Isle of Man Ship Registry

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Casualty Investigation Report No. CA 128

M/V Cheshire

Ammonium nitrate fertiliser cargo decomposition

on the **14th August 2017**

Statement of Intent

Extract from

The Isle of Man Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2001 – Regulation 4:

“*The fundamental purpose of investigating a casualty, an accident, or an incident under these Regulations is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future.*

It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame”

Contents

Summary

On 6th August 2017, MV Cheshire departed her load port in Norway bound for Thailand with a full cargo of ammonium nitrate based fertilisers.

Within a few days and when opening number four cargo hold hatch cover drains for daily atmospheric checks, small collections of water, and a barely discernible "light dust" were observed.

This continued to deteriorate, a foul smell was subsequently detected and the cargo manufacturers were contacted for advice. They advised that a cargo thermal decomposition was most likely occurring and the Master was instructed to open the cargo hold openings and if possible the main hatches for maximum ventilation/gas dispersion purposes.

With rising temperatures and increasing quantities of (confirmed to be) toxic gas, by 12th August and despite attempts at cooling the decomposition front with water, the situation was clearly worsening and the manufacturer dispatched a cargo surveyor to render expert assistance on board the vessel to deal with, a now confirmed cargo thermal decomposition.

Prevailing still weather conditions, danger to personnel caused by the toxic gas cloud and a rapid deterioration of the on-board situation ultimately resulted in the Master ordering evacuation from the vessel.

Spain MRCC responded using two search and rescue helicopters and successfully landed the crew and cargo surveyor in Las Palmas.

The Isle of Man Ship Registry would like to officially thank Spain MRCC for their very well co-ordinated and ultimately successful rescue operation which resulted in twenty three lives being saved.

The vessel, being no longer under command or power, drifted (under MRCC supervision) in a South-Westerly direction further away from land whilst the decomposition continued.

The vessel was eventually salvaged under Lloyds Open Form – with "SCOPIC" invoked, towed to Puerto Motril for discharge and repair assessments but was ultimately declared a constructive total loss since cost-effective repairs could not be carried out.

Glossary, abbreviations and acronyms used throughout

Contents table and section titles are hyperlinked, link and Back navigate through the document.

Master Highest ranked officer on board the vessel and having overall responsibility for the crew, the vessel and the cargo and the owners' representative on-board the vessel.

C/E Chief Engineer – Highest ranked Engineering Officer and having responsibility for the engine department and the safe maintenance and operation of all supporting systems on board the vessel.

C/O Chief Officer – highest ranked Navigating Officer having responsibility for safely navigating the vessel, the deck department and all cargo related operational matters.

2/O Second Officer – subordinate to C/O but having similar responsibilities.

2/E Second Engineer – subordinate to the C/E but having similar responsibilities.

E/E Electrical Engineer – part of the engineering staff normally reporting to **2/E.**

Bosun Chief petty officer of the deck crew – works closely with the **C/O.**

AN Ammonium Nitrate (UN 1942) in its purest form, it is often mixed with other compounds and stabilising substances to determine how the final product behaves.

ANBF Ammonium Nitrate Based Fertiliser, is currently categorised into three groups two of which are determined to be "hazardous" (UN 2067 and UN 2071), the third is classified ANBF "non-hazardous" (and has no UN number assigned).

Australian ladder

A steel combination vertical/spiral hold access ladder fitted with a steel protection boundary and lighting for safety.

BCSN Bulk Cargo Shipping Name – the defined shipping name of the product (IMSBC code section 1.7).

Bilge(s) Lowest points within spaces of a ship's structure and where water accumulates, normally fitted with alarms which should be the first indication of a leak or excessive moisture collection.

Booby Hatch One or more small hatches located in the main hatch coaming to allow a measure of ventilation to take place without compromising the integrity of the main hatch seals, they can be easily opened and closed manually.

Caking Damp cargo can have a tendency to cake or form a crust and become stuck to the cargo hold, this has safety implications during discharge and is best avoided.

Cleats Mechanical devices located all around the periphery of the cargo hatch and used to securely hold the hatch in position and compress the seals to keep water out.

CTL Constructive Total Loss – the cost of economical repair far exceeds the cost of future commercial viability and the insurance underwriters effectively draw a line under the claim such that further unnecessary work is not carried out.

Deflagration

Defined as a combustion event progressing at subsonic speeds as opposed to a detonation where supersonic speeds are involved, in the context of this report where combustion is not actually taking place - the name given to the sudden expulsion of cargo from the top of the cargo hold due to the large volumes of gas being generated by the energetic reactions occurring within the semi-enclosed hold space.

Exhaust temperature deviation alarm

For correct operation of the engines, the exhaust temperatures from each cylinder are monitored if the power output between the highest and lowest cylinder deviates more than a prescribed amount an alarm sounds that there is a problem with the engine, if the difference continues to a grow, at a second set point, for safety purposes and prevent engine damage they are designed to stop.

HFO Heavy Fuel Oil.

IMSBC International Maritime Solid Bulk Cargoes Code.

LOF Lloyds Open Form – a standard salvage agreement where the terms of salvage are already pre agreed, such that the actual operation can be immediately commenced rather than wasting time discussing the terms and remuneration divisions.

Matrix Irregularly shaped, fused mass, formed when the fertiliser has decomposed and capable of retaining heat energy.

Mayday Emergency distress call to which nearby interests must respond and co-ordinated by the nearest rescue centre picking up the distress message.

NUC Not under command.

nm Nautical Miles.

Pilot Certified navigator with local experience of currents, streams and tides and utilised to assist with the safe navigation of the vessel.

Prills A specific shape given to the cargo as part of the production process, prills are treated to ensure better handling properties, e.g. to prevent caking and reduce moisture absorption.

SAR Search and Rescue.

SCBA Self-Contained Breathing Apparatus – Required ships equipment provided for firefighting purposes and use in smoke filled environments, it provides clean breathable air for approximately 30 minutes (depending on air demand by the user).

Schedules Extracts of the IMSBC pertinent to the cargo being carried.

SCOPIC Special Compensation P&I clause.

SDS Safety Data Sheet.

Ships sweat A condition (described in the company SMS 9.11) where moisture from the hold atmosphere is deposited on cool surfaces caused by temperature variations (similar to a steamed up bathroom window), SMS 9.15 and 9.16 expand on the likelihood of ships sweat in relation to the moisture content of the cargo itself and the effect this has on ventilation requirements.

SMRCC Spain Maritime Rescue Coordination Centre – the local coastal authority taking control of the land (and sea) rescue resources available in the area.

SMS Safety Management System – the operational and safety requirements advised by the management company (in the form of the SMS) to be followed by the crew in order to safely operate the vessel.

SOLAS International convention for the Safety Of Life At Sea.

SSD Self-Sustaining Decomposition – Thermal decompositions can become self-sustaining decompositions **(SSD)** if sufficient energy remains within the reaction process, even if the heat source causing the initial decomposition is removed. IMSBC schedules refer the "S.1 - trough test" as described in the UN manual of tests and criteria part III subsection 38.2 to determine if the cargo has SSD properties or not.

Thermal Decomposition

A very complex chemical reaction that only requires heat and cargo to continue, heat is taken in, component products break down giving off heat and also recombine taking in more heat, oxygen is not required for this to happen and the proportions of constituents and amount of available energy, affect how the reaction behaves. Fixed CO_2 fire extinguishing systems are ineffective on thermal decompositions.

Thermographic Scan/photograph/image

An emitted infra-red scan of an area whereby different temperatures are indicated by different brightness or colours, brighter in contrast or lighter in colour (depending upon equipment/software used) indicates a higher temperature than the surroundings, correctly calibrated and/or higher resolution equipment can indicate differences in temperature as little as two degrees.

TMP Temperature measuring point, a small diameter tube penetrating the vessel’s deck into the cargo hold such that the cargo bulk temperature can be measured at different heights by means of a thermometer protected in a brass case attached to a line (appendix 5 shows their locations).

Trough test

Or “UN.S1 test” this is the test used to classify if ANBF has self-sustaining decomposition (SSD) properties or not and classified either as ANBF UN 2071 Dangerous goods class 9, Group B, or ANBF (non-hazardous) Group C according to the results.

Originally developed as one of the means for the classification of fertilisers being stored and transported in packaged form, it is a clearly defined test, understood and utilised globally. For the same classification purpose it was adopted into the IMSBC code for storage and transportation in bulk form, it is described in IMSBC appendix 2 - section 4.

ULT Ultrasonic leakage test – a non-destructive test carried out to determine the sealing properties of the hatch sealing rubbers which are normally compressed by the weight of the hatch to the hold or the close fit of each hatch segment.

Victor Lance

A water directing nozzle designed by Gewerkschaft Victor, carried on the end of a water pipe and recognised as the best way to quickly get cooling water deep into a bulk pile and as close to the decomposition front as possible.

Narrative of events

Any stated times, unless otherwise indicated, are ship’s time.

The vessel was fixed for a cargo of Ammonium Nitrate Based Fertiliser (non-hazardous) **(ANBF)** from Porsgruun in Norway to Koh Sichang in Thailand, following discharge of her current cargo of steel coils in Antwerp, Belgium.

Discharge in Antwerp completed on 28th July and the vessel then proceeded to Porsgruun, cleaning her cargo holds of the previous steel residues whilst under passage, ready for survey to receive the fertiliser cargo.

The Master was advised the vessel would be berthing on arrival and expected to load into Cargo Hold No.3 **(“CH#3”)** being the largest of the vessel’s five cargo holds, accordingly this was prepared to accept cargo first.

The vessel berthed as planned and was alongside and secure by late evening 30th July whereupon the cargo manufacturer’s surveyors and the vessel’s Chief Officer **(C/O)** examined the hold to confirm its suitability to receive the cargo.

The inspection included visual inspection of the complete hold internally, to confirm the hold is clean and dry and an Ultrasonic Leakage Test **(ULT)** of the sealing rubbers on the hatch cover. Upon completion, the Master received written confirmation of the hold’s physical suitability to load cargo.

Upon leaving the cargo hold, as part of the ship’s technical manager’s (“The Company”) Safety Management System **(SMS)**, requires that manhole covers and other openings be secured and that electrical lighting power be isolated (although since #3 cargo hold can also be used as an emergency ballast tank it is not provided with electrical lighting or power), CH#3 was then confirmed ready by the vessel to receive cargo, which commenced at 00.10hrs on 31st July.

At 07.00hrs the following day, CH#1, CH#2, CH#4 and CH#5 underwent the same survey process, the electrical power to the lights on the Australian ladders was isolated (SMS 3.7.3) to make the holds ready for receiving cargo and all of them gained confirmation they were considered suitable to load the cargo by 09.30hrs.

The vessel commenced loading the cargo grades hold by hold, starting and stopping cargo, opening and closing the cargo hatches according to the cargo plan and prevailing weather conditions (loading must stop and hatches must be closed during precipitation).

Loading proved to be uneventful, there were no accidents and no cargo claims and by the evening of 5th August, the vessel had finished loading and commenced preparations for departure Porsgruun.

Despite the cargo being declared on all shipping paperwork as a homogenous grade, for operational reasons the manufacturers chose to load CH#4 with approximately 70 % of the nominated 15-15-15 grade cargo and load on top the 30% balance with 16-16-16 grade cargo which was the same as loaded into CH#3.

This change was not advised to the Master or C/O, nor was the cargo documentation changed to reflect the true situation, either prior to loading the cargo, or prior to the vessel's departure.

Part of the preparation for transportation was to cover the heaped cargo with "plastic foil" sheet to reduce exposure to air and hence limit moisture absorption possibilities. Although this cargo does not self-heat (a common problem with moisture in other cargoes), it does become wet/slippery on the surface of the **prills** (which are designed to dissolve) and as a result, is susceptible to **caking** which can make unloading more difficult and reduces the quality of the product for its intended purpose in agriculture.

Because the cargo had already been loaded and heat sources have to be avoided, the lighting system for the **Australian Ladder** could not be used and this work had to be performed with available ambient light only, it was however safely concluded in all five cargo holds and the vessel could be made ready to put to sea.

On 6th August the **pilot** boarded the vessel at 02.45hrs whilst it was undergoing the required pre-departure checks. These checks were completed by 02.55hrs and the vessel departed the berth at 03.25hrs under pilotage until the pilot disembarking position was reached and he left the vessel.

Continuing on passage, due to restricted manoeuvrability and heavy marine traffic, the vessel had to increase the watch-keeping schedules so creating minor deviations from prescribed hours of work and rest, however the crew were afforded ½ day compensatory rest in addition to normal rest following their watches to manage the situation.

Within 24 hours of departure (7th August) the C/O commenced his routine operational checks which include cargo hold security (all physical openings closed/secured) and measuring cargo hold atmosphere conditions (testing for oxygen, methane, carbon monoxide and temperature). These results are recorded on Company form DRY04 on a daily basis.

On 8th of August the voyage progressed without due concerns, everything appeared normal.

Conducting his daily checks on 9th August and whilst opening the cargo hatch cover drains, C/O noticed a very small amount of water (drips) and a very faint smell from CH#4 but he wasn't sure if the drips and faint smell were due to "**ship's sweat**" or not. Other cargo hold atmosphere measurements, required to be recorded by the company SMS were input into form DRY04.

By 10th August C/O observed small collections of water (0.5L or less) from the hatch cover drains, very small quantities of "dust" and upon first opening a very slight overpressure, which stopped when the small drain plug was removed.

“Ship’s Sweat” is defined in the company SMS (Dry Cargo procedures section 9.11) and can occur under certain conditions when carrying low moisture content cargoes, because the smell was much stronger than the previous day the C/O reported his concerns back to the Master since “sweating” is not typical for fertiliser cargoes.

Going back to the cargo hold with C/O to determine the situation for his own benefit and witnessing the unusual signs first hand, the Master raised a Notice Of Protest **(NOP)** to cargo interests indicating the possibility of an off-specification cargo in CH#4 upon discharge in Thailand.

By 11th August and although the recorded cargo hold temperatures were still below the 50^{0}C maximum permitted by the cargo schedule, this sweat had developed somewhat in CH#4 with further small quantities of water being collected at the drains. The “dust” however had become “more like smoke” in appearance and it was now accompanied by a “foul smell”.

Cargo temperatures are monitored at specific temperature measuring points **(TMP)** within the hold space and one of the requirements of the cargo schedule is that the cargo should not be stowed adjacent to fuel tanks unless the temperature can be monitored and controlled such that it does not exceed 50^{0}C during carriage. Melting/decomposition commences well above the 169^{0}C melting point of Ammonium Nitrate and more likely to be over 200^{0}C for all five grades of the ANBF loaded onto Cheshire.

Due to the previous day’s NOP, concerns were starting to be raised ashore and the possibility of a cargo thermal decomposition was considered by the vessel operators (cargo, managers and owners). The Master was required by them to check for any possible sources of heat (lights, heating, pipelines etc.) and to increase the hold space temperature monitoring frequency and reporting requirements.

HFO heating coil steam valves (confirmed as being closed in the managers initial access to the vessel) [2]

The IMSBC schedules require that “the cargo spaces carrying this particular cargo shall not be ventilated during voyage” therefore all openings to the cargo hold remained closed.

Despite CH#4 now showing observable signs of a decomposition event, monitored temperatures were first seen rising sharply in CH#5 and not in CH#4. Late that evening, instructions were given by the Company to the Master to ensure crew safety, for him to contact the cargo manufacturers for cargo-specific advice on how to deal with the situation and to monitor the temperatures on an hourly basis.

The crew were duly advised of the situation and how they should behave from this point going forward. It was clearly indicated this was not a drill and that it was a real situation. Crew were instructed to close all of the accommodation ventilation inlets and not to go outside the accommodation due to toxic gas being evolved from the cargo, working was to be restricted to conducting watches on the bridge and in the engine-room only.

Upon receiving the Master’s communication (late on 11th August), the manufacturers considered the information provided to them and quickly confirmed it was highly likely a thermal decomposition was taking place in CH#4 and provided the Master with specific advice and information how to proceed.

Early on 12th August and to reduce the possibility of a pressure build-up within the cargo hold and in an attempt to slow the decomposition down, the Master was requested to immediately open the cargo hold ventilation (including the main hatch if possible) – it was going to be a very busy day.

Examples of the conditions described by the crew on the 13/14th August (toxic gas enveloping the accommodation and being drawn into the engine-room ventilation system) these pictures taken after the vessel was evacuated with CH#3, # 4 & #5 decomposing and toxic gas plume visible from 14nm away. [1]

Ship’s staff proceeded to open booby hatches, Australian ladder access hatches, sounding pipe covers first and then commenced releasing the cleats on the main hatch cover.

The manufacturers also offered to supply one of their own cargo surveyors to assist with the decomposition control process to which the owners agreed.

The manufacturers advised the best way to stop the decomposition was to cool the area with water directly by means of a **Victor lance** and had given the vessel instructions how to make these. There is currently no requirement for their provision, the vessel had no such equipment on board and so fabrication commenced. In the same communication, it was also advised that if Victor lances were not available, crew were to produce alternatives by using ordinary water pipelines of ½ or ¾ inch diameter as means of injecting water into the cargo.

Ship’s staff followed these ventilation instructions and whilst waiting for Victor lances to be fabricated by the engineers, the main hatch cover cleats were released and the main cover of CH#4 opened by the Chief Officer and Bosun. At that time there was a following wind of some 20~30 knots which kept the decomposition products clear of the main-deck.

Once the main hatch cover was opened, the “plastic foil” placed over the cargo heaps before departure was lifted off using a rope with a hook attached allowing the cargo surface itself to be viewed, “smoke” was seen thickest in CH#4 at the aft transverse bulkhead, on the port side, in the area of the **Australian ladder.**

Supplied by managers for taking surface temperatures of engine-room equipment, the vessel had a reflected infra-red thermometer on board which was then used to confirm this area was hotter than the surrounding cargo bulk and it was concluded by the crew, this area is where the seat of the decomposition was located.

C/O and **Bosun** tried spraying the cargo in the bulkhead area from above with two ordinary fire hoses. This appeared to have some measure of success as a 10^{0}C fall in temperature was recorded at CH#5 port forward TMP (nearest the hot spot), water application was stopped, but the temperature continued to be monitored on an hourly basis.

The vessel proceeded towards Las Palmas (Gran Canarias) where she was intending to pick up stores and fuel oil for the continuing voyage to Thailand. Pre-arrival notification required information of any problems with the vessel and the Master duly notified the port authorities they had an ANBF decomposition in CH#4 which was thought to be under control, but he requested specialised local fire-fighting assistance via the vessel’s agent in any case.

Having subsequently been apprised of the actions taken so far, the Spanish authorities believed sufficient steps had been taken already, that this specialised assistance would not be justified and would also be logistically difficult to arrange at short notice.

Having had previous experience of ANBF decompositions (M/V Ostedijk off the coast of Galicia), knowledge of the health hazards they can present and the difficulties of arresting a decomposition, the Gran Canarias port authorities refused the vessel entry to port limits and instead instructed them to hold position approximately 15nm South of Gran Canarias until the decomposition was confirmed as extinguished and the prospect could be reviewed once more.

Joining crew and the cargo manufacturer’s surveyor, instead of boarding by launch East of Las Palmas as the vessel took fuel on board, would now have to rendezvous at the vessel’s holding position South of Gran Canarias.

After the initial cooling attempts on 12th August appeared to be successful and due to the fact the cargo schedules required cargo holds to be kept closed, CH#4 main cargo hatch was closed overnight, although the booby hatches were kept open (to prevent any pressure build up and more easily monitor the hold) with temperatures being monitored hourly.

Unfortunately these temperatures started showing an increase again and the hatch cover needed to be opened once more under specific instruction from the manufacturers. It was now clearly understood that the decomposition had not in fact been arrested.

By early morning 13th August and whilst the vessel proceeded to the holding position, the wind dropped to almost still air conditions and the Master had to make continuous vessel movements to try and keep clear of the cloud of decomposition products escaping the cargo hold and “washing over” the accommodation.

By the afternoon of the 13th and having reached the holding area, the still air conditions meant the toxic gases being more freely evolved from the cargo would not clear the vessel’s proximity and rather than drifting, the Master tried to manoeuvre the vessel so these gases cleared the decks.

All forward movements enveloped the accommodation and engine-room air intakes (the latter needing to be open for propulsion and power production) and whilst the accommodation had been safely sealed on the 11th, the engine-room could not be sealed. As a result it started filling up with toxic gas and decomposition particulates drawn in by the ventilation system.

Trying to manoeuver slowly astern to clear the accommodation, the vessel continuously veered off the steered course and back into the toxic cloud. The particulates started blocking the main engine and auxiliary engine turbocharger filters giving rise to air starvation which affected their power output and started giving exhaust temperature deviation alarms.

The only way to clear these deviation alarms is by manually cleaning the filters (or they could be completely removed but abrasive engine damage would be highly probable). This was done by C/E changing over load, stopping the affected machine, cleaning the filters so the engine could be put back in standby, changing the load around again and stopping the newly affected running machine, repeating the process continuously between all of the auxiliaries.

This whole time, the cleaning process needed to be performed in self-contained breathing apparatus **(SCBA)** due to the toxic engine-room environment. Because SCBA bottles only last approximately 20-30 minutes (under non-stressful conditions), this required frequent visits to the accommodation to change them over for recharging. 2/E was stationed by the air compressor, now sited inside the accommodation to perform this function (the SCBA air compressor is normally sited outside in “fresh air” but the outside air around the vessel was toxic).

Post salvage photograph of the engine control room giving some indication of cargo decomposition particulates that were drawn into the engine-room by the ventilation and blocking the turbocharger filters (approx. ½ ton of dust was removed from the ER) – note that structural fire insulation is designed to offer protection for hours, not days and why fire damage was also evident in the engine-room. [3]

The blocking filters and high deviation temperatures caused by the particulates, prevented the vessel from going fast enough astern to gain sufficient steerage to clear the gas cloud, this meant that the situation was going to continue until the wind outside the vessel picked up enough for the vessel to finally clear the significantly sized cloud evolving from CH#4 and completely surrounding the vessel, since there was little or no wind to disperse it.

When drifting/manoeuvring, the distance to Gran Canarias was increasing approximately 5nm per hour, so the Master turned onto a reciprocal course and manoeuvred as best he could (at slow speed due to turbocharger fouling) to close the distance with the personnel launch. During the day all cargo hold openings on CH#4 were open according to the manufacturer’s instructions to provide maximum ventilation, but the main hatch cover was temporarily closed for the protection of embarking personnel later that night.

At approximately 23.30hrs on 13th August, the on-signing relief C/O, **E/E** and the manufacturer’s surveyor **(Surveyor)** boarded the vessel, despite that the hatch was temporarily closed to reduce the potential for exposure to toxins. The Surveyor made a brief initial inspection to determine condition as he passed by on his way to see the Master on the bridge and took temperature readings of the decks and cargo hatch surrounding areas with a reflected infra-red thermometer.

Photographs taken by the surveyor soon after boarding [4]

After arrival on the bridge and discussing what was required to be done and how to do it, the Surveyor advised the first priority was to open the main hatch cover again, and since the hydraulic controls for CH#4 hatch were located on the port side of the vessel where the gas cloud was thickest, the vessel had to be turned again to try and clear the deck so this could be safely done.

The Master started turning the vessel to starboard to clear the hatch controls but the still air conditions and the volume of gas now being evolved from CH#4 meant that the vessel couldn't clear it. Despite turning a full 360^0 the deck area didn't clear. The engine-room ventilation (needed for power and manoeuvrability) continued to draw decomposition products, and the bridge itself started filling up until the sliding leaf access door was closed and the frames stuffed with rags to slow ingress.

C/O and Bosun who were waiting in SCBA to open CH#4 main hatch again, were instructed to stand by inside the accommodation until needed on deck, C/E and 2/E were told to wait inside the accommodation and only enter the engine-room if an alarm sounded (4 x SCBA provided to the vessel all needed).

Unable to clear the vessel, the Master tried to manoeuvre slowly astern (with zero visibility) until "a heavy vibration was felt". Checking his radars, he was satisfied that the area was clear of other vessels and checking sounding readouts everything appeared normal. Even checking verbally with the engineers everything seemed to be normal and the Master was left wondering what the heavy vibration was.

Following this vibration and at approximately 00.40hrs on 14th August there was a “dull explosion” following which there was a sound “like heavy rain” on the bridge. During a brief spell of limited visibility and under the vessel’s deck lighting, it became obvious that CH#4 hatch cover had been forced open to an angle of approximately 70^0 from horizontal and cargo was seen all over the deck, the toxic gas colour had also changed from white to orange indicating a more advanced stage of decomposition.

CH#4 hatch cover following the initial “explosion” and burning wood pallets ignited from hot cargo.[4]

Not wanting to endanger his crew, the Master again instructed that no-one was to go outside until daylight when the situation could be properly assessed. During another brief period of visibility from the bridge (under deck lighting) it could be seen there were “some parts on deck”. These were assumed to belong to the hydraulic system or hatch fittings (later confirmed in daylight).

The vessel’s condition was monitored overnight. Limited manoeuvring astern was undertaken to try and keep the vessel clear of the toxic gas whilst discussing with the Surveyor subsequent actions to be followed.

By 14th August these still air conditions continued and the Master commenced permanently going slowly astern to try and keep the vessel clear of the gas cloud, however the vessel’s handling characteristics at this speed meant the bows kept turning to starboard and the accommodation, bridge and engine-room continued to be enveloped by toxic gas, a situation that showed no imminent improvement.

The Master informed the owner of his decision to send a distress signal to Spain Maritime Rescue Co-ordination Centre **(SMRCC)** to evacuate the crew from the vessel, whilst it was still capable of being positioned to provide a degree of egress safety. The Master had explained to SMRCC the situation regarding the difficulties experienced trying to avoid the toxic gas cloud and that it was seriously affecting the vessel's power and manoeuvrability capabilities, without which the vessel and crew would all be placed in a dangerous situation.

SMRCC confirmed the request and immediately sent a light aircraft for initial situation response assessment (distance from land, current vessel condition). They subsequently sent two Search and Rescue **(SAR)** helicopters to evacuate the crew; and a salvage fire-tug to stand-by in the vicinity of the vessel but at a safe distance should it be needed.

During the SAR, ship's staff deliberately blacked out the vessel so it would simply drift under the influence of local tidal streams in a South-Westerly direction away from land. Not long after the last persons were taken off the ship, CH#4 had a second **deflagration** (recorded by the helicopter crew), thankfully however all 23 persons were safely evacuated and landed at Las Palmas.

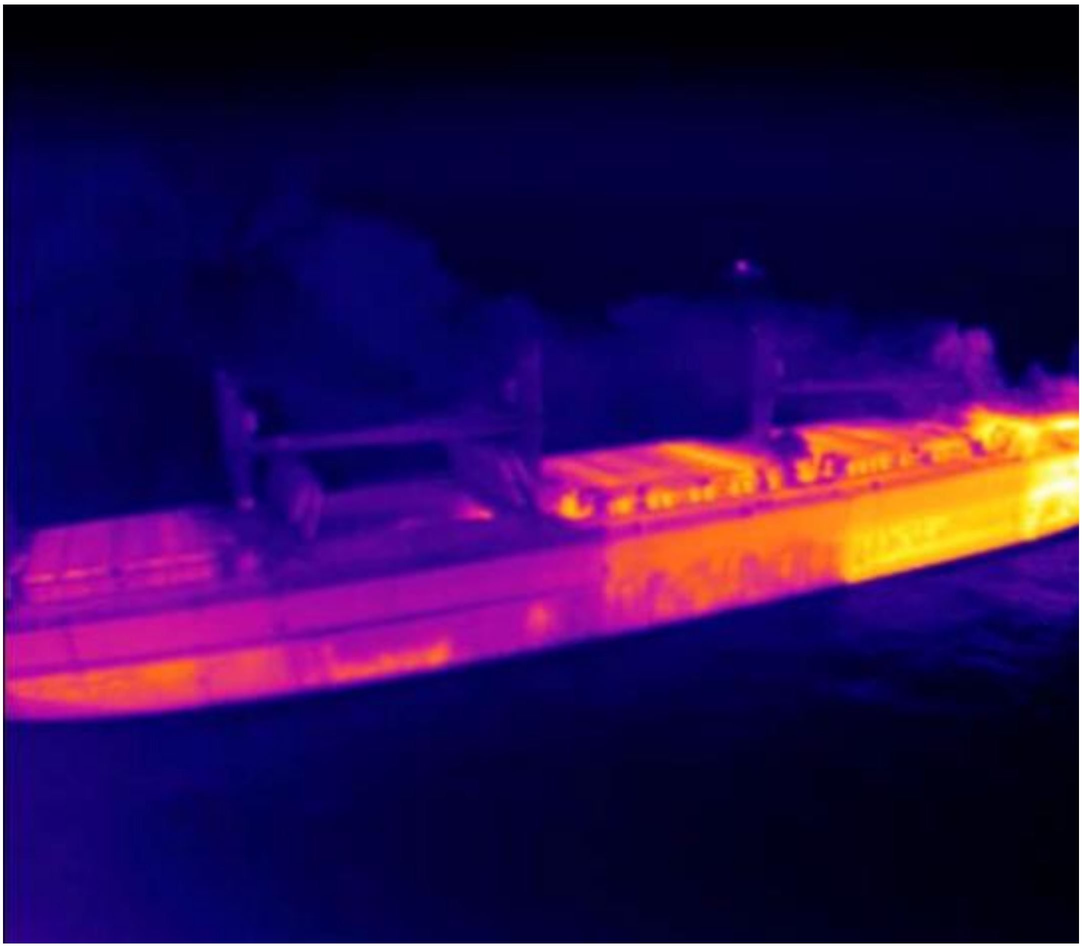
The original salvage stand-by fire tug continued to wait near the vessel whilst the salvage teams mobilised with a larger vessel and equipment ready to proceed to site.

Cargo manufacturers advised the possibility of further deflagrations or explosions and in the first few days, safe access to Cheshire was impossible. As the wind and sea picked up, the toxic gas cloud cleared the vessel's vicinity and it could be approached from upwind for boundary cooling which was undertaken by the fire tug.

The boundary cooling did not arrest the decomposition and it continued within the cargo in CH#4 eventually progressing to the extremities of the hold and started decomposition processes in CH#5 and CH#3.

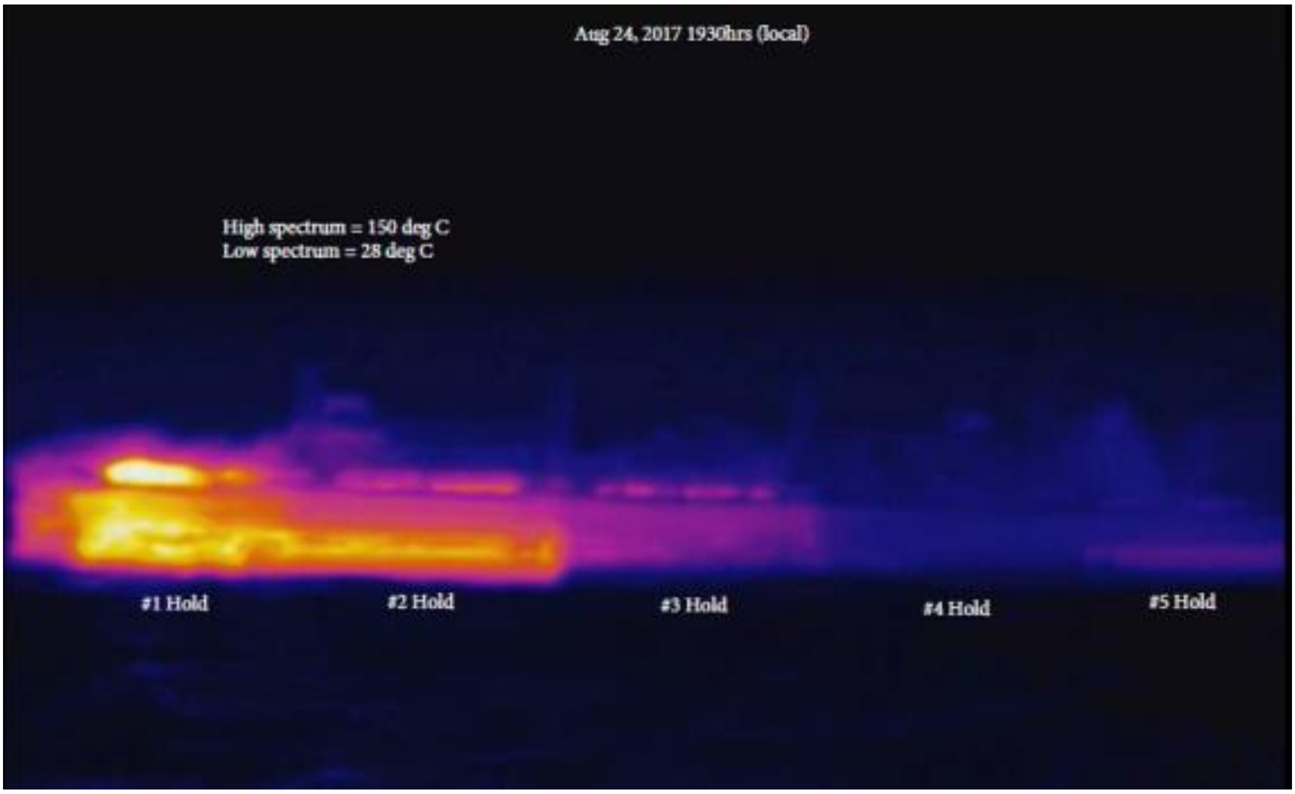
Since the hatch covers on remaining cargo holds could not be opened as a result of the damage to the hydraulics (and the vessel being abandoned for crew safety), maximum ventilation could not be achieved and decomposition reaction heat inevitably built up within the cargo holds, sustaining and accelerating the reactions and allowing them to progress in the same fashion throughout the entire vessel.

Salvors stood by the vessel and continuously tried to secure a tow line. Prevailing weather and decomposition conditions meant that this could not safely be achieved until 15.00hrs 21st August by which time the decomposition reaction had also significantly run its course and subsided.



Thermographic and visible images of CH#5, #4, #3, #2, and #1 left to right (CH#1 hottest,CH# 4 coolest) [1]

Although damaged in its entirety by the decomposition, approximately 23,183 tons (54%) of the cargo was consumed by the reaction and by toxic decomposition products being released to the atmosphere, only 19,471 tons (46%) remained on board after the event. [1]

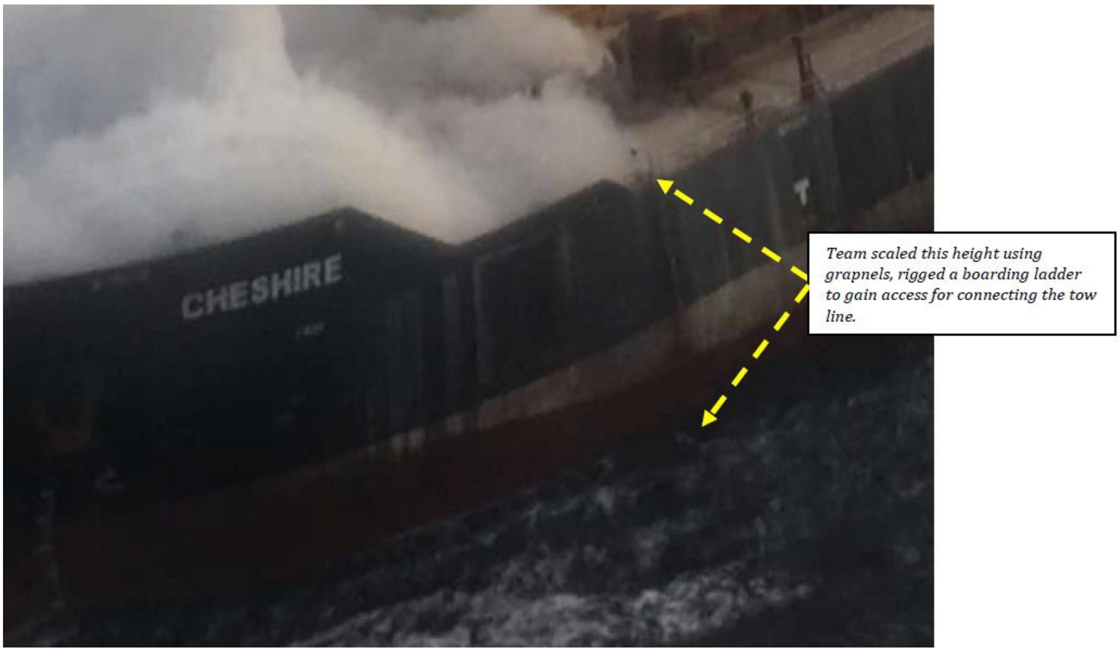


Thermographic and visible images of CH#1, #2, #3, #4, and #5 left to right, prior to initial salvage access. CH#1 is hottest followed by #2,(CH# 3, #4 and #5 reactions have largely run their course and CH#4 is now the coolest hold) [1]

Not smoke but toxic gas that is harmful to life [1]

Cheshire was successfully boarded by Salvage teams for initial damage assessment and tow line connection and although the trim of the vessel had changed due to loss of cargo from all five cargo holds (due to the reaction process), the vessel was still determined stable enough to be towed under good weather conditions to a port with suitable handling facilities for the decomposed cargo.

Initial salvage access to vessel, by gas colour CH#2 is seen to be at a more advanced stage of decomposition than CH#1[1]



Manufacturers advised Puerto de Motril was one such location and this is where the vessel was eventually to be towed for discharge and damage assessment.

Assessment of the initial salvage response actions to be made and also for the subsequent tow, the current situation was relayed back to interested parties in the form of a daily "Sit-Rep" which was supplemented by photographs, thermographs, weather reports, positional updates etc. allowing a continuing understanding of the ongoing reaction/salvage/casualty process to be determined.

Under **LOF – SCOPIC** the tow continued to Puerto de Motril. At one point the tow line parted due to lack of lubrication at contact points with the hull but this was rectified very quickly and the vessel was eventually secured alongside at 19.30hrs on 13th September. Following chemist assessment to determine and certify it was safe to gain access, Owners, underwriters and the vessel's Class Society surveyors, managers and local authorities were able to get their first close-up inspection of Cheshire.

27th / 1700 hrs - Vessel Position 27°15.426'N 014°53.081'W

The vessel remains under tow by the tug 'RED SEA FOS', proceeding at around 3.5 knots. The convoy will steam around 27° 26.8'N, 015° 34.7'W maintain 12 miles south of Gran Canaria. This location was advised by SASEMAR Miguel De Cervantes.

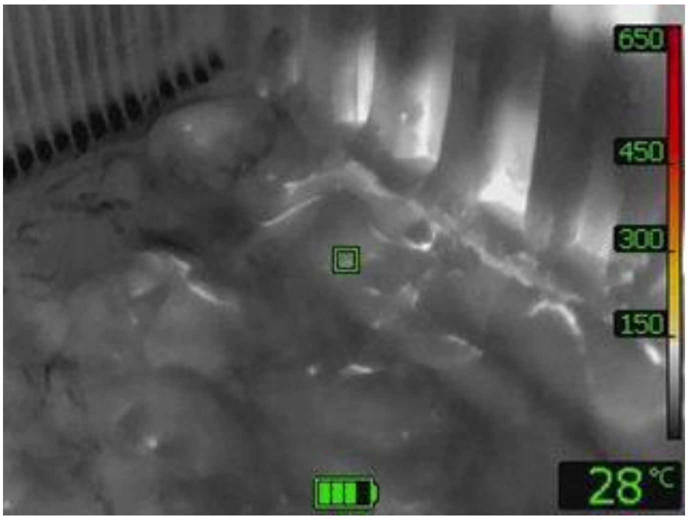
The operation to transfer personnel from the Hispania to the casualty was postponed due to deteriorating weather conditions. At 11:00 hr the Super Puma helicopter departed Las Palmas airport to winch down one fire fighter and a new Chief Officer for 'RED SEA FOS', both of whom replaced outgoing crewmembers returned to Las Palmas on same trip. Additional equipment including SCBA sets, spare SCBA compressor delivered to 'VB HISPANIA'. The helicopter returned to the airport at 12:35 hrs.

Sitrep extracts when vessel was under tow[1]

- Overnight Casualty continues under tow by Red Sea FOS proceeding towards Bay of Cadiz. Vessels were facing gale force winds BF 8, significant wave heights of 3.5m. The tow is doing about 2.2 knots, expect to improve once she clears the local disturbance.
- Demobilization of Helicopter & equipment at air base
- Cargo owner's Yara advised that Puerto Motril Spain (Near Malaga) as a possible port for discharge, Approx distance to go is around 750 miles, at present tow continues towards Bay of Cadiz.

Equipment damage assessment and immediate repairs to enable the use of the vessel's own equipment were made, portable generators were provided for power and experts from all interested parties put an action plan for the safe examination, unloading and proper hull structural damage assessment together.

Although the fertiliser mass itself acts as an insulator, manufacturers advised Matrix formation could assist a decomposition reaction by retaining heat at the reaction front. It was observed that a Matrix had in fact formed over the decomposed cargo and had retained heat. One of the conditions placed on the vessel for safe discharge of cargo by Motril port authorities, was that any decomposed cargo landed on the quayside must be less than 50^0C – this was to prove difficult due to the Matrix retaining heat and being hard, requiring it to be broken up to enable access to the hot cargo below it. As a result the unloading was expected to take a long time.



Insulating Matrix formed over the cargo retaining heat [1]

Matrix formed over cargo and blades welded to cargo grabs to help break it up[2]

During the ongoing unloading process, inspections were made by interested parties as and when cargo holds were cleared of decomposed product and assessments regarding hull condition were undertaken by structural surveyors throughout the vessel (taking alignment measurements, structural and metallurgical considerations etc. into account).

It was becoming more and more clear that significant structural deformation had occurred in addition to the visibly obvious structural damage and on 4th December 2017 under the vessel's hull and machinery policy, the underwriters declared the vessel a Constructive Total Loss **(CTL)**.

Cargo hold no.2 structural damage. [3]


Deformed/rippled cross decks. [1]

Deformed/rippled superstructure[1]

Because these discharged cargo maximum temperature requirements were stipulated for environmental and personnel safety, despite repairing and using the vessel's own cranes to move hot cargo to cooler cargo holds (to assist cooling down to 50^{0}C), the vessel was not completely unloaded until 7th December (four months and one week following the initial decomposition event).

Cheshire was regularly attended at Puerto de Motril by numerous representatives of all interested parties during the entire discharge period, trying to determine actual cause of the incident and determine the structural aspects and future commercial viability of the vessel.

Full and detailed inspection of the entire vessel had been possible since 8th December however as of the date of publication of this report, the actual cause of the decomposition remains to be determined.

Upon first proper access to the vessel, identifiable sources of heating/hot spots were confirmed to be isolated. Unfortunately we are unable to say when they were actually put into this isolated condition but if actual cause can be positively concluded at some future date, we will supplement this report with an addendum.

Referring back to our opening statement of intent - The fundamental purpose of the report is to improve the safety of life at sea and avoidance of similar accidents in the future. The aim is not to apportion liability, or unless it is necessary to the purpose of the report, to apportion blame.

We believe therefore that our recommended actions should be communicated to the industry as a whole to make improvements in conditions of carriage, equipment carried and information provided, to enhance the safer carriage of these very heat-sensitive products, in advance of the actual cause of the decomposition being determined.

Comment and Analysis

CA1

Analysis - A cargo hold inspection is undertaken before loading commences to ensure the cargo holds are in a suitably clean and dry condition to accept the cargo. It involves a physical inspection inside the cargo holds to visually confirm all areas are clear of residues from the previous cargo (which can cause incompatibility issues) and also any water in the hold bottom in order to ensure the vessel is fit to safely receive the cargo.

Analysis - Because ANBF cargo is susceptible to damage by water - making it unfit for the intended agricultural purpose - additional precautions are undertaken such as ensuring the cargo hold hatch cover seals are effective (determined by additional ULT) and the surface of the cargo is additionally covered over by plastic sheeting (in case the covers leak during extremely heavy weather on voyage and to limit moisture absorption from the atmosphere).

Comment – in addition to moisture, all ANBF cargoes are sensitive to heat and all manufacturers warn against exposing them to external sources of heat.

CA2

Analysis - SOLAS Ch. VI regulation 1-2 (enforcing IMSBC regulation 2 in respect of bulk cargoes) requires that the shipper provide the Master with appropriate information (indicated in IMSBC regulation 4) on the cargo, sufficiently in advance of loading, to enable the precautions which may be necessary for proper stowage and safe carriage of the cargo to be put into effect.

Analysis - Manufacturers provided the SDS sheets for each grade, together with the Cargo Information form indicating the proper shipping name "Ammonium Nitrate Based Fertiliser (non-hazardous)" (group C) and cargo loading plan showing the amounts of which grades would be put into each cargo hold (10088 M/T of 15-15-15 grade Bulk NPK fertiliser in CH#4 indicated).

Analysis - Due to warehouse and production utilisation the homogenous 15-15-15 grade expected to be loaded in CH#4 was only approximately 70% loaded, with the cargo balance for this hold made up with approximately 30% of 16-16-16 grade (link). We could locate no evidence to suggest that this change to the plan was communicated to the Master or Chief Officer who are made responsible for the cargo loaded for transportation prior to the decomposition event, but have since determined the whole parcel was commercially sold as the lesser 15-15-15 grade (which the 16-16-16 grade exceeds).

Analysis - The makers clearly understand these grades are close in terms of composition and how they would behave, so did not anticipate any adverse effects from loading one grade on top of the other, the 16-16-16 grade specification exceeds the 15-15-15 grade specification but not vice versa so the entire parcel had to be commercially sold as 15-15-15 grade.

Following the incident and as a precaution, the manufacturer re-tested the grade stocks loaded onto Cheshire in the correct proportions as loaded (70/30), to determine their properties were indeed as the manufacturer required production parameters; and to positively confirm that loading both grades into CH#4 would not have any unexpected effects, the independent test results confirmed that there were no unexpected effects.

Comment - The potential risks of decomposition of a mixed grade and the effect on the activity levels of reaction in connection with two cargo grades being loaded into the same hold had been carefully considered by the makers, the individual grades are compatible and were commercially sold as a complete package of the lesser grade, accordingly the makers felt justified in not needing to advise the true situation in CH#4.

CA3

Analysis - The day after departure the required information on DRY04 was being completed daily by C/O. Unfortunately this information did not appear to be trended anywhere, otherwise it may have been recognised the oxygen level in CH#4 was falling, the percentage flammable gas was rising and the carbon monoxide level was off scale since the vessel was loaded.

Analysis - Manufacturers advised these unusual readings in CH#4 may be due to some admixture/contamination with combustible material which if it had occurred must be from an external source.

Comment - In these modern times there is a huge recording requirement placed upon ship's staff (both automatic and manual recording) however automatic monitoring steps could very easily be built into a manual recording process (link).

CA4

Analysis - The Company SMS explains "Ship's Sweat" or "Cargo Sweat" shows itself in a fashion similar to condensation on a bathroom mirror. This condensation forms on the ship's structure or the cargo surface depending which is the cooler and if the cargo or the hold atmosphere has a higher moisture content.

Analysis - Under the right conditions a warmer moist cargo would deposit small quantities of water on the cooler ship's structure and the moisture being observed at the hatch drains was at first thought to simply be "ship's sweat" and not cause for immediate concern.

Analysis - The vessel has been provided with a number of multi-gas detectors calibrated to detect the gases manually recorded each day of the voyage on form DRY04. A tube is inserted into the cargo hold atmosphere and a sampling pump within the detector draws this “atmosphere” over calibrated measuring cells giving a visual display of the measured readings. The C/O inserted these readings into form DRY04 upon his return from the deck area as he was required to do by the SMS.

Analysis – The SMS section “Dry Cargo Operating Procedures” have specific references to hazards associated with certain cargoes or types of cargo and would be the go-to source for “non-standard” cargo specific information.

Comment - Unfortunately ANBF (and the preceding symptoms outlined) is not included here.

CA5

Analysis - A small quantity of water from the drains at first thought to be “ship’s sweat” and a very slight “overpressure” from the hatch drain (which stopped once the small drain plug was removed), together with what was described as small amounts of “dust”, did not cause immediate concern on 9th August until it was accompanied by a foul smell on 10th August. Something was wrong and the C/O reported the issue to the Master who then raised a NOP (link) for possible off-specification cargo.

Comment –ANBF cargoes contain very little moisture when manufactured (<0.5%) and would be unlikely to cause the sweating phenomenon that other bulk cargoes can evince. Presence of water and a foul smell (likely to be oxides of nitrogen and ammonia evolved as part of the reaction process) are early indicators of a decomposition problem.

IMSBC schedules, SDS sheets and company SMS could easily have this ANBF specific information included on them such that this particularly heat sensitive cargo can be even more safely transported.

CA6

Analysis – Company SMS form DRY04 (link), shows that over the recorded period following departure, the cargo hold temperatures generally rose by 3 or 4 degrees in CH#1-4, however from 9-11th August CH#5 rose by 11 degrees. Although all indications from the investigation point towards the initial hot spot being in CH#4, the temperature measuring point in CH#5 was nearer to the hottest area and indicated the fastest temperature rise first.

Analysis – Cargo temperatures rise and fall normally with ambient temperatures as the sea temperature and outside air temperatures rise and fall, often by a few degrees each day, however an 11 degree rise over two days in CH#5 could not be considered a normal change.

Analysis - Over the same period, oxygen content by volume in CH#4 was diminishing on a daily basis whilst other holds remained normal. IMSBC schedules for the “hazardous” ANBF cargoes all point toward oxygen levels being affected and temperature rises in a decomposition event, the “non-hazardous” ANBF schedule does not – despite this cargo is similarly heat sensitive.

Comment – Although Oxygen is not consumed by the decomposition process, it is displaced by the gases evolved during decomposition and by monitoring the atmosphere within a non-ventilated hold space, early warning signs which are representative of the entire cargo hold space can be safely achieved.

Oxygen content measurement can be taken anywhere within the hold and would give largely similar readings at any point within the hold space, whereas the TMP’s are extremely location-specific and; as seen in this instance may not be representative of the true situation. The actual decomposition was in CH#4 but the rapid temperature rise was first recorded at CH#5 port forward TMP since that one was closer to the decomposition front (**hotspot**) than the TMP’s in CH#4 (link).

CA7

Analysis - DRY04 has a note section at the bottom indicating operational controls in respect of Ammonium Nitrate, which indicate that this cargo should be carried with “vents closed”.
It also has sub-notes 1) Prevention of wet damage by ingress of seawater (vents closed)
2) Response to *self-heating* or its possibility (vents closed).
It does not have any sub-notes concerning warning signs to be alert for in respect of decomposing cargo (which are specific to ANBF).

Analysis – Under normal conditions, the IMSBC schedules for all ANBF cargoes require transportation under no ventilation and this is one of the reasons why the hatch seals are ULT’d before loading (another being to prevent water ingress which renders the product unfit for its intended purpose).

Hazardous ANBF schedules state “the temperature of this cargo shall be monitored” (further referring to heating and oxygen depletion), the IMSBC schedule for Cheshire’s ANBF (nh) cargo states “cargo hold temperatures may be monitored” and does not refer to heating and oxygen depletion in a similar fashion. This is potentially a dangerous inconsistency considering that all current classifications of ANBF are heat-sensitive and liable to decomposition (which temperature and oxygen depletion measurement can be used to detect).

Under abnormal conditions, keeping the ventilation closed for a bulk cargo which may self-heat is the normal response. It is however the wrong response for decomposing ANBF which does not self-heat, but undergoes a complex chemical reaction (which does not require oxygen) if it becomes subjected to an external heat source above the melting temperature of the cargo.

Comment - In the case of an ANBF decomposition event, because oxygen is not needed for the reaction, cargo hold fixed CO_2 systems are ineffective and natural ventilation must be increased to the maximum possible to disperse heat and toxic gases to slow the reaction process and to reduce the possibility of explosion.

Unless unsafe to do so (such as in heavy weather) it must be kept that way until the decomposition is confirmed to be under control. The cargo is going to be damaged by the reaction itself making it unfit for use and water damage will not be of any concern since water needs to be directly applied to the hotspot in order to remove the energy needed for the reaction to continue.

Since the cargo itself does not self-heat, DRY04 is perhaps a little misleading and specifically for ANBF cargo may be better worded "2) Response to *decomposition* or its possibility (increase ventilation to maximum possible)" with a further sub-note referencing specifically developed ANBF cargo SMS procedures (how to prepare to load, what to measure during transport, what warning signs to specifically look out for related to "suspected decomposition" etc.)

CA8

Analysis - SDS information was provided for each cargo grade by the manufacturer. These have grade-specific chemical makeup information and handling information. Whilst the IMSBC schedules for ANBF under "Stowage and Segregation" show "separated from" sources of heat and ignition, there are no similar specific warnings within the cargo SDS themselves, other than to store the product out of direct sunlight, in a dry, cool and well-ventilated area.

Section 5 – Fire Fighting measures of the SDS details hazards arising from the substance or mixture in connection when heated or decomposing but nothing relating to early warning signs of decomposition or to specifically prevent decomposition from initiating.

Comment – As the cargo hold contents are transported out of direct sunlight, normal ambient temperatures should remain below 50^0 but the IMSBC schedules require carriage to be non-ventilated and so directly conflicts with this last requirement, potentially affecting the Master's decision to close CH#4 main hatch following the first cooling attempt – he was simply following what the IMSBC said was necessary.

Analysis - Although the SDS information had no specific guidance on the warning signs of a decomposing cargo, or how to effectively deal with a decomposition emergency included within them, the manufacturer did provide cargo-specific information to the Master in the form of a "Light and Heat source" document (link) giving instructions highlighting the dangers of heat sources and the need to prohibit them whilst any cargo is on board. As a control for charterer's purposes, these aspects are covered in the second and third point of the hold inspection checklist (link).

Analysis - An emergency situation is not the time to start learning how to respond to it and why seafarers have a monthly requirement to train in emergency response for fires or other life-saving situations (SOLAS III reg. 19).

Actions to be followed and the information to allow the Master to arrive at the conclusion that “a decomposition event is highly likely” were not readily available on board the vessel such that the crew could look for and train for this particular scenario and its specific associated hazards.

Analysis – IMSBC schedules for AN and ANBF have sections indicating “Special emergency equipment to be carried”, “Emergency procedures” and “Emergency action in the event of a fire” for a cargo space containing this material and for a fire in an adjacent space.

Comment – The nature of shipping means emergency assistance may not be readily available and the only people able to respond to an emergency situation are the crew members themselves. The whole purpose of IMSBC schedules, Manufacturers’ SDS and operators’ SMS is to provide safety information for use by those involved in the transportation of the material, yet key safety information is not easily found where it might be expected.

It is essential that the cargo manufacturer is contacted as soon as there is any suspicion of a cargo decomposition in progress, since they have full knowledge of the chemical composition of the cargo and how it will be expected to behave, they can provide the best advice, based on feedback received on a situational basis. Although by no means a simple process, a decomposition event can be arrested if quickly and appropriately attacked.

Information on warning signs to look for (such as oxygen depletion, water accumulations, visible vapours, temperature increases and smells of ammonia - discernible and detectable at low concentrations) etc. and what steps to take for effective decomposition arrest (maximum ventilation, hotspot location identification, specifically directed cooling) etc. should be included in operational/shipping information, such that it is immediately to hand.

Specialist equipment in the form of Victor lances and reflected infra-red thermometers, or infra-red camera/analysis equipment are used by any salvage team dealing with an ANBF decomposition as are multiple SCBA for personnel safety in the toxic environment. These items should be strongly considered as additional equipment to be supplied to ships when any ANBF cargoes are taken on board a vessel – It’s far better to carry equipment and not need it than to need it but not have it.

Manufacturers, made aware of this SDS potential improvement during the course of the investigation, have indicated this will be addressed at their next SDS review, they have also agreed to consider the inclusion of safety information concerning the use of specialist equipment recommended for dealing with ANBF decomposition. It is the Author’s opinion that IMSBC schedules and operators’ Safety Management Systems need similar treatment.

CA9

Analysis – In the days prior to the obvious signs of a decomposition and “smoke” being evident coming from CH#4 drains and openings, for some reason a cargo hold fire detection alarm was not listed in the alarm history and the deck area fire detection zone is not recorded as having been isolated. There is an open system fault (16.55hrs 23.05.17 onwards) on the log maintained on the bridge by ship’s staff recovered after the incident (link) – but the description does not make it clear how the fault might have affected the system.

Comment – Specific maintenance records have not been located, no spare parts were ordered and an explanation of a simple failure to close the record once power was restored to the system has since been offered by the C/O. Photographs taken following the incident show what may be a blockage on the sampling line/cargo hold connection points and may possibly explain this failure to alarm, but this blockage is most likely a result of the cargo activity (sampling points were higher than the cargo and would not be expected to have been blocked), accordingly at this time the Author is unable to explain why an alarm is not shown in the alarm logs pertaining the cargo area and therefore did not raise awareness of a problem, in the period since departure.

CH#4 smoke detection sampling points (the cargo surface lay below the sloping surface at the bottom of the second picture, upon completion of loading). [3]

Analysis - Upon receiving the Master’s communication, Manufacturers quickly determined, from the information provided to them that it was highly likely a thermal decomposition was in progress.

Comment – Had relevant information been readily available (by means of the IMSBC cargo schedules, cargo grade SDS sheets and Safety Management System specifically developed operating procedures) – ship’s staff would have been far better prepared to arrive at this conclusion themselves and contact the manufacturers much sooner, so responding to the warning signs at a very early stage of the decomposition and quite possibly arresting it within the confines of CH#4 (particularly if specialised emergency equipment had been additionally provided on-board the vessel).

CA10

Analysis – In simple terms - Fires are a combustion process which requires three key components to occur - heat, fuel and oxygen, remove any one of these and fire simply cannot exist.

Decompositions are a chemical process which requires only two components to occur – heat and fuel, remove either one of these and a decomposition simply cannot exist. Since the cargo is the "fuel" component and exclusion of oxygen has no effect, this leaves only one option for decomposition arrest – remove the heat component.

The Manufacturers advised the best way to stop the decomposition was to cool the area with water directly by means of Victor lances (if available), or to use plain ½ or ¾ inch water pipelines if they weren't, since it is very important to inject water close to the source of the decomposition as quickly as possible. If the source of the decomposition is deep within the bulk pile, watering from above reduces the effectiveness of application since the water is dispersed as it falls through the pile (link).

Analysis - The manufacturers gave the vessel instructions how to make these specialised nozzles (link), fabrication on board commenced but took some time and whilst this was happening, crew removed the cargo covering and sprayed the bulk pile from above with water (link), which is not as effective as direct injection (even from a plain ½ or ¾ inch flattened pipe) and the initial arrest response was not as effective as it may have been. This was evidenced by temperatures seen to be rising again over the evening of 12th August following the first cooling attempt.

Comment - Despite being recognised by the fertiliser industry as the most effective means to cool decomposition; Victor lances are not standard items of equipment required to be carried by either SOLAS or the cargo charter party. Thermal imaging devices which are also valuable to assist in identifying the hottest location are not required either (fortunately the vessel had one and it was used to correctly identify the hot spot to be in CH#4 adjacent to the Australian ladder). A quick efficient response by a well-informed, well equipped and well trained crew may have saved the vessel from being lost.

Formation of a Matrix at the reaction front can assist the decomposition process by retaining the heat energy, needed by the reaction, for it to continue. The victor lance design water pattern is capable of penetrating a caked (or compressed) cargo, however the mechanisms for Matrix formation need to be understood such that steps may be undertaken to prevent this from happening.

CA11

Analysis – Because the air surrounding the vessel at the rendezvous point was relatively still, the toxic gas cloud did not easily disperse and remained within the vicinity of the vessel. This meant that decomposition products were being drawn into the engine-room ventilation system (needed for the engines to run) and fouling the turbocharger filters causing air starvation and exhaust temperature imbalance, which if it exceeded set parameters would trip the engines for their protection.

Analysis - The only way to prevent such air starvation is to clean these filters manually or remove them altogether. Because the engine-room was now filled with toxic gas, this cleaning operation had to be done wearing SCBA. C/E commenced doing so alone on an almost continuous basis, whilst 2/E (who was forced to bring the recharging compressor inside the accommodation to draw breathable air) recharged the exchanged air bottles for him.

Comment - Without power and without manoeuvrability the vessel would be helpless to do anything to protect itself and being unable to go faster (for better manoeuvrability) to try and clear the toxic gas, the situation would be unlikely to improve.

CA12

Analysis – Limited manoeuvrability arising from a single propeller and lack of bow or stern thrusters, limited visibility caused by the surrounding still air conditions and with decomposition particulates being drawn into the engine turbochargers caused additional restrictions on vessel operation which had to be dealt with by the navigators and engineers.

Analysis - Bridge-wing doors normally left open when navigating (sound plays an important part in safe navigation) had to be closed to prevent the toxic gas from entering the bridge and since they were not designed to be gas tight, the frames had to be stuffed with rags to slow the ingress of this acrid, toxic gas. The engine-room was also full of this toxic gas and the turbocharger filters needed to be manually cleaned whilst wearing SCBA having approximately 20-25 minutes use per bottle before the air supply had to be exchanged.

Analysis – The main hatch for CH#4 was temporarily closed to permit the safer boarding of personnel (who had no protection from the toxic gas). Conditions meant the cover controls were in the thickest part of the toxic gas so the Master changed course to assist C/O and Bosun, using remaining SCBA with opening the main hatch once more.

Whilst the specialist surveyor was on board and before they (C/O and Bosun) could go out on deck a "dull explosion" was felt by the Master and a deflagration (link) from CH#4 occurred, forceful enough to deposit hot cargo on top of the bridge itself and during which the main cargo hatch and associated hydraulic systems became damaged.

Comment – Since a major reaction was occurring in CH#4, energetic enough to create a large volume of escaping gas, sufficient to cause the hatch cover to be forced open, sufficient to damage the hatch hydraulic system and sufficient to deposit cargo on deck hot enough to ignite wooden pallets. Understandably, the Master forbade C/O and Bosun from going out on deck from this point forward.

CA13

Analysis – The still air conditions persisted on 14th August and being unable to manoeuvre the vessel clear of the toxic cloud (due to the turbocharger fouling reducing engine power and poor rudder steerage at slow speeds as a result) the situation on board did not improve. Fearing a blackout and thus unable to further protect the crew in any form at all, the Master called rescue services with a request to abandon the vessel and informed the Company of his decision.

Analysis – Spain MRCC, who had been monitoring the vessel since it passed by Gran Canarias reacted quickly to the Master’s Mayday message. As the last remaining crew were taken away, another deflagration occurred.

Comment - With the main hatch hydraulics disabled and despite the main and smaller openings being open, CH#4 was affected in its entirety causing the 4/5 and the 3/4 transverse bulkheads to become “external heat sources” for the cargo contained in CH#5 and CH#3 respectively.

The Master’s concern was that, without remaining main hatch cover operability, similar events to CH#4 (cargo decomposition) were possible in the remaining holds. Without the wind picking up to disperse the toxic gas and improve survival chances, in the author’s opinion the correct decision to abandon the vessel was taken at the time (link).

CA14

Analysis - Although the first salvage tug dispatched by Spain MRCC stood by the vessel, based upon the video footage they sent back, manufacturers indicated that further deflagrations were possible and advised that safe access to the vessel would not be possible.

Comment - Without means to ventilate to maximum (no hydraulics), with the hot transverse bulkheads from CH#4 providing the heat source and without the means to cool the sources of the decomposition fronts in the adjacent cargo holds, it was highly likely that the decomposition would spread.

Analysis – The reaction was allowed to continue without intervention due to immediate safety concerns. As it progressed through the vessel and as the fuel (the cargo) for the decomposition was consumed, the decomposition process lost sufficient energy to permit safer boarding. Salvors managed to do this for initial assessment and to connect up a tow wire by 21st August.

Comment – The reactions taking place in each cargo hold ran their courses and only lost the energy for decomposition to continue, as the fuel for the reaction itself (the cargo) was consumed, giving the impression they were self-sustaining.

CA 15

Analysis – All five grades of the cargo were categorised non self-sustaining (according the UN S.1 "trough test") allowing them to fall into the ANBF(non-hazardous) Cargo group C, classification and so permitting them to be carried on board this vessel.

Analysis - S.1 tests are carried out annually and additional testing is carried out if grade changes are made that may affect the product safety, by the manufacturers. In respect of the two grades loaded into CH#4 the 15-15-15 grade was last tested 21.01.17 and the 16-16-16 grade was last tested 11.01.17. Company production continuous quality and parameter control are the means to assert the grade compositions, and so the classifications, remain valid between annual "trough tests".

Analysis - The UN S.1 "trough test" was originally utilised to determine SSD properties of dangerous goods transported in packaged form and cargo classification as ANBF UN 2071 - class 9 dangerous goods, or ANBF (non-hazardous) depend upon the test results.

Comment - For packaged dangerous goods, the criteria considered are the mass of material in the package itself (from as little as ten grams to a few hundred kilograms per package), the type of packaging/containment (paper, plastic, wood, steel etc.) and the stowage/separation from other goods where it can be positioned on board the vessel (on deck only, under deck, adjacent to another material, separated by a cargo hold from incompatible materials etc.) and the availability of ventilation which can be natural or forced, all of which are designed to protect the cargo, the vessel and the crew from harm.

For bulk cargoes, there is no containment other than the steel cargo hold bulkheads, the mass can be as much as a few thousand tons, segregation can be achieved to a lesser degree than with packaged DG and any ventilation is usually limited to surface ventilation only, since the product resists the free flow of air through it.

The S.1 test was adopted into the IMSBC code for storage and transportation in bulk form, it is described in IMSBC appendix 2 - section 4.

All of YARA Porsgruun ANBF grades are manufactured to be non SSD types and test as such using the S.1 method.

Comment - As the cargo was categorised as a non-SSD type (according UN S.1 test), as the decomposition front distanced itself from the initiating "hotspot", it should have lost the energy to continue decomposing - this didn't happen!

The S.1 test (IMSBC appendix 2 section 4) is carried out with an open gauze containment system (15x15x50 centimetres) on a relatively small 11-12kg sample. Heat and hot gases readily escape from all six sides of the "trough" dissipating the energy and so naturally the reaction slows without additional heat input unless the product is particularly "energetic"!

Because it is not contained, the "S.1 test" does not include the effect of contained heat and its effect upon the reaction process. CH#4 was approx. 31.2 x 32.2 x 16.2 metres holding two grades of cargo amounting to 10,088tons.

A hazard identified in the IMSBC schedule for Cheshire's cargo "…..**if heated strongly**…..", heat dissipation is key to arresting a decomposition event but heat does not readily dissipate from a bulk cargo. Any hot gas, or indeed conducted heat, has to first pass through the bulk pile to escape. Heating the bulk pile up as a complete mass will tend to encourage the reaction making it more energetic and may go some way to explaining the deflagrations seen on board Cheshire.

CA 16

Analysis - From the start of the incident and their initial involvement, Salvors kept everyone apprised of the vessel's ongoing situation, temperatures, weather etc. The cargo manufacturers were surprised at the rapidity of the observed decomposition process. Based upon the latest received report and obvious deflagration in CH#4 they advised two things on 14th August - 1. "Not to board the vessel for any salvage action" and 2. "stay away from the vessel".

Up until that point limited boundary cooling was undertaken by the fire tug (from an upwind direction only due to the quantity of toxic gases being generated), but it moved away as instructed for safety reasons.

Analysis – After a number of days and following decomposition progression throughout the length of the vessel, once it was determined safer to approach, boundary cooling was again undertaken. Eventually weather condition improvement and more subdued reactivity levels permitted Salvors to gain access to the vessel to determine its initial condition, report back same and to connect up a towline.

Analysis – This initial inspection permitted the cargo holds to be visually inspected through the open booby and small access hatches for more accurate temperature determinations. It was observed and confirmed that a crust (Matrix) existed on top of the cargo which was cracked in places. It was also confirmed that the temperatures in these cracked areas were higher than the surface of the cargo, indicating insulating properties of the surface.

Comment - In the early days of the incident and because of the risk of further deflagrations meaning it could not be safely approached, boundary cooling could not be applied and therefore additional heat could not be taken away from the hold spaces. These higher temperatures may have permitted the formation of a “Matrix” which the manufacturers confirm could have an adverse effect on the reaction.

CA17

Analysis – Initially thought to be salvageable, considerable resources were placed to tow the vessel to a port handling facility capable of receiving the hull and her decomposed cargo. Following a long and protracted unloading process and close-up inspection and measurement by ship structural surveyors, it was determined the vessel was beyond economical repair and the vessel was declared a **CTL**.

Analysis - Determination of the actual initial cause of the decomposition is still being attempted by interested parties from the evidence collected. The vessel has since been towed for recycling at a certified facility.

CA18

Analysis - The safety investigators’ primary aim is to enhance future safety, based upon the evidence presented by a sequence of past events leading up to an incident and to attempt to prevent a re-occurrence by raising awareness of the circumstances involved and making recommendations for areas of potential improvement.

Analysis - Fertiliser manufacturers maintain that “carriage of ANBF is safe” and that safety awareness is the only thing which needs to be elevated. They support this statement by citing the quantity of product shipped versus the number of serious incidents.

Analysis - The cargo manufacturer should be contacted as soon as there is any suspicion of cargo decomposition in progress, since with appropriate equipment to hand, a directed early arrest response may potentially prevent further decomposition.

Comment – the author can agree with the fertiliser industry to a degree by saying “under controlled and specified conditions it is safe to carry”, but if something goes wrong and/or “under uncontrolled conditions”, decomposing ANBF is anything but safe.

By using appropriate measures in the initial stages of a decomposition will avoid and/or prevent further escalation

Not only safety awareness needs to be improved and the following conclusions and recommendations highlight issues identified by this investigation.

Conclusions

1) A thermal decomposition of the Ammonium Nitrate Based Fertiliser (non-hazardous) cargo commenced and despite arrest attempts being made, continued to its conclusion on board Cheshire.

2) Guidance submitted to the IMO by fertiliser industry bodies emphasises that ammonium based fertilisers can be safely transported, provided existing safeguards are followed

   These safeguards are evidenced as having been carried out on Cheshire, yet a thermal decomposition still initiated.

3) The UN S.1 “trough test” is used to determine self-sustaining decomposition properties of ammonium nitrate based fertiliser to classify the Cargo Group.

   The individual grades of cargo carried on Cheshire passed the S.1 test and were thus classified as “Cargo Group C” (non-hazardous) six months prior to shipment on Cheshire. This vessel was not arranged, equipped or certified to carry ammonium nitrate based fertiliser cargoes of higher classifications which may exhibit self-sustaining decomposition properties.

   The circumstances surrounding this particular casualty however allowed the decomposition to spread through the entirety of all five cargo grades.

4) Based upon the fact that the atmosphere readings in Cargo hold #4 were seen to be changing abnormally since loading the cargo whilst the other four holds were not, indicates there were issues in Cargo hold #4 very early in the voyage.

5) There were observable and measurable symptoms of a decomposition event taking place in Cargo hold #4 which included - reduction in the cargo holds’ atmospheric oxygen content, small accumulations of water at the hatch cover drains, “foul smells”, later on there was a temperature increase and the evolution of “smoke” but these, were not at first, understood as cause for concern on-board the vessel.

6) Instructions within the IMSBC schedule and within the supplied SDS directly contradict each other with regard to ventilation.

   a) Material safety data sheets provided for each cargo grade by the manufacturer (section 7.2) advise “store in original container protected from direct sunlight in a dry, cool and well-ventilated area away from incompatible materials…”

   Whereas:

   b) The IMSBC schedule (ventilation section) requirements state “the cargo spaces carrying this cargo shall not be ventilated during voyage.”

7) Cheshire was not required to carry or equipped with specialist equipment to deal with a thermal decomposition event on board.

8) All attempts to bring the on-board situation under control with available resources were ineffective which resulted in the vessel being abandoned for the safety of the crew.

9) As a result of the decomposition event in its entirety, the hull was structurally damaged beyond economical repair, requiring that the vessel be scrapped.

Recommendations

It is in the interests of the industry to avoid the incidence of an Ammonium Nitrate Based Fertiliser decomposition at any stage of the handling and transportation process.

Should a decomposition event commence, a swift, knowledgeable, well equipped response is key to arresting the process.

The following recommendations are based upon the investigation’s findings.

Area one - controls

- It is recommended that the IMO and marine industry together, discuss the merits of introducing a requirement for thermo-graphic determination, as an additional safeguard, to ensure that hot spots do not exist in cargo hold boundaries prior to loading any ANBF cargoes.

Area two - information

- Safety Management Systems contain ship and cargo specific operational procedures. It is strongly recommended that operators of vessels certified for, and intending to carry, ANBF at any time develop these to include ANBF-specific guidance, including which measurements should be recorded and trended. The provision of any specialist equipment would require crew training and information as to its proper use.

- For sea transportation, it is recommended that fertiliser manufacturers include specific emergency information related to cargo decomposition symptoms and suppression within their Material Safety Data Sheets for each grade manufactured, highlighting the unique dangers decomposition presents and urging early contact.

- IMSBC schedules already have specific sections with emergency information and equipment. Cargo decomposition can produce a rapidly evolving emergency situation and it is recommended that IMO populate these sections for all grades of ANBF with consistent information, what signs to look for, how to respond and what type of specialist safety equipment may be provided for use in a decomposition event.

- In light of these events, the categorisation of ANBF as “Non-hazardous” appears misleading. It is recommended that IMO consider changing the BCSN from “Ammonium Nitrate Based Fertiliser (non-hazardous)” to “Ammonium Nitrate Based Fertiliser (not otherwise classified)”

- IMO are requested to consider providing additional guidance specifically in connection with ANBF cargo decomposition by means of an MSC circular.

Area three – requirements

- It is recommended that Operators of vessels carrying ANBF cargoes consider the carriage of additional equipment (Victor Lances, additional SCBA, thermal detection etc.) in order ship's staff may be in a better position to respond quickly *and* effectively to a decomposition event.
- Within a closed cargo hold, temperature increase and oxygen depletion can give early warning of cargo problems. Although temperature monitoring is addressed in the IMSBC code for specified bulk cargoes, it is recommended that the IMO consider the merit of introducing a requirement to monitor cargo hold oxygen content as an added safeguard.

Area four – testing/classification

- Since cargo classification is determined by the results of the S.1 test, it is strongly recommended that IMO and industry experts re-consider whether the S.1 test is truly representative of the bulk mode of transportation.
- It is recommended that fertiliser manufacturers advise how containment affects the decomposition process and if carriage of more than one grade together may produce unexpected results.
- For a better understanding of the decomposition event hazards, it is recommended that fertiliser manufacturers determine how Matrix formation can be prevented and promulgate the results to industry.

Appendix 1 – Vessel details

Ship Type	–	Bulk Carrier
Flag	–	Isle of Man
Classification Society	–	Lloyds Register
IMO No.	–	9593646
Year Of Build	–	8th June 2011 (keel laid), 20th Feb 2012 (delivered)
Call Sign	–	2FEQ5
Length Overall	–	213.60m
Registered Length	–	185.64m
Beam	–	32.26m
Moulded Draught	–	12.80m
Gross Tonnage	–	33042t
Net Tonnage	–	19132t
DWT	-	57000t
Crew Complement	–	22 Officers and Crew + 1 Cargo Surveyor *(normal complement is 20)*
Cargo on board	–	42654 tonnes of NPK ammonium nitrate based fertiliser (five different grades split across five cargo holds)
Fire pumps	–	Two main pumps - each with 110 m^3/hr capacity, one emergency pump with 72 m^3/hr capacity.

Vessel owners
Bibby Transport Limited. 105 Duke Street, Liverpool, L1 5JQ. United Kingdom.

Vessel managers
V.Ships Asia Group Pte. Ltd., 10 Hoe Chaing Road, 24-01 Keppel Towers Singapore.

Cargo charterers
J. Lauritzen Singapore – 1 Harbourfront Avenue, 16-08 Keppel Bay Tower, Singapore.

Cargo manufacturers
YARA Porsgruun, Herøya Industripark AS, Hydrovegen 55, 3936 Porsgrunn, Norway.

Salvors
RESOLVE Salvage & Fire (Europe), Ltd. Holland House, 4 Bury Street London EC3A 5AW United Kingdom

Appendix 2 – Victor lance design

The Victor lance was developed by Gewerkschaft Victor and is especially useful to extinguish decompositions in small quantities of a few hundred tonnes or in piles of bagged fertilisers. The lance consists of a nozzle [see diagram] fitted to a tube of 3m length and a diameter of 25mm. If necessary this lance can be lengthened by connecting other 3m pieces with the aid of screw couplings. At a water pressure of 8 bars this nozzle has a water capacity of about 280 l/min. The lance is easy to handle and pierces through the fertiliser very quickly to reach the heart of the decomposition ***(see figure two)***, even if the product is caked. Furthermore, extinguishing can be achieved with less water compared to a normal nozzle or spray.[6][7]

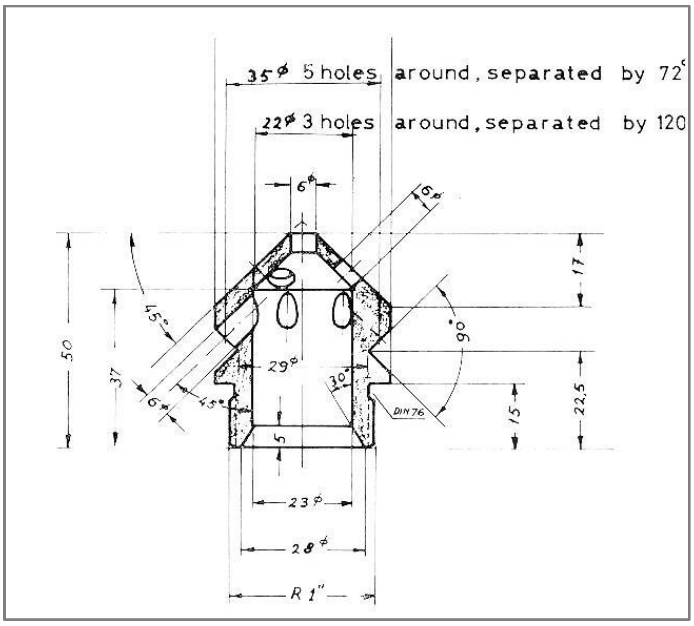


Diagram of Nozzle of Victor lance with dimensions in mm [6]

Victor nozzles for fitting to 1” dia. lance. [7]

Victor nozzle spray pattern (red lance). [7]

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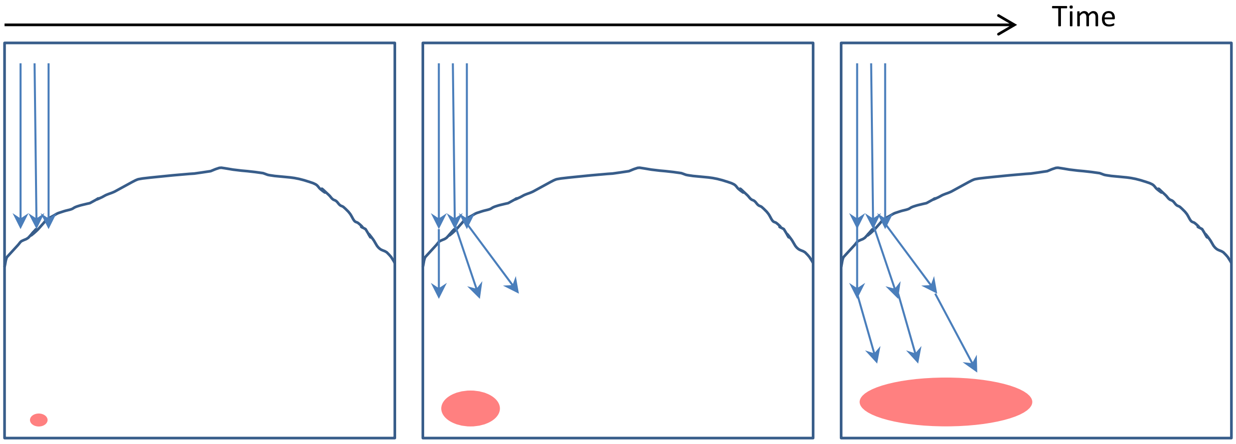
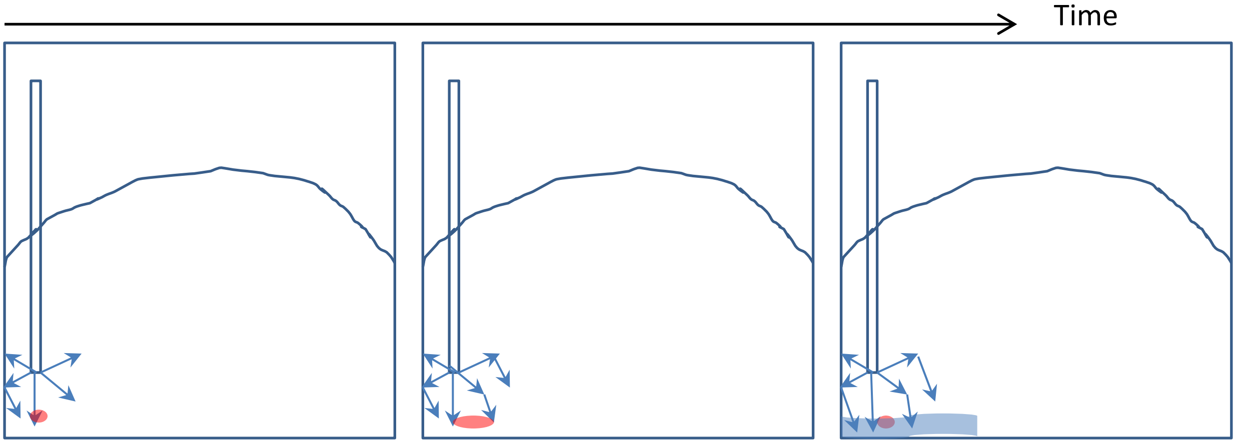
Decomposition attack

Figure one - Hose cooling from the cargo surface, time is taken for the water to fall through the bulk pile - large quantities of water are required for cooling effect to be observed (can cause stability issues for the vessel and significant cargo water damage!)



Hot spot detected. Hotspot size increased. Hotspot progressed beyond reach, pooling water not yet arrived.

Figure two - Victor Lance application of water directly at the source of the decomposition – much smaller quantities of water are required (very effective use of it, minimal stability impact and less cargo water damage)



Hot spot detected. Hotspot size maintained. Hotspot size diminished, pooling water on site.

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Appendix 3 – Hold inspection extracts, cargo loading plan and cargo safety information.

Vessel Details

Question	Response	Details
Cargo quantity		
Tonnes to load:	42650	
VESSEL DETAILS		
Hatch covers type	Steel Folding	
Engine Room Bulkhead		
A60 Bulkhead?	A60	
Last 3 cargoes		
Last Cargo 1.	Steel products	
Last Cargo 2.	Salt in bulky	
Last Cargo 3.	Coal	
Are all Hold Ventilations closed	Yes	
Electrical circuits/lights in all holds shall be turned off, disconnected with fuses out and fuse boxes locked.	Yes	
No heat sources i.e. lights pipelines shall be located in the cargo space	Yes	
Is a stevedore platform or alternative available at all holds?	Yes	

Inspection checklist

Question	Response	Details
ULD TEST		
ULD Test passed?	Yes	Only hold no 3 checked, All holds inspected and approved at 09:27 AM
HOLD INSPECTION		
Hold(s) accepted?	Yes	Only hold no 3 inspected and accepted for loading, All holds inspected and approved at 09:27 AM

Signatures

<table>
<tr><th colspan="2">Question</th><th>Response</th><th>Details</th></tr>
<tr><td colspan="4">Final result of inspection</td></tr>
<tr><td colspan="2">Inspection Number:</td><td colspan="2">1</td></tr>
<tr><td colspan="2">Vessel accepted for loading</td><td>Yes</td><td></td></tr>
<tr><td colspan="2">Time of acceptance</td><td colspan="2">7/31/17 12:37 AM</td></tr>
<tr><td colspan="4">Inspector:</td></tr>
<tr><td>Signature</td><td>[redacted]</td><td></td><td>[redacted]</td></tr>
<tr><td colspan="4">Master/Chief Officer:</td></tr>
<tr><td>Signature</td><td>[redacted]</td><td></td><td>[redacted]</td></tr>
<tr><td colspan="4">Disclaimer:
This checklist 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 with respect to the condition of the vessel. It may not be construed as a waiver of any of the charterer's party, applicable laws and/or conventions.
Declarations:
We have checked, where appropriate jointly, the items on this checklist, and have satisfied ourselves that the entries we have made are correct to the best of our knowledge, and arrangements have been made to carry out repetitive checks if necessary.</td></tr>
</table>

Cargo hold safety checklist extracts [3]

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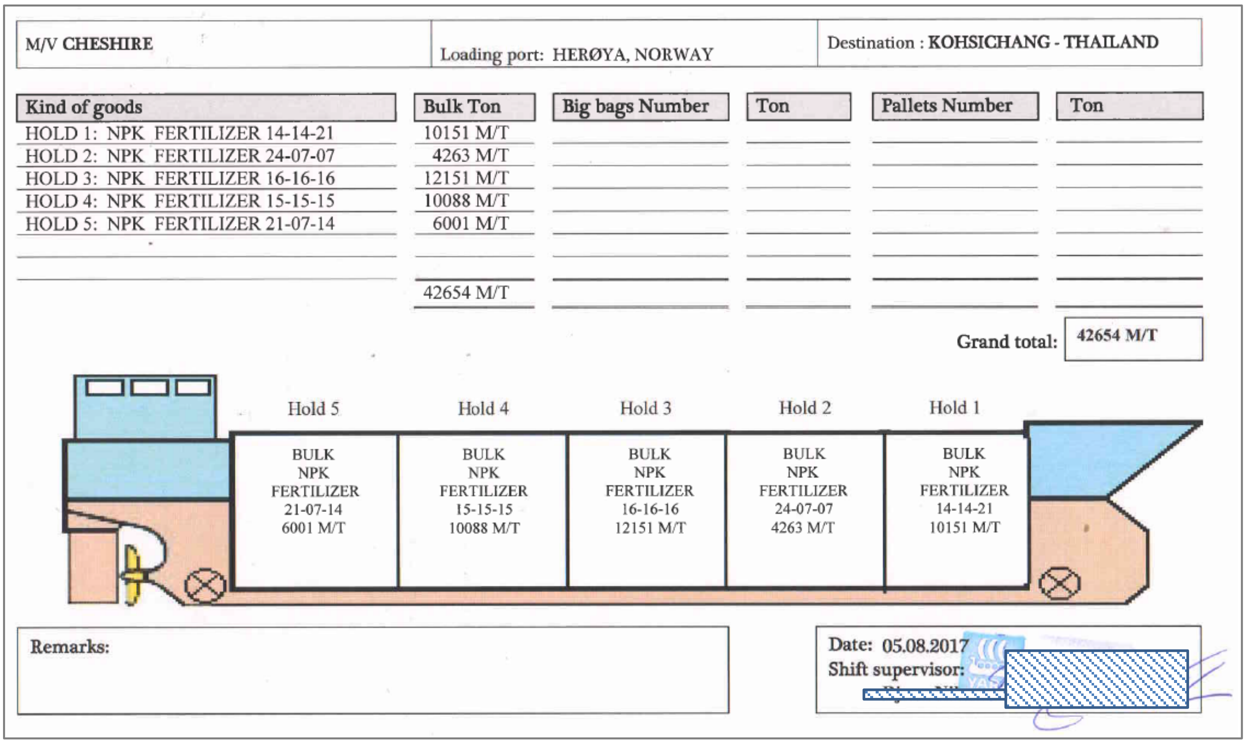


M/V CHESHIRE	Loading port: HERØYA, NORWAY	Destination : KOHSICHANG - THAILAND

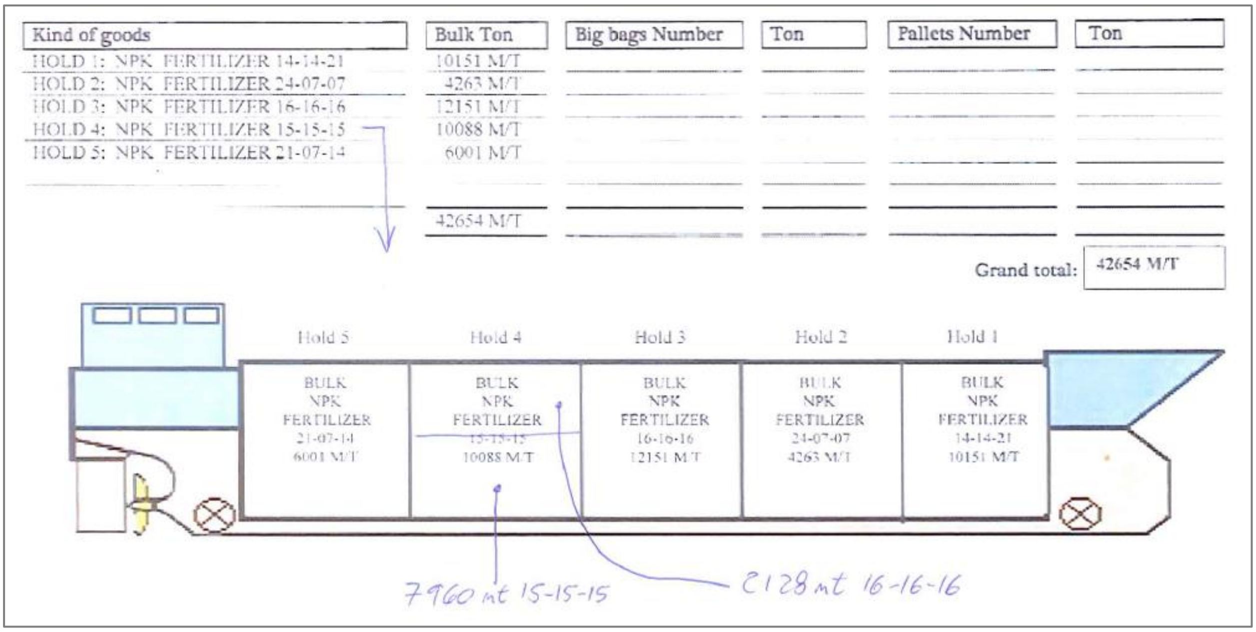
Kind of goods	Bulk Ton	Big bags Number	Ton	Pallets Number	Ton
HOLD 1: NPK FERTILIZER 14-14-21	10151 M/T				
HOLD 2: NPK FERTILIZER 24-07-07	4263 M/T				
HOLD 3: NPK FERTILIZER 16-16-16	12151 M/T				
HOLD 4: NPK FERTILIZER 15-15-15	10088 M/T				
HOLD 5: NPK FERTILIZER 21-07-14	6001 M/T				
	42654 M/T				

Grand total: 42654 M/T

Remarks:

Date: 05.08.2017
Shift supervisor: [redacted]

Cargo as declared for loading[4]



Kind of goods	Bulk Ton	Big bags Number	Ton	Pallets Number	Ton
HOLD 1: NPK FERTILIZER 14-14-21	10151 M/T				
HOLD 2: NPK FERTILIZER 24-07-07	4263 M/T				
HOLD 3: NPK FERTILIZER 16-16-16	12151 M/T				
HOLD 4: NPK FERTILIZER 15-15-15	10088 M/T				
HOLD 5: NPK FERTILIZER 21-07-14	6001 M/T				
	42654 M/T				

Grand total: 42654 M/T

Cargo as actually loaded [4]

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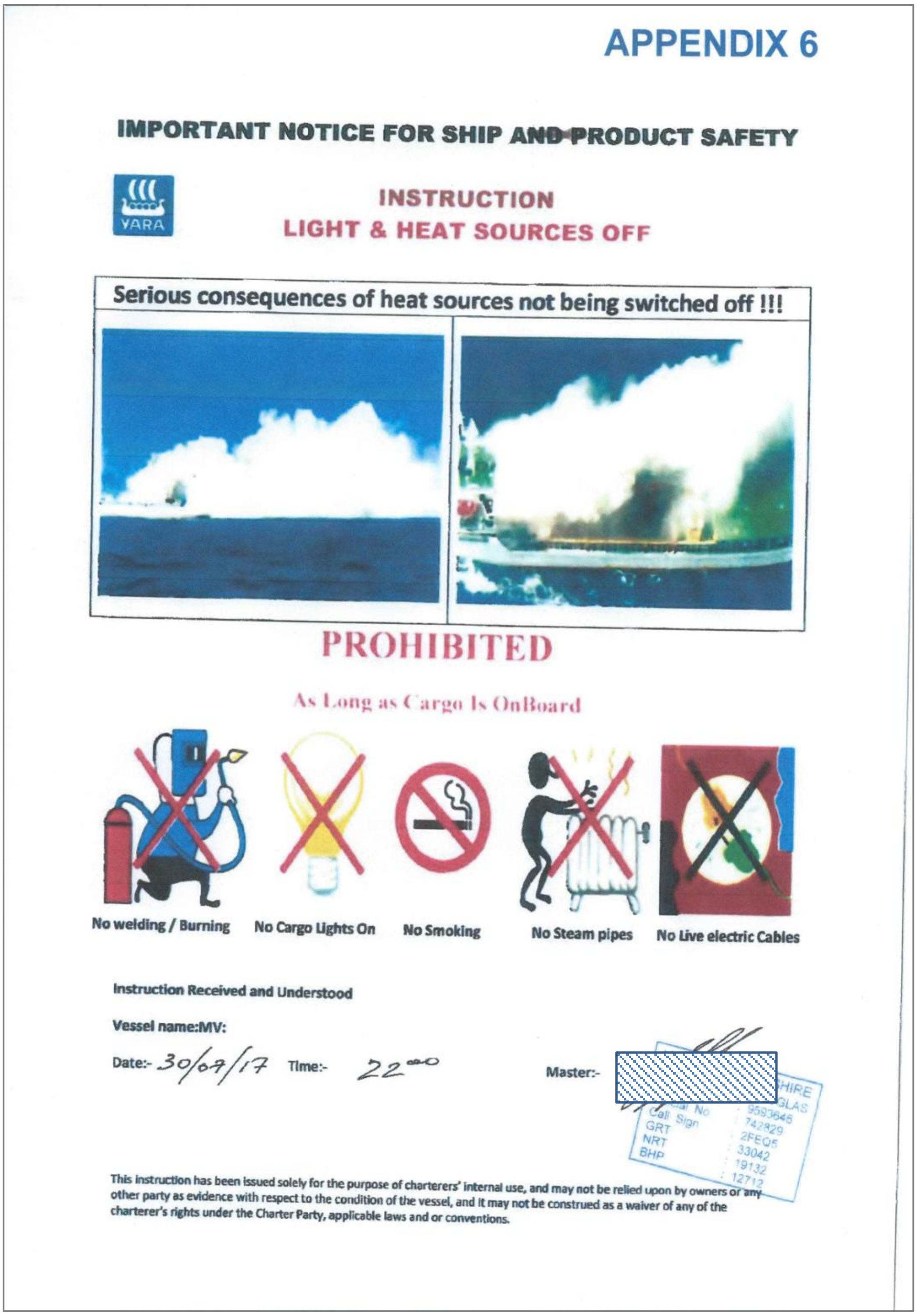

APPENDIX 6

IMPORTANT NOTICE FOR SHIP AND PRODUCT SAFETY

INSTRUCTION
LIGHT & HEAT SOURCES OFF

Serious consequences of heat sources not being switched off !!!

PROHIBITED

As Long as Cargo Is OnBoard

Instruction Received and Understood

Vessel name:MV:

Date:- 30/07/17 Time:- 22:00 Master:- [redacted]

This instruction has been issued solely for the purpose of charterers' internal use, and may not be relied upon by owners or any other party as evidence with respect to the condition of the vessel, and it may not be construed as a waiver of any of the charterer's rights under the Charter Party, applicable laws and or conventions.

Heat and light source warning document provided by the cargo manufacturer. [4]

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4	It is important to note that the above-mentioned products are not self-heating and are stable. *Moreover, they do not decompose unless exposed to substantial amounts of heat energy or high temperatures.*

Extract from IMO Editorial and Technical session 25 (E&T 25/3/6) dated 08.01.2016

Appendix 4 – Notice of Protest possible off spec cargo

m/v Cheshire
Port: At sea
Ref: Fertilizer NPK in bulk
Date: 10th August 2017

To: Yara Asia Pte Ltd as Shipper
To: Grieg Ships Services as Agent
To: Lauritzen Bulkers A/S as Sub-Charterer
To: Pacific Gulf Shipping as Charterer
To: Bibby Transport Ltd as Owner
To: Whom it may concern

Dear Sirs,

Note of Protest

As Master of the above named vessel I hereby draw your attention to the fact formation of dew of cargo 10088mt Fertilizer NPK grade 15-15-15 in bulk in hold no. 4 and passing toxic gas / accumulate water approximately 0.5liters per day in drainage pipes of hold no. 4 which was commenced from vessel's departure port Heroya.

All holds from time of departure port Heroya are tightly closed including hatch covers, ventilation covers, man access covers to holds, drainage pipes, bilge and temperature sounding pipes. All lights of access ladders in holds are switched off. All bilges all holds are dry. All temperature of cargo all holds are less 40 digress.

I hereby lodge protest and hold you responsible for any damage which may arise from above described situation.

Accordingly, I do hereby reserve the right of the vessel's Owners and/or Operators and/or Charterers to refer to this matter at a later date and place convenient and to take such actions as may be deemed necessary.

Yours faithfully

Vessel: M/V CHESHIRE
Port of Registry : DOUGLAS
[redacted]MO No : 9593646
[redacted]icial No : 742829
[redacted] Sign : 2FEQ5
[redacted]T : 33042
NRT : 19132
BHP : 12712

[redacted]

[redacted]
Master

Acknowledged Receipt By: ....

Notice of protest [3]

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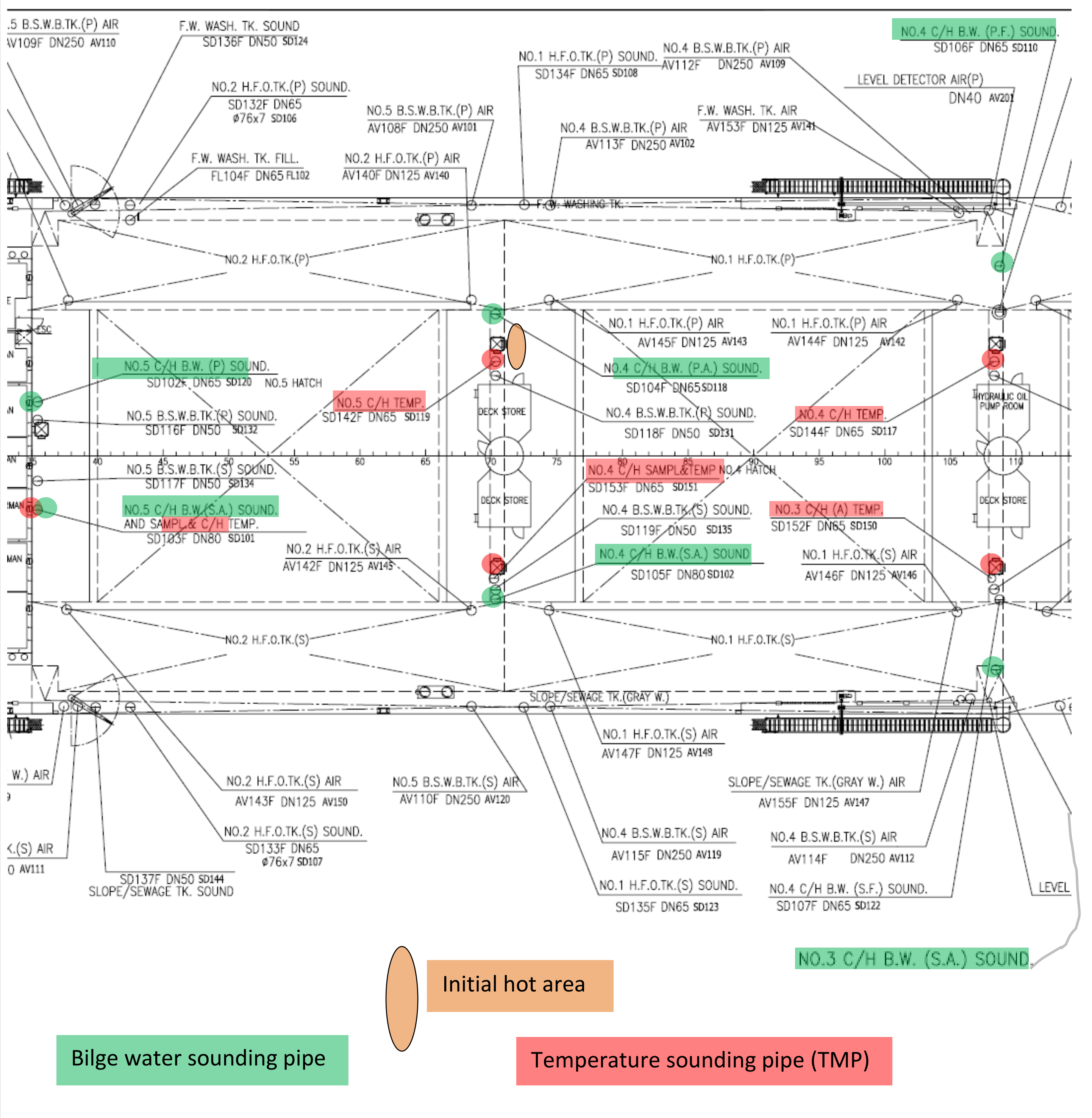
Appendix 5 - Layout of Sounding points



Ships sounding pipes [3]

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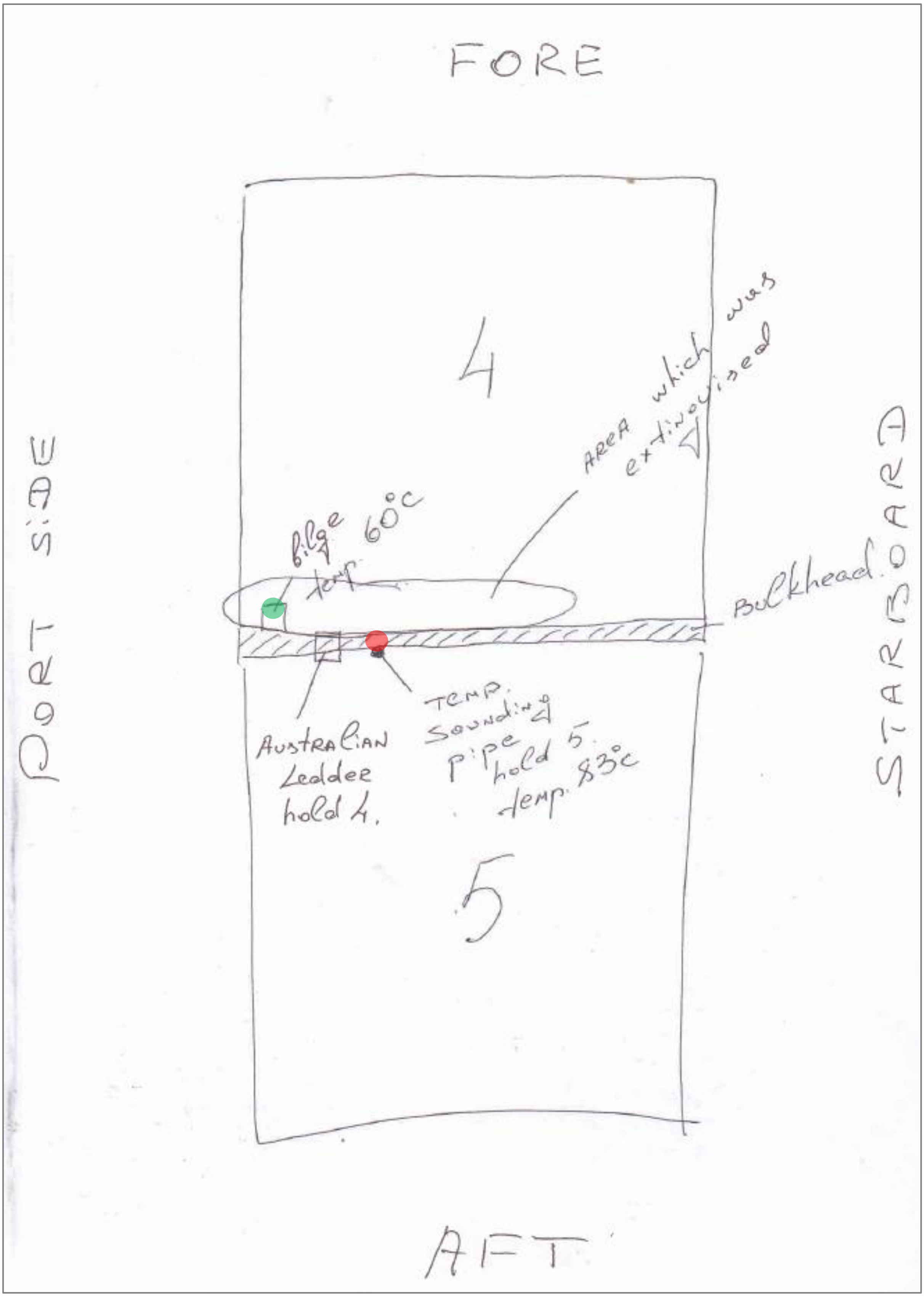

Sketch of initial hot-spot location and cooled area. [3]

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Appendix 6 - Cargo hold atmosphere trend

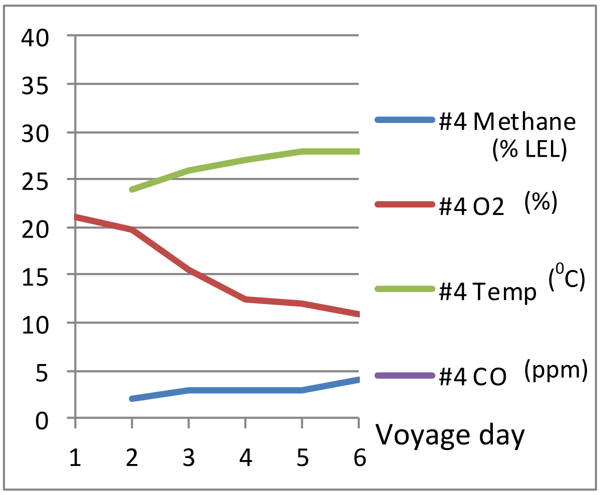
Date	06/08/2017	07/08/2017	08/08/2017	09/08/2017	10/08/2017	11/08/2017
#1 Methane		0	0	0	0	0
#1 Oxygen	21	20.8	20.9	20.8	20.9	20.9
#1 Temp		20	21	23	23	23
#1 Carbon monoxide		5	10	17	17	19
#2 Methane		0	0	0	0	0
#2 Oxygen	21	20.9	20.8	20.9	20.8	20.9
#2 Temp		19	20	21	22	23
#2 Carbon monoxide		0	0	0	0	0
#3 Methane		0	0	0	0	0
#3 Oxygen	21	20.9	20.9	20.8	20.9	20.9
#3 Temp		26	26	28	30	32
#3 Carbon monoxide		2	5	8	8	9
#4 Methane		2	3	3	3	4
#4 Oxygen	21	19.7	15.6	12.5	12	10.9
#4 Temp		24	26	27	28	28
#4 Carbon monoxide		OS	OS	OS	OS	OS
#5 Methane		0	0	0	0	0
#5 Oxygen	21	20.8	20.9	20.9	20.9	20.9
#5 Temp		25	26	27	30	36
#5 Carbon monoxide		6	7	7	7	8

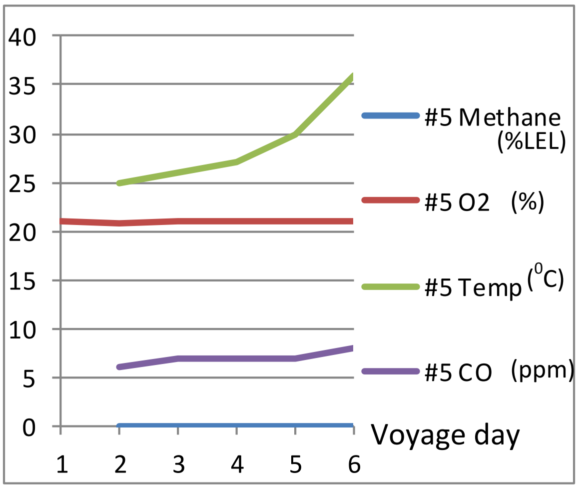
06/08/2017 Oxygen levels (21%) inserted for reference purposes on loading only

Falling Oxygen levels in #4 since loading

#4 Carbon Monoxide ppm off scale when measured (all days)

Quickly rising temperature in #5 from 9th Aug (voyage day 4)





Hold atmosphere conditions trended from information obtained during the investigation.

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DRY04 – Record of Gas and Temperature in Cargo Hold

Vessel CHESHIRE **Loading Port & Date:** HEROYA, NORWAY
Voy. No 201701 **Discharging Port & Date:** KOHSICHANG, TAILAND

Hold No	Brand & Quantity	Date / Condition	07.08	08.08	09.08	10.08	11.08	12.08	13.08	14.08	15.08	16.08
1 Fwd	AMONIUM NITRATE 10151 mt	Methane LEL %	0	0	0	0	0					
		Oxygen Vol %	20.8	20.9	20.8	20.9	20.9					
		Carbon Mon. PPM	5	10	17	17	19					
		Temperature ºC	20	21	23	23	23					
		Ventilation	Closed	Closed	Closed	Closed	Closed					
2 Aft	AMONIUM NITRATE 4263 mt	Methane LEL %	0	0	0	0	0					
		Oxygen Vol %	20.9	20.8	20.9	20.8	20.9					
		Carbon Mon. PPM	0	0	0	0	0					
		Temperature ºC	19	20	21	22	23					
		Ventilation	Closed	Closed	Closed	Closed	Closed					
3 F/A	AMONIUM NITRATE 12151 mt	Methane LEL %	0	0	0	0	0					
		Oxygen Vol %	20.9	20.9	20.8	20.9	20.9					
		Carbon Mon. PPM	2	5	8	8	9					
		Temperature ºC	26	26	23/28	23/30	23/32					
		Ventilation	Closed	Closed	Closed	Closed	Closed					
4 F/A	AMONIUM NITRATE 10088mt	Methane LEL %	2	3	3	3	4					
		Oxygen Vol %	19.7	15.6	12.5	12.0	10.9					
		Carbon Mon. PPM	OVER	OVER	OVER	OVER	over					
		Temperature ºC	24	26	27/25	28/26	28/26					
		Ventilation	Closed	Closed	Closed	Closed	Closed					
5 Fwd	AMONIUM NITRATE 6001mt	Methane LEL %	0	0	0	0	0					
		Oxygen Vol %	20.8	20.9	20.9	20.9	20.9					
		Carbon Mon. PPM	6	7	7	7	8					
		Temperature ºC	25	26	27	30	36					
		Ventilation	Closed	Closed	Closed	Closed	Closed					

Note:
The Ammonium Nitrate should be carried with the vents kept “closed”.
The following should be taken into consideration:

1) Prevention of wet damage by ingress of sea water (vents closed)
2) Response to self- heating or its possibility (vents closed)

Chief Officer Master

Page 1 of 1 **DRY 04 – Pre-Arrival and Discharge Checklist**
Revision Number: 4.0

Company SMS form DRY04 [3]

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Appendix 7- Fire zone isolation records

ISOLATION CARD

ZONE ISOLATED	DATE/TIME COMMENCE	DATE/TIME COMPLETED	OOW SIGNATURE
ZONE 10	08.08.15 0935 LT	1230 LT	[illegible]
ZONE 10	01-11-15 1440 L/T	1625 LT	[illegible]
Zone	02-11-15 0800 LT	02-11-15 1200 LT	[illegible]
ZONE 10 & 8	16-12-15 0800 LT	16-12-15 1140 LT	[illegible]
ZONE 8 & 15	21-12-15 0800 LT	21-12-15 1635 LT	[illegible]
Zone 2	07-02-16 0925 LT	1150 LT	[illegible]
Zone 3	21-02-16 0845 LT	1130 LT	[illegible]
Zone 8, 10, 11	16-03-16 0800 LT	1445 LT	[illegible]
ZONE 15	25-04-16 0917 LT	1200 LT	[illegible]
ZONE 8	28-06-16 1406 LT	1500 LT	[illegible]
ZONE 10	04-07-16 1100 LT	04-07-16 1130 LT	[illegible]
ZONE 11	13-07-16 1320 LT	13-07-16 1520 LT	[illegible]
ZONE 15	14-07-16 0930 LT	14-07-16 1145 LT	[illegible]
ZONE 8 and ZONE 15	30-07-16 1430 LT	30-07-16 1655	[illegible]
ZONE 8 & ZONE 15	12 02 17 0820 LT	12-02-17 0930 LT	[illegible]
ZONE 12	14 02 17 1100 LT	14-02-17 1145 LT	[illegible]

M/V "CHESHIRE"

ISOLATON CARD

ZONE ISOLATED	DATE/TIME COMMENCED	DATE/TIME COMPLETED	OOW SIGNATURE
ZONE 15	06 APR 17 / 0800 LT	06 APR 17 / 0830	3/0 [illegible]
ZONE 11 (TANK TOP)	11,04,17 / 1345 LT	11/04/17 1800 LT	2/0 [illegible]
ZONE 12 (FORECASTLE)	11,04,17 / 1600 LT	11,04,17 / 1700 LT	2/0 [illegible]
ZONE 12 (FORECASTLE)	13,04,17 / 1700 LT	16/04/ 1700 LT	2/0 [illegible]
Zone 5 (UPPER DECK)	20,04,17 / 1630	20/04/17 1800 LT	2/0 [illegible]
FAULT: 1 CENTRAL & CHARGER IN 4 BATTERY CABLE/FUSE FAULT/ESR	23/05/17 / 1655		C/O [illegible]

Fire zone isolation records [2]

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Appendix 8 – Other media

Deflagration [5]

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Evacuation [5]

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Acknowledgements

Reproduced with kind permission from:
[1] RESOLVE Salvage & Fire (Europe), Ltd.
[2] Bibby Transport Limited
[3] Vships Asia Group Pte. Ltd.
[4] YARA Porsgruun
[5] CIAIM/SASEMAR – Marine Accident and Incident Investigations Standing Commission and the Spanish Maritime Safety and Rescue Agency.

Extracts from Informational documents sourced from the public domain
[6] Fertilizers Europe – guidance for fighting fires and/or decomposition involving solid mineral nitrogen-based fertilizers - 2015 (page 14)

[7] Agricultural Industries Confederation - AIC Guide - The storage, handling and transportation of Ammonium Nitrate based fertilisers - 2015 (page56)