DUTCH
SAFETY BOARD

Flare launched with fatal consequences

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The Hague, 25 September 2024

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The Dutch Safety Board

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N.B.: This report has been published in the Dutch and English language. If there are differences in interpretation the Dutch report prevails.

CONTENTS

1 INTRODUCTION

1.1 Background

In the night of 31 December 2022 to 1 January 2023, a Dutch flagged sailing ship was sailing on the Pacific Ocean. When launching a flare to celebrate the New Year, the flare did not launch as expected but instead exploded almost directly in the hand of the crew member. First aid was administered but proved ineffective; the victim died of internal injuries suffered as a result of the impact of the explosion.

1.2 Investigation decision

The vessel in question is a Dutch registered and flagged sailing yacht. The occurrence does not come under the obligation to conduct an investigation.
In view of the fact that the incident was caused by a flare, a compulsory safety item carried by every seagoing vessel, the decision was taken to investigate this occurrence.

1.3 Objective and investigation questions

Based on this investigation, the Dutch Safety Board aims to draw, where possible, lessons from the occurrence, thereby preventing a repetition. This will be done by establishing how this occurrence could have taken place. In doing so, the investigation will consider the method of use, the production and the possible differences between the procedures for the production of the flare and the working methods used. The investigation will focus on the following questions:

1. Did the pyrotechnic safety equipment on board the vessel meet the applicable requirements and was the flare launched correctly?
2. What was the possible failure mechanism that caused the flare to explode?
3. Was the failure of the flare the result of a possible non-conformity in the production process?
4. What lessons can be drawn from this?

1.4 Investigation approach

The occurrence was reported to the Dutch Safety Board the following morning. The Dutch Safety Board launched an preliminary investigation immediately after notification.

Prior to the occurrence on 1 January 2023, there were no recent reports known concerning serious incidents involving the use of this type of safety equipment. This fact prompted the Dutch Safety Board to seek contact with the manufacturer with the help of its Spanish sister organisation CIAIM[1]. The latter was not aware of the occurrence and, following notification, an investigation was launched at the manufacturer in Spain, with the cooperation of the manufacturer.[2]

During the investigation, information was also obtained from the Dutch Public Prosecution Service and the National Police Unit.

1.5 Demarcation

The investigation by the Dutch Safety Board is focused on the failure of the flare on board the sailing vessel. Because the Dutch Safety Board does not have an obligation to launch an investigation, it has no authority abroad to demand information or cooperation.

1 Comisión Permanente de Investigación de Accidentes e Incidentes Marítimos

2 During the investigation, a serious occurrence in the United Kingdom came to light, in which the person setting off a hand-held signal (smoke signal) was seriously injured as a result of a physical explosion that similarly occurred almost directly afterwards. This incident involved a different product of a different make than the flare that is the subject of this investigation.

2 COURSE OF EVENTS AND BACKGROUND INFORMATION

2.1 The occurrence

In the night of 31 December to 1 January 2023, a Dutch flagged sailing vessel was sailing on the Pacific Ocean, approximately 1700 nautical miles south-west of the Galapagos islands. The owner and also skipper (hereinafter: skipper) of the vessel was undertaking one leg of a round-the-world voyage from Curacao via Cuba and the Galapagos Islands to Tahiti. Besides the skipper, there were a further three crew members on board: the skipper's travel companion and two students.

As the New Year was approaching, they discussed whether the occasion should be marked by setting off a flare (see block below) in lieu of fireworks.

Flare
A flare is a light-emitting projectile that can be launched from the hand and is intended to be used as an emergency distress signal. Emergency situations include a sinking ship and rescue operations from lifeboats or other locations where persons are in distress or difficulties. A flare is an item of safety equipment used worldwide that – when it complies with the requirements and is used in accordance with the instructions – should always work reliably.

The skipper has been the owner of the sailing vessel named Bontekoning since May 2021. The sailing vessel is registered in the Dutch Registry of Shipping, making it officially Dutch flagged. Following the purchase of the vessel, the skipper had a complete refurbishment carried out in Alicante (Spain), under the supervision of a Dutch company. Alongside major maintenance, the sails and masts were replaced, and redundancy[3] added to various systems. At the same time, the safety equipment on board was replaced, including the package of pyrotechnic equipment containing light and smoke signals. The replacement package included the flare involved in the occurrence.

3 Various systems are designed in duplicate so that they can replace each other.

Safety training
The skipper of the Bontekoning was trained in Sweden and was qualified to sail as a skipper. Prior to the part of the journey across the Pacific Ocean, the crew in Curacao participated in a safety training where they practiced with all safety equipment. Not only the use of firefighting equipment has been successfully trained, but also operational aspects such as MOB procedure.

The skipper's objective was to sail around the world. As part of this voyage, he also took part in the *Atlantic Rally for Cruisers* (ARC). During the stop at Curaçao, the vessel was again inspected to ensure that it was ready for the next leg of the voyage. This would take it from Curaçao via the Panama Canal and the Galapagos Islands towards Hawaii. In Curaçao, three persons came on board as crew members, the skipper's travel companion and two students. The two students had extensive sailing experience.

The conditions for the two students to sail with the vessel were laid down in an agreement before they came on board. They did so on 28 September 2022.

On New Year's Eve, the topic of where and when to celebrate the New Year given the different time zones was discussed. This prompted the students to ask whether a flare could be launched as an alternative to fireworks. After weighing up the situation, which involved checking for nearby shipping to ensure that there were no vessels located within 50 nautical miles, reading the instructions and checking the expiry date, the skipper agreed that a flare could be launched. Who would launch the flare was decided at random.

Before launching the flare, the later victim removed the two end caps. He then took the flare in one hand, pointed it in an upward direction clear of obstacles and activated the ignition by pulling the cord with his other hand. The flare thereupon exploded virtually immediately, level with his face.

Following the explosion, everyone was completely shocked by what had happened, but they immediately started administering first aid. After the unexpected explosion, the crew made every effort to save the victim using the medical equipment on board and with the help of medical advice from a remote doctor. Their efforts were in vain. At the directions of the remote doctor, medical aid was halted. The victim died after the explosion from internal injuries suffered as a result of the impact of the explosion. It was subsequently found from impact traces on board the vessel that other parts of the flare had narrowly missed other members of the crew.

Repatriation
Following the occurrence and the death of the victim, the body could not remain on board for long in view of the tropical conditions. The nearest port, Nuku Hiva in French Polynesia, was at least eight days sailing away. The skipper was aware that this could lead to an untenable situation.[4] Following the occurrence, the necessary contacts between the skipper and the authorities took place. The Dutch Coastguard identified a cargo ship, BCC Maryland, sailing under the flag of Antigua and Barbuda, located four hours sailing from the Bontekoning, which was willing to take over the body. This ultimately took place under specific conditions following the intervention of the Dutch Safety Board.[5] On 30 January 2023, the body was handed over to the local authorities in Newcastle, Australia and after examination repatriated to the Netherlands.

2.2 Immediate warning after the occurrence

The initial findings during the preliminary investigation prompted doubts as to the reliability of the batch of flares of which the flare in question was part. In coordination with the Spanish manufacturer, the Dutch Safety Board issued a worldwide warning and called on owners of such flares not to use the flares from the production series in question (batch 35-113) and return them to a sales outlet.[6] Following this global recall, some forty flares from batch 113 were returned to the manufacturer. The manufacturer subsequently launched those flares under test conditions without problems. This suggested that there was no generic or standard non-conformity in the manufactured serie.

Prior to the occurrence of 1 January 2023, there were no known recent reports concerning serious incidents involving the normal use of this type of safety equipment. This led the Dutch Safety Board, with the help of its Spanish sister organisation CIAIM[7] and with the cooperation of the manufacturer, to launch an investigation in Spain.[8]

The complexity of this investigation lies in the fact that there was one exploding flare and that no non-conformities have so far come to light in the other flares from the same batch, based on the x-ray photos of the five remaining flares on board in Tahiti and the launching of the returned flares in Spain. Moreover, no other problems were known.

4 Articles 18 to 25. These articles relate to the treatment of the bodies of persons who die at sea on board Dutch vessels.
5 See also appendix A1.
6 See interim warning, appendix: A3.
7 Comisión Permanente de Investigación de Accidentes e Incidentes Marítimos.
8 During the investigation, two more incidents became known: A serious incident in the United Kingdom, where the igniter was seriously injured when a hand trigger signal (smoke signal) was ignited, which immediately resulted in a physical explosion after the ignition. This involved a different product and different manufacturer than the flare in this investigation. A second incident in which a flare was launched and came in the direction of the flare. No further information is known about the second incident.

2.3 Characteristics of the flare

Based on the Dutch Safety Board Act, article 57, paragraph 2.f, the competitively sensitive manufacturing data of the flare in question has been removed from the publication version of this report. The data is known to the Dutch Safety Board.

The pyrotechnic equipment was purchased and brought on board as a package during the major maintenance of the vessel in September 2021. The package consisted of:

- three smoke pots
- three hand-held signals
- six flares, Red Rocket Parachute flare, make Pirolec, type L-35/ L35A (batch 0525/2021 – (35)113).

Certification of the flare

The type approval was requested for product name L35. However, Lloyd's Register Group[9] Limited issued the certificate for L35A. This discrepancy is not relevant for the product as such but is a cause of administrative confusion. Additionally, batch number 113 has been assigned to it in the records. In the release document, this batch is identified with the number 35113.

The supplier also uses two production designations interchangeably; batch and LOT (military). The equipment was well within its expiry date. During the voyage, the pyrotechnic equipment was stored in dry conditions and away from sunlight in a waterproof bag in the cupboard under the staircase to the aft deck, in order to be accessible for immediate use in the event of an emergency. The flare used was a 'Red Rocket Parachute Flare', make Pirolec, type L35A. A flare falls under the group of pyrotechnic devices (fireworks).

A flare is intended to be used as safety equipment in the event of an emergency. The use of the flare is bound by rules insofar as the supplier's instructions must be followed precisely and the user must ascertain that launching the flare will not put persons in the vicinity at risk. Besides being used in emergency situations, flares are also launched for training purposes.

According to the instructions (see appendix A.2), two (blue) end caps must be removed before use. The flare is then held in one hand and pointed upwards, after which the other hand is used to activate the igniter using a pull cord.

9 Lloyd's Register Limited is a registered certification institute (notified body) in accordance with EU directives and an independent certification institute recognised by governments. The document was issued by Lloyd's Register Marine Deutschland GmbH, Uberseeallee 10, D-20457 Hamburg, Germany, a member of the Lloyd's Register group.

After activating the igniter, the flare will ignite the solid propellant[10], causing the contents including the illuminating candle unit to be launched and propelled. The candle unit then ignites after several seconds. After reaching the intended height of approximately 300 metres, the burning flare emits a strong light signal for approximately 40 seconds as it descends suspended from a parachute.

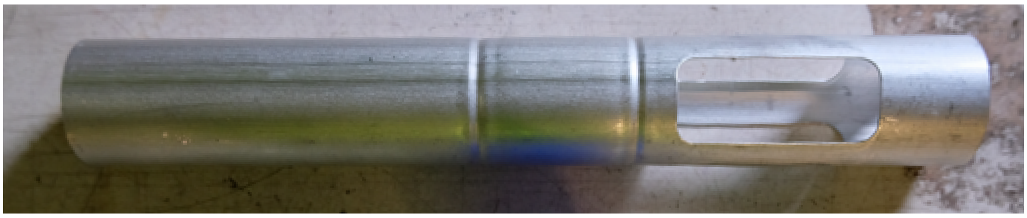
Structure of the flare

The flare (see Figure 1:1) is made up of a number of components. The exterior consists of a cylinder made of high pressure injection moulded plastic within which the fixed part of the igniter is placed. The exterior protects the user against the momentary heat generated when setting off the flare. The interior of the flare consists of an aluminium cylinder within which the motor and the candle unit are wedged (see Figure 1:2). The interior, including the igniter, is pushed into the exterior during assembly.

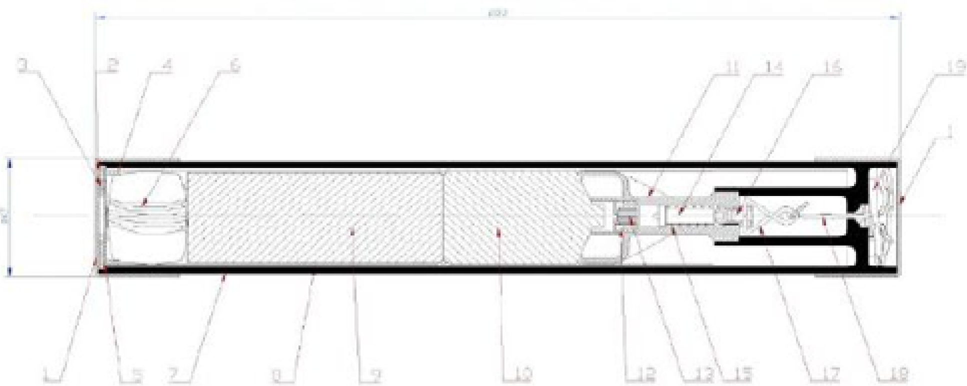
The flare is activated by means of the firing pin (see Figure 1:3), which activates the ignition cap, which in turn causes the solid propellant to ignite. As a result of the ignition of the solid propellant in the motor, the entire interior is ejected. The firing pin remains in the exterior section. Following the launch – the ejection of the interior – the candle unit combusts after being ignited by the transmission charge inside the motor.

10 The solid rocket propellant.

▲ *Figure 1:1: View of the flare.*



▲ *Figure 1:2: Aluminium inner tube within which the motor unit is wedged.*



▲ *Figure 1:3: Cross-section drawing of flare[11] > stated numbers limited to main components: 1 blue caps; 5 aluminium seal; 9 candle unit; 10 motor unit with propellant charge [note: the motor has not been drawn in detail by the supplier] 13 ignition cap; 14 firing pin; 19 pull cord. Source: Lecea manual appendix A.2.*

Preparation of solid propellant

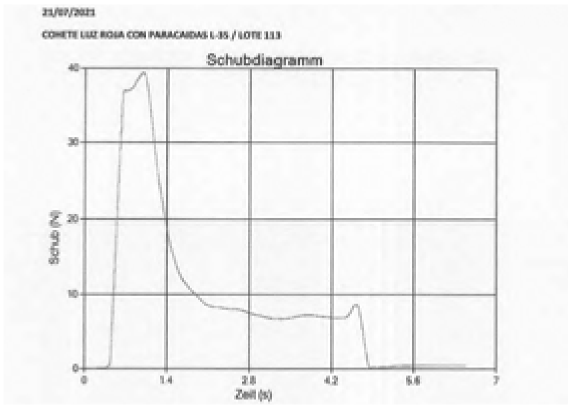
The mixture of which the propellant is composed is made up of potassium perchlorate, black carbon and two resin components, blended with acetone.

The main component potassium perchlorate is a very strong oxidant and the formulation means that a lot of oxygen is available in chemical form for the required rapid, almost explosive combustion.

11 Source: see appendix A2

The propulsion of the flare may be compared to that of a rocket. Combustion of the solid propellant generates combustion gases that provide the kinetic energy of the motor. Following activation, the igniter provides the initial reaction that causes the solid propellant to ignite. Because all the required chemicals are present within the solid propellant, the 'motor' once ignited cannot be stopped. Its operation only ends when the solid propellant has been combusted. The combustion of the propellant generates hot exhaust gases that produce a high ejection velocity caused by the venturi constriction.

The compacted form of the solid propellant in the motor is key to the available combustion surface area and so determines the combustion pattern over time. The design of the flare features a solid form, with a hollow conical form opposite the venturi constriction, with the combustion starting from the top of the cone (x in Figure 2) and first spreading downwards before consuming all the propellant. The flame front moves in layers from the tip of the nozzle of the block to the top of the casing. The exhaust gases produce a strong initial thrust, followed by a more or less constant reduced thrust until the propellant is fully combusted (see the graph in Figure 3).



▲ *Figure 2 (left): X-ray of one of the flares from batch 113 (edited). X marks the starting point of the combustion of the solid propellant. Three arrows indicate the direction of combustion. (X-ray © Gendarmerie France).*

▲ *Figure 3 (right): Pressure/time diagram from power test on batch 113. (Source: © Lecea).*

Production

The flares are manufactured in Spain and are only sold through Spanish business sales outlets, mostly nautical firms. The manufacturer of the flares has a type approval for this product that complies with the requirements of SOLAS 74/96[12] and the IMO Res. MSC.81(70)[13].

12 International Convention for the Safety of Life at Sea (SOLAS), 1974, amendments 1996.
13 International Maritime Organisation, RESOLUTION MSC.81(70) Revised recommendation on testing of life saving appliances.

The type approval was issued by Lloyd's Register under the number LR2003518SSOM following the actual testing of the production process and is valid until May 2025. In addition, Lloyd's Register also has an *EC Type Examination (Module B and D) Certificate*, number R22159802MB, also valid until 2025. With these documents, the product is also permitted in the United States.

The certification requires that all production steps should be documented and traceable. Regarding the production of the solid propellant, the assembly of the flare's propulsion mechanism (hereinafter referred to as the 'motor') and the assembled candle unit, tests are also performed in order to see whether the products comply with the requirements, such as the speed of combustion and the duration of the propellant charge after ignition. Specifically, there are three tests on the motor unit (the propulsion mechanism) during the production phase and three tests, each performed twice, after the assembly of a maximum of ten batches. Tests are performed on flares selected at random.

Prior to manufacturing a new batch, tests are performed on some of the components of the actual candle unit selected at random in order to determine whether they comply with the stipulated requirements in terms of light intensity and burning time. In the opinion of the Dutch Safety Board, this information is not relevant for this investigation[14] as far as the propulsion is concerned and it has therefore not been included in the tests for the part of the production process described.

14 The Netherlands Organisation for Applied Scientific Research (TNO) has a hypothesis that there may be a causal link between hydrogen in the candle unit and the excessive combustion in the motor (see also paragraph 3.6 of this report).

3 ANALYSIS

Introduction

This section describes what the possible cause of the failure of the flare may have been and what steps in the production process may have led to this. An explanation is first given of how the flare could explode, followed by an explanation of the various steps in the production process, focusing on what influence they could have on the flare eventually exploding.

3.1 Excessive speed of combustion of the propellant

Videos of the flare being launched were recorded. Based on these, it has been determined that after activation of the igniter, the solid propellant in the motor ignited as expected. (See Figure 4) The succeeding video fragments[15] (not included in this report) reveal that the explosion took place in two stages. The motor exploded first, immediately followed [one frame ≈ 0.05 second] by the candle unit. Four frames elapsed between ignition of the flare and the explosion, which represents a timespan of approximately 0.2 ≈ 0.25 seconds.

◀ *Figure 4: **Still** image of the flare being launched, in which the first stage of combustion of the solid propellant and the start of ejection of the interior are visible. (Source: Bontekoning)*

In contrast to the intended usual rapid combustion behaviour, the combustion became so excessive that it led to an excessive build-up of pressure in the motor, resulting in an explosion. After the explosion, a number of remnants of the exploded flare were recovered on board (see Figure 5).

15 For the purposes of the investigation, two video fragments of 9 and 8 seconds in length were split into 180 and 246 frames, respectively.

▲ *Figure 5: Recovered remnants of the flare, 1 January 2023. (Source: Bontekoning)*

In order to explain the explosion of the flare, the composition of the propellant was investigated. The main component of the propellant is a very strong oxidant and the composition means that a lot of oxygen is available in chemical form for the combustion. This chemical composition, combined with the preformed internal shape – i.e. the available surface area, which begins to combust following ignition – means that the speed of combustion corresponds to the desired build-up of pressure.

Cavities in the form of gas bubbles and cracks (for example, as a result of shrinkage) will lead to an increase in the available combustion surface area, resulting in more oxygen becoming available for combustion, leading to an extreme acceleration of local combustion. The excessive combustion will lead immediately to excessive pressure. The failure of the casing of the motor was a result of the pressure rising extremely quickly and excessively, resulting in the casing bursting open, i.e. the physical explosion.

Two other causes of failure are known from the literature[16]. One is the possibility of a loss of adhesion between the casing and the solid propellant, also resulting in additional combustion surface area. In addition, the possibility of cracks in the solid propellant is a known issue. This can be caused by excessive tensions and by cavities arising during the manufacturing process. These result in minuscule cracks, leading to additional combustion surface area. Theoretically, these causes of failure could be made visible by means of X-ray photos. However, in view of the (mass) production and the small dimensions of the motor, it is not feasible to take X-ray photos of all the flares in order to be able to identify faults that can lead to an explosion.

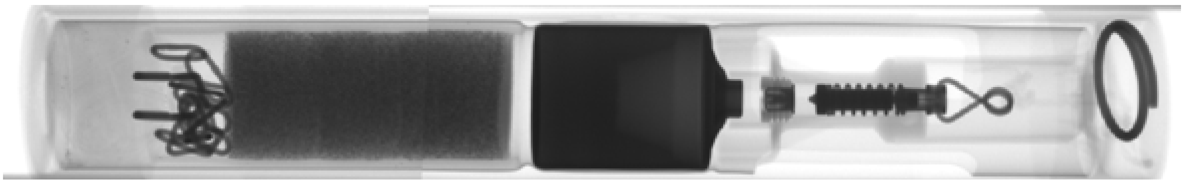
16 Reflections from TNO.

Interim finding
It is highly probable that it was a non-conformity in the combustion surface area that led to the excessive speed of combustion of the solid propellant. This could lead to excessive pressure build-up and consequently to the engine exploding.

3.2 X-ray examination of the remaining flares

Because it had been established that the motor unit failed due to the physical explosion as a result of the excessive pressure, a non-destructive X-ray examination of the remaining flares was immediately performed on Tahiti.

After the occurrence, the crew sailed on to the port of Papeete on Tahiti, the largest island of French Polynesia. Here the remaining pyrotechnic devices on board were seized by the French authorities at the request of the Dutch Public Prosecution Service. Facilitated by a request for mutual legal assistance from the Public Prosecution Service, the French army took X-ray photos of the remaining five flares[17]. Although the photos are of good quality, cracks or losses of adhesion are difficult to detect in the photos. At first sight, the remaining flares match the expected picture. However, in the pressed form in two motor units, small non-conformities are visible in the contour in the cured pressing of the propellant. This could be an indication of 'inhomogeneities' as a result of deficiencies during the production process. Due to the absence of further investigation or sufficient reference material, no conclusion is possible in this regard at present.



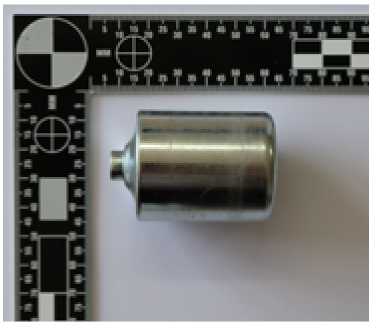
▲ *Figure 6: X-ray photo (taken on Tahiti) of one of the flares from batch 113. (Source: Gendarmerie France)*

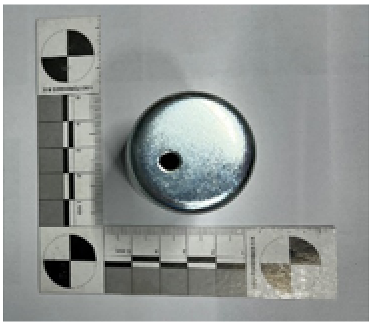
After the occurrence, the Dutch Safety Board and the Dutch Public Prosecution Service made every effort to bring the remaining five flares to the Netherlands for examination. This was unsuccessful due to transport restrictions (because of the 'technically suspect' nature of the flares). In January 2024, the Public Prosecution Service terminated the ongoing investigation and the seizure was supposed to be lifted. On 16 February 2024, the Dutch Safety Board was informed that the remaining flares had since been destroyed without consultation with the Public Prosecution Service.

17 The photos are of a good quality; 'gas bubbles' of >1 mm would be visible but none are observed, which is as it should be.

3.3 Motor of the flare

The motor (see Figure 6) consists of a filled and pressed holder on top of which is a lid which has been hemmed onto it (at a later stage). The closed motor unit is capable of withstanding the normal design pressure in the motor. The thrust of the flare is produced by the compressed combustion gases of the solid propellant leaving the motor via the venturi constriction. The venturi constriction consists of a short narrowed discharge opening, the ‘throat’. This opening deliberately creates a lower pressure at the discharge opening (externally) compared to the pressure at the intake (in the motor), resulting in an increase in the discharge velocity.
The lid that seals off the motor consists of two parts. The parts that make up the motor, the casing, the lid with the venturi constriction stamped into it, and the cardboard inlay (see also 11) are procured externally. The placement of the venturi constriction in the lid is such that it cannot be forced out of the lid by excessive pressure build-up.





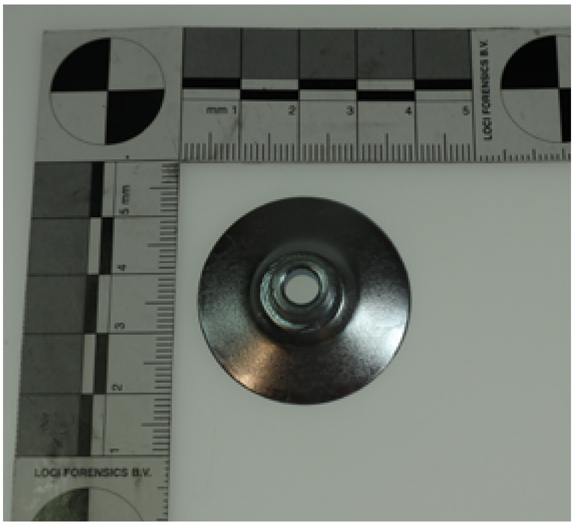
▲ *Figure 7:1 (left): The motor, side view after sealing (hemming) lid.*

▲ *Figure 7:2 (mid): View of the underside of the venturi with the Ø 5.5 mm.*

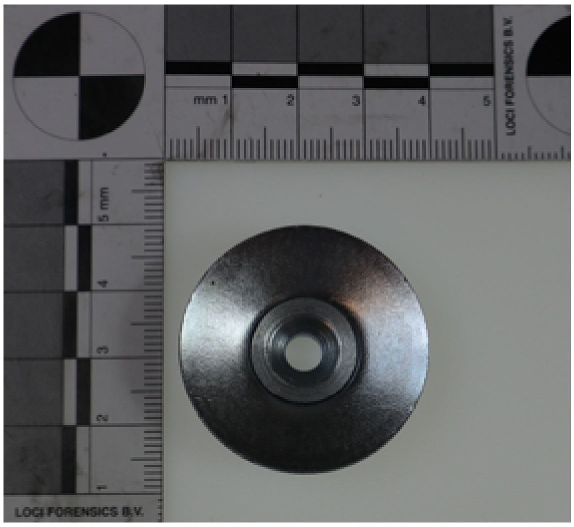
▲ *Figure 7:3 (right): Top of motor unit with opening for the transmission of ignition to the actual candle unit.*

The lid (see Figure 8) is hemmed[18] onto the motor holder by machine. It is unlikely that inadequate sealing of the motor unit led to uncontrolled combustion of the solid propellant outside the casing of the motor unit. If the lid were not properly hemmed, the pressure that would develop in the motor would remain too low, making an explosion unlikely.

18 Hemming is a metalworking technique that can be used to connect (thin) plate material. The edges of the plates are folded together and pressed.



▲ *Figure 8:1: Lid assembly, left photo: top view.*



▲ *Figure 8:2: photo bottom view with the pressed-in venturi constriction.*

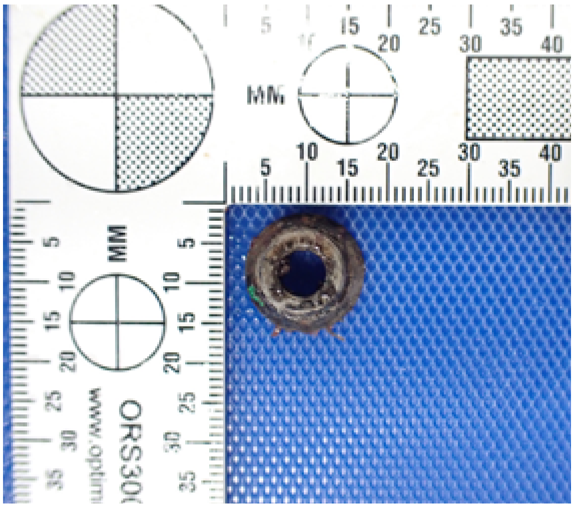
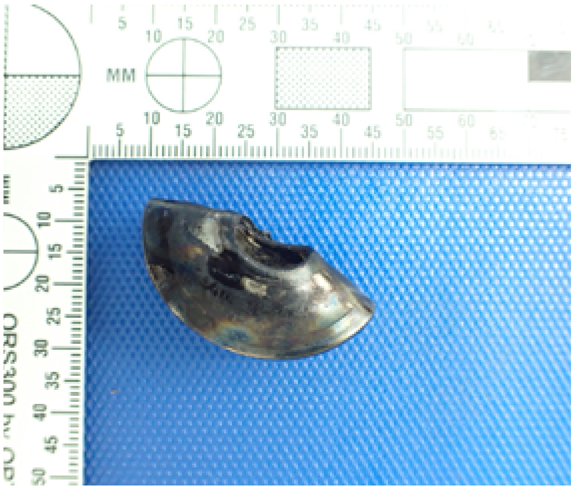
Based on the analysed video fragments, it has been determined that, following ignition, the solid propellant of the motor immediately combusted and propulsion was initiated. In Figure 4, the recess (discharge openings) in the aluminium interior is also visible. This shows that propulsion had been initiated.

The interior composition of the flare was expelled, as is confirmed by ejection of the upper section containing the parachute (see Figure 4).

Based on this fact, it can be determined with certainty that the combustion gases were able to exit the venturi constriction freely via the opening in the motor unit and that the venturi constriction was not, or not completely, blocked.

Postmortem examination

During the postmortem examination of the victim, two foreign bodies were found (see Figure 9). These fragments originated from the flare. They are part of the hemmed[19] lid of the motor. These fragments caused the internal injuries that led to the victim's death. The deformation of the lid fragment and the outward deformation of the pressed-in discharge opening (venturi constriction) from the lid are attributable to the force of the explosion. It is unlikely that the deformation was caused by the impact of these two fragments when penetrating the victim's body.

▲ *Figure 9:1 (left): The fragments found in the victim's body, upper section (lid).*

▲ *Figure 9:2 (right): The pressed-in venturi. (Source: Australian Federal Police).*

Interim finding
It can be deduced from the deformation and distribution of the fragments from the top section (see Figure 9) that were found in the victim's body that (too rapid) combustion of the propellant led to excessive pressure and the explosion of the motor.

3.4 Background and analysis of manufacture of the exploded flare

The finding that the motor unit had exploded prompted the investigators to look in greater depth at the composition of the flare, at the production of this specific batch, and in particular at the solid propellant, because that was where the excessive combustion occurred.

Process steps
The flares on board the vessel belonged to a series manufactured in July 2021, identified as batch number 0525/2021 – (35)113. The manufacturer produced approximately 675 flares in this batch. The manufacturer's workflow for the production of flares contains separate sequential steps. (See Appendix A.4 for the timeline for this process.) When all the conditions and production requirements have been fulfilled, the batch is released with a declaration.
There are three sequential steps in production of the propellant:
1. mixing;
2. drying (i.e. evaporation); and
3. curing (hardening) of the propellant.

After preparation, the mixture – which is the basis for the eventual solid propellant – has to evaporate; this is the first conditional requirement after mixing because otherwise air bubbles may form. The mixture contains an additive in order to create a homogenous mix. During filling and pressing of the motor, the mixture will 'dry' further and this process therefore needs to take place in a controlled manner. Too high a temperature can result in the two resin components in the mixture reacting with one another, either before or during filling and compaction into the final form of the motor. The reaction, the eventual curing, is partly dependent on the specific resin components.

In this phase, during the filling period, the mixture must remain workable. This second conditional requirement means that the processing time is limited, which also entails an upper limit to the processing temperature. After filling and pressing the solid propellant, the product will then cure completely and retain its solid form without cracks or deformations, the third conditional requirement.

For reasons of risk reduction (that is to say, reducing the risk of explosion with a potential domino effect), the various production steps take place in separate, detached buildings. This means that the mixed propellant, still in its workable state, and then also the intermediate products such as the filled motor, are exposed to the open air when being moved from building to building.

After the motor has been filled, pressed and sealed (hemmed), all the components are taken for intermediate storage to the assembly building where the flare is ultimately assembled. After that, the packaged flares are taken to the forwarding department to await dispatch.

Checks and release of batch 113
Analysis of the process documents reveals a number of steps in the process that need to be performed sequentially and are conditional requirements, which is to say that the product must comply with the requirements. Prior to production, three flares are first tested for burning time and light intensity. During actual production of the batch, the checks of the motor unit are of particular importance. As regards batch 113, it has been established – on the basis of the inspection documents required by Lloyd's Register – that the positive power test of the solid propellant was carried out on 21 July 2021 and is intended as the initial release to fill the batch.

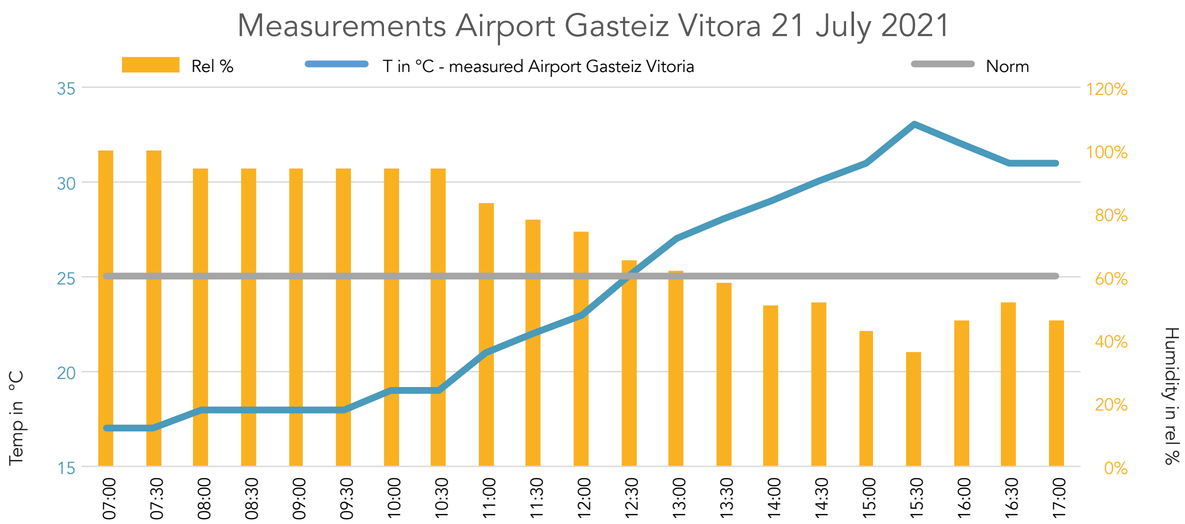
Additional tests must be carried out for every 10 batches of flares that are produced. The subsequent tests consisted of a fall test (carried out on 23 July 2021), temperature tests (carried out in the period between 9 August and 9 September), and humidity control (carried out between 11 and 26 August 2021).

Weather conditions: filling of batch 113 on 21 July 2021
Temperature and humidity play an important role in control of the prepared mixture throughout the production process. The requirements in the evaporation area are <25°C and relative humidity <80%. In this context, the local temperatures and humidity during the production process were investigated. During the filling of batch 113, the

conditions (outside air temperature and humidity) were not experienced as abnormal by the employees present.

The location where the flares were produced is in Northern Spain in the hamlet of Larrea (Barrundia). The production site consists of various detached buildings on a largely forested plot on the southern slope of a hill. Many of the buildings, including the building containing the filling and pressing area, are exposed to the sun.

In order to gain an understanding of the temperatures during the critical production days (mixing and filling), the investigators looked at data from an official meteorological station in the local area. Vitoria Airport (near Vitoria-Gasteiz) lies at a straight-line distance of approximately 20 kilometres and at virtually the same altitude. Comparing the temperatures measured there[20] with the internal requirement that 25°C may not be exceeded reveals that on 21 July, the upper limit of <25°C (in the drying room) was exceeded in the open air between 12.30 and 20.30. Humidity also fluctuated significantly over the course of that day. Initially, there was morning mist, with a relative humidity of 100%. Relative humidity then fell to 88% and only fell significantly to 38% after the sun broke through. The company has stated that the work, including cleaning, was finished by 14.00. Although the graph below does not show the temperature and humidity directly at the product location but 20 km away, the temperatures and humidity do raise the question of how the mixture behaves during these varying conditions. The company's response was that production frequently takes place under summer conditions.



▲ *Figure 10: Graph of progression of temperature and humidity on 21 July 2021, see Appendix A.5. Source: https://www.timeanddate.com/weather/@6355286/historic?month=7&year=2021*

20 See appendix A.5 for detailed measurement data for 21 July 2021 – every 30 minutes.

Interim finding
Batch 113 was filled and pressed on 21 July 2021, on which date the temperature of the outdoor air in the surroundings quickly exceeded the limit of 25°C after 12.30, without this being regarded by the staff who were present as anomalous during production.

Rejection of batches produced previously
Enquiries have revealed that five batches of motors have been rejected and destroyed over the past 10 years:

- Batch 401, January 2014. Due to a breakage in the hydraulic press, it was not possible to press the composition on time and the batch was destroyed.
- Batch 402, January 2014. Following repairs to the press, it was found that the pressure could not be adjusted properly. As a result, it proved impossible to perform the filling and pressing operations on time, and this batch was also destroyed.
- Batch 414, June 2014. Fault in the press pump; the batch could not be pressed and was destroyed.
- Batch 009, August 2020. The prepared mixture turned out to have been incorrectly mixed and as a result was not homogenous. The test subsequently revealed uneven combustion. The batch was destroyed.
- Batch 114, August 2021. As a result of a fault in the temperature sensor of the climate control system, it transpired that the temperature in the drying room had exceeded the maximum limit as a result of the process. When entering the room, it was determined that the temperature was well above 25°C, possibly closer to 40°C, and that the composition had already dried too much, meaning that it could not compact properly. Batch 114 was then destroyed.

Interim finding
The faulty temperature sensor in the drying room was only discovered after the 'evaporation' period of batch 114. The sensor was checked after the temperature in the drying room was 'felt' to be far too high. There was no quality monitoring of the temperature control and/or the sensor.

It therefore cannot be ruled out that the sensor was already not working properly during production of batch 113, which may have resulted in the temperature rising without that being noticed – not to the extreme level as observed in batch 114, but nevertheless above 25°C.

3.5 Analysis of possible causes of the explosion

It has been established that the flare was set off correctly on the evening in question, in accordance with the instructions and before the expiry date. As far as is known, there were no problems on board the vessel regarding storage of the flares, such as moisture and/or excessive temperatures on board. It remains unclear whether the flare was exposed to vibrations between leaving the factory and arriving on the vessel, i.e. prior to being set off. For this reason, the investigation focuses on the process for manufacturing the flare. The manufacturing process is certified and audited, and therefore incorporates a number of safeguards.

There are nevertheless a number of potential 'blind spots' in the production process. In the view of the Safety Board, these are two possible causes of the motor exploding. The first possible cause is drying out and curing during the production process. The second possible cause is the absence of a cardboard inlay. TNO has suggested a third possible cause. The three possible causes are explained below.

Possible cause 1: Shortcomings in process monitoring in the assembly and drying phase
In order to be able to fill a new batch of motors, the manufacturer prepares a mixture that makes up the eventual propellant. This is a precise process in which the substances are mixed sequentially, after being weighed. Following evaporation, the mixture eventually cures to form propellant. The quantity prepared must be processed the following day before the mixture has cured. This means that the quantity that is prepared and processed is limited.

After mixing, the three receptacles containing the mixture are transferred from the mixing room to the drying room, which is located on the other side of the facility in the small mixing building. The mixture must be left there to evaporate for several hours at a set temperature. The room has air conditioning intended to ensure that the temperature in the room does not rise above 25°C. Additionally, the humidity may not exceed 80%.

During production of the flare involved in the occurrence, the mixture remained in the drying room until the morning of 21 June 2021 and was then taken to the filling and pressing room. A month later, it became apparent that the temperature control system was not working properly due to a faulty thermocouple. This led to the following batch (number 114) becoming too hot and thus too dry; it was therefore rejected. This was initially established by the temperature being felt to be too high, and only later by means of actual measurement. The drying room is not equipped with a logging system and/or an external temperature monitoring (notification) system. This means that the drying process is not monitored. Checking visually whether the mixture is still suitable for processing is the only form of quality assurance.

Interim finding
Nothing is logged during the evaporation process. Neither is there any monitoring of the cooling other than physical observation of the temperature or determining visually whether the mixture has already started to dry. Batch 114 could therefore become too hot and this was only noticed when the mixture was too dry to still process.

When evaporation was complete, the three receptacles containing the mixture were transferred the following day to the filling and pressing machine in a building approximately 100 metres away.
For this part of the process, two steps are conditional requirements:
1. the available filling time is determined by the available working time of the operator and
2. the curing of the mixture.

Generally speaking, work is carried out between 06.00 and 14.00. Experience has shown that it is necessary to process the mixture before the end of working hours because the material will otherwise cure and it will no longer be possible to clean the installation components.

Prior to the eventual filling process, the motor unit is provided with a loose cylindrical cardboard inlay. The purpose of the inlay is twofold, namely to reduce heat transfer during combustion and to prevent sparks during pressing.

Possible cause 2: Absence of cylindrical cardboard inlay
Despite the fact that the manufacturer considers it very unlikely, it cannot be ruled out that the cylindrical cardboard inlay was not present during filling. The manufacturer states that the presence of the inlay is a conditional requirement, due to the perceived risk of sparks in the event of contact between the metal sheath of the motor and the metal stamp of the press. Sparks are unacceptable but the absence of the cardboard inlay need not necessarily result in sparks, in view of the installation and the working method.

This is because metallic contact that could cause a spark is virtually excluded. When the mixture is pressed, the motor unit is entirely fixed in the holder. The stamp of the slow-moving hydraulic press has a fixed stroke and the parts do not touch one another and therefore cannot cause any sparks (see Figure 11).

If the propellant in the motor unit is pressed without a cardboard inlay, then the top edge will not be pressed so as to have the same diameter as the motor unit, causing an unwanted edge. As a result, (micro) cracks and cavities can arise in this edge during the curing stage, which can result in additional combustion surface area.

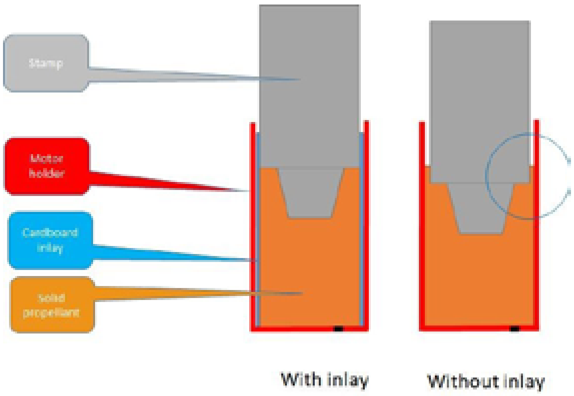


Figure 11: Cross-section drawing of motor unit during pressing, showing effect seen with and without cardboard inlay.

Interim finding

Despite the fact that the manufacturer considers it very unlikely, incorrect filling and pressing of a flare without a cardboard inlay cannot be ruled out and is technically possible.
In the absence of a cardboard inlay, the edges are not pressed, resulting in undesirable transitions that can lead to additional combustion surface area.

The filling and pressing process comprises a number of steps. After being placed in the carousel, the motor unit is filled with black powder. This dose of black powder serves as the prime for ignition and also as the prime/flame passage for the candle unit following complete combustion of the motor. In the next position, the mixture is then added, followed by more black powder in a subsequent position. This dose serves as an accelerator for combustion of the propellant. The contents are then compacted at a pressure of 18 tons. As the final step, the operator removes the filled and pressed motor unit from the carousel and places it in the tray.

The Dutch Safety Board considers that filling and pressing the motor takes place in a relatively dimly lit area. The placement and removal of the motor is routine work, with only disruptions to the process prompting additional attention. In this workspace there is no temperature control by means of air conditioning and/or monitoring of the receptacles containing the mixture. The temperature of the mixture and the initiated drying process are not monitored. Because no interim measurements are taken of the ambient temperature, there is a possibility of the mixture curing unnoticed.

Analysis has revealed that during the filling of batch 113, the ambient temperature eventually rose to 33°C at 15.30. Despite the supplier's assertion that its employees are used to producing at higher temperatures, a higher temperature can accelerate the curing process and so increase the risk of non-conformities. Small cavities, in particular, but also small cracks, can arise unnoticed in this phase during pressing.

The only checks of the products are the three tests previously referred to (see *Checks and release of batch 113 in Section 3.3*). However, these tests are performed on random samples and may not be representative for the end of the filling process. Moreover, it is open to question to what extent the solid propellant has cured sufficiently to be representative by the time the first test takes place.

Interim finding
The tests on the motors are only an indication of the overall composition of the solid propellant.

Despite the fact that there is an existing production methodology, it must be questioned to what extent the current process involving producing approximately 675 motors in the space of six hours in uncontrolled temperature and humidity conditions is amenable to proper control.

3.6 Third possible cause

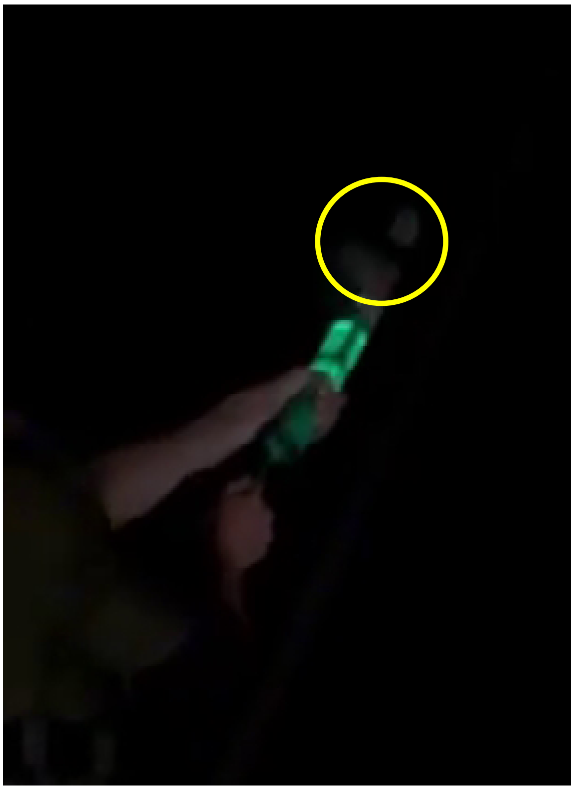
The Dutch Safety Board presented its findings from this investigation to experts at TNO for quality assurance and a second expert opinion. Aside from its reflections on this investigation – in which it confirmed that the failure of the motor unit was the result of excessive combustion – TNO also cannot determine with certainty what caused the excessive combustion.
In addition to the two possible causes discussed above in relation to possible production non-conformities, TNO envisages another possible cause. TNO states:

The videos recorded during the incident reveal details that are not explicable. Flames are visible at the front of the flare and just above the victim's hand shortly after activation of the flare. Based on the positions of the individuals recording the videos in relation to the victim, it is very unlikely that these are light reflections on the flare or on the cable of the mainsail or other components of the vessel. These flames could indicate initiation from the front of the flare (above the motor). Based on the clearly visible dimensions of the discharge opening in the aluminium interior, it is possible to ascertain the dimensions of the flare, the aluminium interior, the discharge opening, the location of the motor, the candle unit, and the parachute shortly before the explosion.

What TNO finds notable is a black area between two visible grey areas (see Figure 12). In TNO's view, these details are not explicable by the normal functioning of the flare. The candle unit itself contains magnesium in order to achieve the intended effect. Compositions containing magnesium[21] can produce hydrogen gas if they come into contact with moisture. The possible presence and ignition of hydrogen gas, for example as a result of static electricity, could have ignited the candle unit and the motor simultaneously, via the hole at the top of the motor. Simultaneous ignition of the solid propellant at the

21 Pyrotechnics used for light effects contain metal particles. Magnesium is a commonly used metal in pyrotechnics.

bottom and top of the motor could also have resulted in excessive pressure build-up and the explosion of the motor.



▲ *Figure 12: The non-visible part.*

In this context, TNO notes that the non-conformities inferred from analysis of the available images could also be an indication of the scenario that the solid propellant in the motor may have ignited simultaneously at the top – i.e. the end where the candle unit is located – due to the ignition of hydrogen gas, if present, which combusted as a result of friction.

This TNO hypothesis cannot be ruled out. Given the fact that the upper part of the flare is sealed with an aluminium seal, the chance of moisture ingress and therefore also of hydrogen gas being produced appears small. The chance of this seal being missing is small, because it is clearly visible after application when the blue cap is applied.

Interim finding

TNO points to the possible presence and ignition of hydrogen gas, for example as a result of static electricity, which could have simultaneously ignited the candle unit and the motor. Simultaneous ignition of the solid propellant at the bottom and the hydrogen gas at the top of the motor could subsequently also have led to excessive pressure build-up and the explosion of the motor.

3.7 Quality assurance through type approval

Besides the three possible causes set out above, the following is relevant to analysis of the flare accident. A type approval was issued for the flare by Lloyd's Register Marine in Germany as the notified body.[22] Certification requires that all production steps must be documented and traceable. The manufacturer, LECEA, states that it has stipulated the various production steps in a number of production instructions. These procedures were inspected and analysed during the investigation. The type approval was issued by Lloyd's Register under number LR2003518SSOM following actual assessment of the production process and is valid until May 2025.

The process is described, for example, for production of the mixture for the solid propellant, filling, assembly of the flare's integrated propulsion mechanism (the 'motor'), and the composition of the assembled candle unit. The production steps are reported and any non-conformities must be immediately reported by the employees. The prescribed tests are also performed in order to see whether the products comply with the requirements, such as the speed of combustion and the duration of the propellant charge after ignition.

This involves three pre-tests in order to see whether the purchased candle unit has the right burning time and light intensity, and three tests of the motor during the production phase to check whether the solid propellant produces the correct thrust. Finally, six more tests follow; these are conducted every ten batches. They are performed on flares selected at random during and after production.

In procedure IPO-03.9, any defects observed are grouped into three categories: These categories are: *CRITICAL DEFECTS, MAJOR DEFECTS, MINOR DEFECTS*.

The instructions set out rejection criteria. In the 'critical' category, these are: *Explosion of the rocket during firing or during some of the final tests and trials to which they have been subjected, or poor functioning with risk to the user*. If this is observed, the batch must be definitively blocked. *The lot will be rejected, without the possibility of counter-testing, if a single critical defect appears.*

This subsequent course of action in the event of such a defect being identified is a paper procedure and does not provide a full guarantee as regards the rest of the batch.

Where the occurrence under investigation is concerned, various tests were performed which – as has been established for the non-tested flare that exploded – provided no guarantee.

22 A notified body (NB, NoBo) is an institution designated by a government/government agency, in this case SOLAS, to assess the conformity of products subject to obligations such as for CE marking.

Interim finding
Internal procedures and accreditation by Lloyd’s Register as the notified body contribute to increasing product safety but never fully guarantee a safe product. Until critical conditions are measured and logged (such as temperature and humidity), unnoticed deviations may occur.

4 CONCLUSIONS

Despite the fact that the Dutch Safety Board had no authority beyond the borders of the Netherlands to demand information or cooperation in this investigation, the Board did receive the full cooperation of the manufacturer, LECEA, and is consequently in a position to answer some of the investigation questions.

Based on the available information, it was determined that the pyrotechnic safety equipment on board the ship met the applicable requirements, that the expiry date had not expired and that the equipment had been properly stored. It has also been determined that the flare was launched correctly.

It has also been determined that the failure mechanism causing the flare to explode was excessive combustion of the solid propellant. This led to the build-up of extreme, excessive pressure, causing the motor to burst open explosively.

From the information available, it is not possible to conclude with any degree of certainty what caused the excessive combustion. Complicating the investigation was the fact that this very serious non-conformity only became apparent during use. To date, no problems or non-conformities have been identified in the recalled flares in Spain or the blocked flares on Tahiti which were X-rayed.

The Safety Board nevertheless identifies blind spots in the quality assurance for the production process as possible causes of the explosion:

- For a relatively long period during filling, no monitoring takes place of the quality of the composition of the mixture during drying and/or the start of curing, in particular during the final period of filling.
- It remains possible that the cardboard inlay was not present in the motor unit. This blind spot may have led to an enlarged combustion surface area. It cannot therefore be ruled out beforehand as regards the occurrence of excessive combustion.
- Finally, the alternative TNO scenario – the simultaneous ignition by hydrogen gas from the propellant – cannot be ruled out either as a possible cause.

The fact that, as far as is known, the issue at hand relates to a single occurrence involving a Pirolec flare means that it is not possible to generically assert a clear system non-conformity in the production of batch 113.

A type approval for the flare was issued by Lloyd’s Register Marine in Germany. In practice, a type approval can give rise to the expectation that the safe use of a product is thus guaranteed, but a type approval only indicates that the product - if produced and assembled as intended - complies with a set standard. Internal procedures and accreditation by Lloyd’s Register as the notified body contribute to increasing product safety. Given the blind spots that have been identified, however, undetected non-conformities may be possible.

5 RECOMMENDATIONS

Based on the findings of this investigation, there are lessons to be learned. The Dutch Safety Board has observed that there are gaps in the production process. The fact that an accident has not previously occurred with this type of flare means that it cannot be generically stated that there was a clear system deviation in production. Since an accident has now occurred and given the importance of air temperature and humidity in the phase of filling and pressurizing the engines with mixture that ultimately forms the solid propellant, the Dutch Safety Board makes the following recommendations:

To Lecea as the manufacturer of the Pirolec flare:

1. Integrate control measures into the production process to prevent the prepared mixture from being exposed to excessive ambient temperatures and/or excessive humidity for too long.
2. Integrate control measures into the process to ensure that the cardboard inlay is always present in the motor unit.

To Lloyd's Register Marine Deutschland as the notified body.

3. Verify whether the working method and the prescribed quality steps, on the basis of which the type approval for this type of flare was issued, are still valid. Include monitoring of air temperature and humidity in the elaboration of this recommendation.

APPENDIX A ADDITIONAL INFORMATION

A.1 Repatriation of the victim

Following the explosion on board the Bontekoning, it proved impossible to save the life of the victim, and he was pronounced dead following consultation with the supporting doctor.
This left the skipper facing a situation in which it would not be possible to transfer the body in a port within the required time period[23] of 36 hours.

The Dutch Coastguard found a vessel that was prepared to assist the crew of the Bontekoning – the BCC Maryland, a cargo ship sailing under the flag of Antigua and Barbuda, which was four hours' sailing away from the Bontekoning.
In view of the destination of the BCC Maryland, Newcastle in Australia, and the strict requirements in force there, it initially did not seem possible for the Maryland to take over the body. This would have had far-reaching consequences for the crew of the Bontekoning.

The Dutch Safety Board took the initiative to use its international contacts with its sister organisations in Antigua and Barbuda, Germany and Australia, the shipping company and the master of the BCC Maryland, to find a way that the body could after all be transferred to the BCC Maryland.

Following intensive consultation with these parties, and in particular the Australian Federal Police in the state of New South Wales and the master of the BCC Maryland, it proved possible to take the body on board the BCC Maryland, under the authority of the Dutch Safety Board.

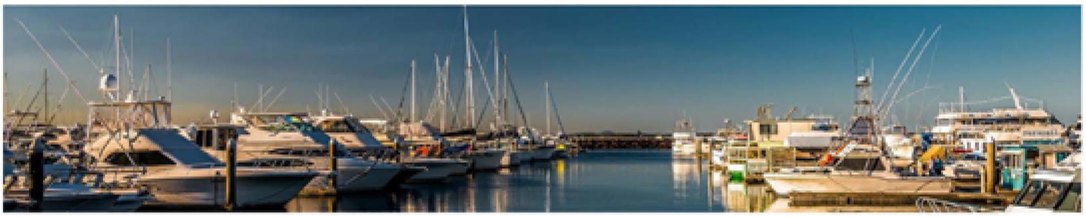
After arrival in Newcastle, the Australian authorities, following a request for mutual legal assistance by the Dutch Public Prosecution Service, took over the authority for the body and a post-mortem examination was carried out at the request of the Dutch Public Prosecution Service and the Dutch Safety Board. Eventually, the victim was repatriated to the Netherlands on 30 January.

23 Article 22 of the Burials and Cremations Act.

A.2 Manual

Red Parachute Rocket L-35

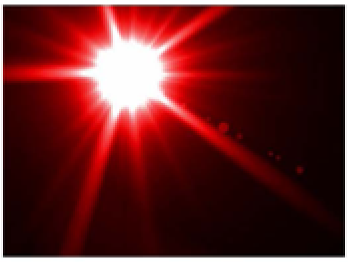
pirolec
PIROTECNIA LECEA SA



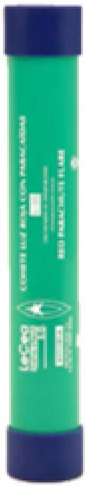
DESCRIPTION: Distress handheld signal used in all types of boats and vessels including in leisure crafts, rafts and lifeboats. Designed to comply with SOLAS 74/96 and IMO Res.MSC.81(70) regulations. It withstands exposure to extremely adverse weather conditions and functions properly even after being submerged under water. Parachute rocket to be launched by hand. Expels an intense red light at a height of more than 300 metres height by a parachute. Easy grip and quick workability in emergency situations.

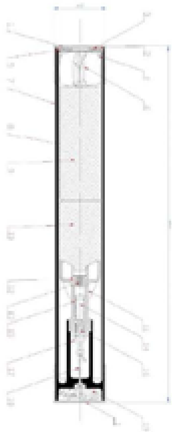
APPLICATIONS:
As a distress signal for all kinds of boats, it is suitable for day or night use with long distance visibility.

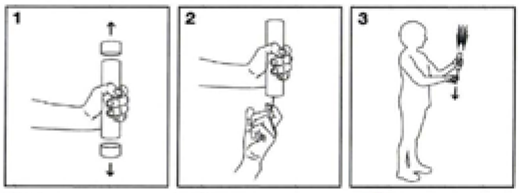
LIGHT COLOUR: Bright Red
DURATION: More than 40 seconds
LIGHT INTENSITY: More than 30,000 candles
IGNITION METHOD: Percussion ignition
DIMENSIONS: ø45×280 mm.
GROSS WEIGHT: 450 g
STANDARD CARTON PACKAGING:
35 units
Weight: 16KG
Carton Dimensions- 310 x 250 x 335 mm



SPECIFICATIONS:







¡Atención!
Peligro de incendio o de proyección. Mantener alejado de fuentes de calor, chispas, llama abierta o superficies calientes. No fumar. No luchar contra el incendio cuando el fuego llegue a los explosivos. Evitar el choque/la fricción. Almacenar en un lugar seco, protegido de fuentes de ignición.

Danger!
Explosive; fire, blast or projection hazard. Keep away from heat/sparks/open flames/hot surfaces. — No smoking. DO NOT fight fire when fire reaches explosives. Store in a dry place protected from sources of ignition.

Lloyd's Register
SOLAS-MED

PIROTECNIA LECEA, S.A.
Barrio Epiztegia, 3, 01280 Larrea- Barrundia, Álava SPAIN
t + 34 945 31 70 24 m +34 619 412 083 e direccion@pirolec.com
www.pirolec.com

A.3 Warning

ONDERZOEKSRAAD VOOR VEILIGHEID

Datum 19 januari 2023 Bladnummer 1 van 3

Bezoekadres
Lange Voorhout 9
2514 EA Den Haag
T 070 333 70 00

Postadres
Postbus 95404
2509 CK Den Haag

onderzoeksraad.nl

To all owners of the Red Rocket Parachute Flare L-35
(Pirolec)

Onderwerp Safety alert for use Red Rocket Parachute Flare L-35 (Pirolec)

The Dutch Safety Board calls on all owners of the Red Rocket Parachute Flare L-35 / L-35A (Pirolec) to take note of this Safety Alert.

In the night of January 1, 2023, a person on board a Dutch sailing ship on the Pacific Ocean died when he fired a flare.

The experienced sea sailor fired the flare, which complied with its requirements, in accordance with the instructions. The flare did not launch as intended, but exploded immediately, with fatal consequences.

After becoming aware of the accident, the Dutch Safety Board started a preliminary investigation. From the initial analysis of the available information, the Dutch Safety Board has not yet been able to determine whether this is a one-off accident or if a more structural problem exists. Given the nature of the incident, there is a risk that it is not a one-off incident.

Because of this risk, contact has been made with the manufacturer in Spain. The Spanish manufacturer has warned its customers in Spain and is recalling the specific batch. Because these products are sold only in Spain, the warning of the Spanish manufacturer is aimed at Spanish customers (see later on). The accident, however, shows that owners (users) are also located outside Spain. For example, Spain can be a final supply station for transatlantic or Mediterranean (sailing) trips.

With this warning, the Dutch Safety Board calls on all owners of Red Rocket Parachute Flare from Pirolec, type L-35/ L35A, batch 0525/2021 – 113, to not use these and to replace them.

Yours faithfully,

CHAIR Dutch Safety Board

On behalf, chair Dutch Safety Board,
Secretary general Dutch Safety Board

mrs mr. C.A.J.F. Verheij

Red Rocket Parachute flare L-35 / L-35A (Pirolec)

Pirolec Red Rocket Parachute flare L-35

Pirolec Red Rocket Parachute flare L-35A
Ongevalsbatch 0525/2021 113 08/2021 – 08/2025

Bron: Onderzoeksraad voor Veiligheid

LECEA
SISTEMAS PIROTECNICOS AVANZADOS

Larrea, 17 January 2023

Subject: Recall of lot 113 of rockets with the commercial designation L-35A

We hereby inform you that we received notification of an accident involving an L-35A rocket from lot 113, manufactured in August 2021. Taking into account the information received, as a preventive measure, it has been decided to recall all rockets of the aforementioned lot. Likewise, it is recommended not to use the L-35A rockets marked with the lot number 113 and to facilitate their return to the factory.

To this end, once this communiqué has been published, all customers who have received rockets from lot 113 will be contacted, indicating the delivery note number and date of sale of the product so that, in turn, they can contact the end customers and proceed with the recovery of the articles. Rockets or equipment withdrawn will be replaced immediately, free of charge.

We regret the inconvenience that this situation may cause, but we understand that it is the quickest and safest preventive solution for the end customer.

We are at your disposal for any questions you may have.

Yours sincerely,

A.4 Timeline

Process step/timeline	Date	Note 1	Note 1
Batch 113 mixture prepared	20-07-2021	Mixing in the morning	Thereafter 20-21 hours in the drying room at approximately 20°C. max ≤ 25°C
Batch 113 filled and pressed	21-07-2021	Transferred to filling room	Filled and pressed in six steps Motor unit placed with inlay Component 1 filled Component 2 filled Component 3 filled Pressed Removed from visual control and placed in the tray n = 105
1st test	21-07-2021	Performance test on rocket motor, 3 separate motors	4.5 mm with overpressure nozzle 5.5 mm normal nozzle
Storage	21-07-2021 11-08-2021	Storage	
2nd test	23-07-2023	SOLAS fall test – conformity 3 assembled flares	
Release	23-07-2021	Test satisfactory result, the Declaration of Conformity is issued on 07/23/2021	Batch declaration/LOT 113 release
Fitting lid/assembly	11-08-2021 21-08-2021	Lid fitted to motor and flare assembled	
3rd test	11-08-2021 26-08-2021	SOLAS temperature test 3 assembled flares	
End of assembly	02-09-2021	Batch 113 complete	

▲ *Table 1 : Timeline for manufacture of Batch 113 July - September 2021*

A.5 Ambient temperatures

Time	Temp	Weather	Wind		Humidity	Barometer	Visibility
7:00	17 °C	Scattered clouds.	2 km/h	↑	100%	1020 mbar	7 km/h
7:30	17 °C	Fog.	No wind	↑	100%	1020 mbar	5 km/h
8:00	18 °C	Fog.	2 km/h	↑	94%	1020 mbar	3 km/h
8:30	18 °C	Fog.	2 km/h	↑	94%	1020 mbar	3 km/h
9:00	18 °C	Fog.	4 km/h	↑	94%	1020 mbar	3 km/h
9:30	18 °C	Fog.	No wind	↑	94%	1020 mbar	3 km/h
10:00	19 °C	Fog.	No wind	↑	94%	1020 mbar	4 km/h
10:30	19 °C	Scattered clouds.	4 km/h	↑	94%	1020 mbar	6 km/h
11:00	21 °C	Scattered clouds.	2 km/h	↑	83%	1020 mbar	6 km/h
11:30	22 °C	Clear.	No wind	↑	78%	1020 mbar	8 km/h
12:00	23 °C	Clear.	4 km/h	↑	74%	1020 mbar	9 km
12:30	25 °C	Sunny.	2 km/h	↑	65%	1020 mbar	16 km/h
13:00	27 °C	Sunny.	2 km/h	↑	62%	1020 mbar	16 km/h
13:30	28 °C	Sunny.	4 km/h	↑	58%	1019 mbar	16 km/h
14:00	29 °C	Sunny.	6 km/h	↑	51%	1019 mbar	16 km/h
14:30	30 °C	Sunny.	6 km/h	↑	52%	1019 mbar	16 km/h
15:00	31 °C	Sunny.	6 km/h	↑	43%	1018 mbar	16 km/h
15:30	33 °C	Passing clouds.	6 km/h	↑	36%	1018 mbar	N/A
16:00	32 °C	Passing clouds.	19 km/h	↑	46%	1018 mbar	N/A
16:30	31 °C	Passing clouds.	17 km/h	↑	52%	1018 mbar	N/A
17:00	31 °C	Passing clouds.	22 km/h	↑	46%	1018 mbar	N/A
Vitoria-Gasteiz Weather History for 21 July 2021							

▲ *Table 2: Observations on 21 July 2021 at Vitoria Airport.*

APPENDIX B RESPONSES TO THE DRAFT REPORT

The draft report was submitted to the various stakeholders and to two maritime experts. These parties were asked to check the report for factual inaccuracies and inconsistencies. The following parties responded to the draft report:

- Relatives
- Owner/crew
- Lecea - Sistemas Pirotécnicos Avanzados, S.A.
- CIAIM - Comisión Permanente de Investigación de Accidentes e Incidentes Marítimos
- Lloyd's Register EMEA

The responses received can be divided into the following two categories:

- Corrections and factual inaccuracies, additional details and editorial comments. The Dutch Safety Board has incorporated these (to the extent correct and relevant). The relevant sections of text have been adjusted in the final report.
- The responses that have not been incorporated are included in the table with the Dutch Safety Board's reasons for not adopting them.

The responses received and the Dutch Safety Board's explanation, are included in a table that can be found on the Dutch Safety Board's website (www.onderzoeksraad.nl).

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