Danish Maritime Accident Investigation Board

MARINE ACCIDENT REPORT
November 2015

TRITON
Foundering on 18 July 2015

The Danish Maritime Accident Investigation Board
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This marine accident report is issued on 4 November 2015.

Front page: Damage to the hull of TRITON. Source: DMAIB

The marine accident report is available from the website of the Danish Maritime Accident Investigation Board (www.dmaib.com).

The Danish Maritime Accident Investigation Board

The Danish Maritime Accident Investigation Board is an independent unit under the Ministry of Business and Growth. It carries out investigations as an impartial unit that is, organizationally and legally, independent of other parties. The board investigates maritime accidents and occupational accidents on Danish and Greenland merchant and fishing ships, as well as accidents on foreign merchant ships in Danish and Greenland waters.

The Danish Maritime Accident Investigation Board investigates about 140 accidents annually. In case of very serious accidents, such as deaths and losses, or in case of other special circumstances, either a marine accident report or a summary report is published, depending on the extent and complexity of the events.

The investigations

The investigations are carried out separately from the criminal investigation, without having used legal evidence procedures and with no other basic aim than learning about accidents with the purpose of preventing future accidents. Consequently, any use of this report for other purposes may lead to erroneous or misleading interpretations.

Content

1. SUMMARY

On 18 July 2015, the pilot boat TRITON foundered as result of a flooded engine compartment caused by a mechanical breakdown of the drive shaft that penetrated the aluminium hull. TRITON was not designed to stay afloat with a flooded engine compartment and foundered approximately 10 minutes after the initial breakdown of the drive shaft.

TRITON was in its design and construction not sufficiently robust to withstand such a mechanical malfunction. The accident thereby shows the importance of having a preventive maintenance program in place on smaller boats that have little or no redundancy in terms of residual buoyancy or emergency bilge pumps.

The boatman managed to abandon the boat in a controlled and calm manner because he responded early and inflated the life raft almost immediately after having observed the ingress of water. Other accidents related to flooding on other small commercial vessels such as fishing vessels highlight the challenges associated with water ingress and the importance of having the lifesaving equipment readily available. Having a life raft forward and aft of the ship enhanced the chances of the boatman abandoning the boat safely.

The owner of TRITON has informed DMAIB about preventive measures taken to make the pilot boat more robust.

2. FACTUAL INFORMATION

2.1 Photo of the ship

Figure 1: TRITON
Source: TV Oest

2.2 Ship particulars

Name of vessel:	TRITON
Type of vessel:	Pilot boat
Nationality/flag:	Denmark
Port of registry:	Copenhagen
Call sign:	XPC7685
Year built:	1997
Shipyard/yard number:	Dockstavarvet AB/412
Classification society:	Unclassed
Length overall:	14.7 m
Breadth overall:	4.63 m
Gross tonnage:	19.9
Draught max.:	2.15 m
Engine rating:	810 kW (2x405 kW)
Service speed:	33 knots
Hull material:	Aluminium
Hull design:	Single hull

2.3 Voyage particulars

Port of departure:	Masnedoe
Port of call:	Masnedoe
Type of voyage:	National
Cargo information:	N/A
Manning:	1
Pilot on board:	No
Number of passengers:	0

2.4 Weather data

Wind – direction and speed:	NW – 6 m/s
Wave height:	0.25 m
Visibility:	Good
Light/dark:	Light
Current:	East 0.1 knots

2.5 Marine casualty or incident information

Type of marine casualty/incident:	Foundering
IMO classification:	Very serious
Date, time:	18 July 2015 at 0730 LT
Location:	1.5 nm east of the Island of Femoe, Denmark
Position:	54°57.42' N 011°38.27' E
Ship's operation, voyage segment:	Manoeuvring alongside ship
Place on board:	Main engine room
Human factor data:	Yes
Consequences:	Ship foundered

2.6 Shore authority involvement and emergency response

Involved parties:	Danish Joint Rescue Coordination Centre (JRCC) Danish coast radio station Lyngby Radio
Resources used:	FRB 20 from Klintholm (Danish Coastal Rescue Service) FRB 09 from Danish Coastal Rescue Service Rescue helicopter RES 510
Speed of response:	Approximately 30 minutes
Actions taken and results achieved:	Pilot boat crewmember was brought to shore by rescue helicopter.

2.7 The ship's crew

Boatman:	Certificate of Competency in Sailing Merchant Vessels. Officer in charge of a navigational watch (STCW II/3). 60 years old. Had been at sea for 30 years and served on TRITON for approximately one year.

2.8 Scene of the accident

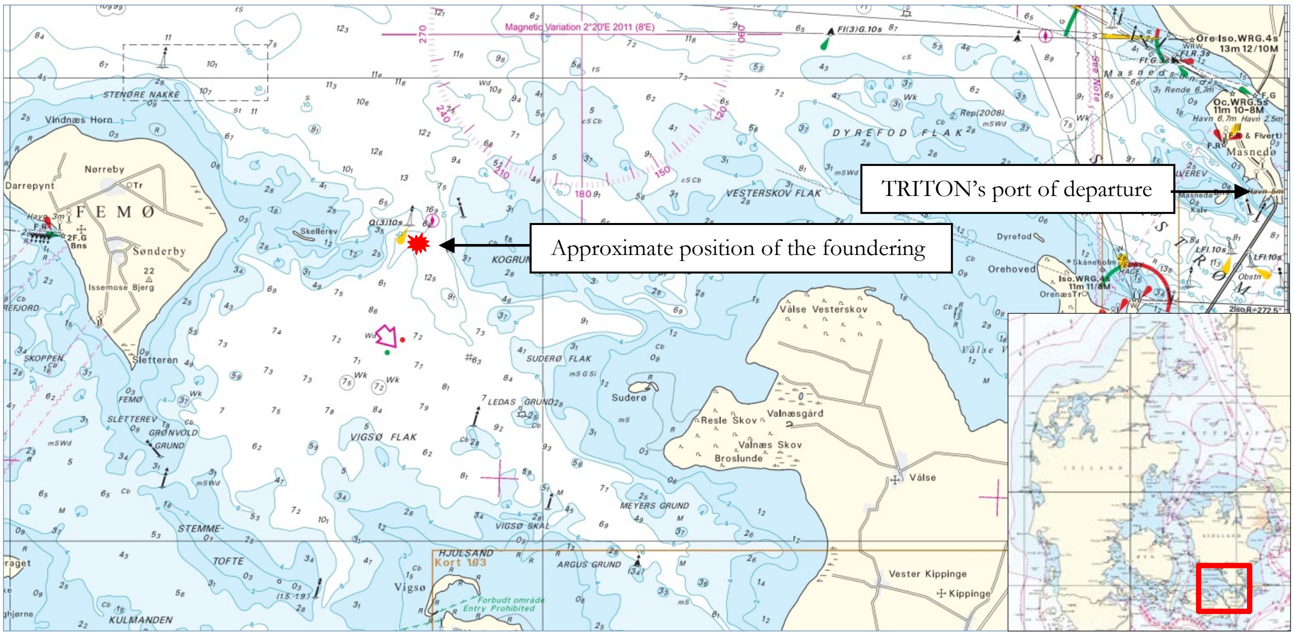

Figure 2: Position of foundering of TRITON
Source: Chart 160 and chart D, Danish Geodata Agency

3. NARRATIVE

3.1 Background

DanPilot was an independent public enterprise under the Ministry of Business and Growth, with the Danish Maritime Authority (DMA) as the supervising authority. Pilotage was provided from 22 pilot stations in Denmark by 32 specialized pilot boats of varying design and equipment. TRITON had an aluminium hull and was one of two pilot boats equipped with a water jet propulsion system.

The pilot boat TRITON operated in Danish local and regional waters, but mainly in the local area of southern Zealand (see figure 2 above). The pilot boat was typically manned with one or two crewmembers depending on the circumstances of the voyage, e.g. weather conditions, distance and the carriage of passengers. On the day of the accident there was one crewmember on board the pilot boat.

Statements of time in this report are given in local time in Denmark (UTC+2), unless otherwise specified.

3.2 Sequence of events

TRITON was scheduled to depart from Masnedoe (figure 2) on 18 July 2015 for embarking a pilot from the cargo ship KONSTANTIN that had been piloted from the nearby port of Nykøbing Falster.

The boatman arrived at the boat in the morning of 18 July 2015 and prepared it for departure, which entailed cleaning the seawater filter and a routine check of the propulsion engine's cooling water and lubricating oil level. Thereafter, at approximately 0630, the boat departed Masnedoe heading for the position for the pilot's embarkation east of Femoe (figure 2).

At approximately 0715, as TRITON was approaching KONSTANTIN from the aft at a distance of approximately 50 metres, the boatman noticed noise and vibrations coming from the water jet propulsion system. He initially thought that the noise came from eelgrass or other organic material that had been sucked into the water jet, which was not uncommon. In order to clear the water jets the boatman, as per routine, reversed the water jet water flow.

Suddenly, a loud crack was heard and the boatman went aft to see if the outboard water jet nozzles were damaged, but found them to be in good order. As he stood on the aft deck, the engine room bilge water alarm sounded from the wheelhouse. He opened the aft deck hatch to the engine room and saw water up to the engine floor. After having stopped the engines, he rushed into the engine compartment in an attempt to close the seawater over board valves. By then the water was knee-deep and he abandoned the attempt to close any valve.

The water level rose rapidly, and it became apparent to the boatman that he had to prepare to abandon the boat. He released the life raft that was lashed on the aft deck, pushed it into the sea and inflated the life raft. When it was inflated, the boatman pulled it to the leeward side and tied it to the boat with a slip knot, whereafter he donned an inflatable lifejacket.

At 0720, he went to the wheelhouse to call the pilot on KONSTANTIN and inform him that the pilot boat was about to sink. The Danish coast radio station Lyngby Radio overheard the VHF call and contacted the boatman by VHF to confirm that he was in need of assistance.

At 0723, Lyngby Radio transmitted a mayday relay that was received by the bridge crew on KONSTANTIN who replied that KONSTANTIN was nearby and would respond. KONSTANTIN was then brought about and close to TRITON.

At approximately 0730, the boatman saw that the aft part of the pilot boat was submerged and water was about to enter the wheelhouse through the door. He took the SART[1] and a portable VHF and jumped into the life raft and pushed it away from TRITON. The release cord was still attached to the pilot boat in order to prevent the life raft from drifting into shallow waters, where he could not be rescued by boat.

On KONSTANTIN the crew prepared the man over board boat in order to pick up the boatman, but at 0747 Lyngby Radio notified the bridge crew that a rescue helicopter had been dispatched and would arrive at the position of TRITON within 10 minutes.

At 0757, a rescue helicopter arrived and picked up the boatman from the life raft.

TRITON stopped transmitting AIS signals at 0750 when the power supply in the wheelhouse presumably failed due to the ingress of water.

On 22 July 2015, TRITON was salvaged and brought to Svendborg Shipyard, Denmark, for repairs.

3.3 Investigation of breakdown and foundering

3.3.1 *Damage*

Figure 3 below gives an overview of the propulsion engine layout. From the right, the following components are highlighted: diesel engine, gear, drive shaft, impeller drive seal and water jet nozzle.

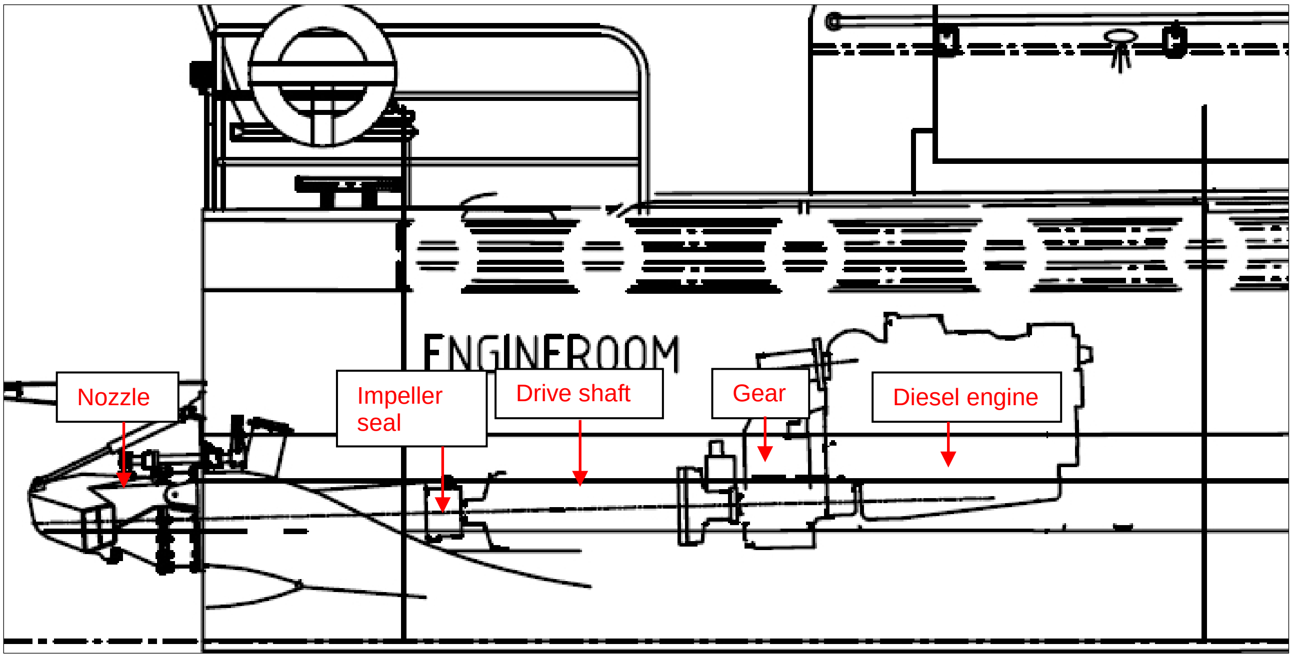

Figure 3: Damage to hull and machinery
Source: DMAIB

When TRITON had been salvaged, extensive damage was found caused by the water ingress into the various compartments of the boat. The initial source of the water ingress was found in the engine compartment. It came from an elliptically shaped hole in the aluminium hull of approximately 250 mm in

[1] Search and Rescue Transponder.

length and 150 mm in breadth. The plating around the edge of the hole was buckled in an outward direction, showing that an object had penetrated the hull from inside the engine compartment. The hole was in the hull bottom plating on the port side aft part of the boat (figure 4).

Figure 4: Damage to hull
Source: DMAIB

Above the hole in the hull the shaft drive was found to be severely damaged (figure 5). All radial link connections were damaged and all fastening bolts, except one, had been torn. The drive shaft was not found in the position seen in below picture, but was placed in an upright position before the photograph was taken. At the time of the breakdown, an aluminium cover was mounted above the drive shaft intended to protect an operator from the rotating shaft.

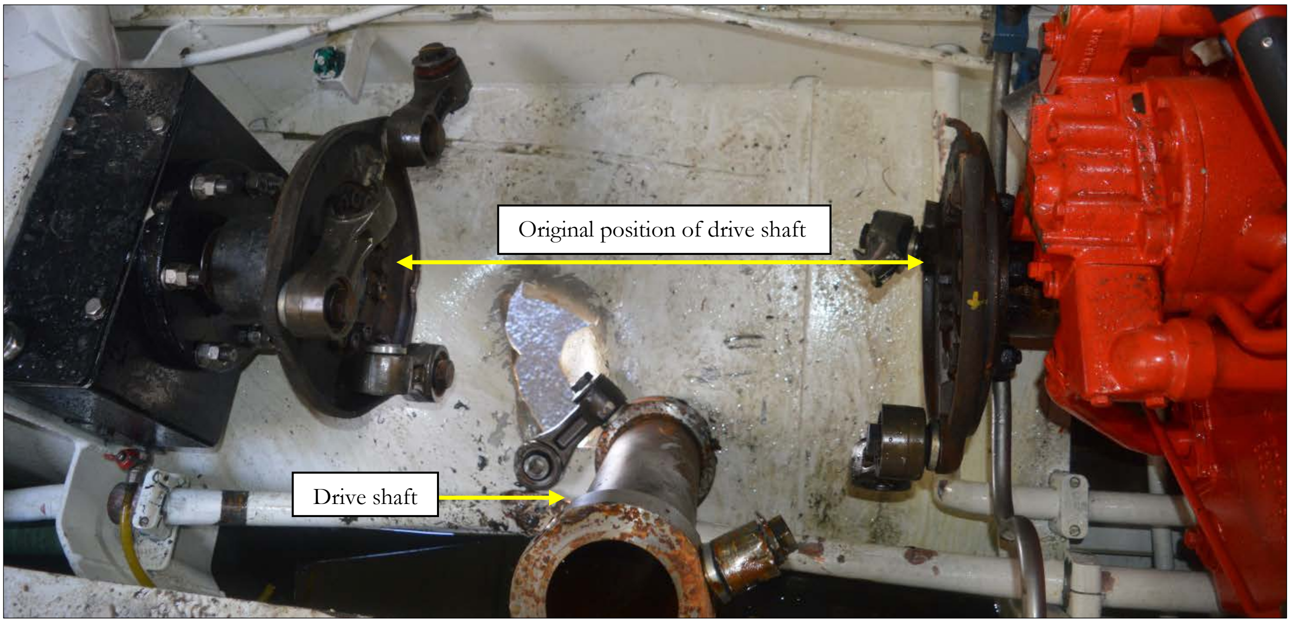

Figure 5: Damage to hull and machinery
Source: DMAIB

A picture of the intact starboard side drive shaft can be seen below on figure 6. The port side engine clutch housing was fractured (figure 7), presumably due to the excessive vibrations from the drive shaft breakdown.

Figure 6: Intact drive shaft system on starboard side
Source: SurveyAssociation

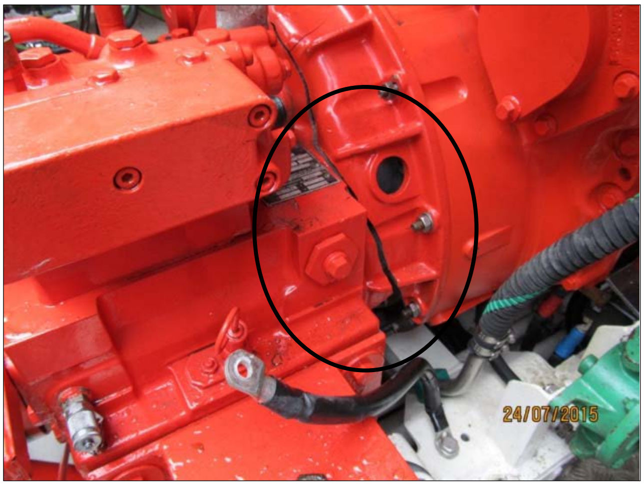

Figure 7: Fracture of clutch housing
Source: SurveyAssociation

3.3.2 *Breakdown*

The drive shaft system consisted of the shaft that was connected to the engine gear and the water jet drive by three links (figure 8). These are designed to minimize the shaft's sensitivity to vibration, to offer electrical insulation and to reduce mechanical noise. The links were attached to the shaft by bolts (figure 9).

The drive shafts had been shortened and the engines moved aft wards approximately one year before the breakdown when vibrations were detected after the replacement of the main engines two years earlier. After the modifications of the drive shaft had been made, the new drive shaft arrangement was surveyed by the DMA.

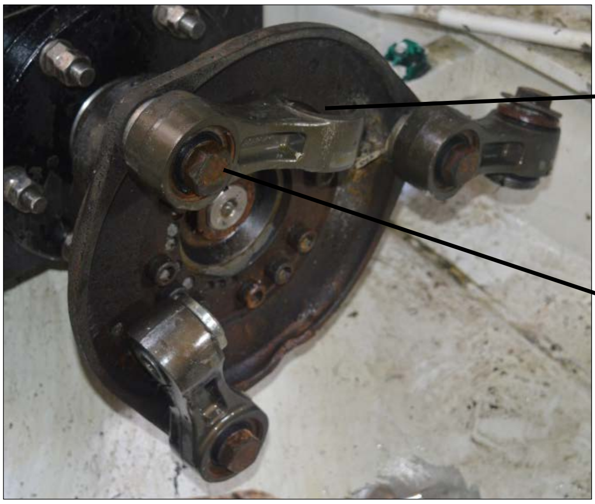

Figure 8: Links on drive shaft
Source: DMAIB

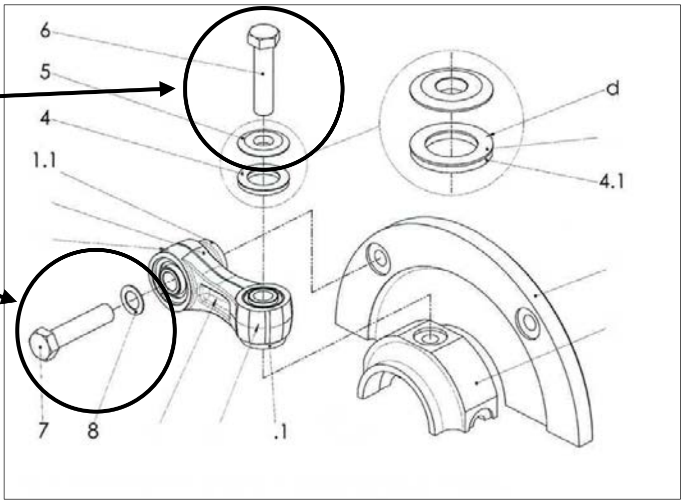

Figure 9: Bolt on drive shaft link
Source: DMAIB

The independent survey company, SurveyAssociation, made an analysis of the damaged drive shaft parts. It was found that one of the bolts that held the aft shaft drive link had loosened and fallen out. This analysis was based on the fact that only one of the bolts had an undamaged thread and only one of the drive shaft links had an undamaged thread.

As the bolt fell out, an imbalance occurred in the alignment of the drive shaft, which caused the vibrations that the boatman experienced. It is likely that the shaft came loose when the boatman reversed the propulsion, and the forces on the radial links shifted. The rotation forces on the shaft made it rotate uncontrollably, and when the shaft came lose, it penetrated the aluminium hull at the bottom of the boat.

It was found that the bolts were standard bolts of unknown grade and specification and not the 10.9 grade bolts as specified in the technical documentation for the drive shaft. Furthermore, there was no indication that the bolts had been secured with thread-locking fluid or wire. Interviews with the service mechanics from the company that modified the drive shaft confirmed that the bolts had not been fastened by using a torque wrench because the general perception was that it was not necessary. It is given that without any specification indicated for the bolt, it would not be possible to determine what would be the correct torque needed to fasten the bolt. Therefore, the bolt would likely be tightened too little or too much. In any circumstance it would eventually become loose and fall out.

The mechanical condition that caused the breakdown of the drive shaft was therefore a non-approved loose bolt in one of the aft radial drive shaft links, which had not been fastened according to the manufacturer's specifications.

3.3.3 *The foundering*

Below in figure 10 is a section of TRITON's general arrangement.

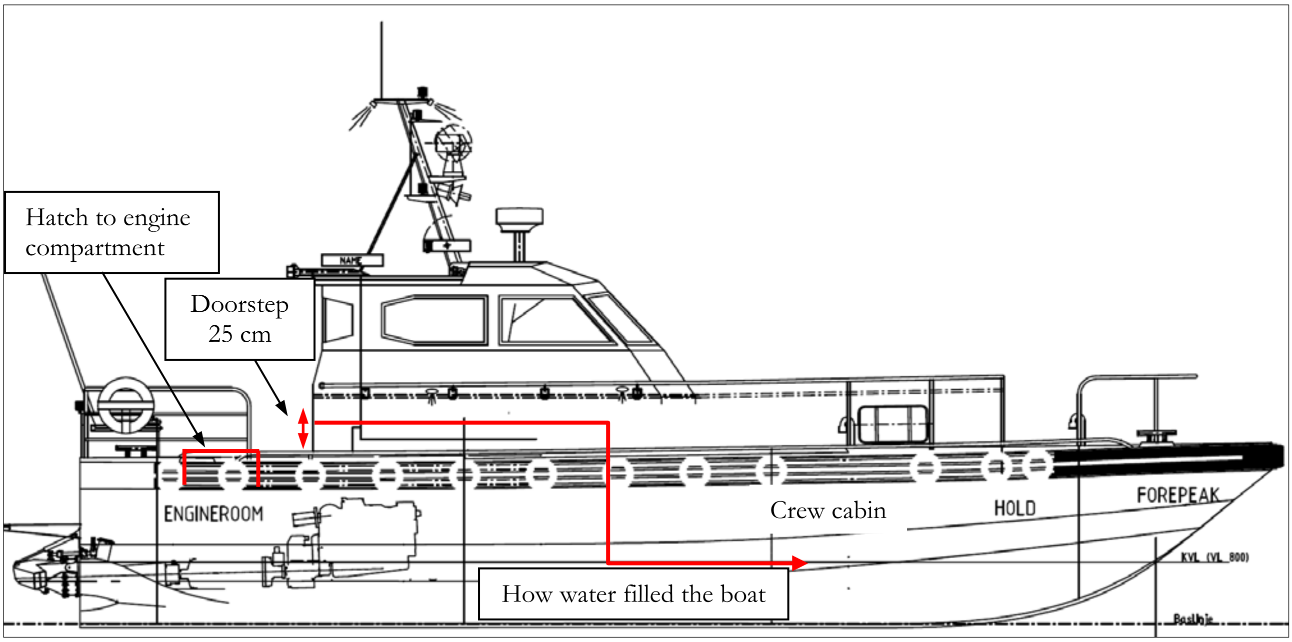

Figure 10: Section from general arrangement
Source: DanPilot

When the damaged drive shaft had penetrated the hull, water gushed in through the 250 mm x 150 mm hole in the bottom of the boat. Based on the boatman's observations, the bilge water alarm was activated within minutes of the time the boatman had reversed the water flow in the water jet, which meant that the damage caused a rapid flooding of the engine compartment.

The boatman assumed that the flooding was caused by a leakage in one of the engine systems and therefore attempted to close the over board valves. Overwhelmed by the extent of the ingress of water, he abandoned the engine compartment and closed the deck access hatch to the engine compartment (figure 10).

As the water level in the engine compartment increased, the stern of the boat was submerged until the water reached the entrance to the wheelhouse. Once the wheelhouse threshold of approximately 25 cm was submerged, the water could fill the entire wheelhouse and crew cabin below via the staircase in the wheelhouse (figure 10).

There was a watertight door between the engine compartment and the forward crew cabin, which was closed at the time of the accident. Usually, it was closed due to the noise and heat from the engine room. The investigation of the wreck of TRITON did not reveal any deficiency or breakdown of the watertight door and/or cable penetrations. Originally TRITON was designed with two doors between the engine compartment and the crew cabin. This design was primarily made for meeting the regulatory requirements about the noise level in the crew cabin

TRITON was not designed to stay afloat with the engine compartment flooded, nor was it a regulatory requirement. Once the water started to fill the engine compartment, the boat would at some point lose all buoyancy. There were two bilge water pumps in the engine room: One electric automatic bilge pump with an indicator light in the wheelhouse indicating when bilge water was being pumped out and, furthermore, one additional bilge/fire pump which was driven by the main engine. The latter could also be used as a general service pump. Neither of the pumps was designed to perform as an emergency bilge pump, but only to pump minor quantities of water from cleaning or minor leakages.

The boatman was not familiar with the flooding limitations of the boat, but once the water reached the wheelhouse door step, he was in no doubt that the boat was about to founder.

When the stern had been completely submerged, the buoyancy in the forepeak and forward part of the crew cabin made the boat float at an angle of approximately 45˚ (figure 11).

Figure 11: Picture of TRITON at 0740 on the day of the accident
Source: Private photo

Approximately 10 minutes passed from the time the boatman noticed irregularities with the propulsion system until he abandoned the boat. When the boat had been abandoned, it drifted semi-submerged in a north-easterly direction before it grounded in shallow waters of approximately 8 metres' depth.

Prior to the accident, one of the boat's two life rafts had been moved from the forward deck to the aft deck close to the wheelhouse. During the foundering of TRITON this position of the life raft enabled the boatman's swift and orderly abandonment of the boat.

3.4 Regulation, survey and maintenance

3.4.1 *Regulation*

TRITON was purpose built as a pilot boat in 1997 according to the Special Service Craft rules and under the survey of Lloyd´s Register of Shipping. The boat was given the class notation +100A1 Danish Coastal Service LMC under LR number 9130365. The boat was later taken out of class which was the normal procedure of the Owner. The boat thereby complied with the standards[2] set out by the DMA. These standards did not specify that the boat was to be built to classification society standards, but standards based on a Nordic boat standard[3] with the additions and amendments necessitated by progress and practical experience.

The technical regulation on small vessels carrying a maximum of 12 passengers[4] stated that the boat should be manned with two crew members. However, under certain circumstances there were exceptions to this requirement, e.g. due to weather conditions, voyage type and when passengers were not on board. In such cases, the boat could be manned with only one crew member.

The minimum safe manning document on TRITON stated that the boat should be manned with one engineer unless the maintenance service of the engine was carried out per an approved shore-based service agreement. Then the engineer could be replaced by a crew member. This crew member should hold a certificate of proficiency in engine operation and have obtained at least 6 months of seagoing service carried out as deck service or engine service, and could simultaneously be employed to perform other types of work on board.

During the voyage on 18 July 2015, the pilot boat was manned by one crew member because the pilot was not considered to be a passenger by the pilot company and the boatman had a certificate of proficiency in engine operation.

3.4.2 *Survey and maintenance*

The ship was not classed and was, therefore, subject to periodical surveys (renewal and intermediate) by the DMA. These surveys consisted of a survey of both equipment and structure. At the latest survey in November 2013, only minor deficiencies were found. There was no indication that the maintenance standards were out of the ordinary.

The company did not have a formalized service agreement with service providers that included all the engine related systems, but used various service subcontractors for solving deficiencies found by the crew member during the daily operations. This meant that on TRITON there was a corrective-based

[2] Technical regulation on pilot vessels, no. 7 of 7 October 1996
Technical regulation on small vessels carrying a maximum of 12 passengers no. 956 of 26 September 2012
Notice F from the Danish Maritime Authority, Technical regulation on the construction and equipment, etc. of small commercial vessels of 18 September 2014

[3] Nordisk Båt Standard, Yrkesbåter under 15 meter 1990, Sjøfartsdirektoratet

[4] Technical regulation on small vessels carrying a maximum of 12 passengers no. 233 of 5 March 2015

maintenance strategy, where maintenance was carried out following detection of an anomaly and aimed at restoring normal operating conditions.

Approximately one year before the accident, an independent technical superintendent had been hired to evaluate and supervise the repairs and refitting of the aging pilot boats, including implementing strategies for a preventive maintenance program, i.e. where maintenance is carried out at predetermined intervals or according to prescribed criteria, aimed at reducing the failure risk or performance degradation of the equipment. The superintendent made a report about his findings. During the company's evaluation of the report, it was found that initiatives were necessary to ensure a unified inspection regime and timely maintenance of all the 32 pilot boats in service. These initiatives were ongoing and not fully implemented when the accident occurred.

4. ANALYSIS

4.1 The breakdown and foundering

As the drive shaft was breaking down and the boatman noticed the vibrations, he responded according to his experience and intuition. He had no reason to assume that the unusual noise and vibrations were not caused by eelgrass, and he therefore reversed the flow in the water jet as a standard response, which likely caused the radial link to come loose. Once the drive shaft had penetrated the hull, no operational initiatives on board could enable a recovery from the situation, e.g. pumping water out or isolating the engine compartment, so the rest of the ship would not be flooded.

Basically the foundering of TRITON was caused by one loose bolt that came lose, which shows how there was little proportionality between the accidental event and the consequences of the accident. Thereby, the pilot boat's lack of robustness towards mechanical malfunction was uncovered.

The lack of robustness in terms of structural strength of the hull, i.e. it could not withstand an impact from a mechanical malfunction, highlights the importance of keeping the mechanical parts in good condition because minor malfunctions can render the boat unseaworthy and endanger the crew. Furthermore, the boat lacked robustness in terms of mechanical or structural redundancy (bilge pumps, survivability with flooded compartment, etc.).

Although standards from the manufacturer were in place to ensure the condition of the shaft drive, these standards were not adhered to. The sub-contractor, who had been hired by the pilot company to realign the drive shaft, did not apply the standards described by the manufacturer because the standards were unknown to the service provider. Within the pilot company there was no strategy for ensuring that the desired standards were upheld when the repair and servicing of the propulsion system was outsourced. Furthermore, in the absence of an effective preventive maintenance system, there would be no continuous check of the condition of machinery systems.

DMA's survey of TRITON's machinery did not specifically address the issue of maintenance, because no readily visible deficiencies were found indicating a general problem with maintenance.

4.2 Evacuation of the pilot boat

The boatman managed to evacuate the pilot boat in a controlled and calm manner because he had prepared the life raft. As the boat started to trim aft wards, it became apparent that the life raft, which was mounted on the forward part of the boat, was inaccessible. It was, therefore, expedient that one of the boat's life rafts was mounted and accessible from the aft deck, so the boatman could communicate by

VHF from the wheelhouse and still be close to the inflated life raft. Thereby, he could quickly abandon the boat when he realized that it was not possible to recover from the situation.

In an emergency scenario, such as flooding, it is essential for the crew to have knowledge about the robustness of the boat, e.g. how much flooding can the boat be subjected to before it will founder. Having this information readily accessible will make it easier for the crew to decide when to abandon the boat or evaluate other options. The survival of the crew can depend on such a swift decision.

There was no formalized information available to the boatman stating that the pilot boat was not designed to keep buoyant with a flooded compartment. The stability booklet, which was made according to the guidance[5] from the DMA, was not designed to be used by a crew member with the maritime qualifications stipulated in TRITON's safe manning document.

5. CONCLUSIONS

On 18 July 2015, a mechanical breakdown of the drive shaft caused a penetration of the aluminium hull whereafter the engine compartment of TRITON became flooded within minutes. TRITON was not designed to stay afloat with a flooded engine compartment and foundered approximately 10 minutes after the initial breakdown of the drive shaft.

On TRITON no system was in place to detect that the drive shaft had been wrongly assembled before the accident happened. As the company had outsourced the competency of evaluating the mechanical condition of the boat, the fault could go unnoticed until the accident happened.

TRITON was in its design and construction not sufficiently robust to withstand such a mechanical malfunction. The accident thereby shows the importance of having a preventive maintenance program in place on smaller boats that have little or no redundancy in terms of residual buoyancy or emergency bilge pumps.

The boatman managed to abandon the boat in a controlled and calm manner because he responded early and inflated the life raft almost immediately after having observed the ingress of water. Other accidents related to flooding on other small commercial vessels such as fishing vessels highlight the challenges associated with water ingress and the importance of having the lifesaving equipment readily available. Having a life raft forward and aft of the ship enhanced the chances of the boatman abandoning the boat safely.

6. PREVENTIVE MEASURES TAKEN

The pilot company has notified DMAIB about the following:

Lessons identified – Lessons learned:
DanPilot is ISO 9001:2008 certified and this means that procedures for non-conformities and handling of corrective actions are already implemented systematically in the organization.

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[5] Vejledning til virksomheder og enkeltpersoner i forbindelse med udfærdigelsen af stabilitetsbøger for fiskeskibe og mindre erhvervsfartøjer, The Danish Maritime Authority, 2015.

When the cause of the damage was found at 28th 2015, - DanPilot immediately organized inspections of all similar or equivalent installations onboard the rest of the fleet. A closer inspection was done onboard the sister vessel Starkad, - but no serious deficiencies in this regard was found.

The inspection of the fleet was carried out by an experienced technician within Centa shafting systems and well-known for years by DanPilot.

As lessons learned actions, - DanPilot has emphasized the requirements and the obligations to suppliers of repairs and deliveries, to ensure that the manufactures instructions and guidelines are strictly followed, and surveyed by the technical superintendent

Preventive actions:

Danpilot has since begin 2015 been in a process for implementation of an improved planned management system, that can be monitored both at the head quarter and locally at the pilot stations. All skippers have participated in a training course and it is expected that the full implementation will be finalized Ultimo 2015.

The planned maintenance system defines routine checks of the vessels critical systems and in detail the surveillance of critical mechanical fitted connections.

It has been decided by the safety board that risk assessment for key shipboard operations shall be maintained for each vessel, and that damage stability information for all vessels shall be investigated and communicated to the skippers, taking their experience and educational background into consideration.