible to open the hatches and hoist the anchor. Since it was assumed that a passage ran between cargo holds 2 and 3, pumping was discontinued at about 1735. According to the ship's management the basis of the assumption was the possibility of cracks in the transverse bulkhead due to the thermal stress. This assumption was not confirmed, however. Neither smoke nor water was found in cargo hold 2 or cargo hold 4. The order to separate the hose connection was given at 1900. According to the CCME, some 1,500 m³ of water had been discharged at this point in time.

In the evening of 29 May 2015, the PURPLE BEACH's superstructure and deck were washed by the NORDIC with the help of the water cannons.

30 May 2015 was spent at sea monitoring the situation. The NORDIC was tasked with suppressing the small cloud of smoke with water. Since poorer weather was forecast for the next few days, the CCME made preparations for the PURPLE BEACH to be towed to a port of refuge. It was also decided to completely fill cargo hold 3 with water. To this end, the NEUWERK went alongside the distressed vessel again at 2030 and firefighters, transported to the PURPLE BEACH from the MELLUM and back by helicopter for this purpose, deployed six B hoses.

At 0820 on 31 May 2015, firefighters were transferred from the NEUWERK to the PURPLE BEACH by means of the shipboard crane and a conveyor cage. They had been instructed to take samples and check the situation. Water was found in cargo hold 2 in the process (water was already above the tween deck's hatch cover). Following that, pumping was discontinued. The NEUWERK cast off from the distressed vessel at 1100. At that time the draft of the PURPLE BEACH was more than 12 m forward and 10.4 m aft.

During the investigation by the fire service, crystalline particles were found on the PURPLE BEACH's deck, possibly originating from the previous cargo. This was later identified as sodium carbonate decahydrate (crystal soda).

The CCME continued to prepare for the towing operation as the day progressed. In the process, Jade-Weser-Port in Wilhelmshaven was determined as the place of refuge, arrangements were made with the towing company selected, and the expected draught was established with the involvement of the ERS.

The NEUWERK went alongside the PURPLE BEACH again on 1 June 2015 and transferred the towing company's boarding team, which by that time had been taken on board, and its equipment. The boarding team had already been ordered to wear appropriate protective clothing during the operation. This was provided by the CCME. The towing connection with the forward tug BUGSIER 10 was made fast at 0652. The PURPLE BEACH's anchor could then be hoisted in, making it possible to start the towing operation at 0836. Due to the liquid balance between cargo holds 3 and 2 the draft was meanwhile about 14 m forward and 9.8 m aft. Since the PURPLE BEACH did not maintain the course of the tug sufficiently due to her forward draught of about 14 m, she was later towed at her stern. The PURPLE BEACH was made fast in Jade-Weser-Port on her starboard side at 2045 on 1 June 2015.



Figure 6: The PURPLE BEACH being towed



Figure 7: The PURPLE BEACH at her berth in Wilhelmshaven

The CCME retained overall command of the operation until 1200 on 12 June 2015. During this period, it organised the ship's security measures, access controls, co-ordination of the competent state authorities and various other things.

3.1.2 Subsequent events

Works to determine the damage to the ship and cargo began after she was made fast at Jade-Weser-Port in Wilhelmshaven. Various administrative bodies from the state of Lower Saxony were involved in respect of the cargo, in particular. Their co-ordination and liaising between all stakeholders were excessive time consuming. In particular, unloading the fertilizer from cargo hold 3, the condition of which had to be proven by extensive sampling from various layers and the associated tests, was lengthy and technically complicated. In addition, the sampling, pumping out and disposal of the large amount of contaminated water also had to be organised. Because of the necessary cargo operations, which were not possible at Jade-Weser-Port, the ship was shifted within Wilhelmshaven on 13 August 2015 to the Braunschweigkai quay and later to the Lüneburgkai. The PURPLE BEACH remained there until she was towed to Turkey for scrapping on 28 March 2017 after being unloaded and sold.

The last joint meeting of the administrative bodies involved in processing the accident and representatives of the other parties was on 12 July 2016. The last remnants of the cargo were also unloaded in July 2016.

3.2 Investigation

3.2.1 PURPLE BEACH

The PURPLE BEACH was a conventional multi-purpose vessel with aft superstructure. She was designed for the transportation of containers, general cargo and solid bulk cargo. Her cargo capacity when used only as a container vessel was 1,320 20-foot containers. She had five cargo holds, where the opening of the forward hold was situated on the elongated forecastle. The cargo holds were closed at the top by a folding cover. The openings of cargo holds 2 to 5 had a longitudinal beam, allowing each cargo hold to be closed with four folding cover pairs. All the cargo holds were equipped with tween decks apart from the first. The tween decks were formed by four pontoon hatch covers on each side. The tween decks had a longitudinal partition, which extended from the tween deck to the longitudinal beam level with the hatch cover. Each partition had an opening fore and aft, which could be passed through by a fork lift. The lower hold did not have a partition.

The cargo holds of relevance in this case (2, 3 and 4) were separated in the tween deck by transverse cofferdam¹⁰ bulkheads. The tween decks and lower holds could be accessed using hold ladders in the area of the cofferdams. The cargo hold ventilation trunks were also in the cofferdams. Accordingly, the transverse bulkhead was only single-walled where the hold ladders or ventilation trunks were situated. Two ventilation shafts extending into the lower room were each located at the fore and aft edge in cargo holds 2 and 4. The shaft's apertures were located about a meter above the bottom. These shafts had no further apertures in the tween deck. Besides, two ventilation shafts were each located at the fore and aft edge of the cargo holds, which had an opening in the tween deck and an outlet to the lower room (see Figures 43 and 62).

The cargo holds were double-walled on the outside. Therefore, all the side walls were smooth in all decks. In the lower holds, the transverse bulkheads were only partially designed as a cofferdam. The transverse bulkheads had several offsets here, where hold ladders or ventilation ducts were located on the other side without a double wall being situated there (see Figure 41).

The ship was equipped with four cargo derricks, which could be used to reach every cargo hold on the ship. They were used to move the pontoon hatch covers. A stowage space for containers, which was equipped with cell guides (devices for guiding and stowing containers), was located between cargo hold 5 and the superstructure.

The ship's class certificate was valid until 28 February 2018 at the time of the accident. The last annual intermediate survey was carried out in February 2015.

¹⁰ A narrow, empty cell between two holds that can be safely separated from one another on ships. Scharnow, Ulrich, et al.: Lexikon Seefahrt (*seafaring lexicon*). 5th edition. Berlin, 1988, p. 285.

The classification society had also issued a document of compliance for the carriage of solid bulk cargoes, also valid until 28 February 2018, on behalf of the flag State. Ammonium nitrate based fertilizer (non-hazardous) was also listed in the corresponding Annex to the cargoes (List of Cargoes). This was marked with footnotes 1 and 5 for cargo holds 2 to 4. The Annex for the explanation of the footnotes (List of Footnotes) was also noted by the investigators. Footnote 1 indicated that the electrical equipment mentioned here, in this case the lighting, must be disconnected from the electrical supply and secured against unintentional starting during the transport of this fertilizer. Footnote 5 indicated that the cargo must not be stowed adjacent to tanks, double bottoms or piping with fuel heated to more than 50 °C. Another Annex concerned the list of equipment. This stipulated that the electrical equipment must reportedly comply with the IIC T4 IP55 standard at least. No explosion protection was stipulated for the lighting. IIC referred to the operating area. In this context, T4 means that the maximum permissible surface temperature of the operating media does not exceed 135 °C in the event of a fault. IP55 referred to protection against foreign bodies and water. The light should be protected against dust and water jets.

The list of equipment included furthermore the carriage requirements for two additional self-contained breathing apparatuses and four sets of full protective clothing resistant to chemical attack.

The annual renewal of the cargo ship safety equipment certificate took place on 11 April 2015.

3.2.2 Crew of the PURPLE BEACH

The ship's crew consisted of 23 people, 21 of whom were Polish nationals. One of the deck officers was a German national and another crew member was from South Africa.

The master of the ship has held an unrestricted master mariner certificate since 2005 and served as chief officer for ten years prior to that. A certificate of training in hazardous cargo carriage on vessels had also been issued in his name. He had worked on various types of ships during his time at sea and had transported fertilizers, too, on a number of occasions. The master started his assignment on 19 May 2015 in Antwerp.

The chief officer had served in this capacity since 2010. He, too, had worked on various types of ships during his time at sea. He went on board on 15 May 2015. He also held a certificate of training in hazardous cargo carriage on vessels.

The course of the marine casualty gave no reason to suspect that fatigue had played a role. Consequently, an investigation into this was not carried out.

3.2.3 Start of the investigation

The BSU was informed of this marine casualty on the morning of 26 May 2015. The opportunity to question some of the crew members of the PURPLE BEACH accommodated in the seamen's mission in Bremerhaven was taken on 28 May 2015. It was also possible to interview the master of the ship later that day in Wilhelmshaven. The management's legal counsel later submitted statements of the key crew members to the investigators.

3.2.4 Analysis of the voyage data recorder (VDR)

Data from the VDR were available for the period 2117 on 25 April 2015 to 0051 on 27 May 2015. The data from 1700 on 25 May 2015 to 1100 on 26 May 2015 were analysed for the investigation. The key events are shown in chronological order below. Comments were inserted where necessary.

25 May 2015

- 1713 Fire alarm on detection line 13 – bosun store in the fore section. The anchor drops at this point in time. The investigators assume that the smoke detector there triggered an alarm because of the resulting dust that typically develops in the process. The master sends a crew member from the forecabin to make a precautionary check. He is unable to detect anything.
- 1717 Discovery of smoke in the area between cargo holds 3 and 4. The master sends the chief officer there.
- 1728 The master notifies the Weser pilots about the ship anchoring in the deep water roadstead on VHF.
- 1738 A booby hatch at the aft edge of cargo hold 3 is opened to investigate the situation.
- 1742 The ship's command now assumes that a fire has broken out in cargo hold 3. Preparations are to be made to use CO₂ as an extinguishing agent. The chief engineer officer is notified of this.
- 1749 Since a smoke detection system alarm has still not triggered, the master sends two crew members (presumably the second engineer officer and the electrician) there to check their condition.
- 1751 A crew member is to take the existing cargo information to the bridge at the request of the master.

- 1752 After the aspirating smoke detection system is serviceable again, it issues an alarm for lines 5 (cargo hold 3's lower hold) and 2 (cargo hold 2's tween deck).
- 1753 The cargo documents indicate that noxious fumes are released if the fertilizer starts to decompose.
- 1754 Light smoke is detected by crew members in the tween deck of cargo hold 2. However, the assumption is that this smoke is coming from cargo hold 3.
- 1756 Line 4 of the aspirating smoke detection system (cargo hold 3's tween deck) now also issues an alarm.
- 1801 The master gives instructions to re-check cargo hold 3's locking mechanism. The ventilation openings should also be looked at in the process.
- 1804 The master calls the ship's management: Initial information about the incident. The master explains that this may be the fertilizer decomposing, even though this is reportedly not possible according to the documents available. As the smoke is toxic, they do not want to endanger the crew. The master rejects opening the cargo hold because he believes fresh oxygen will feed the fire. He suggests discharging CO₂, which is evidently endorsed by the other party.
- 1810 General alarm sounded and announcement informing the crew in Polish and English. All crew members are summoned to the bridge.
- 1815 The master gives instructions to discharge the CO₂ from above because the lower openings might be covered due to the loading condition.
- 1826 Crew members assure the master that they did not detect anything out of the ordinary while in cargo hold 3 on the morning of that day.
- 1852 The electrician is requested to look at the cargo hold lighting and remove the fuses, i.e. to disconnect the system from the power supply.
- 1855 It is mentioned in conversation that sheeting is on the fertilizer load in cargo hold 3. With the exception of the engine control room personnel, all crew members are now on the bridge.
- 1916 Phone conversation between the master and ship's management.

- 2004 Phone conversation between the master and ship's management.
- 2040 Phone conversation between the master and ship's management.
- 2114 Phone conversation between the master and ship's management.
- 2150 Call on VHF from German Bight Traffic: The master relates the actions taken and that smoke was observed.
- 2159 Phone conversation between the master and ship's management.
- 2300 Phone conversation between the master and ship's management.
- 2305 Call on VHF from German Bight Traffic: On being questioned, the master describes the situation as unchanged. It was reported that no increase in temperature could be detected at the edge of the hatch and there was no smoke emission, either.
- 2307 Phone conversation between the master and ship's management.
- 2332 Call on VHF from German Bight Traffic: The number of full CO₂ cylinders on board is requested. This is specified as 83.

26 May 2015

- 0014 Call on VHF from German Bight Traffic: The watchkeeper asks about the situation on board. The second officer confirms that everything is under control.
- 0028 Call on VHF from German Bight Traffic: The affected cargo and its UN number are requested. This is not available because it does not constitute dangerous goods.
- 0058 Call on VHF from German Bight Traffic: The watchkeeper asks about development of the temperature. The second officer explains that it was reportedly only measured by hand but that a drop in temperature was reportedly noticed. Questions as to the smoke's colour and spread, as well as events after the discharge of the CO₂ follow.
- 0106 Call on VHF from German Bight Traffic: The watchkeeper asks whether the ship needs professional assistance. The second officer assumes that the fire is extinguished and therefore no assistance would be necessary. He believes the master will request the fire service in Brake when the cargo hold is opened there. The VTS staff member then collects data on the size of the cargo hold and type of transportation of the fertilizer.

- 0114 Call on VHF from German Bight Traffic: The watchkeeper asks whether the ship intends to open the cargo hold in the roadstead. The second officer says no.
- 0142 The PURPLE BEACH calls the Weser pilots and asks if the time arranged for the pilot transfer, 0500, still stands. This is initially confirmed. One minute later the ship is informed that the nautical supervisor has issued a prohibition on entry. It is also announced that someone will board to check the situation on board.
- 0314 Phone call between the master and an office which the master refers to as "Cuxhaven" during the playback. During the conversation, the master describes the course of events on board and actions taken. He is subsequently informed that a team will board at about 0400 to investigate the situation. The setting down position is also discussed.
- 0451 A helicopter is at the ship and starts to lower the first six firefighters.
- 0535 The MELLUM approaches the PURPLE BEACH.
- 0615 The master explains to the firefighters that the change of the colour of the shell plating in the area of cargo hold 3 was caused by the previous cargo
- 0645 The fire brigade detects smoke while opening the booby hatch of cargo hold 2.
- 0649 The fire brigade notices that the lightning in the cargo hold access trunk of cargo hold 2 is switched on
- 0656 The lightning in the trunk goes out
- 0708 The ships command explains vis-à-vis the fire brigades head of operation the difficulty of the description of the fertilizer in cargo hold 3 in the provided documents, since it is declared as non-hazardous and non-decaying.
- 0709 The master informs the fire brigade of the fact that nobody was in the hatch when the cargo hold 3 was loaded with fertilizer and that the cargo was finally not trimmed
- 0713 The fire fighters in cargo hold 2 report smoke emission out of an opening in the tween deck of cargo hold 2 on the port side.

- 0746 A helicopter lowers a second group of fire fighters onto the PURPLE BEACH.
- 0818 In a telephone call, the fire department reports rising temperatures, measured nitrous gases and high hydrogen sulfide values.
- 0821 The fire fighters are withdrawn from cargo hold 2. Due to the contamination of the smoke, it is thought of a possibility to take a shower for the group of fire fighters.
- 0832 The hatch covers should be opened to ventilate cargo hold 3. Due to the risk of explosion, only indispensable persons should stay on board during the ventilation.
- 0837 The leader of the FFT speaks with a representative of ship's management about further actions.
- 0845 Announcement: The crew has to assemble in the mess room.
- 0901 Intensified smoke development in cargo hold 3.
- 0918 All are called upon to disembark.
- 0919 General alarm is sounded.
- 0922 The fire departments head of operations requests a helicopter and a CCT in order to treat and airlift the injured.
- 0926 The boat of the MELLUM is deployed to evacuate the last fire fighters
- 0935 PURPLE BEACH's ships command is requested by the head of operations to evacuate the crew by means of their own boat.
- 1005 A helicopter of the Federal Police hauled the first five injured from the MELLUM.
- 1006 The life boat of the PURPLE BEACH is on the water.
- 1059 The new On Scene Coordinator (OSC) is lowered onto the MELLUM.

3.2.5 On-scene surveys

3.2.5.1 Survey on 5 June 2015

The first survey of the PURPLE BEACH by investigators from the BSU together with the police took place on 5 June 2015 at the berth in JadeWeserPort. Access to the ship was previously restricted in consultation with the WSP and CCME to preclude any changes on the ship. Since cleaning work had yet to be carried out in the superstructure and the situation when the cargo holds were opened was still unclear, the inspection was only permitted with a chemical protection suit, full-face mask and breathing air filter. Accordingly, the main purpose of this survey was documentation of the condition. The bridge was inspected first. Since the crew did not save data after the event in the voyage data recorder (VDR) before abandoning the ship, the investigators disconnected the power supply to the VDR's computing unit. This prevented any further overwriting operations in the data memory.

Following that, the VDR's final recording medium located on the observation deck was dismantled and secured.



Figure 8: Final recording medium being secured by the BSU

The aspirating smoke detection system's display was checked on the bridge. This indicated an error. The labelling found next to the system's display indicated that this detection line referred to cargo hold 3's lower hold (Figure 9).



Figure 9: Smoke detection system's display on the bridge

An inspection was later made inside the superstructure, various storage rooms, the CO₂ room, engine room, and engine control room. It was found in the CO₂ room that certain connections (for the aspirating smoke detection system connecting hoses) of the cargo hold valve group were closed off with blanking plugs (Figure 10). The two closed connectors referred to cargo hold 3. According to information given by the chief engineer officer, a leak was found there when the CO₂ was discharged in cargo hold 3. This was possibly due to the fact that after the alarm was triggered by the smoke detection system, an attempt was made to determine the cause of the fire with an odour test by removing the hoses and that the system was no longer sufficiently tight subsequently. The blanking plugs did not interfere with the discharge of CO₂ into cargo hold 3.

In a storage room/workshop used by the bosun in the superstructure level with the main deck, a visual inspection was made of the switch cabinet for the cargo hold lighting (Figure 11). Two readily accessible switch rows were identified. The labelling indicated that the upper switch row was intended for the lighting in the respective cargo holds. The lower switch row was used to switch on the lighting for the hold ladders for each cargo hold. All the switches were in the 'null' (or off) position. Part of the switch cabinet was closed by a cover secured with a padlock, meaning it could not be checked at this point.

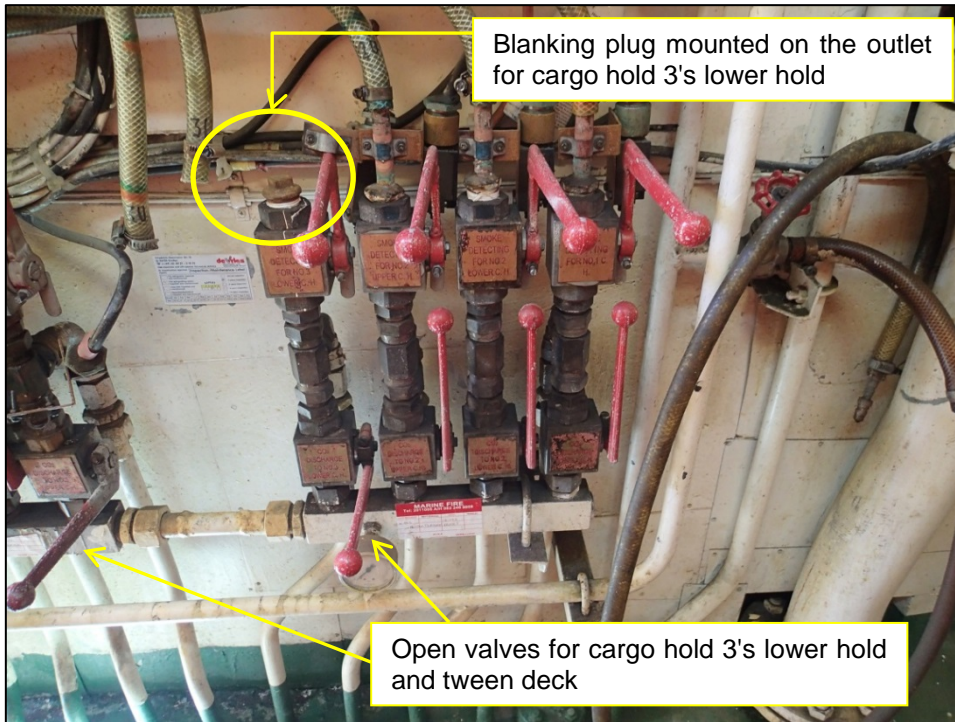


Figure 10: Valve group for the cargo holds in the CO2 room

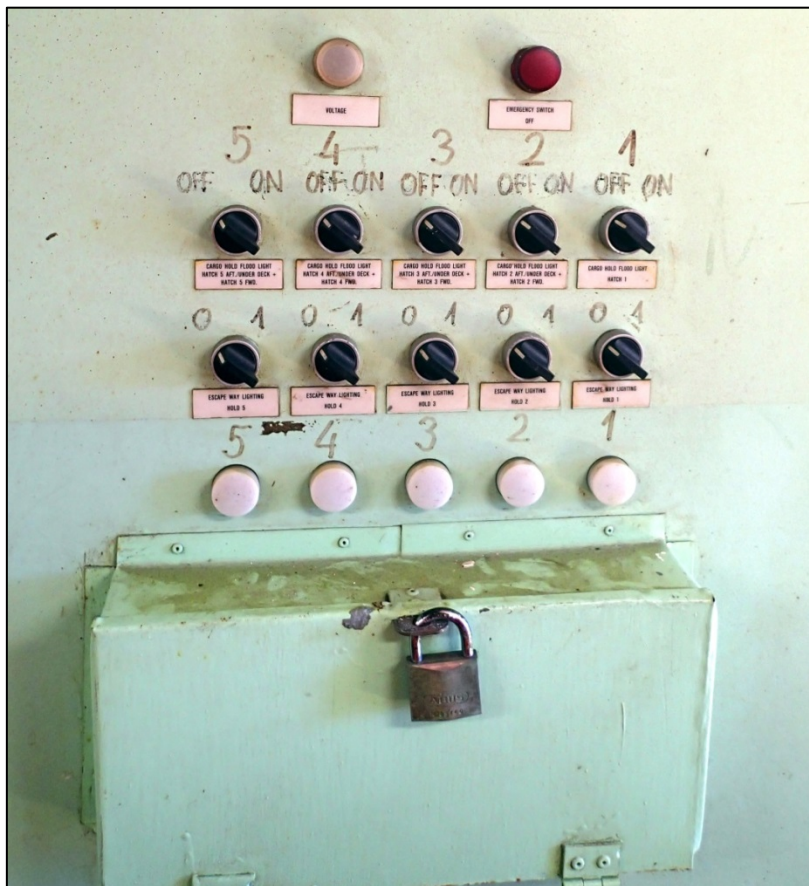


Figure 11: Switches of the switch cabinet for the cargo hold lighting

The hatch covers for cargo holds 2 and 3 were to be opened in the afternoon of 5 June 2015. Due to technical problems, it was only possible to open the port sides of the hatch covers. It had previously been established that only the hatch covers of cargo hold 3 were secured with the corresponding mechanical locks (cleats) (Figure 12). Accordingly, the hatch covers for cargo holds 1, 2, 4 and 5 were only resting on the hatch.

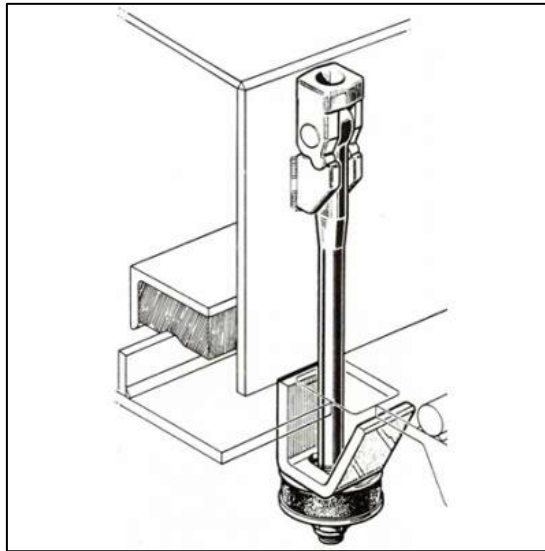


Figure 12: Quick acting cleats¹¹, exemplary illustration

The following findings were made after the hatch cover was opened:

- on the port side of cargo hold 3, large cylindrical steel structures were stowed in the aft area. They were heavily corroded due to the aggressive combustion gases and water which covered all the parts in the meantime. Other machinery parts were stowed further aft. The wood packaging that was there previously was destroyed due to exposure to temperature. A large amount of charred wooden parts and a meshed container were found in the forward area of the tween deck (Figures 14, 16, 17);
- there was no cargo in cargo hold 2's tween deck. The tween deck was completely covered with extinguishing water. Due to the fluid equalisation between cargo holds 2 and 3, the water level at the aft edge of cargo hold 2 was approximately 48 cm above the hatch covers and thus corresponded to the water level at the forward edge of cargo hold 3 (Figure 18 and 19).

¹¹ <http://www.pacificmarine.net/marine-deck/hatch-cover-spare-parts/13-00-ship-quick-acting-cleat-hatch.htm>, retrieved on 31 May 2018.



Figure 13: Cargo hold 3, tween deck, port side, aft section of the cargo hold after loading



Figure 14: Cargo hold 3, tween deck, port side, 5 June 2015



Figure 15: Cargo hold 3, tween deck, port side aft, condition after loading



Figure 16: Cargo hold 3, tween deck, port side aft, 5 June 2015



Figure 17: Cargo hold 3, tween deck, port side forward, 5 June 2015



Figure 18: Cargo hold 3, tween deck, starboard side forward, 5 June 2015



Figure 19: Cargo hold 2, tween deck, starboard side aft, 5 June 2015

Detail to the water level in the cargo hold.

On 8 June 2015, more photographs of the tween decks were taken by WSP Wilhelmshaven after the starboard side of cargo hold 3 was opened. A photo of the original condition has been inserted for comparison here, too (Figures 20 and 21).

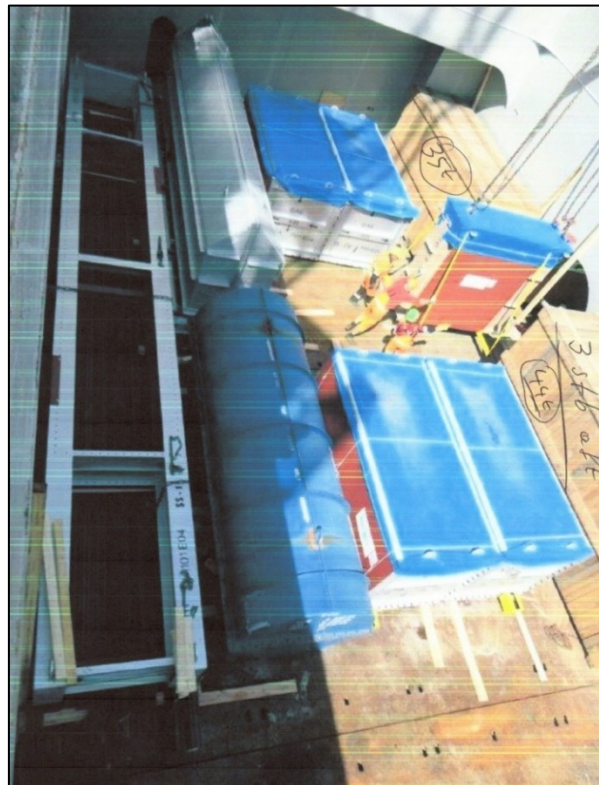


Figure 20: Cargo hold 3, tween deck, starboard side aft, condition after loading



Figure 21: Cargo hold 3, tween deck, starboard side aft, 8 June 2015

3.2.5.2 Survey on 5 August 2015

The second survey of the PURPLE BEACH by investigators from the BSU took place on 5 August 2015. This inspection was attended by the fire investigator appointed by the police, a representative of the Ship Safety Division (BG Verkehr) and several police officers.

The investigators of the BSU initially used the inspection as an opportunity to remove and secure the hard disk of the VDR's computing unit.

At the time of the survey, the water previously in the tween deck of cargo hold 3 had been pumped into a tank vessel to such an extent that unimpeded access to the tween deck was now possible. The fertilizer previously dissolved in the water had settled on the floor in a thick layer. At the transverse bulkheads to cargo holds 2 and 4, the effects of escaping hot combustion gases could be detected at the ventilation openings and the access openings to the hold ladders (Figures 22 and 23).

Due to the surface structure of the wooden parts in the tween deck of cargo hold 3, which did not exhibit any fire scars, the fire expert of the police was of the opinion that the cause of the fire was not to be found in the tween deck. He attributed the damage to the wood to the hot combustion gases from the lower hold.

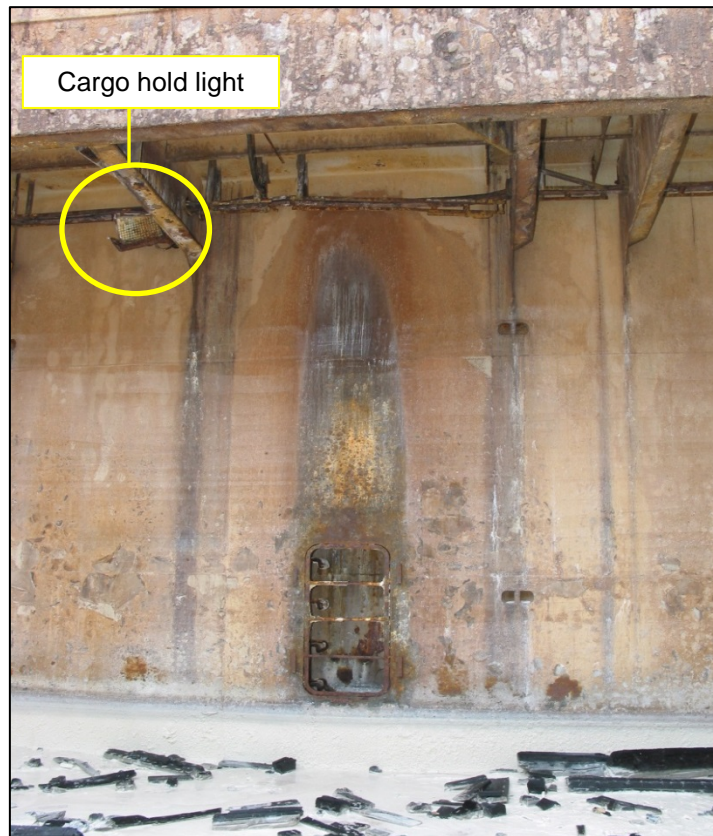


Figure 22: Cargo hold 3, tween deck, port side, ventilation trunk in the bulkhead to cargo hold 2

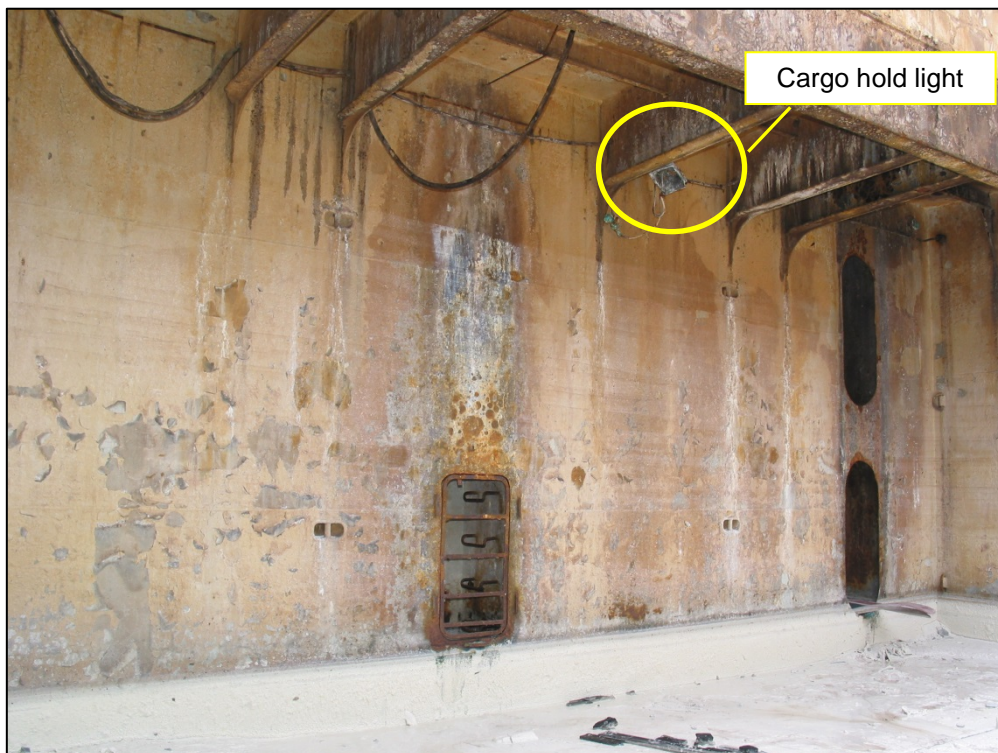


Figure 23: Cargo hold 3, tween deck, starboard side

The ventilation trunk in the middle of the picture and on the right the openings for the hold ladder

The fingers of fire on the transverse bulkheads, which were also found on the aft edge of the tween deck, and the type of thermal conversion supported the fire expert's assumption that the source of the hot gases was to be found in the lower hold.

During the survey, it was found that four cargo hold lights were installed in the tween deck (see Figures 22 and 23).

The switching equipment on the bridge for the cargo hold lights was also checked during the survey. Only one key switch for turning off all cargo hold lights was found. It was positioned in the bridge console in the area of the switches for the deck lighting. The key switch was labelled 'CARGO HOLD LIGHTING BY EXPLOSIV [sic] GROUP II C' (Figure 24). Next to it was a visual display, which apparently indicated whether the cargo hold lighting was switched on or off.

The control panel for the cargo hold lighting was also inspected again. Key switches were found under the on the 5 June 2015 locked cover, which the holder of the key could use to define the option of switching on the lighting for the tween decks and the access trunks together and/or the lower holds (Figure 24). The switches above the cover then only permitted a previously defined switching. It was no longer possible to determine the basic settings on the control panel and the key switch on the bridge from the time of loading until the accident or whether the cover was locked during this period. Similarly, it was not possible to determine whether the fuses for the area of the cargo holds were removed, which would have represented an even deeper intervention. There were no corresponding entries in the deck log book.



Figure 24: Control panel for the cargo hold lighting with cover open



Figure 25: Master switch for the cargo hold lighting on the bridge

The BSU lifted the prohibition on entering cargo hold 3's tween deck at the end of the survey, meaning unloading and cleaning could begin there.

The prohibition on entering the superstructure (for the purpose of the investigation) was lifted by agreement between the WSP and BSU on 9 June 2015.

3.2.5.3 Survey on 26 August 2015

Experts from other parties also took part in this inspection of the cargo hold. At this point, cargo hold 3's tween deck was unloaded and cleaned superficially. In addition, the water previously discharged had been pumped into other sections of the ship to such an extent that the fertilizer present there became visible.

Crew members lifted several pontoon hatch covers with the help of a loading crane to gain an overview of the situation in the lower hold. It was then possible to gain a more detailed overview with the help of a conveyor cage. It was found in the process that neither of the two cargo hold lights was still present. The level of the fertilizer found did not allow any conclusions to be drawn as to the original loading condition. Firstly, the load seemed to have collapsed due to the introduction of water; secondly, it could have floated due to the introduction of water and thus been able to reach all areas of the lower hold. In addition, the product had lost mass and volume due to the chemical reaction.

Left behind B hoses from the firefighters were noticed in the lower hold of cargo hold 3 at the forward edge on starboard side and at the aft edge port side.

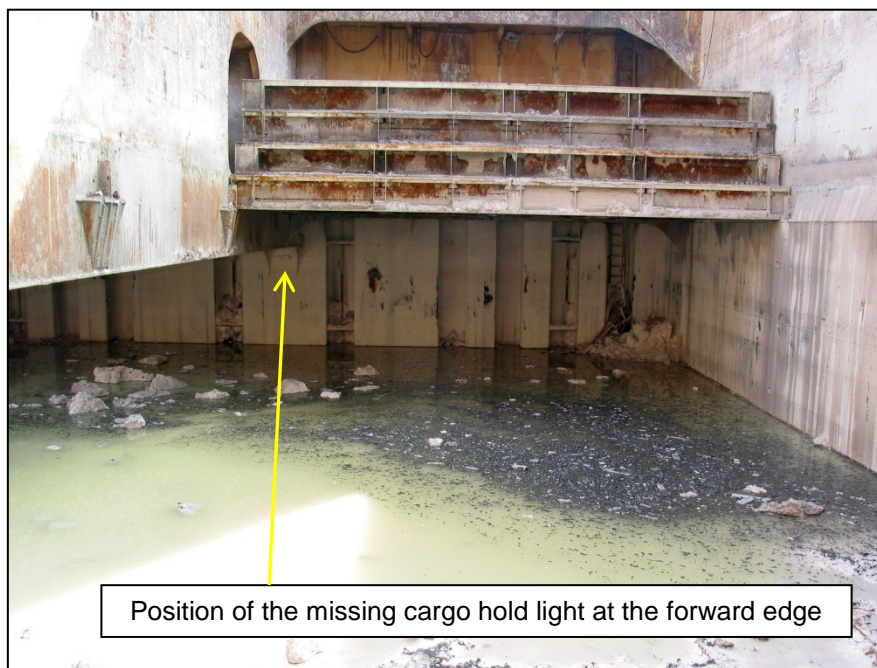


Figure 26: View into cargo hold 3's lower hold

The D-rings installed in cargo hold 3's tween deck were surveyed and it was found that the size of the ring was smaller on some of them. In this case, the ring's length was 10 cm instead of the 12 cm found otherwise. Two of these D-rings were mounted on the aft pontoon hatch cover. Two others were on the outer side wall in this area. The four D-rings were additionally welded on in Antwerp for securing the load in the tween deck.



Figure 27: Additionally mounted D-rings

View of the port side of the aft edge of cargo hold 3 and the aft pontoon hatch cover

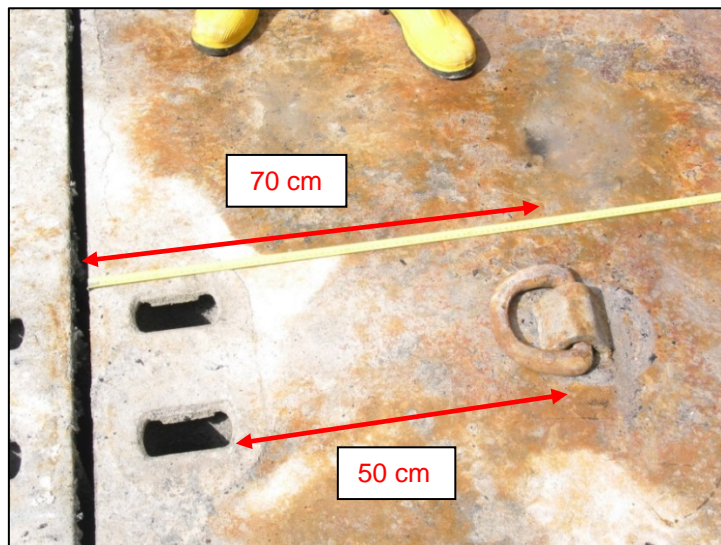


Figure 28: Top view of the aft pontoon hatch cover

Openings for attaching the crane gear for the hatch cover and D-ring

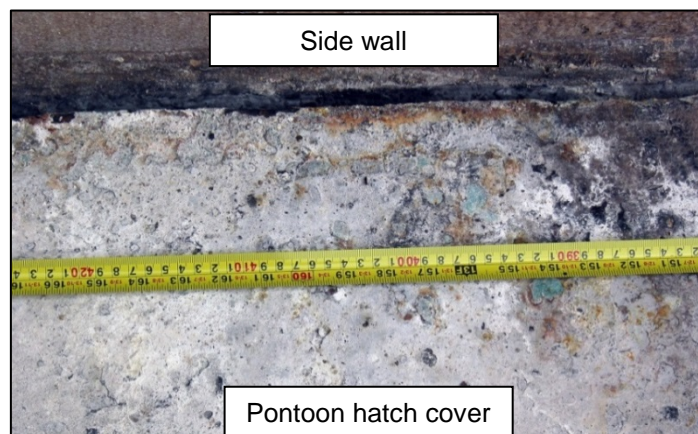


Figure 29: Gap between side wall and pontoon hatch cover

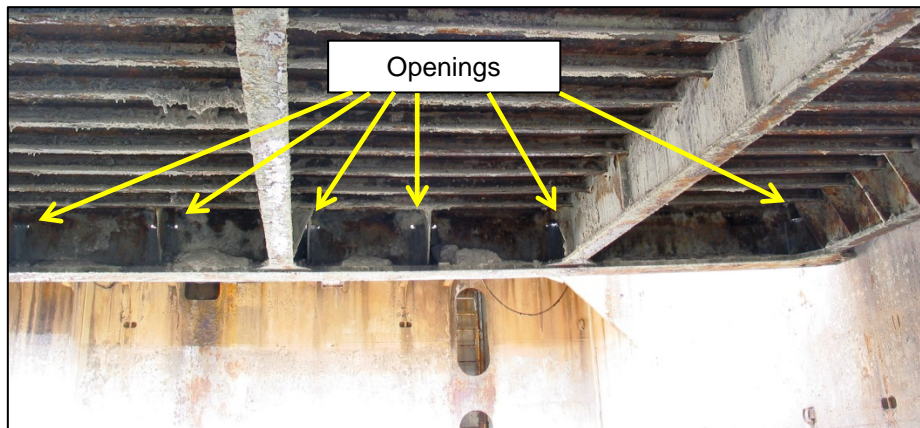


Figure 30: Inward openings in pontoon hatch cover

During the examination of the pontoon hatch cover, it became clear that it did not close tightly on the lower hold. This was derived from the clearance required to mount the covers and the openings to the surface of the covers for attaching the lifting gear. Since the lids were open on the inside, there was an opening to the lower hold at these points (Figure 30).

During the survey, it was also found that watertight integrity between cargo holds 3 and 2 was no longer given in the tween deck due to rust penetration in the transverse bulkhead. Large holes were found in the areas of the hold ladder's trunk on the port side (Figures 33 and 34) and of partition B (see Figure 31). These were located at a distance of about 70 cm and 90 cm from the outer wall in the area of the floor. The exact dimensions were difficult to establish due to the adhered incrustations (Figure 32).



Figure 31: Rust penetration at the bottom of the cargo hold 3 to cargo hold 2 bulkhead



Figure 32: More rust penetration at the bottom of the bulkhead



Figure 33: Rust penetration in the hold ladder's trunk on the port side (here the cargo hold 3 to cargo hold 2 bulkhead)



Figure 34: More rust penetration in the hold ladder's trunk
Cargo hold 3, forward edge of the tween deck, port side. View to the left from the entrance toward void space B (see Figure 35)

Rust penetration was also detected from cargo hold 2 in the transverse bulkhead to 3. This was in the areas of the hold ladder's trunk to cargo hold 2 and of void space B. Since there was a regular opening between A and B, the water could also enter cargo hold 2 there.

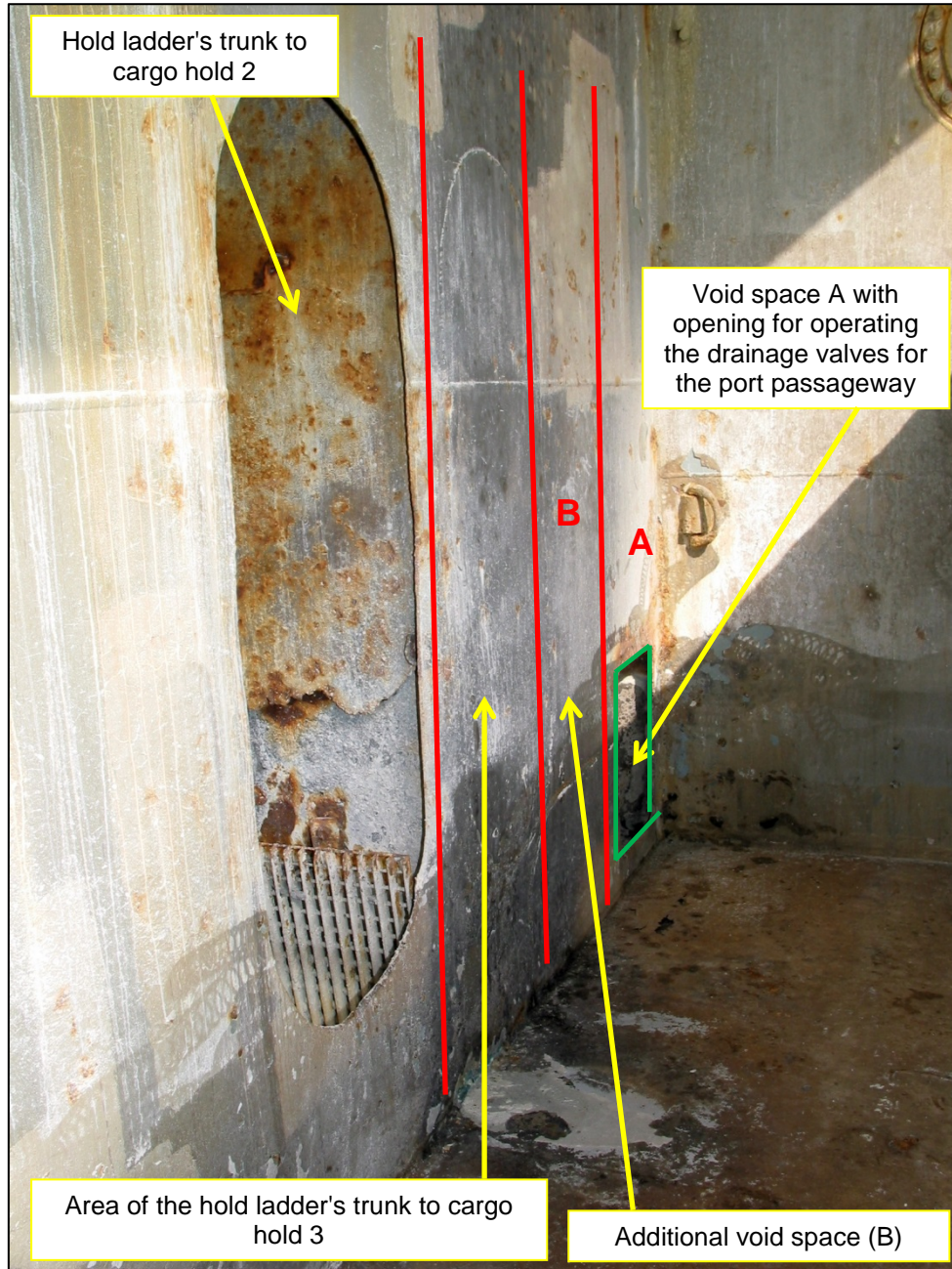


Figure 35: View from cargo hold 2 to the aft transverse bulkhead

Annotation: The BSU assumes, that the opening on the bottom of section A (green marked in figure 35) is the one which the firefighters saw the smoke emitting at their inspection on 26 May 2015.



Figure 36: View in the opening to void space A and B

Highlighted yellow: Rust penetration in the bulkhead to cargo hold 3 (see Figure 31)

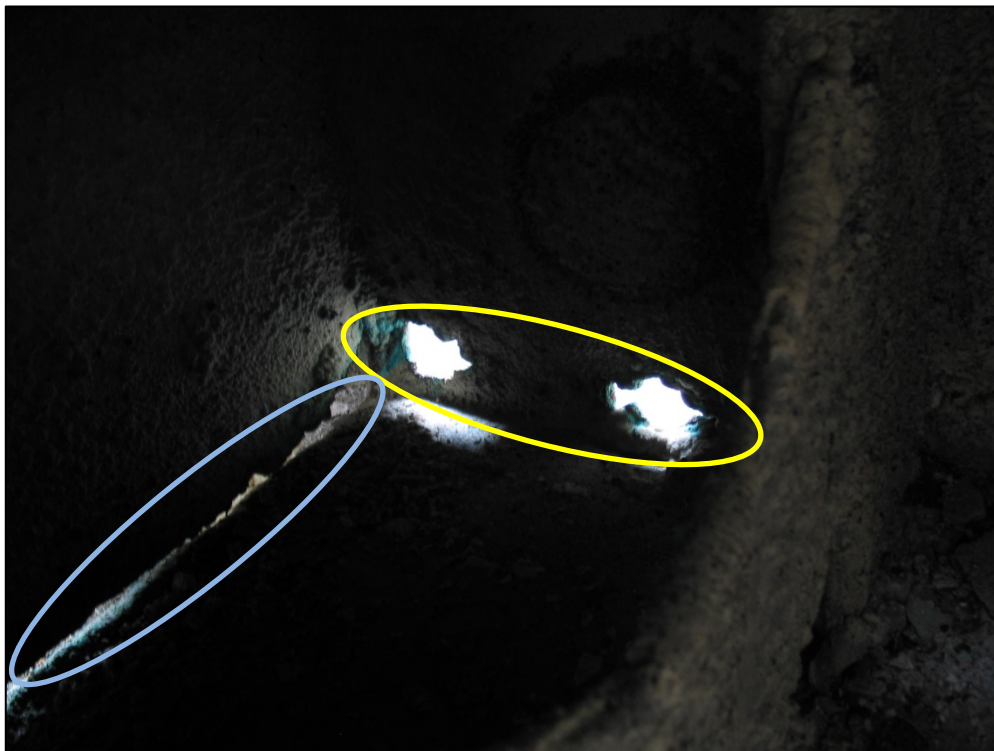


Figure 37: View into void space B from void space A

Highlighted yellow: Rust penetration in the bulkhead to cargo hold 3 (see Figure 31 and 36).
Highlighted blue: Rust penetration from void space B to hold ladder's trunk to cargo hold 2

In addition, a computer from the engine control room secured at an earlier date by the WSP was taken charge of by the BSU on 26 August 2015. The investigators were hopeful that an analysis of this computer would deliver information about the earlier storage temperatures of the heavy fuel oil (HFO) in the fuel tanks in the area of cargo hold 3. This was important because the ambient temperature of the fertilizer load affects the load itself. The ambient temperature should not exceed 50 °C.

Basically, it should be noted that there are two options for controlling the temperature. One is the option of manual control, which is independent of the pre-set or current temperature and achieved by the remote-controlled opening and closing of the corresponding valve in a remote switch cabinet in the engine room. The other option is by means of the secured computer, where the tank temperature can be set and the system controls independently. The actual and target values are displayed. The condition before the accident is unknown and was not saved by the computer. Temperatures or other data were not saved either. The situation shown in Figure 38 was found after logging in to the computer.

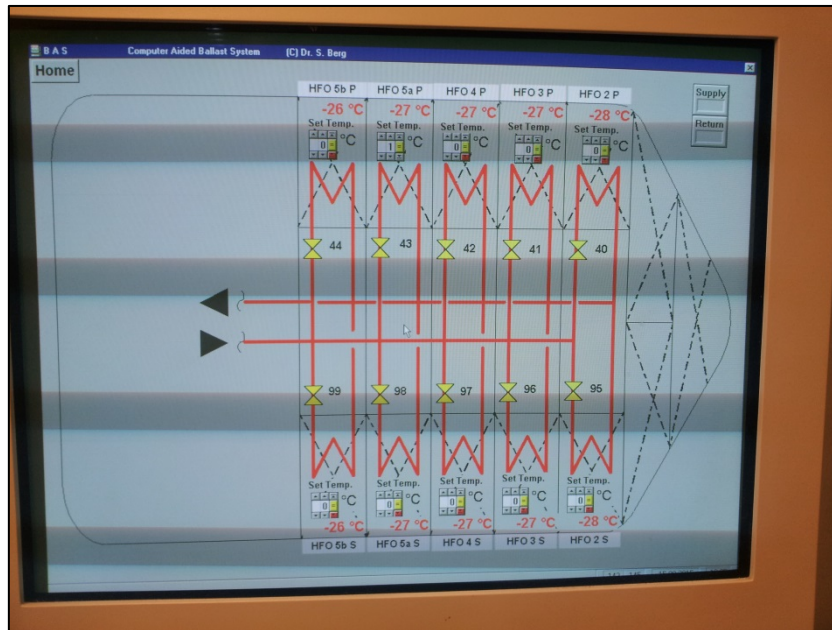


Figure 38: Computer screen display

After consulting with a representative of the system's manufacturer, it was concluded that the figures shown after it was switched on at the BSU made no sense, as the temperatures measured cannot be in the minus range. There is no target value set for any of the tanks. This confirmed the earlier finding of 5 August 2015 that in the final operating condition the temperatures of the HFO tanks were controlled manually. During the survey of the ship on that day, the technical inspector of the ship was questioned on the temperature controls for the bunker tanks. The inspector explained that the temperature in all tanks was controlled based on experience and the return temperature of the heating medium by regulating the flow rate.

The investigators concluded that temperature fluctuations or storage temperatures in excess of 50 °C could not be ruled out.

The manufacturer's representative was of the opinion that the large surface area of the surrounding sea water and the adjacent cargo hold would limit the maximum temperature possible to about 70 °C.

3.2.5.4 Survey on 22 June 2016

Work started to remove the fertilizer's slurry phase at the forward edge of cargo hold 3's lower hold using an excavator on 12 January 2016. The cargo hold light previously installed at the forward edge was found in the process. The light was secured by WSP Wilhelmshaven on the following day. For comparison, the ship's management later removed a light from cargo hold 5's lower hold and gave it to the BSU. In addition, the WSP secured a light from cargo hold 2's lower hold. All lamps seemed to be identical in construction.

The lights were inspected in a garage at the WSP station. In addition to the BSU's investigators, the fire investigator appointed by the police, experts from the other parties affected by the accident and a representative of the flag State took part.

The light found in cargo hold 3 exhibited heavy damage and contamination. The light was full of fertilizer and extinguishing water residue. Salt crystals had formed on the upper edge. The light's reflective aluminium lining was severely damaged. According to the fire investigator appointed by the police, the condition of the edges (brittle, burnt) suggested the light was not damaged by the heat of the exothermal self-sustaining decomposition. There were no deformations typical of extensive heat (e.g. on the plastic). The edges of the reflector had not melted. The junction box mounted on the back of the light did not exhibit any traces of extensive heat, either. The wire connections protruding from the box had completely intact plastic insulation. There was no indication of a possible short circuit in the light's distribution box. The illuminant was blackened in a range of 0.8 mm approximately in the middle of the glass tube but was not tested further by BSU. In the BSU's view all attendant experts assumed that none of the examined cargo hold lamp parts from hold 3 could have triggered the decomposition.

None of the lights allowed any conclusions to be drawn about the manufacturer. Therefore, it was not possible to determine the manufacturer's intended classification of the cargo hold lights with regard to approved area of operation, surface temperature and type of protection.



Figure 39: Light from cargo hold 3, as found

3.2.5.5 Survey on 21 July 2016

In addition to the BSU, surveyors from the other parties and WSP officers took part in the inspection of the cargo holds. The investigators entered cargo hold 3's lower hold for the first time during this survey. There were still remnants of the cargo in the lower hold at the time of the survey and the walls were only cleaned superficially. In terms of damage configuration, it appeared that the chemical reaction in the cargo had affected the cargo hold's aft area on the starboard side more than the port side. More white (converted) residues of the fertilizer were to be found there, while the fertilizer's reddish original colour was still generally visible in the remainder of the cargo hold. Moreover, it was found that decomposition was especially deep in the area of the aft edge almost in the middle (Figure 40).

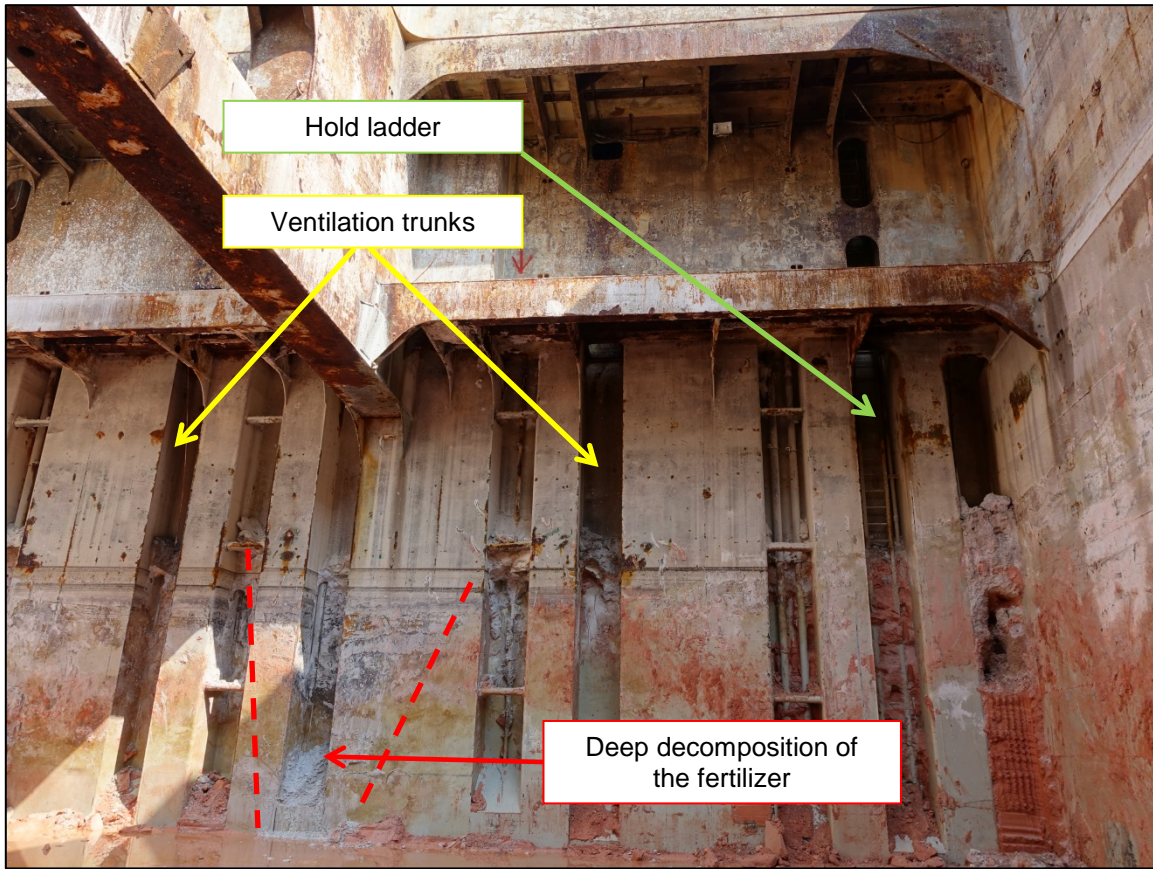


Figure 40: Aft edge of cargo hold 3, port side



Figure 41: Aft edge of cargo hold 3, starboard side

The cargo hold light from the aft edge of the lower hold could not be found when the cargo was unloaded. The junction box, remnants of the wiring harness of the cargo hold lights and a signal transmitter still installed below the tween deck were dismantled and secured for further investigation.

It was not possible to enter the lower hold of 2, as this was not yet completely unloaded.

3.2.5.6 Survey on 27 July 2016

This inspection of the ship was also carried out by a larger group. Cargo hold 3 had been completely washed by this time and fertilizer deposits were no longer visible on the walls (Figure 42). This made it possible to clearly identify changes in colour caused by high temperatures at the aft edge of cargo hold 3. This transverse bulkhead stood in contrast to the forward transverse bulkhead, on which minor changes were evident. The lower edge of the cone with signs of intense heat was some 2.2 m above the deck.

There was still about 0.5 m of water in the lower hold of cargo hold 2 at the time of the survey. However, there was nothing to suggest water had run into cargo hold 3.

The BSU lifted the prohibition on entering the cargo hold after the inspection of cargo hold 3.



Figure 42: Cargo hold 3's lower hold, aft bulkhead edge
Traces of intense heat on the aft transverse bulkhead from a height of 2.2 m

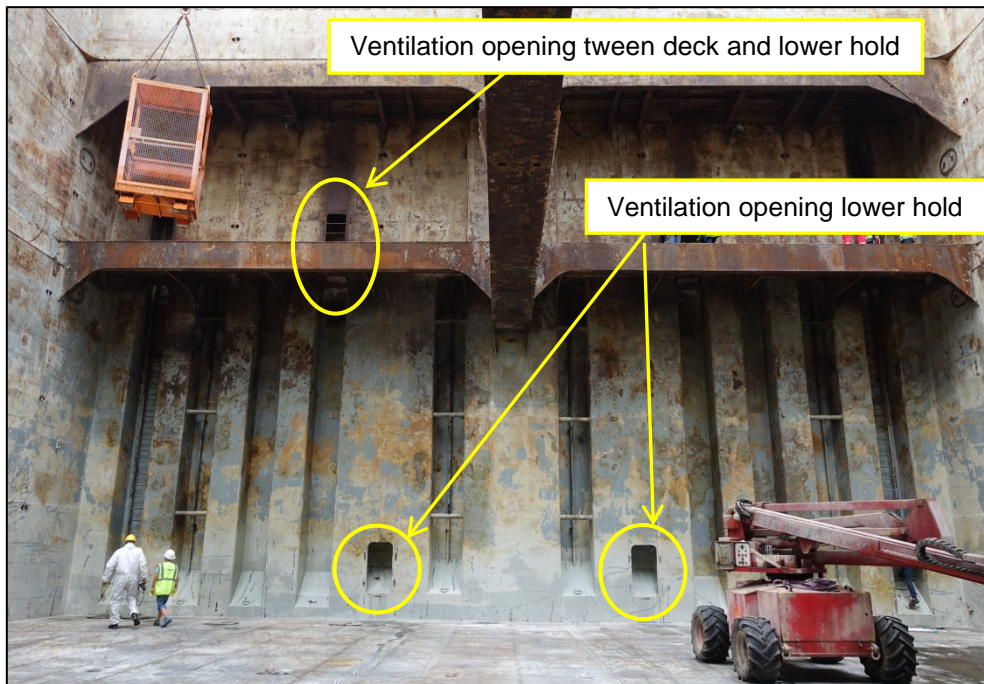


Figure 43: Cargo hold 3, lower hold, forward bulkhead

Cargo hold 4 was then surveyed, where changes to the colour of the coating were found on the transverse bulkhead as a result of the high temperatures in cargo hold 3. Cargo hold 4 still contained remaining items of cargo at this point. Consequently, the walls were not yet cleaned, meaning the previous filling level was still easy to discern there due to the deposits. It was apparent here that the cargo had been loaded well trimmed. The majority was in the aft section and it seemed as if the aft cargo hold light was at least in the immediate vicinity of the cargo.

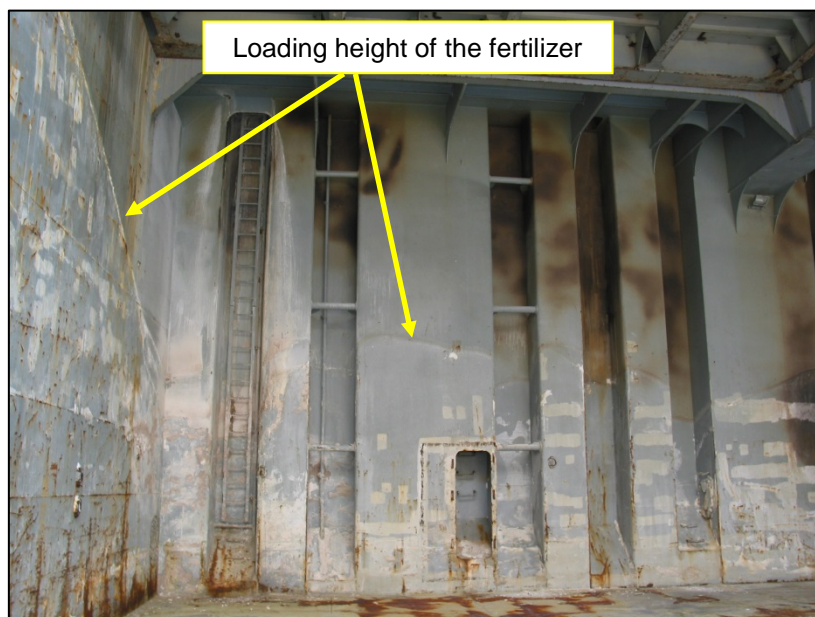


Figure 44: Cargo hold 4, forward bulkhead, port side



Figure 45: Cargo hold 4, forward bulkhead, view toward the starboard side



Figure 46: Cargo hold 4, lower hold, aft cargo hold light

3.2.5.7 Survey on 11 and 12 August 2016

The first of the two days was spent examining the secured components of the electrical installations in cargo hold 3 thoroughly. In addition to the BSU investigator, one expert from each of the two parties affected by the accident and one fire investigator from the Lower Saxony State Office of Criminal Investigation participated in the investigation solely on behalf of the BSU.

Where necessary, fertilizer deposits were removed from the objects, so that they could then be dismantled or uncovered. The following parts were examined:

- socket for connecting the cargo hold light from cargo hold 3, lower hold, aft edge;
- socket for connecting the cargo hold light from cargo hold 3, forward edge;
- electric junction box from cargo hold 3, lower hole, forward edge;
- melted alert horn from cargo hold 3, lower hold, forward edge;
- cable remnants found in the cargo in cargo hold 3, lower hold, aft edge;
- cable remnants found in the cargo in cargo hold 3, lower hold, aft edge.

The following was also available for comparison:

- the light source (halogen tube) from a cargo hold light found in cargo hold 3, tween deck at the forward edge;
- a cargo hold light from cargo hold 3, tween deck, aft edge together with corresponding cable, plug and socket;
- the cargo hold light from cargo hold 5.

During the examination of the plug still in the corresponding socket of the aft cargo hold light from cargo hold 3's lower hold, it was found that there was no cable or remnants of a cable on the cable entry side of the plug. Ring tongue terminals, in which the respective cores could be fixed by crimping, were screwed onto all three contact pins of the naval connector. To determine whether a cable had been attached to it at any point in time, the cable terminals were sawn or filed open and examined microscopically on site. It was found that there were still cable traces under the cable terminal for the protective conductor. Given the position of the plug inside the socket, the BSU's investigators believe that a light was located at the aft edge of cargo hold 3's lower hold at the time of departure from Antwerp.

During the partly microscopic examination of the objects found, no melting points or other indications could be detected on any part or individual wire that would indicate a defect caused by a short circuit.



Figure 47: Setup for the microscopic examination

The second day was initially spent measuring and documenting the temperatures this light was exposed to based on the light from cargo hold 5. The light source's output was first determined to be 750 W. Four measuring points were attached to the light for temperature measurement. These were on the glass on the light emission side, on the upper side of the light housing, on its rear side and on its underside. All the measuring points were connected to a recording device for the temperature curve at the sensors.



Figure 48: Measurement setup for determining the surface temperature of the cargo hold light

At the front of the glass, a temperature of only 140 °C was initially measured with the tip of the measuring wire. Later, the measuring wire was attached to the glass surface using aluminium adhesive tape, where 244 °C was then reached. The temperature was then measured at 298 °C with aluminium adhesive tape covering a larger area. The temperatures at certain distances from the front of the glass were to be determined in a further test. A temperature of 74 °C was measured at a distance of 10 cm and 70 °C at a distance of 20 cm.

The other temperatures measured on the housing were:

- upper side about 114 °C;
- rear side about 102 °C;
- under side about 100 °C.

The temperature measurement was later repeated at the premises of the BSU using a laser thermometer. The following temperatures were measured in the process:

- upper side about 122 °C;
- under side 117 °C;
- side about 113 °C;
- front of glass in the middle 260 °C and at the sides about 170 °C.

Most of the items were returned to the ship's management after this examination.

A further assessment during the afternoon of that day revealed that power to the supply lines for cargo hold 3's lighting could be measured if the switches on the control panel were set accordingly.

The BSU also documented the extent of rust penetration in the area of the tween deck between cargo holds 2 and 3. The investigators only ascertained minor alterations to the size of rust penetrations in comparison to the measurements on 26 August 2015, although the cargo holds were cleaned using high pressure with 400 bar to 700 bar according to the ship's management.

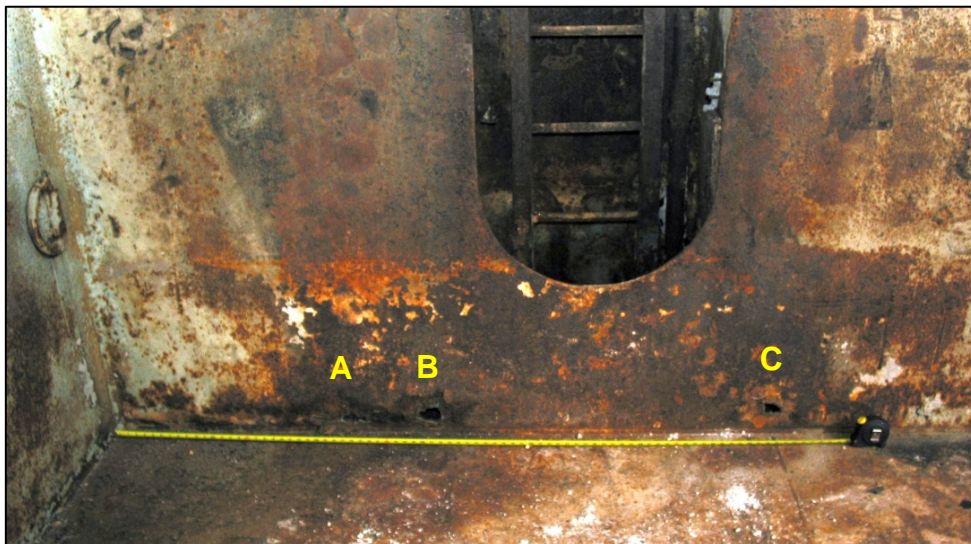


Figure 49: Cargo hold 3, tween deck, transverse bulkhead to cargo hold 2, port side



Figure 50: Close-up taken from Figure 49



Figure 51: Close-up to figure 49, holes A and B



Figure 52: Close-up to Figure 49, hole A



Figure 53: Close-up to Figure 49, hole B



Figure 54: Close-up to Figure 49, hole C



Figure 55: Rust penetration in the area of a hold ladder

In this case, cargo hold 3's hold ladder trunk, tween deck, aft edge, port side, view aft from the access opening to the right



Figure 56: Rust penetration in the area of a hold ladder

In this case, hold ladder trunk at the aft edge of cargo hold 2, tween deck, starboard side, view from the access opening to the bottom right



Figure 57: Cargo hold 2, tween deck, aft edge, port side



Figure 58: Close-up taken from Figure 57



Figure 59: View in the void space A (see also image 36)



Figure 60: Hold ladder trunk to cargo hold 2

In this case hold ladder at the aft edge of cargo hold 2 at port side. Rust penetration in the direction of hold ladder trunk from cargo hold 3; see also figures 37 and 56.

After documenting the condition of the transverse bulkhead between cargo holds 2 and 3, cargo hold 2's lower hold was entered.



Figure 61: Cargo hold 2's lower hold, port side of aft edge with discolouration



Figure 62: Cargo hold 2's lower hold, aft edge, starboard side

In consultation with WSP Wilhelmshaven, the investigation on the PURPLE BEACH herself was declared closed on 23 August 2016 and the ship was released.

3.2.6 Loading of the PURPLE BEACH in Antwerp

The PURPLE BEACH called at the ports of Rotterdam and Immingham before Antwerp to unload cargo there (cargo hold 4's lower hold was unloaded in Rotterdam). In Immingham, sodium carbonate was unloaded from the lower holds of cargo holds 2, 3 and 5 and from cargo hold 1. The PURPLE BEACH sailed out of Immingham at about 0530 on 17 May 2015 and reached her first berth at Antwerp's Europort, where the loading of cargo hold 2's lower hold began at 0705 on 18 May 2015. 5,030 t of ENTEC 26 fertilizer was loaded, which corresponded to a cargo volume of 5,250 m³. On 20 May 2015, the ship moved to a berth at EuroChem for the loading of cargo hold 4's lower hold. 5,000 t of ammonium sulphate was loaded, which corresponded to a volume of 5,000 m³. This loading operation was completed on the morning of 21 May 2015. Cargo hold 5's lower hold was then loaded at the same berth. The fertilizer loaded there (NPK Special) weighed 5,250 t, corresponding to a volume of 5,000 m³. The cargo hold 5 loading operation was completed at 1035 on 22 May 2015. From 1110 on 22 May 2015, cargo hold 3's lower hold was loaded with 6,000 t of NPK 15¹², corresponding to a cargo volume of 5,400 m³.

¹² Abbreviation for Nitrophoska® 15+15+15+2 S.

Cargo hold 3's lower hold loading operation was completed at 0755 on 23 May 2015.

Before the lower holds of cargo holds 2 to 5 were loaded only the condition of cargo hold 2 was surveyed by an external inspector. However, the Stevedoring department of the fertilizers producer did confirm in the 'Statement of Loading' that the holds were inspected upon the arrival of the ship ("hold passed inspection"). A detailed checklist, e.g. as proposed by Fertilizer Europe¹³, which (in addition to 15 other items) includes switching off the electrical circuits and lighting, was not worked through.

The ship's management sought to prove the cargo holds had been cleaned by submitting a copy of a work order to an external company. The contract was concluded in Rotterdam on 11 May 2015. The works were to be carried out on 11 to 18 May 2015. It is possible that this involved a group of workers travelling with the ship. The work report issued in Antwerp on 18 May 2015 after completion of the works describes the scope of work as follows: "Repair and maintenance of holds no 1; 2; 3; 4; 5 on the m/v Purple Beach." The hired company confirmed later that the washing of cargo holds was meant. In the deck log book, which the BSU has at its disposal for the period starting 14 May 2015, only one entry relating to the washing of cargo hold 5 could be found. The PURPLE BEACH was in Immingham during the period 14 May 2015 to 16 May 2015, where she discharged soda ash, among other things. This is relevant insofar as the cargo residues found on the deck (see section 3.1.1, page 21) originated from this cargo. If the two substances (soda ash and ammonium nitrate based fertilizer) come into contact with water or strong humidity, then an exothermic reaction may occur with the formation of gaseous ammonia. According to the material safety data sheet (MSDS) (section 10.3) for Nitrophoska[®] 15+15+15+2 S, contact with alkaline solutions should be avoided as this may cause gaseous degradation products, which may lead to an increase in pressure in tightly sealed containers.

The shipping company submitted a pre loading survey report, carried out on 24 April 2015, concerning the loading of Soda Ash. The included pictures showed a good condition of the lower holds of cargo holds 1, 2, 3 and 5.

During the loading of fertilizers in Antwerp some fuel operations took place. As cargo hold 3 was being loaded on 22 May 2015, a bunker barge was alongside for about four hours supplying fuel. A large quantity (1,000.6 mt) of HFO was loaded in the process, including in the double bottom tanks beneath cargo hold 3.190 mt was stored in TK 3 STB and 300 mt in TK 3 PS in the process. The capacity of each tank was 315.5 m³.

¹³ Fertilizer Europe: Guidance for the Sea Transport of Ammonium Nitrate Based Fertilizers, Appendix 1 - Example of a checklist for the inspection of cargo holds prior to loading (for all fertilizers). Issue 2014.

Refuelling also took place when cargo hold 5 was loaded on 21 May 2015. However, this was completed within 15 minutes. 5,000 litres of lubricating oil were taken on board. A bunkering operation was also carried out as cargo hold 4 was being loaded on 20 May 2015, where 160 mt marine diesel oil (MDO) was taken on board. The end of the operation was not recorded in the deck log book. According to the oil record book, the operation was completed within about 1.5 hours.

Since the IMSBC¹⁴ Code states that the temperature of tanks adjacent to cargo holds laden with ammonium nitrate based fertilizer (non-hazardous) may not exceed 50 °C, the ship's management was questioned about the temperature of the HFO taken on board. The ship's management handed over a "Certificate of barge tank measurement" for the bunker delivery on 22 May 2015 issued by a marine surveyor. It was recorded, that the transfer temperature was lower than 50 °C.

Noteworthy was, that the entries regarding the fuel operations were done for the day after. There was no information about the fuelling of lubricating oil in the engine logbook. The entries into the deck log book and into the oil record book corresponded to the factual circumstances.

On 23 May 2015, after cargo hold 3 was loaded, the vessel shifted to a new berth. Loading with general cargo in cargo hold 1 began on 24 May 2015. Cargo hold 3's tween deck was then loaded with general cargo. In addition, the fertilizer load was stowed in cargo hold 2's lower hold. All operations were completed at 1133. The ship cast off at 1412 and began her voyage to Brake.

During the sea passage, on the morning of 25 May 2015, a group of crew members carried out cleaning and tidying works on the deck, the hatch covers and in the tween decks of various cargo holds. Cargo hold 3's tween deck was cleaned in the process. One of the crew members responsible reported in his statement that the cargo hold lighting was switched off. He also stated that no unusual odours or other irregularities were noticed during the works. This was confirmed by another crew member. The crew stated that during the cleaning works in cargo hold 3's tween deck, the cargo hold hatch covers were opened slightly in the interest of adequate lighting.

3.2.7 Cargo details

The entire shipment of fertilizer was bound for the port of Altamira, Mexico. The investigation focuses on the details of the cargo in holds 2 to 4 in the following section, as these were directly affected by the chemical reaction in cargo hold 3 and the water ingress in cargo hold 2.

¹⁴ International Maritime Solid Bulk Cargoes Code.

Before continuing, it should be noted that no part of the ship's cargo was classified as dangerous goods at the time of the accident.

3.2.7.1 Cargo hold 2

Cargo hold 2's tween deck remained free. Entec[®] 26+13S fertilizer was stowed in the lower hold. The components of this fertilizer are ammonium nitrate and ammonium sulphate. However, it is classified as ammonium nitrate based fertilizer. The material safety data sheet (MSDS) of the manufacturer states that the fertilizer does not constitute dangerous goods for the purposes of the IMSBC Code and is incombustible. The product should be kept away from heat and sources of ignition, however. A risk of decomposition prevails from temperatures in excess of 170 °C. This should not give rise to self-sustaining decomposition. Dangerous gases are released during decomposition. Potential decomposition can be halted by adding a large amount of water. Bunkering a ship with fuel during loading is prohibited.

The volume of the cargo (5,250 m³) in relation to the volume of the cargo hold (5,299.9 m³/for bales) implies that the lower hold was almost completely filled.

Because of the temperatures in cargo hold 3 during the exothermal self-sustaining decomposition the activation of the same process in cargo hold 2 could not be excluded. So far, there is no evidence to suggest, that the cargo in cargo hold 2 was subject to decomposition.

3.2.7.2 Cargo hold 3

The Nitrophoska[®] 15+15+15+2 S fertilizer was carried in this cargo hold's lower hold¹⁵. According to the manufacturer's MSDS, the components of this fertilizer are ammonium nitrate, ammonium salts, phosphates, calcium salts, potassium carbonate and possibly magnesium and other trace elements. Accordingly, the fertilizer does not constitute dangerous goods and is not flammable. However, it must be kept clear of heat and ignition sources. Contact with organic materials should be avoided during storage. When heated above 130 °C, dangerous gases may develop due to the onset of decomposition. These gases include nitrogen monoxide, nitrogen dioxide and nitrous oxide. The MSDS states that sand, foam, CO₂ and chemicals are not suitable for firefighting (respectively the termination of a thermic decomposition). According to the MSDS water in larger quantities is the suitable media to stop the thermic decomposition.

The volume of the cargo (5,400 m³) in relation to the volume of the lower hold (5,526 m³/for bales) also implies that this cargo hold was completely filled, which was also confirmed by the crew.

¹⁵ The name NPK is derived from the names for the constituent materials: nitrogen (N), phosphorous (P) and potassium (K).

Accordingly, the lower hold was filled up to the lower edge of the pontoon hatch cover. Based on that, it is not entirely improbable that the two lights in cargo hold 3's lower hold were subsequently either in the immediate vicinity of or even covered by the fertilizer.

According to statements made by the crew, the top of the fertilizer was covered with plastic tarpaulins to protect the cargo. No remnants of the tarpaulins could be found when the lower hold was opened. The investigators assume that these tarpaulins were completely destroyed due to the heat in the lower hold.

3.2.7.3 Cargo hold 4

The fertilizer ammonium sulphate was carried in this cargo hold's lower hold. The investigators had the MSDS and the individual schedule for this cargo. This cargo does not constitute dangerous goods for the purposes of the IMSBC Code, either. This product does not start to decompose until temperatures in excess of 280 °C. According to the data sheet on hand, there are no restrictions with regard to the extinguishing agents used with this substance.

Moreover, there are no restrictions on the bunkering of fuels during loading or unloading for this substance.

Cargo hold 4's lower hold was not completely filled. For example, only about half the transverse bulkhead to cargo hold 3 was covered with fertilizer.

At the time of the accident, other general cargo was in the tween deck of cargo hold 4. This had been taken on board in another port of loading before Antwerp and was scheduled to be unloaded in Brake. The cargo was stowed such that a smaller part was loaded on both sides at the aft edge under the deck girder, where it did not obstruct opening the pontoon hatch cover in the aft area. Larger boxes were in the forward part of the tween deck, which also occupied the first forward hatch cover. In each case, only three covers could be lifted out there.

Because of the temperatures in cargo hold 3 during the exothermal self-sustaining decomposition the activation of the same process in cargo hold 2 could not be excluded as well, but it was less likely due to the necessary higher temperatures.

3.2.8 Nitrophoska[®] 15+15+15+2 S

Further consideration of the PURPLE BEACH's fertilizer load focuses only on Nitrophoska[®] 15+15+15+2 S because this was the cargo in which the chemical reaction began.

The 6,000 mt of Nitrophoska[®] 15+15+15+2 S from the cargo on the PURPLE BEACH was a partial quantity of 11,992 mt produced at the Antwerp production site between 21 and 26 April 2015. The entire quantity produced was subsequently stored in a separate hall at the Antwerp terminal of the manufacturer.

3.2.8.1 IMSBC Code

The IMSBC Code regulates the transportation of solid bulk cargo on ships. In the interest of uniform application, any solid bulk cargo or substance is designated by the bulk cargo shipping name (BCSN) and only this is used in the Code. A cargo which may liquefy during shipment is classified under Group A. A load posing the risk of a chemical reaction during transportation is classified under Group B. All other cargoes were allocated to Group C. Solid bulk cargo posing a risk in packaged form, too, is additionally classified according to the IMDG Code and given a UN number. The Code contains an individual schedule for each item of solid bulk cargo. This schedule contains the following information, *inter alia*:

- description of the substance with condition and composition;
- properties such as angle of repose, bulk density, stowage factor, grain size, group;
- hazards;
- stowage and segregation;
- loading;
- precautions
- emergency procedures.

Fertilizer transported as solid bulk cargo is classified in accordance with the requirements of the IMSBC Code, where the ratio of ammonium nitrate to the other components is of importance to provisional classification. Actual classification depends on the result of various tests, which are also described in the IMSBC Code¹⁶. Since nitrate based fertilizers are prone to decomposition when exposed to considerable heat, the procedure includes testing this property. This trough test, so called because of the test setup, is also referred to as UN Test S.1. Resistance to detonation is examined in two other tests¹⁷. These tests are referred to as UN Test 1 (a) and (b).

A brief description of the trough test follows. The material requiring examination is placed in a trough with the dimensions 150 mm x 150 mm x 500 mm for the test. The trough is made out of a firm, metal, mesh material. A heating system which acts on a steel plate is situated on one of the narrow sides. The heater is operated electrically or by two gas burners. Temperatures of 400 °C to 600 °C must be reached in the process, i.e. dark red. The temperature development in the trough is determined with the aid of a number of thermocouples in the sample. Heating is continued until decomposition has developed within the test material over an area of 3-5 cm.

¹⁶ IMSBC Code, Appendix 2, section 4 – Trough test for determination of the self-sustaining exothermic decomposition of fertilizers containing nitrates. See also section 38 of the Recommendation on the Transport of Dangerous Goods – Manual of Tests and Criteria.

¹⁷ IMSBC Code, Appendix 2, section 5 – Description of the Test of Resistance to Detonation.

Progress is then monitored after the heater is switched off. The IMSBC Code reads: *If propagation of the decomposition continues throughout the substance the fertilizer is considered capable of showing self-sustaining decomposition. If propagation does not continue throughout the substance, the fertilizer is considered to be free from the hazard of self-sustaining decomposition.*"¹⁸

In the tests carried out for the certification, Nitrophoska[®] 15+15+15+2 S was classified as a product not prone to self-sustaining decomposition. Accordingly, it was not a substance that presented a chemical hazard within the meaning of the IMSBC Code. As there was no need to fear liquefaction the good was allocated to Group C. At the same time, classification as dangerous goods for the purposes of the IMDG Code was precluded. This means that the EmS Guide¹⁹ and the associated emergency schedules were not relevant in the event of fire or leakage, as the guide only refers to dangerous goods within the meaning of the IMDG Code. However, the emergency procedures are part of an individual schedule.

Nitrophoska[®] 15+15+15+2 S fertilizer is classified under the bulk cargo shipping name 'Ammonium nitrate based fertilizer (non-hazardous)'. The associated schedule (Annex 9.1) contains inter alia the following information of relevance to this investigation:

- **Hazard:** *This cargo is non-combustible or has a low fire risk. Even though this cargo is classified as non-hazardous, some of the properties of the ammonium nitrate based fertilizer classified in class 9 under UN 2071 are exhibited when heated strongly. When this cargo is heated strongly, it will decompose and give off toxic gases with the risk of toxic fumes in the cargo space, adjacent spaces and on deck. Monitoring of the cargo temperature may give an early indication of decomposition.*
- **Stowage & segregation:** *The compatibility of non-hazardous ammonium nitrate based fertilizers with other materials which may be stowed in the same cargo space should be considered before loading. "Separated from" sources of heat or ignition (see also Loading). Not to be stowed immediately adjacent to any tank, double bottom or pipe containing heated fuel oil unless there are means to monitor and control the temperature so that it does not exceed 50°C.*
- **Hold cleanliness:** *Clean and dry as relevant to the hazards of the cargo.*
- **Weather precautions:** *This cargo shall be kept as dry as practicable. This cargo shall not be handled during precipitation. During handling of this cargo all non-working hatches of the cargo spaces into which this cargo is loaded or to be loaded shall be closed.*

¹⁸ IMSBC Code, Appendix 2, section 4.4 – Test criteria and method of assessing results.

¹⁹ Emergency Response Procedures for Ships Carrying Dangerous Goods and Emergency Schedules.

- **Loading:**

Prior to loading, the following provisions shall be complied with:

- *All electrical equipment, other than that of approved intrinsically safe type, in the cargo spaces to be used for this cargo shall be electrically disconnected from the power source, by appropriate means other than a fuse, at a point external to the space. This situation shall be maintained while the cargo is on board.*
- *Due consideration shall be paid to the possible need to open hatches in case of fire to provide maximum ventilation and to apply water in an emergency and the consequent risk to the stability of the ship through fluidization of the cargo.*
- *In addition, if decomposition occurs, the residue left after decomposition may have only half the mass of the original cargo. Due consideration shall be paid to the effect of the loss of mass on the stability of the ship.*

During loading, the following provisions shall be complied with:

- *Bunkering of fuel oil shall not be allowed. Pumping of fuel oil in spaces adjacent to the cargo spaces for this cargo, other than the engine-room, shall not be allowed.*

- **Precautions:**

No welding, burning, cutting or other operations involving the use of fire, open flame, spark- or arc- producing equipment shall be carried out in the vicinity of the cargo spaces containing this cargo except in an emergency. The master and officers are to note that the ship's fixed gas fire-fighting installation will be ineffective on fires involving this cargo and that applying copious amount of water may be necessary. Smoking shall not be allowed on deck and in the cargo spaces and "NO SMOKING" signs shall be displayed on deck whenever this cargo is on board. The hatches of the cargo spaces, whenever this material is on board, shall be kept free to be capable of being opened in case of an emergency.

- **Emergency procedures:**

Wear protective clothing and self-contained breathing apparatus.

Fire in a cargo space containing this material: Open hatches to provide maximum ventilation. Ship's fixed gas fire-extinguishing installation will be inadequate. Use copious quantities of water and isolate the source of heat, if any. Flooding of the cargo space may be considered but due consideration should be given to stability.

Fire in an adjacent cargo space: Open hatches to provide maximum ventilation. Heat transferred from fire in an adjacent space can cause the material to decompose with consequent evolution of toxic fumes. Dividing bulkheads should be cooled.

The investigators assume that the ship's command of the PURPLE BEACH had access to extracts or all of the IMSBC Code and was therefore aware of the information contained in the schedule²⁰.

3.2.8.2 Other guidance and information

The manufacturer provided the ship's command with several information sheets drawn up in English relating to the loading of cargo hold 3 in Antwerp (Annex 9.2). The master confirmed receipt. The information contained in the documents is reproduced below in abridged form:

- **Instructions to the ship's crew for the handling of emergencies involving the decomposition of ammonium nitrate based fertilizers** (Annex 9.3):
 - If at sea, contact ship agent, shipping company or the supplier
 - Avoid breathing fumes, as they may be toxic.
 - Open hatches immediately to maximise ventilation.
 - If possible, remove the heat source and extinguish the fire or decomposition.
 - If not possible to remove or separate, drench the fertilizer in the cargo hold with water (salt or fresh).
 - DO NOT fight the decomposition by using foam, carbon dioxide, steam, sand or fertilizer or by keeping the hatches closed.

- **Instructions to the ship's crew concerning avoidance of heat sources when loading/unloading and carrying ammonium nitrate based fertilizers** (Annex 9.4):
 - Switch off all light and heat sources in cargo holds prior to loading and during the whole voyage as long as the fertilizer is onboard.
 - Remove electric fuses to cargo holds and keep them removed until cargo is unloaded.
 - Do not allow welding or other hot work that can affect the fertilizer.
 - Display 'No Smoking' signs.

- **Cargo information** (Annex 9.5):

This sheet referred to ammonium nitrate based fertilizer (non-hazardous) specifically. In addition to such technical information as stowage factor and grain size, it was stated that the product is incombustible and will decompose when heated. The decomposition would start at a temperature of about 130 °C. It was also pointed out that the substance should be kept away from ignition or heat sources.

²⁰ In accordance with Marine Notice No. 1-000-3 Rev. 11/12 of the Republic of the Marshall Islands, there is an obligation to carry the IMSBC Code on board ships flying this flag.

- **General guide to the sea-transport and handling of compound fertilizers (Annex 9.6):**

This document is an aid for the handling of fertilizer mixtures for member companies published by the EFMA²¹ and IFA²². The three-page guide deals with class 5.1 (UN 2067) and class 9 (UN 2071) fertilizers, as well as those without a UN number (Group C) based on ammonium nitrates. The guide contains general information and recommendations for handling and stowage on the ship. It included the information shown above. Emergency measures are also listed in the guide. If an area in which decomposition is taking place is identified, then the following measures may be taken immediately:

- if the zone of decomposition is still small and easily accessible, an attempt may be made to remove it from the main body of the fertilizers by the use of picks and shovels, and to cool it down by localized quenching of water.
- when it is impossible to remove the zone of decomposition, the fertilizer involved must be soaked as rapidly as possible with a large quantity of water directed through high pressure jets against the centre of decomposition. To fight the decomposition by other means (for example, foam, carbon dioxide, steam, covering with sand or fertilizer) is useless, and may even promote the decomposition.
- the course of the ship should be so chosen that any harmful fumes evolved will drift as little as possible over the ship, especially towards the crew's quarters and the bridge.
- to provide maximum ventilation the hatches should be opened unless weather conditions make this impossible. A gas-tight closure of the affected hold should in any case be avoided.
- if copious quantities of water to control the decomposition should be necessary, flooding of the hold should be considered.
- if suppression of the slow decomposition should prove impracticable, there will not necessarily be immediate danger to the ship if the decomposition has to be left to come to an end in the affected hold. Suitable precautions should, however, be taken to prevent the spread of decomposition or fire to cargoes in adjacent holds.

- **Do's and don'ts with fertilizers**

This information sheet was on board but not submitted to the investigators.

- **MSDS for Nitrophoska[®] 15+15+15+2 S (Annex 9.7):**

On the content of the MSDS, see section 3.2.8.1.

- **Mooring arrangements & document removing domestic waste**

This information sheet was on board but not submitted to the investigators.

3.2.8.3 Tests at the BAM

The parties affected by the marine casualty had agreed in the course of arbitration proceedings to carry out or commission a joint investigation into Nitrophoska[®] 15+15+15+2 S fertilizer. To this end, an authorised company took samples from

²¹ The European Fertilizer Manufacturers Association.

²² The International Fertilizer Industry Association Ltd.

various sections of the fertilizer (about 5000 mt) stored in the warehouse at Antwerp on 3 July 2015. These were later sent to the BAM²³, which had been commissioned to carry out tests to determine the properties. The testing was carried out there between 5 and 12 January 2016. In the process, the fertilizer was examined for its properties with regard to self-sustaining decomposition, volatility and self-heating. Testing was carried out according to the relevant standard procedures. The product was heated in a trough by means of an electrical heating plate. In summary, the following findings were made:

- none of the tests indicated that the product ought to have been classified to IMDG Code Class 1 – Explosive substances;
- none of the tests indicated that the product ought to have been classified to IMDG Code Class 4.2 – Substances liable to spontaneous combustion;
- all six trough tests resulted in complete self-sustaining decomposition of the material over the entire length of the trough;
- accordingly, this fertilizer should have been classified as 'Ammonium nitrate based fertilizer, UN No 2071, Class 9 – 'Miscellaneous dangerous substances and articles, Group B'.

The result therefore stands in contrast to the findings of the manufacturer, which continuously carried out its own trough tests during the production process. This test was carried out every eight hours according to the documents provided. An average decomposition depth of 10 cm was determined in the 16 documented tests.

During the trough tests carried out at the BAM, six temperature measuring points were installed inside the trough and the first measuring point was in direct contact with the heat source. Temperatures of 380 °C to more than 500 °C were measured at this point during the six tests. At the second measuring point, 10 cm from the heating plate, temperatures of 335 °C to 355 °C ($\bar{\varnothing}=342.7$ °C) were found. At the fourth measuring point, 30 cm from the heating plate, the temperatures were 325 °C to 342 °C ($\bar{\varnothing}=335.2$ °C). At the sixth measuring point, 50 cm from the heating plate, the temperatures were 210 °C to 275 °C ($\bar{\varnothing}=246.3$ °C).

In the course of each test, the change in colour of the reddish raw material was clearly visible. The decomposed material took on a whitish colour (see Figures 63 and 64).

²³ Federal Institute for Materials Research and Testing.



Figure 63: Photo of the trough made ready for the first test

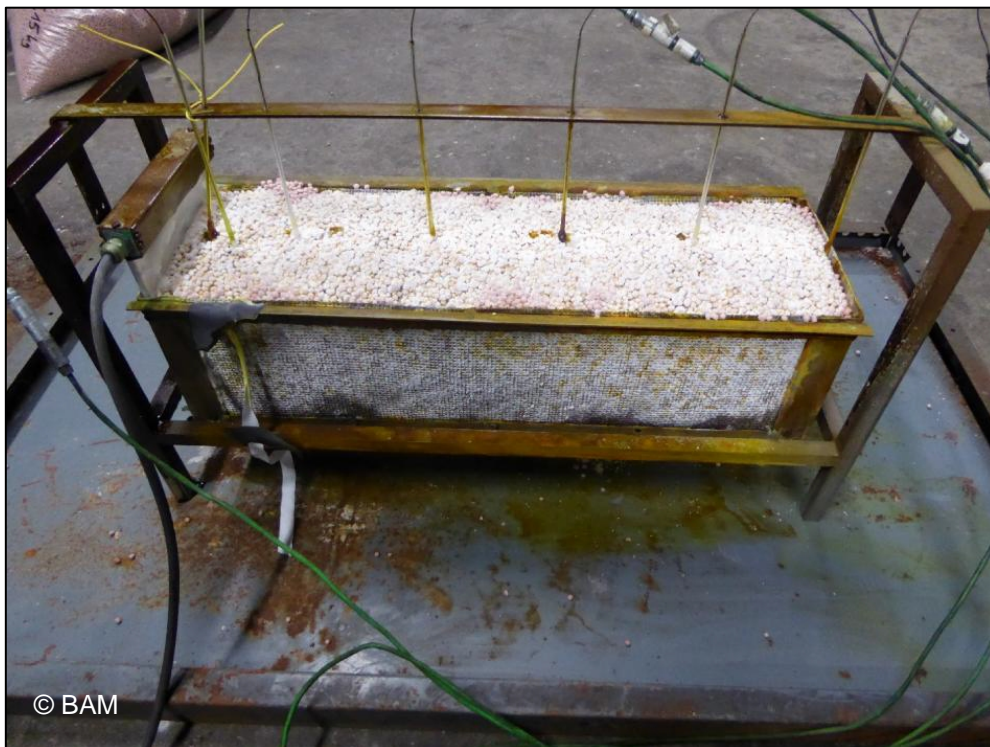


Figure 64: Result of the fifth trough test with fully reacted sample

The investigators and researchers from the BAM jointly considered carrying out another test against the backdrop of the fertilizer possibly coming into contact with or even covering the cargo hold lights. This involved inserting an electric heating

element into the fertilizer. The aim of the test was to establish whether decomposition could be started at temperatures lower than those in the trough test. In contrast to the trough test, the use of a Dewar vessel²⁴ was planned to simulate the adiabatic situation of a covered cargo hold light, which the researchers believe would exist.

In the ensuing test, an electric heating element, which was heated up to 205 °C, was inserted into the middle of a cylindrical Dewar vessel filled with a comparable fertilizer (UN Test S.1 'positive'). A lower temperature was chosen than the highest temperature at the surface of a cargo hold light. Decomposition started after 135 minutes. The resulting temperatures were measured at 129 °C at the bottom, 396 °C in the middle and 372 °C at the top.

The parties involved agreed that the test should be repeated with a sample of the Nitrophoska[®] 15+15+15+2 S transported on the PURPLE BEACH. Since the other parties involved in the test were of the opinion that an adiabatic situation would not be caused if the light was covered, the BSU dispensed with carrying out the test using Nitrophoska[®] 15+15+15+2 S.

Nevertheless, a test that is comparable according to the BAM and BSU indicates that a decomposition reaction can be started at much lower temperatures than those in the trough test when a light is covered.

3.2.9 CCME

During the analysis of the CCME's accident log and the recordings of the ships involved, a number of questions arose which could be clarified in a meeting with representatives of the CCME. This meeting also presented an opportunity to clarify issues arising from a conversation with representatives of the management.

During the meeting, the CCME staff explained the existing difficulties in obtaining and passing on information, as well as in documentation in a comprehensible manner. It was made clear that the OSC has to put aside secondary activities because of the workload during the operation. This can also include the documentation. Since the crew of any vessel supporting the OSC is also under considerable pressure during the operation, little assistance can be provided by crews, either. It also became clear that the operational command, which is not directly at the scene, is dependent on the input and forwarding of information of all involved. There is still room for improvement in this regard.

The representatives of the CCME went on to explain the problems arising from the particular operational situation. Due to the toxic and aggressive gases released, the ships deployed were forced to operate with gas protection.

²⁴ An insulated vessel, also known as a Dewar vessel, reduces the three possible heat transfer processes of conduction, radiation and convection.

This was the only way to move close enough to the PURPLE BEACH to suppress the gas cloud using extinguishing water cannons, to discharge water into the PURPLE BEACH with the help of ship pumps and to set down firefighters directly on board, as transfer by helicopter in chemical protection suits is not possible.

Transfer of the firefighters from the ships operating with gas protection, their carriage and retrieval by crane and conveyor cage and their decontamination necessary after the time spent on board the PURPLE BEACH before retrieval limited the firefighters' deployment to about 15 minutes. Due to these time constraints, but also to keep the risk to the firefighters as low as possible, only simple, rapid and the most promising measures were carried out on board the PURPLE BEACH. In the opinion of the CCME, this ruled out the deployment of personnel not belonging to the fire brigade. The investigators were able to understand this. The firefighters were briefed on the bridge of the NEUWERK before their deployment on board the PURPLE BEACH. All the firefighters deployed were members of units specially trained in fighting ship fires. Inasmuch, the CCME assumes that the activities necessary on board the PURPLE BEACH were carried out properly.

DNV GL's ERS also calculated the flooding of cargo hold 2 in advance. This was due to the fact that there were several indications of a connection between cargo holds 2 and 3 according to information of the CCME. If nothing else, the firefighters on board the PURPLE BEACH had reported about this. Since such information was not available for cargo hold 4, there was no reason to consider flooding this hold.

The amount of water actually discharged into the PURPLE BEACH could only be estimated during the operation because of the ships' current level of equipment. Beyond that, the BSU found the documentation to be of little use. The CCME has recognised the problem and is planning improvements in this regard.

The CCME found the possibility of deploying the ATF from Hamburg Fire Service to be extremely helpful. Remote sensing techniques made it possible to determine the size of the gas cloud and its components even from a greater distance. The ATF's assessment of the hazards and its recommendations were incorporated directly into the decisions of the operational command. Furthermore, the members of the ATF were able to operate the measurement instrumentation on board the multipurpose vessels. This enabled a continuous monitoring of the situation. The CCME is hopeful that the deployment of an ATF will be a calculable component in similar scenarios.

3.2.10 Weather

The wind and sea conditions shown in Spreadsheet 1 prevailed from the day of the accident until the ship was towed to Wilhelmshaven.

Date	Time	Source ²⁵	Air pressure [mbar]	Wind direction	Wind force [Bft]	Sea state [Bft]	Swell height ²⁶ [m]	Temperature [°C]
25/05/2015	1600	PB	1018	W	3	2		16
	2400	PB	1018	WNW	4	3		11
26/05/2015	0800	NW	1015	NW	3	2		11
	1200	PB	1017	NW	4-5			11
	1300	NW		NW	5-6	4-5	1.5-2	
	2400	NW	1022	NW	5-6			10
27/05/2015	0800	NW	1022	W	3-4			10
	1200	PB	1023	WNW	4	3		13
	1200	NW	1023	W	3-4			10
	2400	NW	1016	SW	3-4			11
28/05/2015	0800	NW	1008	SW	6-7		2.5-3	12
	1200	PB	1010	SW	5-6-7	5	Swell W 2	14
	1200	NW	1009	W	6		2.5-3	12
	2400	NW	1012	WSW	5		2	11
29/05/2015	0800	NW	1004	SSW	4-5		1-2	12
	1200	PB	1009	S	4	3-4		15
	1200	NW	1004	S	4-5		1	11
	2400	NW	1000	SW	8		3-4	12
30/05/2015	0800	NW	1006	W	5-6			11
	1200	PB	1010	WSW	5-6	4		11
	1200	NW	1006	W	5-6		2-3	11
	2400	NW	1013	WSW	5		1-2	10
31/05/2015	0800	NW	1011	SSW	5-6		1-2	11
	1200	PB	1007	S	6-7	4	Swell SW 3	14
	1200	NW	1009	S	5			13
	2400	NW	1005	W	5-6		1-2	11
01/06/2015	0800	NW	1012	W	5-6		2-3	11
	1200	PB	1015	SW	4-5	3-4		13
	1200	NW	1012	W	5-6			11

Spreadsheet 1: Overview of the wind and sea conditions

²⁵ PB: PURPLE BEACH, NW: NEUWERK.

²⁶ The swell heights were taken from the recording of the NORDIC.

4 ANALYSIS

4.1 Condition of the ship

The ship was 18 years of age at the time of the accident based upon the date her keel was laid down. The ship was proceeding from Antwerp to Brake equipped with valid papers.

The investigators believe the ship's condition was good. This assessment did not include the transverse bulkhead between cargo holds 2 and 3 in the area of the tween deck. There were found considerable rust penetrations on the port side during the inspection on 26 August 2015. This included the partition walls within the cofferdam and the access trunks to cargo hold 3 and 2. Further observations were made on the aft edge of cargo hold 3 and at the starboard side access trunk in the tween deck at the aft edge of cargo hold 2.

As regards the cause and the time in which the detected small holes and long openings developed (see by way of example figures 31 and 34), the opinions of the BSU and the vessels management differ. The management states that the aggressive fertilizer-water-mixture and the long exposure time caused the rust penetrations and the material shrinkage at the surfaces. Furthermore, the high temperatures occurring during the decomposition of the fertilizer were said to have caused the thermal stress which in turn caused the cracks. Extinguishing water could have possibly entered and increased the stress.

The ships management submitted several documents which were supposed to prove the good condition of the ship. These include ultrasound-thickness measurements dating from 2012, which were made on the occasion of the upcoming class renewal in 2013. However, they do not apply to the affected transverse bulkhead. The material thicknesses were in the usual range and were therefore unobtrusively. Moreover, documents concerning scraping and colouring works in cargo hold 3 were submitted, which were carried out in February 2015 in Houston. In addition, photos taken during other Pre Loading Surveys were provided. On the one hand since the exif-files lacked, it could not be established when the most of the photos were taken. On the other hand, the photos did not show the areas of question. Basically, the Pre Loading Surveys were cited as evidence for the good condition of the vessels cargo holds, since she could not have loaded the cargo. In the opinion of the BSU, the photos available produce evidence to suggest that the vessels hatches were visual generally in a good condition and clean.

Furthermore, the vessels management states that the classification society did not detect any abnormalities during the annual surveys. The survey report dated February 2015 and known to the investigators does only refer to the engine.

The investigators accessed the tween deck of cargo hold 3 initially on 5 August 2015. At this time, no fertilizer-water-mixture was in the tween deck anymore. During this survey, the investigators focused on the cargo stowed there. Therefore the corrosions were only detected during the second inspection of the cargo holds on 26 August 2015.

The BSU did not commission an expert to carry out an examination of the material properties with regard to the detected corrosions.. The investigators assume that the corrosions already existed, at least partly, prior to the accident, and were only covered by paint. This is supported by the seize of the openings/corrosions, the limitation of a local area, and the findings by the fire department concerning the smoke emission and an indefinite substance in the tween deck of cargo hold 2 during the operation on 26 May 2015.

The fire departments report states that the fire fighters squad detected constructive openings with a seize of about 40 x 50 cm in both edges of the tween deck of cargo hold 2 at the transverse bulkhead a cargo hold 3. They were located about 10 cm above the bottom. Yellow smoke emitted from the opening on starboard²⁷. Further constructive openings were equipped with grids²⁸, but unobtrusive. Two double manholes to reach the ladders were also unobtrusive.

Due to the description, the investigators surmise, that the opening emitting smoke is the constructive opening marked green in figure 35.

The firefighters made the following observations in cargo hold 2 during the second operation: Instead of the smoke, a yellow liquid emitted from the constructive opening in the transverse bulkhead. According to the statement made by the firefighting squad, it sounded as if it cooked in the partition wall. Subsequently, the clothing donned during the operation shoed clear yellow discolorations. Therefore it was considered to decontaminate the firefighters deployed on board the vessel.

The vessels management submitted an expertise from the Scandinavian Underwriters Agency Hamburg prepared with regard to this smoke emission. The expertise, inter alia, outlines that the heat in the adjoining cargo hold 3 could have started the formation of smoke in the fertilizer in the lower room of cargo hold 2 or to a smouldering of the paint or other residues in the compartments. In the opinion of the expert, this smoke could have possibly emitted at another site as the vent or the room ladder in the tween deck of cargo hold 2. However, according to the investigators opinion, there were no other connections between the lower room and the tween deck.

²⁷ The investigators assumed a mistake, because the port side was reported via two-way radio.

²⁸ This is related to the ventilation shaft (see figure 19).

In the opinion of the BSU, the assumption that smoke developed in the lower room of cargo hold 2 is not entirely implausible, since the temperatures prevailing there and in the lower room of cargo hold 3, respectively, at this time are unknown. The yellow colour of the smoke and the fact that the firefighters only detected smoke emission at this site and not out of the more obvious vents or the openings of the room ladders, points to the decomposition in cargo hold 3 and the passage of the smoke through the transverse bulkhead. The investigators attribute the emission of the indefinite yellow substance also to the decomposition of the fertilizer in cargo hold 3. Such an advanced decomposition of the fertilizer in cargo hold 2 would have rendered the operation of the firefighters there impossible. The possibility, that cargo residue in the interspaces A and B (s. Figures 35 and 36) of the cofferdam started gassing due to the heat development and later on diluted, cannot be entirely ruled out. Due to the temperatures measured by the firefighters, the investigators are of the opinion that the temperatures in these interspaces did not suffice at this time.

In Summary, the BSU is of the opinion, that at least smaller openings in the form of corrosions in the transverse bulkhead between cargo hold 3 and 2 existed at the time of the firefighting operation in cargo hold 2. In the opinion of the investigators, these were located in the area shown in figure 31, 36 and 51, respectively. Possibly, they were concealed under a loose adhesive colour coat and were therefore not visible for the crew. The investigators cannot rule out, that the longer openings/cracks (figures 34 and 37) detected during the survey on 26 August 2015 and later on, were caused or increased by thermal stress. In the opinion of the investigators, the openings formed in the transverse bulkhead in the course of the accident on 25 May 2015, were sufficient to emit smoke and a substance into the cargo hold 2.

The investigators estimated the total area of the rust penetrations and openings on the basis of the photos made on 26 August 2015 and 12 August 2016 at 157.5 cm². The ship's management, as described earlier, pointed to the aggressive acidic water mixture and its long retention period in cargo hold 3, which must have led to a magnification of the holes. For this reason, the area of openings was degraded to 50% of the original area for the purpose of the calculation. It was assumed that the constriction coefficient was 0.66. According to the numerical estimate the investigators believe that also the reduced scale of the rust penetration when cargo hold 3 was completely flooded by the emergency services, 4,500 t of the 6,500 t of water discharged was able to flow into and ultimately also flood cargo hold 2 to above the level of the tween deck.

In the view of the the ship's management, the flooding of cargo hold 2, if not completely but to a substantial extend, was caused by the fact that the emergency services erroneously also placed fire hoses into the booby hatches of cargo hold 2.

This could have been due to confusing the immediately adjacent booby hatches. The numbering on the booby hatches marked using seam welds were reportedly overlooked in the process.

Furthermore, it was considered possible that water entered via cracks and leaks in the area of cargo hold 2, which could have developed through heat exposure. This possibility was not checked by the BSU during the investigations carried out on board and can therefore not be ruled out completely. In the opinion of the vessel's owner, water could have entered into cargo hold 2 via the hatch covers, the access hatches or the crane posts during the long period of time cooling water was impinged on the PURPLE BEACH with high pressure by the deployed vessels.

4.2 Cargo

4.2.1 Ammonium nitrate based fertilizer (non-hazardous)

In the opinion of the BSU, the attachment “not harmful” is ambiguous and led to many persons involved in the case of PURPLE BEACH drawing false conclusions. Many fertilizers, such as the fertilizers transported in cargo hold 2, 3 and 4, are able to decompose, albeit at different temperatures. That means that a sufficiently heated source of heat can trigger the decomposition. This decomposition continues as long as the source of heat is active. The decomposition process only continues after the removal of the source of heat in self-sustaining fertilizers which are prone to decomposition. The trough-test is used for determining this property. The test offers a standardized comparability. However, the test has only little practical relevance due to the test set-up that means because of the used metal netting for the trough and the associated heat dissipation. A heat source poured in such as a cargo hold lamp, has a much greater effect on the fertilizer because of the non-existent or lower heat dissipation inside the pile and requires less energy and a lower temperature in order to start and sustain decomposition, respectively. Therefore also ammonium nitrate-containing fertilizers which are classified as “not harmful”, are in fact comparable harmful, as long as a corresponding active source of heat exists. Without a particular source of heat, thus at normal stowing temperatures, no ammonium nitrate-containing fertilizer will start a decomposition-process. This behaviour is independent of the stowage period.

4.2.2 Stowage plan

Consideration of the stowage plan only concerns cargo hold 3, as this was where the problems identified accumulated when the chemical reaction started.

With regard to stowage plans of the charterer and/or management, a statement was submitted to the BSU by the legal counsel. This indicated that the charterer of the ship was, on 5 May 2015, already aware that the ship would load Nitrophoska® 15+15+15+2 S in Antwerp, as the chartering agent sent the MSDS on that date.

The charterer also knew that the ship was expected to carry cargo in the tween deck. The cargo was accepted by MACS Cross in consultation with the Sales and Operation departments of the same company. The charterer's cargo stowage planner was responsible for preparing the stowage plan. According to information submitted, the master of the ship was given the charterer's stowage plan proposal and checked/approved it. The investigators assume that the master on board at the time of the accident was not involved in this transaction due to the long timeframe.

According to the statement given by the management, its ISM manual references the relevant provisions for loading. Accordingly, planning, loading, unloading and stowage should generally be carried out in accordance with the regulations of the IMSBC Code, the IMDG Code and SOLAS. In this case, only the rules for non-dangerous cargo have reportedly been applied, however.

The statement also pointed out that, as a general rule, the management of the ship and the charterer would not accept ammonium nitrate based fertilizer classified as dangerous goods for transportation.

4.2.3 Acceptance of the cargo

Acceptance of the entire cargo of fertilizer took place at Antwerp. Disruptions in the acceptance of cargo due to drizzle or rain only occurred on 18 and 19 May 2015 during the loading of cargo hold 2. There were no disruptions during the loading of cargo hold 3's lower hold. In contrast to general cargo, there was only an inspection of cargo hold 2 by an independent cargo surveyor prior to or when the fertilizer was loaded. However, the shipper confirmed in the 'Statement of Loading' that the cargo holds were surveyed upon arrival of the ship ("holds passed inspection"). The investigators consider this to be sufficient.

Bunkering operations were carried out in parallel throughout the loading operation, which involved taking on board HFO, MDO and lubricants. The IMSBC Code prohibits operations of this nature. During the loading of cargo hold 3's lower hold, HFO was bunkered in the fuel tanks below the cargo hold.

The temperature in the bunker tanks was not controlled automatically, i.e. the ship's crew controlled it manually. This means that it is not possible to rule out temperatures in excess of that permissible (50 °C) in the immediate vicinity of the fertilizer loads. This also applies to cargo hold 3's lower hold. In this case, this would mean a violation of the provisions of the IMSBC Code for this type of fertilizer.

During the surveys of cargo hold 3's lower hold by the investigators, that of 21 July 2016 in particular, no evidence was found that would indicate that the decomposition of the fertilizer began at the bottom of the hold. This was evident from the colour difference of the fertilizer in the upper and lower area of the cargo. The granules in the lower area were reddish in colour throughout.

The crew stated that plastic sheets (or tarpaulins) were spread over the fertilizer load after cargo hold 3's lower hold was loaded. However, this was not referenced in the deck log book nor was there any photographic evidence. In this case, the load would have been well protected, as the fertilizer reacts sensitively to contamination with organic substances²⁹. Certain items of general cargo stowed in the tween deck were machine parts that may have been filled with organic or partially organic lubricating oils. Should these substances leak, which is not inconceivable, decomposition would not start. This contamination might have lowered the starting temperature, however.

After completion of the loading of the ship with fertilizers in Antwerp, loading of the general cargo began. The general cargo was loaded in cargo hold 1 and in the tween deck of cargo hold 3. Since the D-rings in cargo hold 3 were not sufficient for securing the load, two additional D-rings were welded onto the aft pontoon hatch cover on the port side and two further D-rings were welded onto the outer side wall in the same area.

According to the schedule for ammonium nitrate based fertilizer (non-hazardous), welding operations may not be carried out in the vicinity of cargo holds carrying this material. There was no fact justifying the exceptional circumstances of the emergency.

On being questioned in this regard, the management stated that the welding operations were organised by the local Supercargo³⁰. The works were reportedly carried out by experienced and qualified crew members under the supervision of the foreman of the company responsible for lashing the cargo. All parties involved reportedly had assumed that the cargo in the lower hold was harmless.

It was not possible to determine whether or how the risk analysis for issuing the permit for the welding operations was carried out because the investigators only became aware of the welding operations after the relevant crew members had returned home. The investigation suggests that the result of the risk analysis was more than doubtful because it appears that not only the binding requirements of the IMSBC Code were ignored. Moreover, the information, notes and warnings handed over to the ship's command by the handling company at the start of loading were also overlooked.

The welding operations for attaching the D-rings were carried out in the immediate vicinity of the cargo. One of the D-rings was attached at a distance of 70 cm from the edge of the pontoon hatch cover and one at a distance of 50 cm from the next opening (Figure 28). The D-rings attached to the side wall were also welded on in the immediate vicinity of one edge of the pontoon hatch cover, as it stretched as far as the side wall, where a gap was produced (Figure 29). Accordingly, it was not entirely

²⁹ MSDS for Nitrophoska® 15+15+15+2 S (section 7.2).

³⁰ Consultant of the ship's command for the loading of the ship not belonging to the crew.

unlikely that weld spatter, i.e. glowing metal particles, could have entered the lower hold there. Since these metal particles can exhibit temperatures of 500-1,000 °C, the ensuing hazard was not insignificant. However, no tests were carried out in this regard. The spread out over the fertilizer load would not have prevented a glowing metal particle from entering the fertilizer.

The brochure³¹ of the BGHW³² defines the horizontal range of an area exposed to the risk of fire and explosion as being up to 7.5 m for manual gas and arc welding. The vertical range is indicated as 20 m. Based on that, welding on the D-rings involved considerable risk. This is all the truer given that many reports can be found where welding spatter could cause a fire in remote areas, meaning the amount of energy contained therein was quite sufficient.

The ship's management also stated that the fire expert it had commissioned had ruled out the welding operations as a possible cause. The fire expert argued that even if hot particles had passed through the openings into the lower hold and burnt through the tarpaulin spread out there, the amount of energy contained would hardly have been sufficient to cause the ensuing reaction. The fire expert also reportedly believed that the time span between welding operations and damage was far too long. In the expert's opinion, the damage configuration was not consistent with welding operations possibly causing the decomposition of the fertilizer to start, either. This was indicated by the distribution of the damaged cargo, in particular. The expert assumed, that the tarpaulin placed, did not constitute a barrier for the smoke emission into the tween deck. Furthermore, it was pleaded that the cargo hold was accessed by crewmembers during the cleaning work carried out in the late morning of the day of the accident. However, they did not notice any abnormal odour.

The ship's management's fire expert's opinion that the time span between welding operations and damage is reportedly far too long cannot be followed insofar as the start of the decomposition need not have coincided with the time of detection by the crew. Assuming the lashing and associated welding operations were completed when the loading of cargo hold 3's tween deck was finished at 1133 on 24 May 2015, some 30 hours had passed before detection by the crew. However, it is possible that decomposition initially started on a small scale without being noticed. The sheet spread out over the cargo may also have prevented faster detection and produced a situation in which only little or no heat was exchanged with the environment, thus promoting the decomposition. The sheet and the shape of the base of the pontoon hatch covers may also have prevented the spread of smoke

³¹ BGHW-Prävention (publ.): Brandschutz bei feuergefährlichen Arbeiten (BGI 563) (fire safety during hot work). In BGHW-Kompakt No. 19, 2010.

³² Berufsgenossenschaft Handel und Warenlogistik (employers' liability insurance association for trade and logistics).

Moreover, the smoke detection system, at least for cargo hold 3 and 2, was potentially out of order, therefore, a smoke emission could not be detected.

However, the investigators have no knowledge of comparable long-term tests or tests on starting decomposition with the smallest of heat sources in an adiabatic situation.

During the investigation no indication was found concerning the operational capability of the smoke detection system for the cargo holds at the time leaving the berth in Antwerp or concerning the reasons for the malfunction of the lines for cargo hold 3 at the time of the accident. Also the state of knowledge of the crew was remained unknown by BSU.

4.2.4 Cargo hold lightning

It was not possible to clarify what the switch positions on the control panel for the cargo hold lighting were during the investigation. This applies to the key switches under the locked cover, in particular. Basically, it would have been possible to switch off the power supply to all the lower holds at the control panel with the key switches, to switch on the tween decks and access trunks, and then to lock this area with the cover. Above the cover, only the tween decks and access trunks could have then been switched on by every crew member. Since the lighting in the hatch access trunks was relatively weak and no direct contact with the fertilizers prevailed there, the risk associated with the various fertilizer loads would have been relatively low. However, since the cargo hold hatch covers were opened in order to provide lighting and ventilation for cleaning works, all cargo hold lighting options could have been deactivated using the key switches. The investigators were not able to make any findings with regard to the crew's access to the keys for the key switches or the key for the lock on the key switch cover.

Alternatively, due to the danger posed by the hot halogen spotlights used as cargo hold lighting, the entire cargo hold lighting could have been switched off using the master switch installed on the bridge. The investigators assumed that this option was not made use of, because the firefighter's observed that the entrance lighting in cargo hold 2 was switched on.

In principle, it can be determined, that the halogen spot lights generally pose a risk due to the high temperatures developing on its surface. As a consequence, the safety-related requirement can be derived to only use lamps with a limited surface temperature in cargo holds.

The finding of the firefighters with regard to the lighting being switched on in the access trunks for cargo hold 2 does not allow any conclusions to be drawn about the lighting situation in cargo hold 3 (and that of cargo hold 3's lower hold, in particular). It is noteworthy, however, that this lighting was switched on, as the firefighters entered the cargo hold 2, despite the assurances of the ship's command that the cargo holds were disconnected from the power supply. This applies all the more given that the master had instructed a crew member to remove the fuses for the electrical circuits of the cargo holds after the fertilizer started to decompose. The investigators also regard this fact as an indication that this did not happen before they started or when they finished loading the fertilizers, as otherwise it would no longer have been necessary.

4.2.5 Stowing over the pontoon hatch covers

The schedule for Nitrophoska[®] 15+15+15+2 S states that it may be necessary to open the cargo holds in the event of fire³³ to achieve maximum ventilation. The "General guide to the sea-transport and handling of compound fertilizers" (Annex 9.6), which was provided to the ships command by the manufacturer, recommends the opening of the affected cargo hold as well. In the tween deck of cargo hold 3, cargo was stowed over two pontoon hatch covers on the port side such that they could not have been opened. A third cover was at least partially obstructed by supporting lumber, which protruded onto it (Figure 13). This meant that only one cover could actually be moved freely. On the starboard side, two hatch covers were obstructed by the cargo stowed there.

In its statement, the ship's management expressed the opinion that sufficient air exchange could have taken place through the void spaces between the pontoon hatch covers and their lateral supports and that they could also have provided a route for the extinguishing water to enter the lower hold. Furthermore, it would be normal to always have the pontoon hatch covers in place because of the positive effect on the hull's strength. The investigators can only follow this reasoning in part. Although the IMSBC Code does not require that hatches be opened, which can also only apply to tween deck hatches, maximum ventilation and heat dissipation in the event of an incident is only possible when they are completely open. The investigators believe this can only be achieved if all pontoon hatch covers can be opened.

The 'General guide to the sea-transport and handling of compound fertilizers' (Point 3.2.8.2) recommends furthermore the removal of smaller quantities of decomposing cargo. This is only possible when the hatches are open, since this is the only way to obtain a nearly unobstructed view over the surface of the cargo. The targeted application of water or use of water lances is also only possible with the hatch covers open.

³³ The investigators assume that decomposition is being referred to here.

Laying sheeting on the surface of the fertilizer was understandable against the background of preventing the fertilizer from becoming contaminated. However, this was counterproductive in respect of ventilation, heat dissipation, fighting fires or the substance's incipient decomposition.

The investigators do not believe that the use of pontoon hatch covers influences the strength of the hull, as this does not produce a rigid connection. The opinion of the investigators is supported by the fact that according to the general arrangement plan, in between, for example. The classification society of the vessel shares the same opinion.

In principle, the BSU is of the opinion that tween decks with hatch covers that cannot be moved automatically by electric or hydraulic drives should always be open. This is the only way to ensure that tween decks can be opened to allow maximum ventilation or heat dissipation in rough seas, too. Furthermore, this is the only way to stop a fire or an incipient decomposition at an early stage with selective measures.

4.3 Course of the voyage

The voyage proceeded under moderate conditions up until the deep water roadstead. The deck log book recorded westerly winds of 4 Bft and 3 Bft for 24 May 2015 and 25 May 2015, respectively. This may have meant that the hatch covers of all cargo holds were not secured in a seaworthy manner. This did not have any influence on the further course of events or start of a chemical reaction, however.

4.4 Cargo hold lights

Class T4 cargo hold lights are reportedly installed on the PURPLE BEACH, meaning their surface temperature should not exceed 135 °C³⁴. Measurements on the comparison light revealed temperatures of more than 200 °C and the light source's output was 750 watts. In the opinion of the investigators, it cannot be ruled out that the cargo hold lights installed in cargo hold 3's lower hold exhibit a similar characteristic. On one hand, this would mean that the temperatures on their surface may have been above the permitted temperatures specified in the document and, on the other hand, above 130 °C, at which dangerous decomposition gases are released according to the Nitrophoska[®] 15+15+15+2 S MSDS.

The investigators found no indication concerning the manufacturer, the type of the lamp or information concerning the technical features or protection classes on any of the inspected cargo hold lamps.

³⁴ Document of compliance for the carriage of solid bulk cargoes, Appendix: List of equipment. (See also section 3.2.1.)

The investigation did not reveal any evidence of short circuits in the electrical components belonging to the lighting in cargo hold 3's lower hold. Similarly, no evidence was found that would suggest the lights in cargo hold 3's lower hold were switched on at any time prior to the accident during the voyage from Antwerp to Brake. Only the traces of intense heat visible in Figure 42 in the area below the longitudinal beam at the aft end of cargo hold 3's lower hold, and thus below the installation site of the cargo hold light, could be an indication. However, the cargo hold light installed there was not found. It also remains unclear why both cargo hold lights were no longer at their installation site or why one of the lights had fallen into the cargo.

4.5 Discovery of the fire and actions of the crew

The term fire is used here because the crew evidently assumed there was a fire, at least during the initial phase. It is not clear how long this assumption persisted, however. According to the cargo manifest, none of the items of general cargo in the tween deck of cargo hold 3 posed a particular fire hazard and no dangerous goods were loaded there.

In fact, the occurrence at the PURPLE BEACH was not a fire. The removal of oxygen, for example by the use of CO₂, leads not to a stop of the exothermal self-sustaining decomposition. But in a case of a fire this would be happen.

The fire was detected by the crew visibly. The measures then taken by the crew, i.e. the establishment of watertight integrity, the attempts at clarification, and the deployment of fire hoses for cooling the area were appropriate to the situation.

It is possible that a conclusion might have been drawn about the real cause of the smoke after the aborted attempt to enter cargo hold 3. This obviously did not happen because the ship's command decided to discharge CO₂ after liaising with the DPA.

The investigation could not establish why the ship's command only informed an agency on the German coast about the events on board two and a half hours after starting to discharge CO₂ into cargo hold 3. In the opinion of the BSU, the DPA would also have had a duty to notify.

The investigators believe that the crew of the PURPLE BEACH was sufficiently qualified and experienced to recognise the risks the transportation of fertilizers involve and to act in accordance with the rules and regulations. The firefighting measures were started in a practised manner. It seems that deficits then occurred during the identification of the actual cause of smoke and the initial communication with the competent agencies on the German coast (see section 4.5).

During the master's phone conversations, he repeatedly pointed out that the smoke development would be indicative of a decomposition process within the fertilizer (so even on 25 May 2015, 1804) but that this was reportedly not possible according to the papers. The investigators have little indication of what information the ship's command was referring to. The documents provided by the product's manufacturer were found on the master's desk during the first survey of the ship, however (Annexes 9.2 to 9.6). One of these documents did actually point out that the product was reportedly not flammable³⁵. See the cargo information submitted by the manufacturer (Annex 9.5 – paragraph: Instructions or other matters), for example. The investigators therefore consider it likely that the ship's command did not clearly recognise the differences between the possible events of fire and decomposition.

The schedule for ammonium nitrate based fertilizer (non-hazardous) would also have been of little help here. Although the 'Hazard' section points to the risk of cargo decomposition due to excessive heating, the 'Emergency procedures' only address the occurrence of fire and make no mention of possible decomposition.

In the phone conversations, the master justified the use of CO₂ by stating that he feared that opening the hatch covers of cargo hold 3 and the ensuing influx of oxygen would ignite the fire. This is another indication of the processes in cargo hold 3 being misunderstood.

The ship's command rejected a survey of cargo hold 3 by crew members as this might place crew members at risk. This is understandable given the circumstances. Since the hatch covers were not open, it is safe to say that the smoke density in the cargo hold was such that a survey was impossible. Due to the closed hatch covers in the tween deck, i.e. no direct view of the cargo there, the gain in knowledge would probably have only been marginal, too.

4.6 Subsequent developments

Subsequent developments ashore were initially marked by gathering and distributing information within the relevant VTSs and the Maritime Security Centre. The unusual flow of the initial information from the ship's command to the pilots may have caused a somewhat faltering start. The well-established communication channels were used later.

The BSU believes it was logical to involve the CCME in the on-scene investigation on board the PURPLE BEACH, as this is the only agency that possessed and possesses the appropriate emergency personnel and resources. The assumption of overall command of the operation should also be viewed in this context.

³⁵ Also in the schedule for ammonium nitrate based fertilizer (non-hazardous)

The FFT arrived on board the PURPLE BEACH and started its work there about 7.5 hours after VTS Bremerhaven became aware of the accident.

The investigators believe that the recommendation of the fire service's operational command (or OSC) subsequently made to the ship's command of the PURPLE BEACH (to abandon the ship) was logical given the prevailing situation. Considering the amount of smoke that subsequently prevailed and its material composition, the crew would have been endangered beyond all measure had it remained on board. Since the ship's superstructure could not be sealed gas-tight, it would have been impossible to stay there.

4.7 Sampling of the fertilizer at the BAM

In the course of the testing at the BAM, all samples with Nitrophoska[®] 15+15+15+2 S reacted over the entire length of the sample vessel. This was a surprise and not consistent with the results of tests carried out by the manufacturer during the actual manufacturing process. As a result, the BAM's testing confirmed the behaviour of the fertilizer in cargo hold 3's lower hold, as exothermal self-sustaining decomposition followed after the fertilizer started to decompose.

The manufacturer of the Nitrophoska[®] 15+15+15+2 S fertilizer was asked via its legal counsel to submit the results of its investigation into the product's changed behaviour during the trough tests at the BAM. The manufacturer explained in his statement on the draft that the fertilizer, based on the trough test during manufacturing of the relevant product, was not capable of SSD³⁶ at the time of the incident. However, with time, the product can change its properties, thereby making a non-SSD fertilizer capable of SSD. This is the explanation for the BAM results showing that the fertilizer was capable of SSD. At the time the BAM tests were carried out, the fertilizer properties had changed, since the BAM test took place some 9 months after production.

4.8 CCME

The BSU believes that the capability of the multi-purpose ships to operate with gas protection was one of the key prerequisites for a successful operation. Only this enabled the vessels to operate in the immediate vicinity of or go alongside the PURPLE BEACH.

During a conversation with the BSU, the CCME emphasised the importance of the OSC, who guarantees the cooperation of all personnel with his expertise and decision-making authority at the scene. However, the CCME also explained his workload during the operation. Shortcomings in the mission records could be attributed to that.

³⁶ Self-sustaining decomposition.

The CCME believes that improved staffing would result both in the OSC role being carried out in every operation and in an assistant commander being assigned to the OSC in particular future scenarios.

5 CONCLUSIONS

5.1 Rust penetration

The rust penetration found impaired the safety of the ship because the watertight joint between cargo holds 2 and 3 no longer fully existed. The investigators assume that the scale of the rust penetration and openings caused by heat exposure were responsible for the massive transfer of water to cargo hold 2 in the further course of the event. This ultimately led to the fluid equalising between cargo holds 2 and 3. On the other hand, other causes for the water entry in cargo hold 2, like extinguishing water through hatch covers, booby hatches and hidden cracks, cannot be excluded completely.

The investigators have no reliable evidence that would suggest the ship's command was aware of the rust penetration. At least at the date of inspection three month after the accident, the rust penetration had taken on a scale that made it clearly visible.

The investigators took note of the ships owner's statements with regard to the condition of the transverse bulkhead between cargo hold 3 and 2. In hindsight, the investigators could actually not determine the size of the corrosion with certainty. This also applies to perceptibility of the condition by the crew. Possibly the holes were covered with paint. However, the ascertainments of the fire department with regard to the emission of smoke and a substance through the transverse bulkhead are self-explanatory and are an indication for the investigators that there existed a connection through the transverse bulkhead at this time.

5.2 Cargo

5.2.1 Stowage plan

The BSU believes it is reasonable to assume that the ship's charterer and the ship's management were aware of the properties and associated stowage regulations of Nitrophoska[®] 15+15+15+2 S. However, the statement indicates that all parties involved assumed the cargo was harmless. This assumption may have been supported by the substance's classification under Group C of the IMSBC Code. Basic classification under Group B would have marked the cargo more clearly as a substance presenting the risk of a chemical reaction. In addition, the description of the goods on the page of the schedule containing ammonium nitrate based fertilizers **(non-hazardous)**³⁷ may cause the substance to be underestimated.

However, the investigators find it incomprehensible that the charterer and/or the management, with obvious knowledge of the stowage regulations for ammonium nitrate based fertilizer (non-hazardous), provided the master with a stowage plan for approval, which the investigators believe could not have been approved because it violated the stowage regulations of the IMSBC Code due to the pontoon hatch covers being stowed over.

³⁷ Hervorhebung durch die BSU.

In the opinion of the investigators, responsibility was thus transferred to the weakest link in the decision-making chain. It appears that the system of shared responsibility of the ship's command and ship's management, in the sense of the International Safety Management Code (ISM), has vulnerability in this area.

5.2.2 Stowing over the pontoon hatch covers

Stowing over the pontoon hatch covers meant that in the event of a chemical reaction in the cargo, it would neither be possible to ventilate the cargo sufficiently to dissipate the heat generated nor implement targeted control of the exothermic self-sustaining decomposition. In this case, it is also conceivable that earlier detection of the incipient exothermic self-sustaining decomposition was prevented as a result. Early detection may also have been prevented by the sheeting that was laid out.

In the opinion of the BSU, the reasoning in the statement with regard to improving the strength of the hull with pontoon hatch covers inserted does not hold water. The classification society shares the view. The investigators can understand the reasons for leaving the pontoon hatch covers from a commercial perspective, as this is time consuming and may block other stowage spaces. On the other hand, the investigators know how difficult and dangerous moving pontoon hatch covers is in rough seas, which may become necessary if the surface of the cargo has to be reached in an emergency situation to carry out local measurements to stop a chemical reaction.

Accordingly, the BSU believes that the IMSBC Code's formulation is rather impractical: "[...] hatches of the cargo spaces [...] shall be kept free to be capable of being opened in case of an emergency." This is at least true if unpowered tween deck hatch covers are on board. A more stringent requirement should be made here.

5.2.3 Acceptance of the cargo

Since fuel was bunkered during the loading of cargo holds 2 and 3, the provisions of the IMSBC Code were not observed sufficiently during the acceptance of the cargo, either. The ship's command should have been more resolute in ensuring compliance. However, the investigators assume that the decomposition was neither started by the fuel oil tanks underneath cargo hold 3 nor by the bunker procedures into these tanks.

The investigators believe that welding on D-rings in the tween deck of cargo hold 3 represented a potential hazard and was not in compliance with the requirements of the IMSBC Code. It is evident that the crew also contravened the requirements of the ISM Code when the permit for welding operations was issued. Due to the design of the pontoon hatch covers and the laid out sheeting, there was little opportunity to

check any possible effects the welding might have on the fertilizer load during supervision of the work.

The investigators assume that the aspirating smoke detection system was out of order at the time the accident started, at least for the cargo holds 2 and 3. This prevented an early warning of the crew and thereby the initiation of timely actions to end the already started self-sustaining exothermal decomposition.

5.2.4 Fertilizer in cargo hold 3

The manufacturer tested the Nitrophoska® 15+15+15+2 S fertilizer transported in cargo hold 3 continuously during the production process. In no case was a result achieved that would have led to dangerous goods classification. Nevertheless, the product on board the PURPLE BEACH would have been classified as dangerous goods based on the result of the BAM's testing.

The sample taken from the stowed pile for the test carried out at the BAM premises originated from the same batch as the cargo on board the PURPLE BEACH. While taking the sample, the manufacturer did not point to the fact that the product properties changed during the stowage or could have changed. The explanation of the manufacturer within the scope of the statement with regard to the change of the product properties due to the period of stowage, took the BSU therefor by surprise. The explanation possibly points to a quality assurance issue. The BSU assumes that an independent test carried out immediately before shipment would have served the purpose of quality assurance and provided all parties involved with the necessary certainty.

5.3 Actions of the crew

The crew's decision to stop the incipient exothermic decomposition of the fertilizer in cargo hold 3 by means of CO₂ was not appropriate. The BSU believes that a more critical and attentive examination of the documents available to the ship's command (IMSBC Code and documents provided by manufacturer) would have made it possible to deduce the actual cause of the smoke development. In this case, CO₂ would not have been used and the crew would probably have opened the hatch covers and discharged water at an earlier point in time.

The BSU believes that the documents available to the ship's command concerning the ammonium nitrate based fertilizer in cargo hold 3 from the IMSBC Code and the documents provided by the manufacturer were comprehensive and presented all aspects in sufficient detail.

However, the information of relevance to the ship's command in this specific case from the IMSBC Code was not sufficiently identifiable or misleading, e.g. the 'Emergency action in the event of fire' in the schedule for ammonium nitrate based fertilizers (non-hazardous). The investigators suggest a more distinctive presentation, which seems to make more sense especially in situations where a ship's command is under great pressure to make decisions. The following formulation would be more helpful, for example: "Heavy smoke from the fertilizer load is indicative of a

decomposition. The use of CO₂ is futile. Open the hatches for heat dissipation and use water to stop the decomposition." In the investigators opinion is the use of the keywords "emergency actions in the event of fire" worthy of improvement, as decomposition is not a fire.

5.4 Cargo hold lights

In the opinion of the investigators, it is reasonable to assume that the cargo hold lights did not comply with the approved specification³⁸, as the temperatures found on them were too high.

³⁸ Document of Compliance for the Carriage of Solid Bulk Cargoes with Appendix: List of Equipment.

6 Actions taken

The CCME advised that fire main flow meters will be an integral part of the equipment on the multi-purpose ship replacements planned.

The Federal Ministry of Transport and Digital Infrastructure stated that multipurpose vessels are as a standard equipped with a gas detection system and that this also applies for vessels to be procured in the future.

Therefore it was dispensed with a safety recommendation with respect to the aforementioned issues.

7 SAFETY RECOMMENDATION(S)

The following safety recommendations do not constitute a presumption of blame or liability in respect of type, number or sequence.

7.1 Management: Vineta Bereederungsgesellschaft

The Federal Bureau of Maritime Casualty Investigation recommends that the ship's management alter its ISM system with regard to sensitive cargo to avoid future violations of the requirements of the IMSBC Code for stowing over hatch covers that should be kept accessible, for welding in the vicinity of substances listed therein and for the acceptance of fuel while certain cargoes are being loaded or unloaded.

7.2 Management: Vineta Bereederungsgesellschaft

The Federal Bureau of Maritime Casualty Investigation recommends that the ship's management inspect the cargo hold lights installed on its ships, so as to ensure they comply with the specifications set out in the Annex to the List of Equipment of the Document of Compliance for the Carriage of Solid Bulk Cargoes.

7.3 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI urge the appropriate committees of the International Maritime Organization (IMO) to classify ammonium nitrate based fertilizers (non-hazardous) under Group B, so as to highlight the hazards associated with them more clearly.

7.4 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI urge the appropriate committees of the International Maritime Organization (IMO) to ensure that in addition to the manufacturer's product description, ammonium nitrate based fertilizers also be clearly described with regard to dangerous components, such as chloride and phosphate, to provide for better identification.

7.5 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI urge the appropriate committees of the International Maritime Organization (IMO) to ensure that the result of a current trough test (as per UN Manual of Tests and Criteria, part III, subsection 38.2) be provided to masters or their representative before loading.

7.6 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI urge the appropriate committees of the International Maritime Organization (IMO) to ensure that the solid bulk cargo definition suffix 'non-hazardous' be deleted because it fails to account for the hazards actually posed during loading and carriage sufficiently.

7.7 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI urge the appropriate committees of the International Maritime Organization (IMO) to ensure that unpowered tween deck hatch covers always be open to ensure maximum ventilation and heat dissipation even under adverse conditions.

7.8 Federal Ministry of Transport and Digital Infrastructure (BMVI)

The Federal Bureau of Maritime Casualty Investigation recommends that the BMVI ensure the CCME has the necessary to fill the role of OSC in every operation and the role of assistant commander in particular operations.

7.9 Fertilizer manufacturer

The Federal Bureau of Maritime Casualty Investigation recommends that EuroChem Agro GmbH carry out a trough test as part of its quality assurance before each ammonium nitrate based fertilizer (non-hazardous) shipment.

8 SOURCES

- Investigations of WSP Wilhelmshaven
- Written explanations/submissions:
 - Ship's command and other crew members
 - Ship's management
- Witness testimony
- Opinion of the Federal Institute for Materials Research and Testing; one other test report
- Opinion of Messrs Brookes Bell submitted by the ship's management
- Navigational chart of the BSH
- Recordings of VTSs Wilhelmshaven and Bremerhaven relating to this case
- Accident log of the CCME
- Log books and recordings of the ships NEUWERK, MELLUM and NORDIC
- Mission reports of Cuxhaven and Bremerhaven fire services
- Minutes of the periodic meetings of the involved administrative bodies, companies and ship's management
- International Maritime Solid Bulk Cargoes Code (IMSBC Code) (MSC.268(85), as last amended in 2015 by Resolution MSC.393(95) (Gazette of the BMVI, 2015, p. 789).
- International Dangerous Goods Code (IMDG Code), as last amended by Resolution MSC.406(96) (Gazette of the BMVI, 2016, p. 718).
- Guidance for Sea Transport of Ammonium Nitrate Based Fertilizers of the European Fertilizer Manufacturers Association (2004).
http://www.fertilizerseurope.com/fileadmin/user_upload/publications/tecncial_publications/guidance_techn_documentation/Guidance_for_sea_transport_of_ammonium_nitrate_based_fertilizers.pdf
- UN Manual of Tests and Criteria, part III, subsection 38.2.
- Figures 8-11, 14, 16, 17, 21-62 by the BSU, Figures 13, 15 and 20 by VINETA Bereederungsgesellschaft mbH, Figures 18 and 19 by the police.

9 ANNEXES

9.1 Schedule

AMMONIUM NITRATE BASED FERTILIZER (non-hazardous)														
<p>Ammonium nitrate based fertilizers transported in conditions mentioned in this schedule are uniform mixtures containing ammonium nitrate as the main ingredient within the following composition limits:</p> <ol style="list-style-type: none"> .1 not more than 70% ammonium nitrate with other inorganic materials; .2 not more than 80% ammonium nitrate mixed with calcium carbonate and/or dolomite and/or mineral calcium sulphate and not more than 0.4% total combustible organic material calculated as carbon; .3 nitrogen type ammonium nitrate based fertilizers containing mixtures of ammonium nitrate and ammonium sulphate with not more than 45% ammonium nitrate and not more than 0.4% total combustible organic material calculated as carbon; and .4 uniform ammonium nitrate based fertilizer mixtures of nitrogen, phosphate or potash, containing not more than 70% ammonium nitrate and not more than 0.4% total combustible organic material calculated as carbon or with not more than 45% ammonium nitrate and unrestricted combustible material. Fertilizers within these composition limits are not subject to the provisions of this schedule when shown by a 'trough test' that they are liable to self sustaining decomposition or if they contain an excess of nitrate greater than 10% by mass. 														
<p>Description Crystals, granules or prills non-cohesive when dry. Wholly or partly soluble in water.</p>														
<p>Notes:</p> <ol style="list-style-type: none"> 1. All nitrate ions for which there is present in the mixture a molecular equivalent of ammonium ions should be calculated as ammonium nitrate. 2. The transport of ammonium nitrate materials which are liable to self-heating sufficient to initiate decomposition is prohibited. 3. The NPK proportions for a fertilizer should not be used as a guide to its ability to undergo self-sustaining decomposition as this depends on the chemical species present (refer to UN Manual of Tests and Criteria, part III, subsection 38.2). 4. This schedule may only be used for substances that do not exhibit explosive properties of class 1 when tested in accordance to Test Series 1 and 2 of class 1 (see UN Manual of Tests and Criteria, part I). 5. This schedule may only be used if the chemical or physical properties of an ammonium nitrate based fertilizer are such that when tested it does not meet the established defining criteria of any class. 														
<p>Characteristics</p> <table border="1"> <thead> <tr> <th>Angle of repose</th> <th>Bulk density (kg/m³)</th> <th>Stowage factor (m³/t)</th> </tr> </thead> <tbody> <tr> <td>27° to 42°</td> <td>1000 to 1200</td> <td>0.83 to 1.00</td> </tr> <tr> <th>Size</th> <th>Class</th> <th>Group</th> </tr> <tr> <td>1 to 4 mm</td> <td>Not applicable</td> <td>C</td> </tr> </tbody> </table>			Angle of repose	Bulk density (kg/m ³)	Stowage factor (m ³ /t)	27° to 42°	1000 to 1200	0.83 to 1.00	Size	Class	Group	1 to 4 mm	Not applicable	C
Angle of repose	Bulk density (kg/m ³)	Stowage factor (m ³ /t)												
27° to 42°	1000 to 1200	0.83 to 1.00												
Size	Class	Group												
1 to 4 mm	Not applicable	C												
<p>Hazard This cargo is non combustible or has a low fire risk. Even though this cargo is classified as non-hazardous, some of the properties of the ammonium nitrate based fertilizer classified in class 9 under UN 2071 are exhibited when heated strongly. When this cargo is heated strongly, it will decompose and give off toxic gases with the risk of toxic fumes in the cargo space, adjacent spaces and on deck. Monitoring of the cargo temperature may give an early indication of decomposition. Fertilizer dust might be irritating to skin and mucous membranes. It is hygroscopic cargo and will cake if wet.</p>														
<p>* See UN Manual of Tests and Criteria, part III, subsection 38.2.</p>														

Figure 65: Ammonium nitrate based fertilizer (non-hazardous), page 1

Stowage & segregation

The compatibility of non-hazardous ammonium nitrate based fertilizers with other materials which may be stowed in the same cargo space should be considered before loading.

"Separated from" sources of heat or ignition (see also Loading).

Not to be stowed immediately adjacent to any tank, double bottom or pipe containing heated fuel oil unless there are means to monitor and control the temperature so that it does not exceed 50°C. Fertilizers of this type shall be stowed out of direct contact with a metal engine-room boundary. This may be done, for example, by using flame-retardant bags containing inert materials or by any equivalent arrangement approved by the competent authority. This requirement need not apply if the bulkhead is class A-60 or to short international voyages.

Hold cleanliness

Clean and dry as relevant to the hazards of the cargo.

Weather precautions

This cargo shall be kept as dry as practicable. This cargo shall not be handled during precipitation. During handling of this cargo all non-working hatches of the cargo spaces into which this cargo is loaded or to be loaded shall be closed.

Loading

Trim in accordance with the relevant provisions required under sections 4, 5 and 6 of the Code.

Prior to loading, the following provisions shall be complied with:

- All electrical equipment, other than that of approved intrinsically safe type, in the cargo spaces to be used for this cargo shall be electrically disconnected from the power source, by appropriate means other than a fuse, at a point external to the space. This situation shall be maintained while the cargo is on board.
- Due consideration shall be paid to the possible need to open hatches in case of fire to provide maximum ventilation and to apply water in an emergency and the consequent risk to the stability of the ship through fluidization of the cargo.
- In addition, if decomposition occurs, the residue left after decomposition may have only half the mass of the original cargo. Due consideration shall be paid to the effect of the loss of mass on the stability of the ship.

During loading, the following provisions shall be complied with:

Bunkering of fuel oil shall not be allowed. Pumping of fuel oil in spaces adjacent to the cargo spaces for this cargo, other than the engine-room, shall not be allowed.

Precautions

No welding, burning, cutting or other operations involving the use of fire, open flame, spark- or arc-producing equipment shall be carried out in the vicinity of the cargo spaces containing this cargo except in an emergency. The master and officers are to note that the ship's fixed gas fire-fighting installation will be ineffective on fires involving this cargo and that applying copious amount of water may be necessary. Smoking shall not be allowed on deck and in the cargo spaces and "NO SMOKING" signs shall be displayed on deck whenever this cargo is on board. The hatches of the cargo spaces, whenever this material is on board, shall be kept free to be capable of being opened in case of an emergency.

Appropriate precautions shall be taken to protect machinery and accommodation spaces from the dust of the cargo. Bilge wells of the cargo spaces shall be protected from ingress of the cargo. Due consideration shall be paid to protect equipment from the dust of the cargo. Persons who may be exposed to the dust of the cargo shall wear goggles or other equivalent dust eye-protection and dust filter masks. Those persons shall wear protective clothing, as necessary.

Ventilation

The cargo spaces carrying this cargo shall not be ventilated during voyage.

Figure 66: Ammonium nitrate based fertilizer (non-hazardous), page 2

<p>Carriage Hatches of the cargo spaces carrying this cargo shall be weathertight to prevent the ingress of water.</p> <p>Discharge Bunkering of fuel oil shall not be allowed. Pumping of fuel oil in spaces adjacent to the cargo spaces for this cargo, other than the engine-room, shall not be allowed. Ammonium nitrate based fertilizers are hygroscopic and may cake in overhangs, impairing safety during discharge. If this cargo has hardened, it shall be trimmed to avoid the formation of overhangs, as necessary.</p> <p>Clean-up After discharge of this cargo, the bilge wells and the scuppers of the cargo spaces shall be checked and any blockage in the bilge wells and the scuppers shall be removed.</p> <p>Emergency procedures</p>
<p>Special emergency equipment to be carried</p> <p>Protective clothing (boots, gloves, coveralls, and headgear). Self-contained breathing apparatus.</p>
<p>Emergency procedures</p> <p>Wear protective clothing and self-contained breathing apparatus.</p> <p>Emergency action in the event of fire</p> <p>Fire in a cargo space containing this material: Open hatches to provide maximum ventilation. Ship's fixed gas fire-extinguishing installation will be inadequate. Use copious quantities of water and isolate the source of heat, if any. Flooding of the cargo space may be considered but due consideration should be given to stability.</p> <p>Fire in an adjacent cargo space: Open hatches to provide maximum ventilation. Heat transferred from fire in an adjacent space can cause the material to decompose with consequent evolution of toxic fumes. Dividing bulkheads should be cooled.</p> <p>Medical First Aid</p> <p>Refer to the Medical First Aid Guide (MFA), as amended.</p>

Figure 67: Ammonium nitrate based fertilizer (non-hazardous), page 3

9.2 List of the papers submitted to the ship's command



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To the master of mv ".....PURPLE BEACH....."

Concerning : loading of NPK Compound Fertilizers at EuroChem Antwerpen NV, not regulated under the provisions of the IMSBC code.

I, master of the mv ".....PURPLE BEACH....." declare herewith having received from messrs. EuroChem Antwerpen NV, the following documents :

- Information for crew members.....
- Emergency plan for crew members.....
- Cargo Information.....
- General guide to the sea-transport and handling of compound fertilizers
- Do's and don't's with fertilizers
- MSDS
- Mooring arrangements & document removing domestic waste.....

Antwerp,

Master's signature :

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Figure 68: List of the papers submitted to the ship's command

The manufacturer of the fertilizer provided the ship's command of the PURPLE BEACH with the papers listed in the document

9.3 Instructions to the ship's crew for the handling of emergencies



What to do in emergencies – for Master's attention
<p>Disclaimer: This information has been issued solely for the charterer's internal use, and may not be relied upon by the owners or any other party as evidence in respect to the condition of the vessel. It may not be construed as a waiver of any of the charterer's rights under the Charter Party, applicable laws and/or conventions.</p>
<p style="text-align: center;">INSTRUCTIONS TO THE SHIP'S CREW FOR THE HANDLING OF EMERGENCIES INVOLVING THE DECOMPOSITION OF AMMONIUM NITRATE BASED FERTILIZERS</p> <ul style="list-style-type: none">• If in port, contact local emergency services.• If at sea, contact ship agent, shipping company or the supplier• Avoid breathing fumes, as they may be toxic• Open hatches immediately to maximise ventilation.• If possible, remove the heat source and extinguish the fire or decomposition.• If possible, remove or separate the decomposing fertilizer material from the rest of the cargo, and drench it with water (salt or fresh).• If not possible to remove or separate, drench the fertilizer in the cargo hold with water (salt or fresh). It is recommended to use water lances to penetrate the crust of decomposed fertilizers.• DO NOT fight the decomposition by using foam, carbon dioxide, steam, sand or fertilizer or by keeping the hatches closed. <div style="display: flex; justify-content: space-around; align-items: center;"><div style="text-align: center;"></div><div style="text-align: center;"></div></div>

Figure 69: Instructions to the ship's crew for the handling of emergencies

9.4 Instructions to the ship's crew concerning avoidance of heat sources


Special warning concerning heat sources – for the Master's attention
<p>Disclaimer: This information has been issued solely for the charterer's internal use, and may not be relied upon by the owners or any other party as evidence in respect to the condition of the vessel. It may not be construed as a waiver of any of the charterer's rights under the Charter Party, applicable laws and/or conventions.</p>
<p style="text-align: center;">INSTRUCTIONS TO THE SHIP'S CREW CONCERNING AVOIDANCE OF HEAT SOURCES WHEN LOADING/UNLOADING AND CARRYING AMMONIUM NITRATE BASED FERTILIZERS</p> <p>All sources of heat must be kept away from ammonium nitrate based fertilizers, regardless of their classification. Potential heat sources are light bulbs, heating systems, steam pipes, electrical motors, live electrical cabling, naked flames, etc.</p> <p>Therefore:</p> <ul style="list-style-type: none">• Switch off all light and heat sources in cargo holds prior to loading and during the whole voyage as long as the fertilizer is onboard.• Remove electric fuses to cargo holds and keep them removed until cargo is unloaded.• Do not allow welding or other hot work that can affect the fertilizer.• Display 'No Smoking' signs. <p style="text-align: center;"></p>

Figure 70: Instructions to the ship's crew concerning avoidance of heat sources

9.5 Cargo information




	
EuroChem Antwerpen N.V. Haven 725 · Scheldelaan 600 · B-2040 Antwerpen 4	
Cargo Information	
BCSN : AMMONIUM NITRATE BASED FERTILIZER (non-hazardous)	
Shipper <i>See B/L</i>	Transport document number
Consignee <i>See B/L</i>	Carrier
Name/means of transport : Port/place of departure : Antwerp	Instructions or other matters <i>The product is incombustible. It can lower the ignition temperature of combustible substances. Keep away from sources of ignition. Keep away from combustible material. Avoid influence of heat. The product will decompose when heated, giving off toxic fumes (s.o. nitrous gases, ammonia, hydrogen chloride). When decomposing : provide ventilation by opening the hatches.</i>
Port/place of destination :	
General description of the cargo (type of material/particle size) Fertilizer (granulated) - Size between 2 and 5mm	
Specifications of bulk cargo Granules-Mainly soluble in water-Bulk density : 1000-1200kg/m³ Stowage factor : 0.83-1m ³ /ton Angle of Repose : Between 30° and 35° Trimming procedure : <i>The product will be spout trimmed.</i>	
Group of the cargo Group C	Transportable moisture limit : N/A Moisture content at shipment : <1.5%vol
Relevant special properties of the cargo Store well away from other substances, especially organic substances. Protect from sunlight. Protect against heat. Decomposition will start from approximately 130°C. Protect against moisture. The product may cake under the influence of moisture. Avoid contact with acid or alkaline substances, ignitable of oxidisable substances. Not harmful to the marine environment.	Additional certificate(s) <input type="checkbox"/> Certificate of moisture content and transportable limit <input type="checkbox"/> Weathering certificate <input type="checkbox"/> Exemption certificate <input type="checkbox"/> Other : None
Declaration I hereby declare that the consignment is fully and accurately described and that the given test results and other specifications are correct to the best of my knowledge and belief and can be considered as representative for the cargo to be loaded.	Name/status, company/organization of signatory EuroChem Antwerpen NV Antwerp  Roland Decker Operations Manager Logistic Services Fertiliers EuroChem Antwerpen NV
EuroChem Antwerpen NV Haven 725, Scheldelaan 600 B-2040 Antwerpen, België Tel: +32-3-681 52 86 Fax: +32-3-681 38 80	RPR Antwerpen B.T.W. - BE 0837.473.452 Deutsche Bank AG Ref. EUR 826-000549-57 IBAN BE 03 3280 0085 4987 BIC DEUTBE33XXX

Figure 71: Manufacturer's cargo information

9.6 General guide to the sea-transport



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General guide to the sea-transport and handling of compound fertilizers

Compound fertilizers
Compound or complex fertilizers (Engrais composés, Mehrnährstoffdünger) are fertilizers which contain more than one of the 3 main nutrients – nitrogen (N), phosphate (P) and potash (K). They include therefore, the NP-, the NK-, the PK-, and the NPK fertilizers.

General information
These fertilizers are neither explosive nor spontaneously flammable. They are usually produced as prills or granules and are delivered as bagged or bulk cargoes. In order to prevent a possible caking or moisture pickup, fertilizers should always be kept dry and protected against humidity. With regard to this, most types of compound fertilizers require no other precaution during handling and transport. The greater part of nitrogen-containing fertilizers contain ammonium nitrate. Under external influence of fire or heat such fertilizers might decompose or smoulder slowly, if heated to temperatures above 130°C. Normally, in these fertilizers the decomposition will cease when the heating stops, most of these fertilizers are regarded non-hazardous (Type C). With some other (Type B) a decomposition reaction will propagate slowly throughout the mass of the fertilizers at temperatures generally in the region of 300-600°C. This phenomenon is called self-sustaining decomposition" (Décomposition auto-entretenu, Schwelzersetzung). If a decomposition takes place, dense, white-yellowish-brown, pungent toxic fume will be released. During the decomposition the weight of the fertilizer will be reduced. The possibility of a decomposition is to be born in mind, especially if material is shipped in bulk. If these basic recommendations described under section "handling and stowage recommendations" are being observed, decomposition will not occur. For compound fertilizers containing ammonium nitrate, which is liable to self-heating sufficiently to initiate a decomposition, transportation is prohibited. For transport, United Nations "Recommendations on Transport of Dangerous Goods" (Orange Book) apply, classifying the two following compound fertilizers as dangerous materials.

<p>Class 5.1 UN 2067 (Type A)</p>	<p>Ammonium Nitrate Fertilizers Uniform non-segregating mixtures of nitrogen/phosphate or nitrogen/potash or complete fertilizers of nitrogen/phosphate/potash type, containing more than 70% but less than 90% Ammonium Nitrate and not more than 0.4% total combustible material.</p>
<p>Class 9 UN 2071 (Type B)</p>	<p>Ammonium Nitrate Fertilizers Uniform non-segregating mixtures of nitrogen/phosphate or nitrogen/potash or complete fertilizers of nitrogen/phosphate/potash type, containing not more than 70% Ammonium Nitrate and not more than 0.4% total combustible material or not more than 45% Ammonium Nitrate with unrestricted combustible material</p>

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Figure 72: General guide to the sea-transport, page 1



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No UN number (Type C) Fertilizers of the same composition as UN 2071 and within the limits mentioned above, which as a result of special tests, are found to be free of the aforementioned self-sustaining decomposition are regarded non-hazardous. The same apply to all compound fertilizers without any content of Ammonium Nitrate.

Handling and stowage recommendations

1. Before loading fertilizers, ship's holds and hatches must be carefully inspected and assured to be in a thoroughly cleaned condition, particularly when bulk loading takes place. Coal dust, grain, sulphur, oil, other combustible materials, acids and chemicals generally, must be kept away from fertilizers.
2. Where fertilizers are handled or loaded/unloaded, smoking and the use of fire and naked flame must be prohibited.
3. Care must be taken not to expose fertilizers to external sources of heat. For example, fertilizer must not come into contact with steam pipes (even though insulated), heated oil tanks, hot bulkheads, electric cables, electric motors or lighting equipment, whether fixed or with trailing leads. Fertilizers must not be exposed to frictional heat from the operation of mechanical equipment (e.g. conveyors).
4. In circumstances in which work may generate heat (e.g. cutting, welding, brazing) the fertilizers must either be removed or effectively protected from heat (e.g. covered with damp sheets of canvas). Hot welding debris must not fall into the fertilizers. Such hot work must be carried out only under continuous expert supervision. After completion of the work, the work-place and its surroundings must be kept under observation for several hours for development of fire or slow decomposition.

Special IMO-requirements for sea-transport of compound fertilizers classified as dangerous materials :

UN 2067, Ammonium Nitrate Fertilizers, type A
Bagged material.
Reference : IMDG code
Ammonium Nitrate Fertilizers, type A4, UN 2067, class 5.1

Bulk cargoes
Reference : Code of Safe Practise for Solid Bulk Cargoes (Appendix B)
Ammonium Nitrate Fertilizers, type A4, UN 2067, class 5.1

UN 2071, Ammonium Nitrate fertilizers, type B
Bagged material
Reference : IMDG code
Ammonium Nitrate Fertilizers, type B, UN 2071, class 9

Bulk cargoes
Reference : Code of Safe Practise for Solid Bulk Cargoes (Appendix B)
Ammonium Nitrate Fertilizers, type B, UN 2071, class 9

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Figure 73: General guide to the sea-transport, page 2



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Special requirements for sea-transport of compound fertilizers, not classified as dangerous materials :

Ammonium Nitrate Fertilizers, type C

Bagged material

No reference to the IMDG code (no special requirements)

Bulk cargoes

Reference : Code of Safe Practise for Solid Bulk Cargoes (Appendix C)

Ammonium Nitrate Fertilizers

Emergency actions

Unless absolutely necessary, avoid hot work when the fertilizer is in the hold.

If a zone of slow decomposition or smouldering of the fertilizers should occur, the following steps should immediately be taken :

1. if the zone of decomposition is still small and easily accessible, an attempt may be made to remove it from the main body of the fertilizers by the use of picks and shovels, and to cool it down by localized quenching of water.
2. when it is impossible to remove the zone of decomposition, the fertilizer involved must be soaked as rapidly as possible with a large quantity of water directed through high pressure jets against the centre of decomposition. To fight the decomposition by other means (for example, foam, carbon dioxide, steam, covering with san or fertilizer) is useless, and may even promote the decomposition.
3. if fumes are present, self-containing breathing apparatus must be employed. Special care must be taken when entering a ship's hold.

If slow decomposition should occur during the voyage the following procedures should also be adopted :

4. the course of the ship should be so chosen that any harmful fumes evolved will drift as little as possible over the ship, especially towards the crew's quarters and the bridge. If the ship lies in a port it may be necessary to move it away from the inhabited area.
5. to provide maximum ventilation the hatches should be opened unless weather conditions make this impossible. A gas-tight closure of the affected hold should in any case be avoided.
6. If copious quantities of water to control the decomposition should be necessary, flooding of the hold should be considered.
7. If suppression of the slow decomposition should prove impracticable, there will not necessarily be immediate danger to the ship if the decomposition has to be left to come to an end in the affected hold. Suitable precautions should, however, be taken to prevent the spread of decomposition or fire to cargoes in adjacent holds.

NOTE : this document is issued by EFMA – The European Fertilizer Manufacturers Association – and IFA – The International fertilizer Industry Association Ltd. – as a general guide for the handling of the compound fertilizer products of their member companies. However, the Associations undertake no legal liability in relation to users of this Guide.

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Figure 74: General guide to the sea-transport, page 3

9.7 MSDS for Nitrophoska® 15+15+15+2 S

The pages of relevance to the accident from the MSDS for this material are shown below.


Material Safety Data Sheet according to Regulation (EC) No. 1907/2008				
Nitrophoska® 15+15+15+2 S				
Version: 3.0		Revision Date: 19.09.2012		
1. Identification of the substance/mixture and of the company/undertaking				
1.1 Product identifier				
Trade name	: Nitrophoska® 15+15+15+2 S			
1.2 Relevant identified uses of the substance or mixture and uses advised against				
1.3 Details of the supplier of the safety data sheet				
Company	: EuroChem Agro GmbH Reichskanzler-Müller-Str. 23 D-68165 Mannheim Germany			
Telephone	: +49 621 87209-0			
Telefax	: +49 621 87209-101			
E-mail address	: info@eurochemagro.com			
1.4 Emergency telephone number				
BASF fire brigade Ludwigshafen Telephone: +49 621 60 43333				
2. Hazards identification				
2.1 Classification of the substance or mixture				
Classification(67/548/EEC,1999/45/EC)				
2.2 Label elements				
Labelling(REGULATION (EC) No 1272/2008)				
Labelling according to EC Directives ()				
Further information	: Not subject to labelling in accordance with EEC Directives.			
2.3 Other hazards				
No particular dangers occur if the regulation/notes for storage and handling are observed.				
3. Composition/information on ingredients				
3.2 Mixtures				
Chemical nature	: NPK - fertilizer containing: Ammonium Nitrate, ammonium salts, phosphates, salts of calcium, potassium and possibly magnesium and trace elements.			
Hazardous components				
Chemical Name	CAS-No. EC-No. Registration	Classification (67/548/EEC)	Classification (REGULATION (EC) No 1272/2008)	Concentration [%]
1/9		Print Date: 19.09.2012		

Figure 75: Material safety data sheet, page 1


Material Safety Data Sheet according to Regulation (EC) No. 1907/2006				
Nitrophoska® 15+15+15+2 S		Revision Date: 19.09.2012		
Version: 3.0				
	number			
Ammonium Nitrate	6484-52-2 229-347-8 01- 2119490981- 27-0050	O; R 8 Xi; R36	Ox. Sol. 3; H272 Eye Irrit. 2; H319	>= 10 - <= 70
ammonium chloride	12125-02-9 235-186-4 01- 2119489385- 24-0017	Xn; R22 Xi; R36	Acute Tox. 4; H302 Eye Irrit. 2; H319	>= 1 - < 25
For the full text of the R-phrases mentioned in this Section, see Section 16. For the full text of the H-Statements mentioned in this Section, see Section 16.				
4. First aid measures				
4.1 Description of first aid measures				
If inhaled	:	On inhalation of decomposition products: Keep person calm, have individual removed to fresh air, seek medical help. If danger of loss of consciousness, place person in recovery position and transport accordingly. Perform artificial respiration if necessary. On inhalation of fertilizer dusts: Fresh air, if necessary medical assistance.		
In case of skin contact	:	Wash off with soap and water.		
In case of eye contact	:	Wash affected eyes for at least 15 minutes under running water with eyelids held open.		
If swallowed	:	Immediately rinse mouth and then drink plenty of water, seek medical assistance.		
4.2 Most important symptoms and effects, both acute and delayed				
4.3 Indication of any immediate medical attention and special treatment needed				
5. Firefighting measures				
5.1 Extinguishing media				
Suitable extinguishing media	:	When decomposing product is handled: Water (attention, larger quantities are necessary to stop the thermic decomposition)		
Unsuitable extinguishing media	:	Sand Foam Carbon dioxide (CO ₂) Dry chemical		
5.2 Special hazards arising from the substance or mixture				
Specific hazards during firefighting	:	At temperatures above 130 °C, dangerous decomposition gases can be emitted: Nitrogen monoxide, nitrogen dioxide, dinitrogen oxide,		
2/9		Print Date: 19.09.2012		

Figure 76: Material safety data sheet, page 2


Material Safety Data Sheet according to Regulation (EC) No. 1907/2006		
Nitrophoska® 15+15+15+2 S		
Version: 3.0		Revision Date: 19.09.2012
ammonia, chloride, hydrogen chloride.		
5.3 Advice for firefighters		
Special protective equipment for firefighters	:	In the event of fire, wear self-contained breathing apparatus.
Further information	:	Fire residues and contaminated fire extinguishing water must be disposed of in accordance with local regulations.
6. Accidental release measures		
6.1 Personal precautions, protective equipment and emergency procedures		
6.2 Environmental precautions		
Environmental precautions	:	Do not let product enter drains, surface water or subsoil water. Retain and dispose of polluted washing water according to regulations.
6.3 Methods and materials for containment and cleaning up		
Methods for cleaning up	:	Use mechanical handling equipment. Rinse off remainders with water.
6.4 Reference to other sections		
7. Handling and storage		
7.1 Precautions for safe handling		
Advice on protection against fire and explosion	:	Keep away from heat and sources of ignition. Keep away from combustible materials. Do not smoke. The product is incombustible. However, it can lower the ignition temperature of combustible substances.
7.2 Conditions for safe storage, including any incompatibilities		
Requirements for storage areas and containers	:	Protect against contamination. Protect against humidity (product is hygroscopic and tends to cake or disintegrate) Keep away from direct sunlight. Protect against heat.
Advice on common storage	:	When stored loosely do not mix with other fertilizers. Store well away from other substances, particularly from organic materials.
Other data	:	If inappropriately or improperly stored caking or disintegration possible.
7.3 Specific end use(s)		
8. Exposure controls/personal protection		
8.1 Control parameters		
3/9		Print Date: 19.09.2012

Figure 77: Material safety data sheet, page 3


Material Safety Data Sheet according to Regulation (EC) No. 1907/2006		
Nitrophoska® 15+15+15+2 S		
Version: 3.0	Revision Date: 19.09.2012	
PNEC		
Ammonium Nitrate	: Fresh water Value: 0,45 mg/l	
	Marine water Value: 0,045 mg/l	
	Ceiling Limit Value Value: 4,5 mg/l	
ammonium chloride	: Marine water Value: 11,2 mg/l	
	Fresh water Value: 1,2 mg/l	
	Ceiling Limit Value Value: 1,2 mg/l	
8.2 Exposure controls		
Personal protective equipment		
Respiratory protection	: If breathable dust is formed: Dust mask.	
Hygiene measures	: At the end of the shift skin should be cleaned and skincare product applied.	
Environmental exposure controls		
General advice	: Do not let product enter drains, surface water or subsoil water. Retain and dispose of polluted washing water according to regulations.	
9. Physical and chemical properties		
9.1 Information on basic physical and chemical properties		
Appearance	: granular	
Colour	: varying, according to dye or colour of the basic materials.	
Odour	: almost odourless	
pH	: ca. 5, (100 g/l, 20°C)	
Water solubility	: mostly soluble	
Thermal decomposition	: Thermal decomposition at above 130 °C., To avoid thermal decomposition, do not overheat., The product is not capable of self-sustaining progressive thermal decomposition (UN-Test S1).	
9.2 Other information		
	: Thermal decomposition at above 130 °C.	
Bulk density	: ca. 1.100 kg/m³	
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Material Safety Data Sheet according to Regulation (EC) No. 1907/2006		
Nitrophoska® 15+15+15+2 S		
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10. Stability and reactivity		
10.1 Reactivity		
10.2 Chemical stability		
10.3 Possibility of hazardous reactions		
Hazardous reactions	: Ammonia in contact with alkaline solutions. The formation of gaseous decomposition products builds up pressure in tightly closed containers.	
10.4 Conditions to avoid		
10.5 Incompatible materials		
Materials to avoid	: Inflammable, oxidizable substances, sourly reacting substances, alkalinely reacting substances.	
10.6 Hazardous decomposition products		
Hazardous decomposition products	: At temperatures above 130 °C, dangerous decomposition gases can be emitted: Nitrogen monoxide, nitrogen dioxide, dinitrogen oxide, ammonia, chloride, hydrogen chloride.	
11. Toxicological information		
11.1 Information on toxicological effects		
<u>Product</u>		
Acute oral toxicity	: LD50: > 2.000 mg/kg, rat, The product was not tested. The statement was derived from products of similar structure and composition.	
Skin corrosion/irritation	: Primary skin irritation/rabbit: Not irritating. (OECD-Guideline 404), Primary mucose irritation/rabbit: Not irritating. (OECD-directive 405)	
<u>Components:</u>		
Ammonium Nitrate :		
Acute oral toxicity	: LD50: > 2.950 mg/kg, rat, OECD Test Guideline 401	
Acute inhalation toxicity	: > 88,8 mg/l, No information available., Not relevant because of low vapour pressure., Not relevant because of low dust formation.	
Acute dermal toxicity	: LD50: > 5.000 mg/kg, rat, OECD Test Guideline 402	
Skin corrosion/irritation	: rabbit, Result: non-irritant, OECD Test Guideline 404	
Serious eye damage/eye irritation	: rabbit, Result: Irritant, OECD Test Guideline 405	
Respiratory or skin sensitization	: Result: Does not cause skin sensitization.	
Germ cell mutagenicity		
Genotoxicity in vitro	: Result: negative, OECD Test Guideline 471	
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