MARINE SAFETY INVESTIGATION REPORT

Safety investigation into the self-combustion of wood pellets in cargo hold no. 5 on board the Maltese registered bulk carrier

V DUE

At Point Lynas Anchorage, Liverpool in position 53° 23.70’ N 004° 09.90’ W on 29 November 2016

201611/043

MARINE SAFETY INVESTIGATION REPORT NO. 26/2017

FINAL

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

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 29 November 2016. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

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

© Copyright TM, 2017.
This document/publication (excluding the logos) may be re-used free of charge in any format or medium for education purposes. It may be only re-used accurately and not in a misleading context. The material must be acknowledged as TM copyright.

The document/publication shall be cited and properly referenced. Where the MSIU would have identified any third party copyright, permission must be obtained from the copyright holders concerned.
CONTENTS

LIST OF REFERENCES AND SOURCES OF INFORMATION .......................................... iv
GLOSSARY OF TERMS AND ABBREVIATIONS ...................................................... v

SUMMARY .............................................................................................................. vii

1 FACTUAL INFORMATION .................................................................................. 1
1.1 Vessel, Voyage and Marine Casualty Particulars ............................................. 1
1.2 Description of Vessel ...................................................................................... 2
  1.2.1 MV V Due ................................................................................................. 2
  1.2.2 Cargo hold fire safety .............................................................................. 3
1.3 Crew .................................................................................................................. 4
1.4 The Cargo ......................................................................................................... 5
1.5 Code of Safe Practice for Solid Bulk Cargoes (BC Code) .............................. 7
  1.5.1 Comparison between the BC Code (2001) and BC Code (2004) ......... 7
1.6 International Maritime Solid Bulk Cargo Code (IMSB Code) .................... 9
  1.6.1 IMSBC Code (2009 – 2012) ................................................................. 9
  1.6.2 IMSBC Code (2016) ............................................................................ 10
1.7 Environment .................................................................................................. 11
1.8 Narrative ........................................................................................................ 12
  1.8.1 Loading .................................................................................................. 12
  1.8.2 Shipper’s cargo declaration ................................................................. 14
  1.8.3 The loaded voyage ............................................................................. 15
  1.8.4 Discharging ......................................................................................... 15
  1.8.5 Return to the anchorage ...................................................................... 16
  1.8.6 Fire in the cargo hold .......................................................................... 17
1.9 Reported Damage ......................................................................................... 26
1.10 The Hazards Associated with Wood Pellets ............................................... 27

2 ANALYSIS .......................................................................................................... 29
2.1 Aim .................................................................................................................. 29
2.2 Immediate Cause of the Fire inside Cargo Hold no. 5 ................................. 29
2.3 IMSBC Code on Board V Due ...................................................................... 30
  2.3.1 Angle of repose .................................................................................. 30
  2.3.2 Loading ............................................................................................... 30
2.4 Ship Sweat during the Loaded Voyage ......................................................... 33
2.5 Discharging Cargo from Cargo Hold no. 3 .................................................... 33
2.6 Time at Anchor following Partial Discharge ............................................... 34
2.7 Procedures for Loading of Bulk Cargoes ...................................................... 34
2.8 Release of the CO₂ Fixed System ................................................................ 36

3 CONCLUSIONS .................................................................................................. 39
3.1 Immediate Safety Factor .............................................................................. 39
3.2 Latent Conditions and other Safety Factors ............................................... 39
3.3 Other Findings .............................................................................................. 40

4 RECOMMENDATIONS ....................................................................................... 41
LIST OF REFERENCES AND SOURCES OF INFORMATION


Crew members and managers MV *V Due*;

Stelte, W. (2012). Guideline: Storage and Handling of Wood Pellets (Danish Technological Institute);


International Maritime Solid Bulk Cargo Code (IMSBC Code), 2009 and 2012;


Photos courtesy Renergy, UK Ltd.
GLOSSARY OF TERMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>Breathing Apparatus</td>
</tr>
<tr>
<td>BC Code</td>
<td>Code of Safe Practice for Solid Bulk Cargoes</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>EEBD</td>
<td>Emergency Escape Breathing Device</td>
</tr>
<tr>
<td>EmS No.</td>
<td>Emergency Response Procedures for Ships Carrying Dangerous Goods Number</td>
</tr>
<tr>
<td>GA</td>
<td>General Arrangement</td>
</tr>
<tr>
<td>GMT</td>
<td>Greenwich Mean Time</td>
</tr>
<tr>
<td>GT</td>
<td>Gross tonnage</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>IMSBC Code</td>
<td>International Maritime Solid Bulk Cargo Code</td>
</tr>
<tr>
<td>kW</td>
<td>Kilowatts</td>
</tr>
<tr>
<td>LBT</td>
<td>Liverpool Bulk Terminal</td>
</tr>
<tr>
<td>LT</td>
<td>Local Time</td>
</tr>
<tr>
<td>m</td>
<td>Metres</td>
</tr>
<tr>
<td>m²t⁻¹</td>
<td>Cubic metres per tonne</td>
</tr>
<tr>
<td>MHB (WF)</td>
<td>Material Hazardous in Bulk (solids that evolve flammable gas when wet)</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetres</td>
</tr>
<tr>
<td>MFAG</td>
<td>Medical First Aid Guide for Use in Accidents Involving Dangerous Goods</td>
</tr>
<tr>
<td>MSIU</td>
<td>Marine Safety Investigation Unit</td>
</tr>
<tr>
<td>Mt</td>
<td>Metric tonnes</td>
</tr>
<tr>
<td>MV</td>
<td>Motor vessel</td>
</tr>
<tr>
<td>N</td>
<td>North</td>
</tr>
<tr>
<td>No.</td>
<td>Number</td>
</tr>
<tr>
<td>O₂</td>
<td>Oxygen</td>
</tr>
<tr>
<td>Abbr.</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>OS</td>
<td>Ordinary seamen</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per million</td>
</tr>
<tr>
<td>RINA</td>
<td>Registro Italiano Navale</td>
</tr>
<tr>
<td>Rpm</td>
<td>Revolutions per minute</td>
</tr>
<tr>
<td>SMS</td>
<td>Safety Management System</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>W</td>
<td>West</td>
</tr>
</tbody>
</table>
SUMMARY

*V Due* arrived at the port of Panama City, Florida, USA on 21 September 2016 and commenced loading on the same day at 0830 (LT). During loading, the weather was fair and dry, with an air temperature of about 30 °C. The loading operation was completed on 30 September 2016 and the vessel departed from the port of Panama City on 01 October 2016, laden with the 29,425 mt of wood pellets. The voyage was uneventful with several days of rough, near head seas and wind of Beaufort forces ranging from 7 to 9.

*V Due* dropped her anchor off Point Lynas on 18 October 2016 at 2105 in position 53º 24.3’ N 004º 12.2’ W. After 22 days at the anchorage, *V Due* finally came alongside at Liverpool Gladstone Dock on 10 November 2016. During the discharging from cargo hold no. 3, the stevedores noted an excessively high cargo temperature and stopped all the work. *V Due* was ordered to sail out of the port of Liverpool and drop anchor again, but since Gladstone Lock had developed a fault, the vessel could only sail out on 20 November 2016 at 1228. Subsequently, the vessel dropped anchor just off Point Lynas, in position 53º 23.7’ N 004º 09.9’ W.

On 29 November 2016, the second engineer walked out on the main deck after his watch, some minutes after 2000. As he walked out of the accommodation block on the vessel’s starboard side, he noticed smoke coming from cargo hold no. 5, aft rotating type mushroom ventilator. This was reported and the crew commenced firefighting with fire hoses rigged for boundary cooling around cargo hold no. 5. The efforts continued during the night. On the following day, *i.e.* 30 November 2016, the smoke was seen escaping from the sides of the cargo hold hatch cover. On the same day, the owners’ and insurers’ appointed salvage team boarded the vessel. The team consisted of a fire expert, a chemical expert and a technical consultant.

A decision was eventually made to allow the vessel back inside the port and on 08 December, *V Due* heaved up anchor and proceeded towards Liverpool docks, arriving on the following day at 0709. The discharge of cargo proved to be a complex operation, necessitating the release of the CO₂ fixed installation because of the high CO levels. The cargo self-igniting during the discharge operation but was eventually safely discharged about one week later.
The safety investigation found that the immediate cause of the fire was excessive heat generated within the stowed bulk cargo, as a combination of ship sweat, moisture, chemical and biological degradation of the cargo. It was also not excluded that the partial discharge of the cargo during the first port call, the delays at anchor upon arrival from the trans-Atlantic voyage, and during the anchorage periods before entry and after the vessel had left the port, had aggravated the situation as a result of increased moisture and air inside the cargo holds.

One recommendation has been made to the flag State Administration, to publish an Information Notice in order to raise awareness on the potential of fire hazards related to this type of cargo.
# 1 FACTUAL INFORMATION

## 1.1 Vessel, Voyage and Marine Casualty Particulars

<table>
<thead>
<tr>
<th>Name</th>
<th>V Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flag</td>
<td>Malta</td>
</tr>
<tr>
<td>Classification Society</td>
<td>RINA</td>
</tr>
<tr>
<td>IMO Number</td>
<td>9698202</td>
</tr>
<tr>
<td>Type</td>
<td>Bulk carrier</td>
</tr>
<tr>
<td>Registered Owner</td>
<td>Visentini Giovanni Trasporti Fluvio-Marittimi Srl</td>
</tr>
<tr>
<td>Managers</td>
<td>Seaquest Shipmanagement d.o.o.</td>
</tr>
<tr>
<td>Construction</td>
<td>Steel</td>
</tr>
<tr>
<td>Length overall</td>
<td>181.00 m</td>
</tr>
<tr>
<td>Registered Length</td>
<td>175.00 m</td>
</tr>
<tr>
<td>Gross Tonnage</td>
<td>23,687</td>
</tr>
<tr>
<td>Minimum Safe Manning</td>
<td>14</td>
</tr>
<tr>
<td>Authorised Cargo</td>
<td>Bulk</td>
</tr>
</tbody>
</table>

| Port of Departure      | Panama City, Florida, USA    |
| Port of Arrival        | Liverpool, UK                |
| Type of Voyage         | International                |
| Cargo Information      | Wood Pellets in Bulk (29,425 mt) |
| Manning                | 18                           |

| Date and Time          | 29 November 2016 at 20:10 (GMT +1) |
| Type of Marine Casualty| Serious Marine Casualty         |
| Place on Board         | Cargo hold no. 5               |
| Injuries/Fatalities    | Self-combustion of the cargo of wood pellets |
| Damage/Environmental Impact | None reported               |
| Ship Operation         | On anchorage off Point Lynas (Anglesey, UK) |
| Voyage Segment         | On anchor                      |
| External & Internal Environment | Night time. Visibility was good with a Southwesterly light breeze. The wave height was about 0.3 m. Air temperature was 7 °C. |

| Persons on Board       | 18                           |
1.2 Description of Vessel

1.2.1 MV V Due

MV V Due, is a 23,687 gross tonnage (GT) geared bulk carrier, with five cargo holds (Figure 1). She was built in 2015 and is registered in Valletta, Malta.

Figure 1: MV V Due GA plan
V Due is owned by Visentini Giovanni Trasporti Fluvio-Marittimi Srl, managed by Seaquest Shipmanagement d.o.o. and classed by RINA. The vessel’s length overall is 181.00 m, with a loaded draught of 10.62 m and deadweight of 37,650 tonnes. Propulsive power is provided by a MAN B&W, slow speed, two-stroke, diesel main engine, producing 6,050 kW at 99 rpm, via a fixed pitch propeller. This gives the vessel a service speed of about 13.8 knots.

1.2.2 Cargo hold fire safety

V Due is equipped with cargo holds’ fire detection and fixed CO₂ fire-fighting systems. The fire detection system, which was manufactured by ‘Safetec’, is a smoke detection system, which consists of a smoke detection panel in the CO₂ room, a control panel on the bridge, and a fan unit for drawing air from the cargo holds (forward and aft). The main CO₂ room and its control station are located on the starboard side of the upper deck on the accommodation block. Fire extinguishing and smoke detection systems are connected to the same network of pipes by means of three-way valves. The fire detection display panel (Figure 2) is located on the bridge.

A network of pipes (the same used for the distribution and release of CO₂), is used to simultaneously draw air samples from all cargo spaces, which are then fed into the smoke detection panel (Figures 3 and 4).

Figure 2: Smoke Detection System SDS-48
Figure 3: Network of pipes on *V Due* for smoke detection and CO$_2$ discharge

Figure 4: Fire detection display panel

1.3 Crew

*V Due* had a crew complement of 18 from Croatia, Philippines, Monte Negro and Serbia. The number was in excess of the minimum safe manning specified in the vessel’s Minimum Safe Manning Certificate, issued by the Flag State Administration. The crew on board at the time of the accident comprised of the master, chief mate, second and third mates, bosun, three ABs, two OS, chief engineer, second engineer,
one third engineer, electrician, two oilers, cook and messman. All officers and ratings were duly certified with appropriate STCW qualifications for their respective ranks.

The master was 60 years old and had 40 years of seagoing experience. He had obtained his master’s Certificate of Competency in 1994 and was given his first command two years later in 1996. He had joined the Company in 2015.

The chief mate was 57 years old. With 17 years experience in this rank, he signed his first contract with the Company in September 2016. Prior to accepting this position, he had been sailing as a master since 2003.

The second engineer, who first discovered the fire, was 49 years old and had 24 years of seagoing experience. He had obtained his current Certificate of Competency in 2005 and has been working in his present rank for 10 years. He had joined the Company in 2014.

1.4 The Cargo

Wood pellets are a compressed solid biomass fuel, prone to mechanical degradation, chemical decomposition and other changes such as moisture absorption during handling and storage. Mechanical degradation during handling can generate fines and dust, which can be a cause of fires and explosions\(^1\).

Pellets are produced from sawdust and wood shavings, which are dried, and then milled into particles of up to approximately 2 mm particle size. The particles are then compressed approximately 3.5 times into pellets, typically between 10 mm and 20 mm long and between 3 mm and 12 mm in diameter, the pellets are light blond to dark brown in colour, depending on the variety of trees from which they are made\(^2\) (Figures 5a and 5b).

---

\(^1\) The Pellet Handbook: The Production and Thermal Utilization of Biomass Pellets.

\(^2\) BMT Surveys.
Wood Pellets are produced under high pressure and high temperatures. One of the steps in the process of manufacture is densification, when the feedstock is compressed, leading to an increase in temperature and resulting in a plasticized surface appearance. The temperature of the pellets immediately after the process can vary between 80 ºC and 130 ºC, which is why cooling before storage is necessary\(^3\). The pellets typically have a moisture content of 4% to 8%. When used as animal bedding, the moisture content is typically between 8% and 10%. Wood pellets are used as a fuel in district heating and electrical power generation as well as a fuel for small space heaters such as stoves and fireplaces\(^4\).

There are two main types of wood pellets: Industrial Pellets, used for power and heating plants, and the so-called ‘Prime Quality’ pellets, which are used for heat production in private houses and small heating plants. The latter is normally transported in bags placed on wooden pallets and inside large bags\(^5\) (Figures 6a and 6b).

The cargo on board \textit{V Due} belonged to the group of non-cohesive bulk cargoes.

---

\(^3\) The Pellet Handbook: The Production and Thermal Utilization of Biomass Pellets.

\(^4\) IMSBC Code 2016, Individual schedules of solid bulk cargoes, p. 359.

\(^5\) Renergy UK Ltd.
1.5 Code of Safe Practice for Solid Bulk Cargoes (BC Code)

The BC Code was first adopted by the International Maritime Organization (IMO) as a recommendatory code in 1965 and has been updated at regular intervals since then. The aim of the BC Code was to bring to the attention of those concerned an internationally accepted method of dealing with the hazards to safety, which may be encountered when carrying cargo in bulk. The BC Code became a main reference document for seafarers engaged in the carriage of bulk cargoes and a revised version of the BC Code was adopted in 2004.

1.5.1 Comparison between the BC Code (2001) and BC Code (2004)

The 2001 Edition of the BC Code contained a short entry for ‘wood pulp pellets’ (Table 1).

The entry is considered to be misleading because wood pulp is not normally formed into pellets and wood pellets are not considered as pulp. Furthermore, while referring to $O_2$ depletion and generation of $CO_2$, the entry did not refer to the formation of carbon monoxide (CO).
Table 1: BC Code (2001) entry for wood pulp pellets

<table>
<thead>
<tr>
<th>BC No.</th>
<th>IMO class</th>
<th>MFAG table No.</th>
<th>Approximate stowage factor (m$^3$t$^{-1}$)</th>
<th>EmS No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>080</td>
<td>MHB</td>
<td>615*</td>
<td>3.07</td>
<td>B6</td>
</tr>
</tbody>
</table>

Properties

Some consignments of wood pulp pellets may be subjected to oxidation, leading to depletion of oxygen and an increase of carbon dioxide in cargo space.

Segregation and stowage requirements

Segregation as required for class 4.1 materials *.

Special requirements

Entry of personnel into cargo spaces containing this material should not be permitted until the master of the ship or the reasonable officer is satisfied that it is safe to do so after taking into account all safety precautions.

* Class 4.1 materials are defined as flammable solids or substances.

This was revised in the 2004 Edition of the BC Code. In addition to Wood Pulp Pellets, an entry for Wood Pellets was added. A reference was also made to an increase of CO level and the associated hazards such as asphyxia.

Additional and important entries were added for Wood Pellets in the 2004 Edition pertaining to their loading and carriage. It was stated that a cargo of wood pellets had to be loaded to the boundaries of the cargo space to minimize the risk of shifting and to ensure that adequate stability is maintained during the voyage. The angle of repose was given as “approximately 30°” (Table 2).

Table 2: Individual schedule for Wood Pellets in the BC Code (2004)

<table>
<thead>
<tr>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of repose</td>
</tr>
<tr>
<td>Approximately 30°</td>
</tr>
<tr>
<td>Bulk density (kgm$^{-3}$)</td>
</tr>
<tr>
<td>600 to 750</td>
</tr>
<tr>
<td>Stowage factor (m$^3$t$^{-1}$)</td>
</tr>
<tr>
<td>1.4 to 1.6</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td>Cylindrical with 3 mm to 12 mm</td>
</tr>
<tr>
<td>Diameter: 10 to 20 mm</td>
</tr>
<tr>
<td>Class</td>
</tr>
<tr>
<td>MHB</td>
</tr>
<tr>
<td>Group</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

The entry for Ventilation stated: ‘Do not ventilate’.
1.6 International Maritime Solid Bulk Cargo Code (IMSBC Code)

In 2008, amendments to SOLAS chapter VI were adopted by the Maritime Safety Committee to make the new IMSBC Code mandatory. The amendments entered into force on 01 January 2011 and the IMSBC Code replaced the BC Code. Since 2011, there have been three amendments to the IMSBC Code: 01-11, 02-13 and 03-15. Amendment 03-15 contains changes to the Individual Schedule for Wood Pellets.

1.6.1 IMSBC Code (2009 – 2012)

The IMSBC Code, 2009 Edition contained an Individual Schedule for Wood Pellets (and Wood Pulp Pellets) with several amendments pertaining to loading, ventilation and precautions sections. The loading section required cargoes of wood pellets to be trimmed in accordance with sections 4 and 5 of the Code. Ventilation of enclosed spaces adjacent to a cargo hold before entry was also mentioned. Under the precautions section, the necessary level of O₂ and CO before entry into cargo and adjacent confined spaces was stated. There was no mention of cargo hold ventilation and the entry ‘do not ventilate’ had been removed within the updated edition.

The 2012 Edition contained amendment 01-11, which was adopted in May 2011. The schedule for wood pulp pellets was deleted in its entirety.

There was only one minor change in the Individual Schedule for Wood Pellets, section ‘Loading’ in the 2012 Edition; in addition to sections 4 and 5 of the IMSBC Code, trimming had to be done in accordance with section 6 of the IMSBC Code as well.

Section 4 of the IMSBC Code puts the onus on the shipper to provide appropriate cargo information to the master. Information had to be provided sufficiently in advance of loading, to enable the necessary precautions for proper stowage and safe carriage of the cargo (section 4.2.1). This includes a correct angle of repose.

Section 5 of the IMSBC Code makes a reference to cohesive and non-cohesive cargoes. Non-cohesive cargoes are those exhibiting the properties of a non-cohesive material. Depending on the non-cohesive cargoes’ angle of repose, the stowage and

---

6 It has already been stated in section 1.4 that the cargo on board V Due belonged to the group of non-cohesive bulk cargoes.
carriage differs. Section 5.4.3 states that non-cohesive bulk cargoes having an angle of repose of less than or equal to 30º, flow freely like grain and have to be carried according to the provision applicable to the stowage of grain cargoes.

Section 5.4.4 states that non-cohesive cargoes, having an angle of repose greater than 30º to 35º inclusive, have to be trimmed so that the unevenness of the cargo surface measured as the vertical distance between the highest and lowest levels of the cargo surface shall not exceed B/10, where B is the beam of the ship in metres, with a maximum allowable vertical distance of 1.5 m; or loading is carried out using trimming equipment approved by the competent authority.

Section 6 of the IMSBC Code lists recommends methods of determining the angle of repose.

There is no mention of cargo holds ventilation.

1.6.2 IMSBC Code (2016)

The IMSBC Code (2016) incorporated amendment 03-15 where the Individual Schedule for Wood Pellets had been deleted, and two new entries incorporated:

1. wood pellets containing additives and/or binders; and

2. wood pellets not containing any additives and / or binders\(^7\).

This change in the IMSBC Code could have been applied in whole or in part on a voluntary basis as from 01 January 2016. Mandatory compliance commenced on 01 January 2017.

The present description and all the information for both types of the cargo are just the same as in previous edition of the IMSBC Code, except for the entry in the table ‘Characteristics’. In this table, wood pellets containing additives and/or binders are classed as Material Hazardous in Bulk (MHB) - solids that evolve flammable gas when wet (WF), (Table 3), which is not applicable in this case.

\(^7\) This is what was declared on the shippers cargo declaration.
Table 3: Characteristics for wood pellets containing additives

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Angle of repose</th>
<th>Bulk density (kg m(^{-3}))</th>
<th>Stowage factor (m(^3) t(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approximately 30°</td>
<td>600 to 750</td>
<td>1.33 to 1.67</td>
</tr>
<tr>
<td>Size</td>
<td>Class</td>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>Cylindrical with 3 mm to 12 mm</td>
<td>MHB (WF)</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Diameter: 10 mm to 20 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wood Pellets not containing any additives and/or binders are Classed as Material Hazardous in Bulk (MHB) – Other Hazards (OH), (Table 4).

Table 4: Characteristics for wood pellets not containing additives

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Angle of repose</th>
<th>Bulk density (kg m(^{-3}))</th>
<th>Stowage factor (m(^3) t(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approximately 30°</td>
<td>600 to 750</td>
<td>1.33 to 1.67</td>
</tr>
<tr>
<td>Size</td>
<td>Class</td>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>Cylindrical with 3 mm to 12 mm</td>
<td>MHB (OH)</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>Diameter: 10 mm to 20 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.7 Environment

The weather when the fire was detected, was cloudy and the air temperature was 7 °C. A light breeze was blowing from the Southwest and the sea was calm. Visibility was good.
1.8 Narrative

1.8.1 Loading

*V Due* arrived at the port of Panama City, Florida on 21 September 2016 and commenced loading on the same day at 0830 (LT). During loading, the weather was fair and dry, with an air temperature of about 30 °C.

The cargo temperature during loading was recorded at the shore facility; figure 7 below shows the data recorded then. For instance, the temperature of the cargo loaded in cargo hold no. 1 was recorded to have reached 40 °C on 27 September.

![Figure 7: Data recorded when the vessel was at the shore facility](image)

Available literature and the safety investigation into this casualty revealed that during hot periods in the summer (30 °C and more), the risk of self-heating of wood pellets increases. Temperatures above 50 °C are undesirable because the temperature

---

8 Unless otherwise stated, all times are local time GMT +1.
dynamics of wood pellets are relatively unpredictable and critical temperatures are typically between 40 °C and 50 °C\textsuperscript{9}.

During loading, two water spray guns were placed on the quay on each side of the conveyor (Figure 8) to control the spread of dust. There were no concerns that the cargo would get wet because the conveyor was of the closed-type; then, the water from the spray guns was not directed towards the conveyor belt.

![Figure 8: Water spray gun](image)

After six days of loading, the Panama City Port Captain held a safety meeting with the crew on 27 September 2016 and requested that fire hoses be rigged on deck in case the cargo caught fire on the conveyer and inside the cargo holds\textsuperscript{10} (Figure 9).

\textsuperscript{9} The IMSBC Code offers no guidance on the temperature aspect of wood pellets cargoes.

\textsuperscript{10} There was no further explanation provided to the crew. However, it is very probable that this was a precaution since the temperature of the cargo was 40 °C and hence, at the lower end of the critical temperature range.
Figure 9: Fire hoses rigged on the main deck

The loading operation was completed on 30 September 2016 and the vessel departed from the port of Panama City on 01 October 2016, laden with the 29,425 mt of wood pellets. *V Due* was drawing a forward draught of 8.71 m and an aft draught of 9.61 m.

The shipper within the Shipper Cargo Declaration had issued specific instructions that all cargo hatches had to be kept dry and free from oxygen ingress by sealing them with approved tape. Furthermore, the shipper’s cargo declaration stated that all ventilation to the cargo holds loaded with wood pellets was to be kept shut: “all hatches must be sealed with approved tape to ensure cargo remains dry and free from oxygen ingress” and “all ventilation to the cargo hold where the wood pellets are kept shall immediately be shut off.”

1.8.2 Shipper’s cargo declaration
The cargo was generally described as “Wood Pellets made of wood sawdust, shavings and bark, no additives or binders.” Moisture content was declared between 4% to 10%. The shipper’s cargo declaration (*Annex A*) provided to the master further stated that measurements of O₂ and CO levels had to be recorded during the voyage.
The potential hazards listed in the cargo declaration included:

1. swelling if exposed to droplets and water;
2. O₂ depletion;
3. ignition, thus requiring segregation similar to that required for IMO Class 4.1 cargoes;
4. fermentation over time if exposed to moisture with generation of flammable and asphyxiating gas; and
5. risk of explosion at high dust concentration.

1.8.3 The loaded voyage

The voyage was uneventful with several days of rough, near head seas and wind of Beaufort force ranging from 7 to 9.

O₂ and CO levels were monitored throughout the voyage. O₂ levels recorded were in the range of 20.1% and 20.6% in all five cargo holds. The CO level was zero in all cargo holds.

*V Due* dropped anchor off Point Lynas on 18 October 2016 at 2105 in position 53º 24.3’ N 004º 12.2’ W. After 22 days at the anchorage, *V Due* finally came alongside at Liverpool Gladstone Dock on 10 November 2016. Following a ‘gas free’ inspection, discharging of cargo started from cargo hold no. 3 on the same day at about 2215.

1.8.4 Discharging

During the discharging from cargo hold no. 3, which had only been partially loaded, an excessive cargo temperature was noted by the stevedores, who stopped all the work. The temperature of the cargo measured by the stevedores in cargo hold no. 3 was about 69 °C and between 50 °C and 60 °C in the other cargo holds. The cargo discharge operation was suspended on 16 November 2016, with the stevedores remarking that the work could not be carried out due to the condition of the cargo¹¹.

¹¹ During the consultation period, the Company submitted that the master was informed neither about cargo temperature data, nor about higher cargo temperatures. Moreover, the Company stated that the master had been verbally informed that there was no space in the silos and therefore, the vessel had to vacate the berth.
At the time, the total cargo which had already been discharged was 4,841 mt.

### 1.8.5 Return to the anchorage

*V Due* was ordered to sail out of port and drop anchor again, but since Gladstone Lock had developed a fault, the vessel could only sail out on 20 November 2016 at 1228. The vessel dropped anchor just off Point Lynas, in position 53º 23.7’ N 004º 09.9’ W.

The measurements of O₂ and CO continued throughout the vessel’s stay at the anchorage. This time, the crew was also instructed to monitor the cargo temperatures in all the cargo holds. However, due to the adverse weather and heavy rain, it was reportedly impossible to ventilate the cargo holds and measure the temperatures until 24 November 2016. The temperatures taken from 24 November to 29 November (the date of the accident) obtained through the temperature pipe on the main deck (Figure 10) measured between 8 ºC and 20 ºC in cargo holds nos. 1, 3 and 4, between 30 ºC and 44 ºC in cargo hold no. 2, and between 50 ºC and 54 ºC in cargo hold no. 5.

![Temperature measurement pipe on the main deck](image)

**Figure 10: Temperature measurement pipe on the main deck**

During the consultation process, the Company advised that once the vessel arrived at the anchorage, the crew members noticed problems with the cargo. It was stated that charterers provided instructions to the vessel on cargo ventilation and a de-humidifier was sent on board and placed in cargo hold no. 5 and used for one day. The Company submitted that the master noticed no improvement in the situation inside cargo hold no. 5 and to this effect, he insisted that the de-humidifier is removed. This happened at 1330 on 29 November, *i.e.* a few hours before smoke from cargo hold no. 5 was observed (at 2000) – *vide* sub-section 1.8.6.
The O₂ reading in all the five cargo holds was 20.9% and the CO level was reading zero. However, on 29 November, the O₂ level started dropping in all cargo holds, showing 20.2% in cargo holds nos. 1 to 4 and 16.5% in cargo hold no. 5, where the CO reading was simultaneously noticed to be increasing.

1.8.6 Fire in the cargo hold
Some minutes after 2000, on 29 November 2016, the second engineer walked out on the main deck after his watch. As he walked out of the accommodation block on the vessel’s starboard side, he noticed smoke coming from cargo hold no. 5, aft rotating type mushroom ventilator. The ventilator is similar to the one reproduced in Figure 11.

Figure 11: Rotating type mushroom ventilator

Unclear as to what was happening, the second engineer had left the accommodation door open. Smoke was drawn into the accommodation and the fire alarm on the
bridge was activated at 2010, showing fire in zone no. 6 (upper deck passage starboard) (Figure 12)\textsuperscript{13}.

\textbf{Figure 12: Fire detection display panel on the bridge}

There had been no prior warning up until this time. It has to be submitted that during the trans-Atlantic passage and the first period at anchor (awaiting berth), the cargo holds’ smoke detector was not in operation because the cargo had been loaded to the top of the hatch coamings (Figure 13a) in all the cargo holds, except for cargo hold no. 3, thus covering the sampling holes through which the air is drawn into the smoke detector system (Figure 13b). The same holes, indicated by the red arrows in Figure 13b, are used for the release of CO\textsubscript{2} into the cargo holds via a three way valve arrangement within the piping system.

\textbf{Figures 13a and 13b: Cargo holds loaded to the top, covering the CO\textsubscript{2} / smoke detection sampling holes}

\textsuperscript{13} The time shown on the fire alarm indicates 2031, because the system clock runs 20 minutes fast.
However, during the second anchorage, after the vessel had left the berth in Liverpool and hence following the partial discharge of the cargo, the sampling holes would have been uncovered.

The crew commenced fire-fighting with fire hoses, which were rigged for boundary cooling around cargo hold no. 5. The efforts continued during the night. However, on the following day *i.e.*, 30 November 2016, smoke was seen escaping from the sides of the cargo hold no. 5 hatch cover (Figure 14).

![Figure 14: Smoke leaking from under the hatch cover](image)

On the same day, the owners’ and insurers’ appointed salvage team boarded the vessel. The team consisted of a fire expert, a chemical expert and a technical consultant. A 500 m temporary exclusion zone was established around the vessel and access was restricted to the ship’s crew and the salvage team.

In the meantime, the escape of smoke was getting progressively worse during the day and the following days (Figure 15a). The only fire-fighting measure undertaken at this stage was boundary cooling (Figure 15b).
The measurements of CO levels in the engine-room and the accommodation were reportedly high and well above the safe limit. CO build-up inside the accommodation spaces was monitored and ventilated. The salvage team’s technical consultant reported that all other cargo holds’ parameters were checked frequently and CO build-up was noticeable, except in cargo hold no. 3, which was half empty.

On 03 December, a leak of CO was identified inside the engine-room and it was determined that the leak was through cargo hold no. 5 water level sensor (Figure 16).

In order to ventilate the gas out of the engine-room, a duct vent with an extractor fan was installed around the sensor and passed out of the engine-room via a store’s hatch.
The tug assisted by turning the vessel as necessary while at anchor to direct the gas away from the vessel.

The salvage team’s fire expert continued monitoring levels of O₂ and CO in the cargo holds, accommodation spaces, main deck and engine-room. The crew movement around the vessel was restricted and crew members were escorted around the vessel by the salvage team chemist using Emergency Escape Breathing Device (EEBD) or Breathing Apparatus (BA).

On 05 December 2016, the level of CO inside the cargo holds increased and movement of the crew on the main deck and the engine-room was suspended, unless authorised by the chemical expert and wearing an EEBD or BA.

Since the evening of 29 November, regular and frequent meetings were held ashore between interested parties on the best action and place of refuge for V Due to discharge the cargo. The decision was made one week later and on 08 December, V Due heaved up the anchor and proceeded towards Liverpool docks, arriving on the following day, on 09 December at 0709. An Exclusion Zone of 50 m was established around the vessel.

The Liverpool Fire Brigade boarded the vessel on 10 December at about 0815 (Figures 17a and 17b).

Soon afterwards, the Fire Brigade advised that before the hatch cover for cargo hold no. 5 could be opened, the CO levels inside had to be considerably reduced by purging, using carbon dioxide (CO₂) gas, which was released at 1243 (Figure 18).
Figure 18: CO$_2$ released into cargo hold no. 5

About 45 minutes later, at 1335, cargo hold no. 5 was fully opened (Figures 19a and 19b).

Figure 19a: Cargo hold no. 5 with a CO$_2$ blanket  Figure 19b: Cargo hold no. 5 prior to its discharge

Discharging of cargo started at 1422 on 10 December. However, the first two grabs of cargo discharged from the vessel resulted in severely smouldering and burning cargo (Figures 20a and 20b).
Figures 20a and 20b: Smouldering and burning cargo

Flames and billowing smoke were noticed inside cargo hold no. 5, in the upper port side aft part (Figure 21).

Figure 21: Cargo on fire inside cargo hold no. 5

The Fire Brigade maintained boundary cooling and started spraying water inside the cargo hold (Figures 22a and 22b) as well as ashore onto the landed cargo.
The temperature was high enough that some of the cargo, which had already been landed ashore, self-combusted (Figure 23). In fact, the temperature of much of the discharged cargo was very high indeed, with temperatures reaching 210 °C.

In order to mitigate the situation, the landed cargo was spread thinly on another part of the quayside, to further reduce its temperature prior to being loaded onto road haulage wagons and transported approximately 400 m away inside the Liverpool Bulk Terminal, where it was to be stored outdoors until onwards movement (Figure 24).
Three days later, on 13 December, most of the cargo from cargo hold no. 5 had been discharged. Approximately 200 mt of the cargo could not be removed by the crane grab due to the shape of the cargo hold and the temperature of the cargo. Some cargo was ‘stuck’ to the bulkheads (Figure 25) and had a surface temperature of 150 °C.
The Fire Brigade attempted to remove the remaining cargo using water, which was, however, an unsuccessful attempt. A cherry-picker was then lowered inside the cargo hold to facilitate as much cargo removal as possible. The discharging from cargo hold no. 5 was officially completed on 15 December 2016 at 1730. Small amounts of cargo remained in the cargo hold, sticking to the bulkhead and side shell framing (Figure 26).

![Figure 26: Cargo remaining and burnt area in cargo hold no. 5](image)

Cargo holds nos. 1 and 4 remained closed\(^{14}\).

The crew members had been visited by a doctor, and five crew members, most likely to have had the greatest exposure to CO, were admitted to hospital for a more detailed check-up. No medical concerns had been reported.

### 1.9 Reported Damage

*V Due* was attended by a Class surveyor for a damage survey. Close-up survey criteria were applied during the inspection of the cargo hold. The survey of cargo hold no. 5 revealed burn marks towards the top of the cargo hold, including the internal plates of the hatch coaming. Several areas had burnt coating. Small cracks

\(^{14}\) A discharge plan was still being drafted at the time of writing of this safety investigation report, although at the time of publication of this safety investigation report, this had long been achieved and all the cargo discharged.
were identified on the port side weld seams, connecting the coaming to the fuel oil tank slope plate. The hatch cover seal was also found damaged in several areas.

1.10 The Hazards Associated with Wood Pellets

In addition to dust formation (which can cause fires and explosions), problems that can arise when handling large amounts of wood pellets are related to ‘off-gassing’ and ‘self-heating’. It is known that different problems can occur during handling and storage, depending on the quality of the pellets, which is subject to large variations. The quality depends on pellets’ origin, size, composition and moisture content.\(^{15}\)

Pellets decompose over time and emit CO and CO\(_2\). In the process, O\(_2\) is consumed in chemical oxidation reactions and microbiological decay. This release of toxic gases is called ‘off-gassing’. The danger of off-gassing is present even at lower bulk temperatures during storage of wood pellets,\(^{16}\) although it can be accelerated by elevated temperatures.

Another important safety aspect for pellets related to the decomposition of pellet content is self-heating and self-ignition in bulk storages. Although this is not a fully understood phenomenon, technical research has shown that self-heating of wood pellets can occur either by chemical oxidation reactions and/or microbiological decay.\(^{17}\) The fresher the biomass and the higher the moisture content, the greater is the risk of self-heating and potential self-ignition.

Heat development due to microbiological decay depends, to large extent, on the moisture content and the surface area. Research trials, especially concerned with self-heating and self-ignition in pellet storages, showed that the growth of microorganisms is normally limited by the low moisture content of the pellets. However, temperature rises on the basis of chemical oxidation processes, have been observed, especially in storages of freshly produced pellets.

\(^{15}\) W. Stelte: Storage and Handling of Wood Pellets.

\(^{16}\) ibid.

\(^{17}\) The Pellet Handbook: The Production and Thermal Utilization of Biomass Pellets.
In some cases, temperature rises have led to self-ignition. Self-heating also appears to depend on the raw material used for the production of the pellets. It is assumed that high contents of unsaturated fatty acids promote self-heating of pellets. Condensation heat, caused by the absorption of vapour in air onto pellets, is a heat-releasing process (exothermic reaction). Besides condensation heat, differential heat, which is caused by the levelling of moisture content between different pellet layers, is also contributory to self-heating, although in a much lower magnitude\textsuperscript{18}.

It follows that self-ignition of wood pellets depends on factors such as:

1. moisture content;
2. temperature of the biomass (which may increase during the transfer from storage to a transportation vessel due to friction and hence overheating);
3. length of time in storage (longer time allowing longer period for development of microbiological decay and chemical oxidation);
4. condensation heat; and
5. age of the biomass.

Specialists in the trade of bio fuels advise that when wood pellets are to be loaded on board a ship, a temperature of between 50 °C and 55 °C has to be regarded as critical and as such, the cargo should not be taken on board. It is also advised that if hot spots are observed in the cargo, loading should be stopped immediately, because these may ignite the cargo during the sea passage. Wet spots in the wood pellets cargo have to be treated with extreme caution as well. It is also cautioned that high moisture content in wood pellets may trigger an exothermic reaction and consequently, a fire during the voyage\textsuperscript{19}.

\textsuperscript{18} ibid.

\textsuperscript{19} Renergy UK, Ltd.
2 ANALYSIS

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

2.2 Immediate Cause of the Fire inside Cargo Hold no. 5

In all probability, the immediate cause of the fire was excessive heat generated within the stowed bulk, as a combination of ship sweat, moisture, chemical and biological degradation of the cargo. It was also not excluded that the delays, both at anchor upon arrival from the trans-Atlantic voyage and during the anchorage after the vessel had left the port, in addition to the partial discharge of the cargo before the second anchorage had aggravated the situation as a result of increased moisture and air inside the cargo holds.

Research\textsuperscript{20} has shown that it is not uncommon to observe an increase in wood pellet temperatures of between 10 °C and 20 °C after an ocean voyage of about four to six weeks. The temperature at the time of loading was already 40 °C. \textit{V Due} had the cargo on board for 41 days prior to the start of the discharge operation, 10 days in port for discharge and 17 days at anchor after the vessel had been partially discharged and left the port. This added up to 68 days or about 10 weeks before the fire broke out.

In addition to the length of time the cargo was on board, all the cargo holds had been opened for discharge, with fresh, cold and moist air introduced inside the cargo holds potentially accelerating the exothermic process.

During the voyage, the cargo holds were sealed in order to prevent air ingress. However, during the anchorage, following the partial discharge, the crew was instructed to carry out ventilation of all cargo holds and monitor the temperatures as well as the gases.

\textsuperscript{20} The Pellet Handbook: The Production and Thermal Utilization of Biomass Pellets.
2.3 IMSBC Code on Board V Due

At the time of loading, the IMSBC Code on board the vessel was a 2013 Edition in which the Individual Schedule for Wood Pellets was the same as in the 2016 Edition, except for the Class (MHB – Materials Hazardous in Bulk). The amendment 03-15 was not yet mandatory, and the change in the type of Class in the schedule was not significant to influence the procedure for cargo loading and care during transport.

The most important instructions given in the Individual Schedule for Wood Pellets within the IMSBC Code for the analysis of the V Due accident were: angle of repose, loading and stowage, and segregation. However, there was neither guidance on temperature nor on the requirement for temperature monitoring of the cargo.

2.3.1 Angle of repose

The Individual Schedule for Wood Pellets refers to an angle of repose of approximately 30°. This is the only cargo in the Code with an approximate angle of repose. There are several cargoes for which a range of angles of repose is given such as Urea - 28° to 45°, and other cargoes for which ‘less than’ is given, such as Grain Screening Pellets with an angle of repose of less than 30°, or Wood Torrefied, with an angle of repose of 35° or less. It would appear that the onus was therefore on the shipper to provide the actual angle of repose for the cargo to be loaded.

2.3.2 Loading

The angle of repose for the cargo of wood pellets provided by the shipper to the master was 35°. Since the cargo belonged to the group of non-cohesive bulk cargoes, having an angle of repose greater than 30° up to 35° (inclusive), it was not necessary to have the cargo loaded to the top of the cargo holds’ hatch coamings, but trimmed in accordance with Section 5.4.4 of the IMSBC Code.

Nevertheless, this cargo was loaded to the top of the hatch coaming in all the cargo holds (Figure 13a) except for cargo hold no. 3, which was slack. Taking into consideration the potential hazards associated with wood pellets, it may be submitted that this was necessary, in order to reduce the headspace above the cargo surface, and minimize the air / oxygen content inside the cargo holds. Such measure would have reduced the volume of oxygen, and minimised the volume of hot air, which could have been entrapped in the cargo hold during the loading operations. In turn, this
would have reduced condensation during the sea passage – a potential cause of self-heating of the cargo. Moreover, this would reduce the presence of air between the top and the underside of the cargo hatch cover. On the other hand, when the cargo was loaded to the very top of the hatch coamings, it blocked the smoke sampling / CO₂ discharge holes located close to the top of the hatch coaming, potentially jeopardising early warnings for fire detection and extinction very difficult, if not impossible.

It has to be submitted, however, that the sampling holes of the smoke detection system (Figure 13a) for cargo hold no. 5 were uncovered during the second anchorage after the vessel left her berth²¹. The fact that there was no activation of the alarm inside this cargo hold when the vessel was on anchor, may be suggestive that the holes may have been (partially) blocked with traces of cargo particles. The risk of partial / complete blocking of the sampling holes cannot be ignored and the loading of cargo in accordance with the recommendations within the IMSBC Code, Section 5.4.4 is nonetheless encouraged.

The air temperature during the loading operation was recorded at 30 °C, whilst the temperature of the cargo, as recorded at the shore facility on the 27 September, was 40 °C, at the lower end of the critical temperature range. The crew members were instructed by the Port Captain to rig several fire hoses because of the risk that the cargo could catch fire, either on the conveyor or inside the cargo holds. There was no further information provided or preventative measures taken at this stage.

The shipper’s instructions on cargo hold ventilation, where wood pellets were stored, required that these “… shall immediately be shut off. All hatches must be sealed with approved tape to ensure cargo remains dry and free from oxygen ingress.” The crew was instructed to “monitor and record O₂ and CO contents of holds while at sea²².” The records of O₂ and CO contents were in accordance with information provided in the IMSBC Code Individual Schedule for Wood Pellets i.e., “[s]hipments are subject to oxidation leading to depletion of oxygen and increase of carbon monoxide…”.

²¹ It has already been stated elsewhere that the holes have a duel function and are also utilised for the release of CO₂ into the cargo hold.

²² The safety investigation did not establish how O₂ and CO levels were being monitored, given that the cargo holds were sealed. It was hypothesised that this had been carried out through the temperature monitoring points.
However, the IMSBC Code does not provide any information on cargo hold ventilation and the care of cargo during transit. Reference is only made to the ventilation of cargo and adjacent confined spaces in case of personnel entry.

The shipper provided neither information nor instructions on the importance of monitoring the cargo temperature. Moreover, the IMSBC Code makes no reference to monitoring of wood pellets cargo temperatures, which could have provided an additional preventative barrier during transit, even because the vessel was fitted with temperature measurement pipes, to avoid the introduction of fresh air into the cargo holds during the measurement of temperature.

Both the IMSBC Code and the shipper provided information that the cargo of wood pellets must be segregated as for Class 4.1 materials. IMO Class 4.1 Flammable Solids are readily combustible solids that can cause a fire through friction and self-reactive substances, which are thermally unstable and liable to undergo a strong exothermic decomposition even without participation of oxygen (air).

SOLAS regulation VII/7-3 requires that dangerous goods in solid form in bulk, which are liable to spontaneous heating or combustion, shall not be carried unless adequate precautions have been taken to minimize the likelihood of the outbreak of fire. Precautions as per IMSBC Code are: keep cool and dry, and away from all sources of heat or ignition (Section 9.3.2). However, the missing protective barrier systems here are the monitoring of the cargo holds via the smoke detection system and the temperature monitoring.

In addition to other information, within the IMSBC Code and given by the shipper, the vessel was provided with an MSDS (Material Safety Data Sheet) apparently for the cargo; however, the MSDS refers to ‘Wood Dust’, (not Wood Pellets) and while the pellets would have generated dust during the loading and discharge operations, this MSDS was not directly appropriate and relevant for the cargo.
2.4 Ship Sweat during the Loaded Voyage

The air temperature dropped during the voyage and was as low as 9 °C during V Due’s stay at the anchorage off Point Lynas, where the vessel spent 22 days prior to the commencement of cargo discharge. When a ship is loaded in a warm region and is steaming towards colder climates, the warm air inside the cargo hold coming in contact with the cold steelwork, will form ship sweat. Thus, when passing from a warm region to a cold region, full ventilation is recommended to continue whenever possible, so that moist air from the cargo hold is replaced by the drier external air. In this case, due to the nature of the Wood Pellets cargo loaded on V Due, ventilation was not permitted during the voyage. Therefore, ship sweat was inevitable.

With a temperature difference of about 30 °C between the cargo as loaded (at about 40 °C) and the ambient (sea, air) temperature at the Point Lynas anchorage, it was very probable that condensation inside the cargo holds had occurred. The shippers cargo declaration (under potential hazards) stated that fermentation over time occurs if exposed to moisture, generating flammable and asphyxiating gas.

2.5 Discharging Cargo from Cargo Hold no. 3

The cargo discharge operation was stopped when a high temperature was recorded by the stevedores in cargo hold no. 3 (which was slack during the voyage). It was not excluded that this was possibly due to the larger volume of hot air above the cargo surface inside cargo hold no. 3, which had been entrapped at the loading port. Therefore, more condensation in cargo hold no. 3 would have been present compared to other cargo holds, which in turn, could have caused self-heating of the cargo.

High temperatures in the other cargo holds may also be explained by condensation. Moreover, this may have also been the case due to the microbiological decay and chemical oxidation of the cargo in an enclosed, unventilated space (cargo holds).
2.6 Time at Anchor following Partial Discharge

Recording of cargo temperatures commenced one week after the completion of the partial discharge (this time included waiting for the Gladstone dock to be repaired and several days of adverse weather at the anchorage). During that time, the temperature of the cargo inside cargo hold no. 3 dropped to about 13 °C. The cargo temperatures recorded by the crew members inside cargo hold no. 1 and cargo hold no. 4 were about 8 °C and 16 °C respectively. However, these temperatures were taken through the temperature measurement pipes and it was not clear to the safety investigation as to how the different temperature measurement techniques and locations would have affected the comparative readings, with those taken alongside by the stevedores in Liverpool, also due to the possibility of poor heat transfer through the cargo.

High temperatures were recorded inside cargo hold no. 2 and cargo hold no. 5, i.e. 42 °C and 54 °C respectively. The levels of O₂ and CO were still 20.9% and 0 ppm respectively until just prior to the accident on 29 November 2016, when the O₂ level in cargo hold no. 5 dropped to 16.5% and the CO level was above 500 ppm and beyond the range of the vessels monitoring equipment.

The fact that the fire started in cargo hold no. 5, which was only slightly slack after the partial discharging, suggested a possible seat of moisture, which could have potentially accelerated the self-heating and combustion of the cargo.

The safety investigation was also concerned that the (necessary) opening of the cargo holds for discharge and prior to being requested to sail out of Liverpool after part of the cargo had been discharged, was a contributory factor. This is explained in subsection 2.7 below. Moreover, chemical degradation of the cargo starts at temperatures of about 50 °C, leading to accumulation of heat inside the stow.

2.7 Procedures for Loading of Bulk Cargoes

The Company’s safety management system (SMS) addressed the loading of bulk cargoes in significant detail. Procedures prescribed in the relevant SMS Manual informed crew members on the preparation of the cargo holds, loading and ballast plans, loading operations and related duties of the crew members. It also made in-
depth reference on the loaded voyage and discharge of the cargoes. The SMS then went on to tackle a number of different example cargoes, but not specific cargos such as Wood Pellets. It also addressed the problems associated with cargo sweat and ship sweat in some detail.

A risk assessment for the loading, carriage and discharge of the cargo had not been compiled. However, with no cargo temperature range guidance available to the crew, this would have been of limited value. The matter is being raised because whereas the cargo in cargo hold no. 1 was loaded at a temperature of 40 °C, research suggests that chemical degradation of the cargo starts to have influence at about this temperature and chemical degradation will exceed biological degradation at about 50 °C. This is considered to be a potential hazard; taking into consideration the poor heat transfer characteristics of the cargo (and its insulating properties), heat can accumulate deep inside the bulk, resulting in self ignition.

As much as the shipper’s cargo declaration made reference to the hazardous nature of the cargo, including the generation of flammable gases, the concerns seemed to be directed more towards occupational accidents resulting from unsafe access into cargo holds. Moreover, it was the opinion of the safety investigation that the document’s primary focus was the quality of the cargo (“important to maintain a low moisture content to preserve high calorific value”), rather than the actual fire hazard and risk of self-heating, in cases of high moisture content.

The document, however, makes a clear reference to the IMSBC Code. The Code explains the relationship of moisture, generation of flammable gases and spontaneous combustion, but offers no guidance on safe temperatures. The master confirmed with the Company that he did make reference to the IMSBC Code prior to the loading of the cargo, however, the MSIU does not believe that this was effective. The ship was ordered to remain on anchor for 22 days after her arrival from a warm climate, but there appears to have been no concern expressed by the crew, or other parties.

---

23 It may be considered that the cargo inside the other cargo holds was either loaded at 40 °C or else at a temperature which was close to this.

24 Unsafe access is actually a legitimate concern because of the generation of toxic gases associated with this type of cargo. The MSIU is aware of fatalities and serious injuries, which have taken place in the past, as a result of CO poisoning.
involved in the shipment, on whether this delay could lead to the generation of ship sweat and a consequent increase in the moisture content inside the cargo holds.

The SMS Manual was selective in the list of typical cargoes. This may have led to lack of awareness on the related hazards. The absence of specific risk assessments for this type of cargo reinforces this concern. Nonetheless, it has to be clarified that this has been the first accident for the Company with this type of cargo and therefore, the actual level of risk on board from the information available at the material time was unclear. To this effect, any risk evaluation may have been compromised.

The mental model which the crew members had was based on literature and information which they had available and any previous experiences with this type of cargo. If these two sources of information were either limited or missing, then it may be submitted that the crew members had a less rich mental model of the circumstances and on how the situation could potentially develop.

To make the situation even more complex, the crew members were not receiving any disconfirming cues and until a late stage, there were no visible conditions on board, known to the crew members, which would have alerted them of the developing dangers. To this effect, neither the crew members, nor the management ashore would have been in an optimal position to predict potential developing hazards.

### 2.8 Release of the CO₂ Fixed System

It would appear to the safety investigation that the release of the CO₂ on 10 December was a measure to purge the cargo hold from the accumulated CO gas. It was interesting to note that although the gas release was successful and a blanket of CO₂ could be observed on the cargo surface, the cargo self-ignited during the initial stage of the discharge.

As indicated elsewhere, the release of the CO₂ gas occurs through the holes located high up in the cargo hold, in way of the hatch coaming. While the design is effective to provide a thick blanket of gas over the cargo surface, it does not appear to be effective with all kinds of bulk cargoes. It was evident that self-heating of these types

---

25 This is to mean the literature and experience.
of cargoes usually occurs deep inside the bulk and the fire seat may be very difficult to reach. It would appear that unless the cargo hold is also fitted with gas monitoring and injection at different heights\textsuperscript{26}, the injection of CO\textsubscript{2} gas may only create a blanket and would have limited effect to extinguish the fire, which may then only flare up as soon as the cargo is discharged and fresh air introduced.

\textsuperscript{26} On a similar principle (albeit on a different matter altogether), in cases of cargo fumigation, this issue is normally addressed by the installation of a J-System inside the cargo hold, which ensures distribution of the fumigant throughout the cargo hold.
THE FOLLOWING CONCLUSIONS AND RECOMMENDATIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.
3 CONCLUSIONS

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

3.1 Immediate Safety Factor

.1 The immediate cause of the fire was excessive heat generated within the stowed bulk cargo, as a combination of moisture from ships sweat, chemical and biological degradation of the cargo.

3.2 Latent Conditions and other Safety Factors

.1 It was also not excluded that the delays, both at anchor upon arrival from the trans-Atlantic voyage and during the anchorage after the vessel had left the port, in addition to the partial discharge of the cargo before the second anchorage had aggravated the situation as a result of increased moisture and air inside the cargo holds.

.2 The formation of ship sweat as a result of the vessel’s transit from a warm to a cold climate contributed to an increase in the moisture content inside the cargo hold.

.3 The increase in temperature inside cargo hold no. 3 is attributed to the fact that the cargo was excessively slack within the hold, creating an increased volume of air over the cargo surface.

.4 The fact that the fire started in cargo hold no. 5, which was only slightly slack after the partial discharging, suggested a seat of moisture, which could have potentially led to self-heating and combustion.

.5 A risk assessment for the loading, carriage and discharge of the cargo had not been compiled, however, with no cargo temperature range guidance available to the crew, this would have been of limited value.

.6 As much as the ship was ordered to remain on anchor for 22 days after her arrival from a warm climate, there was no specific concern expressed by the crew, or other parties involved in the shipment, on whether this delay could
have led to the generation of ship’s sweat and as a consequent increase in the moisture content inside the cargo holds.

7 Since the release of the CO₂ gas occurs through holes located high up in the cargo hold in way of the hatch coaming, it does not appear that this was effective in extinguishing a fire seated deep inside the cargo.

3.3 Other Findings

1 The crew members had no instructions to monitor the cargo temperatures during the voyage, which would have been indicative of an exothermic reactions inside the cargo holds.

2 The SMS Manual provided guidance on some typical cargos but did not address specifically wood pellets.

3 The shipper’s cargo declaration made reference to the hazardous nature of the cargo, including the generation of flammable gases, but the concern seemed to be more directed to occupational accidents resulting from unsafe access into cargo holds.
4 RECOMMENDATIONS

In view of the conclusions reached,

The Merchant Shipping Directorate is recommended to:

26/2017_R1  Publish an Information Notice to raise awareness on the potential of fire hazards related to this type of cargo.
Annex A  Shipper’s Cargo Declaration

SHIPPER CARGO DECLARATION

<table>
<thead>
<tr>
<th>Loading Date:</th>
<th>Part of Loading:</th>
<th>Name of Vessel:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panama City, Florida / USA</td>
<td>&quot;V DUE&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shipper:</th>
<th>Name and Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General: Description of Cargo:
WOOD PELLETS made of wood sawdust, shavings and bark, no additives or binders.
Moisture content 4-10%, angle of repose 35 degrees.
Product is used as heating fuel.

Important to maintain a low moisture content to preserve high calorific value.
Wood pellets are not hazardous to the marine environment per the 2012 guidelines for the implementation of MARPOL Annex V.

For further details refer to the IMSBC Code.

Potential hazards:
Swelling if exposed to droplets and water.
Oxygen depleting.
Ignitability, segregation as required for IMO Class 4.1 cargo
Fermentation over time if exposed to moisture, generates flammable and asphyxiating gas.

Risk of explosion at high dust concentration.

<table>
<thead>
<tr>
<th>IMSBC No.</th>
<th>UN No.</th>
<th>IMSBC Class</th>
<th>UN No.</th>
<th>IMDG Code</th>
<th>IMDG No.</th>
<th>IMDG Group</th>
<th>IMDG Number</th>
<th>IMDG Number</th>
<th>IMDG Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 250</td>
<td>616</td>
<td>5003</td>
<td>40 250</td>
<td>616</td>
<td>5003</td>
<td>1.3 - 3 cub/ton</td>
<td>500°C</td>
<td>500°C</td>
<td>500°C</td>
</tr>
</tbody>
</table>

Safety Precautions:
All hatches must be sealed with approved tape to ensure cargo remains dry and free from oxygen ingress.
All ventilation to the cargo hold where the wood pellets are kept shall immediately be shut off.
Avoid moisture ingress during voyage.
Shield from heat sources, lights in cargo holds and all electrical fittings in cargo holds.

Remove wet material. If not removable, secure ventilation in compartments with wet material.

Due to Oxygen depletion, ventilate all spaces in connection with pellets prior to entry, with special emphasis to mast houses and cargo hold access and stairways.
Avoid generation of high dust concentration during handling material.

Label all accesses to cargo holds with ‘Low Oxygen Risk Area’ or similar.

 Obtain entry permit (IMO-280E Appendix F) and measure oxygen and carbon monoxide content prior to entering enclosed spaces.

Self-contained breathing apparatus (SCBA) shall be used if entering space without ventilation.
Inform stevedores, inspectors, and all other occasional personnel of the required safety precautions.
Monitor and record O2 and CO content of holds while at sea.

In Case of Fire:
Batten down, limit access of air.
Extinguish fire with CO2, foam or water. (NFPA 10 Class A - paper and wood material).

Emergency Contact:
Closest Coast Guard Station:

Declaration:
I hereby declare that the consignment is fully and accurately described and that the given test results and other specifications are correct to the best of my knowledge and can be considered as representative for the cargo to be loaded.

| Name / Position representing Shipper: |
| Signature: |
| Name / Position: |
| Company: |
| Ship's Stamp: |

Received:  
Captain:  
Place:  
Date:  

42