



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

Investigation Reports 455/15 and 58/16

Serious Marine Casualties

**Charcoal cargo fire
on the container vessels
MSC KATRINA
in the Elbe estuary
on 20 November 2015
and
LUDWIGSHAFEN EXPRESS
in the Red Sea
on 21 February 2016**

28 May 2018

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

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

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

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1 Summary

Fires broke out in containers loaded with charcoal in bulk on the Panamanian-flagged MSC KATRINA and on the German-flagged LUDWIGSHAFEN EXPRESS. In each case, the cargo originated in the island of Borneo, Indonesia, and was destined for the same consignee in France.

The MSC KATRINA was in the Elbe estuary when the smoke detection system discovered the fire, meaning the Central Command for Maritime Emergencies (CCME) was able to arrange for the deployment of specially trained firefighters. It was possible to extinguish the fire with no damage to the ship and only minor damage to the cargo. The container affected by the fire was situated within a free-standing stack in the cargo hold, making it easier to fight the fire.

The LUDWIGSHAFEN EXPRESS was sailing in the Red Sea when the outbreak of fire was noticed during an inspection. Consequently, firefighting was incumbent upon the crew on its own. The affected container was stowed directly on a hatch cover, making it possible to extinguish the fire quickly using the equipment available on board. Neither the ship nor other cargo sustained any damage.

Due to the similarity of the cause of the fire, the investigation of the two cases was summarised in one investigation report.

2 FACTUAL INFORMATION

2.1 MSC KATRINA

2.1.1 Photo of the MSC KATRINA



Figure 1: MSC KATRINA

2.1.2 Ship particulars: MSC KATRINA

Name of ship:	MSC KATRINA
Type of ship:	Full-container vessel
Nationality/Flag:	Panama
Port of registry:	Panama
IMO number:	9467445
Call sign:	3EZD3
Owner:	Potty Holding S.A.
Operator:	MSC Mediterranean Shipping Company S.r.l.
Year built:	2012
Shipyard/Number:	STX Offshore & Shipbuilding Co. Ltd./S-3021
Classification society:	DNV GL
Length overall:	365.74 m
Breadth overall:	48.44 m
Gross tonnage:	140,096
Deadweight:	54,157 t
Draught (max.):	15.50 m
Engine rating:	72,240 kW
Main engine:	MAN Diesel & Turbo 12K98MC-C7
(Service) speed (max.):	25.2 kts
Hull material:	Steel
Manning:	24

2.1.3 Voyage particulars: MSC KATRINA

Port of departure:	Antwerp, Belgium
Port of call:	Hamburg, Germany
Type of voyage:	Merchant shipping, international
Cargo information:	Containers
Draught at time of accident:	11.5 m
Manning:	24
Pilot on board:	Yes, two
Number of passengers:	None

2.1.4 Marine casualty information

Type of accident:	Serious marine casualty; cargo fire: fire in a container carrying charcoal in cargo hold 2 (CH 2)
Date, time:	20 November 2015, 0349 ¹
Location:	River Elbe, kilometre mark 763
Latitude/Longitude:	ϕ 53° 59.5'N λ 008° 15.0'E
Ship operation and voyage segment:	Harbour mode
Consequences:	Cargo destroyed in one container and several others damaged by extinguishing water

2.1.5 Shore authority involvement and emergency response

Agencies involved:	CCME, Waterway Police (WSP) Hamburg, Vessel Traffic Service (VTS) Cuxhaven, Cuxhaven Fire Service, Bremerhaven Fire Service
Resources used:	Water pollution control vessel NEUWERK, a federal police helicopter, three firefighting units (FFUs), two emergency physicians on board the ship as part of the FFUs, search and rescue cruiser HERMANN HELMS, police boat BÜRGERMEISTER BRAUER
Actions taken:	Ship prohibited from entering and ordered to proceed to roadstead on the Outer Elbe, crew and later the fire service surveyed the scene, fire service flooded affected container with water
Results achieved:	The ship was permitted to sail into Hamburg after the fire was extinguished. No injuries or environmental damage

¹ Time in Central European Time (CET).

2.1.6 Navigational chart

Extract from Navigational Chart ENC DE 421040,
 Federal Maritime and Hydrographic Agency (BSH)

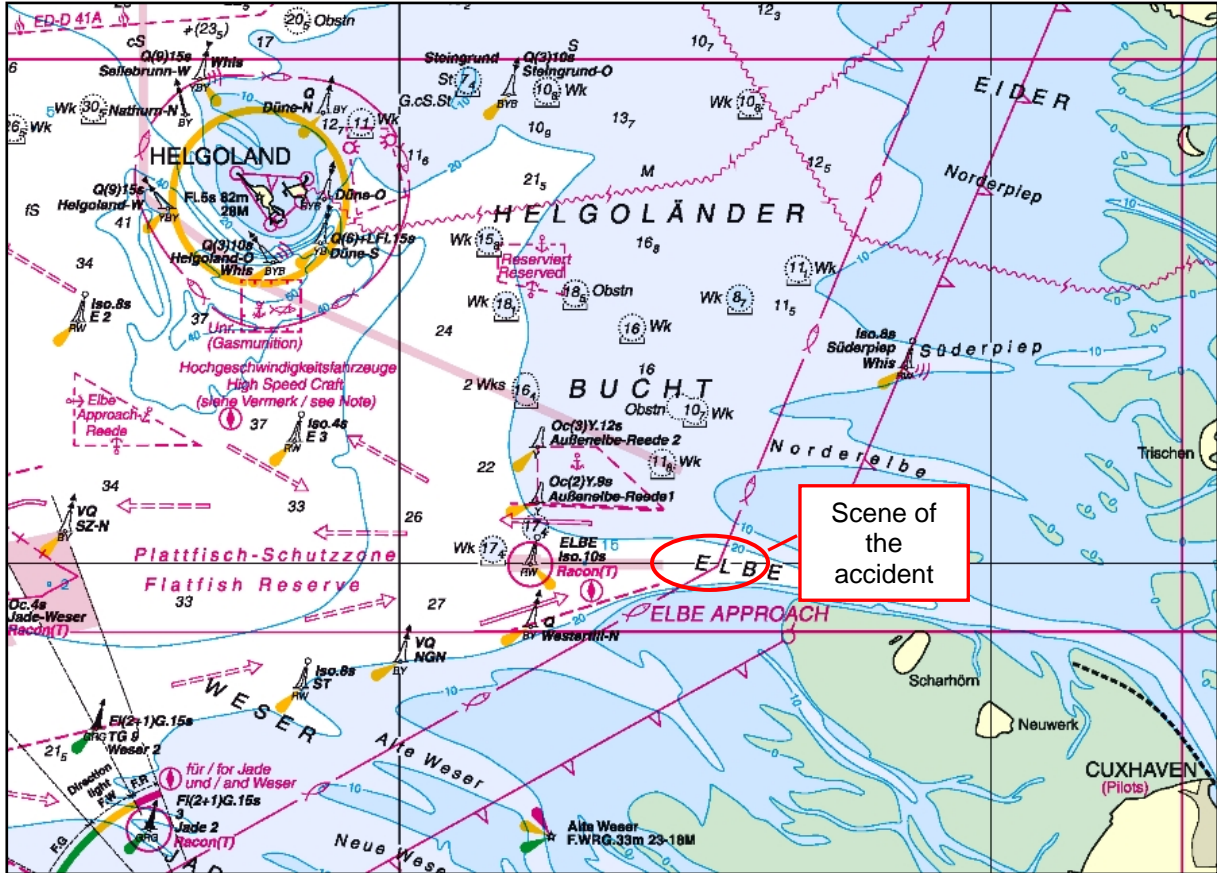


Figure 2: Navigational chart showing the scene of the accident

2.2 LUDWIGSHAFEN EXPRESS

2.2.1 Photo of the LUDWIGSHAFEN EXPRESS



Figure 3: LUDWIGSHAFEN EXPRESS

2.2.2 Ship particulars: LUDWIGSHAFEN EXPRESS

Name of ship:	LUDWIGSHAFEN EXPRESS
Type of ship:	Full-container vessel
Nationality/Flag:	Germany
Port of registry:	Hamburg
IMO number:	9613018
Call sign:	DDOR2
Owner:	Hapag-Lloyd AG
Operator:	Hapag-Lloyd AG
Year built:	2013
Shipyard/Number:	Hyundai Heavy Industries/2499
Classification society:	DNV GL
Length overall:	366.52 m
Breadth overall:	48.35 m
Gross tonnage:	142,295
Deadweight:	127,113 t
Draught (max.):	14.50 m
Engine rating:	45,100 kW
Main engine:	MAN Diesel & Turbo 11K98ME7
(Service) speed (max.):	23.6 kts
Hull material:	Steel
Manning:	21

2.2.3 Voyage particulars: LUDWIGSHAFEN EXPRESS

Port of departure:	Singapore
Port of call:	Le Havre, France
Type of voyage:	Merchant shipping, international
Cargo information:	Containers
Draught at time of accident:	11.5 m
Manning:	24
Pilot on board:	No
Number of passengers:	None

2.2.4 Marine casualty information

Type of accident:	Serious marine casualty; cargo fire: fire in a container carrying charcoal on the upper deck of bay 70 (cargo hold 9 (CH 9)), increased temperature in an adjacent container, later fire in another container
Date, time:	21 February 2016, 1630 ²
Location:	Northern part of the Red Sea
Latitude/Longitude:	ϕ 24° 00.5'N λ 036° 35.1'E
Ship operation and voyage segment:	High seas
Consequences:	Cargo destroyed in one container and flooded in two others

2.2.5 Shore authority involvement and emergency response

Agencies involved:	No agencies involved
Resources used:	The ship's firefighting equipment
Actions taken:	Temperature measurements using infrared thermometer, extinguishing and cooling
Results achieved:	Cargo of the first container affected by the fire washed into the sea. Le Havre port operator immersed second container affected by the fire in the inner harbour and then put it ashore. No injuries or environmental damage

² Local time = UTC + 2.

2.2.6 Scene of the accident



Figure 4: Scene of the accident in the Red Sea

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident: MSC KATRINA

The account of the course of the accident is based on the statement by the ship's master, the event log of the Maritime Emergencies Reporting and Assessment Centre (MERAC), reports of the deployed FFUs from Cuxhaven Fire Service and Bremerhaven Fire Service, and the report of VTS Cuxhaven.

The Panamanian-flagged full-container vessel MSC KATRINA was in the Elbe estuary sailing to Hamburg in the early hours of the morning of 20 November 2015. The ship had taken two pilots on board and passed River Elbe buoy 1 when the ship's smoke detection system reported a build-up of smoke in CH 2 at 0343.

The master immediately sent the Chief Technical Officer (CTO) to the CO₂ room to verify the situation there at the smoke detection system. After testing the suction pipe coming out of the cargo hold concerned, the CTO reported a smell of burnt plastic. He then made the CO₂ extinguishing system ready for use. At the same time, the second officer and the bosun were sent into CH 2 wearing breathing apparatus. They confirmed smoke in the cargo hold shortly after. The general alarm was sounded in response to this information.

VTS Cuxhaven was notified of the fact that fire had broken out in CH 2 at 0349. The nautical supervisor issued an order at 0406, reportedly stating the ship must turn around and sail toward the sea. The ship then initially sailed toward the roadstead on the Outer Elbe. Moreover, the nautical supervisor ordered the NEUWERK to proceed to the MSC KATRINA.

In the meantime, the two crew members continued to survey the situation in CH 2 wearing breathing apparatus. The crew also made the shipboard CO₂ extinguishing system for the cargo holds ready for use. After returning from CH 2 at 0421, the second officer reported that no open fire was visible. The smoke then propagated from the ground up to the seventh container tier. The investigation team also identified a wood fire odour. The master then called all the officers and engineers for a briefing on the bridge, where it was decided that CH 2 should be sealed in preparation for the use of CO₂.

VTS Cuxhaven notified the MERAC of the incident at 0410. It alerted Cuxhaven Fire Service shortly after. Arrangements were also made for the search and rescue cruiser HERMANN HELMS to take a FFU from Cuxhaven Fire Service to the MSC KATRINA.

The NEUWERK reached the MSC KATRINA at 0513 and escorted her in the ensuing period, where the ship's command of the NEUWERK and that of the MSC KATRINA maintained constant radio contact.

The nine-member FFU from Cuxhaven Fire Service sailed out of Cuxhaven on the HERMANN HELMS at 0534. Prior to that, information was received that the cargo hold affected by the fire contained 9,000 kg of a class 9 substance according to the IMDG Code³ (UN number 3077⁴). The FFU was in contact with the ship's command of the MSC KATRINA during the approach.

At 0538, Waterways and Shipping Office (WSA) Cuxhaven advised the MSC KATRINA to seal CH 2 and use CO₂ as an extinguishing agent.

Due to the weather situation, other firefighters were to be taken on board the MSC KATRINA with the support of a helicopter. At about 0542, arrangements were additionally made with the federal police, which was to provide the helicopter.

At 0603, the ship's command stated that the smoke had reportedly abated. The FFU, which was already communicating with the ship during the approach, recommended that the use of CO₂ be continued.

The HERMANN HELMS reached the MSC KATRINA at about 0715 and the FFU started to board and transfer its equipment. Due to the sea conditions during the approach, only five firefighters from the FFU boarded the MSC KATRINA. The FFU was informed shortly before that the container affected by the fire was carrying charcoal and positioned in a stack with six other 40-ft containers.

After an initial briefing between the fire service and ship's command, the fire service began to survey the scene of the fire at 0755. Up until this point, no CO₂ had been discharged into the cargo hold.

The helicopter started to winch a second FFU from Cuxhaven Fire Service, comprising five firefighters and an emergency physician, down onto the MSC KATRINA's port wing at 0824. The fire service completed its survey of the scene shortly after.

In the meantime, the CCME assumed overall responsibility for coordinating the operation at 0900.

The master of the NEUWERK was designated on-scene commander (OSC) at 1013. Shortly before, the NEUWERK transferred additional firefighting equipment (fognails⁵, hoses and adapters) to the firefighters on board the MSC KATRINA. A line connection was also established.

³ International Maritime Dangerous Goods Code. This code governs the carriage of dangerous goods on seagoing ships.

⁴ Environmentally hazardous substance, solid, not elsewhere specified

⁵ Special water lance that can be punched into a container.

In the ensuing period, the CCME was also in contact with the Emergency Response Service (ERS) of DNV GL, the ship's classification society, which provided the general arrangement plan and the fire control and safety plan.

Another task force comprising four members of a FFU from Bremerhaven Fire Service and another emergency physician arrived at the MSC KATRINA by helicopter at about 1100.

The NEUWERK went alongside the MSC KATRINA once more at 1214 to transfer additional equipment (foam concentrate and inductor).

The MSC KATRINA started to turn at 1300 and began to sail slowly toward the Elbe estuary. This was based on the finding that the fire posed only an extremely low hazard at this point. The NEUWERK continued to follow her. One hour later, the operational commander of the fire service on board found that any danger had now ceased. Since it was intended that the ship should arrive in Hamburg on the high tide, the passage of the Elbe approach buoy was scheduled for 1630.

The NEUWERK was stood down from the operation at 1430.

At 1536, WSA Cuxhaven granted the MSC KATRINA's master permission to enter the port of Hamburg.

The firefighters from Cuxhaven Fire Service and an emergency physician left the vessel when she passed Cuxhaven. The other emergency physician and four firefighters from Bremerhaven Fire Service remained on board. They remained with the ship until she reached Hamburg and took charge of cooling the relevant containers and measuring the temperature while en route.

The MSC KATRINA was made fast at her berth at the Eurogate Container Terminal at 2312. Following that, the CCME stood down from its role as overall coordinator of the operation at 2336.

After clearance, work on the ship's cargo began with discharging the container stack affected by the fire. All seven containers were taken to a separate location within the port. The container affected by the fire was stored in a tank to collect the escaping extinguishing water. Firefighters from Hamburg Fire Service monitored the discharging of the containers.

3.2 Investigation: MSC KATRINA

3.2.1 Start of the investigation

The BSU became aware of the accident on 20 November 2015 through receipt of the notification on the assumption of overall responsibility for coordinating the operation by the CCME. At 1115, the ship's command of the MSC KATRINA was requested to initiate an emergency backup of the voyage data recorder (VDR) via VTS German Bight and the OSC. This was complied with.

A team from the BSU surveyed the ship at her berth in Hamburg on 21 November 2015. At the same time, the VDR's previously backed up data were downloaded. The BSU interviewed the master, the second officer and the third officer.

3.2.2 CH 2

The MSC KATRINA belongs to the Mediterranean Shipping Company S.r.l. (MSC). She is a full-container vessel with a slot capacity of 12,400 20-ft containers. CH 2 on this ship exhibits limitations in deadweight capacity (see also Figure 5) due to the shape of the hull. The cargo hold is separated in the middle by a passable supporting transverse bulkhead in the usual manner. The fore and aft distance from the transverse bulkhead is 40 feet in each case. Accordingly, the passable transverse bulkhead makes it possible to reach a 40-ft container in the forward section of the cargo hold from one side at least. Some of the container tiers in the aft section of the cargo hold were accessible from two sides because a passable structure is situated on the aft edge. The structure has no platform in the fifth tier, however.

3.2.3 On-scene survey

The cargo hold affected by the fire was already fully discharged at the time of the survey. A large amount of charcoal sludge on the floor of the cargo hold was in the process of being cleaned up. This allowed the conclusion that the fire had destroyed the floor of the affected container in at least one area, as charcoal had evidently been washed out when the fire service flooded the container. The second officer explained that the container stack with the charcoal cargo was standing on its own, meaning there was no imminent risk to adjacent cargo. The fire service was able to access the containers directly at one of the end walls from the passable supporting transverse bulkhead.



Figure 5: Container stack's slot in row 03

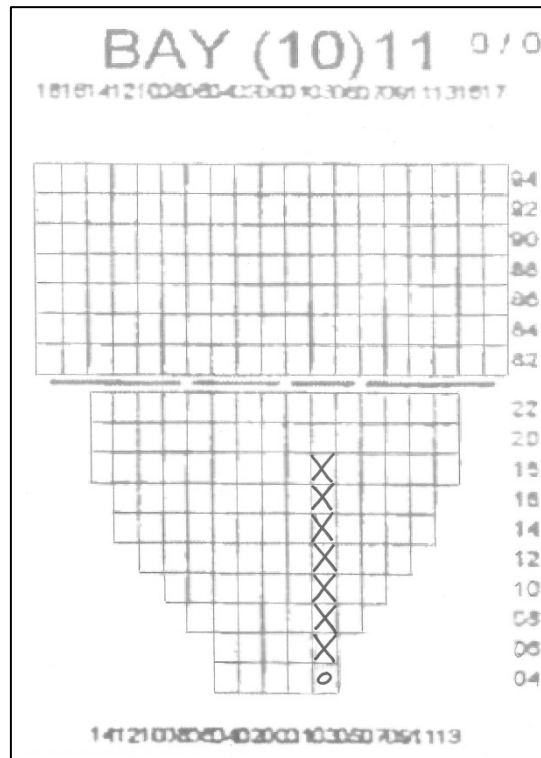


Figure 6: Extract from bay (10) 11's stowage plan

After completion of the survey of the ship, the seven containers making up the stack were viewed at their stowage position in the port. No traces of fire were found on the accessible outer sides of the container affected by the fire. It merely exhibited one large bulge. A fognail and the associated hose were still on one side.



Figure 7: Container affected by the fire with fognail and hose

The BSU initially secured all seven containers that made up the stack in consultation with the WSP. The agencies concerned were informed of this.

A review of the cargo documents revealed that all seven containers were from the same shipper, a company in Indonesia, and were destined for the same consignee via the port of Le Havre in France.

On 23 November 2015, one of the containers not affected by the fire (MEDU 893549/8) was opened in the presence of WSP Hamburg, an expert appointed by the owner (MSC), port employees and the BSU. It was intended that this should assist in the assessment of the nature of the cargo and provide a larger sample. As with the container affected by the fire, this was also a high cube container. These have an external height of 2.9 m and an internal height of 2.7 m. The gross weight (container plus cargo and dunnage) must not exceed 30.4 t.

It was found after the container was opened that the charcoal was loaded inside it in bulk, as per the cargo documents. A partition at the entrance made using unprocessed branches and bamboo sticks prevented the charcoal from escaping after the doors were opened. The charcoal was stowed up to 0.8 m below the roof, i.e. the stowage height stood at about 1.9 m at the highest points.



Figure 8: Open container unaffected by fire



Figure 9: View inside the open container

It was not deemed necessary to open the container affected by the fire, as this would not have facilitated meaningful conclusions about the cargo due to the soaking during the extinguishing operation.

3.2.4 Charcoal cargo

The charcoal cargo destined for a consignee in France was stowed in seven containers. The containers were transported on the MSC MILA 3 from Surabaya to Tanjung Pelepas, where the containers were transhipped to the MSC KATRINA. Hamburg was the next port of call after the ports of Sines and Antwerp. The ship was to then proceed to Le Havre, where the containers would have been discharged.

3.2.4.1 Cargo documents

The owner provided the BSU with the following documents pertaining to the cargo for the investigation:

- Sea waybill issued on 10 October 2015;
- Report of analysis issued on 18 September 2015, and
- Certificate of quantity and quality issued on 12 October 2015.

MSC submitted a copy of the draft **sea waybill**⁶, which listed the Indonesian company Pt. Citra Prima Utama as shipper. The sea waybill included the seven containers loaded on the MSC KATRINA. The container affected by the fire (MEDU 824169/2) had the lowest total weight at 25,915 kg⁷. The container opened for testing had the highest total weight at 25,945 kg. The unladen weight of the two containers was specified at 3,940 kg each. 'Industrial lump charcoal' was specified as the content of each container. Traditionally manufactured charcoal made of hardwood is meant here. The reported particle size was 20-80 mm. Accordingly, all the containers were carrying the charcoal in bulk. According to the cargo documents, the containers were loaded onto the MSC KATRINA on 10 October 2015.

⁶ See section 8.1 of the Annex.

⁷ Based on cargo gross weight.

MSC also submitted the **report of analysis**⁸ (No: 04343/DOEDAI) certificate, which referred to the testing of the hazardous material properties of the charcoal and was drawn up by a company called SUCOFINDO. 18 September 2015 is the date of issue. The documented test was conducted on 2 September 2015 in a laboratory in Indonesia on behalf of a company called Pt. Buana Multiguna Inspection & Testing. In the process, an appropriate test quantity was taken from a total quantity of 35.85 kg. The reference for this was Sampling BMI 044384. The investigators assume that BMI stands for Buana Multiguna Inspection. The findings of the test indicate that the charcoal cargo on the MSC KATRINA was not rated as dangerous goods. The charcoal's properties are listed as follows:

- Moisture content: 3.8%
- Fixed carbon: 85.7%
- Volatile matter: 13.8%
- Ash content: 0.5%⁹

The certificate bore no relationship with the containers on board the MSC KATRINA, however. Accordingly, WSP Hamburg did not accept the certificate. The WSP required from MSC evidence that confirmed the charcoal did not constitute dangerous goods for the onward movement of the charcoal destined for France.

To this end, four plastic buckets were filled with charcoal taken from the cargo for test purposes on 23 November 2015 (see also section 3.2.3). The sample was taken by a staff member of the company Eurofins. The examination to establish the hazardous material properties of the charcoal was carried out by a Freiberg-based company called IBExU – Institut für Sicherheitstechnik GmbH. Similar to in Indonesia and in accordance with the recognised test procedure¹⁰, the test involved filling a wire mesh cube with an edge length of 10 cm and exposing it to a temperature of 140 °C for 24 hours (also referred to as a UN N.4 test or a Bowes-Cameron cage test). The test revealed that the sample does not ignite and that the temperature increase of 6 °C within the cube remains within the limiting values (temperature increase within the sample of less than 60 °C). Accordingly, the charcoal cargo does not constitute dangerous goods for the purposes of class 4.2 of the IMDG Code, as it was not prone to self-heating. This meant that the charcoal could be shipped onwards in a large packing unit such as a container without additional conditions.

⁸ See section 8.2 of the Annex.

⁹ In all cases, the test method according to ASTM D-1762-84 was applied.

¹⁰ Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria. Part III, Section 33.3.1.6.

Mittlere Schüttdichte im Behälter: 0,52 g/cm³

Kantenlänge des Drahtnetz-würfels (Volumen)	Lager-temperatur	Maximale Proben-temperatur T _{max}	Tempe-raturdif-ferenz	Erwärmungs-zeit bis zum Erreichen der Lagertempera-tur	Gesamt-Lager-zeit	Mas-se-verlust	positives Ergebnis
	°C	°C	K	h	h	%	
10 cm (1000 cm ³)	140	146	6	5,0	42,5 h	9,0	nein

Probenrückstand: optisch unverändert; kein sichtbarer Volumenverlust

Spreadsheet 1: Extract from IBExU's test report

During the course of the investigation, MSC submitted an email that the charcoal's shipper apparently sent to MSC on 2 December 2015 in response to the fire. A **certificate of quantity and quality**,¹¹ number 044402, pertaining to the sea waybill for transportation on the MSC MILA 3 and the MSC KATRINA was attached, which differed from the report of analysis in terms of the data documented for the specifications of the charcoal:

- Moisture content: 5.3%
- Fixed carbon: 78.93%
- Volatile matter: 14.59%
- Ash content: 6.48%

Pt. Buana Multiguna Inspection and Testing issued this certificate, which referred to the weighing of the goods in the container and the review of the quality of the product (carried out on 5-8 September 2015 in Surabaya) two days after the MSC MILA 3 set sail on 12 October 2015. The certificate contained no finding as to the hazardous material properties of the charcoal.

3.2.4.2 Shipping provisions of the owner

The ships belonging to MSC are basically not prohibited from carrying charcoal, even if it constitutes dangerous goods, unless it is charcoal dust.

MSC provided the Instructions for Specific Cargo – Charcoal, which stipulates that the provisions of the IMDG Code must be adhered to for the carriage (i.e. that the cargo must undergo appropriate testing). Accordingly, charcoal cargoes that do not constitute dangerous goods must be accompanied by the following documents:

- Self-heating certificate containing the result of the test on the cargo's self-heating properties and
- A detailed analysis report for the product.

¹¹ See section 8.3 of the Annex.

The documents referred to must be available prior to transportation. The owner reserves the right to refuse cargo if the test and analysis are not consistent with its safety standards.

The instruction also stipulates that any containers carrying charcoal must be stored in a buffer zone in the port of loading for at least ten consecutive days before loading takes place, regardless of whether they contain dangerous goods. The above does not apply if the period between the date of production (charcoal cold after the process) and the arrival of the container at the port gate is at least seven days.

3.2.4.3 Transportation route of the charcoal

The BSU assumes that the product was manufactured in Borneo¹² on behalf of or by the shipper¹³. The shipper was contacted in writing with a view to obtaining further information. This went unanswered. On being questioned, MSC advised that the charcoal in the container was shipped some 250 nm to Surabaya, Java, via the port of Banjarmasin in Borneo. MSC stated that the cargo was stowed in containers on 30 September 2015. The cargo left Banjarmasin on 3 October on a feeder ship and reached Surabaya, where the charcoal was unloaded from the containers, on 5 October 2015. The charcoal was stowed in the owner's containers on 8 October.

The onward transportation route of the containers could be determined using the data provided by MSC:

- 10 October 2015 The container vessel MSC MILA 3 is loaded in Surabaya;
- 10 October 2015 The ship sails from Surabaya;
- 12 October 2015 The ship arrives at Jakarta;
- 14 October 2015 The ship sails from Jakarta;
- 18 October 2015 The containers are unloaded in Tanjung Pelepas, Malaysia;
- 26 October 2015 The MSC KATRINA is loaded in Tanjung Pelepas and sets sail.

The further course of the voyage was determined based on AIS research:

- 29 October 2015 Passage of the northerly point of the island of Sumatra;
- 30 October 2015 Passage of Sri Lanka;
- 04 November 2015 Passage of Bab al-Mandab;
- 08 November 2015 Passage of the Suez Canal;
- 10 November 2015 Passage of Sicily;
- 12 November 2015 Passage of Gibraltar;
- 13 November 2015 Arrival at Sines, Portugal;
- 16 November 2015 Passage of Cherbourg;
- 17 November 2015 Arrival at Antwerp;
- 18 November 2015 Sets sail from Antwerp, and
- 20 November 2015 Passage of Elbe 1.

¹² The island is called Kalimantan in Indonesia.

¹³ http://www.bizearch.com/company/CITRA_PRIMA_UTAMA_CV_356808.htm
Retrieved on 21 April 2017.

This equates to a total transportation time of 52 days. Accordingly, the cargo was in the container affected by the fire for 44 days before the fire broke out.

Based on information from the owner that the transport began on 30 September 2015 in Borneo, that the loading of the MSC MILA 3 took place on 10 October 2015, and that the process of preparing the charcoal corresponded to that of the weathering certificate of the LUDWIGSHAFEN EXPRESS, the minimum duration of seven days prior to loading required by MSC was complied with.

Germany's National Meteorological Service (DWD) provided the outside temperatures for each leg of the voyage shown in Diagram 1.

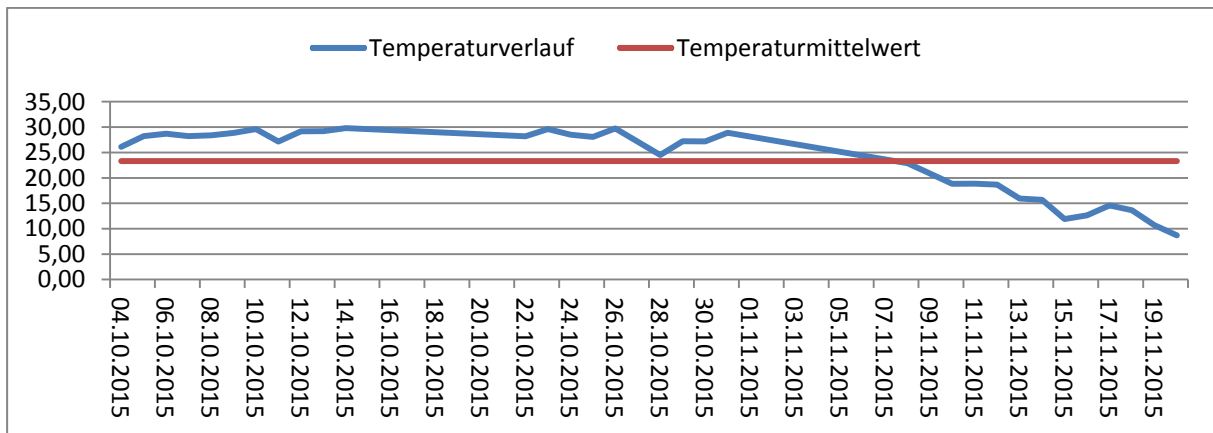


Diagram 1: Variations in outside temperature during transportation¹⁴

3.2.4.4 Charcoal as dangerous goods

Charcoal may be classified as dangerous goods under certain conditions because it is prone to self-heating. Self-heating substances are defined as follows:

"A self-heating substance or mixture is a liquid or solid substance or mixture, other than a pyrophoric¹⁵ liquid or solid, which, by reaction with air and without energy supply, is liable to self-heat; this substance or mixture differs from a pyrophoric liquid or solid in that it will ignite only when in large amounts (kilograms) and after long periods of time (hours or days). Self-heating of substances or mixtures, leading to spontaneous combustion, is caused by reaction of the substance or mixture with oxygen (in the air) and the heat developed not being conducted away rapidly enough to the surroundings. Spontaneous combustion occurs when the rate of heat production exceeds the rate of heat loss and the auto-ignition temperature is reached."¹⁶

¹⁴ The blue graph shows the arithmetic mean of the daily temperature. The red graph shows the average temperature of the entire voyage.

¹⁵ Solid substances and mixtures that ignite even in small quantities at room temperature and in the air after a brief period.

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

"The auto-ignition temperature ([...]) is the temperature to which a substance or contact surface must be heated for a combustible (solid, liquid, their vapours or gases) to ignite spontaneously in the presence of air due to its temperature alone, i.e. without a source of ignition, such as a spark. It is different for each substance and pressure-dependent in many cases. Spontaneous combustion is caused by an exothermic oxidation reaction when the rate of heat production exceeds heat dissipation through conduction, radiation or convection. There is no correlation between the auto-ignition temperature and the boiling or flash point temperature of a combustible. Rather, it constitutes a measure for the substance's oxidation sensitivity. The auto-ignition temperature is not a substance parameter in the stricter sense, as it depends particularly on the volume of the substance considered. Larger volumes ignite at lower temperatures."¹⁷

Charcoal of animal or plant origin is classified as a self-heating class 4.2 substance according to the IMDG Code's List of Dangerous Goods. Shipments of charcoal not fulfilling the criteria of a self-heating substance according to the test described in the Manual of Tests and Criteria¹⁸, part III, 33.3.1.6 are exempt from other regulations according to the special provision 925 of the IMDG Code. The test procedure, described in the Manual of Tests and Criteria, part III, 33.3.1.6, serves to ascertain whether a substance need not be assigned to class 4.2 following the exclusion criteria from section 2.4.3.2.3.1. This is the case if:

- 1. a negative result is obtained in a test using a 100 mm cube sample at 140 °C.*
- 2. [...]*

The basic test already discussed above involves exposing a sample of the substance in a wire mesh cube with a side length of 100 mm to a temperature of 140 °C for 24 hours. In the process, the internal temperature of the sample may not exceed the oven temperature by more than 60 °C (UN N.4 test). If the internal temperature of the sample remains below this 60 °C (negative result), then the substance is not classified as class 4.2 dangerous goods (see above). Further tests must be carried out to determine the packing group if the result is positive.

¹⁷ Translation of German definition at <https://de.wikipedia.org/wiki/Zündtemperatur> (14/08/2017).

¹⁸ United Nations: Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria. The recommendations form the basis of the transport provisions of the various carriers.

Section 33.3.1.3.3.1 of the Manual of Tests and Criteria also states the following:

"Tests are performed to determine if substances in a 25 mm or 100 mm sample cube, at test temperatures of 100 °C, 120 °C or 140 °C, undergo spontaneous ignition or dangerous self-heating, which is indicated by a 60 °C rise in temperature over the oven temperature within 24 hours. The classification schema is illustrated in Figure 33.3.1.3.3.1. These criteria are based on the auto-ignition temperature of charcoal, which is 50 °C for a sample cube of 27 m³. Substances with a temperature of spontaneous combustion higher than 50 °C for a volume of 27 m³ should not be assigned to Division 4.2."^{19 20}

This means that the sample size of 27 m³ was scaled down to a manageable size for practical implementation.

3.2.4.5 Investigation of the charcoal

Despite the negative result of the testing to establish the charcoal's hazardous material properties, the BSU's investigators attribute the outbreak of fire on board the MSC KATRINA to self-heating. The BSU requested its own expert opinion from Dr.-Ing. G. Krause of Dr.-Ing. Krause GmbH to determine the transport conditions and ensuing risks. The remaining amount of about 7 kg of the sampling on 23 November 2015 was available for the tests.

At the beginning of the assessment, the laboratory commissioned determined the physical properties of charcoal. The following values were established in the process:

– Specific heat capacity:	$c_p = 1293$	[J/kg*K]
– Density:	$\rho = 601 \pm 70$	[kg/m ³]
– Density at a particle size of 20 mm	$\rho = 670.0$	[kg/m ³]
– Density at a particle size of 80 mm	$\rho = 530.0$	[kg/m ³]
– Thermometric conductivity:	$a = 1.9 \cdot 10^{-7}$	[m ² /s]
– Thermal conductivity:	$\lambda = 0.15$	[W/(m*K)]
– Moisture:	8.1	[%]
– Particle size:	20-80	[mm]

Following that, the charcoal's kinetic properties were determined experimentally. This involved subjecting the charcoal to isoperibolic, i.e. with a constant oven temperature, and adiabatic²¹ hot storage tests, where the coal was preheated to a predetermined temperature level.

¹⁹ Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria – 5th Revised Edition ST/SG/AC.10/11/Rev.5, New York and Geneva, 2009.

²⁰ Underlined by the BSU.

²¹ Thermodynamic process that occurs without heat exchange with the environment. Systems in which adiabatic processes occur are thermally insulated. In practice, this is usually achieved by using suitable insulated vessels.

In this context, the UN N.4 test already carried out by IBExU was first repeated, however. This test produced the same result. A temperature increase of approximately 6 °C within the sample meant the result was definitely within the possible temperature increase of up to 60 °C.

3.2.4.5.1 Adiabatic hot storage test

During the adiabatic hot storage test, the company commissioned inserted a sample of the charcoal into a 125 cm³ wire basket with an overtemperature²² of 2 K. The starting temperature was 140 °C. The expert noted the following in this context: "The adiabatic test has the advantage that it is not affected by volume. This means that numerous conclusions can be drawn from a single test. The test [...] was repeated for reasons of quality. This did not affect the test result."²³

"Adiabatic [hot storage] tests with self-ignitable material assist in determining material characteristics such as Arrhenius rate and apparent activation energy. A test with a small sampling is sufficient. In the adiabatic hot storage test, the oven temperature is first increased to an appropriate set value. When the temperature of the sample has reached that of the oven, the internal heat production should have started. Adiabatic hot storage test means that the oven temperature follows the core temperature in the sample when the core temperature exceeds the oven temperature."²⁴

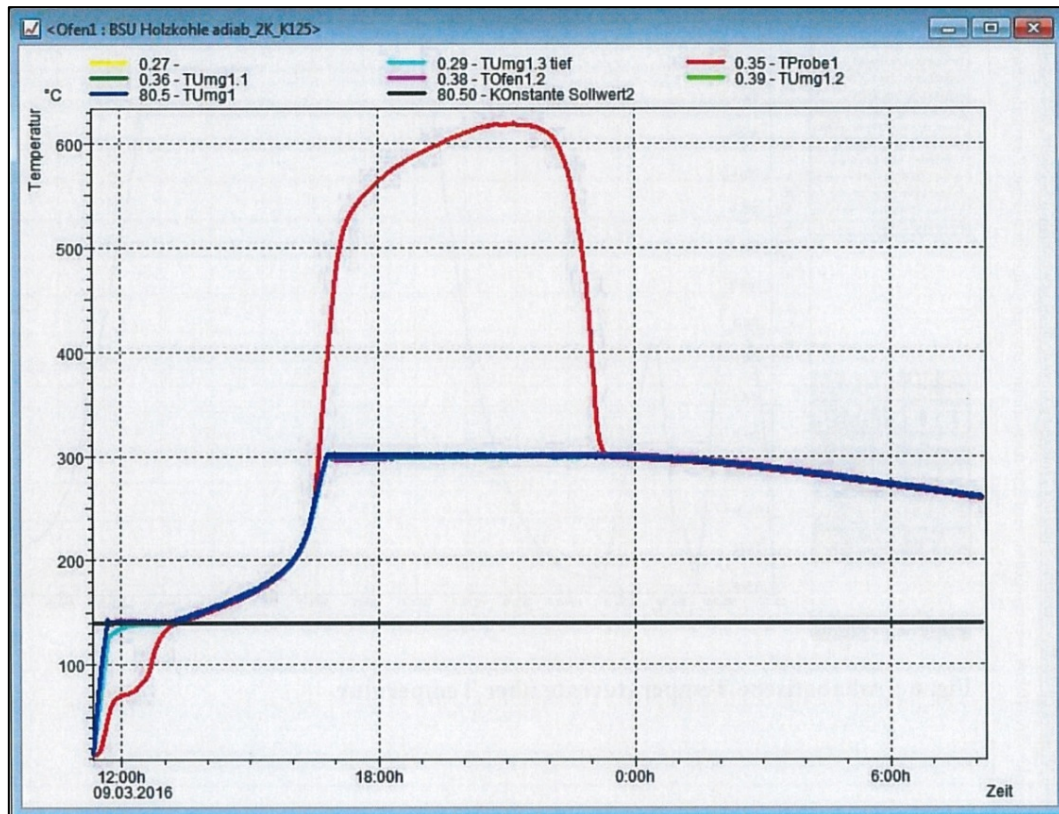
The test produced the temperature curve shown in Diagram 2. The oven temperature followed the core temperature of the sample up to a temperature of 300 °C. The temperature of the sample then rose independently up to about 620 °C.

For the other data determined, such as adiabatic temperature rate over the temperature and reaction heat flow of charcoal over the temperature, see the expert opinion in its entirety (see note in section 8.12 of the Annex).

²² Temperature difference between the oven temperature and the core temperature of the sample.

²³ Dr.-Ing. Krause, G.: Thermal behaviour of Indonesian charcoal. Classification for transport. Self-ignition of charcoal on the MV KATRINA. Expert opinion. Potsdam 2016. Referred to below as 'Dr.-Ing. Krause's expert opinion'.

²⁴ <http://www.selbstentzuendung.com/de/leistung/labor.html> (15 August 2017).

Diagram 2: Adiabatic temperature-time curve in 125 cm³ cube

"[Diagram 3] permits the following conclusion: At a storage temperature of e.g. 25 °C, a reaction heat flow of 3 J per kg and hour is produced. This is the internal heat production of the charcoal. A mass of about 33 t of charcoal, which is carried in each container, produces a reaction heat of about 100 kJ per hour. This corresponds to 28 W [per hour] per container. This does not seem to be very much. This heat must be dissipated into the environment through the cargo hold's ventilation. Otherwise, the cargo hold is heated constantly. At a storage temperature of e.g. 50 °C, that of the reaction heat is 183 W [per hour]."

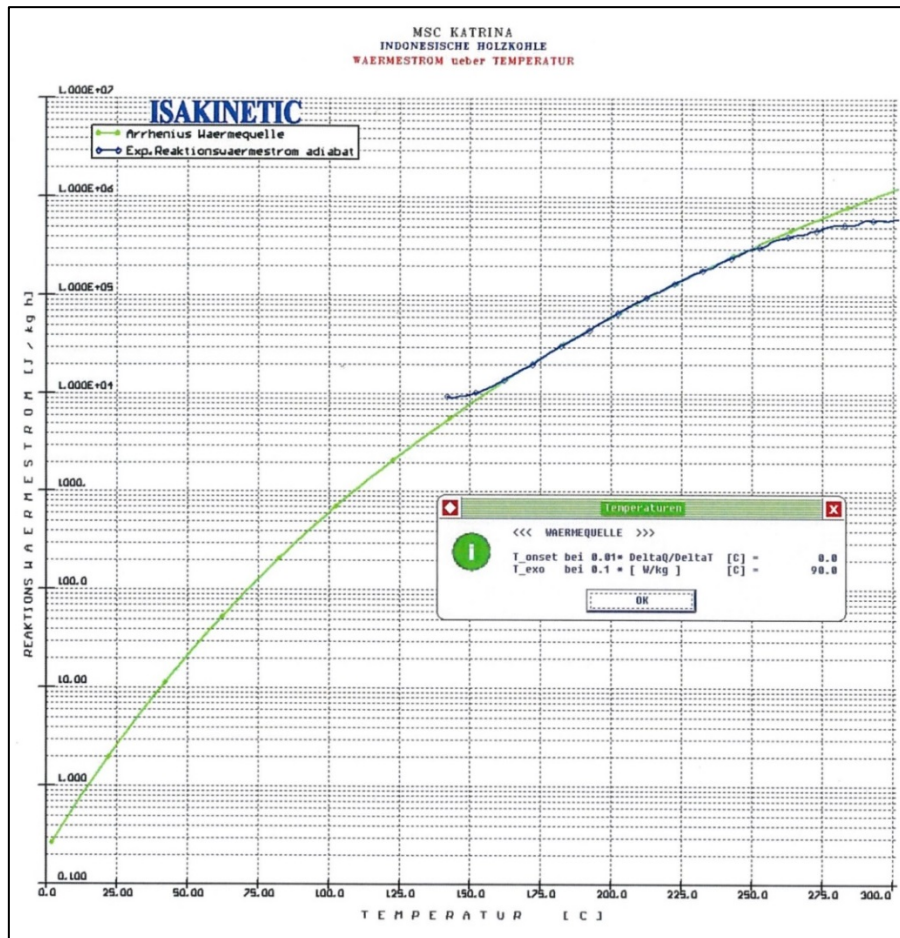


Diagram 3: Review of the Arrhenius heat source

3.2.4.5.2 Isoperibolic hot storage test

"Isoperibolic hot storage tests assist in determining volume-dependent auto-ignition temperatures experimentally. The term isoperibolic means constant ambient (oven) temperature."²⁵

"In an isoperibolic hot storage test, the material requiring examination is inserted into a wire basket, such as a cube or a cylinder. This basket is placed in an oven. The temperatures inside the oven and in the sample are measured. The oven temperature is kept constant and represents the storage temperature of the substance. The oven is supplied with sufficient oxygen through openings in the interior. The temperature development at the centre of the sample shows whether an increase above oven temperature occurs. If this is the case, then self-ignition will occur sometime later. The induction period arises from the time-temperature curve."²⁶

²⁵ Ibid.

²⁶ <http://www.selbstentzuendung.com/de/leistung/labor.html> (15 August 2017).

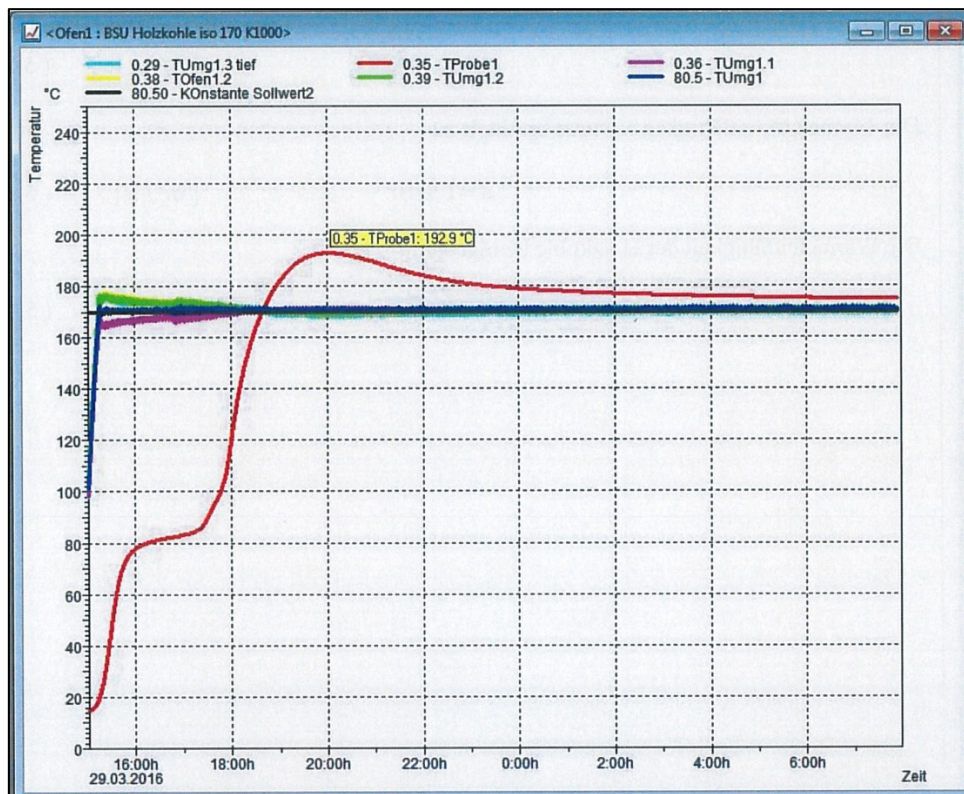


Diagram 4: Isoperibolic temperature-time curve of charcoal in a 1 litre cube at 170 °C.

"A wire cube with a volume of 1 litre was used in the isoperibolic hot storage tests. This isoperibolic test is carried out to establish the auto-ignition temperature of the charcoal at this volume. [Previously] it was merely determined that the auto-ignition temperature is greater than 140 °C."²⁷

The expert found the following with regard to this test: "The maximum temperature of the charcoal is 193 °C. An increase in temperature of 23 °C occurs. There is no ignition. The auto-ignition temperature of charcoal in the 1 litre cube is slightly higher. The test result [...] clearly indicates that the charcoal examined here is either a mixture with other substances or specially prepared charcoal (activated charcoal)."²⁸

In his analysis, the expert considered the volume-dependent critical ambient temperatures. The ambient temperatures are critical in so far as they may not be exceeded if spontaneous combustion is to be avoided.

²⁷ Dr.-Ing. Krause's expert opinion.

²⁸ Dr.-Ing. Krause's expert opinion.

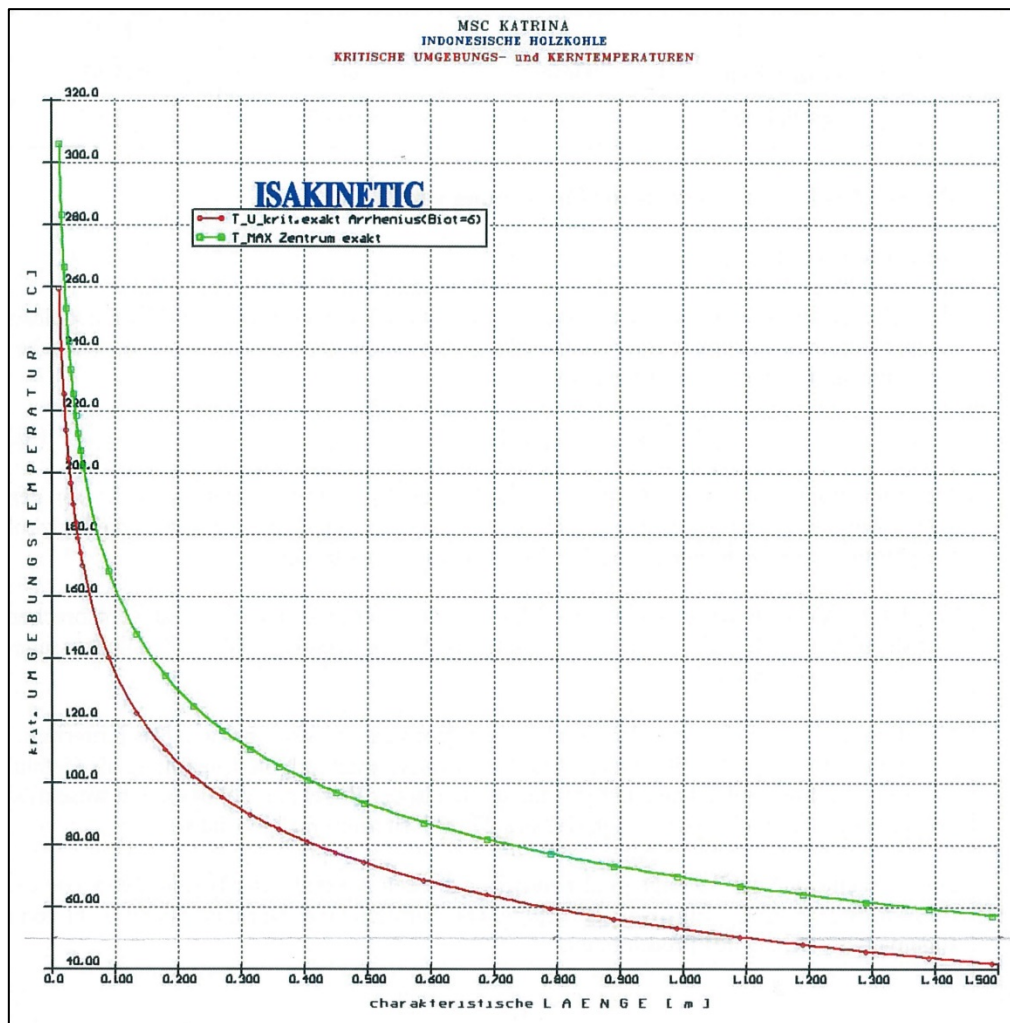


Diagram 5: Volume-dependent critical ambient temperature for charcoal

"The function $T_{U, \text{krit.}}(L)$ in relation to the characteristic length L ²⁹ is based on the [previously determined] kinetic parameters [...] and on the thermometric conductivity [...]. The specific sea container is still not included in this consideration at this stage."³⁰

The graph for $T_{U, \text{krit.}}$ was calculated as per the thermal explosion theory.

"[Diagram 5] shows the critical ambient temperature for a volume of 27 m³. This volume corresponds to a characteristic length of $L = 1.5$ m. The critical auto-ignition temperature is

$$T_{U, \text{krit.}}(27 \text{ m}^3) = 41 \text{ }^\circ\text{C}$$

The temperature of 41 °C for a volume of 27 m³ is well below the [auto-ignition] temperature required by UN N.4 of [$>$] 50 °C. This means that the charcoal would constitute dangerous goods according to this provision, [...].

²⁹ For the model of the ideal stirred container in heat transfer theory, the ratio of volume to surface is used for the characteristic length (reciprocal value of the surface-to-volume ratio), https://de.wikipedia.org/wiki/Charakteristische_Länge (17 August 2017).

³⁰ Dr.-Ing. Krause's expert opinion.

The 1 litre test, which produced an auto-ignition temperature of clearly $>> 140\text{ °C}$, prevents the classification of charcoal as dangerous goods according to the flowchart³¹ [...]. However, the statement is clear according to [Diagram 5]."³²

3.2.4.5.3 Adiabatic induction periods

"The adiabatic induction period plays a key role in chemical safety engineering. It represents the period that lapses until the runaway of a chemical reaction from a predetermined ambient temperature under adiabatic conditions. The adiabatic induction period is generally conservative, i.e. on the side of caution.

It follows from this that the entire period, consisting of storage and transportation, must be less than the induction period. If this is not the case, then the substance concerned (i.e. the charcoal) will ignite during storage or transport."³³

A calculation of adiabatic induction period produces the graphs shown in Diagram 6.

"The specific container is not included in the calculation but rather only the kinetics of the substance.

[Diagram 6] indicates that an induction period of 72 days applies for a temperature of 40 °C , for example. If the temperature rises to 50 °C , then the induction period reduces to 32 days. This is an indication of how much the induction period depends on ambient temperature. The transportation period at sea was 46 days. It must be assumed that the charcoal's storage period until setting sail in Surabaya was at least ten days. Overall, the induction period must be set at greater than 56 days if ignition is to be avoided.

Based on these general considerations, a temperature of 44 °C arises according to [Diagram 6] under adiabatic conditions."³⁴ This means that at a constant temperature of 44 °C in the container, a runaway reaction can be expected after 46 days, i.e. a fire will develop.

³¹ Section 8.10 of the Annex.

³² Dr.-Ing. Krause's expert opinion.

³³ Ibid.

³⁴ Ibid.

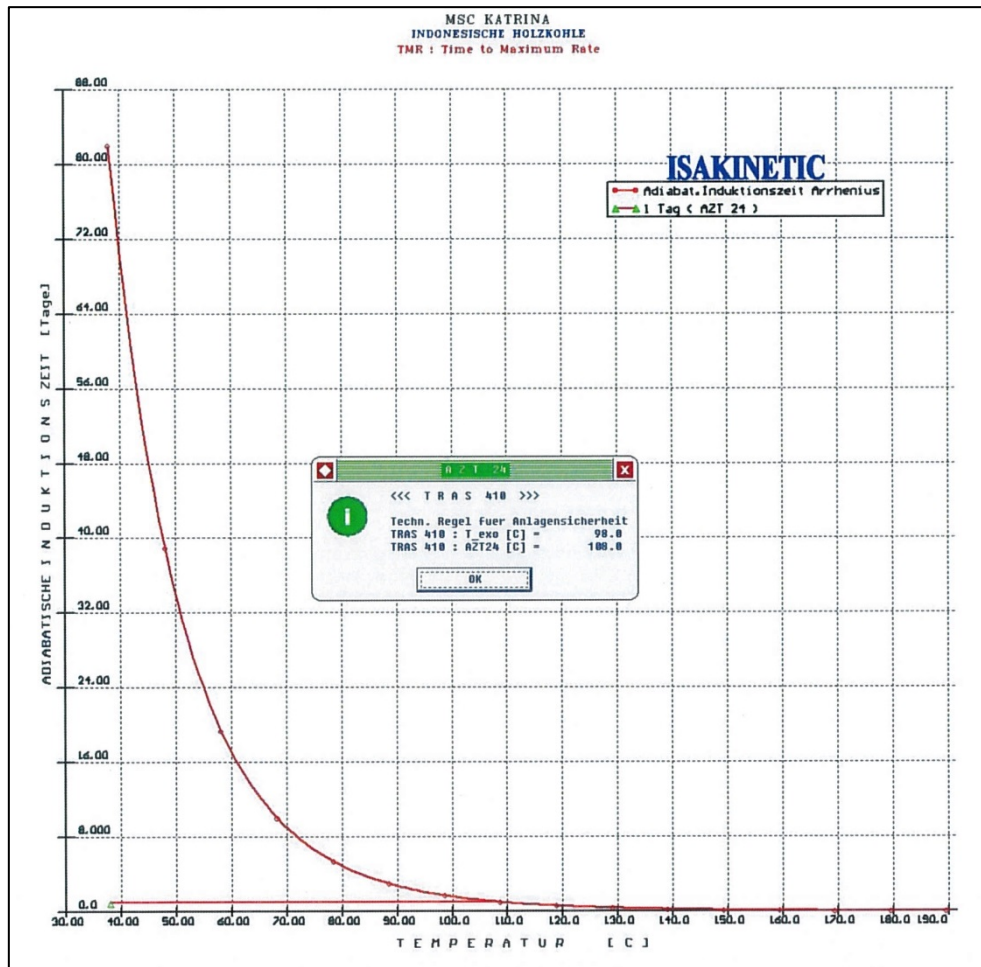


Diagram 6: Adiabatic induction periods for Indonesian charcoal

3.2.4.5.4 Finite element analysis for the high cube container used

"In addition to the prior considerations and calculations, a container [...] should be modelled with finite elements. This computational model is subjected to a temperature load typical of Indonesia for the season in question and transport by sea to Hamburg."³⁵

The following data (internal dimensions and weight) were adopted for the 40-ft high cube steel container:

Length	$l = 12.032$	[m]
Breadth	$b = 2.350$	[m]
Height	$h = 2.700$	[m]
Volume	$V_C = 76.3$	[m ³]
Unladen weight	$G_L = 3,940$	[kg]

"The finite element model maps the container with charcoal inside. The filling level is approximately 72%. The assumed filling height is 2.0 m.

³⁵ Ibid.

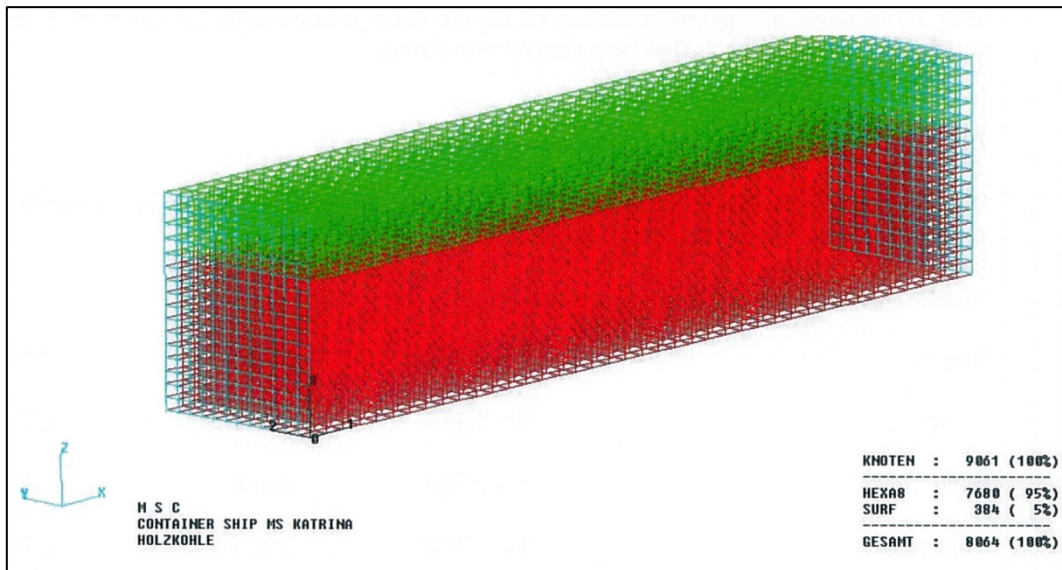


Figure 10: Container model with charcoal, air layer and heat transfer

The entire model comprises 8,069 elements and 9,067 nodes. It is a volume model. The red volume element is charcoal and the green element the layer of air. The heat transfer elements are the colour cyan.

The steel container can only emit heat to the outside via the end faces. Neighbouring containers were situated at the side faces, on the top and bottom surfaces.³⁶ Heat exchange between adjacent containers is only possible to a limited extent, as all containers had to exhibit the same temperature in the port of Surabaya, regardless of type of cargo."³⁷

The development of the temperatures in the cargo hold is uncertain, as no corresponding recordings were made. The temperatures are determined by the ambient temperature (air and water), the ship's black shell plating's exposure to sunlight, the temperatures of the tanks adjacent to the cargo hold, and the ventilation of the cargo holds. It is important to note that after the cargo holds were closed on 26 October 2015, they were not opened again until 13 November 2015 in Portugal. The outside temperatures referred to in section 3.2.4.3 aim to provide guidance. They were included in the numerical simulation.

³⁶ Note by the BSU: The assumption differs from the actual conditions. Due to the conservative method of calculation, the expert believes this would not have affected the result.

³⁷ Dr.-Ing. Krause's expert opinion.

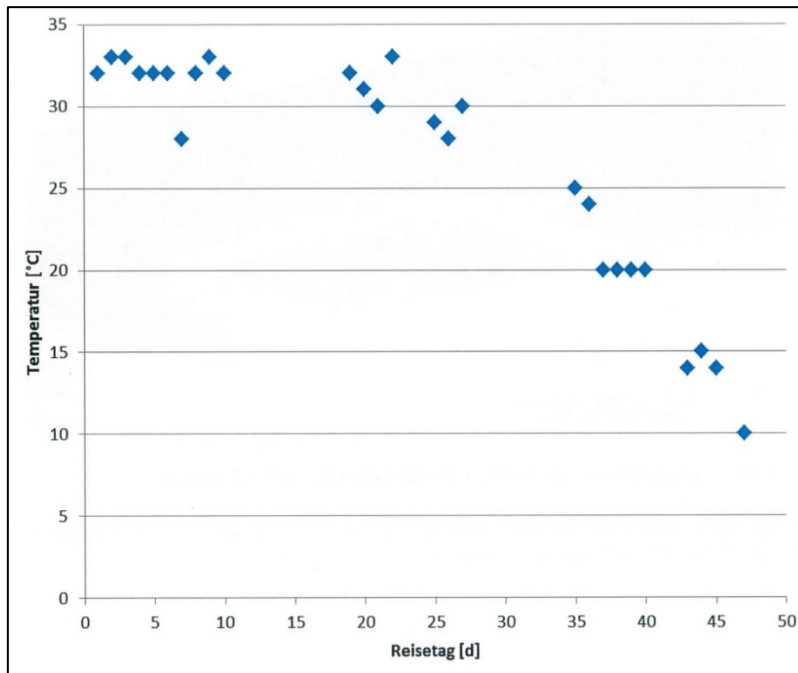


Diagram 7: Outside temperatures during the voyage of the MSC KATRINA

As an initial condition for the numerical simulation, a temperature of 45 °C³⁸ was adopted for the charcoal.

"The calculation delivers a period, in days, after which a temperature of 100 °C is reached in the container, which the fire service observed during the firefighting operation. [Figure 11] shows the temperature distribution in the charcoal and in the air layer."³⁹

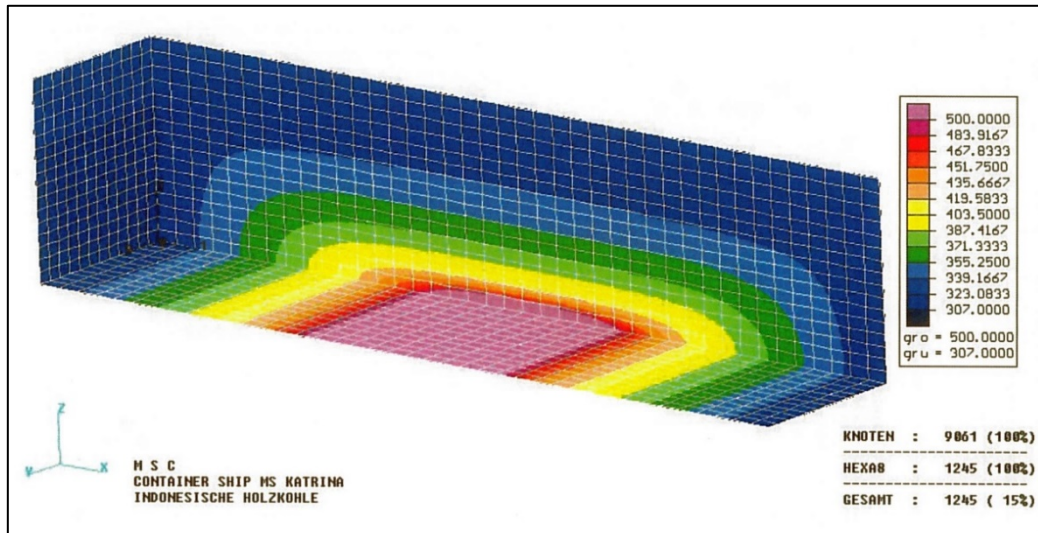


Figure 11: Temperature distribution in the charcoal after 52 days

³⁸ Dr.-Ing. Krause's expert opinion, page 1, para. 2.

³⁹ Dr.-Ing. Krause's expert opinion.

"Under the agreed conditions, a hot zone forms at the bottom of the container. After 52 days, a thermal explosion⁴⁰ occurs – see [Diagram 8]."

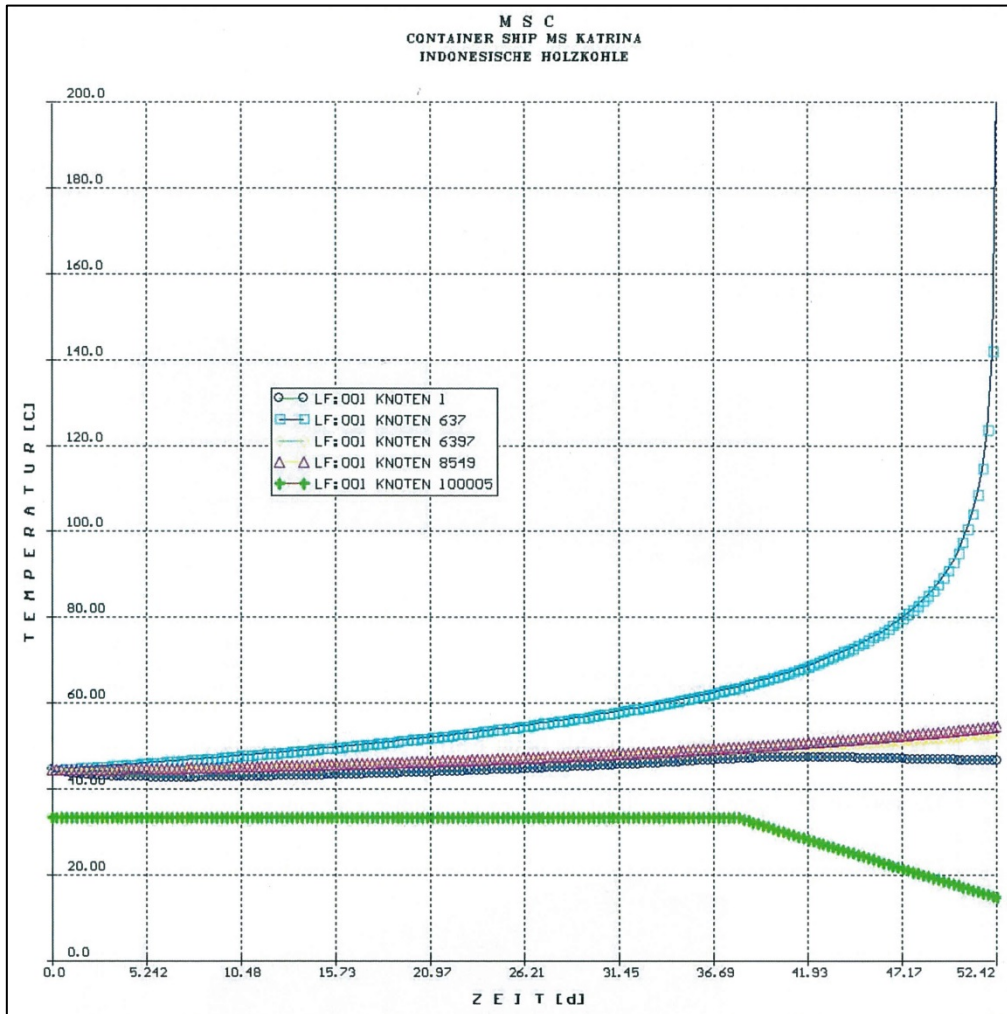


Diagram 8: Temperature curves at selected positions in the charcoal

"[Diagram 8] shows that a temperature of 100 °C is reached at the bottom of the container after 50 days. The green line in [Diagram 8] reflects the idealised ambient temperature curve."⁴¹

In a further simulation, the expert adopted an initial charcoal temperature of 40 °C. A notional hotspot, i.e. a certain amount of charcoal at an elevated temperature of 60 °C, was also included. Despite the lower initial temperature, this was sufficient to ignite the charcoal after 40 days. See attached opinion for details.⁴²

⁴⁰ Thermal explosions occur when the [energy of a thermodynamic system] cannot dissipate quickly enough, thus causing the temperature of the system to increase. The increase in temperature leads to an increase in the reaction rate, causing even greater heat release and finally an explosion. (Theories of Semenov, Frank-Kamenitzkii and Thomas.)

<http://www.chemie.de/lexikon/Explosion.html> (17 August 2017).

⁴¹ Ibid.

⁴² Section 8.12 of the Annex.

3.2.4.6 Weight of the charcoal cargo

The shipper of the cargo specified a charcoal weight of 25,920 kg (cargo weight⁴³) in the sea waybill for the container investigated.⁴⁴ Accordingly, the particle size should be 20-80 mm.

In the report of analysis of 18 September 2015, the particle sizes were specified as follows:

0-3 mm	0.8%
3-5 mm	0.3%
5-10 mm	0.7%
10-20 mm	1.8%
20-150 mm	96.4% ^q
+ 150 mm	0%

The maximum particle size was specified as 75 mm in a separate box (top size). There was no information on the bulk density.

The certificate of quantity and quality issued on 12 October 2015, forwarded by the manufacturer (or shipper) to MSC by email on 2 December 2015, also contained no information on the bulk density. The distribution of particle size was specified in that as follows:

0-3 mm	7%
3-5 mm	11.38%
5-20 mm	81.62%

However, it was stated in the body of the message that the bulk density was reportedly 510 kg/m³.

During the tests carried out by IBExU, the average bulk density of the cargo was determined at 520 kg/m³.

Dr.-Ing. Krause determined a particle size of 20-80 mm for the opinion. Here the density was between 530 kg/m³ (particle size: 80 mm) and 670 kg/m³ (particle size: 20 mm). A bulk density of approximately 600 kg/m³ was determined as the mean value.

This bulk density was not established in any of the documents issued in Indonesia. The bulk density referred to in the email of the shipper differed from the values determined in Germany by the laboratory appointed by the BSU. The bulk density referred to in the email appears to be illogical, as it ought to be higher given the particle size of 0-20 mm specified in the certificate of quantity and quality. Dr.-Ing. Krause measured a bulk density of 670 kg/m³ for a particle size of 20 mm, for example.

Based on the bulk density of 510 kg/m³ and the weight of 25.9 t referred to in the email and sea waybill respectively, a stowage height for the charcoal in the container of about 1.8 m would arise in the case of the container opened in Hamburg. The stowage height would be about 1.73 m and the cargo weight about 26.9 t for a bulk density of 530 kg/m³.

⁴³ In the sense of the net weight of the load alone (cargo net weight).

⁴⁴ Cargo net weight + packaging (tare weight) = gross cargo weight.

The average stowage height noted by the BSU's investigators stood at 1.90 m, however. A stowage height of 1.90 m and bulk density of 510 kg/m³ would produce a cargo weight of 27.4 t. It would actually be about 28.5 t if the bulk density was 530 kg/m³. At a bulk density of 600 kg/m³, the cargo weight would be about 32 t.

3.2.4.7 Additional findings

The following assertions were made in the charcoal manufacturer's email to MSC, which was sent after the fires on the MSC KATRINA and the MSC SVEVA:

- at 5-20 mm, the particle size of the charcoal destined for Le Havre was smaller than that shipped to other destinations of 20-150 mm;
- given the extremely hot weather in southern Borneo with temperatures of about 37 °C, the water content was only about 5%. The water content would usually be about 20%. Charcoal with a higher water content can supposedly absorb much more heat;
- given the lower particle size, the bulk density is greater. For example, the bulk density is 510 kg/m³, as compared to the other particle size specified at 350 kg/m³;
- some 35% of empty space would remain if the container was laden with about 26 t. This empty space causes a greenhouse effect of sorts. When exposed to sunlight, some of the heat is absorbed by the material inside the container. Long-wave radiation, in particular, is reflected within the container, leading to the air and contents inside the container heating further, however;
- charcoal with a smaller particle size has a greater surface area than that with a larger particle size. Accordingly, it responds more actively to factors like heat and oxygen;
- the email concludes with the assertion that charcoal with a small particle size can no longer be transported to all destinations.

3.2.5 Firefighting

After the fire service's operational commander contacted the ship's command of the MSC KATRINA and preliminary arrangements had been made, the fire service carried out its own survey of the scene. It was found in the process that the outer side of a container in the fifth tier⁴⁵ had heated up to more than 100 °C. The container beneath also exhibited an increased temperature in the empty space above the actual charcoal cargo. The firefighting then began. Two nozzles were initially used for external cooling to prevent the fire from spreading.

⁴⁵ Part of the inner hull and a 20-ft container formed the first tier.



Figure 12: The fire service cooling the container stack

The container affected by the fire could not be reached by ladder due to the stowage height. Consequently, high-altitude rescuers belonging to the second fire service group fixed rope safety equipment on the uppermost container of the stack concerned. The firefighters were then able to abseil down from there and attach a fognail to the container affected by the fire.



Figure 13: Erecting safety equipment on the roof of the uppermost container

The container beneath the one affected by the fire could be reached by ladder. It was cooled using two fognails punched into the area above the cargo. The development of the temperature in the containers was continuously monitored until the end of the operation using a thermal imaging camera and a laser thermometer.

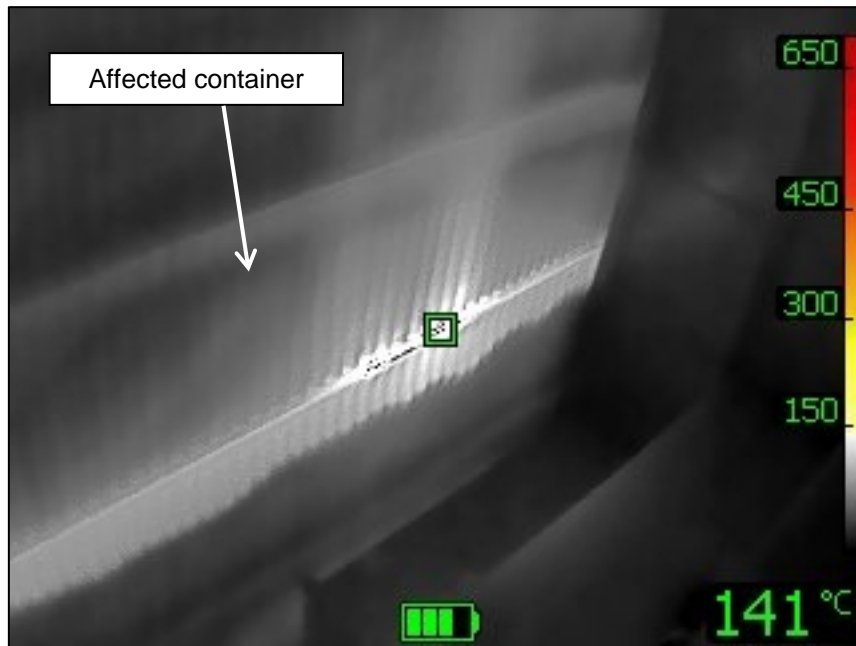


Figure 14: Temperature measurement by the fire service on the starboard side of the stack: 141 °C



Figure 15: Temperature measurement by the fire service on the starboard side of the stack: 8 °C

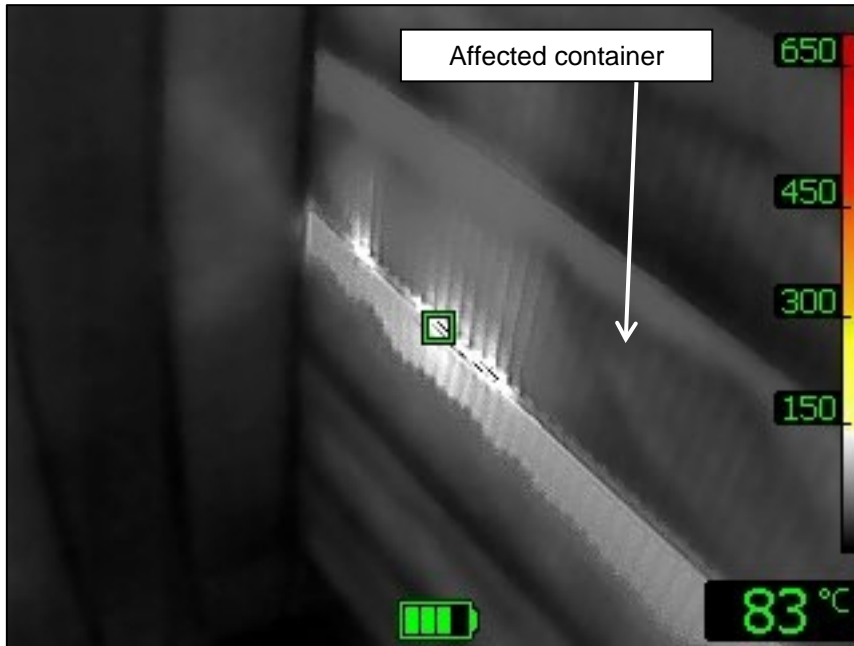


Figure 16: Temperature measurement by the fire service on the port side of the stack: 83 °C

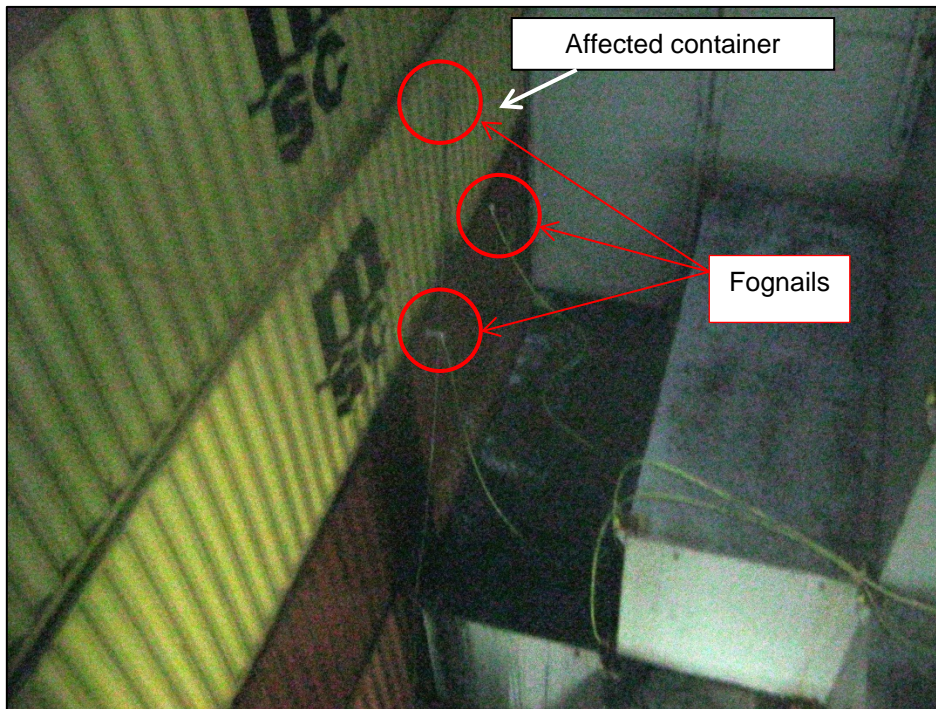


Figure 17: View of the starboard side of the stack with three fognails attached

The temperature measurements show that the area in which the outer skin of the container reached 130-141 °C was spatially confined and mainly on the right-hand side. The temperature dropped immediately adjacent to it and was only slightly above the ambient temperature of about 4 °C. It is also evident that the temperature in the area over the cargo in the container beneath the one that was on fire exhibited higher values (more than 20 °C) than the empty space of the burning container. This is probably due to the fact that much of the wood bottom of the container affected by

the fire was no longer present, meaning glowing charcoal was directly on the roof of the container below.

3.2.6 Subsequent events

In addition to the certificate of quantity and quality belonging to the sea waybill for the transportation on MSC MILA 3 and MSC KATRINA (see section 3.2.4.1) accompanying the email of 2 December 2015 from the manufacturer/shipper to MSC, such a certificate was also sent for the shipment on the MSC GIANNA of ten containers carrying charcoal. This certificate was issued on 26 October 2015. The investigators used this as an opportunity to enquire with MSC about events during this transportation. MSC replied that a fire had also occurred on the MSC SVEVA, which had taken over these containers from the MSC GIANNA in Tanjung Pelepas to carry them to Le Havre.

The master of the MSC SVEVA reported in his statement, which MSC submitted to the BSU, that in the early afternoon hours of 23 November 2015 en route between Suez and Algeciras, the bridge crew saw clouds of smoke rising from the area of the containers in bay 18 in front of the bridge of the ship. The container concerned could be identified using a laser thermometer. Glowing charcoal was subsequently found on the hatch cover. In addition to extensive cooling measures on the container stack, the affected container was opened and flooded as part of the firefighting operation. The crew was thus able to fight the fire successfully. There were no dangerous goods in the vicinity of these containers.

3.3 Course of the accident: LUDWIGSHAFEN EXPRESS

On 23 February 2016, the ship owner, Hapag-Lloyd, reported to the BSU that in the afternoon hours of 21 February 2016 a cargo fire in a container was noticed on board and fought in the ensuing hours.

The report by the ship's command of the LUDWIGSHAFEN EXPRESS sets out the events in greater detail. This indicated that the ship was in the Red Sea en route from Singapore to Le Havre at the time the fire broke out. During an inspection of the refrigerated containers at about 1630 local time, an able seaman noticed that smoke was rising from one of the containers on deck. He immediately notified the chief officer, who was also on the deck. The chief officer verified this finding, as well as the container's slot (701182⁴⁶). After the master received notification on the bridge, he sounded the general alarm at 1640. After the crew was mustered, it equipped itself for the firefighting operation. The electrical power and fans in the vicinity of CH 9 were switched off. At 1655, the chief officer found glowing charcoal under the relevant container.

⁴⁶ In the aft section of the ship behind the funnel next to cargo hold 10.

During the inspection of the stowage plan and the documents relating to the dangerous goods, it was found that there were no dangerous goods in the vicinity and that the cargo in the container concerned consisted only of charcoal. Cooling the outer shell and vicinity of the burning container with sea water started at 1657. At 1703, two crew members wearing breathing apparatus punched a fognail into the affected container with a view to flooding it with sea water. At the same time, the ship was trimmed slightly to starboard to make it easier for the water to run off.

Using a laser thermometer, the crew found that the immediately adjacent container (slot 700982) also exhibited a high temperature at 1720. The cargo documents indicated that this container was also carrying charcoal. A fognail was also punched into this container to discharge water into it. The inspection of CH 9 was completed at 1747. No irregularities were found.



Figure 18: Attachment of a fognail

The first container was still emitting smoke at 1800. Since the wood floor was now partially burnt, glowing charcoal washed out of the container onto the hatch cover. Cooling and flooding the two containers continued.

At 2010, the crew opened the container that was noticed first. They found that the charcoal was stowed in bulk and parts of it were still glowing. Following that, the crew began to wash the charcoal out of the container and overboard. To this end, the ship was trimmed by the stern.



Figure 19: Charcoal cargo washed out

A further inspection of CH 9 was completed at 2230 without any notable findings.

All the charcoal from the first container was washed out by 0054. Accordingly, the fire was extinguished in this container. The fognail on this container was then also fixed to the second container affected and activated.



Figure 20: Container bottom burnt through

A temperature measurement at 0535 revealed no further increase in temperature. Nonetheless, a fire watch was deployed shortly after and the cooling continued. The

temperature dropped after some time and the crew then declared the fire extinguished.

3.4 Investigation: LUDWIGSHAFEN EXPRESS

3.4.1 Start of the investigation

In the days after the initial notification, the ship owner obtained various cargo documents from OOCL⁴⁷ and forwarded them to the BSU. A team from the BSU surveyed the LUDWIGSHAFEN EXPRESS on 8 March 2016 in Hamburg.

3.4.2 On-scene survey

Since the containers with charcoal had already been discharged in Le Havre, the investigators merely viewed the scene of the fire and the firefighting equipment. A member of the ship's command gave the investigators an account of the firefighting training the crew receives and of the measures taken and observations made while firefighting at the container.

3.4.3 Charcoal cargo

3.4.3.1 Shipment

A total of eight containers carrying charcoal were transported on the LUDWIGSHAFEN EXPRESS. They were part of a cargo of 15 containers, which had been shipped by the WARNOW CHIEF from Surabaya to Singapore. The other seven containers left Singapore on board the HYUNDAI TENACITY. All 15 containers had the same consignee and were to be shipped to it via Le Havre.

The contracting carrier of the cargo was OOCL, which co-operated with Hapag-Lloyd in slot charter within the framework of an alliance. Only limited information but no cargo documents were submitted.

As was to be expected, the ship's command of the LUDWIGSHAFEN EXPRESS was not aware of the exact content of the containers because the charcoal was not declared as dangerous cargo due to passing the test. A representative of Hapag-Lloyd stated that the containers would not have been transported if the content had been known because charcoal from Indonesia was on the company's exclusion list. This list is reportedly also known to partners of the alliance. OOCL or the shipper specified the content only in very broad terms as 'general cargo'.

The HYUNDAI TENACITY also transported the containers within the framework of the alliance in slot charter.

⁴⁷ OOCL: Orient Overseas Container Line.

The extract from the stowage plan (Figures 21 and 22) gives an overview of the position of the charcoal containers. It is evident that all the containers carrying charcoal were shipped as deck cargo.

During the temperature measurements carried out periodically on the other charcoal containers after the fire, all the cargo units were initially normal, even though three containers were exposed to increased sunlight due to the slot.



Figure 21: Extract from the stowage plan (bay 22)⁴⁸

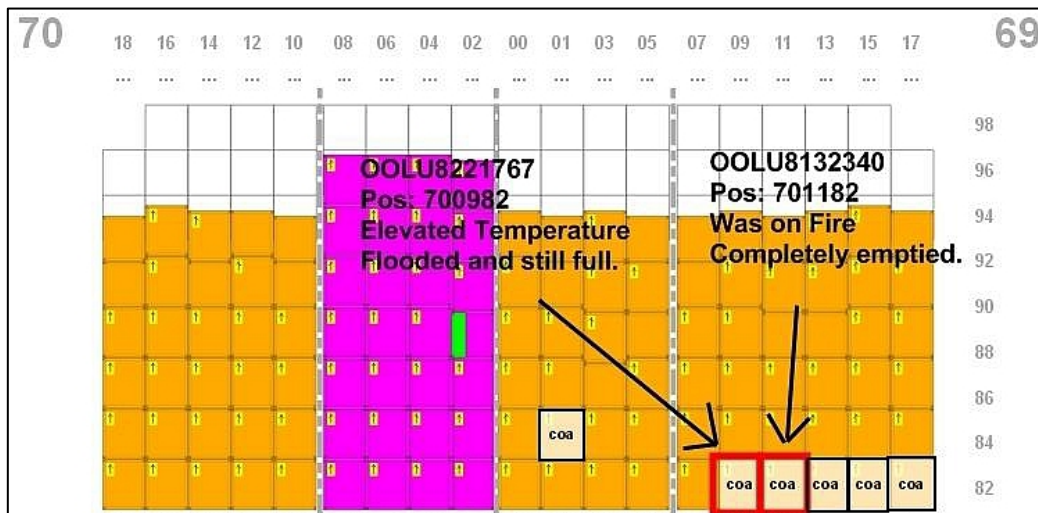


Figure 22: Extract from the stowage plan (bay 70)

3.4.3.2 Second fire

During the inspection of the ship by the investigators in Hamburg, the ship's command reported that another burning container was noticed in the port of Le Havre while they were preparing to unload.

⁴⁸ The containers outlined in black in Figures 21 and 22 indicate the containers carrying charcoal.

Its increased temperature was reportedly first noticed during one of the inspections. The crew reportedly later detected a burning smell. It concerned the container at slot 221884, which was thus in the second layer.

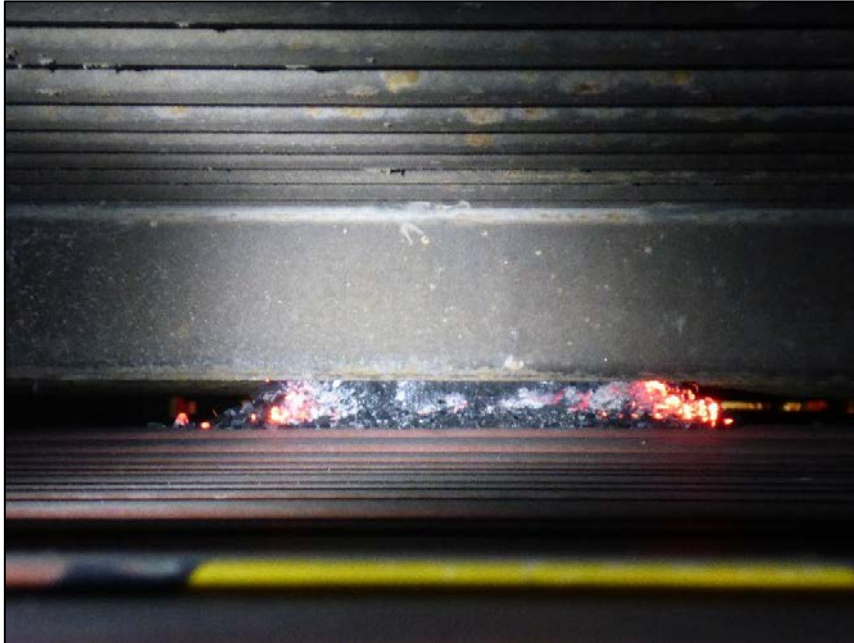


Figure 23: Glowing charcoal beneath the container at slot 221884

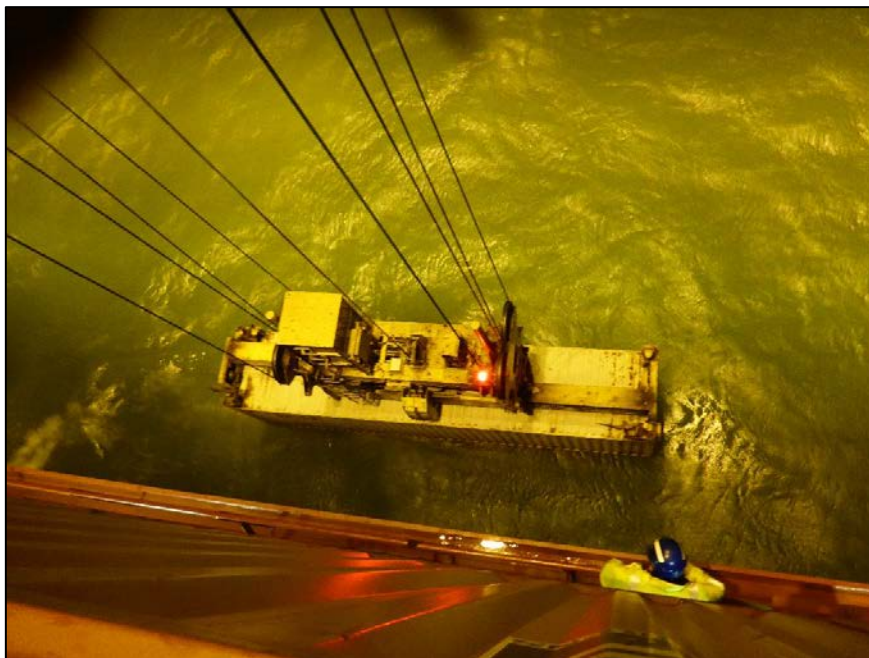


Figure 24: Unconventional firefighting

Since the container was overstowed and could not be unloaded immediately, the crew responded with the proven firefighting method of fixing fognails to the container's front and back. This was maintained until unloading by the terminal operator. While unloading was taking place, the operator of the container gantry crane immersed this container on the ship's seaward side.

The container in bay 22 was transported well away from the containers that caught fire, meaning it is reasonable to assume spontaneous combustion occurred here, too. All three containers were assessed together in Le Havre by surveyors from the insurance companies. The associated report by the surveyor acting on behalf of Hapag-Lloyd indicates that the containers transported on the HYUNDAI TENACITY reached LE HAVRE without any incidents.

3.4.3.3 Transportation route of the charcoal

The 15 containers carrying charcoal were shipped from Surabaya to Singapore on the WARNOW CHIEF on 28-30 January 2016. The LUDWIGSHAFEN EXPRESS took some of these containers on board on 11 February 2016 and discharged them on 2 March 2016 in Le Havre.

The other seven containers left Singapore on 4 February 2016 on board the HYUNDAI TENACITY and reached Le Havre on 25 February 2016.

Accordingly, the discussed sea transport of the containers on the LUDWIGSHAFEN EXPRESS from Surabaya took 35 days, including the stay in Singapore. The containers on the HYUNDAI TENACITY reached Europe after 29 days.

3.4.4 Cargo documents

Hapag-Lloyd obtained the following documents from OOCL for the charcoal cargo:

- Report of analysis issued on 6 January 2016;
- Weathering certificate industrial lump charcoal issued on 7 January 2016;
- Material safety data sheet issued on 7 January 2016;
- Producing process certificate industrial lump charcoal issued on 13 January 2016;
- Vanning⁴⁹ survey report issued on 25 January 2016, and
- Sertifikat Akreditasi for SUCOFINDO valid for the period 26 November 2014 to 25 November 2018.

The **report of analysis**⁵⁰, certificate number 00051/DOEDAJ, produced by SUCOFINDO confirms that a sample received on 18 December 2015 was tested on 28 December 2015 on behalf of Pt. Citra Prima Utama and that the charcoal passed the UN N.4 test in the process. Since neither the seal number of the sample (or the sample labelling) referred to in the document nor the certificate number appears in one of the other documents, classification to the charcoal cargo in question is not possible. The BSU was not provided with the document cited as a reference for sample number BMI 044432. It presumably refers to a certificate of quantity and quality, which Pt. Buana Multiguna Inspection and Testing could have issued analogously for the MSC KATRINA.

⁴⁹ Alternative expression for packing/stowing cargo in a container.

⁵⁰ See section 8.4 of the Annex.

The **weathering certificate industrial lump charcoal**⁵¹ issued by the charcoal manufacturer, Pt. Citra Prima Utama, refers to charcoal with the specification as defined in the certificate of quality [sic] of an independent surveyor. The certificate of quality referred to was not enclosed with the weathering certificate. The following specifications are listed:

- General size: 5-200 mm
- Maximum moisture content: 8%
- Fixed carbon: 80%
- Volatile matter: 19%
- Ash content: 1%

The document also defines the origin of the raw material and the manufacturing process. It is explained that a six-day cooling period follows after heating to 550-600 °C has been completed. The finished charcoal is then packed into plastic bags and stored at the production site for at least three days. After that, the charcoal was transported about 150 km to Banjarbaru in southern Borneo for subsequent processing. The charcoal remained there for a period of 14-30 days and was then loaded into containers for the sea transport. The manufacturer also assures with the document that the charcoal's temperature had reportedly been inspected to ensure its condition was safe.

The weathering certificate provided contains no indication that would permit a conclusion with regard to the charcoal cargo in question.

The **material safety data sheet**⁵² was also issued by the manufacturer. Apart from the usual information on risk prevention and measures in the event of fire or leakage of the substance, this also listed the following specifications for the charcoal:

- Moisture content: 4-7%
- Fixed carbon: 75-90%
- Volatile matter: 10-20%
- Ash content: 0.5-3%

Point 17 of the document references a report of analysis dated 18 September 2015 (No. 32091/DBBPAH) issued by SUCOFINDO. This was not included with the documents submitted. However, given the date of issue alone, the investigators assume it is not connected with the charcoal cargo in question.

The **producing process certificate industrial lump charcoal**⁵³ document was also issued by the manufacturer. It refers explicitly to the WARNOW CHIEF and her voyage 304W. The specifications are listed as follows in this document:

⁵¹ See section 8.5 of the Annex.

⁵² See section 8.6 of the Annex.

⁵³ See section 8.7 of the Annex.

- General size: 50-100 mm
- Moisture content: 4-7%
- Fixed carbon: 85-90%
- Volatile matter: 5-10%
- Ash content: 0.5-3%

Banjarmasin⁵⁴ is cited as production site. According to the certificate, the charcoal was produced on 26 October 2015 and packed on 7 January 2016.

The **vanning survey report**⁵⁵ drawn up by Pt. Buana Multiguna Inspection and Testing also refers to voyage 304W of the WARNOW CHIEF. It states that the UN N.4 test was passed "[...] in our analytical laboratory [sic] [...]" and that the sample's moisture content is 8.36%. The investigators from the BSU assume that this refers to the aforementioned report of analysis, even though the manufacturer is listed as client in this case.

The stowage report confirms that the containers were dry and in good condition prior to loading. It also states that on completion of loading in bulk, the cargo was secured toward the door with a 'fence' made using bamboo canes.

3.4.4.1 Investigation of the charcoal

During the survey of the ship in Hamburg, the investigators also acquired a sample quantity of the charcoal. The sample was not analysed further, as this material must have come into contact with a large volume of sea water during the extinguishing process and thus no longer corresponded to the original condition.

A further assessment of the containers planned in the port of Le Havre by a surveyor appointed by the owner was not allowed by the authorities. Consequently, additional samples were to be taken at the consignee. However, the consignee had already unloaded the containers by the time the surveyor arrived, meaning classification was no longer possible.

⁵⁴ Banjarmasin is about 30 km away from Banjarbaru by road.

⁵⁵ See section 8.8 of the Annex.

4 ANALYSIS

4.1 Cargo documents

The IMDG Code states that special provision 925⁵⁶ applies for charcoal that does not have hazardous material properties and should not be transported as dangerous goods:

"The provisions of this [IMDG] Code do not apply to:

- [...]*
- a consignment of carbon if it passes the tests for self-heating substances as reflected in the United Nations Manual of Tests and Criteria (see 33.3.1.3.3), and is accompanied by a certificate from a laboratory accredited by the competent authority, stating that the product to be loaded has been correctly sampled by trained staff from that laboratory and that the sample was correctly tested and has passed the test [...].*

The certificate from an accredited laboratory on the test passed negatively according to UN N.4 is therefore the only document that must accompany a charcoal load that does not constitute dangerous goods. In addition, ship owners may require other documents, e.g. a weathering certificate or a stowage certificate.

4.1.1 Cargo documents: MSC KATRINA

The absence of the hazardous material properties was supposedly confirmed by the report of analysis (No: 04343/DOEDA1) provided. The content of this report permitted no conclusions with regard to the MSC MILA 3, the MSC KATRINA or the sea waybill, however. Inasmuch, the rejection of this report by the WSP was logical, as it was reasonable to assume the report did not concern the charcoal in question. In each of the following tests (UN N.4 test), the non-hazardous material properties of this charcoal cargo within the meaning of the IMDG Code were confirmed.

The certificate of quantity and quality, number 044402, provided was consistent with the sea waybill, as it referred to ship, voyage number and other data, making precise identification possible. The certificate confirmed the weight of the cargo and the physical parameters of the charcoal according to an analysis of the issuing company. The certificate contained no statement as to the hazardous material properties of the charcoal.

All the physical parameters of the charcoal listed in the certificate of quantity and quality differed from those listed in the report of analysis. Furthermore, the referenced sample number (044384) of the report differed from that listed in the certificate (044402). This supports the assumption of the investigators that the report provided does not relate to this charcoal cargo.

⁵⁶ Chapter 3.3.1 IMDG Code.

The report of analysis provided contained no indication as to whether the executing laboratory was an accredited laboratory. Corresponding queries sent by email to the issuing company's email addresses provided in the documents could not be delivered.

4.1.2 Cargo documents: LUDWIGSHAFEN EXPRESS

Of the documents concerning the charcoal cargo provided, only the vanning survey report was clearly related to the charcoal cargo on the LUDWIGSHAFEN EXPRESS. Based on the findings in the vanning survey report, the BSU's investigators assume that the charcoal cargo did not exhibit any hazardous material properties, however. All the other documents were neither related to each other (or to this voyage) nor were the physical parameters specified consistent. The report of analysis contained no details on the physical parameters of the charcoal, nor any indication of an existing accreditation. However, Hapag-Lloyd sent a separate document, which certified SUCOFINDO's accreditation.

A request emailed to OOCL for further cargo documents during the investigation went unanswered.

4.2 Charcoal as dangerous goods

Charcoal can constitute dangerous goods, as it is capable of self-heating without the supply of energy and only through contact with oxygen (in the air) when transported in large quantities for an extended period. A smouldering fire with no open flame forms in such cases. "In the process, temperatures of up to 1,300 °C can be reached. Gases are produced during the combustion. Heavy smoke emission by these gases was not observed in the laboratory. The gases are odourless."⁵⁷

A test carried out prior to transportation was designed to clarify whether the charcoal requiring shipment constitutes dangerous goods. The IMDG Code stipulates that the test for determining hazardous material properties must be carried out according to the description in section 33.3.1.6 of the Manual of Tests and Criteria. Due to the simplified handling, the test is not carried out with a sample of 27 m³. A quantity of charcoal that fits into a cube with an edge length of 10 cm is sufficient for the preliminary test. A substance is not classified to class 4.2 if the result of this test is negative. The charcoal carried on the two container vessels underwent this test in Indonesia probably with a negative result. This is at least indicated by the tests that were passed negatively at a later date. Accordingly, the charcoal did not constitute dangerous goods.

For the report on behalf of the BSU, Dr.-Ing. Krause carried out the UN N.4 test again. The result of his test was also that the charcoal passed the preliminary test negatively and thus did not constitute dangerous goods.

⁵⁷ Dr.-Ing. Krause's expert opinion.

Further experimental and theoretical examinations did show that the auto-ignition temperature was 41 °C for a quantity of 27 m³, however. This means that the substance satisfies the criteria referred to in section 33.3.1.3.3.1 of the Manual of Tests and Criteria that at an auto-ignition temperature of less than 50 °C for a volume of 27 m³, the substance must be classified to division 4.2 (the IDMG Code refers to *class 4.2*). This examination was not conducted prior to dispatch, however. Accordingly, the inconsistency went undetected.

The evaluation of the expert's opinion also reveals that the time spent and temperatures arising in transport are further facts requiring consideration when transporting charcoal. It is hardly possible for shipowners to influence the time spent in transport, which to some degree remains unknown within the transport chain. In this case, this at least applies to the period of the production of the charcoal up to the port of Banjarmasin. However, the manufacturer/shipper does state in the weathering certificate for the cargo on the LUDWIGSHAFEN EXPRESS that there could be between 17 and 33 days between production and loading in a container, for example. Similarly, temperatures arising during transport are also unknown, as these are usually not recorded. In addition, the conditions within a group of containers are variable because of the resulting variations in exposure to sunlight, ventilation or the influence of external sources of heat due to different possible slots ashore and on board ships. In this respect, the outside temperature curve shown in Diagram 1 only provides an approximation.

The time spent in transport and resultant temperatures have a decisive influence on the development of the situation in a container, however. In illustrating the adiabatic induction periods (section 6.2 of the expert's opinion), i.e. the relationship between a constant storage temperature and time spent in transport, the expert acting on behalf of the BSU gave an indication as to how critical these are for a shipment if the ignition of the substance is to be avoided. For example, a temperature of 40 °C resulted in an induction period of 72 days. At a temperature of 50 °C, the induction period dropped to 32 days.

In the further consideration of the expert acting on behalf of the BSU, the statement on the relationship between the time spent in transport and prevailing temperature was expanded upon in section 7.4 of the expert's opinion. Based on the outside temperature curve at the container from Diagram 1 and an initial charcoal temperature of 45 °C, Dr.-Ing. Krause demonstrated with a computational simulation that a heat explosion would occur after 52 days, which was confirmed in reality.

It is conceivable that the assertions made in the charcoal manufacturer's email to MSC influenced the development of the fire. Here the greenhouse effect is especially noteworthy, which means that the infrared heat radiation of heated cargo may not be able to penetrate the walls of the container, meaning it is reflected from the walls of the container, thus causing the heat to rise further.

4.3 Weight of the charcoal cargo on the MSC KATRINA

Inconsistencies in the ratio of net container weights to particle size or the resultant bulk densities were identified in the course of the investigation. Based on the assumption that the report of analysis submitted does not apply to the cargo on the MSC KATRINA, the statements in the certificate of quantity and quality on the particle size and in the associated email on the bulk density and the findings on particle size and bulk density made during the assessments in Germany are available for subsequent consideration. The investigators are clear on the fact that the samples available in each case represent only a fraction of the cargo in its entirety and that the composition of the sample depends, *inter alia*, on the method of sampling. Nevertheless, it should be noted that according to the certificate, more than 80% of the sample had a particle size of 5-20 mm and the bulk density was specified at 510 kg/m³, whereas Dr.-Ing. Krause identified bulk densities of 670 kg/m³ and 530 kg/m³ for particle sizes of 20 mm and 80 mm respectively.

It should also be noted that the particle size of 20-80 mm referred to in the sea waybill was not consistent with the predominant particle size of 5-20 mm in the certificate of quantity and quality. This inconsistency was not investigated further within the framework of this report.

The container weights were not re-examined in the course of the investigation. Consequently, it remains open whether the container weights recorded in the sea waybill corresponded to the actual weights or whether the containers were overloaded.

4.4 Outbreak of fire and firefighting

4.4.1 Outbreak of fire

The BSU's investigators assume that the way the fire broke out, i.e. the development of the fire within the container, was identical on both ships. Due to the different stowage positions, the identification or alerting varied. On the MSC KATRINA, the resulting smoke was detected by the smoke detection system. On the LUDWIGSHAFEN EXPRESS, a crew member discovered the fire during an inspection of the refrigerated containers stowed on deck.

4.4.2 Firefighting: MSC KATRINA

Firefighting on the MSC KATRINA was facilitated by the fact that the charcoal was in 40 ft containers and the design of the cargo hold made access possible at least from one side. Moreover, firefighting was also facilitated by the fact that all the containers carrying charcoal were in a free-standing stack. This made it easier for the firefighters to access the seat of the fire in the middle of the container concerned and prevented the fire from spreading to adjacent containers.

Firefighting would have been impossible if, hypothetically, the cargo was in a 20-ft container, the stowage position was at the leading edge of the cargo hold (see Figure 25) and the container affected by the fire was overloaded. It would not have been possible to extinguish the fire within the container using the fixed CO₂ fire-extinguishing installation on board. It is also questionable whether it could have prevented the fire from spreading to the adjacent containers. This cargo hold was not equipped with a water-based fixed fire-extinguishing installation, which would have at least made it possible to delay the spread of the fire to the adjacent stack. The slot would not have been accessible to the ship's response team.

Even in the case of a 20-ft container, firefighting would have been possible at least at an end wall if transported on deck.



Figure 25: Example for a poorly achievable storing position of a 20-ft container

The firefighters and emergency physicians deployed on the MSC KATRINA belonged to units specially trained in fighting ship fires. Accordingly, the group had the ability to abseil down to the seat of the fire. This was necessary because the container affected by the fire could not be accessed using the portable ladders available on board. Since access was limited to the end wall of the container, reaching the seat of the fire would have been complicated or impossible.

4.4.3 Firefighting: LUDWIGSHAFEN EXPRESS

On the LUDWIGSHAFEN EXPRESS, it was easy for the crew to reach the first container affected by the fire because its slot was on the hatch cover. The second container affected by the fire was also easy to reach. Transportation on deck meant that both end walls of the 40-ft container were accessible.

The crew of the LUDWIGSHAFEN EXPRESS fought the fire on its own without any external support. In the opinion of the investigators, the successful outcome was facilitated by the fact that

- an appropriate extinguishing device was available in the form of the fognails;

- the crew was experienced in handling this extinguishing device;
- the fire was discovered at an early stage;
- there was no other flammable cargo in the immediate vicinity, and
- all the charcoal containers were transported on deck and within normal reach, meaning they were easy to access for firefighting.

5 CONCLUSIONS

5.1 Determining the hazardous material properties of the charcoal

Dr.-Ing. Krause was able to demonstrate in his report that it is not possible to fully determine the hazardous material properties of charcoal based on the UN N.4 test alone. This is at least true of charcoal that passes the preliminary test and is then transported in large packages or in bulk in large sea containers, for example. The UN N.4 test does not sufficiently address the dependency on the volume of the goods transported.

The fires involving charcoal cargo known to the BSU seem to confirm the finding that the usual method is not free of errors in the classification. Fires involving negatively tested charcoal cargo are not confined to the MSC KATRINA and the LUDWIGSHAFEN EXPRESS, for example. The BSU's research revealed the following other fires:

- SAFMARINE NOMAZWE, 2011, charcoal cargo;
- SANTA ROSA, 2014, transportation of charcoal from Argentina packed in sacks in containers as deck cargo;
- CAROLINE MAERSK, 2015, transportation of charcoal from China in containers in a cargo hold⁵⁸;
- MARENO, 2015, charcoal cargo packed in sacks in containers as deck cargo, and
- MSC SVEVA, 2015, charcoal cargo in bulk in containers as deck cargo.

It was confirmed by subsequent tests at least in the case of the SANTA ROSA that the charcoal transported passed the UN N.4 test negatively and thus did not constitute dangerous goods prone to auto-ignition. However, the research showed that the other cargoes did not constitute dangerous goods, either.

The expert acting on behalf of the BSU demonstrates⁵⁹ that classification of self-heating substances is possible with a somewhat more complex method, which is based on the actual volume transported and which also eliminates the inconsistencies⁶⁰ in the classification according to the IMDG Code. With that in mind, the BSU's investigators believe that the existing test procedure needs to be revised. This applies to all substances prone to self-heating which may need to be classified according to 4.2 of the IMDG Code.

5.2 Cargo documents

The cargo documents examined in connection with this case did not meet with the expectations of the investigators because of multiple instances in which no link with the cargo to be transported could be established. This is especially true of the certificate on passing the test for self-heating substances required under special

⁵⁸ Danish Maritime Accident Investigation Board (DMAIB). Marine Accident Report April 2016 – CAROLINE MAERSK – Fire in containers on 26 August 2015.

⁵⁹ Dr.-Ing. Krause's expert opinion.

⁶⁰ Krause, Gerhard: Ein Beitrag zur UN-Klassifizierung zum Transport selbstentzündlicher Stoffe nach Unterklasse 4.2. (*paper on UN classification for the transport of self-heating substances according to division 4.2*). In: Chemie Ingenieur Technik, 81. 2009, Issue 10, pages 1653-1663.

provision 925 of the IMDG Code. Both documents were accepted by the MSC and OOCL, even though they do not contain the required information.

For example, the report of analysis for the cargo on the MSC KATRINA did not indicate its relationship with the cargo, nor was it evident that the executing laboratory was accredited. The certificate of quantity and quality may serve as confirmation that qualified personnel took and tested the samples correctly.

The report of analysis for the cargo on the LUDWIGSHAFEN EXPRESS did not indicate its relationship with the cargo, either. Moreover, the report did not contain any physical parameters for the cargo or information about the laboratory's accreditation. The investigators believe the vanning survey report certifies sampling was carried out properly. However, the certificate on accreditation was sent as a separate document, which was not in English.⁶¹

As a result of the investigation of the cargo documents, the BSU believes that especially ship owners taking over cargo should issue appropriate guidelines to shippers for the structure of the documents required. They should also pay attention to the substantive relationship of the documents submitted.

The operators of the website CargoHandbook.com view the situation similarly. This website provides the following recommendations for the transport of charcoal not classified as dangerous goods:

- *Check that the laboratory certificate is applicable to the customer [...]*
- *Check that the laboratory is accredited by the Competent Authority [...]*
- *Check that the manufacturers name is shown on the laboratory certificate [...]*⁶²

Another requirement made there is that "*The laboratory certificate must accompany the shipment, after stuffing of the containers the container numbers that are applicable are to be added to the certificate (hand written is acceptable) and placed on board the vessel [...]*."⁶³ As already outlined, information on the container numbers was not included in any of the reports.

Point 2 of the Guidelines for the Carriage of Charcoal and Carbon in Containers, published in October 2017 by CINS (Cargo Incident Notification System) and IGP&I (International Group of P&I Clubs), additionally recommends the following:

"It is of the utmost importance that Charcoal / Carbon not subject to the provisions of the IMDG Code should be declared by the shipper to the receiving carrier."

This requirement is reemphasised in point 6.2 of the guidelines:

⁶¹ See section 8.9 of the Annex.

⁶² BMT Surveys: Charcoal. URL: <http://cargohandbook.com/index.php/Charcoal>. Information as of 2 February 2016.

⁶³ Ibid.

"Therefore, it is of the utmost importance that Charcoal / Carbon not subject to the provisions of the IMDG Code (under IMDG Code Special Provision 925) is declared as special cargo to the shipping line and has a self-heating test certificate as required, which is accepted by the shipping line. [...]

This enables the shipping line to arrange proper stowage on board the vessel and inform the master accordingly."

As regards the LUDWIGSHAFEN EXPRESS, the BSU's investigators assume that OOCL was acting as contracting carrier on behalf of Hapag-Lloyd. Accordingly, OOCL was in possession of the necessary cargo documents and cargo information. Hapag-Lloyd acted as actual carrier but was not aware of the cargo, even though the BSU believes charcoal would have necessitated this given its inherent risk. This would enable other ship owners within the alliance, which carry charcoal not declared as dangerous goods in slot charter, to minimise the risk through appropriate stowage.

5.3 Firefighting

It may be noted that a charcoal load not classified as dangerous goods and transported in containers poses a relatively high risk of fire due to the inadequate test procedure defined in the IMDG Code. To give a crew the opportunity to fight a fire, containers carrying charcoal should always be transported on the deck of a ship and not higher than in the second tier. This is the only way to facilitate good identification of a container affected by fire and sufficient accessibility in the event of fire.⁶⁴

Section 5.1 of the Guidelines for the Carriage of Charcoal and Carbon in Containers discussed above now also recommends the following: *"However, stowage ON DECK and ACCESSIBLE is strongly recommended under these guidelines."*

In addition, as already outlined in section 5.2, it is necessary for the shipper to advise the carrier of a charcoal cargo in any case. This should also apply to the forwarding of information between the various carriers.

⁶⁴ As regards the difficulties with below-deck loads, see also the DMAIB's investigation report concerning the CAROLINE MAERSK (section 3.2.1 – Discovering and fighting the fire).

6 SAFETY RECOMMENDATIONS

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

6.1 Federal Ministry of Transport and Digital Infrastructure

The Federal Bureau of Maritime Casualty Investigation recommends that the Federal Ministry of Transport and Digital Infrastructure call on the committees of the International Maritime Organization to amend the regulations of the IMDG Code in order to prevent the ignition of charcoal that is not classified as class 4.2 dangerous goods, during the sea voyage.

6.2 Federal Ministry of Transport and Digital Infrastructure

The Federal Bureau of Maritime Casualty Investigation recommends that the Federal Ministry of Transport and Digital Infrastructure call on the committees of the International Maritime Organization to consider stowage requirements that ensure that any type of self-heating substance is always transported on deck with sufficient accessibility.

6.3 Ship owner: Mediterranean Shipping Company

The Federal Bureau of Maritime Casualty Investigation recommends that Mediterranean Shipping Company state in its procedural instructions and guidelines pertaining to cargo that self-heating substances carried in containers should always be transported on deck with sufficient accessibility.

6.4 Ship owner: Orient Overseas Container Line

The Federal Bureau of Maritime Casualty Investigation recommends that Orient Overseas Container Line forward information on cargo to partners within the slot charter agreement even if it does not constitute dangerous goods but poses a heightened risk, such as that of self-heating.

7 SOURCES

- Inquiries of WSP Hamburg into the fire on the MSC KATRINA
- Written statements of the ship's commands of the MSC KATRINA and the LUDWIGSHAFEN EXPRESS and witness testimony from crew members
- Various cargo documents and reports made available by MSC and Hapag-Lloyd
- MSC Instructions for Specific Cargo – Charcoal
- Statement of the ship's command of the MSC SVEVA
- Dr.-Ing. Krause's expert opinion
- IBExU's expert opinion
- Navigational chart of the BSH
- Official weather report of the DWD
- Event log of the CCME pertaining to the fire on the MSC KATRINA
- Situation reports of the CCME
- Mission reports of Cuxhaven Fire Service and Bremerhaven Fire Service
- Report file of VTS Cuxhaven
- Bridge log and mission records of the water pollution control vessel NEUWERK
- Photos:
 - Figures 1 and 3: Dietmar Hasenpusch Photo-Productions
 - Figures 5 and 7-9: BSU
 - Figures 12-17: CCME
 - Figures 18-20, 23 and 24: Hapag-Lloyd

Ref.: 455/15 and 58/16


8 ANNEXES

8.1 Sea waybill for charcoal cargo on the MSC MILA and MSC KATRINA

<p>See website for large version of the reverse Ver página Web para términos y condiciones Смотрите веб-сайт для ознакомления с условиями и положениями 请单击的条款和条件详细网站 www.msc.com</p>													
<p>m SC MEDITERRANEAN SHIPPING COMPANY S.A. 12-14, chemin Rieu, 1208 GENEVA, Switzerland Website : www.msc.com</p>													
<p>SEA WAYBILL No. MSCUJ8812024 NOT NEGOTIABLE</p>													
<p>NO. & SEQUENCE OF SEA WAYBILLS: 00 / ZERO NO. OF RIDER PAGES: 2</p>													
<p>SHIPPER: PT. CITRA PRIMA UTAMA JL. TOMAT NO.35 BANJARBARU, KALIMANTAN SELATAN (70711) INDONESIA TEL/FAX: +62-511-4773843</p>													
<p>CARRIER'S AGENTS ENDORSEMENTS: (Include Agent(s) at POD) SHIPPER'S LOAD, STOWAGE, COUNT AND SEAL FCL/FCL Said to contain, the carrier had no means to verify shipper's representation and the latter to be ultimately responsible for shortages established at destination in case the container is discharged with the same seal as noted on this bill of lading.</p>													
<p>CONSIGNEE: [REDACTED], FRANCE</p>													
<p>NOTIFY PARTIES: (No responsibility shall attach to the Carrier or to his Agent for failure to notify - see Clause 20) [REDACTED], FRANCE</p>													
<p>VESSEL & VOYAGE NO. (see Clauses 8 & 9) MSC MILA 3 HC541R</p>													
<p>PORT OF LOADING SURABAYA, INDONESIA</p>													
<p>PLACE OF RECEIPT: (Combined Transport ONLY - see Clauses 1 & 5.2) XXXXXXXXXX</p>													
<p>BOOKING REF. (or) SHIPPER'S REF. 460T37GM9IK 411IN1508278</p>													
<p>PORT OF DISCHARGE LE HAVRE, FRANCE</p>													
<p>PLACE OF DELIVERY: (Combined Transport ONLY - see Clauses 1 & 5.2) XXXXXXXXXX</p>													
<p>PARTICULARS FURNISHED BY THE SHIPPER - NOT CHECKED BY CARRIER - CARRIER NOT RESPONSIBLE (see Clause 14)</p>													
<table border="1"> <thead> <tr> <th>Container Numbers, Seal Numbers and Marks</th> <th>Description of Packages and Goods (Continued on attached Sea Waybill Rider page(s), if applicable)</th> <th>Gross Cargo Weight</th> <th>Measurement</th> </tr> </thead> <tbody> <tr> <td>7</td> <td>40'HC CONTAINER see attached rider page(s)</td> <td>IN KG</td> <td>IN CBM</td> </tr> <tr> <td>TOTAL:</td> <td>7 + Total Tare</td> <td>181511,0 27360,0</td> <td></td> </tr> </tbody> </table>		Container Numbers, Seal Numbers and Marks	Description of Packages and Goods (Continued on attached Sea Waybill Rider page(s), if applicable)	Gross Cargo Weight	Measurement	7	40'HC CONTAINER see attached rider page(s)	IN KG	IN CBM	TOTAL:	7 + Total Tare	181511,0 27360,0	
Container Numbers, Seal Numbers and Marks	Description of Packages and Goods (Continued on attached Sea Waybill Rider page(s), if applicable)	Gross Cargo Weight	Measurement										
7	40'HC CONTAINER see attached rider page(s)	IN KG	IN CBM										
TOTAL:	7 + Total Tare	181511,0 27360,0											
<p>FREIGHT & CHARGES Cargo shall not be delivered unless Freight & Charges are paid (see Clause 16). FREIGHT PREPAID</p>													
<p>AGENT AT PORT OF DISCHARGE: MSC - Mediterranean Shipping Company France S.A. C.H.C.I. 182 QUAI GEORGE V. CS 41339 76065 LE HAVRE CEDEX FRANCE Phone +33 23 274 6800 Fax +33 23 274 6810 Email msclshavre@mscfr.mscgva.ch</p>													
<p>RECEIVED by the Carrier from the Shipper in apparent good order and condition unless otherwise stated herein the total number or quantity of containers or other packages or units indicated in the box entitled "Carrier's Receipt" for carriage subject to all the terms hereof from the Place of Receipt or the Port of Loading, to the Port of Discharge or Place of Delivery, whichever is applicable. IN ACCEPTING THIS SEA WAYBILL THE SHIPPER EXPRESSLY ACCEPTS AND AGREES TO, ON HIS OWN BEHALF AND ON BEHALF OF THE CONSIGNEE, THE OWNER OF THE GOODS AND THE MERCHANT, AND WARRANTS HE HAS AUTHORITY TO DO SO, ALL THE TERMS AND CONDITIONS WHETHER PRINTED, STAMPED OR OTHERWISE INCORPORATED ON THIS AND ON THE REVERSE SIDE AND THE TERMS AND THE CONDITIONS OF THE CARRIER'S APPLICABLE TARIFF AS IF THEY WERE ALL SIGNED BY THE SHIPPER. Unless instructed otherwise in writing by the Shipper delivery of the Goods will be made only to the Consignee or his authorised representatives. This Sea Waybill is not a document of title to the Goods and delivery will be made, after payment of any outstanding Freight and charges, only on provision of proper proof of identity and of authorisation at the Port of Discharge or Place of Delivery, as appropriate, without the need to produce or surrender a copy of this Sea Waybill. IN WITNESS WHEREOF the Carrier, Master or their Agent has signed this Sea Waybill.</p>													
<p>DECLARED VALUE (only applicable if Ad Valorem Charges paid - see Clause 7.3) XXXXXX CARRIER'S RECEIPT (No. of Cntrs or Pkgs rcvd by Carrier - see Clause 14.1) 7 SIGNED on behalf of the Carrier MSC Mediterranean Shipping Company S.A. MSC Germany S.A. & Co. KG as agent only for MSC MEDITERRANEAN SHIPPING COMPANY S.A., GENEVA</p>													
<p>PLACE AND DATE OF ISSUE NUJK 10.10.2015 SHIPPED ON BOARD DATE 10.10.2015</p>													
<p>Sea Waybill Standard Edition - 02/2015 TERMS CONTINUED ON REVERSE</p>													

Figure 26: Sea waybill for charcoal cargo on the MSC MILA and MSC KATRINA, page 1

See website for large version of the reverse | Ver página Web para términos y condiciones | Смотрите веб-сайт для ознакомления с условиями и положениями | 提单的条款和条件详情请见网站 | www.msc.com

 MEDITERRANEAN SHIPPING COMPANY S.A. 12-14, chemin Rieu, 1208 GENEVA, Switzerland Website : www.msc.com		SEA WAYBILL No. MSCUJ8812024 RIDER PAGE
SCAC Code: MSCU		Page <u>1</u> of <u>2</u>


CONTINUATION OF PARTICULARS FURNISHED BY THE SHIPPER - NOT CHECKED BY CARRIER - CARRIER NOT RESPONSIBLE (see Clause 14)			
Container Numbers, Seal Numbers and Marks	Description of Packages and Goods (Continued on further Sea Waybill Rider page(s), if applicable)	Gross Cargo Weight	Measurement
TGHU8580047 SEAL: FEJ6396467	1 40'HC CONTAINER TARE	IN KG 3870,0	IN CBM
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25925,0	0,0
TGHU8777036 SEAL: FEJ6396468	1 40'HC CONTAINER TARE	3870,0	
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25925,0	0,0
TCNU7950968 SEAL: FEJ6396469	1 40'HC CONTAINER TARE	3900,0	
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25947,0	0,0
MEDU8763531 SEAL: FEJ6396470	1 40'HC CONTAINER TARE	3940,0	
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25924,0	0,0
MEDU8241692 SEAL: FEJ6396727	1 40'HC CONTAINER TARE	3940,0	
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25915,0	0,0
MEDU8935498 SEAL: FEJ6396728	1 40'HC CONTAINER TARE	3940,0	
	1 INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID	25945,0	0,0
FSCU6925558 SEAL: FEJ6396729	1 40'HC CONTAINER TARE	3900,0	

PLACE AND DATE OF ISSUE	SHIPPED ON BOARD DATE	SIGNED ON behalf of the Carrier MSC Mediterranean Shipping Company S.A.
10.10.2015	10.10.2015	MSC Germany S.A. & Co. KG as agent only for MSC MEDITERRANEAN SHIPPING COMPANY S.A., GENEVA

Sea Waybill Standard Edition - 02/2015

Figure 27: Sea waybill for charcoal cargo on the MSC MILA and MSC KATRINA, page 2

See website for large version of the reverse | Ver página Web para términos y condiciones | Смотрите веб-сайт для ознакомления с условиями и положениями | 提单的条款和条件详情请见网站 | www.msc.com

	MEDITERRANEAN SHIPPING COMPANY S.A. 12-14, chemin Rieu, 1208 GENEVA, Switzerland Website : www.msc.com	SEA WAYBILL No. MSCUJ8812024 RIDER PAGE SCAC Code: MSCU Page <u>2</u> of <u>2</u>
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CONTINUATION OF PARTICULARS FURNISHED BY THE SHIPPER - NOT CHECKED BY CARRIER - CARRIER NOT RESPONSIBLE (see Clause 14)


Container Numbers, Seal Numbers and Marks	Description of Packages and Goods <small>(Continued on further Sea Waybill Rider page(s), if applicable)</small>	Gross Cargo Weight	Measurement
1	SAID TO CONTAIN INDUSTRIAL LUMP CHARCOAL G RAIN SIZE : 20 MM - 80 MM TOTAL GROSS WEIGHT : 181.5 11 M. TONS TOTAL NET WEIGH T : 181.336 M. TONS BULK IN CONTAINER FREIGHT PREP AID CARRIER HAS NO LIABILITY OR RESPONSIBILITY WHATSOEVER FOR THERMAL LOSS OR DAMAGE TO THE GOODS BY REASON OF NATURAL VARIATIONS IN ATMOSPHERIC TEMPERATURES DURING THE WINTER PERIOD, AND/OR CAUSED BY INADEQUATE PACKING OF THE GOODS FOR CARRIAGE IN DRY-VAN CONTAINERS AND/OR INHERENT VICE OF THE GOODS, IN SUCH TEMPERATURES.	IN KG 25930,0	IN CBM 0,0

PLACE AND DATE OF ISSUE 10.10.2015	SHIPPED ON BOARD DATE 10.10.2015	SIGNED on behalf of the Carrier MSC Mediterranean Shipping Company S.A. MSC Germany S.A. & Co. KG as agent only for MSC MEDITERRANEAN SHIPPING COMPANY S.A., GENEVA
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Sea Waybill Standard Edition - 02/2015

Figure 28: Sea waybill for charcoal cargo on the MSC MILA and MSC KATRINA, page 3

8.2 Report of analysis for charcoal cargo on the MSC KATRINA



Certificate No. 04343/DOEDAI
Date: September 18, 2015



Issuing Office:
Jl. Jend. A. Yani Km 7,8 No 21A Banjarmasin 70654, Indonesia
Phone/Facs: +62 625113271080/+625113258111
Email: customerbjm@sucofindo.co.id

REPORT OF ANALYSIS

PRINCIPAL : PT. BUANA MULTIGUNA INSPECTION & TESTING
: QQ. PT. CITRA PRIMA UTAMA
ADDRESS : Jl. Tomat No. 35 Banjarbaru, Kalimantan Selatan
SUBJECT : INDUSTRIAL LUMP CHARCOAL
DESCRIPTION OF SAMPLE : Packing : sealed plastic bag with seal number : **000984**, the sample was supplied by The Principal.1 (one) sample was received on September 2, 2015
DATE OF ANALYSIS : September 2, 2015
SAMPLE MARK : CPU - CHARCOAL
YOUR REFERENCES : SAMPLING BMI 044384

ANALYSIS RESULTS :

Sample Weight	: 35.85	kgs
Top Size	: 75	mm

PARAMETER TEST	RESULT	STANDARD METHOD
SELF HEATING TEST	Passed	Oven 140°C for 24 hours

Method of Test : The self-heating substances test was performed according to United Nations "Recommendation on the Transport Dangerous Goods, Manual of Test and Criteria" (33.3.1.3.3) Self-heating substances, using method on UN 33.3.1.6 "Test N.4 : Test method for self-heating substance"


PARAMETER TEST	RESULT	STANDARD METHOD
MOISTURE (ADB)	3.8 %	ASTM D-1762-84 ITEM 7
ASH CONTEN (ADB)	0.5 %	ASTM D-1762-84 ITEM 7
VOLATILE MATTER (ADB)	13.8 %	ASTM D-1762-84 ITEM 7
FIXED CARBON (ADB)	85.7 %	ASTM D-1762-84 ITEM 7

SIZE ANALYSIS :

+150 MM	0.0 %	ISO 728-1995
20 – 150 MM	96.4 %	ISO 728-1995
10 – 20 MM	1.8 %	ISO 728-1995
5 – 10 MM	0.7 %	ISO 728-1995
3 – 5 MM	0.3 %	ISO 728-1995
0 – 3 MM	0.8 %	ISO 728-1995

This Certificate/report is issued under our General Terms and Conditions, copy of which is available upon request or may be accessed at www.sucofindo.co.id

BJMB04201502158



2055942

SCI-2007A

Dept. of Commercial & Mineral & Coal Testing

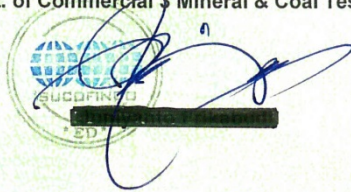



Figure 29: Report of analysis for charcoal cargo on the MSC KATRINA

8.3 Certificate of quantity and quality for charcoal cargo on the MSC KATRINA




PT. BUANA MULTIGUNA INSPECTION & TESTING

In co - operation with
 RITCHIE & BISSET (FAR EAST) Pte, Ltd.
 NIKKAKEN SERVICE Pte, Ltd.

Head Office : Jl. Boulevard Barat Raya, Kav. A3 / 49 Plaza Pasifik Kelapa Gading
 Phone : (021) 45840558 (Hunting) Fax : (021) 45840587 E-mail : buanamulti@jakarta.cline.net.id. JAKARTA 14240, INDONESIA
 Branch Office : Jl. Kembangan Bakti No. 64 Telp. (031) 3545412 Fax : (031) 3545412 E-mail buanasby@sby.dnet.net.id SURABAYA – 60176

No. 044402



Sampling number

CERTIFICATE OF QUANTITY AND QUALITY

CONSIGNMENT : 7 X 40'FT HC CONTAINERS OF INDUSTRIAL LUMP CARCHOAL
 SHIPPER(S) : PT. CITRA PRIMA UTAMA
 JALAN TOMAT NO.35 BANJARBARU
 KALIMANTAN SELATAN INDONESIA

CONSIGNEE : CARBONEX
 LIEUDIT CORDELON
 10250 GYE SUR SEINE, FRANCE

VESSEL : MSC MILA HC541R
 B/L NO. / DATE : MSCUJ8812024, dt. October 10, 2015
 PORT OF LOADING : SURABAYA, INDONESIA
 PORT OF DISCHARGE : LE HAVRE, FRANCE

Interventions : (1) Supervision of Weighing; (2) Sampling and Quality Analysis
 Date and Place of Interventions : October 5 up to October 8, 2015, on Jalan Prapat Kurung, Surabaya
 Type of Packing : In Bulk
 Supervision of Weighing : Weight of the consignment was ascertained by weighing the tare and gross weight the containers over a weigh-bridge with the following result :

Containers No.	Seal Nos.	Gross (Kg)	Tare of Big Bags, Bulk Head (Kg)	Cargo Weight (Kg)
TGHU8580047	FEJ6396467	25925	25	25900
TGHU8777036	FEJ6396468	25925	25	25900
TCNU7950968	FEJ6396469	25947	25	25922
MEDU8763531	FEJ6396470	25924	25	25899
MEDU8241692	FEJ6396727	25915	25	25890
MEDU8935498	FEJ6396728	25945	25	25920
FSCU6925558	FEJ6396729	25930	25	25905
TOTAL WEIGHT		181511		181336

Sampling and Quality Analysis : Samples were drawn by PT.BUANA MULTIGUNA Inspection & Testing, as the Indonesian Independent Surveyor, Analytical and Testing Laboratories. Drawn properly every one hour of each container randomly and prepared in accordance to ISO 2309:1980, representing the 7 x 40'FT HC Full Containers Loaded with the following result of analysis:

Parameter	Results	Method
Fixed Carbon, % (dry basis)	78.93	ASTM D1762-84 (2001)
Ash Content, % (dry basis)	6.48	ASTM D1762-84 (2001)
Volatiles, % (dry basis)	14.59	ASTM D1762-84 (2001)
Moisture Content, % (ADB)	5.30	ASTM D1762-84 (2001)
Size analysis, % (5 mm up to 20 mm)	81.62	ISO728:1995
Size analysis, % (3 mm up to 5 mm)	11.38	ISO728:1995
Size analysis, % (0 mm up to 3 mm)	7.00	ISO728:1995

This Certificate refers to quality and quantity only and does not deal with any other matter. It reflects our findings at time and place of intervention and is issued without prejudice.

Surabaya, October 12, 2015
 SL

PT. BUANA MULTIGUNA
 Inspection & Testing
 Surabaya Branch






Figure 30: Certificate of quantity and quality for charcoal cargo on the MSC KATRINA

8.4 Report of analysis for charcoal cargo on the LUDWIGSHAFEN EXPRESS



Certificate No. 00051/DOEDAJ
 Date: January 6, 2016



Issuing Office:
 Jl. Jend. A. Yani Km 7,8 No 21A Banjarmasin 70654, Indonesia
 Phone/Facs: +62 625113271080/+625113258111
 Email: customerbjm@sucofindo.co.id

REPORT OF ANALYSIS

PRINCIPAL : **PT. CITRA PRIMA UTAMA**
 ADDRESS : Jl. Tomat No. 35 Banjarbaru, Kalimantan Selatan, Indonesia 70711
 SUBJECT : Industrial Lump Charcoal
 DESCRIPTION OF SAMPLE : Packing : Sealed plastic bag with seal number : 000971, the sample was supplied by The Principal.1 (one) sample was received on December 18, 2015
 DATE OF ANALYSIS : December 28, 2015
 SAMPLE MARK : **CPU – CHARCOAL**
 YOUR REFERENCES : Sampling BMI 044432


ANALYSIS RESULTS :

PARAMETER TEST	RESULT	METHOD
SELF HEATING TEST	: Passed	Oven 140 °C for 24 hours


Method of Test : The self-heating substances test was performed according to United Nations *“Recommendations on the Transport Dangerous Goods, Manual of Test and Criteria”* (33.3.1.3.3) Self-heating substances, using method on UN 33.3.1.6 *“Test N.4 : Test method for self-heating substances”*.

This Certificate/report is issued under our General Terms and Conditions, copy of which is available upon request or may be accessed at www.sucofindo.co.id

Dept. of Commercial 3 Mineral & Coal Testing



BJMB04201503172




2155652

SCI-2007A

Figure 31: Report of analysis for charcoal cargo on the LUDWIGSHAFEN EXPRESS

8.5 Weathering certificate for charcoal cargo on the LUDWIGSHAFEN EXPRESS



PT. CITRA PRIMA UTAMA

Office : Jalan Tomat No.35 Banjarbaru, Kalimantan Selatan

Tel/Fax: +62-511-4773843

Branch : Jalan Kalimas Baru No.29 Blok D-9, Surabaya. Tel.+62-31-3286609

WEATHERING CERTIFICATE

INDUSTRIAL LUMP CHARCOAL

We certify Weathering Report of Industrial Lump Charcoal produced by PT. Citra Prima Utama:

Name and Description of the Product:

Name of Goods : INDUSTRIAL LUMP CHARCOAL

Specifications : Basis Certificate of Quality issued by the independent surveyor.

- o General size: 5 mm Top 200 mm
- o Moisture Content, max 8.00% (as received)
- o Fixed Carbon, min 80.00% (dry basis)
- o Volatile Matter, max 19.00% (dry basis)
- o Ash Content, max 1.00% (dry basis)

Manufacturing Process:

1. Raw material
 - o The most environmental friendly, 100% of raw material are legally picked from waste of timber cutting in South Kali-mantan by having a special license from Forest Department, Rep. of Indonesia.
2. Production
 - o The charcoal made by Clay Kilns and Brick Kilns.
 - o The raw material woods are firstly debarked, all woods should be free of barks, then dried under sunshine for 25 to 30 days.
 - o Carbonizing process in 21 days with the following stages:
 - 15 days process converting wood into charcoal.
 - ~ Drying woods in the kilns at 0-270°C.
 - ~ Raising the temperature in the kilns to 270°C to start spontaneous pyrolysis.
 - ~ Final heating to around 550-600°C to drive off tar and increase the fixed carbon to an acceptable figure.
 - 6 days cooling.
 - o The charcoal in well packed in polypropylene (pp) bags soon after discharged from the kilns.
 - o The charcoal are stored for at least 3 days in production area before they are transported to our warehouse & processing unit.

Storage and Processing:

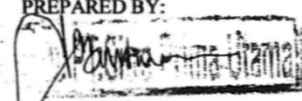
1. After 3 days stored in the production area, the charcoal are transported to warehouse & processing unit of PT. Citra Prima Utama in Banjarbaru, +/- 150 km far away from the area.
2. At the processing unit, the charcoal are treated for sizing, screening, and packaging, then stored within 14 – 30 days in our warehouses in Banjarbaru, South Kalimantan.

Loading into Container:

- o After 14 – 30 days processed and stored in warehouse, the charcoal are loaded into containers on whether into local containers or export containers.
- o Total days after production to container loading in between 17 – 33 days.
- o We check the charcoal temperature to ensure the charcoal in safe condition for transportation before they are loaded in to container(s).

BANJARBARU, 7 January 2016

PREPARED BY:



PT. CITRA PRIMA UTAMA

Figure 32: Weathering certificate for charcoal cargo on the LUDWIGSHAFEN EXPRESS

8.6 Material safety data sheet for charcoal cargo on the LUDWIGSHAFEN EXPRESS


	PT. CITRA PRIMA UTAMA	1
MATERIAL SAFETY DATA SHEET		
DATE REVISED : 7 January 2016 ISSUED BY : PT. CITRA PRIMA UTAMA		
1. Trade Name and Supplier		
<ul style="list-style-type: none"> • Trade Name : INDUSTRIAL LUMP CHARCOAL • Indonesian Name : ARANG • Product Type : Industrial Lump Charcoal produced in kiln or retort (0-150 mm) • Supplier : PT. CITRA PRIMA UTAMA • Address : <u>Head Office:</u> Jalan Tomat No.35 Banjarbaru, Kalimantan Selatan, Indonesia 70711, Tel/Fax. +62-511-4773843, <u>Representative & Warehousing Office:</u> Jalan Kalimas Baru No.29 Blok D-9, Surabaya, Indonesia Tel/Fax.+62-31-3286609 		
2. Chemical Composition – Hazardous Ingredient		
<i>Composition:</i>		
<ul style="list-style-type: none"> • Moisture : 4.0% - 7.0 % as received ASTM D1762-84 • Ash : 0.5% - 3.0 % dry basis ASTM D1762-84 • Volatile Matters : 10.0% - 20.0% dry basis ASTM D1762-84 • Fix Carbon : 75.0% - 90.0% dry basis ASTM D1762-84 		
3. Hazards Identification		
<ul style="list-style-type: none"> • Industrial Lump Charcoal must never be contaminated with oil. Under some circumstances Industrial Lump Charcoal contaminated with oil may cause self-heating. 		
4. First Aid Measures		
<ul style="list-style-type: none"> • Eye Contact : Flush with water. • Skin Contact : Flush with water. • Inhalation : With the reference to section 3, lack of oxygen may occur during fire. Personnel must be removed to fresh air as fast as possible. Loosen all tight cloths and if breathing stopped, give artificial respiration. If breathing is difficult. Give oxygen, Call physician. • Ingestion : - 		
5. Fire Extinguishing Media		
<ul style="list-style-type: none"> ▪ Water 		
6. Fire Fighting Procedure		
<ul style="list-style-type: none"> • If the material is inside silo/warehouse during fire, use “front-loader” and/or crane equipped with grab to remove the burning Industrial Lump Charcoal. Remove the cargo to an area where water is available. Be sure to kill the fire in each batch of Industrial Lump Charcoal before next batch is placed together with the previous one. If the storage of Industrial Lump Charcoal is not in open air the content of carbon monoxide in the air has to be controlled continuously as long as there may exist any risks of fire. • People in the area nearby and/or people involved in the fire extinguishing have to wear artificial aid all the time as long as they may be exposed to high content of CO₂-gas. • <i>Note:</i> CO₂-gas is not visible and does not smell and could be extremely poisoned if the content in the air is too high. 		

Figure 33: Material safety data sheet for charcoal cargo on the LUDWIGSHAFEN EXPRESS, page 1



	PT. CITRA PRIMA UTAMA	2
<p><i>Fire and explosion risk:</i></p> <ul style="list-style-type: none"> ○ Be careful with open fire/smoking, welding etc. near by Industrial Lump Charcoal as it is easy to ignite. Self heating of lump Charcoal has been reported. Risk of self heating may be increased especially in Industrial Lump Charcoal with high moisture content were raising temperature may be started by "oxidation". In turn the oxidation may accelerate the oxidation-process in a pile of Industrial Lump Charcoal up to self-heating temperature. 		
7. Spill or Leak Procedures		
<ul style="list-style-type: none"> ● Steps to be taken in case material is released or spilled: No special steps to be taken other than to take care of the esthetics. ● Always secure the Industrial Lump Charcoal is kept well away from open fire, glows/sparks or other high-temperature areas, keep away from oil as mentioned in this safety data sheet. 		
8. Precautions to be taken in storage & handling		
<ul style="list-style-type: none"> ● Keep away from heat, spark, open flame and other sources of ignition. ● Keep away from oil. Under some circumstances Industrial Lump Charcoal mixed with oil may cause a self-heating process to start. ● Also refer section 5 in the MSDS 		
9. Exposure Controls/Personal Protection		
<ul style="list-style-type: none"> ● Preventive Actions to be taken <ul style="list-style-type: none"> ○ <u>Respiratory protections</u>: Dust-preventing mask under normal conditions. For emergency and other conditions where there is a risk of fire in the Industrial Lump Charcoal, always use an approved positive pressure self contained breathing apparatus. ○ <u>Eye protections</u>: During handling or working with dry Industrial Lump Charcoal use protecting goggles. ○ <u>Protective gloves</u>: YES 		
10. Physical & Chemical Properties		
<ul style="list-style-type: none"> ● Color : Black. ● Smell : No smell or odor like and old fireplace. ● Solvability : Not solvable in water. 		
11. Stability & Reactivity		
<ul style="list-style-type: none"> ● Chemical Stability : Stable. ● Reacts with : Oxidizing materials. ● Hazardous Decomposition Products: <ul style="list-style-type: none"> ○ During heating or combustion especially with sufficient quantity of aid this product gives out CO and CO₂, as well as condensed, tar from volatile compositions. ○ During transport of wet Industrial Lump Charcoal in bulk/and or during storing in silo a risk of an initial self-heating process may exist. This process may cause CO₂ or CO to be given and gases will cause the ordinary air to leave or turn into a poison mixture, extremely dangerous to breathe in. ● Hazardous Polymerization: Will Not Occur. 		
12. Toxicological Information		
<ul style="list-style-type: none"> ● Eyes : Contact with the solid or dust will be irritating to the eyes. ● Skin : None. ● Inhalation : None ● Carcinogenicity : Not considered to be a carcinogen. ● Mutagenicity : None. 		

Figure 34: Material safety data sheet for charcoal cargo on the LUDWIGSHAFEN EXPRESS, page 2



PT. CITRA PRIMA UTAMA

3

- Reproductive Effects : None identified.

13. Ecological

- Eventual spill of Industrial Lump Charcoal into the environment does only have an esthetic influence, but the Industrial Lump Charcoal should be removed and the area should be cleaned by water.

14. Disposal Considerations

- Leftovers or garbage from not contaminated Industrial Lump Charcoal may be burned or delivered to a suitable deposit place for non-toxic garbage. Industrial Lump Charcoal may be stored for an unlimited time without any influence on its quality as long as the storing conditions are dry, clean and safe.

15. Transport Information

- Shipping Name : INDUSTRIAL LUMP CHARCOAL
- IMO : NOT CLASSIFIED in IMO CLASS 4.2.
As long as to be proven by Certificate of Analysis for Self-Heating Test for Industrial Lump Charcoal in accordance with the test method given in the United Nations, Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria.
- Division : GENERAL CARGO
- IATA / ICAO : Not regulated
- IMO / IMDG : Not regulated

16. Regulatory Information

- Prior to loading, the manufacturer or shipper should give the master a certificate stating that the cargo is not class 4.2 based on tests carried out in accordance with Appendix D.6. For Industrial lump Charcoal screenings it should also be stated that the prescribed weathering period has been observed.
- Industrial Lump Charcoal screenings should be exposed to the weather for not less than 13 days prior to shipment.
- Hot Industrial Lump Charcoal screenings in excess of 55 o C should not be loaded.
- The moisture content of Industrial Lump Charcoal screenings should not be more than 10%.


17. Other Information

REFERENCE

- SUCOFINDO, Indonesia, Report of Analysis, "Self-Heating Test", No. 32091/DBBPAH, date September 18, 2015.

SUPPLIER REMARKS:

Information on this form is furnished solely for the purpose of compliance with the Occupational Safety and Health Act and shall not be used for any other purpose. PT. Citra Prima Utama urges the customers receiving this Material Safety Data Sheet to study it carefully to become aware of the hazards, if any, of the product involved. In the interest of safety you should notify your employees, agents and contractors of the information on this sheet.



PREPARED BY: XXXXXXXXXX
PT. CITRA PRIMA UTAMA

Figure 35: Material safety data sheet for charcoal cargo on the LUDWIGSHAFEN EXPRESS, page 3

8.7 Producing process certificate industrial lump charcoal for charcoal cargo on the LUDWIGSHAFEN EXPRESS


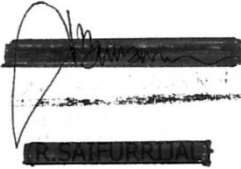

 PT. CITRA PRIMA UTAMA Office : Jalan Tomat No.35 Banjarbaru, Kalimantan Selatan Tel/Fax: +62-511-4773843 Branch : Jalan Kalimas Baru No.29 Blok D-9, Surabaya. Tel.+62-31-3286609	
<u>PRODUCING PROCESS CERTIFICATE INDUSTRIAL LUMP CHARCOAL</u>	
Booking no	: 2569139080
Commodity	: Industrial lump charcoal
Feeder	: WARNOW CHIEF 304W
Stored location	: Warehouse Pergudangan Suri Mulya jl margomulyo 44 blok CC1, Surabaya, East Java. Indonesia
Port of Loading	: SURABAYA
Port of Destination	: LE HAVRE
Specifications	
Surveyor	: Basis Certificate of Quality issued by the independent <ul style="list-style-type: none"> • General Size 50mm-100mm • Moisture 4.0%- 7.0 % ASTM D-1762-84 ITEM7 • AS CONTEN 0.5% -3.0%ASTM D-1762-84 ITEM7 • VOLATILE MATTER 5.0%-10.0 % ASTM D-1762-84 ITEM7 • FIXED CARBON 85.0 % - 90.0%ASTM D-1762-84 ITEM7
<p>We hereby advice that our industrial lump charcoal have gone through the following process before we deliver to the port.</p> <p>Factory Location: BANJARMASIN.</p> <p>a. Date of production/batch : Oktober 26th, 2015</p> <p>b. Date of packaging : January 7th, 2016</p> <p>I hereby certify that this booking satisfies the step-by-step procedure set out in the applicable stored Procedure of Industrail lump charcoal, including checks of the parties and cargo.</p> <p>Surabaya, January 13th, 2016</p> <div style="text-align: center;">  </div>	

Figure 36: Producing process certificate industrial lump charcoal

8.8 Vanning survey report for charcoal cargo on the LUDWIGSHAFEN EXPRESS



PT. BUANA MULTIGUNA INSPECTION & TESTING
 In co - operation with
 RITCHIE & BISSET (FAR EAST) Pte, Ltd.
 NIKKAKEN SERVICE Pte, Ltd.

Head Office : Jl. Boulevard Barat Raya, Kav. A3 / 49 Plaza Pasifik Kelapa Gading
 Phone : (021) 45840558 (Hunting) Fax : (021) 45840587 E-mail : buanamulti@jakarta.cline.net.id JAKARTA 14240, INDONESIA
 Branch Office : Jl. Kalimas Barat 2 No. 4 Phone/Fax. (031) 3545412 E-mail : buanasby@sby.dnet.net.id SURABAYA - 60163

VANNING SURVEY REPORT

THIS IS TO REPORT THAT, upon request of PT.CITRA PRIMA UTAMA, we have drawn representative sample of the consignment of INDUSTRIAL LUMP CHARCOAL for self-test and conducting a vanning survey report during cargo stuffing into container(s) and would report as follow:

SHIPPER : PT. CITRA PRIMA UTAMA
 JL.TOMAT NO.35 BANJAR BARU
 KALIMANTAN SELATAN INDONESIA 70711

CONSIGNEE : CARBONEX LIEUDIT CORDELON
 10250 GYE SUR SEINE, FRANCE

DESCRIPTION OF GOOD : 15 X 40' of INDUSTRIAL LUMP CHARCOAL in BULK
 WEIGHT : NETT: 379,686 GROSS: 380,061

VESSEL : WARNOW CHIEF Voy. 304W
 LOADING REPORT : SURABAYA PORT INDONESIA
 DESTINATION : LE HAVRE, FRANCE
 CONTAINER : OOLU9778510/OOLCYK5805, OOLU8222130/OOLCYK5872,
 OOLU8068853/OOLCYK5810, OOLU9854918/OOLCYK5801,
 OOLU8728319/OOLCYK5802, OOLU8241948/OOLCYK5803,
 OOLU8667893/OOLCYK5804, OOLU8328204/OOLCYK9281,
 OOLU8125254/OOLCYK5808, OOLU8252921/OOLCYK5879,
 OOLU8493908/OOLCYK5807, OOLU8221767/OOLCYK5809,
 OOLU8132340/OOLCYK5880, OOLU8091426/OOLCYK5806,
 OOLU9426000/OOLCYK5871.

BOOKING NO. : 2569139080

RESULT OF SELF HEATING TEST

COMMODITY	SPECIFICATION	RESULT
INDUSTRIAL LUMP CHARCOAL	SPONTANEOUS COMBUSTIBLES @140 DEG C FOR 12 HOUR	PASSED
	MOISTURE CONTENT (%WT) @110 DEG C FOR 1 HOUR	8,36%

BASED ON THE ABOVE ANALYSIS RESULT TESTED IN OUR ANALYTICAL LABORATORY, WE HEREBY CONFIRM THAT SAMPLES DRAWN PASSED THE TEST.

Figure 37: Vanning survey report for charcoal cargo on the LUDWIGSHAFEN EXPRESS, page 1



 <p>PT. BUANA MULTIGUNA INSPECTION & TESTING In co - operation with RITCHIE & BISSET (FAR EAST) Pte, Ltd. NIKKAKEN SERVICE Pte, Ltd. Head Office : Jl. Boulevard Barat Raya, Kav. A3 / 49 Plaza Pasifik Kelapa Gading Phone : (021) 45840558 (Hunting) Fax : (021) 45840587 E-mail : buanamulti@jakarta.cline.net.id JAKARTA 14240, INDONESIA Branch Office : Jl. Kalimas Barat 2 No. 4 Phone/Fax. (031) 3545412 E-mail : buanasby@sby.dnet.net.id SURABAYA - 60163</p>
<p>FINDINGS GENERAL CONDITION:</p> <ol style="list-style-type: none">1. -CONTAINER: BEFORE VANNING STARTED WE CARRIED OUT VISUAL INSPECTION AND WE FOUND THE CONTAINER WAS CLEAN DRY AND NO ODOUR FREE FROM SUCH CONTAMINANT -DOORSHEET WAS FOUND IN GOOD CONDITION AND GOOD ORDER PROPERLY -ROOF AND FLOOR WAS FOUND NOT ANY LEAKAGE -THE CONTAINER WAS GENERALLY GOOD CONDITION FOR LONG TRANSPORTATION2. CARGO WAS STUFFIED INTO THE CONTAINER IN BULK3. AT THE COMPLAITION OF STUFFING THE CARGO WAS SUPPORTED BY BAMBOO FENCE4. AFTER STUFFING COMPLETED CONTAINER WAS CLOSED TIGHTLY AND SEALED BY SHIPPING LINE
<p>THIS CERTIFICATE REFERS TO SAMPLING ONLY AND DOES NOT DEAL WITH ANY OTHER MATTER. IT IS ISSUED WITHOUT PREJUDICE.</p>
<p>Surabaya, 25 Januari 2016</p>
<p>PT BUANA MULTIGUNA Inspection & Testing Surabaya Branch</p> 

Figure 38: Vanning survey report for charcoal cargo on the LUDWIGSHAFEN EXPRESS, page 2

8.9 Sertifikat Akreditasi for SUCOFINDO



SERTIFIKAT AKREDITASI

LP-242-IDN

Ditetapkan tanggal : 26 November 2014 Berlaku hingga: 25 November 2018

Diberikan kepada

LABORATORIUM CABANG BANJARMASIN PT SUCOFINDO (PERSERO)

di

Jl. Ahmad Yani Km. 7,8 No.21, Banjarmasin, Kalimantan Selatan 70654

yang telah menunjukkan kompetensinya sebagai

LABORATORIUM PENGUJI

dengan menerapkan secara konsisten

SNI ISO/IEC 17025:2008 (ISO/IEC 17025:2005)

Persyaratan Umum Untuk Kompetensi Laboratorium Pengujian dan Laboratorium Kalibrasi

untuk ruang lingkup seperti dalam lampiran

KOMITE AKREDITASI NASIONAL

KETUA

Sertifikat ini memberikan hak kepada laboratorium untuk menggunakan tanda akreditasi pada sertifikat laporan yang diterbitkan oleh laboratorium. Untuk tujuan promosi, sertifikat ini tidak boleh diproduksi sebagian, kecuali secara keseluruhan, tanpa izin tertulis dari Komite Akreditasi Nasional.

Figure 39: Sertifikat Akreditasi for SUCOFINDO

8.10 Classification of self-heating substances according to the IMDG Code

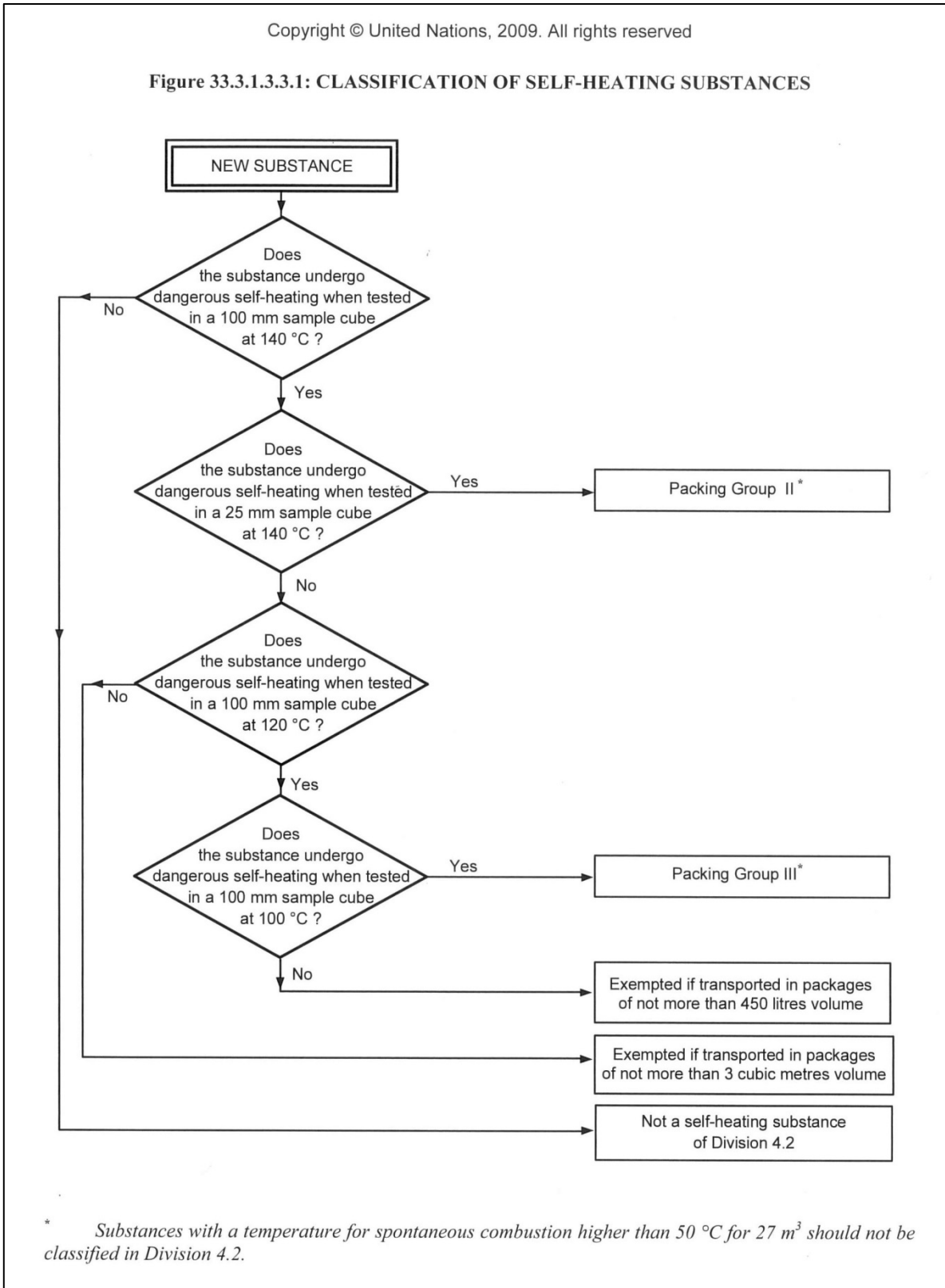
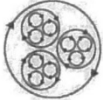


Figure 40: Schema of the IMDG Code for classification of self-heating substances

8.11 Thermal properties of the charcoal on the MSC KATRINA

<p>Dr. Krause GmbH : Safety Testing Laboratory Potsdam</p>	<p>Page 1</p>	
<p>Thermo-physical Properties CHARCOAL KATRINA</p>		
<p>No. : BSU_001</p>		
<p>1. Company</p>		
Employer :	Bundesstelle für Seeunfalluntersuchung	
Department :		
Order number :	455 / 15	
Name :	[REDACTED]	
Street :	Bernhard-Nocht-Str.	
House no. :	78	
City :	20359 Hamburg	
Tel :	040 3190-0	
Fax :	040 3190 8340	
e-mail :	[REDACTED]	
<p>2. Material</p>		
Identifier / Trade name :	Charcoal	
Delivery date :	12. 02. 2016	
Delivery quantity :	≈ 10 kg	
As-received condition :	dry, no hot spots, grain size 20 – 80 mm	
Chemical compound :	unknown	
Toxicity :	none	
Class of dangerous goods :	not classified by the shipper	
Colour :	black	
Smell :	none	

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Figure 41: Thermal properties of the charcoal, page 1

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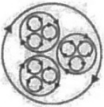
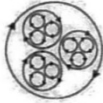
Dr. Krause GmbH : Safety Testing Laboratory Potsdam		Page 2																													
3. Experiments																															
Editor :	Dipl. Phys. K. Zielke																														
3.1 Heat capacity																															
Container :	Dewar-container by KGW Isotherm, FB 0 CAL																														
Original sample mass :	15.4		[g]																												
Reference liquid :	Water																														
Mass of the reference liquid :	32.0		[g]																												
Spec. heat capacity of the reference liquid :	4.182		[J/(g*K)]																												
Heat capacity of the pure calorimeter C_K :	119.		[J/K]																												
Start temperature liquid :	47.9		[°C]																												
Start temperature sample :	16.3		[°C]																												
Temperature of equilibrium :	44.4		[°C]																												
Start date of the experiments :	21.03.2016																														
End date of the experiments :	21.03.2016																														
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Measurement</th> <th style="text-align: center;">Spec. Heat Capacity [J / (kg K)]</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">No. 1</td><td style="text-align: center;">1357.</td></tr> <tr><td style="text-align: center;">No. 2</td><td style="text-align: center;">1194.</td></tr> <tr><td style="text-align: center;">No. 3</td><td style="text-align: center;">1293.</td></tr> <tr><td style="text-align: center;">No. 4</td><td style="text-align: center;">1380.</td></tr> <tr><td style="text-align: center;">No. 5</td><td style="text-align: center;">1332.</td></tr> <tr><td style="text-align: center;">No. 6</td><td style="text-align: center;">1314.</td></tr> <tr><td style="text-align: center;">No. 7</td><td style="text-align: center;">1409</td></tr> <tr><td style="text-align: center;">No. 8</td><td style="text-align: center;">1237</td></tr> <tr><td style="text-align: center;">No. 9</td><td style="text-align: center;">1188</td></tr> <tr><td style="text-align: center;">No. 10</td><td style="text-align: center;">1220</td></tr> <tr><td style="text-align: center;">No. 11</td><td style="text-align: center;">1225</td></tr> <tr><td style="text-align: center;">No. 12</td><td style="text-align: center;">1320</td></tr> <tr><td style="text-align: center;">No. 13</td><td style="text-align: center;">1308</td></tr> </tbody> </table>			Measurement	Spec. Heat Capacity [J / (kg K)]	No. 1	1357.	No. 2	1194.	No. 3	1293.	No. 4	1380.	No. 5	1332.	No. 6	1314.	No. 7	1409	No. 8	1237	No. 9	1188	No. 10	1220	No. 11	1225	No. 12	1320	No. 13	1308
Measurement	Spec. Heat Capacity [J / (kg K)]																														
No. 1	1357.																														
No. 2	1194.																														
No. 3	1293.																														
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No. 6	1314.																														
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No. 9	1188																														
No. 10	1220																														
No. 11	1225																														
No. 12	1320																														
No. 13	1308																														
Comments :																															
Mean spec. heat capacity of the sample :	1293.		[J/(kg*K)]																												

Figure 42: Thermal properties of the charcoal, page 2

Dr. Krause GmbH : Safety Testing Laboratory Potsdam
Page 3


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3.2 Thermal diffusivity

Container : steel wire cube

Volume of sample : 0.027 [1]

Material preparation : no

Kind of heat storage : isoperibolic

End temperature of the oven : 100° [°C]

Start temperature of sample : 13° [°C]

Half time : 459 [s]

Date of the experiment : 14.03.2016

Thermal diffusivity : 1.9 E-7 [m² / s]

3.3 Density :

Volume of sample : 0.050 [1]

Measurement	Weight [g]
No. 1	32.0
No. 2	33.0
No. 3	31.1
No. 4	33.2
No. 5	34.7

Volume of sample : 0.100 [1]

Measurement	Weight [g]
No. 6	67.5
No. 7	65.9
No. 8	68.4
No. 9	69.4
No. 10	70.0

Figure 43: Thermal properties of the charcoal, page 3

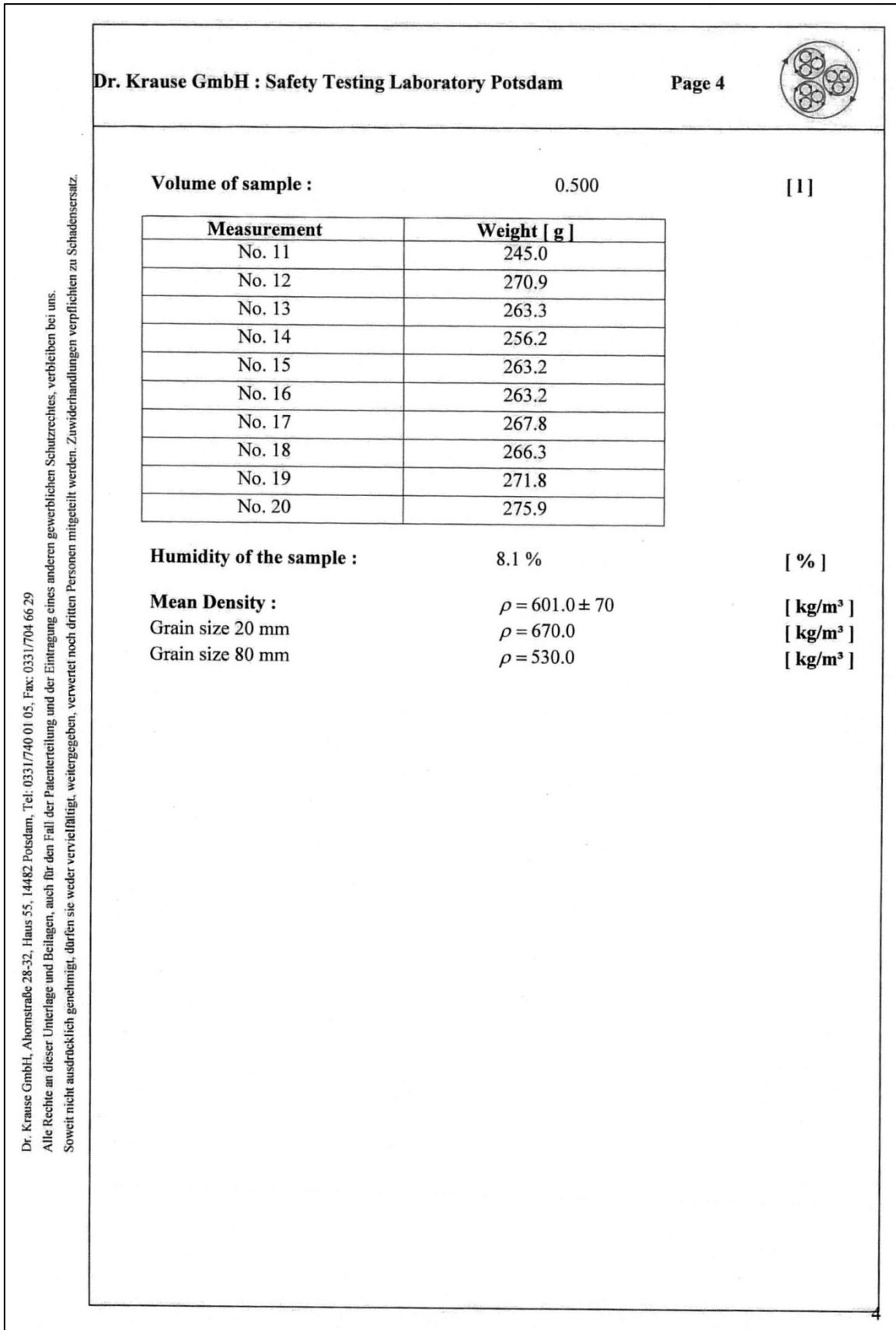
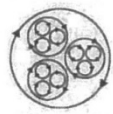
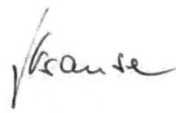


Figure 44: Thermal properties of the charcoal, page 4

Dr. Krause GmbH : Safety Testing Laboratory Potsdam	Page 5																							
<p>Summary of the experiments</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Spec. heat capacity of the sample :</td> <td style="width: 20%; text-align: center;">1293.</td> <td style="width: 30%; text-align: right;">[J / (kg*K)]</td> </tr> <tr> <td>Density of the sample :</td> <td style="text-align: center;">601. ± 70</td> <td style="text-align: right;">[kg / m³]</td> </tr> <tr> <td>Thermal diffusivity sample :</td> <td style="text-align: center;">1.9 E-7</td> <td style="text-align: right;">[m²/s]</td> </tr> <tr> <td>Thermal conductivity sample :</td> <td style="text-align: center;">0.15</td> <td style="text-align: right;">[W/(m*K)]</td> </tr> </table> <p>4. Summary</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Project number :</td> <td style="width: 50%;">GK_BSU001</td> </tr> <tr> <td>Author :</td> <td>Dr. Krause</td> </tr> <tr> <td>Number of pictures / graphs :</td> <td style="text-align: center;">0</td> </tr> <tr> <td>Number of pages of this document :</td> <td style="text-align: center;">5</td> </tr> <tr> <td>Notes :</td> <td style="text-align: center;">None</td> </tr> </table> <p>Declaration : All measurements refer only to the material which has been received in section 2.</p> <p>Date : 29 / 03 / 2016 Potsdam</p> <p>Signature : </p> <p style="text-align: center;">Dr. Krause GmbH Ahornstr. 28-32 Haus 55 14482 Potsdam</p>			Spec. heat capacity of the sample :	1293.	[J / (kg*K)]	Density of the sample :	601. ± 70	[kg / m ³]	Thermal diffusivity sample :	1.9 E-7	[m ² /s]	Thermal conductivity sample :	0.15	[W/(m*K)]	Project number :	GK_BSU001	Author :	Dr. Krause	Number of pictures / graphs :	0	Number of pages of this document :	5	Notes :	None
Spec. heat capacity of the sample :	1293.	[J / (kg*K)]																						
Density of the sample :	601. ± 70	[kg / m ³]																						
Thermal diffusivity sample :	1.9 E-7	[m ² /s]																						
Thermal conductivity sample :	0.15	[W/(m*K)]																						
Project number :	GK_BSU001																							
Author :	Dr. Krause																							
Number of pictures / graphs :	0																							
Number of pages of this document :	5																							
Notes :	None																							

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Figure 45: Thermal properties of the charcoal, page 5

8.12 Dr.-Ing. Krause's expert opinion

The expert opinion of Dr.-Ing. Krause prepared in connection with this investigation is available to download on the website of the BSU.