Investigation Report

C3/2010M

JEANNEAU PRESTIGE 42S, A-58990 (FIN), sinking off Inkoo on 28 May 2010

This is an abridged version of the investigation report, and it only deals with the technical aspects of the incident. The investigation report in its entirety including all the factors considered in the investigation is available in Finnish.

Onnettomuustutkintakeskus
Olycksutredningscentralen
Safety Investigation Authority, Finland

Osoite / Address:	Sörnäisten rantatie 33 C FIN-00500 HELSINKI	**Adress:**	Sörnäs strandväg 33 C 00500 HELSINGFORS
Puhelin / Telefon: **Telephone:**	(09) 1606 7643 +358 9 1606 7643		
Fax: **Fax:**	(09) 1606 7811 +358 9 1606 7811		
Sähköposti/ E-post/ Email:	turvallisuustutkinta@om.fi		
Internet:	www.turvallisuustutkinta.fi		

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SUMMARY

JEANNEAU PRESTIGE 42S, A-58990 (FIN), SINKING OFF INKOO ON 28 MAY 2010

A Jeanneau Prestige 42S-type planing hull motorboat departed from Espoo in a westward direction Ekenäs as its destination on 28 May 2010. The boat was brand-new and preparations had been made to stay overnight. In Inkoo, on a 5.5-metre fairway, the skipper first decided to turn to starboard, on a crossing fairway, in order to take the motorboat to Inkoo for the night. Immediately after the turn he changed his mind and made a sharp turn further to starboard in order to return to the original fairway after a 270 degree headway change. After the curve had ended, the boat did not, however, return to the intended fairway but instead turned next to the fairway. The boat drove almost with full speed over an under-water shoal whereupon her Volvo Penta IPS drive units hit a rock. This resulted in a serious, uncontrollable leakage and the boat sank next to the fairway. There were three adults and five children onboard the boat and they were rescued to other boats located in the vicinity. There were no injuries to persons, but the boat was completely destroyed. The investigation concludes that the grounding was not caused by any technical failure, which means that the loss of situational awareness after the turn with high speed can be regarded as the immediate cause of the accident and the sudden change in the voyage plan as a contributing factor.

The drive unit did not break off in a controlled way so that the hull of the boat would have remained watertight, but instead the impact caused by the collision broke the weakly-constructed hull of the boat. The boat did not have watertight compartments and the water which flooded into the engine compartment spread into the whole boat which then sank rapidly.

A similar accident occurred the same summer of 2010 when the chartered boat IDA 1 ran aground with similar effects[1]. Both accident boats were equipped with two Volvo Penta IPS drive units. Because not a single of the three drive units which hit a rock broke off in the manner specified by the manufacturer, it was decided that factors related to the structure of IPS drive units would be studied in co-operation by both investigations. Problems were found in the strength pyramid of the drive unit and in the integration of the drive unit and the hull.

The construction of Jeanneau Prestige 42S was found out to be weak at the joint between the transom and the bottom, and the joint of the IPS drive unit and the hull carelessly and poorly completed. The visibility from the wheelhouse on this kind of a boat was also found out to be restricted when the roof hatch is closed.

As a result of the investigation, the Safety Investigation Authority recommends that boat construction regulations are changed in such a way that boats similar to the accident boat remain afloat after the engine compartment makes water, that Volvo Penta check the functioning of the strength pyramid of the IPS drive units and the requirements on the structure of the boat.

In addition to the safety recommendations, the investigators point out to boaters that if there are changes in the voyage plan, enough time must be reserved for getting familiar with the new voyage plan. When this is done, situational awareness is better under control.

[1] C4/2010M M/S IDA 1 (FIN), grounding and sinking in Kvarken, Finland on 17 August, 2010

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Figure 1. Jeanneau Prestige 42S on the web pages of the manufacturer. The picture does not portray the accident boat and the persons are not related to the accident.

FOREWORD

Accident Investigation Board of Finland (The Safety Investigation Authority) decided on 4 June 2010 to appoint an Investigation Commission under Section 5 in the Accident Investigation Act (373/1985) to investigate the accident. M.Sc.(Tech.) Klaus **Salkola** was appointed as the investigator-in-charge per his consent and Master Mariner Juha **Sjölund** and M.Sc.(Tech.) Ville **Grönvall** were appointed as members.

A member from the Investigation Commission was there to observe when the accident boat was lifted and at the same time he had the opportunity to question the boat's skipper on the causes which had led to the accident. In addition, the investigator visited the scene of the accident together with the owner of the boat after the boat had been lifted. In Inkoo the lifted boat was moved to a dock hall where the Investigation Commission went three times to examine it.

The Finnish Transport Safety Agency was asked for executive assistance in order to determine the requirements compliance of the motorboat especially concerning the strength of aft hull and the visibility of the boat's operator. A request for clarification on which inspecting establishment, according to the Recreational Craft Directive, had approved the boat was also enclosed to the executive assistance request.

In connection with the investigation, the IPS drive unit of charter boat IDA 1, which ran on a rock with similar results, was disassembled. The report on this inspection can be found as an appendix in both this investigation report and in the investigation report on IDA 1 (C4/2010M).

The final draft of the investigation report has been sent for statements to the involved parties on 15 June 2012. The statements are attached to the end of this investigation report. The investigation report has been reviewed when this has been considered necessary on the basis of these statements. This abridged version of the investigation report, which only deals with the technical aspects of the incident, has been translated from Finnish to English by Minna Bäckman.

1 EVENTS AND INVESTIGATIONS

1.1 The boat

1.1.1 General information

Figure 2. The accident boat in the dock hall after being lifted from the sea.

Brand and model	Jeanneau Prestige 42S
Type	Sterndrive motor boat
Production material	Glassfibre reinforced plastic
Boat design category	B[2]
Construction year	2010
Commissioning year	2010
Max. length/hull length	13.36 m/ 11.98 m
Max. beam	4.16 m
Draught	1.05 m
Displacement	9350 kg
Number of persons	10
Engine	2 x sterndrive Volvo Penta IPS500 (model 2010)
Fuel	diesel
Fuel tanks	2 x 450 l
Power	2 x 272 kW (= 2 x 370 hp)
Reported max. speed	40 knots

[2] In the design category B the vessel is regarded as being designed to be used in a significant wave height of max. 4 metres and in a wind of max. 8 Beaufort (Force 8 equals with 17.2-20.7 m/s). These kinds of conditions may be encountered on longer voyages in the open sea or in the proximity of the coast if there is no protection. The wind is assumed to reach 21 m/s in gusts.

1.1.2 General arrangement

The following can be found in the hull of the boat: engine compartment (in the aft), accommodation spaces, sanitary facilities and galley. There is an open space on the main deck (in the aft) as well as a combined wheelhouse and a saloon. In the rear of the open space there is a dinghy garage. There is some open space on the upper deck. There is no flybridge on the top of the wheelhouse, but on the roof there is a large hatch which can be opened.

1.1.3 Structure of the boat

The boat is built of glassfibre reinforced plastic (polyester/glassfibre). The main framing is longitudinal and it is supported by transverse bulkheads. The glassfibre-reinforced parts are cast in a mould and attached to each other.

The bottom frame also forms the engine bed for the engines. It was discovered that the part of the frame which had been pre-cast in a mould had been cut between the engines and the drive unit. Aftwards from there the frame had been replaced by the glassfibre reinforced plastic mount ring of the Volvo Penta IPS drive unit and by an extra stringer attached to it (Figure 3).

Figure 3. The rear part of the bottom frames has been replaced by a Volvo Penta mount ring and the stringers supporting it. The picture was taken after the engines were demounted and the engine compartment was cleaned.

On the basis of the test samples taken from the damaged area, it can be concluded that the bottom is compact laminate and the transom is a sandwich structure, the core material of which is resin-impregnated microbead mat. There are four longitudinal stringers in the bottom and at the bulkheads there are high transverse stringers (Figure 4). The stringers are cast in a separate mould and glued to the hull by using glue mass (Figure 5).

Figure 4. The structure of the bottom at the engine compartment.

Figure 5. The way the bottom frames are jointed to the hull. The stringers were not completely jointed to the bottom. The fitting had been done by using glue filler.

The interior is mainly wood. The supporting structures are plywood or glassfibre reinforced plastic.

Bulkheads are laid on the transverse stringers without any solid and tight joint to them. Between the plywood bulkheads and the frame there is a gap of a couple of centimetres which has been filled with elastic cellular plastic (Figure 7).

The deck and upper structures have been fitted to the hull at the sheer.

1.1.4 Engine compartment

The engine compartment (Figure 6) is located at the aft of the boat and it confines to the transom. It can be reached through a hatch located on the after deck. Two diesel engines functioning as propulsion machinery were located in the engine compartment, and one enclosed diesel generator was placed between them, close to the transom. In addition, the boat's fuel tanks were located in the engine compartment, on both sides of the boat.

Figure 6. The engine compartment of the accident boat after it had been cleaned. The cardboard boxes contain equipment related to repairing the engines after the sinking and they are not related to the accident.

The engine compartment has been separated from the rest of the boat by a plywood bulkhead, which joins with the top of a transverse frame (Figure 7). The plywood does not, however, quite reach the glassfibre reinforced frame but there is a gap as wide as one's hand. This gap has been sealed with elastic cellular plastic (Styrofoam). Hoses and electrical wires between the engine compartment and the rest of the boat have been led through the gap between the bulkhead and the frame within the bounds of elasticity of the cellular plastic. The structure is not watertight, but judging by the double plywood bulkhead, the boat manufacturer has felt a need to isolate engine sounds efficiently. Because the structure was not intended to be watertight, it was not deemed necessary to study progression of flooding in closer detail.

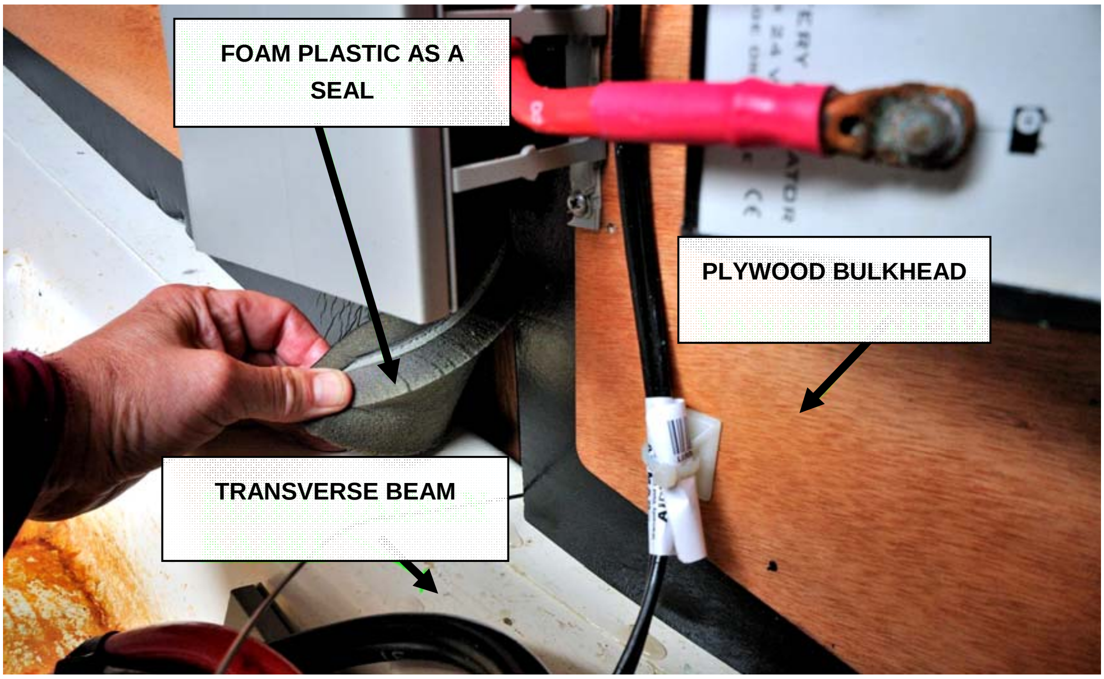

Figure 7. The plywood bulkhead and the bottom frame had not been fitted closely together. The gap was sealed with loose Styrofoam.

1.1.5 Machinery

The propulsion machinery of the boat includes two Volvo Penta IPS500 diesel engines equipped with two IPS-type sterndrive appliances (Figure 8). In the drive unit there are forward-directed, counter-rotating propellers. The machinery in its entirety is a standard model Volvo Penta delivery which in practice includes everything related to the machinery excluding only fuel tanks and their piping systems.

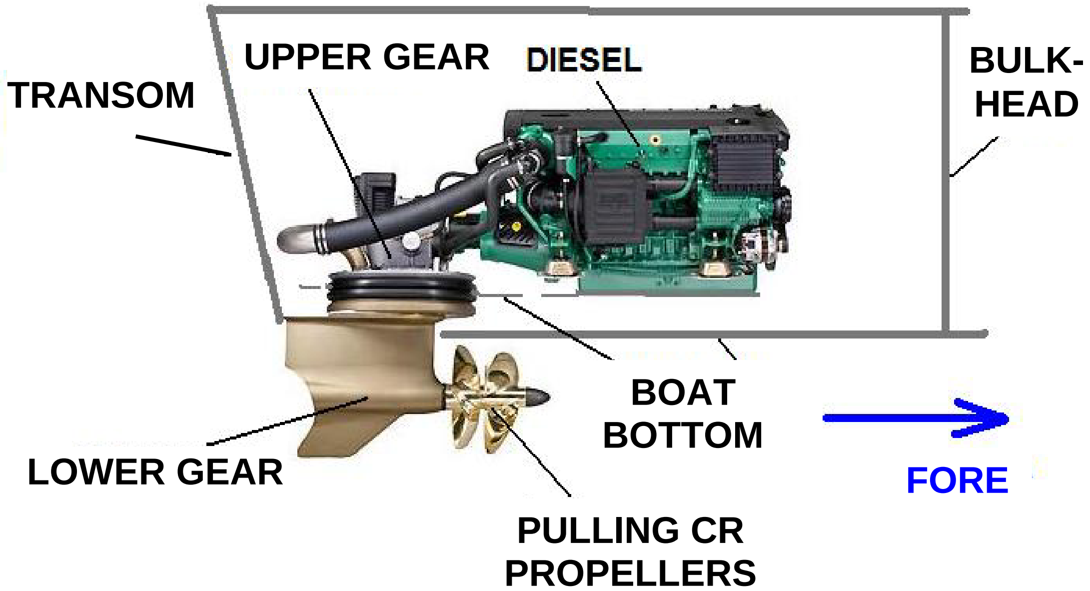

Figure 8. Volvo Penta IPS 500 diesel and drive unit, the principle of the mounting to the boat. (The picture is based on a picture in a Volvo Penta brochure)

Diesel engines, technical particulars in short (per engine):

Engine Displacement	5500 cm^3
Cylinders	straight 6
Crankshaft power	272 kW
Propeller shaft power	259 kW
Weight	887 kg (the whole unit including the drive unit etc.)

The engines were supercharged and intercooled.

Drive units

The drive units have inside the boat angle transmission-type upper gear, collar bushing realised tightly through the bottom and under the bottom of the boat also angle transmission-type lower gear. The lower part of the drive unit forms a unit resembling an outboard motor; the direction of the thrust can be controlled by turning it. Under the lower gear there is also a fin which functions as a course-stabilizing rudder.

The drive unit has pulling, counter-rotating propellers. The exhaust gas is discharged underwater to a channel which is an extension of the gear of the drive unit. The material of the underwater part of the drive unit and the propellers is bronze, "T5 nibral" according to the brochure on the propellers.

An IPS drive unit has been designed to break in a controlled manner when touching ground in such a way that there is no leakage in the boat. According to Volvo Penta, the functioning of the drive unit and the endurance of the mounting have been simulated and tested in practical experiments. Volvo Penta does not, however, guarantee that the drive unit would break loose in a safe manner in all collision situations.

The drive units have been described in closer detail in Appendix 1.

1.2 The accident event

At the time of the accident, the wind was blowing approx. 7–8 metres per second from bearing 248°. The sun was shining from bearing 287° and its angle of altitude was 15 degrees. The weather was clearing up. The investigation has not looked into the direction or the height of waves.

The accident boat was new. It had been handed over to the skipper on Tuesday 25 May 2010, when the skipper had then driven the boat on her transfer journey from the quay of the vendor to the home-quay in Espoo. The boat had been tested during the voyage, and in this connection for instance a wheel over turn had been completed. According to the skipper he had been boating his whole life and with reasonable big boats (over 10 m). He had passed the inshore navigation course and he was on the coastal navigation course at the time of the accident. He had sailed approximately 300 hours during the summers 2008 and 2009, which describes his boating activity. He was familiar with the Southern Finland's coastal fairways.

The accident voyage started on Friday afternoon on 28 May 2010 at 18.00–18.30. The voyage proceeded via Porkkala and Upinniemi end over the open sea of Porkkala and then north of Vormö Island along the 5.5-metre deep coastal fairway. The final destination was Ekenäs. There were eight persons onboard, three adults and five small children. The navigation method consisted of a simultaneous use of a paper chart and chart plotter. In the chart plotter, the radar image had been placed on the chart image and the whole plotter display was used by the chart.

For the first part of the voyage, the skipper drove the boat in a standing position with his head out from the open roof hatch. At the open sea of Porkkala, the roof hatch was closed and the skipper sat down and kept lookout through the windows of the boat. The visibility from the helm is then distinctly poorer due to the lowness of the window, its distance and the broad window frames than when manoeuvring the boat while standing at the open roof hatch. Because of this, the speed had been reduced from 27 knots to 23 knots. According to the skipper, the evening sun was glaring directly into his eyes.

The boat passed the green spar buoy northwest of Fagerö by driving on the port side of the fairway area, and instead of yawing proceeded on her earlier course aiming to navigate gently into the northeast-bound fairway and from there to the 13-metre deep fairway leading to Inkoo. Immediately after the turn the skipper suddenly changed his mind and turned the boat back to the 5.5-metre fairway. In the fairway intersection there was an underwater rock which was marked on the chart and indicated with an east sparbuoy. The skipper was aware of the existence of the rock. He therefore decided to make a turn via starboard approx. 270° thus aiming to use the turn to return to the 5.5-metre fairway which he had used earlier but which now led to southwest.

The turn was carried out in two phases (Figure 9). First the boat was turned quite sharply to the return course and after a while a new turn was completed to the presumed navigation line and the direction of the 5.5-metre fairway. According to the skipper, the turn was monitored with the help of a compass at the beginning and end of the turn. During the turn the progress was monitored on the chart plotter by using an HDG heading vector. According to the skipper, at the end of the turn his eyes were fixed on the sea view, not on the chart plotter.

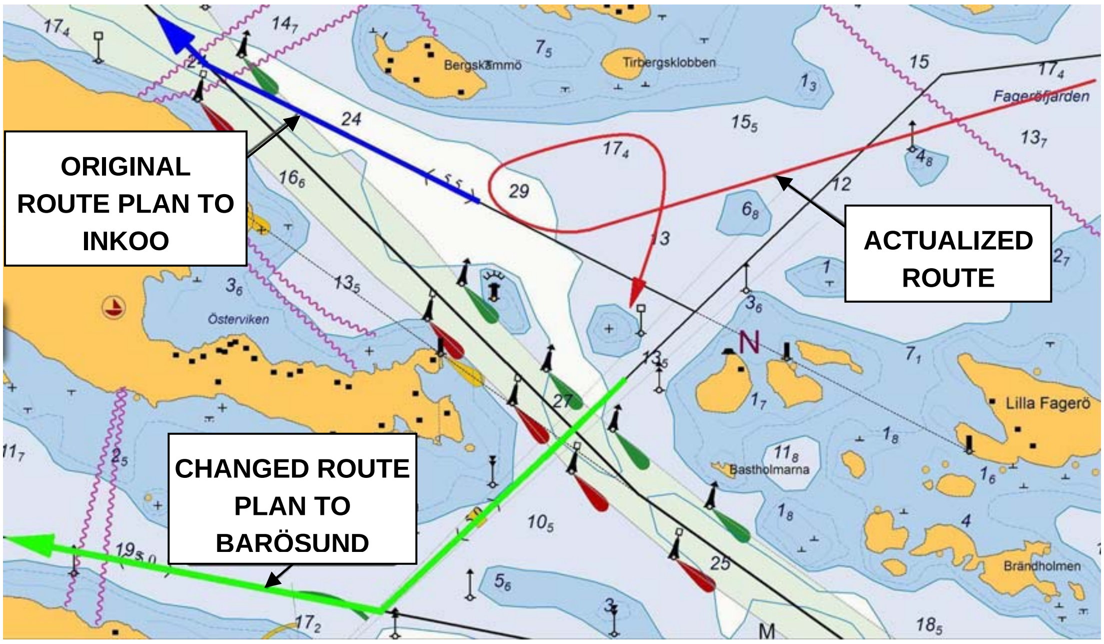

Figure 9. The boat's turn towards Inkoo and return again towards Barösund based on what the skipper has told. The course after the turn might have been to a greater extent in the line with the 5.5-metre fairway than what is described here. The red lateral spar buoy next to the rock had been changed into a cardinal spar buoy before the accident. (Chart: The Finnish Transport Agency, presented using Uusi Loisto programme)

According to the skipper's estimate, the speed was reduced to 18 knots in the curve. When the speed dropped, the aft of the boat sank and the visibility through the windscreen deteriorated. The bow of the boat was somewhat elevated immediately after the turn, but came quickly down as the speed increased back to 20–22 knots.

According to the skipper, the evening sun affected the lookout in such a way that the rock could not be perceived visually and it was not possible to discern clearly the colours of the cardinal spar buoy. The skipper has told that he thought that the turn took the boat to the 5.5-metre fairway. In reality the boat had turned too sharply and her course led it directly aground.

The boat ran aground at 19.50. It continued with her old speed over the rock and stopped after it because the engines did not run any longer. The boat sank (Figure 10) and because of this was a constructive total loss. There were no injuries to persons.

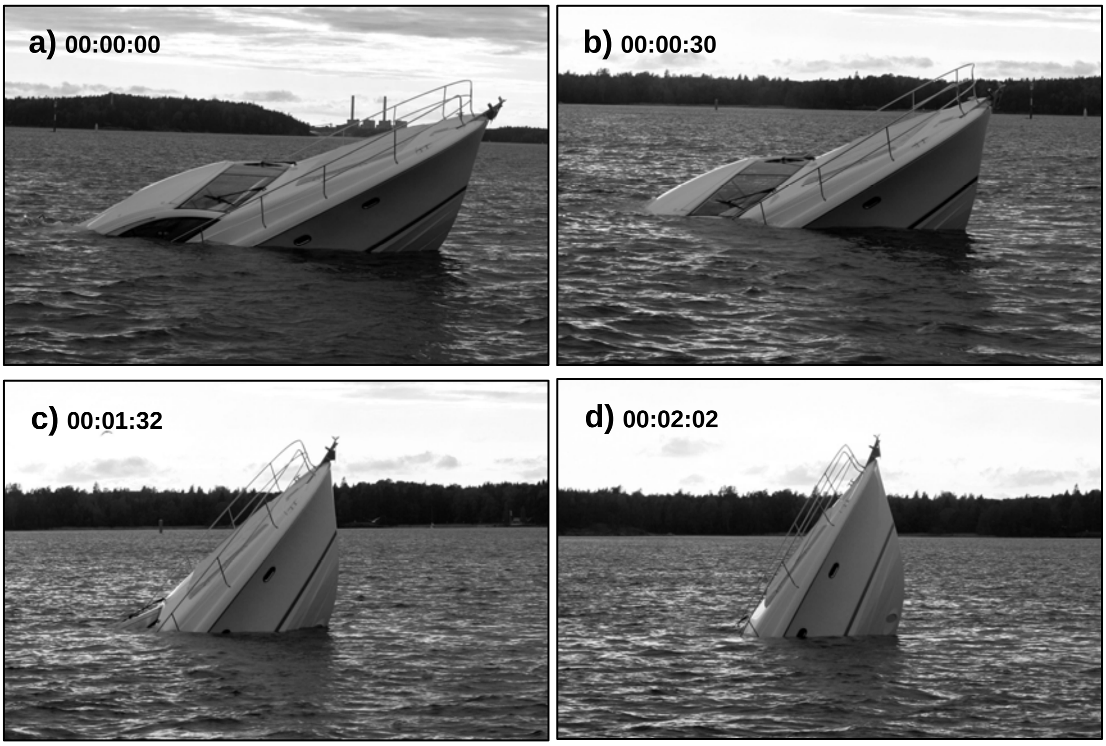

Figure 10. The sinking of the boat photographed onboard P/V FAGERÖ. The timeline marked on the pictures illustrates the speed with which the boat sank. The time in the first picture in the series has been set to zero. The times have been obtained from the EXIF file of the photos. The persons onboard the boat were rescued approx. 10 minutes before the first photo (10a) was taken. (© Max Weckström)

1.3 Special investigations

1.3.1 Investigations onboard the accident boat

The boat was examined in the dock hall after it had been lifted on 31 May 2010. The following observations were made concerning the boat:

There were no marks on the bottom or elsewhere in the glassfibre hull caused by the boat hitting the rocks. The transom had been torn off from the bottom of the boat on the starboard side for the most of its breadth. The joint was open more than 10 cm. On the underside of the swimming platform there was an impression which matched the rear edge of the drive unit. On the starboard side the trim tab had cut a hole on the underside of the swimming platform.

The drive units had not broken off from their mounting brackets at the plane of the bottom. They were still attached to the bottom. The starboard drive unit was more badly damaged than the portside one. The propeller shaft of the starboard side drive unit had bent upwards, the fin of the drive unit had broken off and one propeller blade had come loose. One of the two O-rings sealing off the bushing of the drive unit had partly come out. The propeller shaft of the port drive unit was straight and there were no marks on the fin. Propeller blades had deflections and there were pieces missing from them. The mounting plate of the drive unit in the bottom of the boat was attached, unbroken and straight. There were strong impact marks on the drive unit and the fin was deflected to the side.

In the engine compartment there was a fairly steep step between the engine bed and the sterndrive units which was attributable to the structure of the boat[3]. The bottom of the vessel was deflected inwards at this point. There were cracks on the sides of the mount collar of the drive unit and in the stiffener beams of the bottom. The driving shaft of the starboard engine had broken loose from one end from the flywheel casing, and at the other end the tongue had become loose from the groove; the driving shaft was found on the bottom of the boat, on the starboard side near the transom.

The wheelhouse is located aft from midships. The heavily backwards inclined windscreen is located approx. 2.4 metres in front of the operator. The whole front part of the wheelhouse roof opens up in the form of a large hatch which makes it possible for the operator to drive in a standing position while at the same time keeping lookout over the windscreen. When the roof hatch is closed, the effective observation height forward between the dead zone formed by the upper edge of the windscreen and the steering console is 260 mm. The distance to the operator's eyes is approx. 2.4 metres. Windscreen side pillars form lateral dead zones which are approx. 250 mm wide. Lookout astern takes place through the back wall of the transparent wheelhouse. The measurements taken on the wheelhouse are presented in Figures 11 and 12.

In the wheelhouse the engine levers were running idle in forward-position and the switches of the boat's bilge pumps were in ON-position. A nautical chart was open and showed the chart of the accident position.

3 A steep step makes a so-called notch-effect possible; the stress directed to the bottom structures is higher at the notch than at other points.

Figure 11. General view of the wheelhouse from behind the helm position. The picture was taken onboard the accident boat in the dock hall soon after the boat had been lifted. The height of the windscreen is 330 mm, the operator's console restricts field of vision from the lower part in such a way that the effective height for the visibility is 260 mm. The side pillar is 250 mm wide.

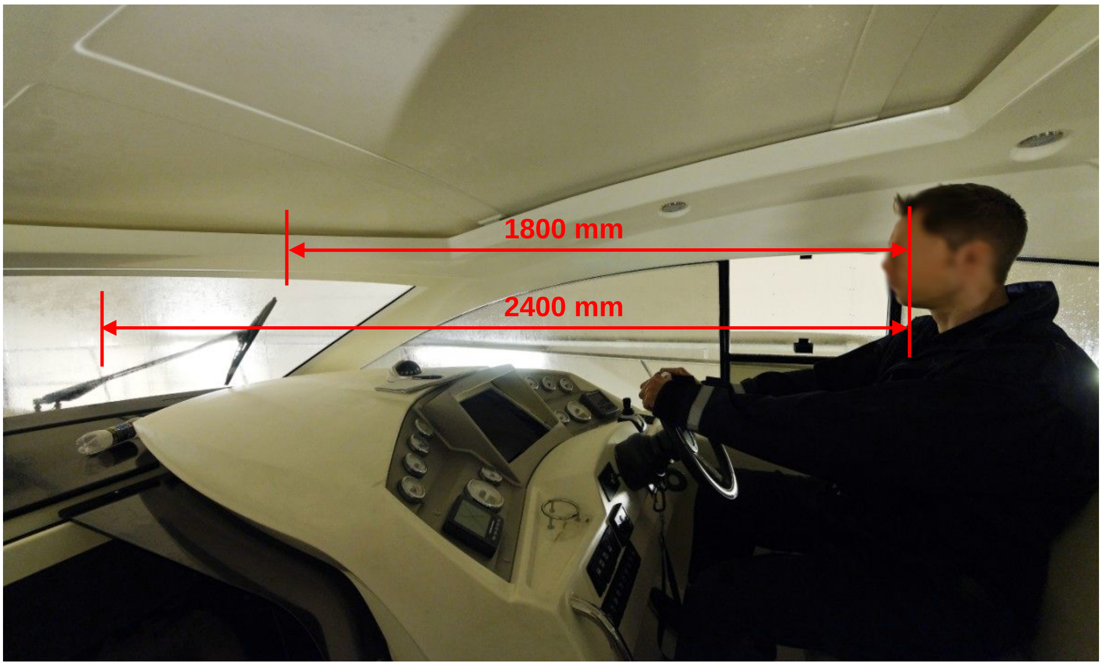

Figure 12. The helm position when the operator is in a sitting position and the roof hatch is closed. The picture was taken onboard the accident boat in the dock hall soon after the boat had been lifted. The distance from the top of the window to the operator is approx. 1800 mm and from the middle part approx. 2400 mm. The upper window beam is exactly in the middle of the visual field of the person seen in the picture. This person shown in the picture is somewhat taller than the skipper of the accident boat.

Figure 13. The helm position while the operator is in a standing position and the roof hatch is closed. When operating the boat in a standing position, there are two heights to choose from. The picture was taken on the accident boat in the dock hall soon after the boat had been lifted. The person shown in the picture is somewhat taller than the skipper of the accident boat.

1.3.2 Investigations on the accident site

According to the divers' approximate visual estimate there was about 60 cm of water above the shoal. There was about 30 cm of water somewhat further in the direction of the boat's heading. Distinct marks left by the boat could be seen on the shoal, and parts which had come loose from the drive units and propellers were in the immediate vicinity of these marks. On the basis of the marks left on the rocks the divers concluded that only the drive units had touched the ground and that the keel had not hit the bottom. Judging by the marks, the heading of the boat was approx. to southwest at the time of the grounding. There was no loose matter on the rock in any degree worth mentioning.

1.3.3 Technical investigations – executive assistance from the Finnish Transport Safety Agency

The investigators asked executive assistance from the Finnish Transport Safety Agency in the form of looking into the requirements compliance of the structure of the hull and the engines. The Boating Unit at the Finnish Transport Safety Agency concluded in its answer that according to a preliminary investigation there is reason to question the strength of the hull at least in the stern and transom areas.

According to the Finnish Transport Safety Agency, assessing requirements compliance of the accident boat has been completed in accordance with the Aa-module, i.e. an internal inspection of the production completed with tests. The inspecting establishment

(ICNN) has only assessed the boat as to the essential safety requirements as stipulated in the sections 3.2 and 3.3 of the Recreational Craft Directive, i.e. stability, freeboard and buoyancy. The assessment of other essential safety requirements has remained the responsibility of the manufacturer.

In its final statement on 3 August 2012 the Finnish Transport Safety Agency notified that on the basis of the investigations by the French authorities and technical documentation there is no reason to doubt the requirement compliance of the structure of the boat model in question.

1.3.4 Examining the laminate of the hull

Test samples were cut for more detailed investigation from the structure at the jointing area of the transom and the bottom. The test samples were examined by approximate visual observation and by measuring. The photos in Figures 14 and 15 portray the details of the test samples.

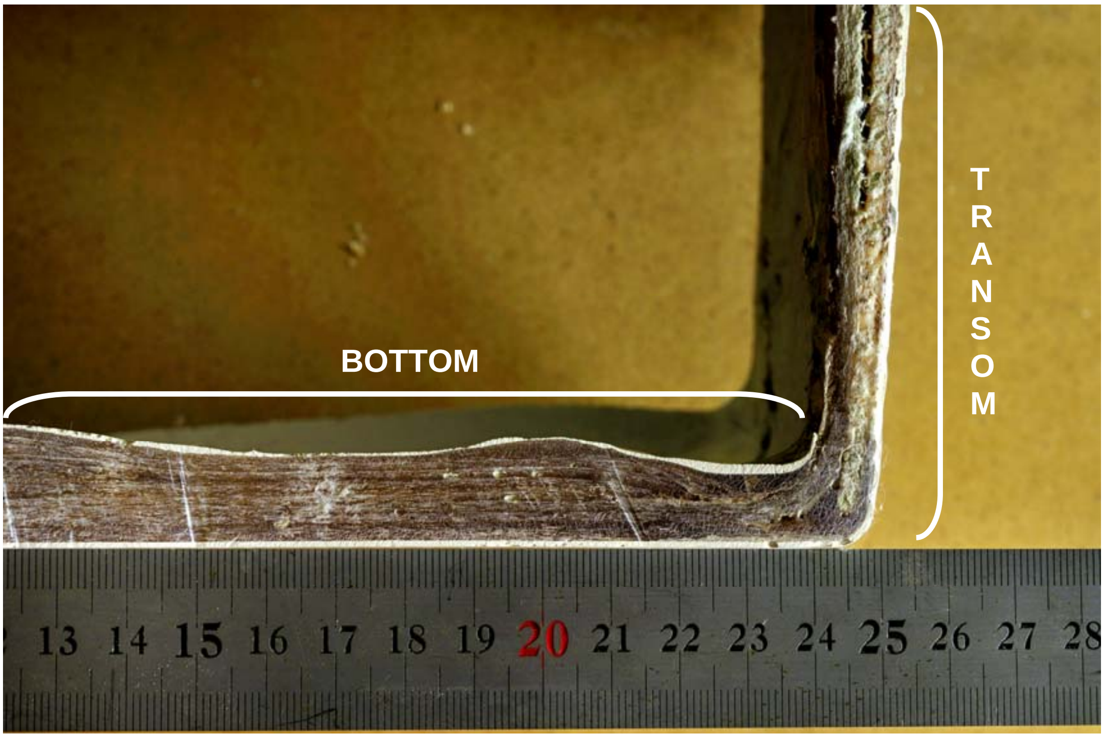

Figure 14. The picture shows a test sample cut from the hull of the boat, from the area where the bottom and transom come together. The test sample was cut off from the port side of the hull, which had remained intact, i.e. where the laminate had not torn. The thickness of the transom is at its lowest approx. 8 mm as shown in the figure. Approx. two 1.5-mm layers of this are glassfibre laminate. Between the laminates there is filling material which appears to be microbead mass and which makes the texture sandwich structure.

Figure 15. Laminate from the lower corner of the transom from the starboard side of the boat, from the area where the bottom and transom got torn. The figure illustrates the high resin content and the ending of the woven cloth, i.e. rowing-layers, immediately before the corner.

1.3.5 Examination of the Volvo Penta IPS drive unit

The drive units of this accident boat were examined externally while the boat was in the dock hall. The drive unit of IDA 1 boat which sank in a similar accident was disassembled and examined in connection with investigation C4/2010M. The investigation results are presented in Appendix 2 of this investigation report. Broken parts from the drive unit were sent to the Technical Research Centre of Finland for more detailed investigation.

1.3.6 Quality systems and directives

The manufacturers of the boat and the engines use the following quality systems which have been applied to the design and production of the accident boat and its engines.

Volvo Penta: According to the brochure information, Volvo Penta has in force ISO 9001 Quality System Certification on design and production and ISO 14001 Environment Management System Certification. The French Bureau Veritas is the certifier.

Jeanneau: The boat is certified to the boat design category b of the Recreational Craft Directive. The certifying establishment is Institut pour la Certification et la Normalisation dans le Nautisme (ICNN). The Finnish Transport Safety Agency (former Finnish Maritime Administration) is responsible for the market surveillance of the boat when sold in Finland.

No application requirements on a quality system are related to the operating the boat and such have not been applied.

According to SPBI, the manufacturer of Jeanneau boats, the boat complies with the requirements of the Recreational Craft Directive.

According to the manufacturer, the vessel complies with the CE standard approval by the French classification society the Bureau Veritas. The technical requirements have been verified by using the standard approval of a larger 46-foot boat in such a way that the structure is thus suitable also for the 42-foot model. According to the manufacturer, the boat complies with the Bureau Veritas, the Germanischer Lloyd and ISO regulations.

According to the investigators' understanding, the supervision of construction phase of the boats has been carried out by the company's own control mechanism without any external construction supervision.

2 ANALYSIS

2.1 Breaking of the hull bottom

When the drive unit hit the rock, a backward force was directed to it. By lever arm principle it leaned on the bottom of the boat in such a way that a force downwards was directed to the bow end of the drive unit and a force upwards, i.e. inwards, was directed to the aft end. This broke loose the bottom plate which was mounted weakly to the transom, and a transverse gap was formed in the bottom (Figure 16).

Figure 16. Tear in the bottom of the boat. The corner between the transom and the side of the boat has been marked with a green line, the bilge of the boat with an unbroken red line, and a red broken line has been used to illustrate the laminate going from the transom to the bottom of the boat. This laminate was torn loose from the actual bottom laminate. A black arrow indicates the direction of the bow.

The mount ring of the starboard drive unit broke partly loose from the bottom of the boat because it was mounted weakly. The large O-ring of the mount collar of the IPS drive unit slipped out from its grooves. This caused extra leakage into the engine compartment.

Some joints of the longitudinal stiffener beams came loose from the bottom. They did not cause leakage, but the observation indicates that the fastening of the beams with the glue mass used by the Jeanneau factory is not strong enough.

Clay in the engine compartment

It was discovered in the dock hall that a large amount of clay had broken into the engine compartment. Because, according to the divers' observation, the impact area of the rock was clean from clay or larger loose matter, the clay must have entered the engine compartment after the boat had sunk stern foremost to the adjacent deep. During the lift the boat was moved back and forth against the bottom, which has caused the loose lower edge of the transom to work like a cheese-slicer scraping clay inside the boat. At the same time the starboard side of the transom has also torn loose more extensively in such a way that the trimplan has hit the bottom of the swimming platform and left visible marks on it (Figure 17). These findings do not result from the collision itself.

Figure 17. The transom of the boat. The laminates of the bottom plate and transom separated from each other in the collision thus leaving in the bottom of the boat a gap the width of which was half the transom. Water filled the engine compartment and the whole boat from this gap and from the opening left by the broken IPS drive unit lead to the sinking of the boat. The transom was torn more loose when the boat was lifted, and the trimplan pressed to the swimming platform the crack visible in the picture. The gap scraped clay from the sea bottom into the engine compartment while the boat was moved along the sea bottom.

2.2 The boat's drive units

2.2.1 Functioning of the drive units in the collision

As there were no collision marks on the hull of the boat, it must have passed over the shoal without hitting it. The drive units, on the contrary, have hit the round edge of the shoal abruptly and the whole impact energy has been directed to them. The glassfibre pieces found on the sea bottom originate from the breakage point of the hull. The ground touching had impact on both drive units, whereof the starboard one was more badly affected. The drive unit did not cave in, which meant that the force directed to it turned it backwards thus breaking the weakly manufactured joint between the transom and the bottom. The skipper noticed this from the wheelhouse as a grinding sound and later described that the collision was smooth and the sounds were faint. Seawater could flood directly into the engine compartment from the large tear between the transom and the bottom, and from there to the cabin spaces through the unsealed intermediate bulkhead.

Both drive units have hit the sea bottom in a similar way, but because the shoal was higher on the starboard side of the boat, the starboard drive unit received a stronger impact which caused a break in the bottom of the boat. The port drive unit hit the shoal with a strong impact, but the bottom of the boat withstood the forces caused by this.

Starboard drive unit

The impact has started in the propeller. It has deflected the propeller shafts abruptly upwards, which has resulted in the drive unit gear getting stuck. The course of events has been very quick, because the uppermost blade of the stern side propeller has not hit anything, i.e. the stopping of the propeller has taken clearly under one propeller rotation.

The quick stop has caused very high torque reactions in power transmission. Because of this, the flexible coupler between the engine and the upper gear has broken, and the driving shaft has hit upwards and broken the cast metal casing between the engine and the upper gear. A deep impact mark corresponding with the grooving of the shaft was left on the casing. The end of the shaft flew upwards and hit the side of the hatch leading to the engine compartment. The impact mark can be seen both on the inside and outside.

After this the shaft has come loose from its grooving and flown upwards and hit the side of the hatch leading to the engine compartment. From there the shaft has flown further to the bottom of the engine compartment, where it was found after the accident.

Figure 18. The broken flexible coupler and the metal casing broken by the shaft.

Figure 19. The impact mark above the hatch of engine compartment. The mark was caused by the end of the shaft hitting below the side of the hatch of the engine compartment.

Figure 20. The gear teeth of the driving shaft correspond with the marks on the broken connecting casing thus proving that the shaft has hit the casing with a great force.

In addition to the propeller, also the skeg of the drive unit has received a severe blow from below. The skeg has broken loose by caving in to port.

Figure 21. When fitting the skeg of the starboard drive unit back into its place, it could be observed that it had yielded to port before it had come loose. When intact, the skeg was in the same line with the body of the drive unit. The picture was taken after a test sample was cut from the transom. There is plenty of clay in the engine compartment.

Port drive unit

The port drive unit has also received an impact on the propeller and the skeg. Each propeller blade has been damaged, by approximate visual observation the shaft line is intact and the skeg has deflected to port. The impact indicates that the shaft has stopped more slowly than in the starboard drive unit. The impact to the port drive unit has been weaker than the impact directed to the starboard drive unit.

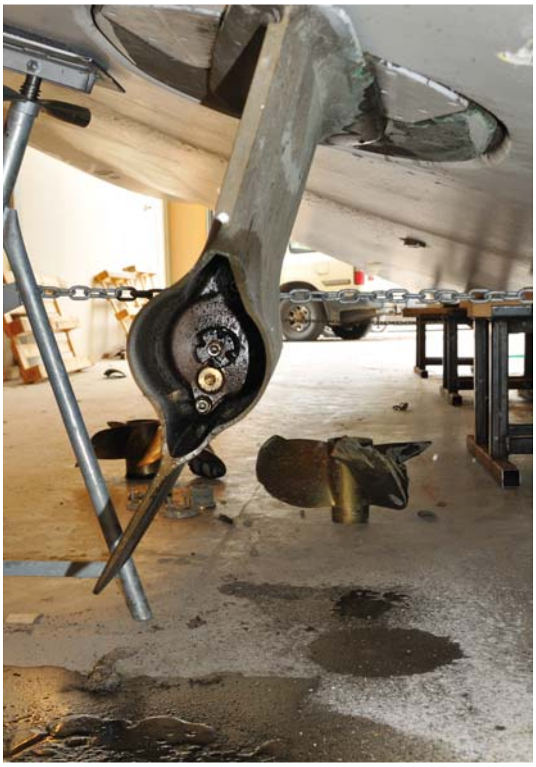

Figure 22. "The port drive unit". The skeg of also the port drive unit has deflected towards port.

On the basis of the damages it can be concluded that the boat has hit an obstruction while the stern was moving towards starboard. This kind of a situation arises when a boat is steered to port or when it hits an inclined surface sloping to port. The impact marks under the starboard side skeg show that the strong blow has come from the starboard side, but the underside of the skeg is intact. The stress directed to the body of the drive unit on the plane of the bottom was bending stress, the direction of which was diagonally backwards and to the port.

Because the boat had been in the middle of a sharp turn to starboard before the collision, the operator of the boat must have found time to straighten the heading of the boat forward or even somewhat to port at the time of the collision.

2.2.2 Structure of the drive unit – comparison with another accident

A similar type of drive unit has also been studied in connection with the grounding of the IDA 1 (investigation report C4/2010M). In the IDA 1 case one of the drive units of the vessel hit a rock and did not break in a controlled way. When one of the drive units of IDA 1 was disassembled, it was discovered that the relief groove which was meant to be the breakage point had not functioned but a crack had escaped out from the groove to the edge of the flange thus leaving the lower body of the drive unit attached to the upper body. The memorandum compiled on the dismantling of the drive unit is presented in Appendix 2 of this investigation report.

2.2.3 Strength pyramid principle as applied to the drive unit

It is worth noticing that the large O-ring between the drive unit and the mount collar attached to the bottom of the boat had slipped out from its groove (Figure 23). A similar phenomenon was discovered when investigating the IDA 1 accident. The O-ring had moved also in that drive unit of Jeanneau which otherwise stayed in its place and was intact as to its structure (Figure 24). On the basis of this it can be concluded that a strong shift of the drive unit in its mounting alone can cause the O-ring to slide from its groove without causing any special damage to the structure of the boat or the drive unit. If the O-ring does not stay in its place, the result is a severe risk of leakage. From a technical point of view, whether the O-ring stays in its place and the drive unit breaks in a controlled way are two separate, unrelated phenomena.

Figure 23. The O-ring between the drive unit and the glassfibre mount collar had slipped out from its groove thus generating an extra point of leakage. Note also that the laminate had broken at the mount collar.

With reference to this accident it can be suggested that the bottom of the boat yielded in the collision to an extent that not enough stress was generated to break off the drive unit. Because the O-ring nevertheless slipped out from its groove, there are reasonable grounds to claim that the strength pyramid principle designed for the IPS drive unit does not work and that improvements should be made in the structure of the IPS drive unit.

Figure 24. The O-ring of the port drive unit had also slipped out even though the impact on this drive unit was weaker.

2.3 The boat

2.3.1 Suitability of the boat for the voyage

The accident boat was as to its model, size and crewing suitable for the voyage. The boat design category in accordance with the Recreational Craft Directive was high enough for the voyage in question.

2.3.2 Equipment and inspection

The accident boat was new and it had been provided with adequate safety and navigational equipment. Some pieces of equipment were still in the sales packaging but nothing suggests that this would have hindered for example rescue activities.

In Finland there is a national boat inspection system operated by boating associations. Within the framework of this system, boats are inspected by yachting societies and their state and equipment are examined. To undergo such an inspection requires membership in the society, and is not mandatory by law.

The accident boat had not been inspected at a yachting society. This fact did not affect the occurrence of the accident. Because the accident boat was new, it would have been unlikely that the defects which led to the sinking of the boat would have been discovered in the inspection. Because the boat was new, it would have been exempted from hull inspection and in any case the inspectors would not have had any possibilities to assess the strength of the bottom. The inspector might have drawn attention to the visibility from the helm and instructed the owner to always keep the roof hatch open when driving the boat. This would have, however, remained a recommendation, and following it would have depended on the will of the operator and perhaps of the whole crew at the given time.

2.3.3 Visibility from the wheelhouse

Jeanneau Prestige 42S[4] is to its style a sporty yacht. In addition to a high maximum speed, a modern and brisk design with long bow and inclined windscreen characterise the boat. The boat type in question does not have an upper wheelhouse, a so-called Fly Bridge, which is typical for larger boats.

According to the skipper, the visibility from the helm position clearly deteriorated when the roof hatch was closed at the open sea of Porkkala on the request of those onboard the boat. The deterioration was caused by the lowness of the window and long distance to it when compared with the extensive view the open roof hatch provided. The skipper reduced the speed from 27 knots to 23 knots.

When examining the boat in the dock hall, the investigators also concluded that the visibility from the helm position was restricted (Figures 11 and 12). Therefore the Investigation Commission included in the request for executive assistance sent to the Finnish Transport Safety Agency an assessment request on the requirements compliance concerning the field of vision of the operator of the boat.

The Finnish Transport Safety Agency inspected the field of vision from the helm in accordance with the ISO standard[5]. The inspection was carried out without any accurate measuring instruments or drawings, and the result is thus an estimate of the standard compliance. In the examination the Finnish Transport Safety Agency concluded that the field of vision from the helm position is unhampered except for the side beam of the starboard side windscreen which formed a visual obstruction. Without drawings and an accurate measuring instrument the Finnish Transport Safety Agency could not say whether the dead zone was larger than allowed in the standard. Later on the Finnish Transport Safety Agency has investigated the matter and concluded that the visibility complies with the requirements of the EN ISO 11591 Standard.

Even though the field of vision from the helm position forward fulfils the requirements, one still has to take into consideration that the effective observation height restricted by the very inclined windscreen, the broad side pillars of the windscreen and by the operator's console and the bow is a safety risk for a boat with the maximum speed of 40 knots. This is further emphasized by the long bow which reaches approx. 7.5 meters forwards from the operator and by the long distance between the windscreen and the helm. Furthermore, if the operator is tall, the upper window beam is at the level of his/her eyes.

The operator of the accident boat was aware of the restricted visibility and reduced speed after the roof hatch had been closed earlier during the voyage. A reduction of speed by four knots is, however, not that significant with reference to the control of the vessel.

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4 The letter "S" in the name of the boat originates from the words "Sport Top".

5 International Standard EN ISO 11591:2000, Small craft, engine-driven – Field of vision from helm position

The restricted visibility from the wheelhouse and the reliance only on optical navigation contributed to the grounding of the vessel after a quick turn.

Keeping the roof hatch closed on the archipelago fairways was a contributing factor in the accident. Restricted visibility from the wheelhouse and relying only on optical navigation contributed to the vessel running aground at the end of a brisk turn.

2.3.4 Hull structure

The bulkheads of the boat were not watertight. The boat had not been designed in such a way that it would have remained afloat if the engine compartment made water. A hole or other leakage at any point of the hull results in the sinking of the boat. The Recreational Craft Directive does not require existence of compartments, but a boat of this size can be constructed in such a way that it fulfils such a requirement. According to the investigators' view, those who buy these kinds of boats are not well-informed on the matters related to the safety of the boat nor are they interested to require a safety level which exceeds the official requirement level.

Glassfibre reinforced plastic

Glassfibre reinforced plastic is composed of fine fibres of glassfibre and of polyester resin which binds the fibres together. The strength of the material is based on the strength of the fibres. The function of the resin is to tie the fibres together in such a way that the load is divided on several fibres. At the same time the structure becomes compact.

When building a boat, the glassfibre material is transported as mould-woven cloths (rowing) and as mats pressed from approx. 50 mm long staple fibres. When laminating, the glass layers are impregnated with liquid resin and then compressed carefully against the surface of the mould so that any air disappears. When the resin hardens, the result is a stiff and hard glassfibre laminate. The proportion of glass has an effect on the strength of the material: 40 percent by weight is considered to be the normative minimum, but a good-quality laminate contains even more glass. Using only resin to make the structure thicker does not bring any more strength but reduces impact resilience.

With reference to strength, it is of uttermost importance that the glassfibres reach without breaks over discontinuity points, e.g. over corners. This should apply to for instance the corner between the bottom and transom. If the glassfibre layers are cut on both sides of the corner, the result is an overly weakened structure and adding resin to the corner area does not improve the situation.

When jointing by using glassfibre reinforced plastic, one has to take into consideration that a new layer does not stick to the sleek surface made against the mould (Gelcoat). In order to achieve adhesion, the joint surfaces have to be made coarse.

Structure of the bottom of a Jeanneau Prestige 42S boat

According to the manufacturer, the Prestige 42S boat has only been constructed equipped with IPS drive units and the boat type is especially designed for IPS drive units.

In an IPS drive unit the thrust of the propellers is directed to the bottom instead of the transom, which means that special attention should be paid to the strengthening of the bottom and to the quality of the supportive structures

The bottom stringers intended for the stiffening of the bottom had been attached to it with glue mass (Figure 26) and not at all by laminating with glassfibre layers as should be done in a proper structure. There were large holes and gaps in the jointing of the stringers (Figure 27) partly due to poor measurement accuracy and approximate positioning of the parts. This kind of structure is not as strong as it could be if it was constructed in the correct way.

From the perspective of the mechanics of materials, the structure comprises discontinuity points which make the structure weaker. The marks on the bottom of the boat show that the structure has cracked and yielded in several places.

Figure 26. Picture of the engine compartment after it had been cleaned and after the engines had been removed. The blue line indicates the location of the bottom stringers and the points where they have been cut off and attached to the mount ring. The joints had been laminated over a sleek surface, and in addition, from the mechanics of materials perspective, precarious discontinuity points weakening the structure were formed.

Figure 27. Bottom stringers have been jointed to the hull with glue mass. The fitting of the parts has not been accurate.

Figure 28. The stringers of the bottom and jointing them to the mount ring. According to the investigators' view, all the gaps visible in the picture have not been caused by the accident but the parts have been loose from each other already before the accident. This is indicated e.g. by the topcoat partly flowing down under the joint surfaces. The strength of the structure is questionable considering the fact that in an IPS drive unit the thrust moves to the hull by the transmission of this structure.

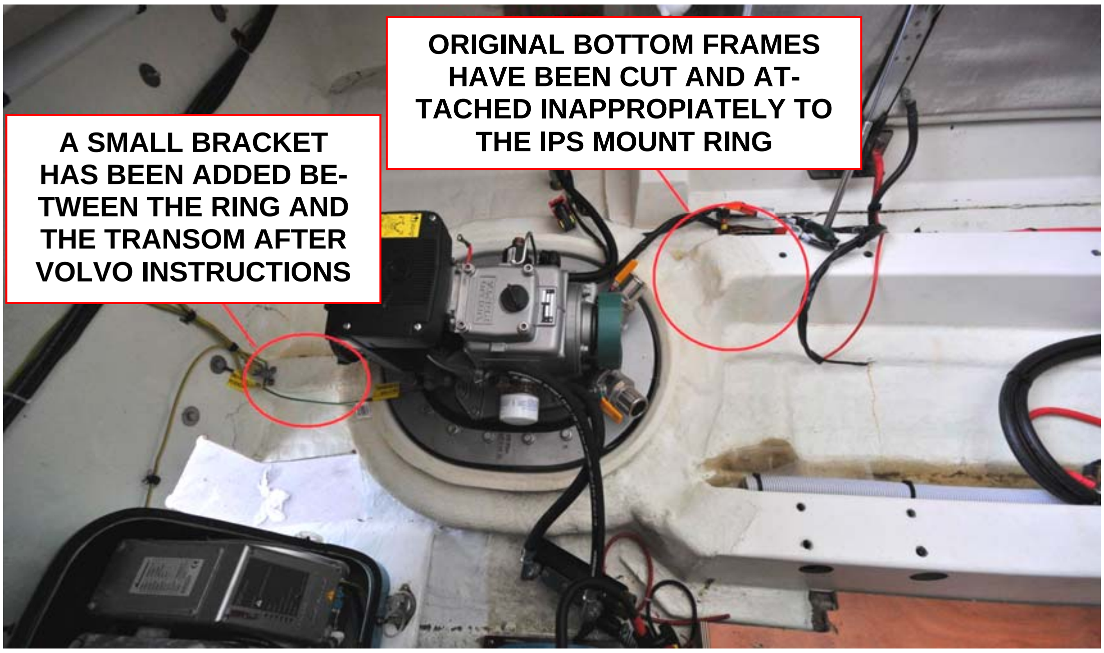

Figure 29. The IPS mount ring has been attached to the bottom frame by cutting off the stringers and then making between the ends of the stringer and the ring a poorly completed joint from the point of view of strength. The picture portrays the port engine bed which remained intact. The point between the bottom and the transom from where the test sample was cut can also be seen in the picture (Figures 14 and 15).

The lamination between the bottom and the transom had been completed incorrectly. Judging by the way of tearing off, the glassfibre layers of the transom had been laminated in one go on the bottom somewhat towards the bow from the transom. After this, the layers of the bottom had been laminated in one go on the previous layers and only the flexible mat layers had been led over the corner between the transom and the bottom.

Figure 30. In the picture taken after the test sample had been cut it can be clearly seen how the transom and the bottom have torn loose from each other. Reinforcement layers have not been lapped in turns but the transom has been completed first and the bottom of the boat has been laminated on it (in a mould). The parts have come loose from each other along the joint between them. The bracket attached in a careless manner between the transom and the IPS mount ring can also been seen in the picture.

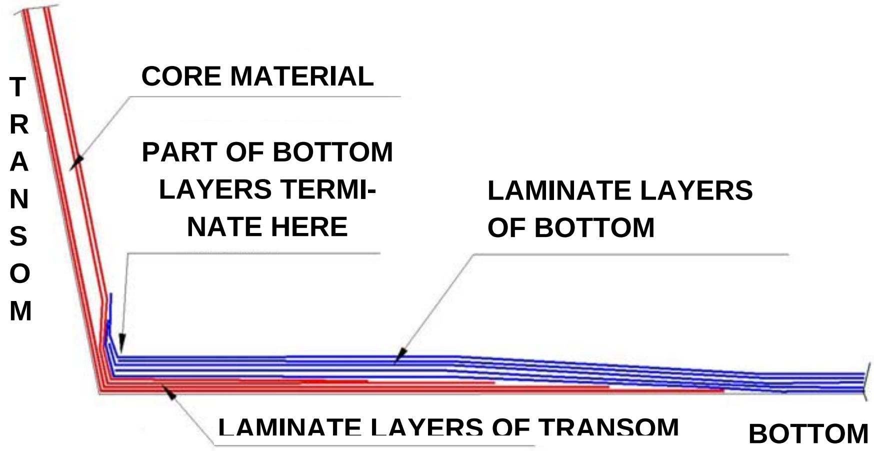

Figure 31. A principle drawing of the joint between the bottom and the transom on the accident boat. The joint between the bottom and the transom had been made by lapping layers of glassfibre. In addition, the rowing-layers of the bottom had been completed only to the corner of the transom. The transom was very thin and became sandwich structure immediately above the bottom. The figure must be compared with the profile picture (Figure 14) and with the picture taken of the broken structure (Figure 15).

The correct method would have been to laminate layers in turns thus lapping them on each other (Figure 32). Reinforcement layers should not have been cut off immediately before the corner, and the overall thickness of the laminate should have been increased at the corner area so that the stress caused by the corner would not have become too high.

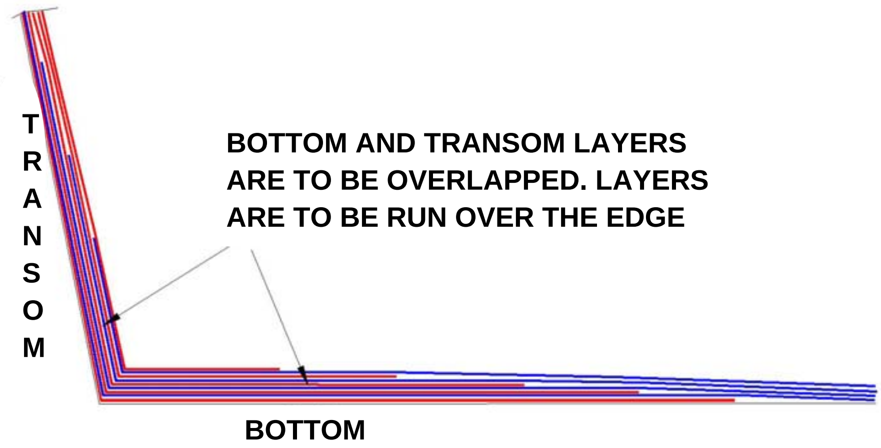

Figure 32. A properly done joint between the bottom and the transom is completed by lapping the glassfibre layers in turns and by taking all the layers over the corner. This guarantees that the bottom and the transom are jointed together and at the same time the corner area becomes thicker than the basic thickness. The corner between the transom and the bottom can also be strengthened by extra layers of glassfibre. The concentration of the propeller thrust on the boat's bottom plate next to the corner must be taken into consideration in the dimensioning. The drawing only illustrates the principle and is not on the scale.

The brackets, which had been laminated between the mount ring of the IPS drive unit and the bottom stringers of the boat, had been laminated directly to the sleek Gelcoat-surface of the bottom stringer. The adhesion of laminate to a sleek surface is weak and does not comply with the requirements on the strength structures of the bottom. In addition to this, the brackets had been made without any adequate original form in such a way that the laminate had been left to harden “on nothing”. Taking into consideration that the poor quality of work has been concentrated on the bottom of the boat and the mounting of the drive unit, this shortcoming includes a safety risk also in other situations than those similar to this accident.

Using glue mass to attach bottom stringers to the hull is not a good-quality way to make joints especially if the fitting of the stringers leaves finger-wide gaps between the stringer and the bottom. Without dealing with the aesthetic and hygienic values of the structure one has to conclude that the strength of such a joint is weaker and that it is not easy to control the stability of the joint.

2.3.5 Hull compartments

The bulkhead on the bow side of the engine compartment did not reach the bottom structures of the boat, but a gap had been deliberately left between the bulkhead and the bottom structures. The gap was sealed with Styrofoam and the obvious intention was that it would act as a noise insulating packing (Figure 33). The hoses and cables which were led through the gap further added to the leakiness. The longitudinal bottom stringers of the boat might also have functioned as leak channels, because their structure and joint to the hull were rather uncertain. Inside the bottom stringers the water can move from one side to the other in the bulkhead of the engine compartment.

Figure 33. The gap between the plywood bulkhead and the glassfibre structure was filled with Styrofoam. It serves as the lead-through point for hoses and cables. By the way of example, also the hand torch of the investigator has been pushed under the bulkhead in the picture.

2.3.6 Leakage and how it proceeded

When the transom broke loose from the bottom of the boat and the drive unit came loose from its mount ring, the engine compartment filled with water. This has happened fairly quickly. The quick stopping of the port engine also supports this conclusion. Water could flow freely past the bulkhead to the bow spaces of the boat, whereupon the whole boat was filled with water and sank quickly (Figure 10). The bulkhead did, however, slow down the proceeding of the leakage to such an extent that the boat remained afloat so long that the people onboard had time to save themselves by boarding a boat which had come to the accident scene.

The fact that the boat did not sink immediately after the engine compartment flooded implies that if the bulkhead of the engine compartment had been entirely tight, the boat might have remained afloat. The case indicates that the boat could have been constructed in such a way that it had remained afloat after the engine compartment had filled with water. This would require the bulkhead of the engine compartment to be completely watertight and the volume of the engine compartment to be small enough. If a boat constructed in this way remained afloat after the engine compartment had filled with water, the safety of the people onboard the boat would increase decisively. In the accident now under investigation human lives were saved only because help was available in vicinity. Jeanneau Prestige 42S boat has been approved for deep-sea usage (Recreational Craft Directive, boat design category B). In the open sea getting prompt assistance would not have been possible, as not in most situations in the archipelago either.

3 CONCLUSIONS

3.1 Factors contributing to the accident

The voyage plan was changed when the boat was proceeding with cruising speed. After a turn completed by using high speed there was not enough time at the end of the turn to check the position of the boat visually or by using navigational aids. In such a situation the safe procedure is to stop the boat and to reduce speed for assessing the situation before continuing the journey by using a new heading.

The integration of the features of the Jeanneau Prestige 42S boat and the Volvo Penta IPS drive unit had failed, which meant that the strength pyramid principle required for the drive unit to break in a safe way did not work. The hull structure of the boat contributed to the effects of the accident, which were as follows:

- The Volvo Penta IPS drive unit did not break loose from the bottom plane of the boat as the result of the collision and a severe damage was caused to the hull.

- The structure of the Jeanneau Prestige 42S boat was found out to be weak at the joint of the transom and the bottom; the transom was tore loose from the bottom and this caused uncontrolled leakage.

- The boat sank because the engine compartment of the boat had not been separated as a watertight compartment and because the boat had not been constructed in such a way that it would have withstood the engine compartment being filled with water.

3.2 Safety observations

The Recreational Craft Directive does not take stand on the boat's behaviour in an accident situation; it only requires that the boat is safe enough when used in a correct manner. The Recreational Craft Directive does also not apply to the constructional quality of an individual boat but to the design and structure of a boat model or series.

When the Recreational Craft Directive and standards are developed further, more attention could be paid especially to the unsinkable nature of the boats equipped with drive units mounted under the bottom and to the general strength of the hull structures of the boats, to the method of construction and to the visibility from the helm.

4 IMPLEMENTED MEASURES

The Finnish Transport Safety Agency has undertaken to study the requirements compliance of Jeanneau Prestige 42S boats. The work has not been completed by the time this investigation was ready.

The Finnish Transport Safety Agency has studied the requirements compliance of Jeanneau Prestige 42S boats in co-operation with the French authorities, the manufacturer of the boat as well as the inspecting establishment. According to this study, there is no reason to question the requirements compliance of this boat model.

5 SAFETY RECOMMENDATIONS

In this accident the boat would not have sunk if the engine compartment had been small enough and watertight. Similar situations have been encountered in several other boating accidents. Therefore the Safety Investigation Authority recommends that:

1. *The Finnish Transport Safety Agency undertake measures to revise the boat building regulations in such a way that boats similar to the accident boat remain afloat when the engine compartment fills with water.*

The strength pyramid principle of the stern drive unit did not work in this accident nor did it work in another similar accident, i.e. in three ground touchings which occurred in connection with two accidents. The bottom or the mount collar of the boats has broken before the IPS drive unit and the rubber O-ring has slipped out from its groove thus causing a leakage. Therefore the Safety Investigation Authority recommends that:

2. *Volvo Penta check the functioning of the strength pyramid principle of the IPS drive units, the requirements on the hull structure of the boat and the instructions on how to mount the unit to the hull as well as remind those buying an IPS drive unit that instructions supplied by the manufacturer must be followed as carefully as possible especially as to the mounting of the unit to the hull.*

In Helsinki, 29 October 2012

Klaus Salkola Ville Grönvall Juha Sjölund

APPENDIX 1. VOLVO PENTA IPS DRIVE UNIT

General description

The Volvo Penta IPS drive unit is a Z-drive unit intended to be used in boats. It differs from ordinary sterndrives in such a way that the unit is mounted under the bottom of the boat instead of being mounted to the transom. For this purpose a fairly large hole is cut to the bottom of the boat. A mount collar is attached to the rim, and the drive unit is connected watertightly to the mount collar. As in a normal drive unit, an upper gear and a lower gear are parts of the IPS drive unit. The driving shaft attached to the engine connects with the upper gear, and the propeller is attached to the end of the shaft of the lower gear. The boat is steered by turning the lower part of the drive unit around it vertical axis. In the Volvo Penta IPS drive unit there are two counter-rotating propellers and they are installed on the bow side of the lower gear as tractive propellers.

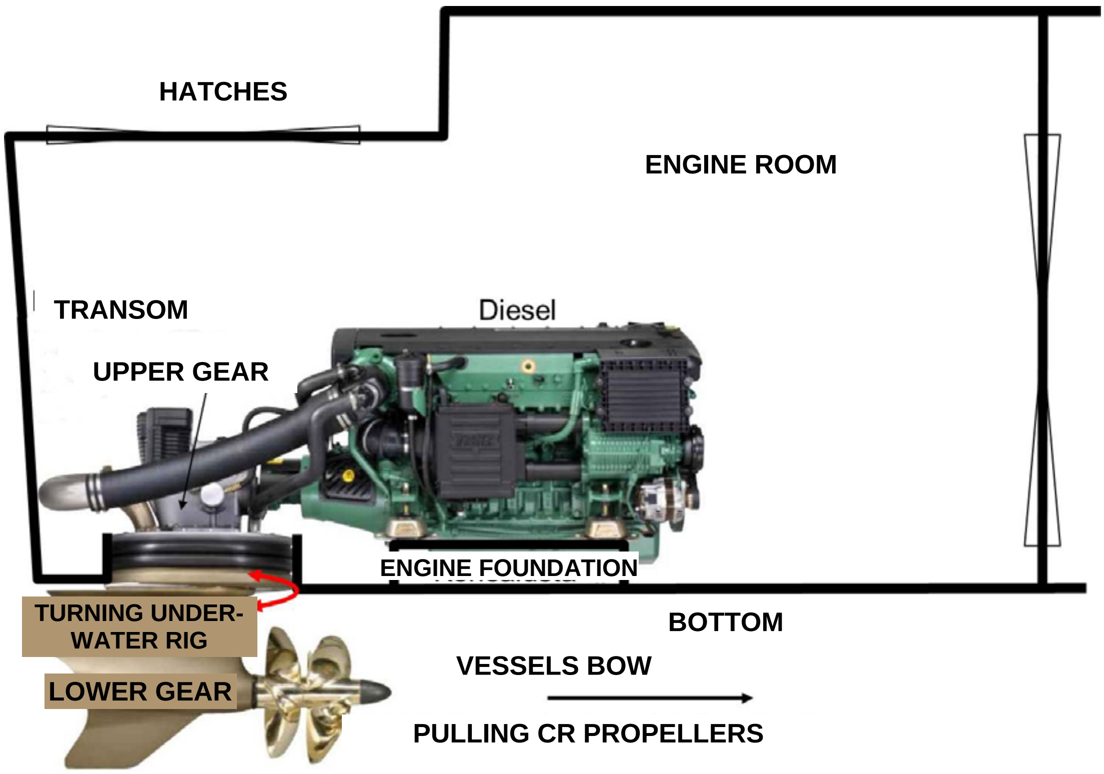

Figure 1. IPS drive unit and its installation principle. (The engine and the drive unit from Volvo Penta brochure)

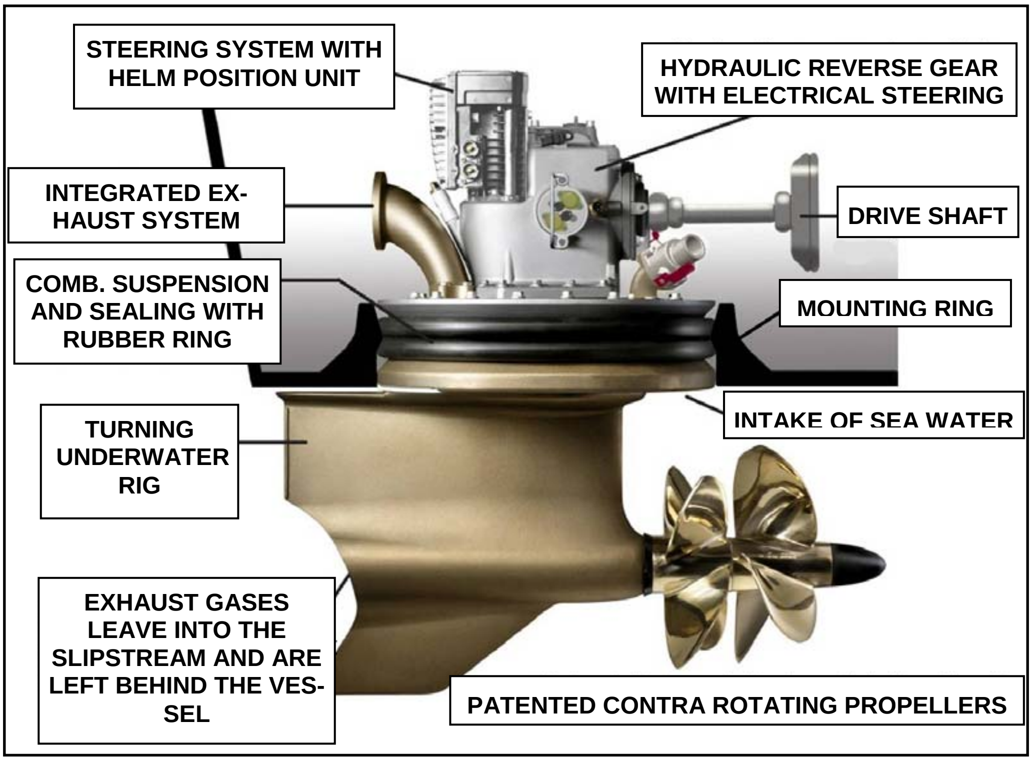

Figure 2a. The principle parts of the drive unit.

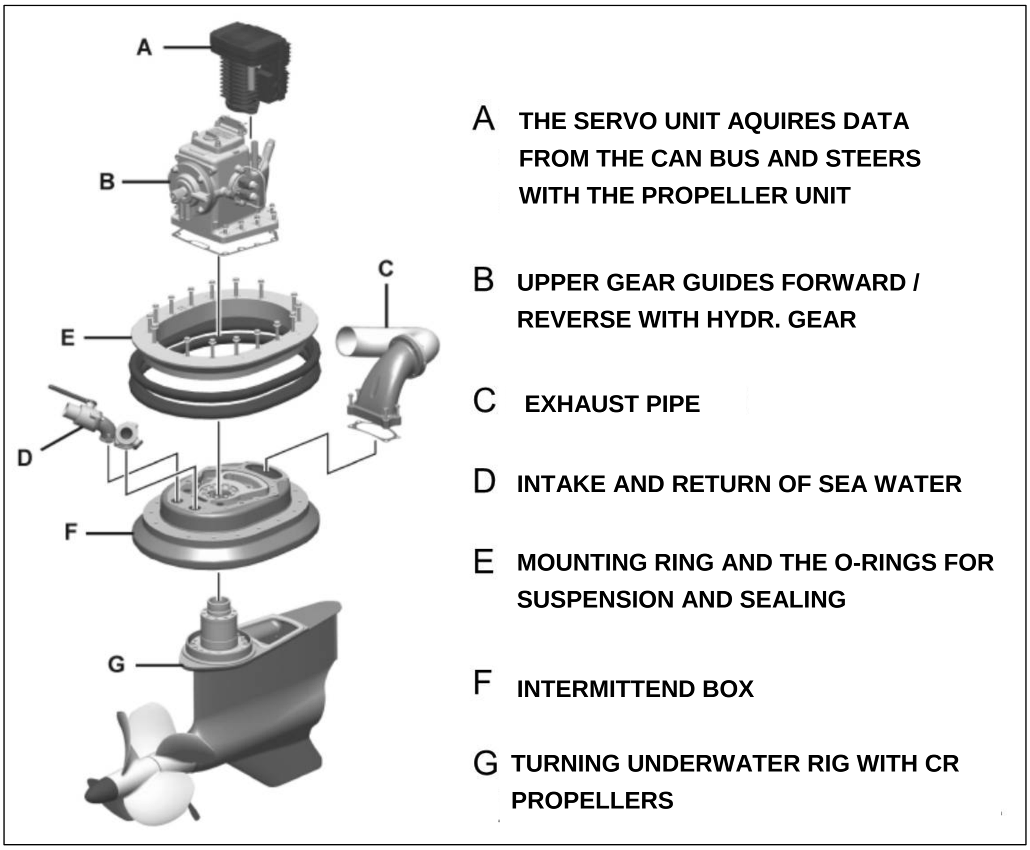

Figure 2b. Specification of the principle parts of the drive unit. (From Volvo Penta manual).

An ordinary stern drive is installed in the bushing of the transom in such a way that the joint and hinge pin in it make it possible for the rig, which is outside the boat and reaches the water, to turn backwards (Figure 3). The hinge pin is used when adjusting the position of the propeller.

The drive unit has been constructed in such a way that it tilts back and upwards when hitting an obstruction. This prevents impact stress from being directed to the hull of the boat and in some cases it also protects the drive unit from major damages.

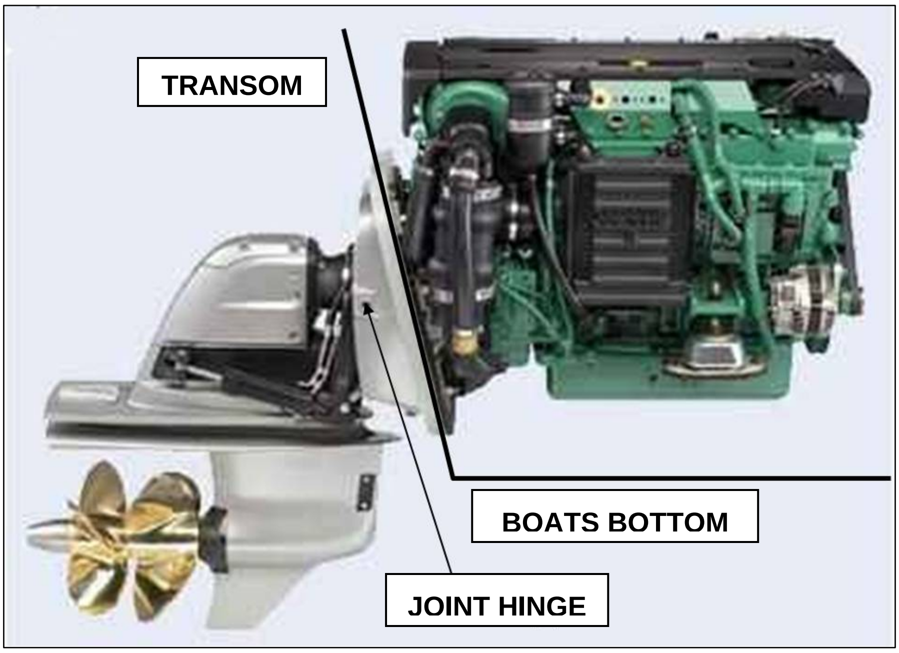

Figure 3. Marine engine with an ordinary sterndrive (From Volvo Penta brochure).

An IPS drive unit cannot turn when meeting an obstruction. When it hits an obstruction the impact moves via the drive unit to the hull of the boat. There is a controlled plane of weakness in the bushing of the steering spindle of an IPS drive unit in order to prevent the tearing of the bottom and leakage, Figure 4.

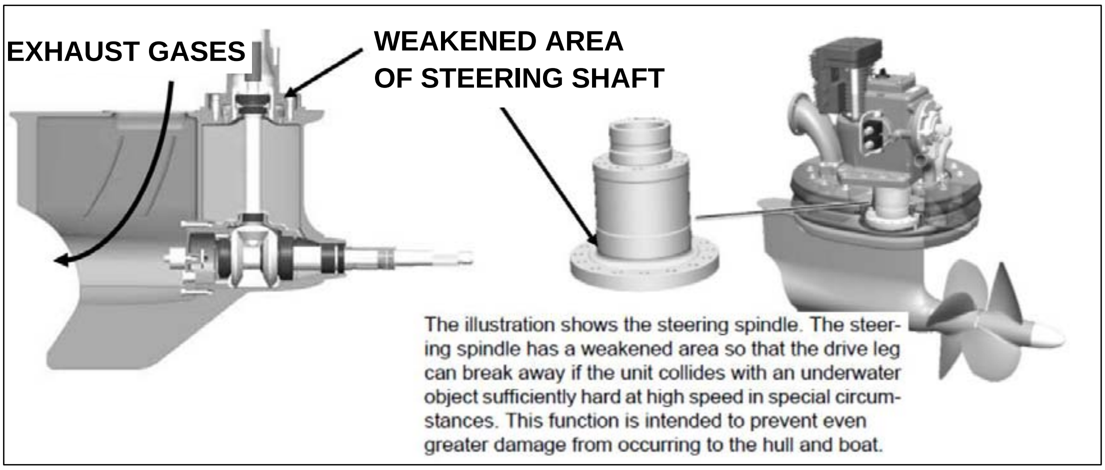

Figure 4. The breakage point of the IPS steering spindle. (From Volvo Penta manual).

Mount collar

The IPS drive unit is mounted to the bottom of the boat, to a welded or laminated (aluminium, glassfibre reinforced plastic) mount collar, in such a way that the thick and flexible O-ring seals are placed on both sides of the flange inside the ring. When the mounting flanges of the drive unit tauten, they press the packings.

In other words the drive unit does not touch the mount ring mechanically but instead leans on it with the help of two flexible rubber rings. These rings seal off the bottom of the boat and at the same time create a flexible mounting for the drive unit to dampen noise and vibrations.

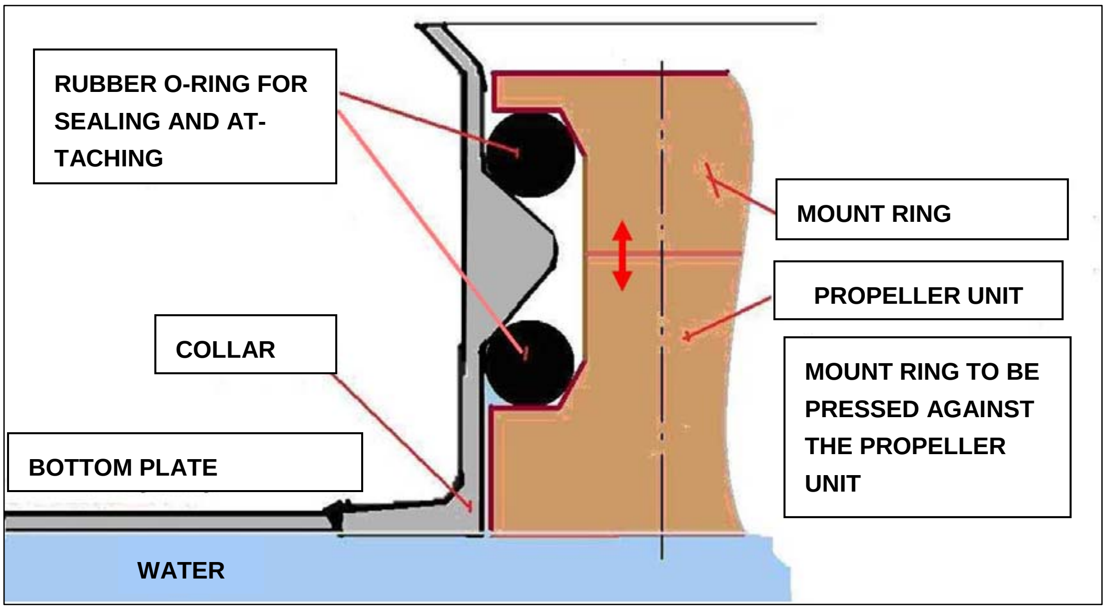

Figure 5. The installation of a drive unit to the mount collar of the hull with two large O-rings and a mount ring. The drawing only illustrates the principle of how the installation is done.

APPENDIX 2. INVESTIGATION OF THE DRIVE UNIT AND HULL OF IDA 1

Dismounting and investigation of the drive unit

The accident vessel was stored in an outdoor location of Kosken Autokeskus Oy after it has become the property of insurance company. The starboard drive unit was dismounted from the hull in April 2011 according to the instructions given by the investigators[6]. In the beginning of May the investigators disassembled and examined the drive unit in order to find out what had happened.

All the parts of the drive unit were disassembled in a warm workshop by using tools and cranes provided by Kosken Autokeskus. Figure 1 shows the hole cut in the bottom of the boat.

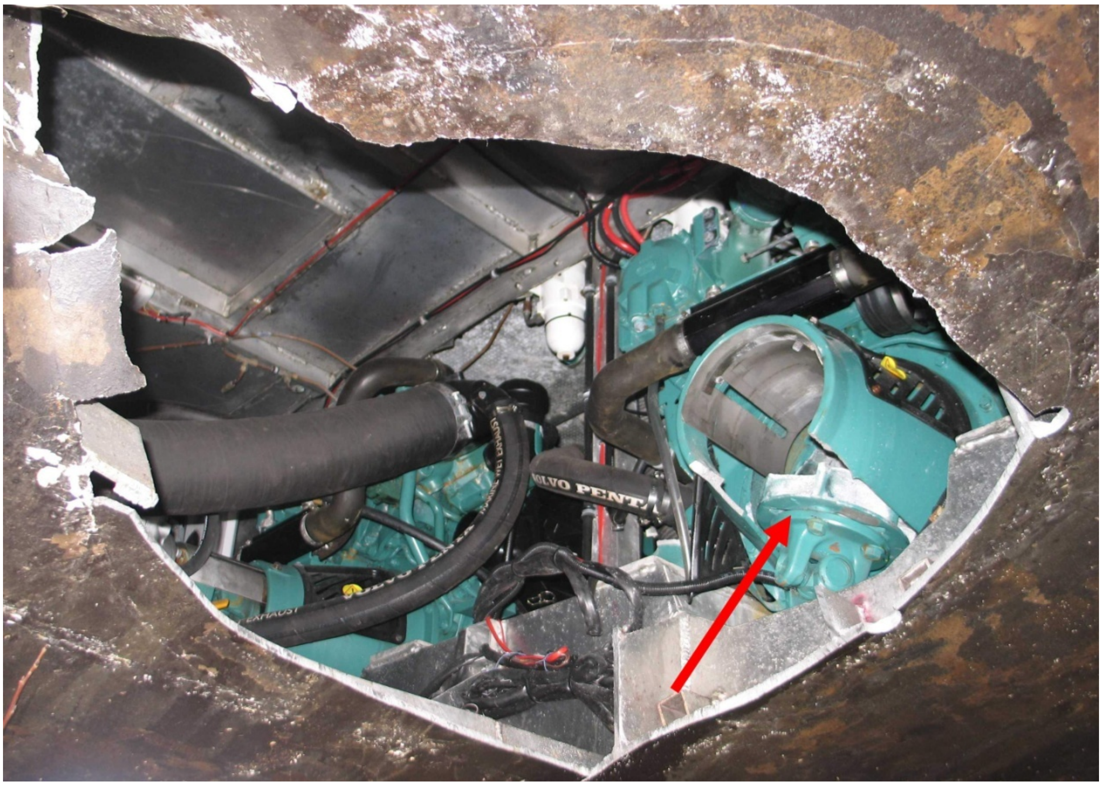

Figure 1. The hole cut in the bottom of IDA 1 after the drive unit had been dismounted. The arrow points to the broken shaft coupling.

Figure 2. The type plate of the drive unit. Type B, reduction ratio 1.94:1.

6 The engine had been dismantled from the drive shaft of the upper gear. In addition, the bottom plate of the boat had been cut around the mount collar of the drive unit.

Preparations

Loose parts were dismantled from the main body. These included the mount ring made of aluminium, hoses and packings. The large O-rings were missing. No important observations from the point of view of the investigation. No need to wash the parts because the material has to be regarded as waste material.

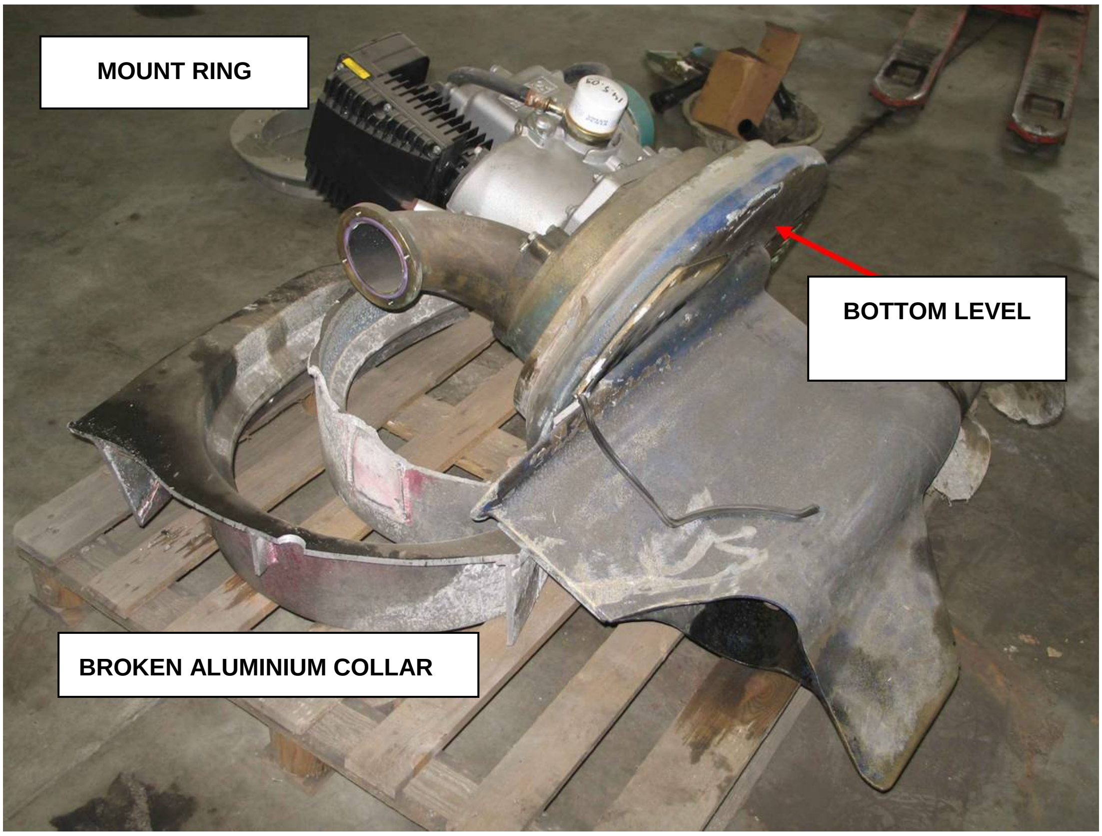

Figure 3. The dismounted drive unit in the workshop of Kosken Autokeskus before it was disassembled.

Disassembling the upper gear

Suspension was used to support the upper and lower gear, and the 10 bolts which retained the gears were dismantled. Some force and chisel/hammer were required to dismantle the parts. No important observations from the point of view of the investigation.

Dismantling of the steering quadrant

The steering quadrant was dismantled by removing the retaining bolts from it. No important observations from the point of view of the investigation.

Dismantling the intermediate housing

The fixed intermediate housing attached to the bottom of the boat was dismantled from the turning rig. It was found out that the flange of the steering spindle had been broken but it was still fast attached to the lower gear. The breakage went some distance along the relief groove made in the corner of the steering spindle and the flange, but then turned through the flange to the outer track at both ends of the breakage. Thus only approx. 1/3 of the flange had broken loose and 2/3 of it still held the rig attached to the steering spindle.

It was discovered that there were 16 bolt holes in the flange but bolts had been fixed only to 10 of them. The empty holes were located symmetrically 3 + 3 on both sides of the appliance, Figure 4.

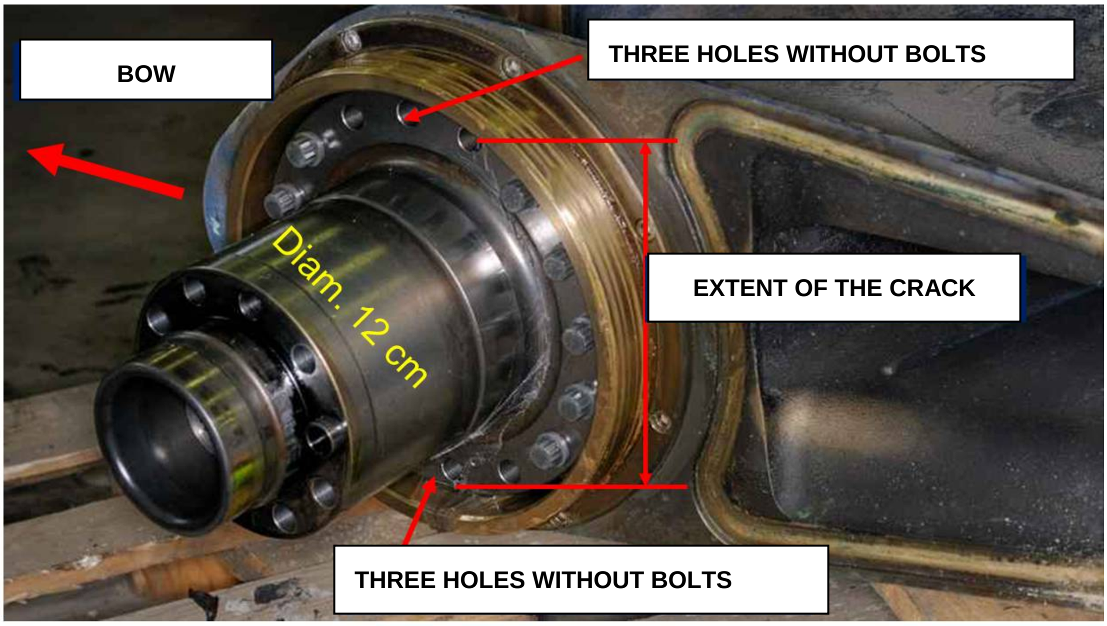

Figure 4. The folding underwater part after being dismantled.

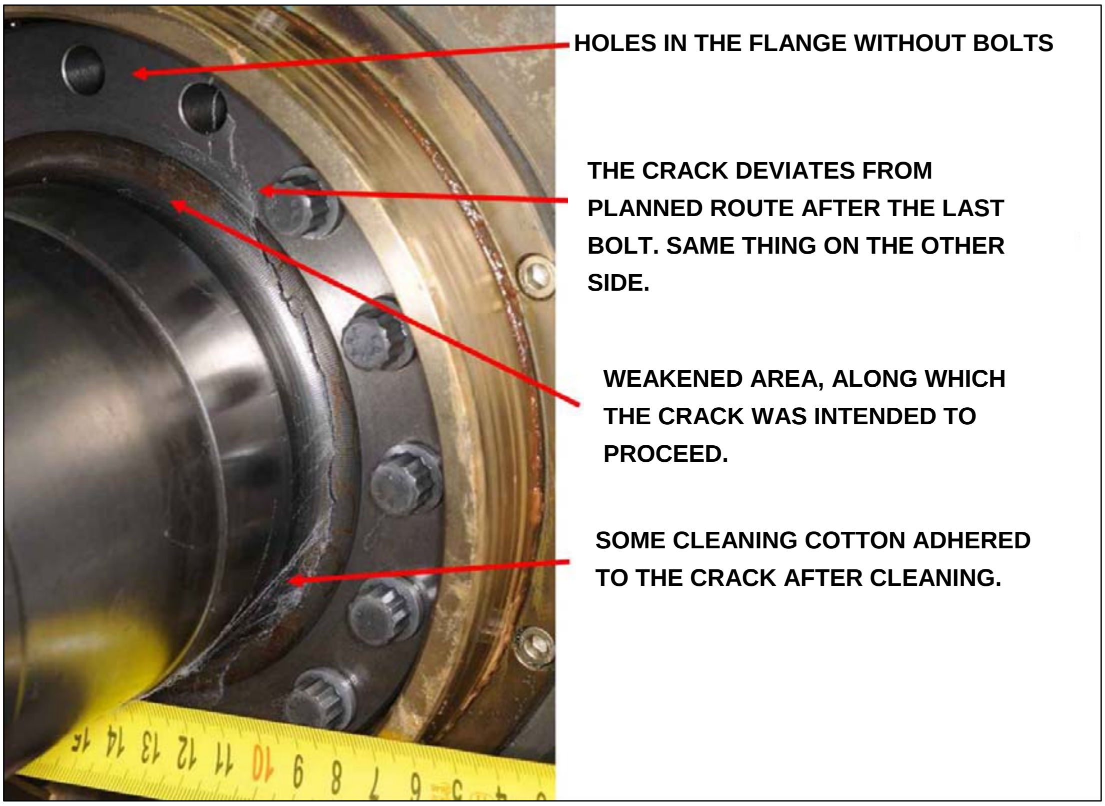

Figure 5. A detail from the other end of the breakage point.

Dismantling the pivot axle

The next step was to unfasten the 10 bolts of the flange of the pivot axle (Figures 4 and 5) in order to get the driving shaft out. It was discovered that the flange of the axle had broken along the crack which had been found earlier. In addition, it was discovered that the structure was such that there were no tapped holes in the rig where the missing 3 + 3 bolts were and that the response surface did not reach to the flange of the pivot axle. The missing of the bolts is thus intentional and based on strength calculations.

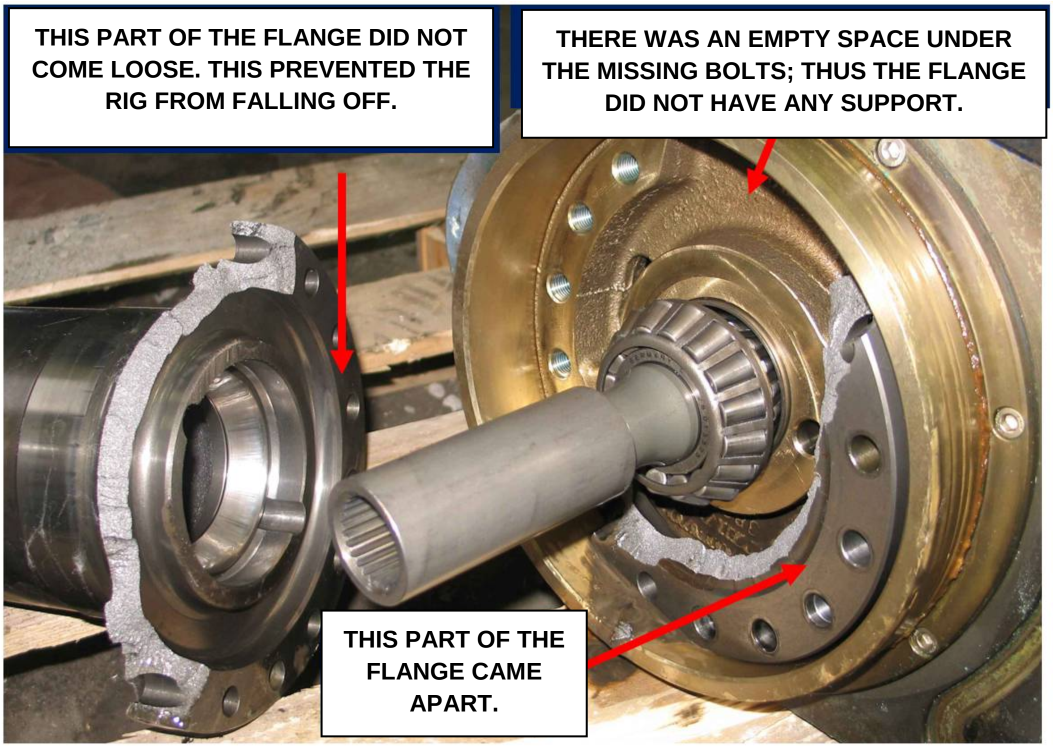

Figure 6. The dismantled drive shaft.

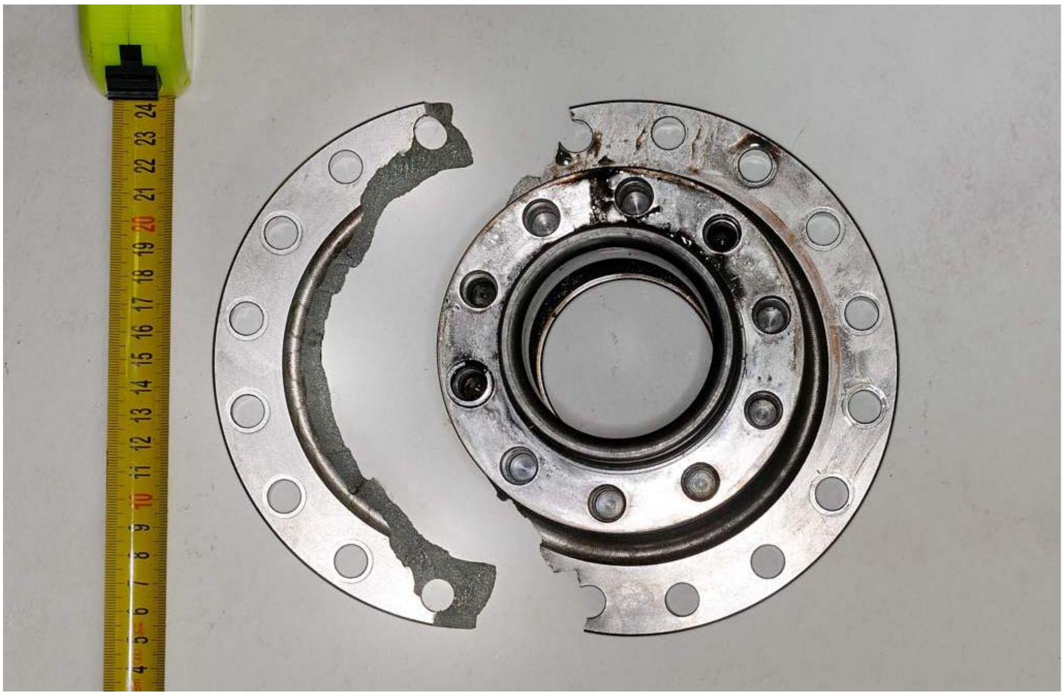

Figure 7. The pivot axle and its partly broken flange.

It was detected that the mount collar had broken into two parts. Parts from the sheared aluminium profiles and a little bit of the boat's bottom plate had fastened to it, Figure 8.

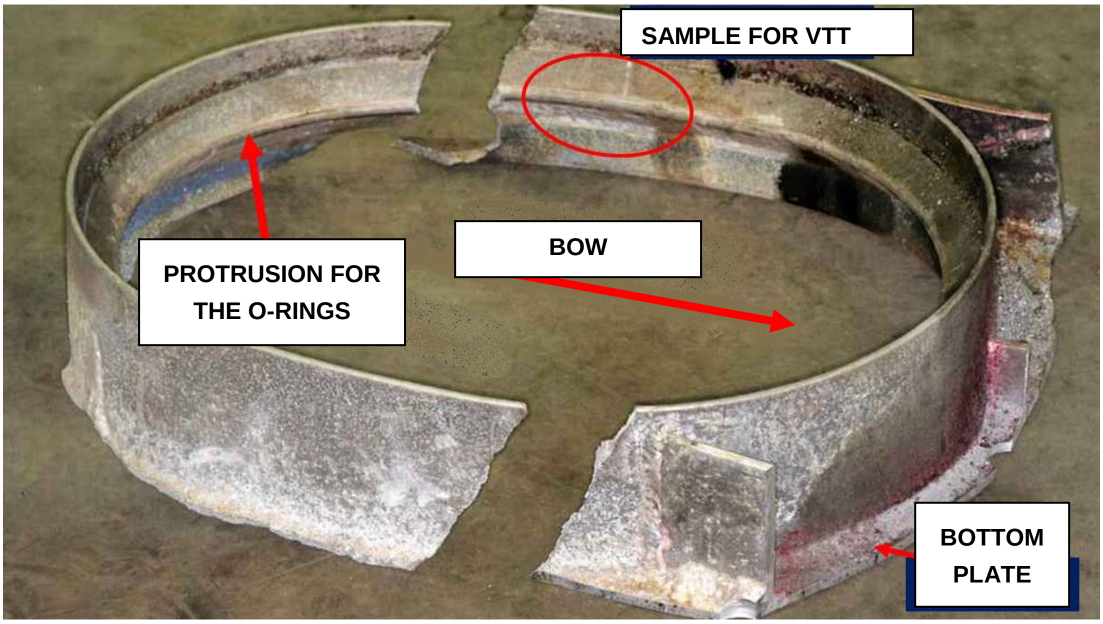

Figure 8. Aluminium collar, test sample place at Technical Research Centre of Finland.

Figure 9. Breakage point of the aluminium collar.

Figure 10. Mount ring from above (left) and from below (right). The mount ring was intact.

LAUSUNNOT/ STATEMENTS

Lausunto 1.	Liikenteen turvallisuusviraston lausunto
Statement 1.	Statement by the Finnish Transport Safety Agency
Lausunto 2.	Veneen valmistajan (SPBI) lausunto
Statement 2.	Statement by the manufacturer (SPBI) of the boat
Lausunto 3.	Perävetolaitteen valmistajan (Volvo Penta) lausunto
Statement 3.	Statement by the manufacturer (Volvo Penta) of the drive unit

TraFi

LAUSUNTO

Päiväys/Datum/Date 3.8.2012

Dnro/Dnr/Ind.no. TRAFI/18826/07.01.00/2012

Viite/Referens/Ref Lausuntopyyntönne 15.6.2012 (203/5M)

SAAPUNUT
07-08-2012
282/5M

Onnettomuustutkintakeskus
Sörnäisten rantatie 33 C
00500 HELSINKI

Liikenteen turvallisuusviraston lausunto tutkintaselostuksen lopulliseen luonnokseen C3/2010M Jeanneau Prestige 42S (FIN), A-58990, uppoaminen Inkoon edustalla 28.5.2010.

Liikenteen turvallisuusvirasto lausuu tutkinnan C3/2010M turvallisuussuosituksista seuraavaa:

Turvallisuussuositus 1.
Liikenteen turvallisuusvirasto ryhtyy toimenpiteisiin veneenrakennussäännöstön muuttamiseksi siten, että onnettomuusveneen kaltaiset veneet jäisivät kellumaan konetilan täyttyessä vedellä.

Trafin lausunto suositukseen:
Liikenteen turvallisuusvirasto on mukana kehittämässä venealan teknisiä standardeja ja voi nostaa esiin turvallisuuden kannalta tärkeitä seikkoja, esimerkiksi Sipoonselällä 2010 tapahtunut uppoamisonnettomuus (D6/2010M) jonka seurauksena veneen varalaitaa, vakavuutta ja kelluvuutta koskevaan standardiin (ISO 12217-1-3) tehtiin turvallisuutta parantava muutos. Tällainen muutos vaatii kuitenkin varsin laajan kansainvälisen yhteisymmärryksen.

Turvallisuussuositus 3.
Liikenteen turvallisuusvirasto markkinavalvontaviranomaisena ryhtyy toimenpiteisiin tällä tavalla rakennettujen veneiden markkinoinnin lopettamiseksi.

Trafin lausunto suositukseen:
Liikenteen turvallisuusvirasto voi ryhtyä toimenpiteisiin, mikäli venemallin epäillään aiheuttavan vaaraa oikein käytettynä tai olevan muuten huvivenedirektiivin vaatimusten vastainen. Tässä tapauksessa ei ole ilmennyt aihetta ryhtyä enempiin toimenpiteisiin.

Tuomas Routa
Ylijohtaja

Liikenteen turvallisuusvirasto • Trafiksäkerhetsverket • Finnish Transport Safety Agency
PL/PB/P.O. box 320, 00101 Helsinki, Finland
Puh./Tfn/Tel.: 358 (0)20 618 500, fax +358 (0)20 618 5095 • www.trafi.fi
Y-tunnus/FO-nummer/
Business ID: 1031715-9

SPBI
S.A. au capital de 51.541.628 €
Parc d'Activités de l'Eraudière
85170 Dompierre sur Yon
RCS 491 372 702 La Roche sur Yon

Dompierre sur Yon, July 23rd of 2012,

Response to the preliminary report of the Safety Investigation Authority dated 15 June 2012

On 4 June 2010, the Safety Investigation Authority of Finland has formed a Commission of Investigation, pursuant to Section 5 of the Accident Investigation Act (373/1985), following a shipwreck of a Prestige 42S-type recreational boat, which occurred on 28 May 2010 at Inkoo in Finland, and which was constructed by SPBI.

A Preliminary Report was drawn up by the Commission on 15 June 2012 (hereinafter the "Preliminary Report").

By letter dated 15 June 2012, received on 20 June 2012, you sent the said Preliminary Report to SPBI for its observations.

We understand that these observations may lead to the amendment of the Preliminary Report, for the purpose of drafting the final report and will be attached as schedules to the latter. We ask that the points analysed below be amended and/or deleted in the Commission's final report.

These observations are made on the basis of the information provided in the Preliminary Report, since SPBI is not in a position to distinguish the physical damage, which is strictly related to the collision with the rock, from that which may have been caused by the sinking, refloating and towing of the boat.

1. INTRODUCTION

The Preliminary Report concludes that the accident which led to the boat sinking on 28 May 2010 was caused exclusively by navigational error (lack of attention; excess speed; sudden change in voyage plan).

No technical defect of the Prestige 42S boat was revealed[1].

This is why SPBI is surprised by certain assertions contained in the Preliminary Report, which seem to call into question the quality of the boat's design and construction. The said assertions are subjective assessments and are not based on the finding of any established breach with the applicable regulations.

The question of a breach by SPBI can, however, only be assessed objectively, solely in the light of the applicable regulations and not on the basis of subjective assessments.

SPBI is a company certified under ISO 9001 and ISO 14001, whose production processes comply with the strictest international standards.

All Jeanneau boats bear the EC certification, which incorporates the essential safety requirements, in particular with regard to stability and structural resistance.

The Prestige 42S boat was designed and produced in complete compliance with the applicable regulations. In this respect, it must be noted that any withdrawal from the market – as discussed on p. 37 of the Preliminary Report – of a product which has been declared to comply with the applicable regulations cannot be considered, other than in those situations strictly provided for by the provisions of EC law.

Since the investigators found that the accident was caused exclusively by a navigational error, it appears that the sole purpose of this investigation is to make recommendations to the Finnish Transport Safety Agency, in order to improve the applicable regulations. Its purpose is not to make a pronouncement regarding any liability of SPBI with regard to the occurrence of the said accident.

In this context, SPBI makes these observations in reply to the request of the Safety Investigation Authority and provides information confirming the compliance of the Prestige 42S boat with the applicable regulations. There is no reason to pronounce upon whether or not it is appropriate to adopt more restrictive regulations.

* *
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[1] P. III: "*The investigation concludes that **the grounding was not caused by any technical failure**, which means that the loss of situational awareness after the turn with high speed can be regarded as the immediate cause of the accident and the sudden change in the voyage plan as a contributing factor*".

2. THE PRESTIGE 42S BOAT COMPLIES WITH THE APPLICABLE REGULATIONS

The investigation conducted by the Safety Investigation Authority related to various parts of the Prestige 42S boat. The submissions which are produced for each of the said parts will be analysed in turn.

2.1 Visibility from the helm position of the Prestige 42S boat

This issue is regulated by European standard EN ISO 11591.

This standard defines the requirements relating to the field of vision towards the bow and the stern from the helm of recreational motor boats whose hull does not exceed 24 metres in length. This standard therefore applies to the Prestige 42S boat.

The EN ISO 11591 standard sets forth the visibility requirements corresponding to various hypothetical positions adopted by the skipper (skipper sitting/standing; high and low eyelevel; horizontal/vertical field of vision).

The visibility from the helm position of the Prestige 42S boat, including the presence of blind spots, complies with all the recommendations of the EN ISO 11591 standard, as certified by the technical documentation which is attached hereto (*exhibit n°1*).

Furthermore, the measurements taken by the Finnish Transport Safety Agency conclude that the EN ISO 11591 standard was complied with.

The question whether the visibility from the helm position is improved if the boat's roof hatch is open is irrelevant, since the visibility measurements are taken with the roof hatch closed.

In these circumstances, the expressions "*the visibility from the helm was poor*"[2] and "*significant safety risk for a boat with the maximum speed of 40 knots*", "*from the point of view of a safe boating*"[3] contained in the Preliminary Report do not correspond to any actual regulations.

Since compliance with the EN ISO 11591 standard has been shown, the said subjective assessments are inappropriate.

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[2] P. 23

[3] P. 24

2.2 Incorporation of the Volvo Penta IPS Drive Units

2.2.1 Design of the bottom of the hull

The Preliminary Report seems to call into question the quality of the incorporation of the IPS unit in the Prestige 42S. It is, in particular, noted that this boat was designed in order to operate with a traditional sterndrive-type propulsion engine[4], and that the incorporation of the IPS drive unit would have required structural modifications to the boat[5].

This assertion is inaccurate: **the Prestige 42S was specifically designed to operate with the IPS drive unit**. This Prestige 42S model has never been sold, fitted with another form of drive system.

The structural design and the partitioning of the boat were not modified in any way as a result of the incorporation of the IPS drive unit.

Consequently, the assertion that "*in an IPS drive unit the thrust of the propellers is directed to the bottom instead of the transom, which means that special attention should have been paid to strengthening the bottom and to the quality of the supportive structures,* [which] *had not been done by the manufacturer of the boat*"[6] is unwarranted.

Similarly, and contrary to what is written in the Preliminary Report[7], the stringers were not modified but were specifically designed for the use of IPS drive units. It must be noted in this regard that the assertion that the gaps, which are visible in the photo on p. 27, were already in existence from when the boat was first manufactured, is not substantiated.

It is therefore inaccurate to assert that SPBI failed to consider the question of the incorporation of the IPS engines during the design phase of the boat. The subjective assertion contained on page 25 of the Preliminary Report, according to which "*the way the hull was constructed becomes apparent when looking into the damages and reflects the intent to build a boat quickly and at a cheap price*" is therefore unjustified.

In general, the violence of the collision suffered by the structure of the Prestige 42S at the time it hit the rock (a boat weighing 9,350 kg / 20-22 knots / stoppage of one of the

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[4] P. 25: "*the boat model has been originally designed for traditional stern drives*".

[5] P. 25: "*the accident boat was modified for the IPS drive units by cutting original supporting structure, by attaching the mount rings of the drive units to the bottom and by adding behind the ring a bracket as described in the Volvo instructions*".

[6] P. 25.

[7] P. 26: "*the blue line indicates the location of the original bottom stringers and the points where they have been cut off and attached to mount ring*".

two propellers during less than one revolution) does not seem to have been taken into account during the analysis of the structural consequences suffered by the boat's hull.

This circumstance is, however, a determining factor.

2.2.2 Assembly of the Volvo IPS 500 engines

The Prestige 42S is equipped with two Volvo Penta brand IPS 500 engines.

The IPS engines were mounted on the Prestige 42S by SPBI in the following manner:

- design of the boat structure and installation of the engines in accordance with the guidelines provided by Volvo Penta (*exhibit n°2*);
- verification of the installation by Volvo Penta itself;
- issue of a certificate of approval by Volvo Penta (*exhibit n°3*).

Since Jeanneau was issued a certificate of approval by the manufacturers of the engines, there is no defect in the installation of the IPS engines.

With particular regard to the "strength pyramid principle", explanations may be provided by Volvo Penta regarding the operation of the fuse switch which enables the drive unit to come loose from the bottom plane.

2.3 <u>The hull strength of the Prestige 42S</u>

Article 8-2 of EC Directive 94/25/EC dated 16 June 1994, as amended by EC Directive 2003/44/EC dated 16 June 2003, sets forth the certification procedures for boats, in accordance with their design category.

The Prestige 42S boat belongs to design category B.

Pursuant to this Article, a self-certification procedure may apply to design category B boats, which are less than 12 metres in length, which is called the "*internal production control plus tests*".

In order to assess the compliance of the structure with the essential requirements of the European Directive, SPBI relies on a design and construction experience of more than 200 models, obtained over more than 40 years, i.e. a quantity of around 150,000 units produced. This experience also relies on the fact that a considerable number of these same structures have been approved by Bureau Veritas.

The self-certification procedure was adopted for the structure certification of the Prestige 42S.

This choice can be explained by the fact that the design of the hull structure and the sample testing of thc Prestige 42S were established on the basis of those implemented in the construction of the Prestige 46, another boat designed and manufactured by SPBI which had itself been certified by Bureau Veritas (*exhibit n°4*).

The Prestige 42S was therefore the subject of a self-certification procedure based on indisputable technical foundations, since they are in turn based on Bureau Veritas' certification of the Prestige 46, a boat of superior size and mass.

With regard to the incorporation of the drive unit, the Prestige 42 S was designed from the outset to accommodate this IPS-type drive unit, in compliance with the recommendations of Volvo Penta.

With regard to the method of applying the layers of fibreglass, it is submitted in the Preliminary Report that the method used does not comply with trade practice and that another method, which is recommended in the Preliminary Report, should have been used.

However, the recommended method (in multiple layers) is not the only method which complies with trade practice. The method used for the Prestige 42 S was certified by Bureau Veritas – which carried out hull resistance tests – as part of the certification for the Prestige 46.

The fact that the accidental collision led to the piercing of the hull does not allow one to reach a conclusion that the regulations were not complied with: there is no standard which imposes structural design requirements for resisting a collision to the bottom of the hull for boats recreational boats (Bureau Veritas, Germanischer Lloyd, ISO rules all specify requirements for boat in intact condition).

For example, Bureau Veritas Regulation NR381 DNP R00 E, which has been used to assess Prestige 46, states in PART III Hull Structure – Section 1-11 – Article 15: "*In accordance with 14 above[related to other national and international regulations], the user and the builder must ascertain the safety conditions relating to freeboard and equipment, superstructures and protection of openings, taking into account the intended area of operation, if applicable*".

Obviously, the collision of a rock is not an intended area of operation.

The tearing apart of the transom and the bottom of the hull, together with the resulting piercing of the hull, do not therefore reveal any non-compliance with European recreational boats regulations.

Once again, the violence of the collision suffered by the boat at the time of the accident does not appear to have been taken into account in the section of the Preliminary Report which relates to the hull of the Prestige 42S.

2.4 <u>The lack of watertight partitions separating the compartments of the Prestige 42S</u>

The Preliminary Report seems to criticise the lack of watertight partitions separating the various compartments of the boat.

However, the EN ISO 12217-1 (2002) standard, which is also applied by SPBI, regulates inter alia the requirements regarding the stability and buoyancy of recreational motor boats (*exhibit n°5*). Part 1 of ISO 12217 specifies the methods for evaluating the stability and buoyancy of boats when intact (i.e. undamaged). The buoyancy features of boats which are vulnerable to flooding are also considered. The Prestige 42 S model was evaluated using option 1 of table 2, taken from the relevant ISO standard 12217-1. This mode of evaluation is dedicated to fully decked boats in design categories A and B (a fully decked boat has its hull totally covered by a deck, as in the Prestige 42 S).

The option 1 mode of evaluation does not mention any requirement for watertight internal partitioning.

Table 2 — Tests to be applied

Option	1	2	3	4	5	6
Categories possible	A and B	C and D	B	C and D	C and D	C and D
Decking or covering	Fully decked [a]	Fully decked [a]	Any amount	Any amount	Partially decked [b]	Any amount
Downflooding openings	6.1.1	6.1.1	6.1.1	6.1.1	6.1.1	6.1.1
Downflooding-height test	6.1.2	6.1.2	6.1.2	6.1.2 [c]	6.1.2	6.1.2
Downflooding angle	6.1.3	6.1.3	6.1.3	6.1.3 [c]		
Offset-load test	6.2	6.2	6.2	6.2	6.2	6.2
Resistance to waves + wind	6.3		6.3			
Heel due to wind action		6.4 [d]		6.4 [d]	6.4 [d]	6.4 [d]
Flotation requirements			6.5	6.5		
Flotation material			Annex F	Annex F		

[a] This term is defined in 3.1.6.

[b] This term is defined in 3.1.7.

[c] This test is not required for boats assessed using option 4 if, during the swamped load test in normative annex E, the boat has been shown to support an equivalent dry mass of 133 % of the maximum total load.

[d] The application of 6.4 is only required for boats where $A_{LV} \geq L_H B_H$.

The SPBI Prestige 42S boat is less than 12 metres in hull length. It is certified as design category B and there are no regulations which require the installation of watertight partitions in recreational motor boats of this category.

Accordingly, the obligations relating to watertight compartments do not apply to it.

The Prestige 42S consequently complies with the applicable regulations, which is moreover acknowledged in the Preliminary Report (p. 24).

The assertion that "*the boat could have been constructed in such way that it had remained afloat after the engine compartment had filled with water*"[8] is therefore subjective and unwarranted, in the light of the applicable regulations.

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As stated on the first page of the Preliminary Report, the investigation enabled a conclusion to be reached that the sinking of the boat had been caused exclusively by the skipper's lack of attention, by too high a speed and by the late decision to change the voyage plan[9].

There is no issue regarding a technical defect of the boat.

We consequently dispute the conclusions contained on p. 33 of the Preliminary Report, according to which the technical causes of the accident were due ("*the technical causes of the accident were*") to the fact that the IPS drive unit fuse switch was not triggered, a weak hull structure and the fact that the compartments contained in the boat were not watertight. In addition to their contents, which seem to contain subjective considerations, the formulation of the said conclusions seems questionable, since the piercing of the hull and its flooding constitute the consequences and not the causes of the accident.

In general, it seems that the violence of the collision has not been adequately taken into account in the analyses contained in the Preliminary Report.

In any event, no breach by SPBI of either trade practice or the European regulations has been brought to light by the investigation. There is accordingly no reason to commence discussions regarding a possible withdrawal from the market (see p. 37).

The sinking of the boat on 28 May 2010 is exclusively due to a navigational error and the physical consequences suffered by the Prestige 42S can be explained exclusively by the violence of the collision suffered by the boat.

* *
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Mr Philippe Thill
Chief Technical Officer

[8] P. 32

[9] P. III: "*The investigation concludes that the grounding was not caused by any technical failure, which means that the loss of situational awareness after the turn with high speed can be regarded as the immediate cause of the accident and the sudden change in the voyage plan as a contributing factor*".

Volvo Penta

SAAPUNUT
9 -10- 2012
(Dnro 372/5M
Diarisoitu 9.10.2012,
Saapunut 23.8.2012)

Safety Investigation Authority of Finland
Att: Martti Heikkkilä
Sörnäisten rantatie 33 C
00500 Helsinki

Date	Direct Telephone	Mail	Our reference
20:th of August 2012	+46 31 3221664	tom,tveitan@volvo.com	TT

Comments on investigation report for Jeanneau Prestige 42S-type Motor Yacht (FIN), A58990, sinking off Inkoo, Finland on 28 May 2010

We have reviewed the draft report dated 15.6.2012. Please find below our comments.

From the report chapter "Summary":
The summary is stating. "Problems were found in the strength pyramid of the drive unit and in the integration of the drive unit and the hull."
And further the summary recommend "..that Volvo Penta check the functioning of the strength pyramid of the IPS drive units and the requirements on the structure of the boat..."

Volvo Penta instructions and pyramid function:
Volvo Penta's experience of the pyramid function is good and in most cases of groundings that have been reported to Volvo Penta, it works as intended. Volvo Penta lamination instructions of engine and IPS bed with surrounding structure is thoroughly tested by

- Real crash tests with IPS units in boat grounding
- Full scale crash tests of IPS unit with laminated beds in rig by Autoliv collecting measurements of stresses in both bed and the drive unit
- By using measurements from rig tests computer simulations have been developed and used to simulate a variety of groundings.

It is however important for the functioning that the lamination work has been performed in accordance with Volvo Penta's instructions and in a professional manner. The IPS-system contains a number of safety related features and has been extensively tested. It is, however, not possible to foresee the exact circumstances of each incident.

Yours sincerely,

AB Volvo Penta

Tom Tveitan
Manager
Dept 48240 Laws and Regulations