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

Investigation Report 160/13

Serious Marine Casualty

Water ingress on the traditional vessel RAKEL on 21 June 2013 in the North Sea about 10 nm south of Heligoland

25 February 2014

The investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law - SUG) of 16 June 2002 in the version applicable prior to 30 November 2011.

According to said Law, the sole objective of this investigation is to prevent future accidents and malfunctions. This investigation does not serve to ascertain fault, liability or claims.

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to the aforementioned version of Article 19(4) SUG.

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

Issued by:
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1 Summary

At about 1630[1] on 21 June 2013, heavy water ingress occurred on board the traditional vessel RAKEL when she was sailing from Bremerhaven to Heligoland. At about 1830, the rescue cruiser HERMAN MARWEDE was summoned to assist by radio. The vessel was kept drained by means of a bucket chain and headed for the port of Heligoland. Eight of the 11 people on board were given preventive medical care. One person suffered a laceration to the eye and another, contusions to the ribs. The vessel was run aground in Heligoland as a precaution and pumped out by the fire brigade.

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[1] All times shown in this report are Central European Summer Time = UTC + 2 h

2 FACTUAL INFORMATION

2.1 Photo

© Hasenpusch Photo-Productions

Figure 1: Photo of ship

2.2 Ship particulars

Name of ship:	RAKEL
Type of ship:	Traditional vessel, ketch
Nationality/Flag:	German
Port of registry:	Bremerhaven
MMSI number:	211379440
Call sign:	DLBG
Owner:	Private
Year built:	1896
Shipyard/Yard number:	Larvik (Norway), built as a wooden fishing vessel
Classification society:	None, registered as a traditional vessel
Length (overall):	28.00 m
Length (deck):	19.00 m
Width (overall):	5.50 m
Draught:	2.50 m
Gross tonnage:	42
Displacement:	50 tonnes
Engine rating:	112 KW (150 HP)
Main engine:	MWM D232, V 6
Hull material:	Wood
Hull design:	Carvel structure, frames with inner ceiling

2.3 Voyage particulars

Port of departure:	Bremerhaven
Port of call:	Heligoland
Type of voyage:	Traditional vessel, national trade, charter
Manning:	11
Draught at time of accident:	Fore: 1.80 m. Aft: 2.50 m
Speed at time of accident:	7.5 kts
Pilot on board:	No
Canal helmsman:	No

2.4 Marine casualty or incident information

Type of marine casualty/incident:	Serious marine casualty
Date, time:	21/06/2013 at about 1630
Location:	Approximately 10 nm south of Heligoland, North Sea
Latitude/Longitude:	φ 54°07' N λ 008°01' E
Ship operation and voyage segment:	Coasting
Place on board:	Hull
Consequences (for people, vessel, cargo)	Vessel damaged, people injured

Excerpt from BSH Nautical Chart No 3014, Sheet 1, Heligoland Bight

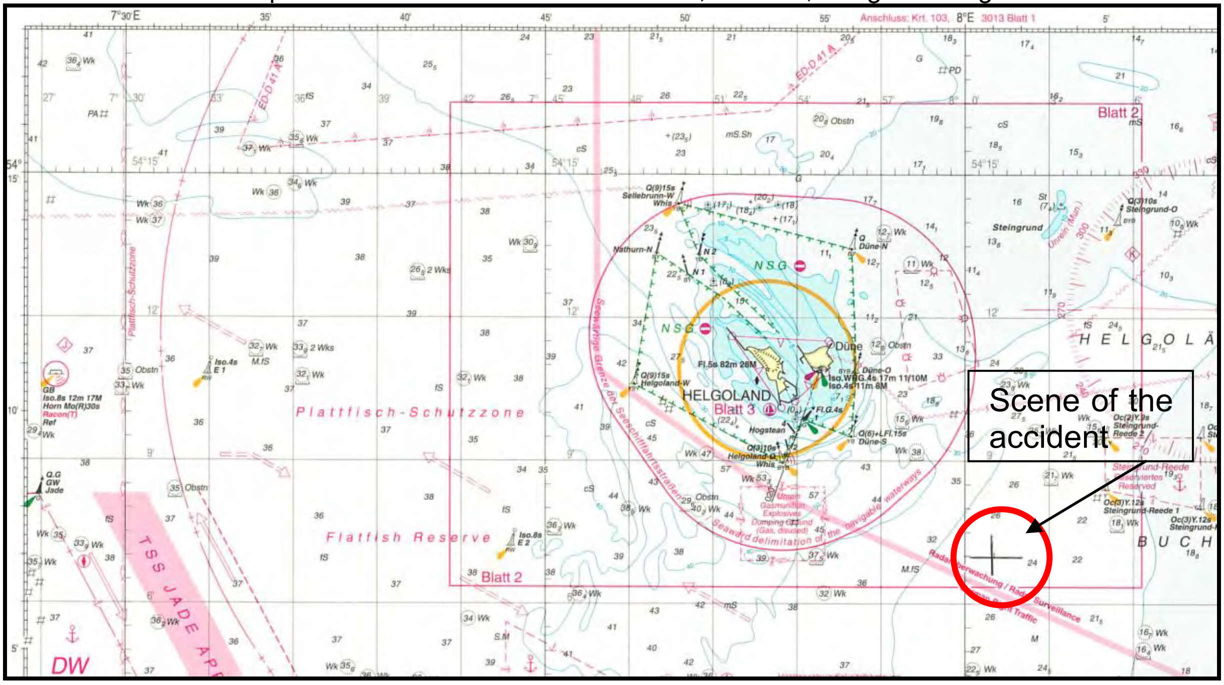

Figure 2: Nautical chart

2.5 Shore authority involvement and emergency response

Agencies involved:	Waterway police (WSP), German Maritime Search and Rescue Service (DGzRS), ambulance, fire brigade
Resources used:	Watercraft, pumps
Action taken:	Vessel drained, primary care for casualties
Results achieved:	Drained condition of vessel preserved, no lasting injuries

3 COURSE OF THE ACCIDENT AND SUBSEQUENT COURSE OF THE VOYAGE

3.1 Course of the accident

The subsequent course of the accident is reproduced according to the written account of the skipper and mission logs of the DGzRS.

At about 1250 on 21 June 2013, the RAKEL cast off in Bremerhaven with 11 people on board. The RAKEL's crew consisted of nine passengers and she was navigated by the owner, who is in possession of a Sportseeschifferschein (German certificate for operating pleasure craft in coastal waters). The holder of a Sportbootführerschein-See (German maritime pleasure yachting navigating licence) was assigned the role of skipper's deputy. According to the owner, the holder of a navigating certificate with many years of sailing experience was also on board.

The first reef was tied into the mainsail because of the weather forecast. The Alte Weser lighthouse was passed at 1605 and they steered a 330-degree course for Heligoland. At about 1630, the skipper felt an impact that he was unable to attribute to swell. At this point, the bilge was drained. At 1700, the two automatic 12-volt yacht bilge pumps were running continuously. However, they short-circuited and failed because of the high water level. A diaphragm pump powered by electricity that was permanently installed in the engine room also failed. The petrol-driven generator on deck was started in order to drain by means of a 220-volt submersible pump. The generator ran only briefly and then also failed. The passengers on board formed a bucket chain and Bremen Rescue (MRCC) was called by radio at 1731 for reasons of safety. The crew of a motor yacht assisted MRCC by relaying radio traffic for the RAKEL, which was barely comprehensible. Fish research vessel WALTER HERWIG III and rescue cruiser HERMANN MARWEDE were at the scene to provide assistance at 1758 and 1803 respectively. The tender VERENA transferred a portable motor-powered pump to the RAKEL at 1824. This pump started but did not draw water. Moreover, it remained inoperable after seeking technical advice by radio. Therefore, the water was drained by means of a bucket chain again. (According to the owner, it was later found that the impeller was defective.) The outer port of Heligoland was reached at about 1849. At 1904, the RAKEL collided with Jetty A while berthing in the port of Heligoland. Eight people from the crew were ordered to go to hospital after the vessel made fast. One person had a laceration above the eye and another suffered contusions to the ribs.

The fire brigade assisted the RAKEL in shifting to the designated grounding area in the outer port at about 2030. The DGzRS finished its mission at about 2112. A leak on the port side just below the waterline was re-caulked[2] and treenailed with the application of lead strips during low tide on 22 June 2013. The shifting manoeuvre was unsuccessful after she was re-floated on the night of Saturday to Sunday. The RAKEL ran aground again and listed at 45 degrees to port, which resulted in the need for renewed intervention by the fire brigade due to water ingress.

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[2] Caulking involves applying oakum or cotton to the joints on a wooden vessel/deck planking by means of a caulking iron and caulking hammer, followed by sealing using pitch or a special rubber caulking compound.

The VERENA returned to the RAKEL at about 0914 but was unable to assist the stricken vessel because she was "completely rotten." At best, more assistance would be needed to deploy oil booms. The RAKEL was unable to shift to the southern port under her own steam until about 1130 on 23 June 2013.

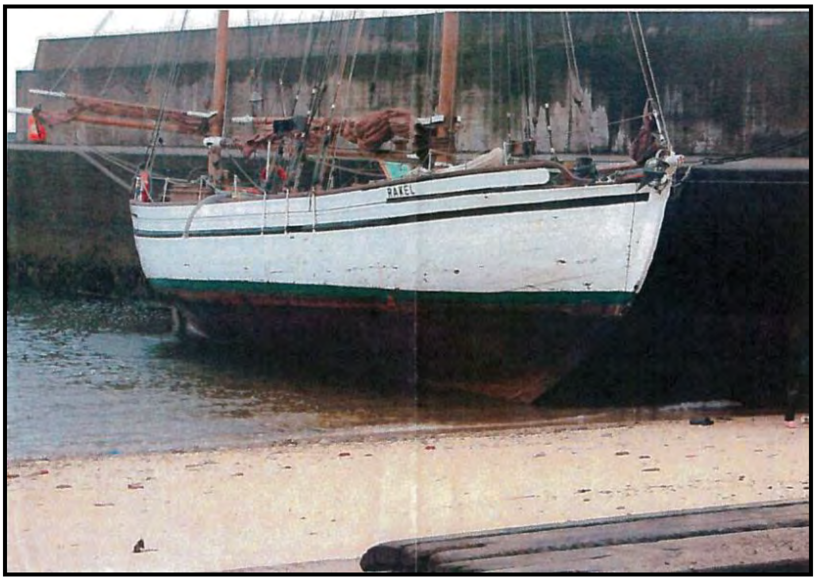

Figure 3: Controlled grounding in Heligoland

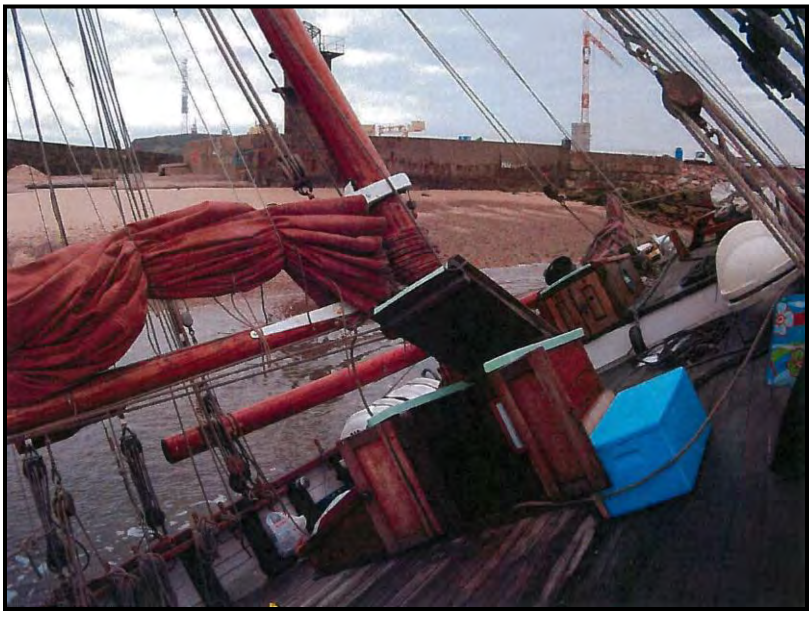

Figure 4: Grounding in the port

3.2 Subsequent course of the voyage

On 21 June 2013, the Ship Safety Division (BG Verkehr) issued a detention order prohibiting the vessel from leaving port and proceeding to sea because her buoyancy was not assured after the ingress of water. Subject to conditions, this detention order was lifted on 28 June 2013 for a single transfer to a shipyard in Cuxhaven. The transfer was made on 2 July 2013 without any complications.

From 3 July to 16 July 2013, the RAKEL was on a slipway at the Boots- und Schiffswerft (boat and shipyard) Cuxhaven and an emergency repair carried out. A second transfer from Cuxhaven to Bremerhaven also passed without any complications and the RAKEL was safely moored at her berth in Fischereihafen 1 at about 2200 on 21 July 2013.

4 INVESTIGATION

This serious marine casualty was reported to the Federal Bureau (BSU) at 1900 on 21 June 2013.
Statements of the owner, mission reports of the DGzRS, documents of the Ship Safety Division, report of the underwriter, and the survey logs of the BSU were available for the investigation.

4.1 Weather report

An official weather report was requested from the Maritime Division of Germany's National Meteorological Service (DWD) for the wind and sea conditions in the German Bight sea area at 1800.

Summary
Weather situation
Prominent pre-summer hot storm conditions over Central Europe evolved into the low-pressure system 'Norbert' on the evening of 20 June 2013. It slowly moved north-east and stood at 1,000 hPa over the North Sea at about 1400 on 21 June 2013. At the same time, a prominent windstorm from the south-west formed in the southern part of the low-pressure system.

Weather conditions
At 1700, the data measured indicate a south-westerly wind of up to force 9 Bft with mean winds of force 6 to 7. Isolated gusts of force 10 Bft would have been possible at 1800.
Wave measured heights beyond the significant swell are barely evident. Certain buoys registered wave heights of 1.5 to 2 m.
It was generally very cloudy to overcast with showery spells and occasional thunder and lightning at the time of the accident.
Visibility stood at 5-8 km.

4.2 History of the vessel

The gaff ketch was built as a non-motorised fishing vessel in November 1896 in Larvik, Norway. She was given the name RAKEL. The present owner bought the vessel in 1981 in Norway when she sailed as a motorised cargo vessel under the name NT362V. He then converted her to the present ketch with the equipment below deck.

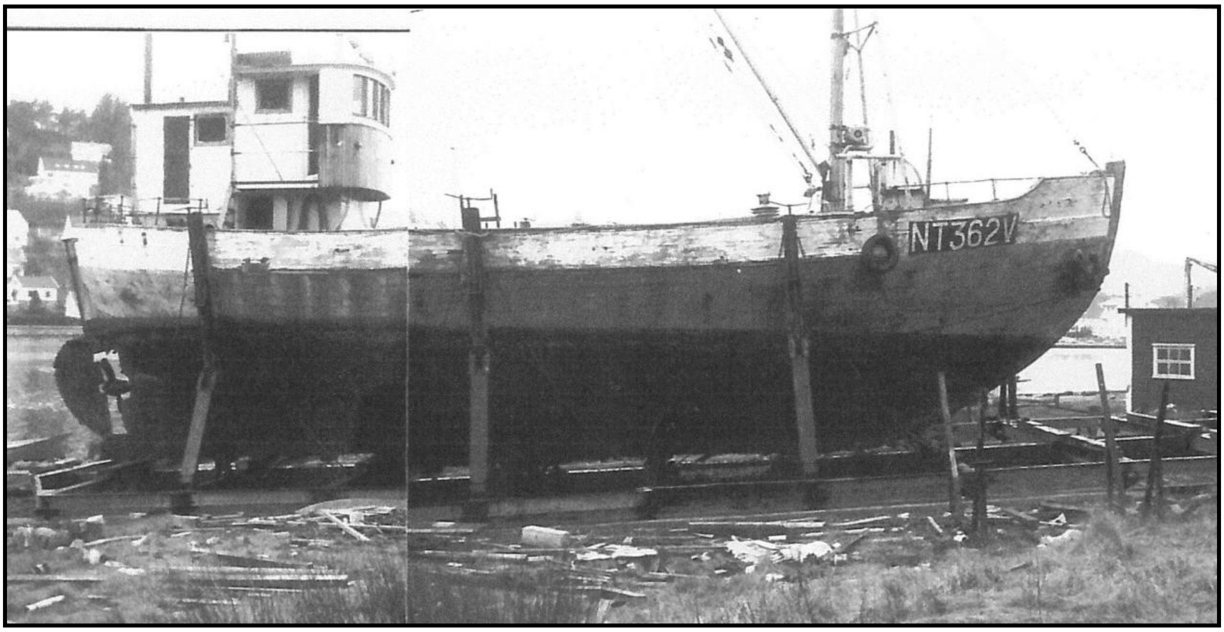

Figure 5: The RAKEL on a slipway in about 1981

According to information given by the owner, beyond normal servicing and maintenance the following work was carried out after she was converted to a sailing vessel:

1991	Machinery replaced by the present MWM engine at the Neptunwerft shipyard in Bremen
2001	Planks replaced at the Deterswerft shipyard in Berne (Weser)
2003	New rudder at the Harmening shipyard in Bremen
2006	Restoration of the bow on the port side
2007	Deck renewed on the port side
2008	Ceiling renewed
2009	Exhaust system replaced by Messrs Mährlander Bremen

4.3 Registration

According to the files of the Ship Safety Division, the RAKEL received a safety certificate pursuant to Germany's Safety Directive for Traditional Vessels for the first time in 2003. In June 2002, the sworn expert for traditional vessels certified *"that in respect of hull, machinery, electrical system, as well as the navigation, radio, and fire protection equipment (design/equipment), the vessel satisfies the Safety Directive for Traditional Vessels (vessel category A)"* for the purposes of this registration. In the notes to this document of compliance, the expert adds that the former cargo hold is divided into accommodation space, engine room, and galley with associated facilities. The engine room with encapsulated motor is reportedly separated from the accommodation space by a lightweight bulkhead. In addition, the following drawing was also submitted for appraisal by the Joint Commission for Historic Watercraft (GSHW). Based on the ensuing opinion of the GSHW, See-BG (marine insurance and safety association, now the Ship Safety Division) issued the safety certificate for traditional vessels for the shipping range 'Trade in near coastal waters/A1' for the first time in 2003.

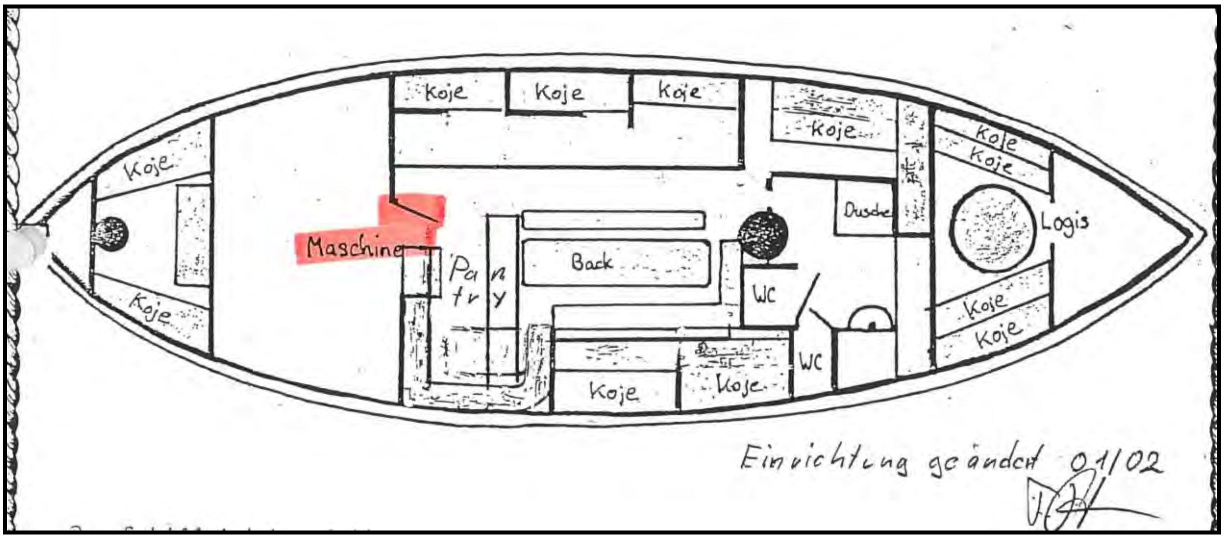

Figure 6: Top view of the RAKEL

The most recent survey was made on 14 June 2012 by the same accredited expert for traditional vessels. In this report, the expert noted that the vessel is in a good state of repair.

4.4 Accident reports that involve the RAKEL

Two accidents involving the RAKEL are stored in the BSU's marine casualty database.

The first report concerns the RAKEL being run into by the traditional vessel FRIDTHJOF at Berth 90 in Rostock on 9 August 2007. This resulted in damage to the bowsprit shrouds, the jib boom was severely overstretched, the deck was raised, and additional consequential damage was feared.

The second report deals with a collision on 8 August 2009 with the 'Seequatze'[3] OLL KORL in the sea area off the eastern pier in Warnemünde. Two people on the OLL KORL fell overboard, the mast was shattered, the bulwark destroyed, and the deck damaged during the collision. The RAKEL's bow stem was slightly scuffed and the bob stay torn off.

4.5 Investigation after the accident on the slipway in Cuxhaven

The Ship Safety Division surveyed the RAKEL on 3 July 2013. Based on the findings of the survey, the following work was carried out and certified at the Boots- und Schiffswerft Cuxhaven:

1.) All the butt joints on the planking were opened, re-caulked, and treenailed with the application of lead strips.
2.) The plank butts on several longitudinal joints forward on the starboard side were re-treenailed and in the area of the waterline treenailed with the application of sheet metal.
3.) The sternpost rabbet was re-caulked and sealed.

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[3] A type of transport boat for live fish that was common on the Pomeranian coast (source: Wikipedia)

4.) All the longitudinal joints on the planking in the hull underbody were checked and re-caulked in places. Particularly large plank joints were covered and then treenailed with the application of lead in some areas amidships on the port side.

5.) In the area of the forepeak bilge, an old PU foam seal was removed and a damaged plank sealed properly.

Figure 7: Plank joints treenailed with the application of sheet metal

Figure 8: Plank joints

Figure 9: Bonded wood strips in longitudinal joints

The expert acting on behalf of the underwriter indicates the point of impact just below the waterline (red arrows). This was treenailed with the application of sheet metal when the vessel was run aground in Heligoland and should be visible in the photo below in the vicinity of the longitudinal joint. According to information given by the owner, the point of impact with an unknown object should be the area visible two strakes lower (black arrow).

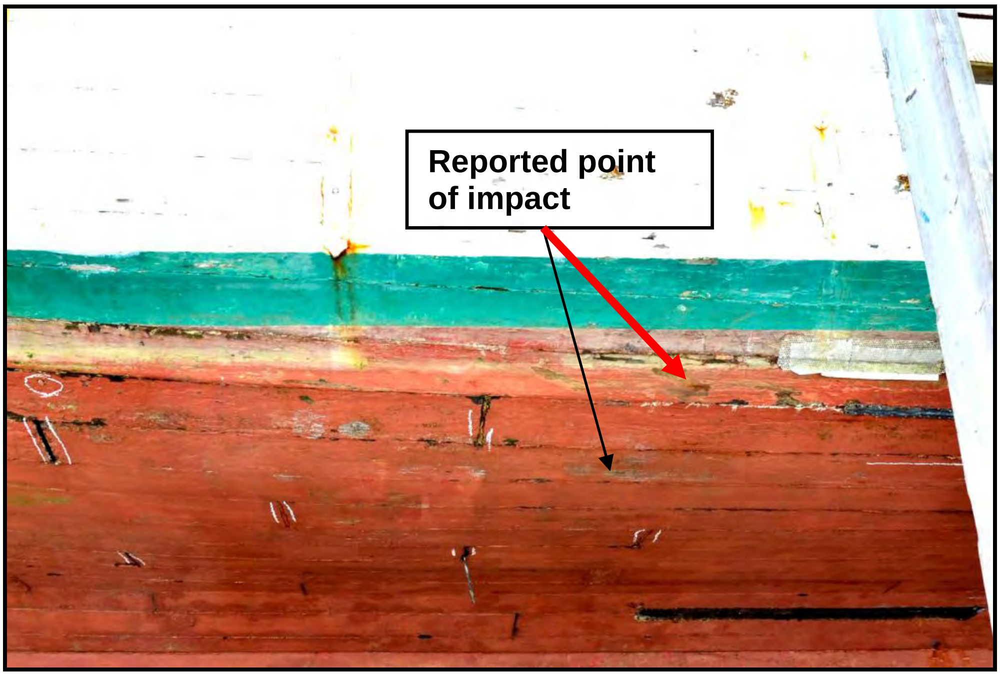

Figure 10: Details of the point of impact

4.6 Survey by the BSU

The vessel was surveyed by two members of the BSU staff at the RAKEL's berth in Bremerhaven (Fischereihafen) on 16 September 2013. Since the mission reports indicated it was not possible to stop the ingress of water, particular attention was given to examining the technical equipment vis-à-vis bilge pumps, the condition of the machinery, as well as the hull.

4.6.1 Bilge pumps

All the pumps on board and the drainage system failed, meaning draining was only possible by many people on board forming a bucket chain.

Hand pump

According to information given by the owner, the hand pump mounted on deck was installed in 1990.

Figure 11: Hand pump

Simple hand pumps of this nature are very effective on fishing vessels because smaller particles in the bilge water do not affect the operation of the pump. The pump on board the RAKEL was not operational and had been taken out of service. The pump handle was no longer attached and the membrane had been replaced by a wooden block.

Pump below deck in the engine room

An electrical diaphragm pump with a pumping capacity of about 2,500 l/h is attached to the engine room bulkhead below deck. Using permanently installed piping and a valve group, it is possible to drain various compartments.

Figure 12: Electrical diaphragm pump

Figure 13: Valve group

However, the pump on the bulkhead did not work because the bolt connecting the pump diaphragm to the handle had broken off.

12-volt yacht pumps

Two 12-volt yacht pumps with mechanical float switches are mounted amidships below the bottom boards. According to information given by the owner, the capacity of the two pumps is about 2,600 l/h. The switching relay and current distribution for both pumps are mounted in a house junction box on the port side beneath the bottom boards.

Figure 14: 12-volt pumps, hoses, and electric cables

According to information given by the owner, both pumps failed because the connections and a switching relay were immersed, thus producing a short circuit in the electric cables.

220-volt pump

During the survey on board, three 220-volt household/hardware store pumps (partly equipped with float switch) were inspected. A portable 2.5 kW petrol-driven generator is available on deck for power generation.

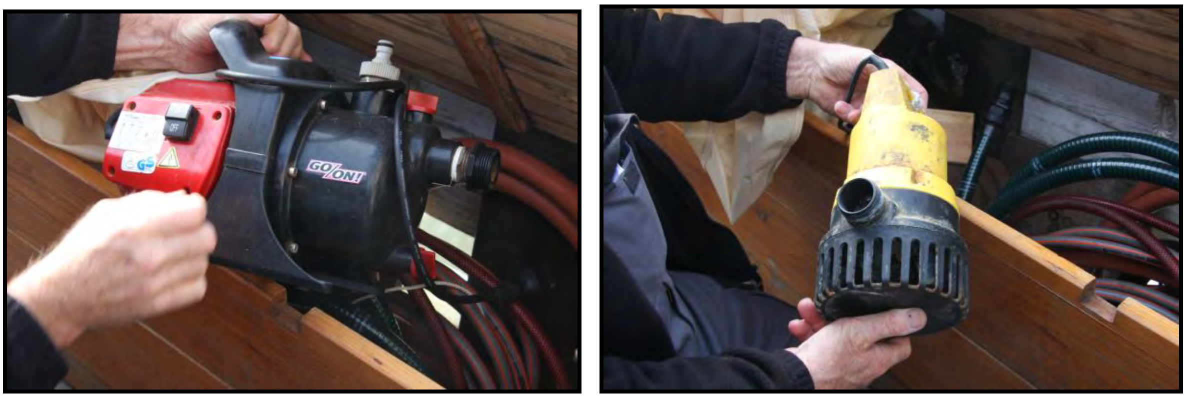

Figure 15: 220-volt household pumps

Figure 16: 220-volt garden pump and petrol-driven generator

The three 220-volt pumps could not be used as the generator failed to run because a fuel hose had a kink in it. According to information given, the old porous fuel hose was replaced before the accident. The replacement hose installed was too long. This resulted in a kink in the hose during operation, thus interrupting the fuel supply.

4.6.2 Electrical equipment

The 12-volt power supply on board the vessel is maintained by batteries and a generator, as well as by shore electric power supply with three 220-volt chargers.

Figure 17: Battery in the engine room (port side)

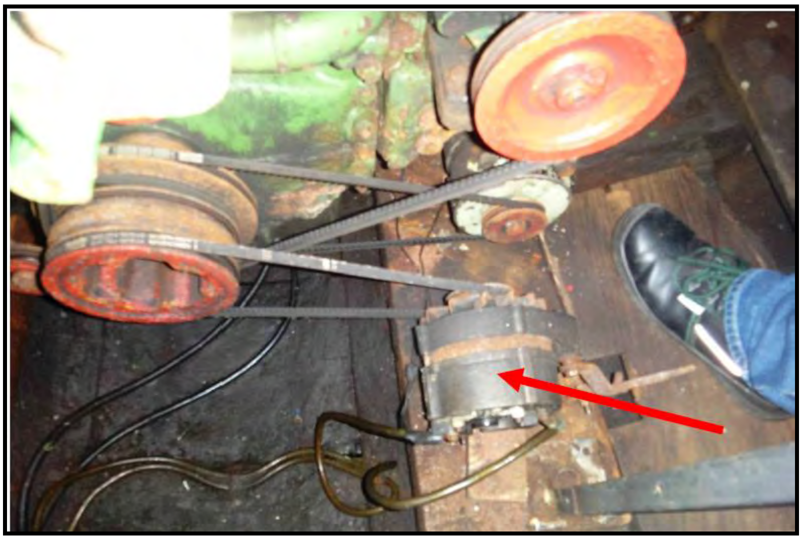

Figure 18: Generator on base

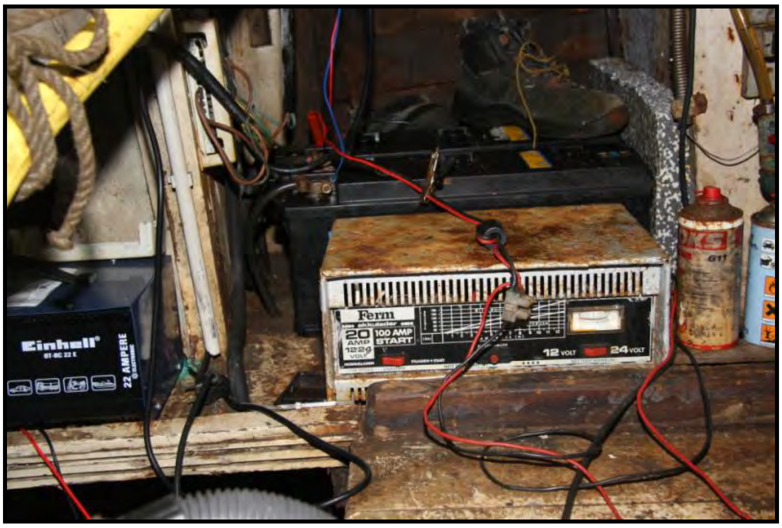

Figure 19: Charger and batteries (starboard side)

Figure 20: Shore electric power supply

4.6.3 Machinery

During the survey of the engine room, it was noted that the floors and frames, the ceiling boards, as well as the deck beams and planking were not coated with foam-forming paint designed to develop an insulating, protective layer in the event of fire. Similarly, the foam-forming paint is not substituted by non-combustible insulation or encapsulation of the main engine. Moreover, no brackets or mounting holes were found for the attachment of lateral insulation and encapsulation of the main engine. No additional bilge pump is attached to the main engine. Moreover, the generator, which is driven by a drive belt, is fixed to the engine base.

Figure 21: View of the engine (starboard side)

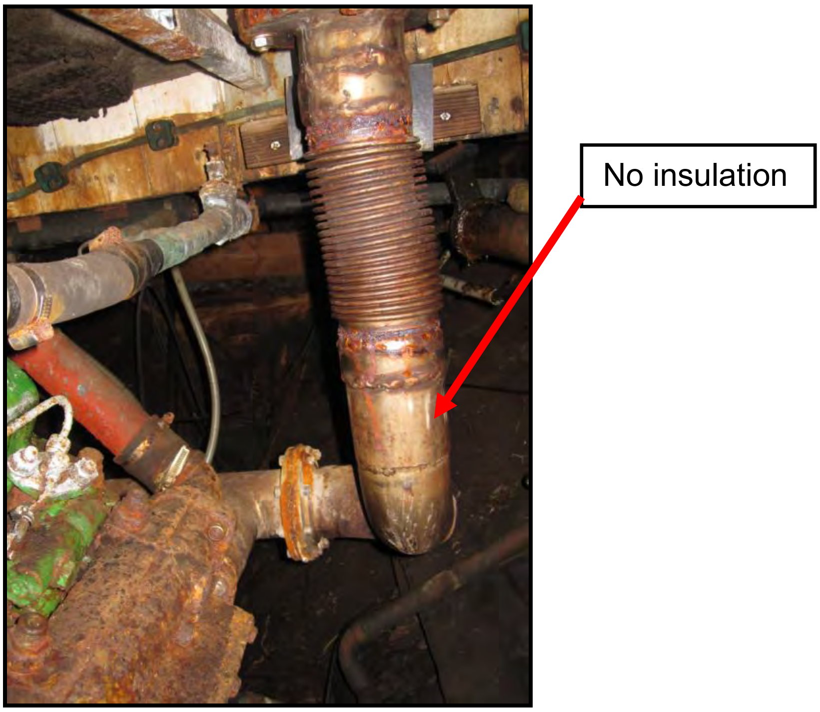

Figure 22: Engine (port side)

The exhaust pipe is not sufficiently insulated and the filling pipe for the diesel tanks located on the port and starboard side is not connected with the filler neck on deck:

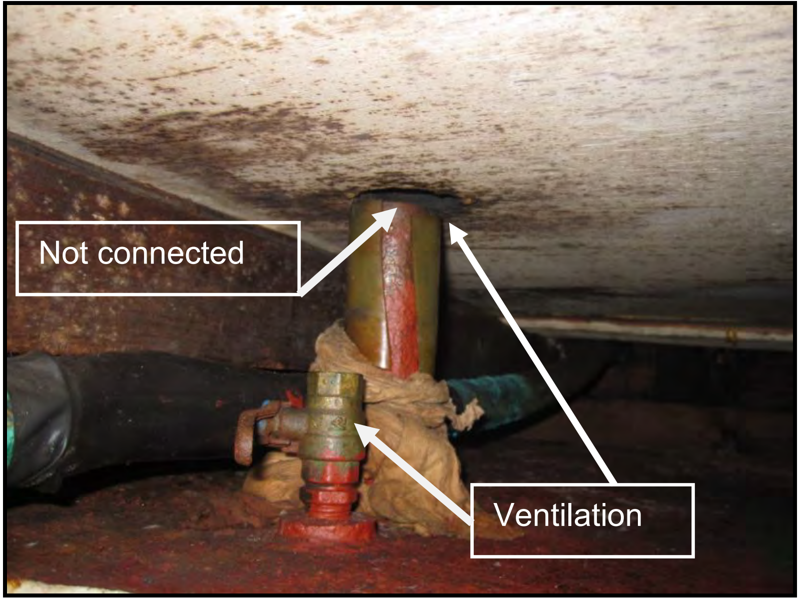

Figure 23: Tank filling and ventilation

The diesel tanks vent in the engine room via the open filling necks or additionally mounted ball valves on top of the tank. The tank filling level is determined using other ball valves at the lowest points of the tanks, which are equipped with a hose for sounding.

The engine room is separated from the galley and accommodation space only by a wooden bulkhead and simple wood door fitted with a wired glass window. Fire extinguishers are available below and on deck for firefighting.

Figure 24: View of the engine room door

4.6.4 Hull

The BSU surveyed the hull when the vessel was afloat. The vessel has an inner ceiling almost throughout. The normal frame level should be 400 mm. The thickness of the planks and ceiling was not determined. The hood ends of the planking are bolted through the frames to the ceiling at several points. Here, additional wood and steel plates were placed below the nuts.

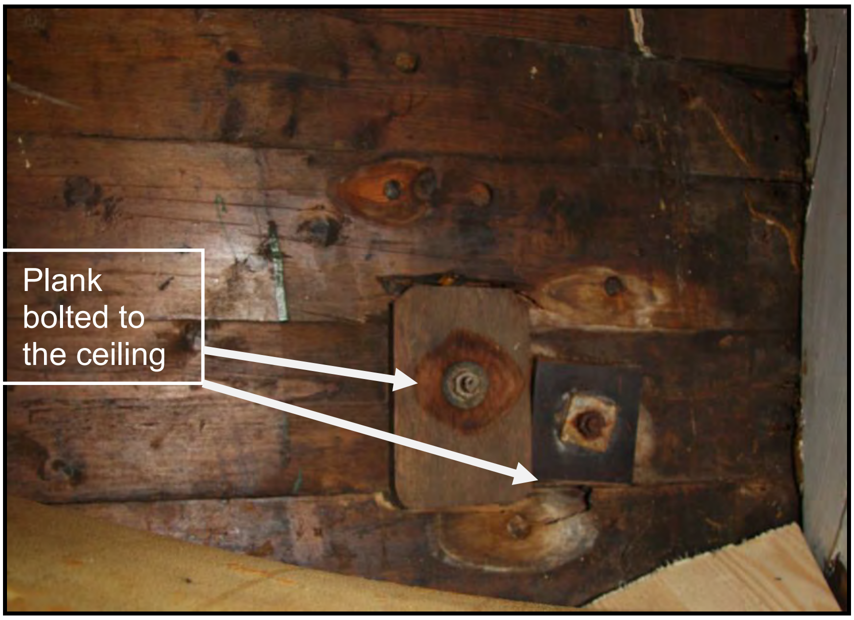

Figure 25: Bolted hood end

The vessel has no transverse bulkheads and the entire hull should be regarded as one unit. The area below the floor in the fore section, which was originally sealed using PU foam, was inspected. A rotten frame on the starboard side has been doubled using new frame pieces.

Figure 26: Frames in fore section

5 ANALYSIS

5.1 Conversion to a ketch

A Tonnage Certificate issued in 1948 was found in the vessel's documentation at the Federal Maritime and Hydrographic Agency. According to the drawing in the rating certificate, the RAKEL had a forward engine room bulkhead, which was also the aft cargo hold bulkhead, and a bulkhead towards the forward accommodation space/cable-tier (the forward cargo hold bulkhead).

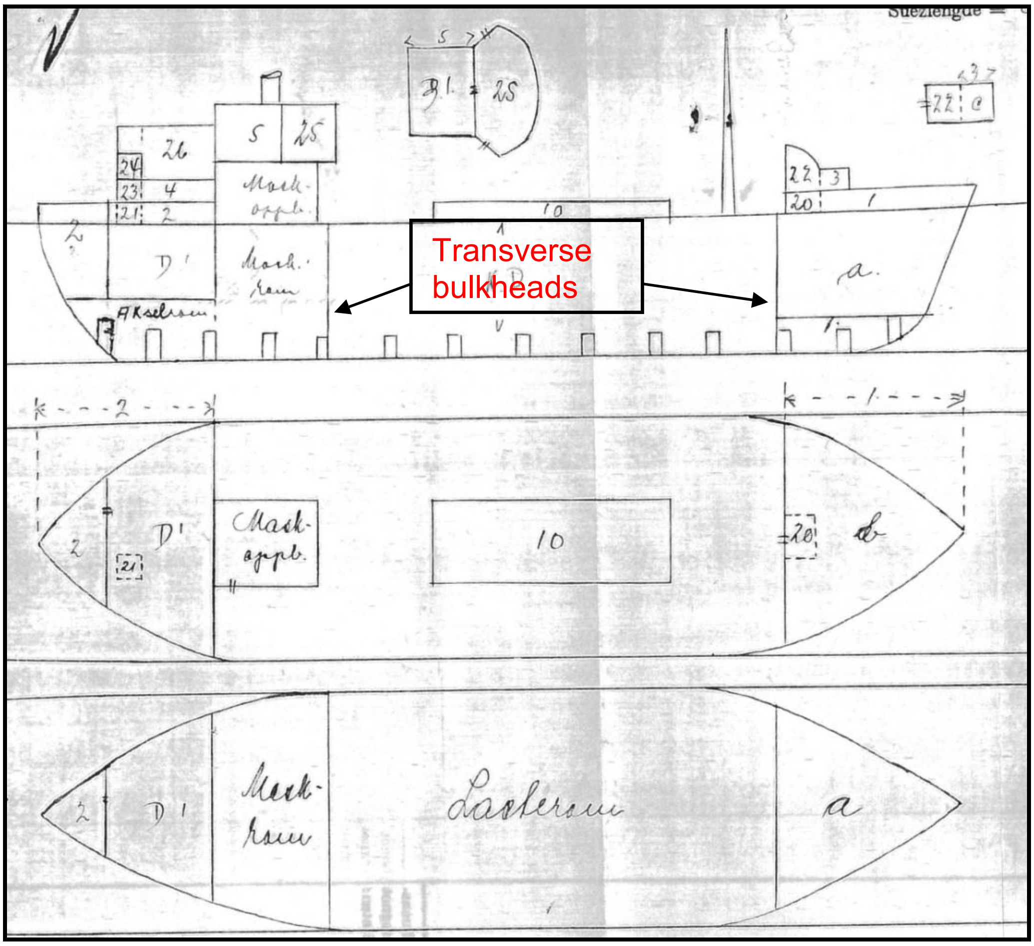
Transverse bulkheads

Figure 27: Rating certificate drawing

These bulkheads divided the vessel into three sections. In the event of leakage, seaworthiness is enhanced if each section can be drained individually. However, the transverse bulkheads have not been watertight since the RAKEL was converted back to a gaff ketch, meaning the vessel consists of only one section.

In the drawing submitted in 2003 to the GSHW for evaluation, the forward bulkhead is shown as a bulkhead, and a door with window is located in the aft engine room bulkhead (see Fig. 6). Such a door – made out of wood, window, no sliding bolt – in a non-watertight bulkhead and bordering with the engine room is not permitted.

The main companionway to the accommodation space has no coaming or washboard, meaning sufficient watertight integrity cannot be established because of the design. The conversion and maintenance work was conducted without the involvement of a classification society, the Ship Safety Division, or an accredited expert for traditional vessels.

Neither the electrical 220-volt system nor the 12-volt system on the RAKEL complies with merchant vessel or yacht standards in respect of type test, wiring or layout.

The venting of diesel tanks in the engine room, incomplete connection of filling lines with diesel tanks, and sounding of tanks using a hose and ball valve are not permitted.

Any exposed timber in the engine room of a wooden vessel should be coated with foam-forming paint or fitted with non-combustible insulation. Alternatively, the engine must be completely encapsulated with insulation. None of these fireproofing measures have been taken on the RAKEL.

According to the Directive for Traditional Vessels, exhaust pipe components that have a possible surface temperature of more than 220 degrees Celsius must be fully insulated. The exhaust pipe on the RAKEL is not adequately insulated.

According to the owner, it was difficult for an expert to inspect the frames and this never happened because of the ceiling.

Approved stability documents and instructions for the operation of sails, as well as manning with sufficient deckhands are not present.

5.2 Underwriter's report and survey of the Ship Safety Division

After the accident, the Ship Safety Division and an expert acting on behalf of the underwriter surveyed the vessel in Cuxhaven.

The expert acting on behalf of the underwriter states that based on the new scuff marks found on the port side (see Fig. 10), it would be possible that a collision with flotsam occurred, which compressed the material enough to cause the underlying plank joint to burst open. However, this leakage of approximately 40 cm in length on the plank joint just below the waterline cannot have been the sole reason for not being able to pump out the water. The expert assumes that significant forces acted on the structure when sailing in swell at 7 Bft and that with probability bordering on certainty additional water could enter at the vertical plank joints, which on the slipway were open to up to 20 mm. The expert assumes that the RAKEL had lost her longitudinal strength and bases this on the fact that on the slipway the ends of the vessel were resting on the cradle and a gap was visible in the middle between cradle and keel rail (hogging).

The expert also assumes that the deficiencies found, the poor longitudinal strength and associated lack of seaworthiness in particular, already existed at the time of the last survey conducted in connection with acquiring the safety certificate for traditional vessels by the accredited expert for traditional vessels.

This marine casualty gave rise to the RAKEL's first survey by the Ship Safety Division. The surveyor from the Ship Safety Division states that all longitudinal joints in the hull underbody and topsides must reportedly be examined and if necessary caulked. Three strake joints were parted from the frames forward on the starboard side. About 80% of the covered butt joints on the planks are reportedly leaking. The sternpost should be re-caulked after drying. The PU foam in the forepeak bilge used for sealing a plank on the starboard side should be removed and the area properly repaired. The deck is reportedly leaking at many points and the deck beams amidships and in the engine room area are reportedly damp and starting to soften. The rudder reportedly has too much play and the shaft and bearing must reportedly be renewed.

5.3 Registration as a traditional vessel

The vessel was in possession of a safety certificate for traditional vessels from the Ship Safety Division in accordance with paragraph 1.1 of the Safety Directive for Traditional Vessels at the time of the accident. The certificate was issued on 2 November 2012 and valid until 30 October 2014. The vessel was registered as a sailing vessel (vessel category A) for trade in near coastal waters with no more than 12 people on board.

The Safety Directive for Traditional Vessels lays down the registration requirements for traditional vessels (directive pursuant to Article 6(1) Schiffssicherheitsverordnung (German ordinance for the safety of seagoing ships)). In cooperation with the GSHW and pursuant to paragraph 1.4, See-BG[4] decides as to whether the conditions for issuing a safety certificate for the operating mode 'Traditional Vessel' are met based on the documentation submitted by the applicant, and for vessels with less than 80 people on board, also a report by an expert on traditional vessels. Individuals responsible according to the Schiffssicherheitsgesetz (German ship safety act) – operators or owners, for example – must also declare that they will operate the traditional vessel in the interest of non-material goals, fostering maritime heritage, as well as for social purposes and the like, and not for sustained monetary gain.

If a written application for a vessel is submitted directly to See-BG, then See-BG makes its own enquiries and surveys before issuing the safety certificate. However, such enquiries or surveys by See-BG are dispensed with for vessels with less than 80 people on board if the application for registration of a traditional vessel is forwarded to See-BG via the GSHW and the latter concludes that the conditions for registration are met based on its own investigations. Accordingly, the GSHW notified:

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[4] Now known as the Ship Safety Division

"A review body from the GSHW will review applications for validity and then forward them to See-BG with an instruction to issue the certificate. See-BG issues the certificate in its capacity as federal ship safety authority without any subsequent investigations of its own."[5]

The owner of the RAKEL opted for a validity review by the GSHW vis-à-vis registration as a traditional vessel and a report was issued by a publicly appointed and sworn expert for traditional vessels on behalf of the owner for the first time in April 2003. Based on this report, the vessel is assigned to vessel category A – registered or up to 12 people and a hull length of less than 25 m. Furthermore, the expert certified full seagoing operation for the performance of single-day voyages with up to 25 people on board in near coastal waters.

At no time was the vessel surveyed by a surveyor from See-BG/Ship Safety Division or a classification society.

The expert for traditional vessels did not survey the frames or floor and was also not consulted during the conversion. In the course of the examination pursuant to the Safety Directive for Traditional Vessels, the expert issued more than one document of compliance, according to which the vessel complies with the Safety Directive for Traditional Vessels in respect of her hull.

5.4 Survey of the hull and bulkheads

The nature and scope of a survey of commercially operated seagoing vessels is clearly defined by the classification societies. For example, in the case of steel vessels the thickness of the plating must be measured to assess with certainty the general and local degree of corrosion. The bulkheads, frames, frame connections, and floors must also be surveyed. However, this may give rise to difficulties or not be possible if the bilges of a former cargo vessel, which is operated as a traditional vessel, are subsequently filled with concrete for reasons of stability.

A survey on a merchant vessel made of wood, such as a fishing vessel, is also clearly defined. For example, Germanischer Lloyd's Rules for Classification and Construction for wooden seagoing vessels clearly provide for class renewal surveys of the hull (4.5): *"The ceiling and insulation of the spaces is to be removed at several points, at the surveyor's discretion.*

With regard to watertight bulkheads, section 4(11) of these rules for wooden seagoing vessels states that the engine room, accommodation space, and cargo or fish hold must be separated by watertight bulkheads on all vessels. Moreover, a watertight collision bulkhead must be provided on vessels exceeding 18 m in length.

The RAKEL is almost completely fitted with a ceiling. With that in mind, the expert for traditional vessels believes it was not possible to survey the structure. Transverse bulkheads and a collision bulkhead do not exist or their design is not watertight.

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[5] Information sheet of the GSHW on safety certificates for traditional vessels dated 23 May 2001

At no time in the past 10 years did the expert for traditional vessels survey the vessel beneath the waterline and despite that certified she was in a good state of repair in June 2012.
A query with the Ship Safety Division revealed that surveyors of the Ship Safety Division inspect vessels in accordance with the aforementioned rules of classification societies, and that bottom surveys are conducted regularly. This approach is not prescribed by the safety directive but is a technical standard for inspecting watercraft.

6 CONCLUSIONS

6.1 Condition of vessel

The 117-year-old traditional vessel RAKEL was not seaworthy when the serious marine casualty occurred. The many improperly sealed longitudinal joints and transverse butts in the hood ends of the planking must be seen as the main cause of the water ingress. The breadth of the joints indicates that the shell could not be adequately sealed because of the planking expanding due to moisture. A single instance of damage that would be solely responsible for the ingress of water was not located. The point of impact indicated on the port side just below the water surface cannot have been the sole cause of the water ingress. This point would only lead to increased water ingress when sailing on port bow at a considerable heel. However, she was sailed on starboard bow, meaning the point on the port side would have been largely above the water surface.
The cause of the water ingress also appears to be the non-connected (or not connected to the frames) strakes. Bolted joints with the inner ceiling are a final measure when frames or floor are rotten or no longer present. The longitudinal strength of the hull is thus no longer given and the plank butts in the planking start to leak when sailing aggressively.
If the vessel was divided into sections (each of which could have been drained separately) by several transverse bulkheads in accordance with the rules for seagoing vessels, then the water ingress could have been localised and watertight integrity enhanced.
The expert did not conduct a survey of the frames and structure behind the planks (or ceiling) and it is difficult to understand why the poor condition of the vessel was not challenged during the survey.
This distress situation could have been avoided if the longitudinal strength was sufficient and the hull watertight.

6.2 Seaworthiness

Inter alia, seaworthiness implies that fixed bulkheads with defined coaming heights[6] are at access points to enclosed superstructure. The establishment of sufficient watertight integrity for the main companionway on the RAKEL was not possible because there was no coaming there whatsoever.

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[6] See classification rules and/or the law concerning the International Convention on Load Lines

Figure 28: Main companionway amidships

Seaworthiness also implies that verified stability documents and information concerning manning with sufficient deckhands are kept on board. The BSU has already pointed to this issue during the investigation of other marine casualties involving traditional vessels and issued corresponding safety recommendations. Reference to the implementation of these safety recommendations was last made on 19 February 2009 in a hitherto unpublished investigation, the distribution of which to the BMVI[7], the Ship Safety Division, and the GSHW was expedient and purposeful. This investigation into the stability of traditional vessels conducted in 2009, including safety recommendations, is reproduced in the annex to this report. Various accidents involving traditional vessels were referred to in the course of this investigation and the BMVI announced a revision of the Safety Directive for Traditional Vessels. To that end, the BMVI charged the Ship Safety Division with the preparation of an initial draft of the revised safety directive. The BMVI is currently considering this draft.

6.3 Equipment and machinery

The condition of the marine equipment on the RAKEL, including pumps and electrical system, does not comply with the normal equipment standards for a seagoing or traditional vessel.

The permanently installed electrical pump in the engine room failed because of a technical fault and the hand pump mounted on deck had been taken out of service.

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[7] The Federal Ministry of Transport, Building and Urban Development (BMVBS) received the designation Federal Ministry of Transport and Digital Infrastructure (BMVI) by administrative order of 17 December 2013

The wiring on the 12-volt yacht pumps beneath the bottom boards – or otherwise – does not conform to standard, meaning an electrical short circuit was to be expected. Use of the large number of 220-volt hardware store/household/garden pumps on board would have been able to stop the ingress of water. However, they could not be operated because the petrol-driven generator on deck failed after a short period because of an inadequate repair to the fuel tube.
With regard to fire protection, the machinery and the engine room are not equipped in accordance with the rules for seagoing or traditional vessels. Fire protection by paint or encapsulation of the main engine in accordance with the Safety Directive for Traditional Vessels does not exist. Insulation of the exhaust pipe is insufficient. According to the Safety Directive for Traditional Vessels, this insulation should be fitted to exhaust pipe system components that have a possible surface temperature of more than 220°C. In the case of the MWM engine, this is even higher. The prescribed temperature of 220°C is the ignition temperature of diesel fuel. This threshold value is taken from the classification rules for seagoing vessels. The value is much too high for accidental-contact/personal protection. The classification rules for sporting craft, which require that exhaust pipes with a surface temperature of more than 80°C be fully insulated, should be applied for confined engine rooms such as that of the RAKEL.

No rule permits the venting of tanks in an engine room.

Given the condition of the systems, it is difficult to understand the expert's document of compliance for traditional vessels, which implies that the machinery, equipment, and electrical equipment complies with the Safety Directive for Traditional Vessels.

6.4 Survey of the traditional vessel

The BSU's investigation revealed that there is no uniform procedure for how surveys are conducted. While surveyors from the Ship Safety Division generally observe the requirements of classification societies, freelance experts may be more willing to tolerate certain issues of relevance to safety. In any accident involving a traditional vessel previously investigated by the BSU, where the vessel had safety-related technical deficiencies, a freelance expert surveyed that vessel. In the interest of vessel safety, a uniform approach would appear to be necessary.
The safety directive does not provide clear instructions as to what approach should be taken in respect of reproductions and major conversions. In the course of the marine casualties involving the Gotland (Ref.: 49/02, published in 2003) and the LISA VON LÜBECK (Ref.: 164/06, published in 2007), the BSU indicated that the Safety Directive for Traditional Vessels should be amended to the effect that major conversions should be conducted under the supervision and approval of a classification society, the Ship Safety Division, or an accredited expert (see annex to the report).

7 SAFETY RECOMMENDATION(S)

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

7.1 BMVI, Ship Safety Division, and GSHW

The Federal Bureau of Maritime Casualty Investigation recommends the urgent revision of the Safety Directive for Traditional Vessels and inclusion of the following provisions:

1. Reproductions and conversions of historic watercraft must be carried out with plan approval and supervision by a classification society or an accredited expert during construction.

2. Traditional vessels must have approved stability documents and sailing instructions on board. These documents must be prepared on the basis of a combined inclining and rolling test in accordance with the requirements of classification societies and under the supervision of a classification society or an accredited expert.

3. A uniform approach for surveying traditional vessels must be defined for surveyors from the Ship Safety Division and experts with the requisite accreditation.

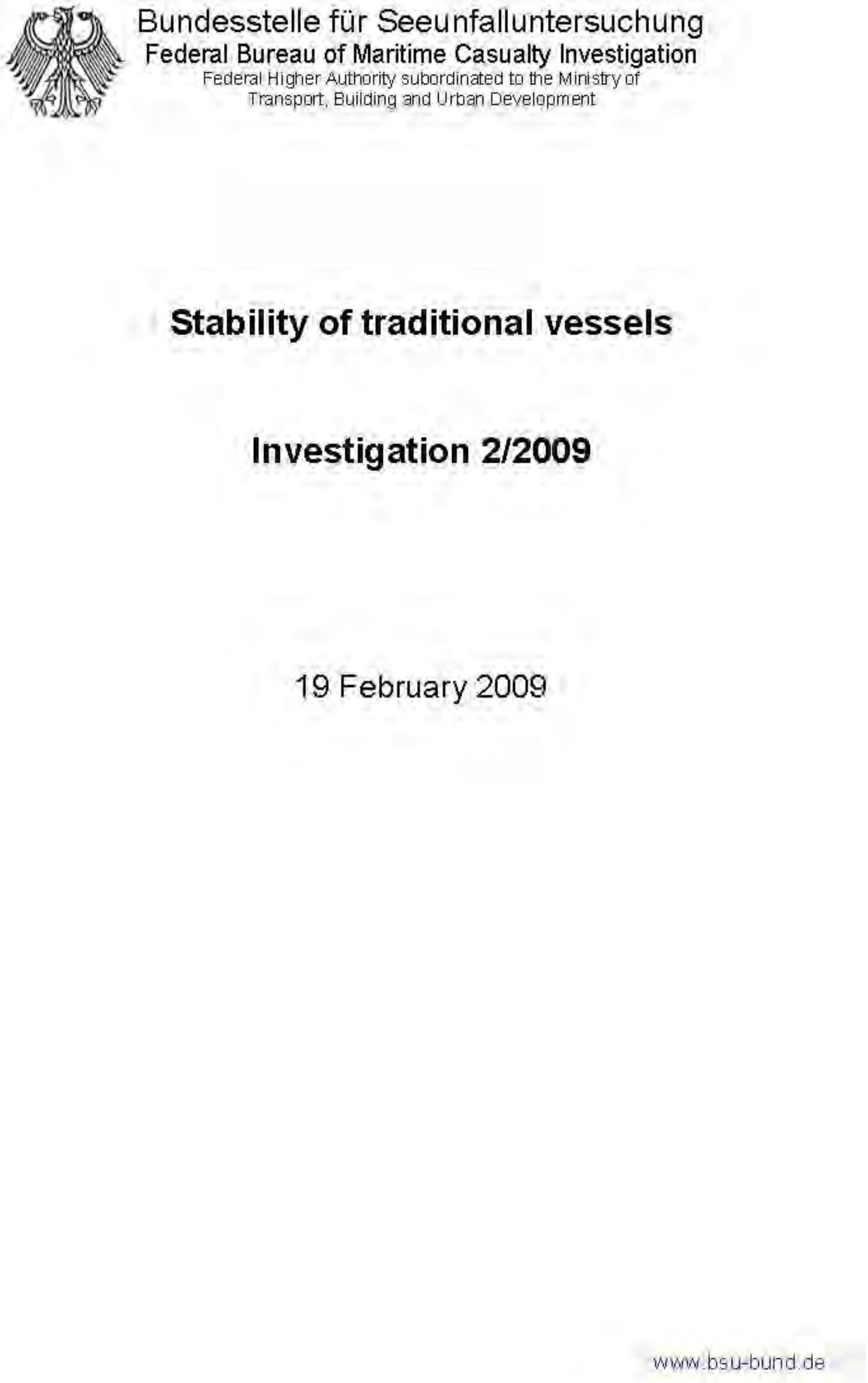
4. The survey defined for the vessel's structure, shell plating, and bulkheads must have a uniform scope. It must be included in the Directive that fittings and ceilings must be partially removed when surveying the frames, floors, and deck beams if necessary.

5. To ensure that persons are protected, exhaust pipes with a surface temperature of more than 80°C must be fully insulated.

8 SOURCES

- Enquiries by the waterway police (WSP)
- Documentation of the DGzRS and MRCC
- Written statements
    - Owner and skipper
- Documentation of the Ship Safety Division
- Underwriter's report (expert: H.U. Brunner)
- Nautical charts and vessel particulars, Federal Maritime and Hydrographic Agency (BSH)
- Official weather report by Germany's National Meteorological Service (DWD)
- Rules for Classification and Construction of Germanischer Lloyd
  . - Part 1 Ship Technology
    . - 0 Classification and Survey
    . - Part 3 Sporting Craft
    . - 13 Wooden vessels, issued in 1994 and reprinted in 2008
- Directives within the meaning of Article 6 Schiffssicherheitsverordnung (ordinance for the safety of seagoing ships) concerning improving the safety of traditional vessels

9 Annex



Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Ministry of
Transport, Building and Urban Development

Stability of traditional vessels

Investigation 2/2009

19 February 2009

www.bsu-bund.de

The investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG) of 16 June 2002.

According to said Law, the sole objective of this investigation is to prevent future accidents and malfunctions. This investigation does not serve to ascertain fault, liability or claims.

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 19(4) SUG.

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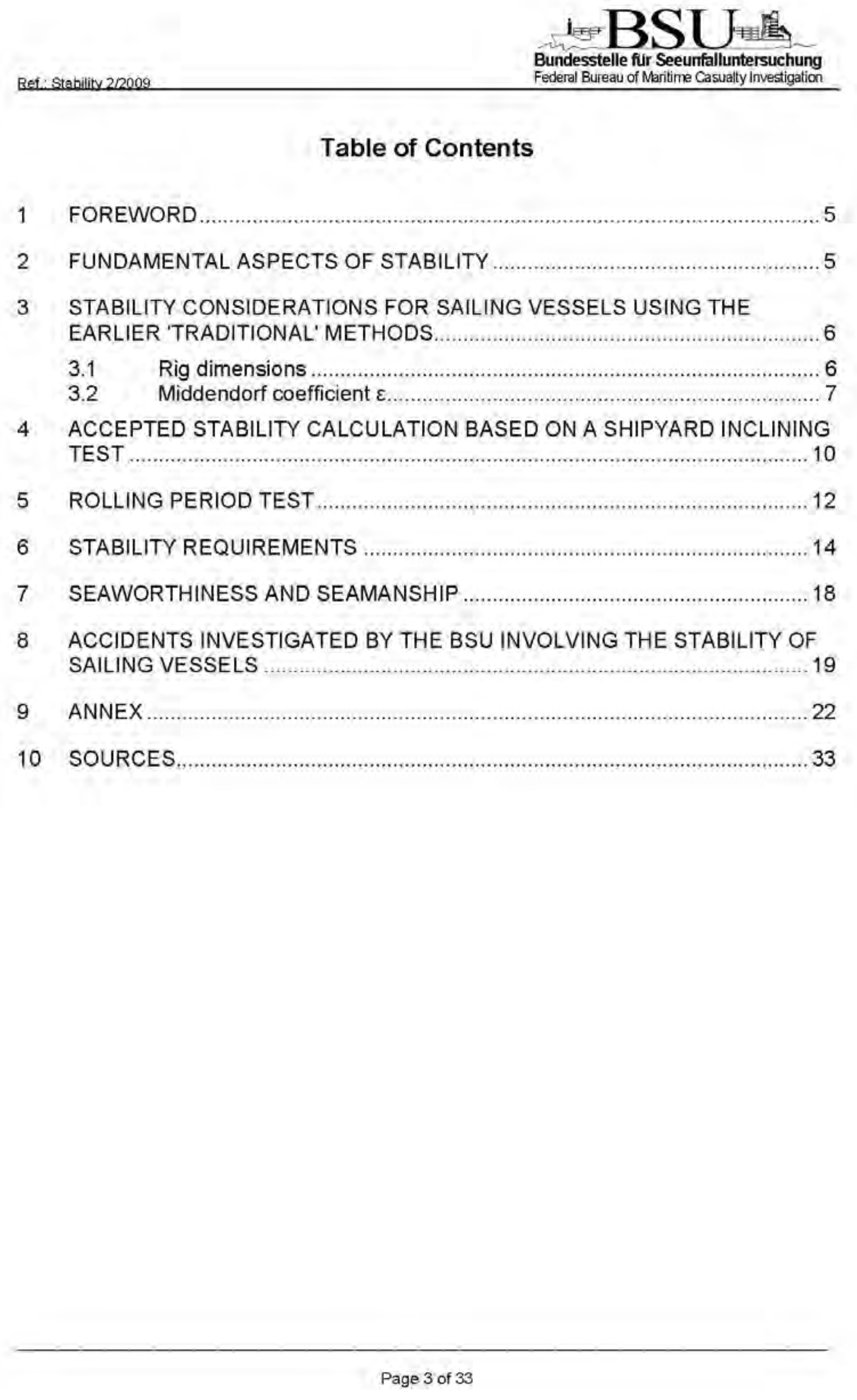

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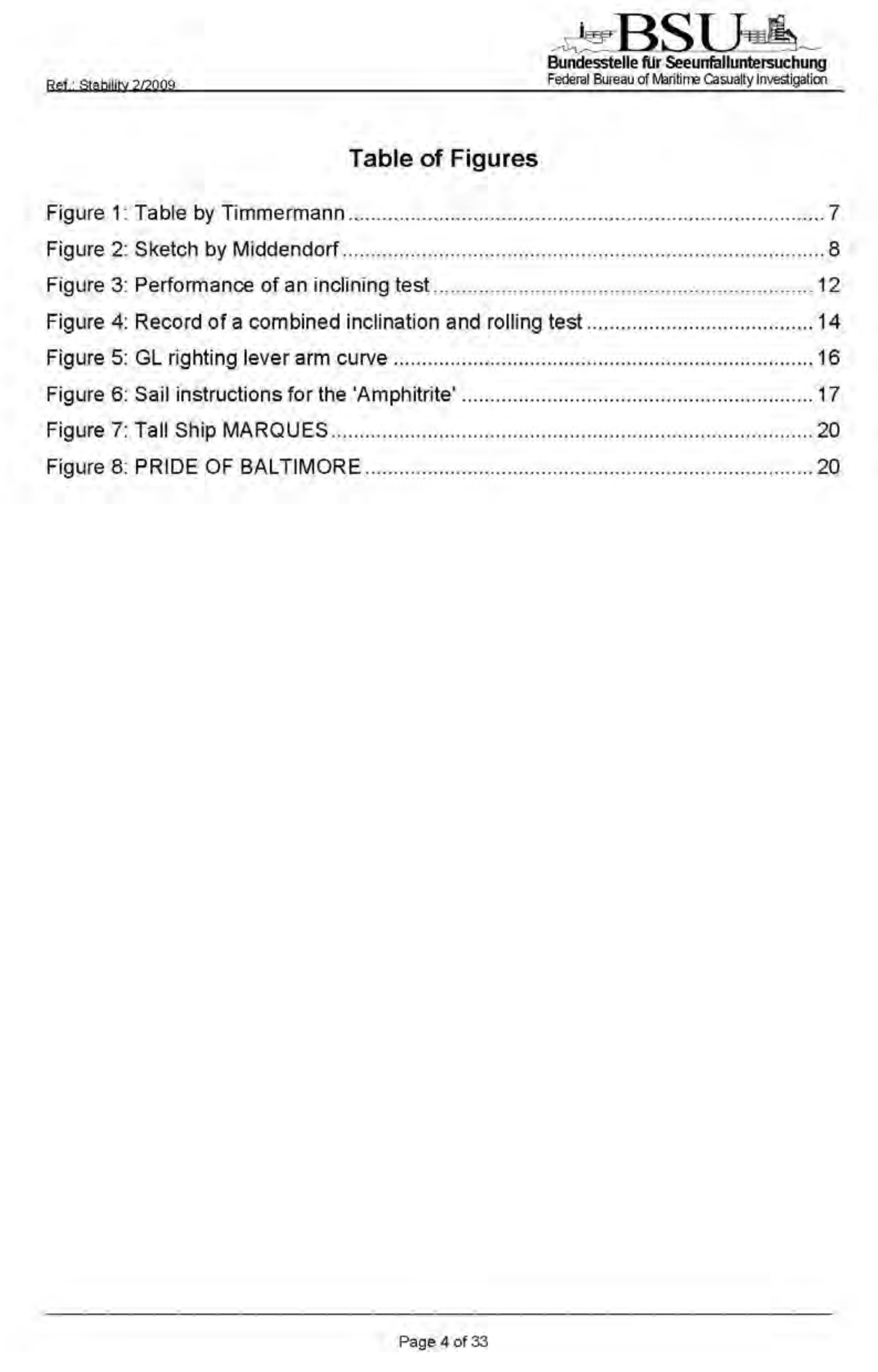

Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
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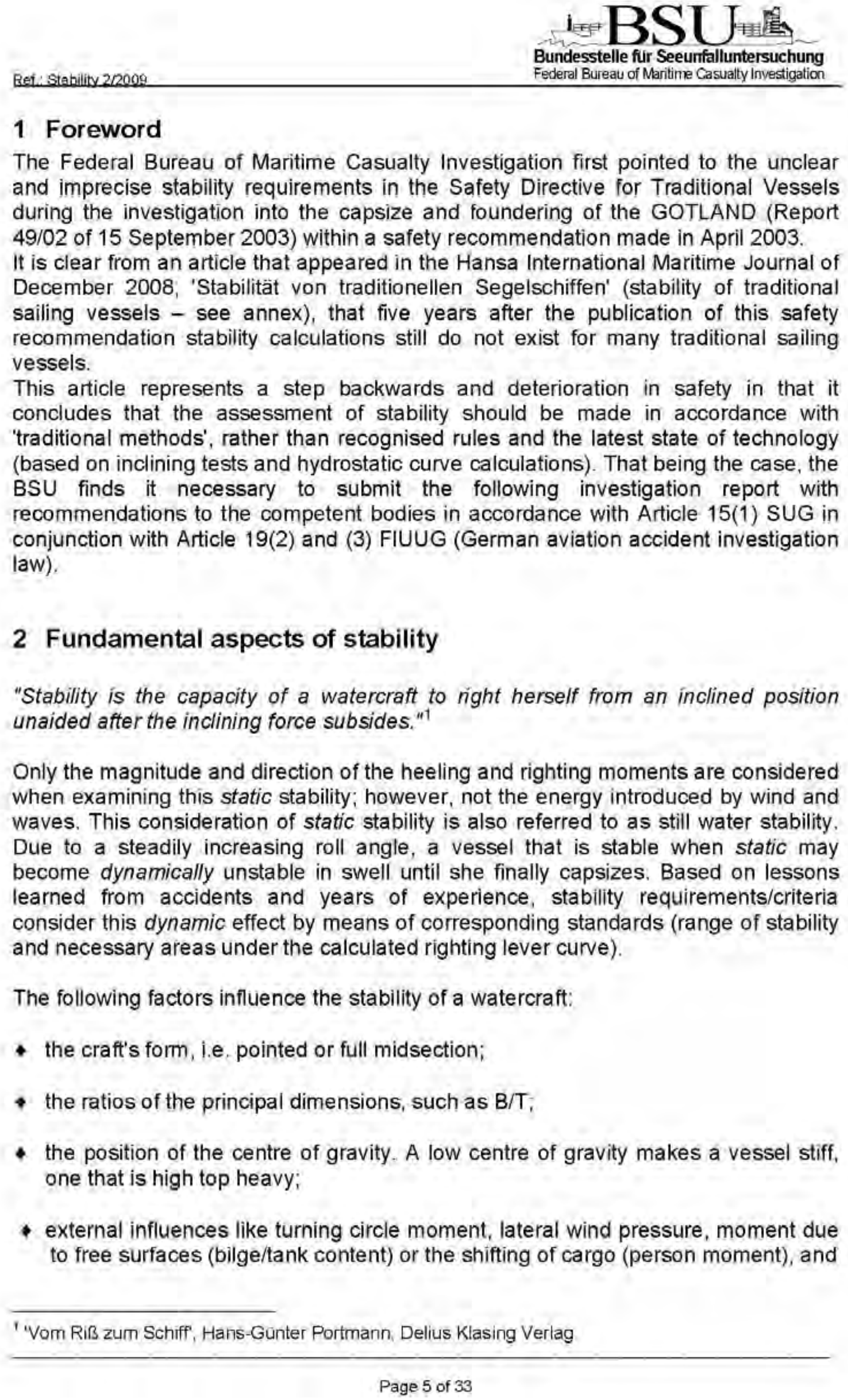

1 Foreword

The Federal Bureau of Maritime Casualty Investigation first pointed to the unclear and imprecise stability requirements in the Safety Directive for Traditional Vessels during the investigation into the capsize and foundering of the GOTLAND (Report 49/02 of 15 September 2003) within a safety recommendation made in April 2003.
It is clear from an article that appeared in the Hansa International Maritime Journal of December 2008, 'Stabilität von traditionellen Segelschiffen' (stability of traditional sailing vessels – see annex), that five years after the publication of this safety recommendation stability calculations still do not exist for many traditional sailing vessels.
This article represents a step backwards and deterioration in safety in that it concludes that the assessment of stability should be made in accordance with 'traditional methods', rather than recognised rules and the latest state of technology (based on inclining tests and hydrostatic curve calculations). That being the case, the BSU finds it necessary to submit the following investigation report with recommendations to the competent bodies in accordance with Article 15(1) SUG in conjunction with Article 19(2) and (3) FlUUG (German aviation accident investigation law).

2 Fundamental aspects of stability

"Stability is the capacity of a watercraft to right herself from an inclined position unaided after the inclining force subsides."[1]

Only the magnitude and direction of the heeling and righting moments are considered when examining this *static* stability; however, not the energy introduced by wind and waves. This consideration of *static* stability is also referred to as still water stability. Due to a steadily increasing roll angle, a vessel that is stable when *static* may become *dynamically* unstable in swell until she finally capsizes. Based on lessons learned from accidents and years of experience, stability requirements/criteria consider this *dynamic* effect by means of corresponding standards (range of stability and necessary areas under the calculated righting lever curve).

The following factors influence the stability of a watercraft:

- the craft's form, i.e. pointed or full midsection;
- the ratios of the principal dimensions, such as B/T;
- the position of the centre of gravity. A low centre of gravity makes a vessel stiff, one that is high top heavy;
- external influences like turning circle moment, lateral wind pressure, moment due to free surfaces (bilge/tank content) or the shifting of cargo (person moment), and

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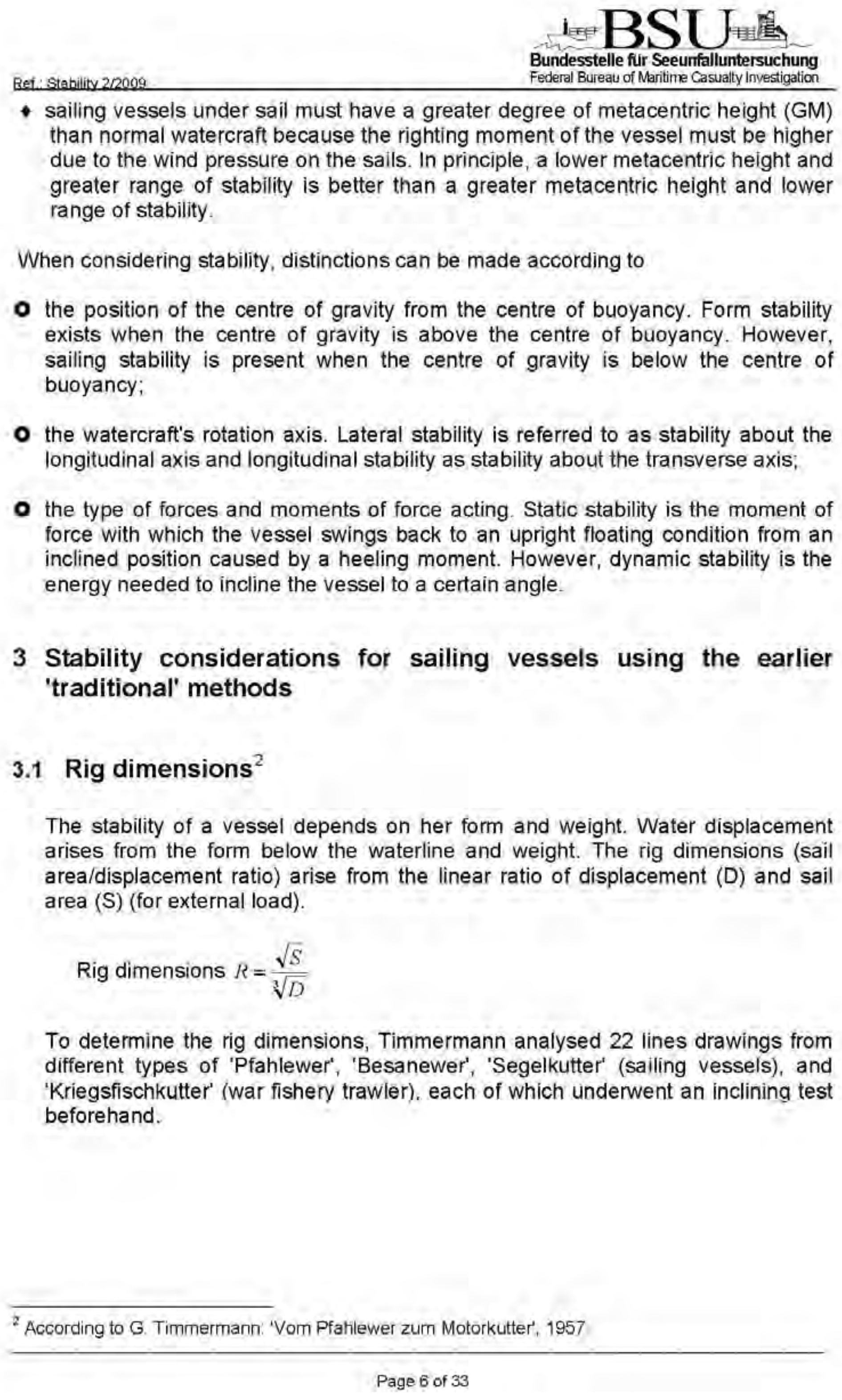
[1] 'Vom Riß zum Schiff', Hans-Günter Portmann, Delius Klasing Verlag



- sailing vessels under sail must have a greater degree of metacentric height (GM) than normal watercraft because the righting moment of the vessel must be higher due to the wind pressure on the sails. In principle, a lower metacentric height and greater range of stability is better than a greater metacentric height and lower range of stability.

When considering stability, distinctions can be made according to

- the position of the centre of gravity from the centre of buoyancy. Form stability exists when the centre of gravity is above the centre of buoyancy. However, sailing stability is present when the centre of gravity is below the centre of buoyancy;

- the watercraft's rotation axis. Lateral stability is referred to as stability about the longitudinal axis and longitudinal stability as stability about the transverse axis;

- the type of forces and moments of force acting. Static stability is the moment of force with which the vessel swings back to an upright floating condition from an inclined position caused by a heeling moment. However, dynamic stability is the energy needed to incline the vessel to a certain angle.

3 Stability considerations for sailing vessels using the earlier 'traditional' methods

3.1 Rig dimensions[2]

The stability of a vessel depends on her form and weight. Water displacement arises from the form below the waterline and weight. The rig dimensions (sail area/displacement ratio) arise from the linear ratio of displacement (D) and sail area (S) (for external load).

Rig dimensions $R = \frac{\sqrt{S}}{\sqrt[3]{D}}$

To determine the rig dimensions, Timmermann analysed 22 lines drawings from different types of 'Pfahlewer', 'Besanewer', 'Segelkutter' (sailing vessels), and 'Kriegsfischkutter' (war fishery trawler), each of which underwent an inclining test beforehand.

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[2] According to G. Timmermann: 'Vom Pfahlewer zum Motorkutter', 1957

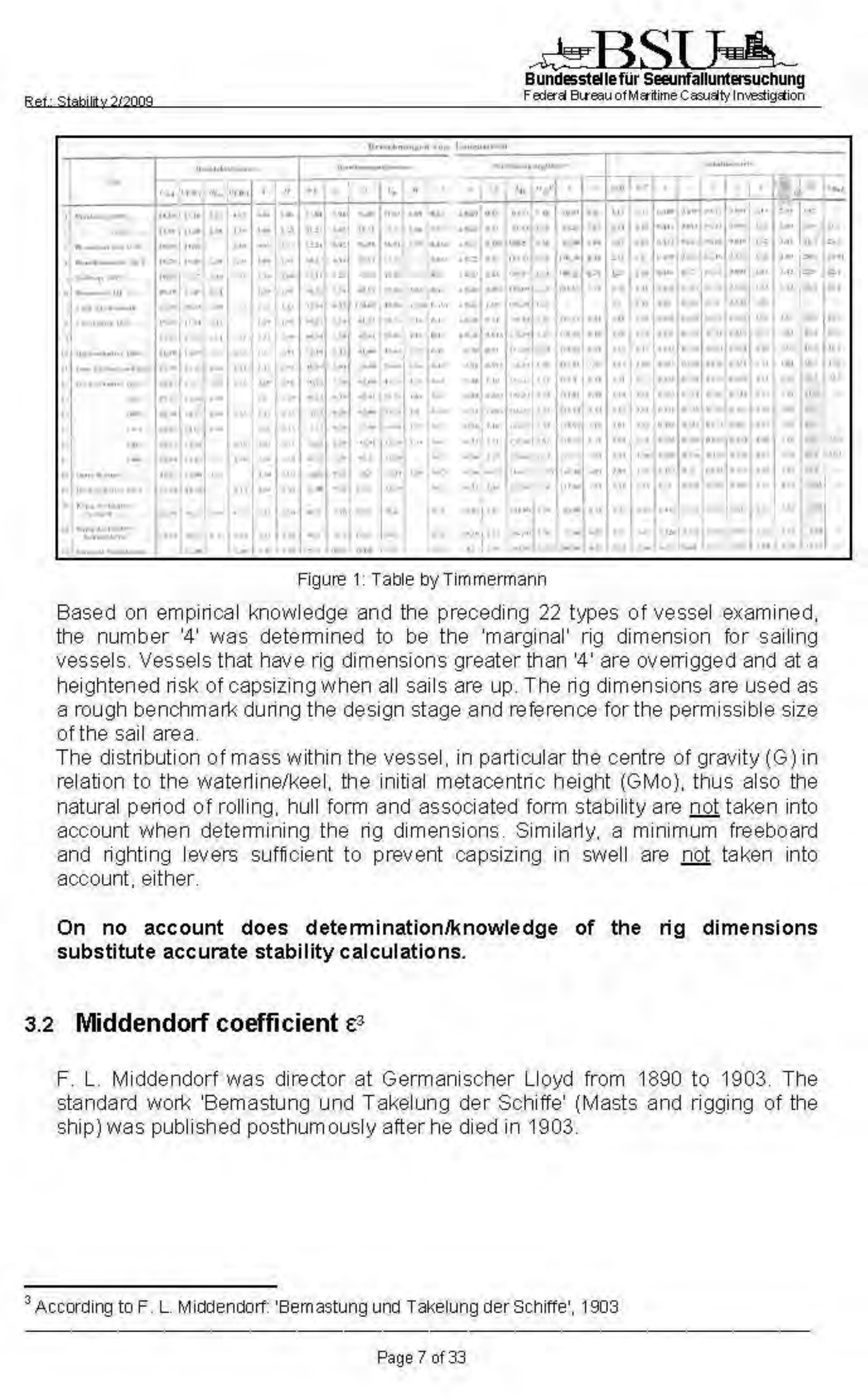

Figure 1: Table by Timmermann

Based on empirical knowledge and the preceding 22 types of vessel examined, the number '4' was determined to be the 'marginal' rig dimension for sailing vessels. Vessels that have rig dimensions greater than '4' are overrigged and at a heightened risk of capsizing when all sails are up. The rig dimensions are used as a rough benchmark during the design stage and reference for the permissible size of the sail area.

The distribution of mass within the vessel, in particular the centre of gravity (G) in relation to the waterline/keel, the initial metacentric height (GMo), thus also the natural period of rolling, hull form and associated form stability are not taken into account when determining the rig dimensions. Similarly, a minimum freeboard and righting levers sufficient to prevent capsizing in swell are not taken into account, either.

On no account does determination/knowledge of the rig dimensions substitute accurate stability calculations.

3.2 Middendorf coefficient ε[3]

F. L. Middendorf was director at Germanischer Lloyd from 1890 to 1903. The standard work 'Bemastung und Takelung der Schiffe' (Masts and rigging of the ship) was published posthumously after he died in 1903.

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[3] According to F. L. Middendorf: 'Bemastung und Takelung der Schiffe', 1903

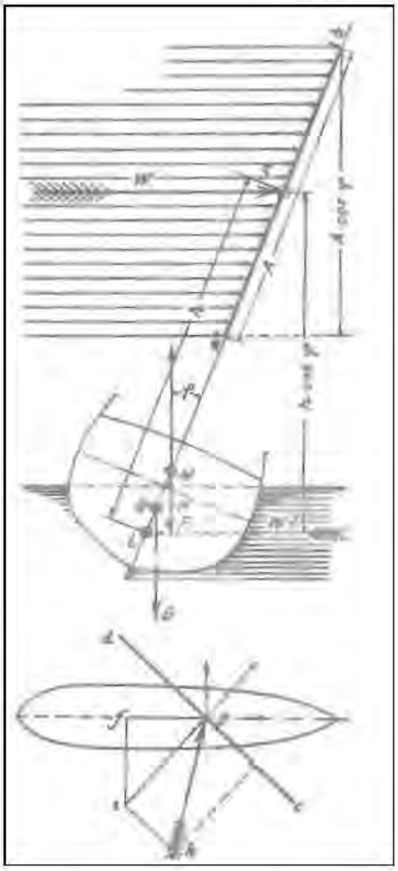

Figure 2: Sketch by Middendorf

"Should the wind now blow at a constant speed, meaning wind pressure is constant, then according to the laws of static stability the moment caused by wind pressure must be the righting moment of the vessel, i.e. the following must happen:

$$p \times A \times h \times \cos^2\varphi = D \times GH = D \times GM \sin\varphi$$ [4]

p = Wind pressure on area A, constant at 5 kg/m²
A = Sail area
h = Distance from centre of gravity
D = Displacement
GM = Metacentric height at initial stability

The Middendorf coefficient ε is determined as follows:

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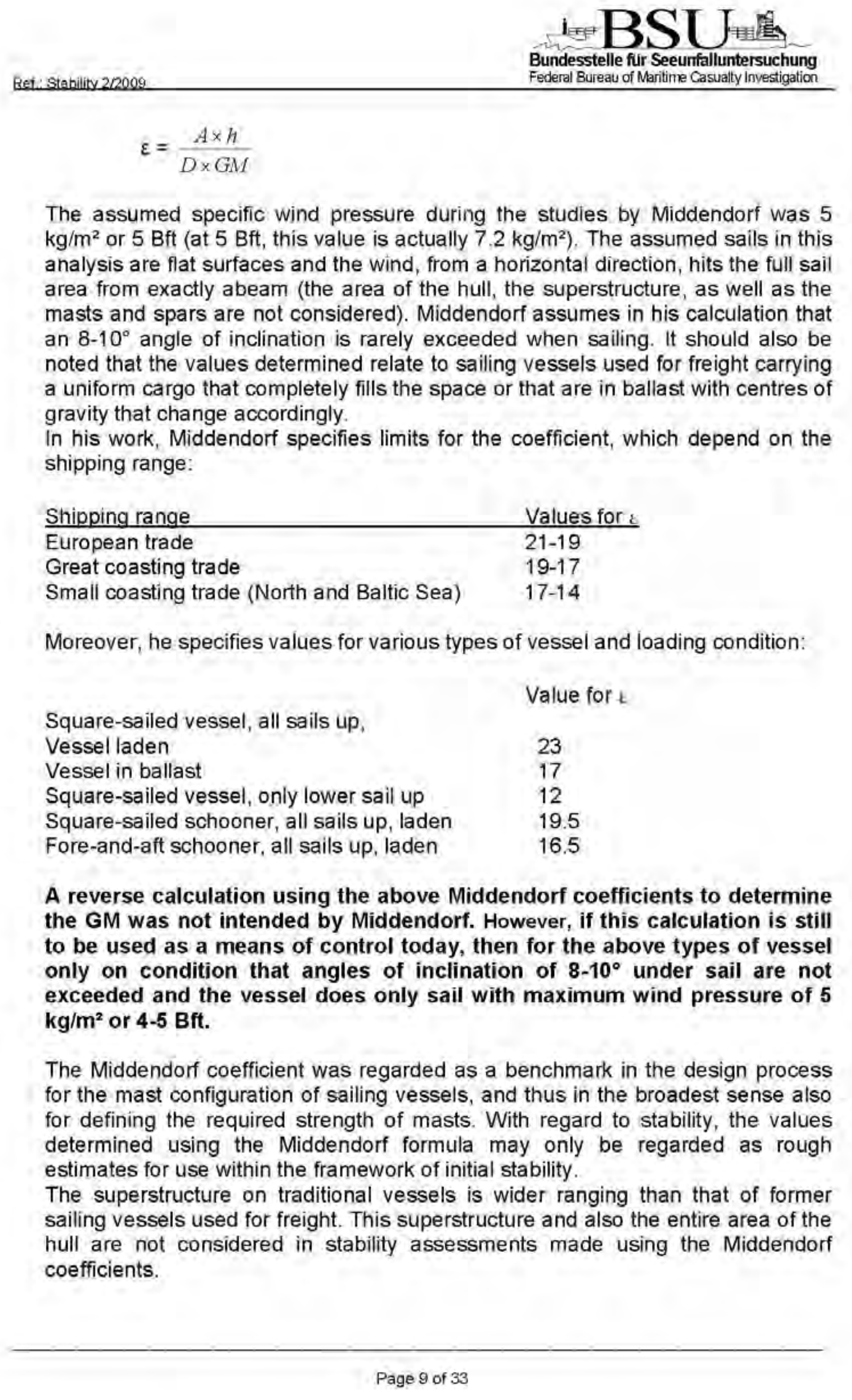
[4] loc. cit., p. 35 below



$$\varepsilon = \frac{A \times h}{D \times GM}$$

The assumed specific wind pressure during the studies by Middendorf was 5 kg/m² or 5 Bft (at 5 Bft, this value is actually 7.2 kg/m²). The assumed sails in this analysis are flat surfaces and the wind, from a horizontal direction, hits the full sail area from exactly abeam (the area of the hull, the superstructure, as well as the masts and spars are not considered). Middendorf assumes in his calculation that an 8-10° angle of inclination is rarely exceeded when sailing. It should also be noted that the values determined relate to sailing vessels used for freight carrying a uniform cargo that completely fills the space or that are in ballast with centres of gravity that change accordingly.

In his work, Middendorf specifies limits for the coefficient, which depend on the shipping range:

Shipping range	Values for ε
European trade	21-19
Great coasting trade	19-17
Small coasting trade (North and Baltic Sea)	17-14

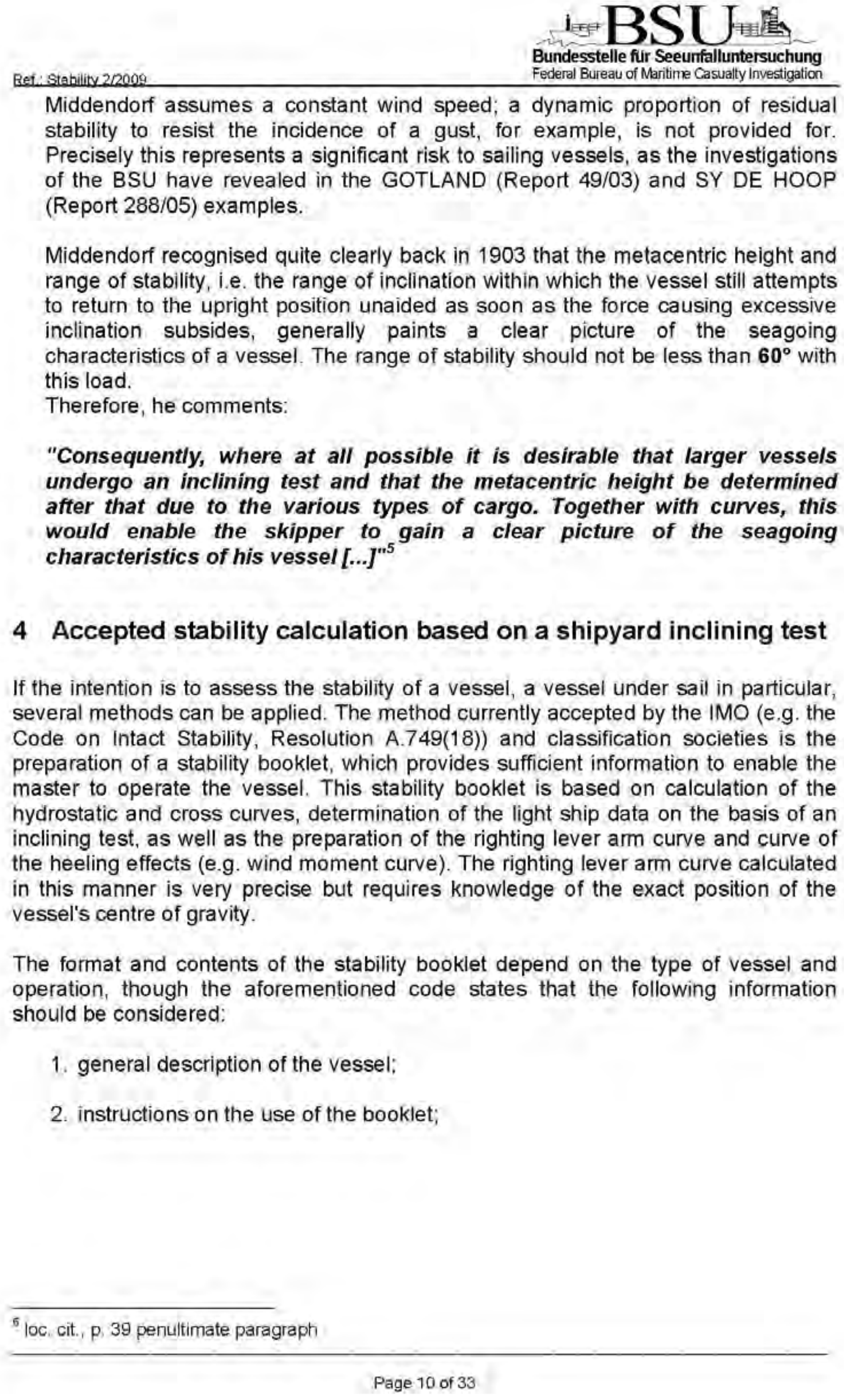
Moreover, he specifies values for various types of vessel and loading condition:

	Value for ε
Square-sailed vessel, all sails up,	
Vessel laden	23
Vessel in ballast	17
Square-sailed vessel, only lower sail up	12
Square-sailed schooner, all sails up, laden	19.5
Fore-and-aft schooner, all sails up, laden	16.5

A reverse calculation using the above Middendorf coefficients to determine the GM was not intended by Middendorf. However, **if this calculation is still to be used as a means of control today, then for the above types of vessel only on condition that angles of inclination of 8-10° under sail are not exceeded and the vessel does only sail with maximum wind pressure of 5 kg/m² or 4-5 Bft.**

The Middendorf coefficient was regarded as a benchmark in the design process for the mast configuration of sailing vessels, and thus in the broadest sense also for defining the required strength of masts. With regard to stability, the values determined using the Middendorf formula may only be regarded as rough estimates for use within the framework of initial stability.

The superstructure on traditional vessels is wider ranging than that of former sailing vessels used for freight. This superstructure and also the entire area of the hull are not considered in stability assessments made using the Middendorf coefficients.



Middendorf assumes a constant wind speed; a dynamic proportion of residual stability to resist the incidence of a gust, for example, is not provided for. Precisely this represents a significant risk to sailing vessels, as the investigations of the BSU have revealed in the GOTLAND (Report 49/03) and SY DE HOOP (Report 288/05) examples.

Middendorf recognised quite clearly back in 1903 that the metacentric height and range of stability, i.e. the range of inclination within which the vessel still attempts to return to the upright position unaided as soon as the force causing excessive inclination subsides, generally paints a clear picture of the seagoing characteristics of a vessel. The range of stability should not be less than **60°** with this load.
Therefore, he comments:

"Consequently, where at all possible it is desirable that larger vessels undergo an inclining test and that the metacentric height be determined after that due to the various types of cargo. Together with curves, this would enable the skipper to gain a clear picture of the seagoing characteristics of his vessel [...]"[5]

4 Accepted stability calculation based on a shipyard inclining test

If the intention is to assess the stability of a vessel, a vessel under sail in particular, several methods can be applied. The method currently accepted by the IMO (e.g. the Code on Intact Stability, Resolution A.749(18)) and classification societies is the preparation of a stability booklet, which provides sufficient information to enable the master to operate the vessel. This stability booklet is based on calculation of the hydrostatic and cross curves, determination of the light ship data on the basis of an inclining test, as well as the preparation of the righting lever arm curve and curve of the heeling effects (e.g. wind moment curve). The righting lever arm curve calculated in this manner is very precise but requires knowledge of the exact position of the vessel's centre of gravity.

The format and contents of the stability booklet depend on the type of vessel and operation, though the aforementioned code states that the following information should be considered:

1. general description of the vessel;
2. instructions on the use of the booklet;

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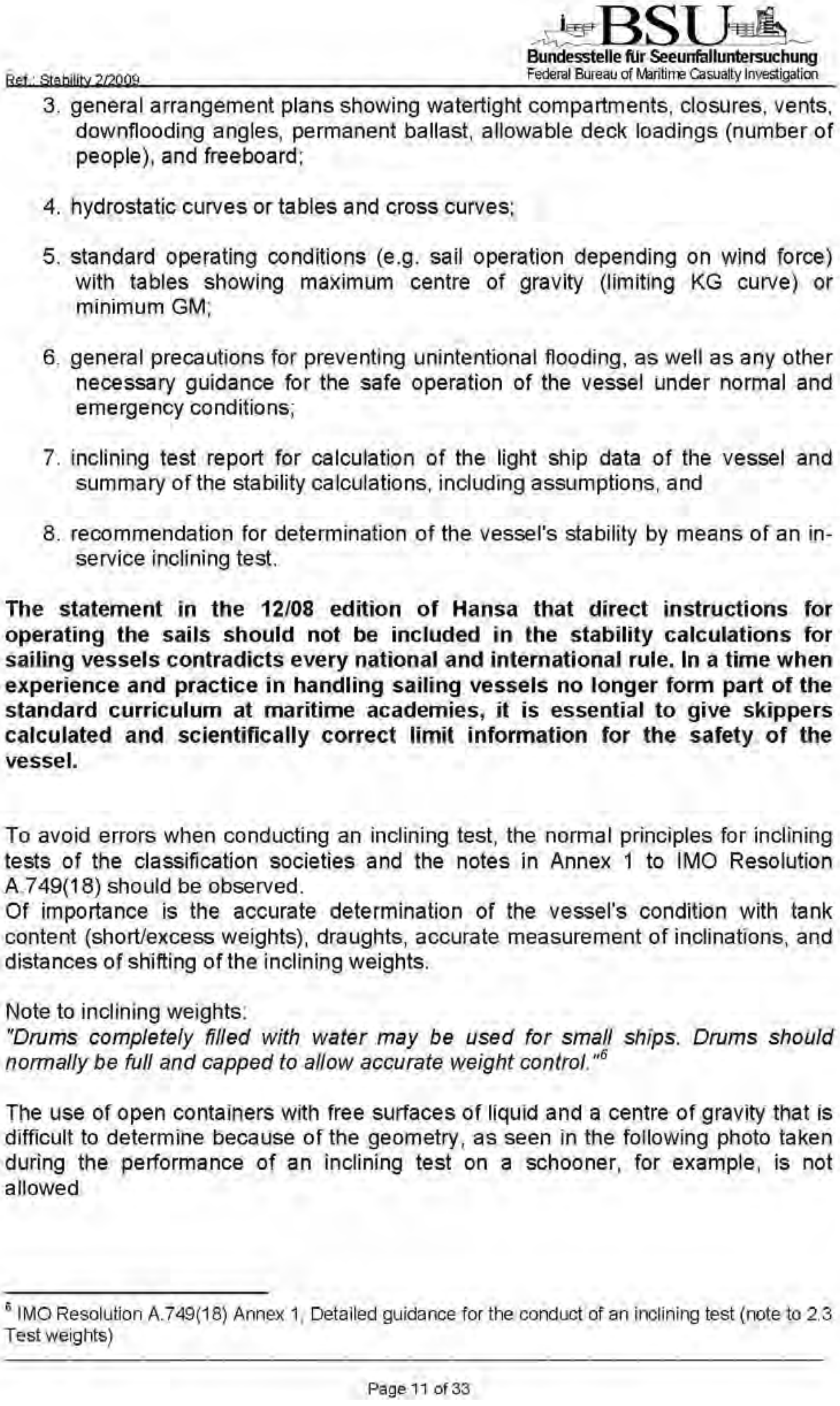
[5] loc. cit., p. 39 penultimate paragraph



3. general arrangement plans showing watertight compartments, closures, vents, downflooding angles, permanent ballast, allowable deck loadings (number of people), and freeboard;

4. hydrostatic curves or tables and cross curves;

5. standard operating conditions (e.g. sail operation depending on wind force) with tables showing maximum centre of gravity (limiting KG curve) or minimum GM;

6. general precautions for preventing unintentional flooding, as well as any other necessary guidance for the safe operation of the vessel under normal and emergency conditions;

7. inclining test report for calculation of the light ship data of the vessel and summary of the stability calculations, including assumptions, and

8. recommendation for determination of the vessel's stability by means of an in-service inclining test.

The statement in the 12/08 edition of Hansa that direct instructions for operating the sails should not be included in the stability calculations for sailing vessels contradicts every national and international rule. In a time when experience and practice in handling sailing vessels no longer form part of the standard curriculum at maritime academies, it is essential to give skippers calculated and scientifically correct limit information for the safety of the vessel.

To avoid errors when conducting an inclining test, the normal principles for inclining tests of the classification societies and the notes in Annex 1 to IMO Resolution A.749(18) should be observed.
Of importance is the accurate determination of the vessel's condition with tank content (short/excess weights), draughts, accurate measurement of inclinations, and distances of shifting of the inclining weights.

Note to inclining weights:
"Drums completely filled with water may be used for small ships. Drums should normally be full and capped to allow accurate weight control."[6]

The use of open containers with free surfaces of liquid and a centre of gravity that is difficult to determine because of the geometry, as seen in the following photo taken during the performance of an inclining test on a schooner, for example, is not allowed

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[6] IMO Resolution A.749(18) Annex 1, Detailed guidance for the conduct of an inclining test (note to 2.3 Test weights)

Figure 3: Performance of an inclining test

5 Rolling period test

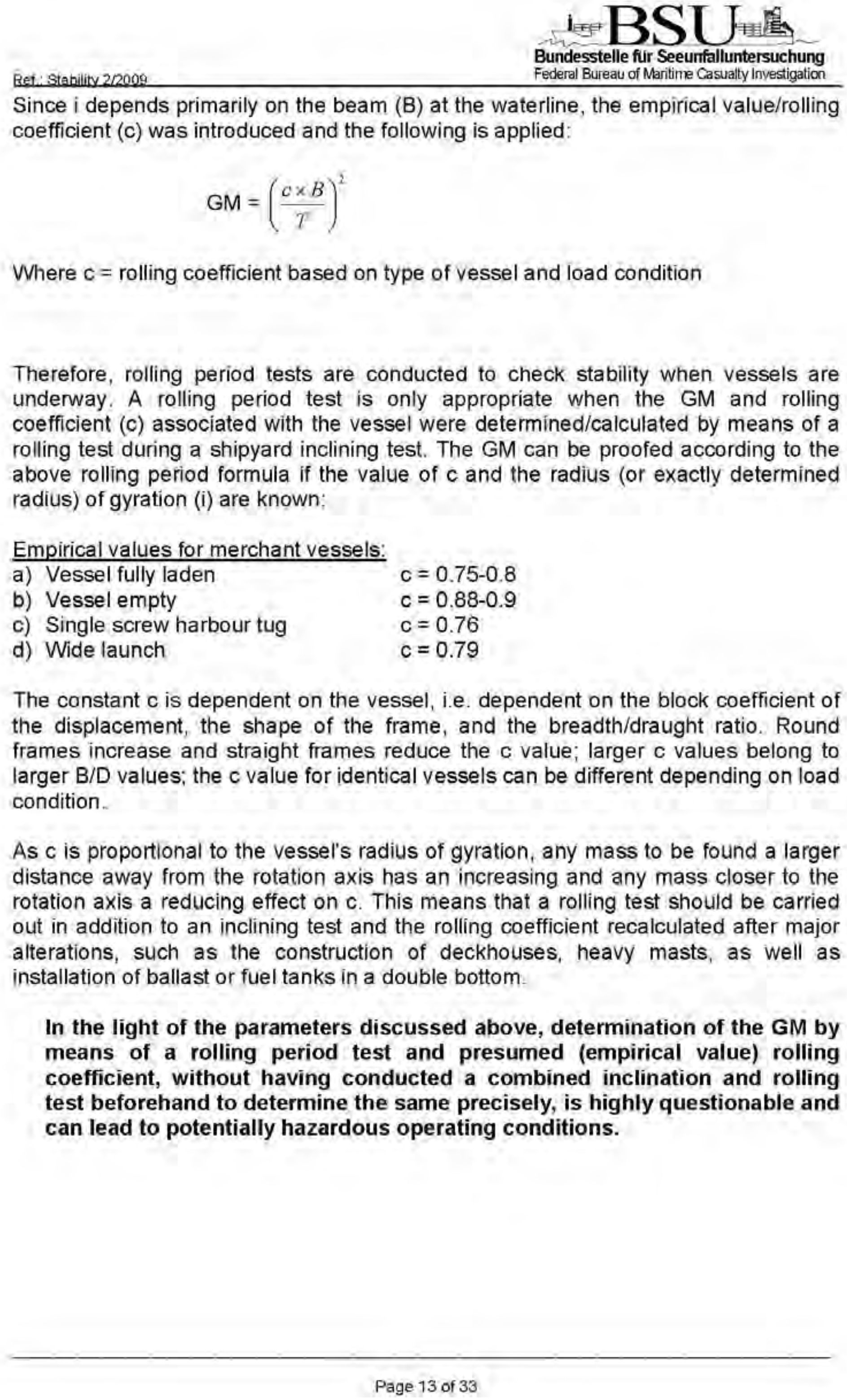
A physical connection exists between GM and roll oscillation period, which can be used to proof the existing GM by measuring the time required for a free oscillation. If, in consideration of the hydrodynamic mass, the radius of gyration (i) is known, then the formula with sufficient accuracy for large GM values is:

$$T = \frac{2\times\pi\times i}{\sqrt[2]{g\times GM}}$$

T = the time in seconds required for a full natural oscillation (from port to starboard)

If $\pi \approx \sqrt[2]{g}$ is applied, then the following can be entered:

$$T = \frac{2\times i}{\sqrt[2]{GM}} \text{ or converted: } GM = \left(\frac{2\times i}{T}\right)^2$$



Since i depends primarily on the beam (B) at the waterline, the empirical value/rolling coefficient (c) was introduced and the following is applied:

$$\text{GM} = \left(\frac{c \times B}{T}\right)^2$$

Where c = rolling coefficient based on type of vessel and load condition

Therefore, rolling period tests are conducted to check stability when vessels are underway. A rolling period test is only appropriate when the GM and rolling coefficient (c) associated with the vessel were determined/calculated by means of a rolling test during a shipyard inclining test. The GM can be proofed according to the above rolling period formula if the value of c and the radius (or exactly determined radius) of gyration (i) are known:

<u>Empirical values for merchant vessels:</u>

a) Vessel fully laden	c = 0.75-0.8
b) Vessel empty	c = 0.88-0.9
c) Single screw harbour tug	c = 0.76
d) Wide launch	c = 0.79

The constant c is dependent on the vessel, i.e. dependent on the block coefficient of the displacement, the shape of the frame, and the breadth/draught ratio. Round frames increase and straight frames reduce the c value; larger c values belong to larger B/D values; the c value for identical vessels can be different depending on load condition.

As c is proportional to the vessel's radius of gyration, any mass to be found a larger distance away from the rotation axis has an increasing and any mass closer to the rotation axis a reducing effect on c. This means that a rolling test should be carried out in addition to an inclining test and the rolling coefficient recalculated after major alterations, such as the construction of deckhouses, heavy masts, as well as installation of ballast or fuel tanks in a double bottom.

> **In the light of the parameters discussed above, determination of the GM by means of a rolling period test and presumed (empirical value) rolling coefficient, without having conducted a combined inclination and rolling test beforehand to determine the same precisely, is highly questionable and can lead to potentially hazardous operating conditions.**

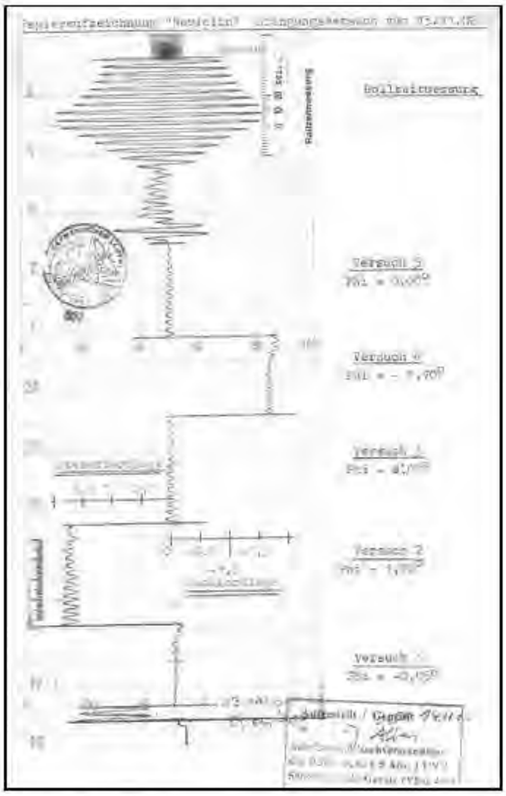


Figure 4: Record of a combined inclination and rolling test

In the case of a traditional vessel that is not permitted to carry cargo, the rolling coefficient determined by means of a rolling test will not change, as long as no alterations are carried out.

6 Stability requirements

In the IMO Code on Intact Stability for all Types of Ships Covered by IMO Instruments[7], the following stability criteria are recommended for cargo and passenger vessels:

Righting lever arm when angle of heel $\varphi = 30°$:	≥ 0.20 m
Maximum righting lever arm:	GZ_{max} at $\varphi > 25°$
GM corrected by free surfaces:	≥ 0.15 m

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[7] Resolution A.749(18)

Area under the righting lever arm curve up to 30°: ≥ 0.055 m rad

Area under the righting lever arm curve up to 40° or φ_f: ≥ 0.090 m rad

Area under the righting lever arm curve between 30° and 40° or $\varphi_f \geq 0.030$ m rad

Range of stability: No information[8]

The angle of inclination φ_f denotes the angle of heel at which openings in the hull, superstructure or deckhouses that cannot be closed so as to be weather tight are immersed.

In the case of passenger vessels, the angle of heel should not exceed 10° as a result of a turning circle, and also as a result of passengers crowded together at the side.

Moreover, such influences as lateral wind pressure, ice accumulation on high parts, water accumulation on deck, roll characteristics, and following seas must also be considered.

A stability reserve must always be provided during voyages. Increases or reductions in weight, for example, due to water absorption, ice accumulation, as well as the consumption of supplies and fuel, must be considered in the process.

The IMO Code is not formulated explicitly for stability requirements on sailing vessels. Therefore, rules of the classification societies, Germanischer Lloyd for example, are referred to.

GL's rules for sporting craft (part 3, section 3, chapter 5) state:

Righting lever arm at maximum righting lever arm curve: ≥ 0.30 m

GM: ≥ 0.60 m

Range of stability: Vessel without ballast keel $\geq 60°$
Vessels with ballast keel $\geq 90°$

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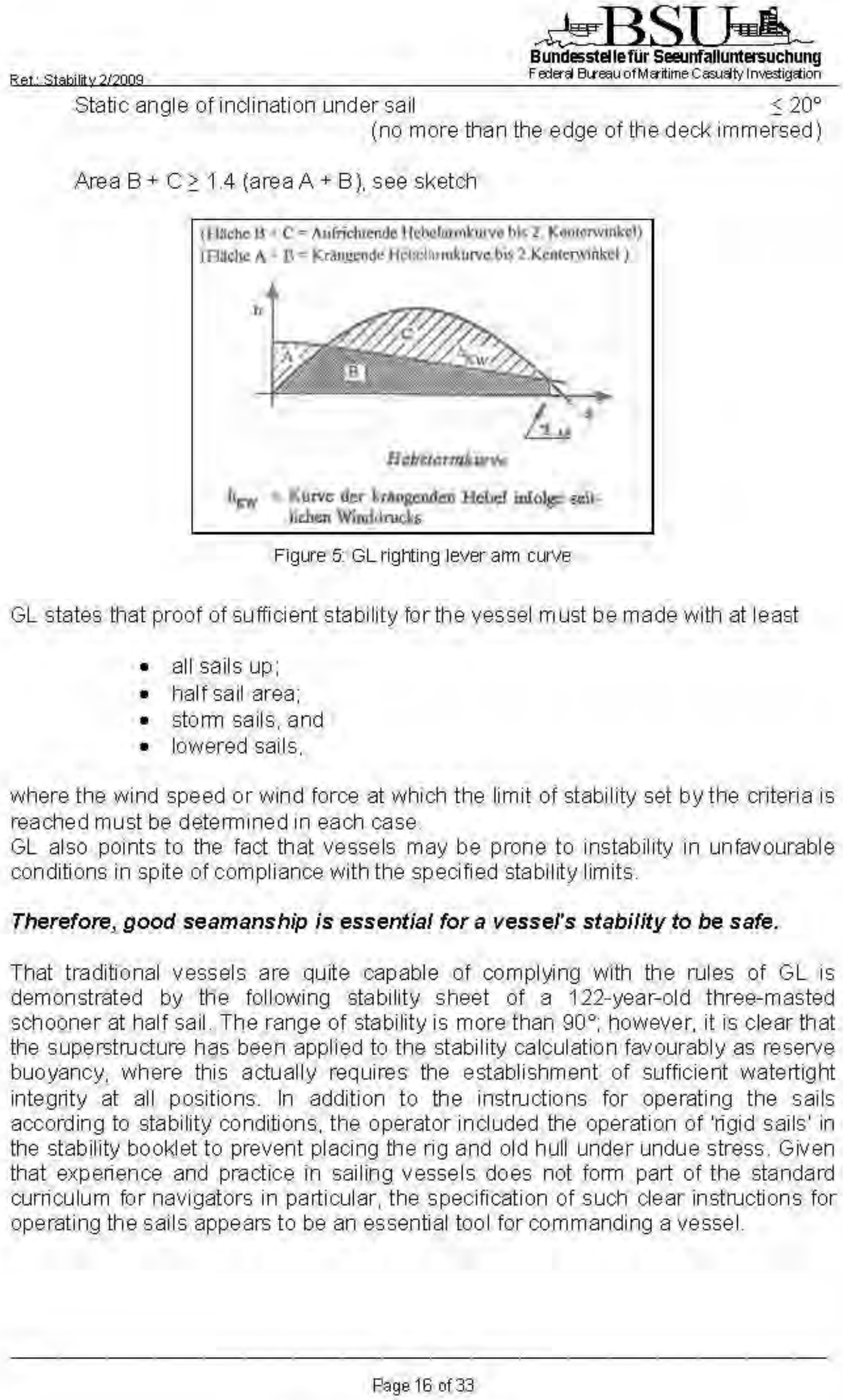
[8] A range of stability was not prescribed in the now inapplicable IMO Resolution A.167, either. At the time, the IMO was unable to arrive at an agreement on whether a range of 60°, 70° or even 80° should be prescribed. Since vessels generally had a range of stability of more than 60° without any requirement for this, the issue was classified as minor and a range of stability not required. However, the SeeBG 'Notice on the application of stability requirements for cargo, passenger and special purpose vessels of 24/10/1984', now also inapplicable, prescribed a stability range of 60° (or 50° when the righting lever arm is at least 0.30 m at an inclination of 30°).



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Static angle of inclination under sail $\leq 20°$
(no more than the edge of the deck immersed)

Area B + C $\geq$ 1.4 (area A + B), see sketch

Figure 5: GL righting lever arm curve

GL states that proof of sufficient stability for the vessel must be made with at least

- all sails up;
- half sail area;
- storm sails, and
- lowered sails,

where the wind speed or wind force at which the limit of stability set by the criteria is reached must be determined in each case.
GL also points to the fact that vessels may be prone to instability in unfavourable conditions in spite of compliance with the specified stability limits.

Therefore, good seamanship is essential for a vessel's stability to be safe.

That traditional vessels are quite capable of complying with the rules of GL is demonstrated by the following stability sheet of a 122-year-old three-masted schooner at half sail. The range of stability is more than 90°; however, it is clear that the superstructure has been applied to the stability calculation favourably as reserve buoyancy, where this actually requires the establishment of sufficient watertight integrity at all positions. In addition to the instructions for operating the sails according to stability conditions, the operator included the operation of 'rigid sails' in the stability booklet to prevent placing the rig and old hull under undue stress. Given that experience and practice in sailing vessels does not form part of the standard curriculum for navigators in particular, the specification of such clear instructions for operating the sails appears to be an essential tool for commanding a vessel.

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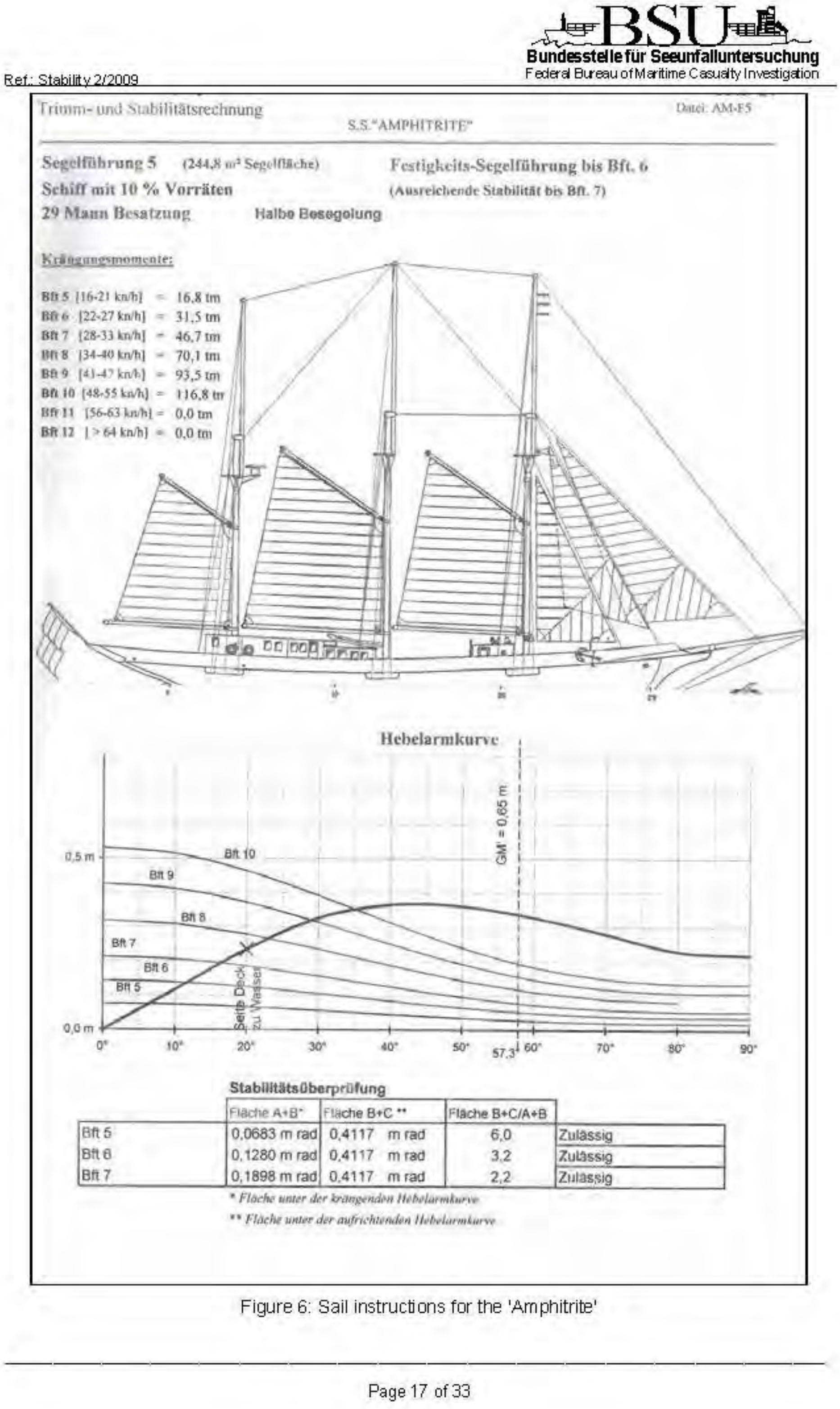


Trimm- und Stabilitätsrechnung
Datei: AM-F5
S.S."AMPHITRITE"

Segelführung 5 (244,8 m² Segelfläche)
Schiff mit 10 % Vorräten
29 Mann Besatzung **Halbe Besegelung**

Festigkeits-Segelführung bis Bft. 6
(Ausreichende Stabilität bis Bft. 7)

Krängungsmomente:

Bft 5 [16-21 kn/h] = 16,8 tm
Bft 6 [22-27 kn/h] = 31,5 tm
Bft 7 [28-33 kn/h] = 46,7 tm
Bft 8 [34-40 kn/h] = 70,1 tm
Bft 9 [41-47 kn/h] = 93,5 tm
Bft 10 [48-55 kn/h] = 116,8 tm
Bft 11 [56-63 kn/h] = 0,0 tm
Bft 12 [> 64 kn/h] = 0,0 tm

Hebelarmkurve

Stabilitätsüberprüfung

	Fläche A+B*	Fläche B+C **	Fläche B+C/A+B	
Bft 5	0,0683 m rad	0,4117 m rad	6,0	Zulässig
Bft 6	0,1280 m rad	0,4117 m rad	3,2	Zulässig
Bft 7	0,1898 m rad	0,4117 m rad	2,2	Zulässig

** Fläche unter der krängenden Hebelarmkurve*

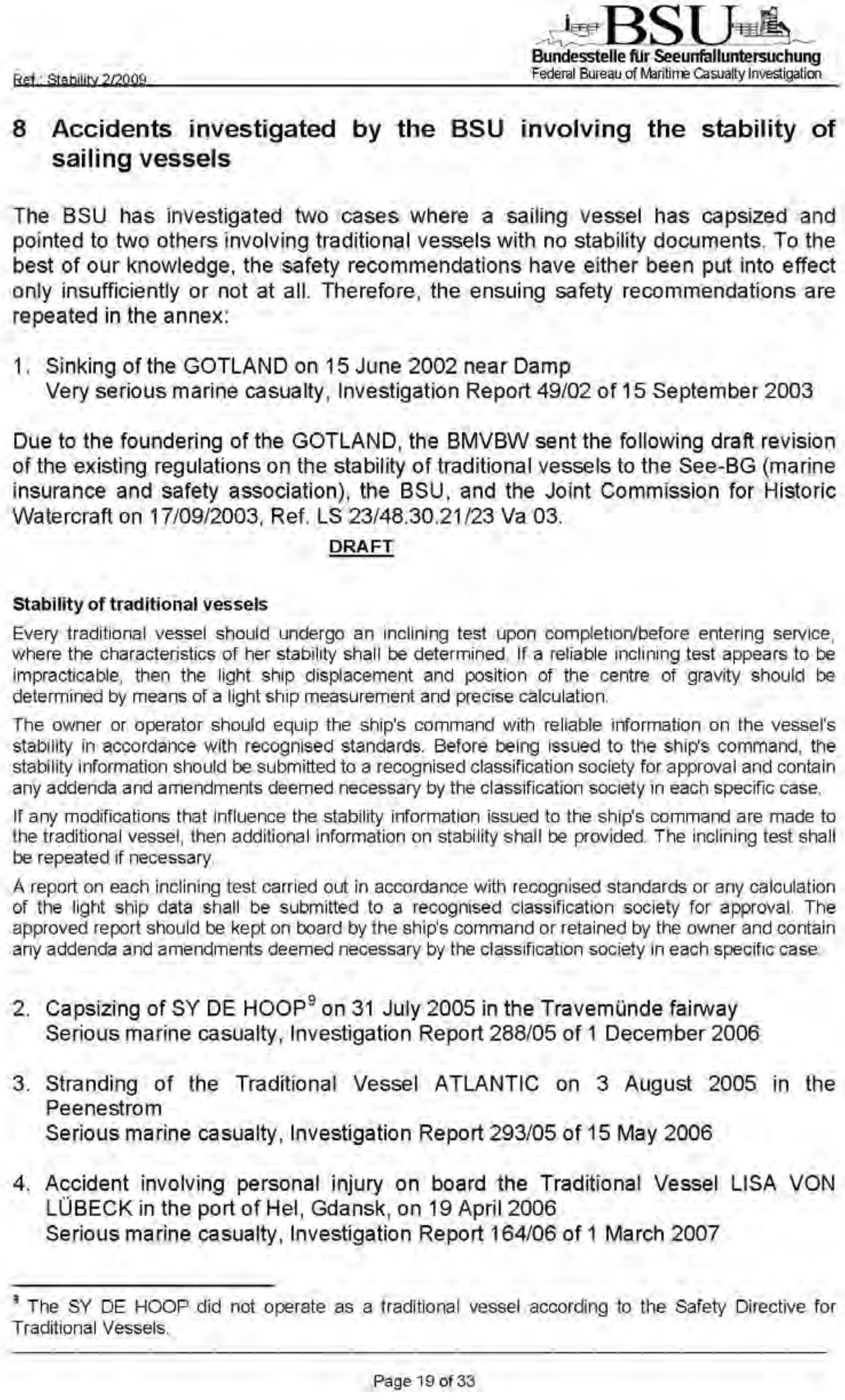
*** Fläche unter der aufrichtenden Hebelarmkurve*

Figure 6: Sail instructions for the 'Amphitrite'

7 Seaworthiness and seamanship

Maintaining stability involves openings not becoming unintentionally immersed beyond the calculated range of stability. The Safety Directive for Traditional Vessels states that a minimum freeboard shall be maintained and watertight integrity flawless. Seaworthiness also involves seaworthy lashing of internal ballast and items of equipment. Similarly, knowledge of the watertight integrity, freeboard, and ballast on board forms an essential basis for the assessment of seaworthiness by the operator and skipper.

Next to the regular crew (navigators and engineers), a sufficient number of qualified deckhands/ratings is required operate a vessel. The number and qualifications of the regular crew are laid down in the Sportseeschifferscheinverordnung (certificate for operators of pleasure craft in coastal waters regulation). In its reports involving accidents on traditional vessels, the BSU urged that the manning of traditional vessels with ratings should be specified as a function of the type and size of vessel, the duration of voyage, and the shipping range.



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8 Accidents investigated by the BSU involving the stability of sailing vessels

The BSU has investigated two cases where a sailing vessel has capsized and pointed to two others involving traditional vessels with no stability documents. To the best of our knowledge, the safety recommendations have either been put into effect only insufficiently or not at all. Therefore, the ensuing safety recommendations are repeated in the annex:

1. Sinking of the GOTLAND on 15 June 2002 near Damp
   Very serious marine casualty, Investigation Report 49/02 of 15 September 2003

Due to the foundering of the GOTLAND, the BMVBW sent the following draft revision of the existing regulations on the stability of traditional vessels to the See-BG (marine insurance and safety association), the BSU, and the Joint Commission for Historic Watercraft on 17/09/2003, Ref. LS 23/48.30.21/23 Va 03.

DRAFT

Stability of traditional vessels

Every traditional vessel should undergo an inclining test upon completion/before entering service, where the characteristics of her stability shall be determined. If a reliable inclining test appears to be impracticable, then the light ship displacement and position of the centre of gravity should be determined by means of a light ship measurement and precise calculation.

The owner or operator should equip the ship's command with reliable information on the vessel's stability in accordance with recognised standards. Before being issued to the ship's command, the stability information should be submitted to a recognised classification society for approval and contain any addenda and amendments deemed necessary by the classification society in each specific case.

If any modifications that influence the stability information issued to the ship's command are made to the traditional vessel, then additional information on stability shall be provided. The inclining test shall be repeated if necessary.

A report on each inclining test carried out in accordance with recognised standards or any calculation of the light ship data shall be submitted to a recognised classification society for approval. The approved report should be kept on board by the ship's command or retained by the owner and contain any addenda and amendments deemed necessary by the classification society in each specific case.

2. Capsizing of SY DE HOOP[9] on 31 July 2005 in the Travemünde fairway
   Serious marine casualty, Investigation Report 288/05 of 1 December 2006

3. Stranding of the Traditional Vessel ATLANTIC on 3 August 2005 in the Peenestrom
   Serious marine casualty, Investigation Report 293/05 of 15 May 2006

4. Accident involving personal injury on board the Traditional Vessel LISA VON LÜBECK in the port of Hel, Gdansk, on 19 April 2006
   Serious marine casualty, Investigation Report 164/06 of 1 March 2007

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[9] The SY DE HOOP did not operate as a traditional vessel according to the Safety Directive for Traditional Vessels.

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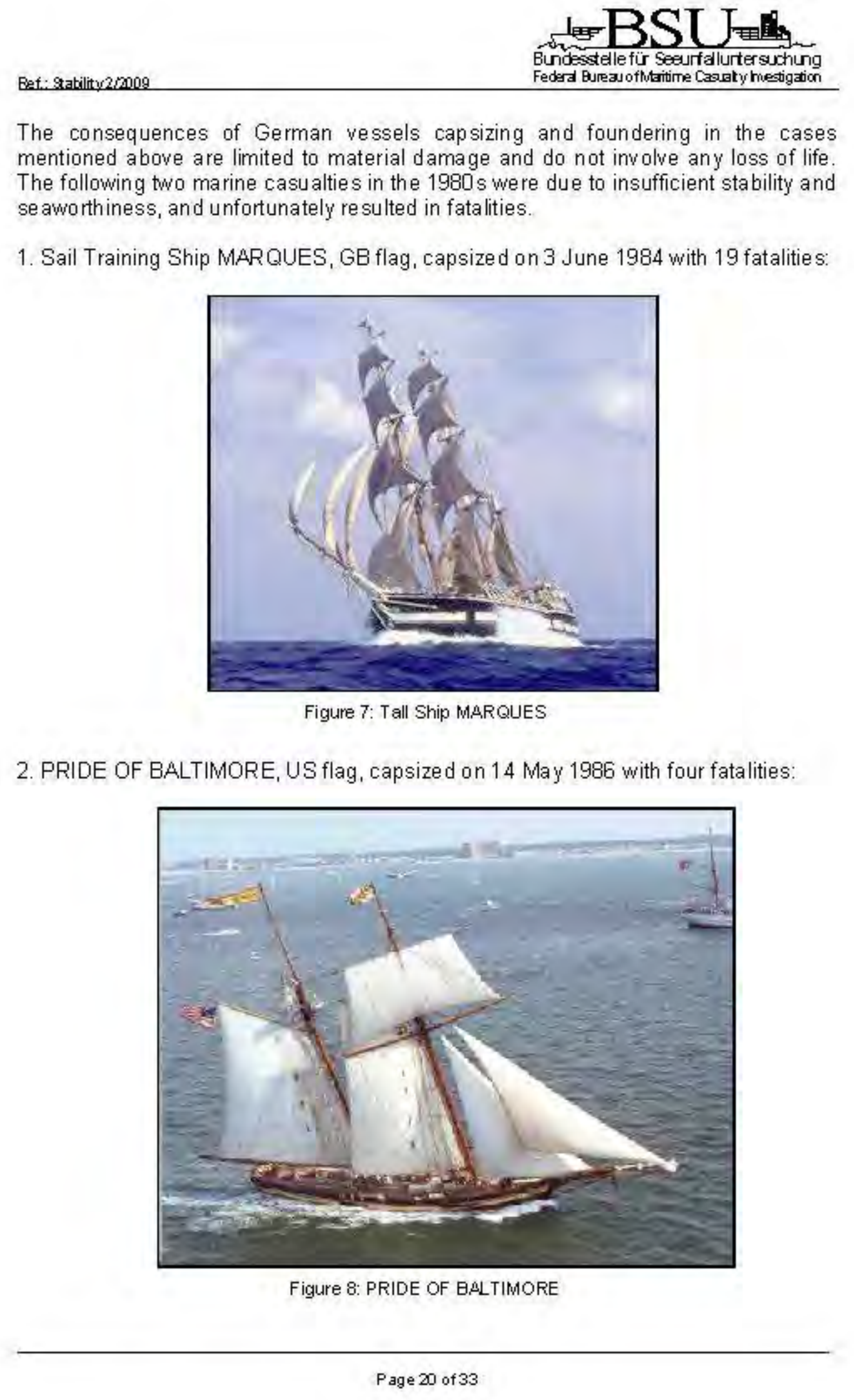


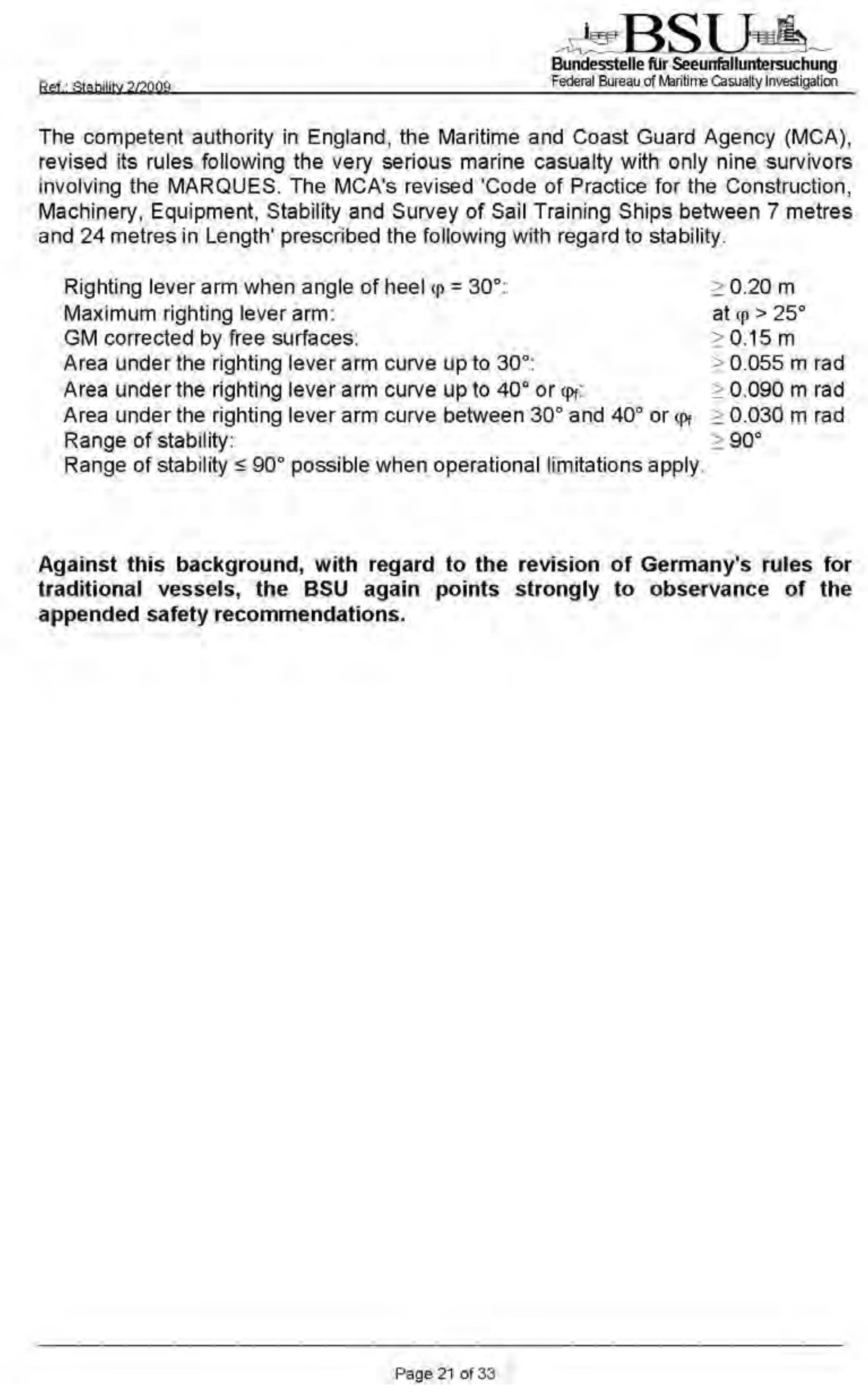
The consequences of German vessels capsizing and foundering in the cases mentioned above are limited to material damage and do not involve any loss of life. The following two marine casualties in the 1980s were due to insufficient stability and seaworthiness, and unfortunately resulted in fatalities.

1. Sail Training Ship MARQUES, GB flag, capsized on 3 June 1984 with 19 fatalities:

Figure 7: Tall Ship MARQUES

2. PRIDE OF BALTIMORE, US flag, capsized on 14 May 1986 with four fatalities:

Figure 8: PRIDE OF BALTIMORE



The competent authority in England, the Maritime and Coast Guard Agency (MCA), revised its rules following the very serious marine casualty with only nine survivors involving the MARQUES. The MCA's revised 'Code of Practice for the Construction, Machinery, Equipment, Stability and Survey of Sail Training Ships between 7 metres and 24 metres in Length' prescribed the following with regard to stability.

Righting lever arm when angle of heel $\varphi = 30°$:	≥ 0.20 m
Maximum righting lever arm:	at $\varphi > 25°$
GM corrected by free surfaces:	≥ 0.15 m
Area under the righting lever arm curve up to 30°:	≥ 0.055 m rad
Area under the righting lever arm curve up to 40° or φ_f:	≥ 0.090 m rad
Area under the righting lever arm curve between 30° and 40° or φ_f	≥ 0.030 m rad
Range of stability:	≥ 90°

Range of stability ≤ 90° possible when operational limitations apply.

Against this background, with regard to the revision of Germany's rules for traditional vessels, the BSU again points strongly to observance of the appended safety recommendations.

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9 Annex

Stabilität von traditionellen Segelschiffen

Beurteilung mit klassischen Methoden

Michael vom Baur, Jan Fock
Alexander Nürnberg

Traditionelle Segelschiffe prägen in den letzten Jahrzehnten zunehmend das Erscheinungsbild vieler Häfen in Europa. Museumshäfen und maritime Großveranstaltungen haben dabei eine besondere Wirkung auf die Öffentlichkeit entfaltet und ziehen viele »Sehleute« an.

Der Betrieb solcher Schiffe, der übrigens nach einer Resolution der Parlamentarischen Versammlung des Europarates aus dem Jahre 2000 im öffentlichen Interesse ist und deshalb von den nationalen Regierungen erleichtert werden sollte, hat aber auch in großem Umfang dazu geführt, dass die dafür erforderlichen Kenntnisse und Fähigkeiten als »traditionelle Seemannschaft« wieder Verbreitung gefunden und dazu geführt haben, dass neben der Berufsschifffahrt, in der die Qualifikation mit einem STCW-Zeugnis ganz anderen Anforderungen entsprechen muss, auch ein Befähigungsnachweis für die Traditionsschifffahrt erworben werden kann.

Die Fähigkeit zur Beurteilung der Stabilität unter Segel wird dabei vor allem mit Erfahrungen in der Praxis erworben. Die Autoren dieses Artikels, von der Ausbildung her Nautiker bzw. Schiffbau-Ingenieure, segeln seit mehr als 20 Jahren verantwortlich auf Traditionsschiffen.

Die bestimmenden Faktoren für einen sicheren Betrieb sind die Segelführung in Abhängigkeit von den Windverhältnissen, vor allem eine rechtzeitige Anpassung der Segelfläche mit den dazu erforderlichen Manövern, sowie der Verschlusszustand des Schiffes bei Krängung. Letztlich ist also die Umsetzung guter Seemannschaft entscheidend, die keine theoretische Berechnung ersetzen kann. Stabilitätsrechnungen für Segelschiffe sind theoretische, auf bestimmten Rechenannahmen basierende Grenzbetrachtungen zur Schiffssicherheit, aus denen sich erfahrungsgemäß kaum realistische, im Bordbetrieb erlebbare Aussagen über das Verhalten des Schiffes, z.B. den zu erwartenden tatsächlichen Krängungswinkel bei gegebener Windstärke, ableiten lassen. Man sollte ihnen daher auch keine direkten Handlungsanweisungen zur Segelführung entnehmen. In der Praxis ermittelt man durch Beobachtung, welche Segel sicher unter welchen Bedingungen gefahren werden können. Ein definierter und zuverlässig herstellbarer Verschlusszustand mit Unterlagen über Rumpfdurchbrüche, Öffnungen im Wetterdeck und Informationen zu den entsprechenden Eintauchwinkeln ist dagegen eine wichtige Voraussetzung. Tatsächlich war bei den wenigen Unfällen, die in den letzten Jahrzehnten mit traditionellen Seglern unter Windwirkung zu verzeichnen waren, nahezu ausschließlich der Wassereinbruch bei unzureichendem Ver-

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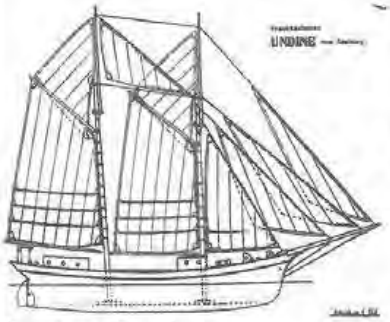
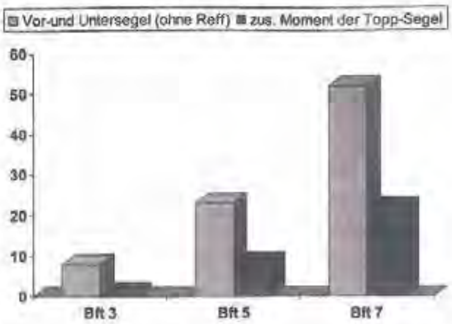


Frachtschoner mit Topsegel



schlusszustand die Ursache des Unterganges.

Die Mehrzahl der traditionellen Segler fand ursprünglich in der Frachtfahrt und in der Fischerei Verwendung. Sie fahren heute mit ähnlichem Rigg und ähnlicher Raumaufteilung, allerdings in den meisten Fällen ohne Ladung oder Fischlast und werden daher mit Ballast in eine Schwimmlage im Bereich der Entwurfswasserlinie gebracht. Damit haben sie meist einen deutlich niedrigeren Gewichtsschwerpunkt als im früheren Einsatz, der kaum veränderlich ist. (In der Regel mit metazentrischen Anfangsstabilitäten von 0,80 bis 1,20 m) und oft auch einen größeren Freibord mit verbessertem Auftrieb bei Krängung (er liegt erfahrungsgemäß ebenfalls bei 0,80 bis 1,20 m). Alle diese Faktoren wirken sich positiv auf die Stabilität aus, sodass bei sachgemäßer Bedienung (»guter Seemannschaft«) grundsätzlich von sicheren Stabilitätsverhältnissen bei heutigen Traditionsseglern ausgegangen werden kann, sofern ihr Rigg nicht radikal gegenüber dem früheren Zustand verändert wurde. Das klassische Gaffelrigg, sei es als Kutter, Ewer, Galeass oder Schoner, führt je nach Schiffsgröße mit Abständen zwischen 6 bis höchstens 12 m zwischen Segelschwerpunkt und Lateralschwerpunkt in der Regel auch nicht an Grenzen im Segeltragvermögen. Die wichtigste Einflussgröße auf die Stabilität von Traditionsschiffen unter Segeln ist das krängende Moment, das der Wind zusammen mit der aktuellen Segelfläche erzeugt. Die Art der Gaffeltakelung ist durch eine über Jahrhunderte bewährte und vielfältige Verteilung der Segelfläche charakterisiert. Ein Blick auf den Segelplan des Schoners »Undine« zeigt, dass der Seefahrer für die aktuelle Segelfläche bei gleichem Wind etliche Variationsmöglichkeiten mit deutlichem Einfluss auf das krängende Moment hat (z.B. Bergen von Toppsegeln, Einbinden von Reffs etc.), die dennoch den Vortrieb und die Manövrierfähigkeit des Schiffes gewährleisten. Durch eine jeweils dem Wetter angepasste Segelführung sind zu große krängende Momente und damit eine Kentergefahr vermeidbar, oder, mit anderen Worten, mit zu viel Besegelung kann man bei starkem Wind jedes noch so gewichtsstabile Schiff umwerfen. Der Schoner »Undine« wurde nach seiner Restaurierung etliche Jahre im Rahmen von Jugendprojekten auch mit »Fracht« (z.B. Holz, Steine) betrieben. Mit einer Nachrechnung der krängenden Momente für einzelne Segel aus dem Stabilitätsbuch der »Undine« wurde z.B. der Einfluss der Toppsegel bei geborgenem Stengestagsegel aufgezeigt:

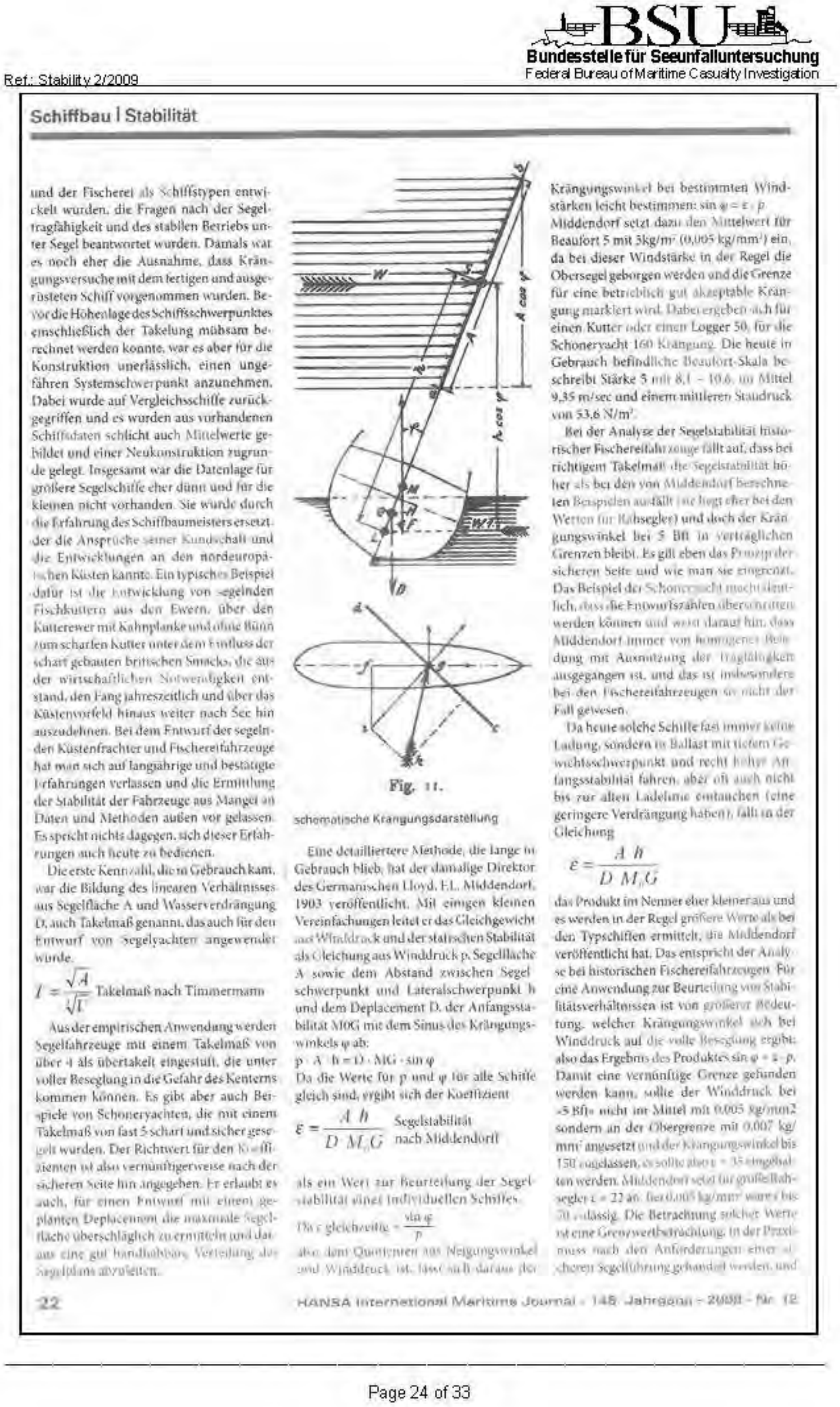
Die Toppsegel allein bringen bei Bft 7 ein krängendes Moment von mehr als 20 mt ein, soviel wie die gesamten Vor- und Untersegelfläche bei 2 Windstärken weniger (!), und vergrößern daher den Krängungswinkel deutlich. Bei Bft 5 würden die Toppsegel in diesem Rechenbeispiel bereits die Seite Deck zu Wasser bringen, was bei mangelndem Verschlusszustand Gefahr bedeuten würde!

In der Praxis würde dieser Zustand aber wohl erst bei ca. Bft 6 erreicht, die Berechnungsannahmen – wie z.B. der geforderte Segel-Widerstandsbeiwert 1,0 (Segel brettsteif quer zum Wind) – führen zu Überzeichnungen.

Der Einfluss einer Verschiebung des Gewichtsschwerpunktes ist bei gleichem Deplacement, gleichem Tiefgang und gleichem Freibord sehr viel geringer als die der Toppsegel. In einem weiteren Rechenbeispiel für die »Undine«, die ja tatsächlich mit unterschiedlichen Ladungen gefahren ist, wurde der Gewichtsschwerpunkt um ca.10% niedriger, entsprechend dem Ersetzen einer Holzladung durch Ballast gleichen Gewichtes. Es zeigt sich, dass im Falle des niedrigen Schwerpunktes ein um ca. 12% größeres krängendes Moment notwendig wäre, um Seite Deck einzutauchen. Schon bei Bft 5 bringen Groß- und Schoner-Toppsegel ein etwa doppelt so großes Moment auf, das Schiff würde also mit gesetzten Toppsegeln bei Bft.5 (oder in der Praxis ~6) in jedem Falle Seite Deck eintauchen, nur ein rechtzeitiges Bergen der Toppsegel könnte das verhindern. Der niedrigere Schwerpunkt hat einen deutlich geringeren Einfluss auf den Krängungswinkel als eine wetterangepasste Segelführung! Diese Erkenntnis sollte für jede Diskussion über Stabilität von Segelschiffen maßgebend sein.

Dass für viele Traditionssegler keine Stabilitätsberechnungen vorliegen, hängt oft damit zusammen, dass für solche Fahrzeuge keine Zeichnungen existieren, weil sie nach Halbmodellen und auf Mallen gebaut wurden. Das gilt vor allem für die kleineren Segler. Vielfach fehlen auch dann Zeichnungen und Berechnungen, wenn ein von den Linien her geeigneter Rumpf später als Segelfahrzeug aufgebaut wurde. Bei Nachbauten und erheblichen Umbauten ist es sicher notwendig, sich ein genaueres Bild vom neuen Gewichtsschwerpunkt und dessen Einfluss auf die Stabilitätsverhältnisse zu machen. Vor allem, wenn das Schiff nach Umbau weit vom bewährten Ursprungszustand abweicht, wie etwa durch neue große Aufbauten, signifikante Veränderung (Vergrößerung) des Segelplans und den Einbau von Tanks mit großen freien Oberflächen, wird es unerlässlich, eine komplette, ingenieursmäßige Stabilitätsberechnung durchzuführen. Aus dem Vergleich mit den Rechenergebnissen für ähnliche Schiffe lassen sich so auch prinzipielle Aussagen über Stabilitätseigenschaften gewinnen.

Vor dem Hintergrund der oft nicht vorliegenden Pläne hilft ein Blick zurück, wie denn zum Ende des 19. und im Anfang des 20. Jahrhunderts, also in der Zeit, in der die charakteristischen Segler der Küstenfahrt



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Schiffbau | Stabilität

und der Fischerei als Schiffstypen entwickelt wurden, die Fragen nach der Segeltragfähigkeit und des stabilen Betriebs unter Segel beantwortet wurden. Damals war es noch eher die Ausnahme, dass Krängungsversuche mit dem fertigen und ausgerüsteten Schiff vorgenommen wurden. Bevor die Höhenlage des Schiffsschwerpunktes einschließlich der Takelung mühsam berechnet werden konnte, war es aber für die Konstruktion unerlässlich, einen ungefähren Systemschwerpunkt anzunehmen. Dabei wurde auf Vergleichsschiffe zurückgegriffen und es wurden aus vorhandenen Schiffsdaten schlicht auch Mittelwerte gebildet und einer Neukonstruktion zugrunde gelegt. Insgesamt war die Datenlage für größere Segelschiffe eher dünn und für die kleinen nicht vorhanden. Sie wurde durch die Erfahrung des Schiffbaumeisters ersetzt, der die Ansprüche seiner Kundschaft und die Entwicklungen an den nordeuropäischen Küsten kannte. Ein typisches Beispiel dafür ist die Entwicklung von segelnden Fischkuttern aus den Ewern, über den Kutterewer mit Kahnplanke und ohne Bünn zum scharfen Kutter unter dem Einfluss der scharf gebauten britischen Smacks, die aus der wirtschaftlichen Notwendigkeit entstand, den Fang jahreszeitlich und über das Küstenvorfeld hinaus weiter nach See hin auszudehnen. Bei dem Entwurf der segelnden Küstenfrachter und Fischereifahrzeuge hat man sich auf langjährige und bestätigte Erfahrungen verlassen und die Ermittlung der Stabilität der Fahrzeuge aus Mangel an Daten und Methoden außen vor gelassen. Es spricht nichts dagegen, sich dieser Erfahrungen auch heute zu bedienen.

Die erste Kennzahl, die in Gebrauch kam, war die Bildung des linearen Verhältnisses aus Segelfläche A und Wasserverdrängung D, auch Takelmaß genannt, das auch für den Entwurf von Segelyachten angewendet wurde.

$$I = \frac{\sqrt{A}}{\sqrt[3]{D}}$$ Takelmaß nach Timmermann

Aus der empirischen Anwendung werden Segelfahrzeuge mit einem Takelmaß von über 4 als übertakelt eingestuft, die unter voller Beseglung in die Gefahr des Kenterns kommen können. Es gibt aber auch Beispiele von Schoneryachten, die mit einem Takelmaß von fast 5 scharf und sicher gesegelt wurden. Der Richtwert für den Koeffizienten ist also vernünftigerweise nach der sicheren Seite hin angegeben. Er erlaubt es auch, für einen Entwurf mit einem geplanten Deplacement die maximale Segelfläche überschläglich zu ermitteln und daraus eine gut handhabbare Verteilung des Segelplans abzuleiten.

Fig. 11.

schematische Krängungsdarstellung

Eine detailliertere Methode, die lange in Gebrauch blieb, hat der damalige Direktor des Germanischen Lloyd, F.L. Middendorf, 1903 veröffentlicht. Mit einigen kleinen Vereinfachungen leitet er das Gleichgewicht aus Winddruck und der statischen Stabilität als Gleichung aus Winddruck p, Segelfläche A sowie dem Abstand zwischen Segelschwerpunkt und Lateralschwerpunkt h und dem Deplacement D, der Anfangsstabilität M0G mit dem Sinus des Krängungswinkels φ ab:

$p \cdot A \cdot h = D \cdot MG \cdot \sin\varphi$

Da die Werte für p und φ für alle Schiffe gleich sind, ergibt sich der Koeffizient

$$\varepsilon = \frac{A \cdot h}{D \cdot M_0G}$$ Segelstabilität nach Middendorf

als ein Wert zur Beurteilung der Segelstabilität eines individuellen Schiffes.

Da ε gleichzeitig $= \frac{\sin\varphi}{p}$

also dem Quotienten aus Neigungswinkel und Winddruck ist, lässt sich daraus der Krängungswinkel bei bestimmten Windstärken leicht bestimmen: $\sin\varphi = \varepsilon \cdot p$

Middendorf setzt dazu den Mittelwert für Beaufort 5 mit 5kg/m² (0,005 kg/mm²) ein, da bei dieser Windstärke in der Regel die Obersegel geborgen werden und die Grenze für eine betrieblich gut akzeptable Krängung markiert wird. Dabei ergeben sich für einen Kutter oder einen Logger 50, für die Schoneryacht 160 Krängung. Die heute in Gebrauch befindliche Beaufort-Skala beschreibt Stärke 5 mit 8,1 – 10,6, im Mittel 9,35 m/sec und einem mittleren Staudruck von 53,6 N/m².

Bei der Analyse der Segelstabilität historischer Fischereifahrzeuge fällt auf, dass bei richtigem Takelmaß die Segelstabilität höher als bei den von Middendorf berechneten Beispielen ausfällt (sie liegt eher bei den Werten für Rahsegler) und doch der Krängungswinkel bei 5 Bft in verträglichen Grenzen bleibt. Es gilt eben das Prinzip der sicheren Seite und wie man sie eingrenzt. Das Beispiel der Schoneryacht macht deutlich, dass die Entwurfszahlen überschritten werden können und weist darauf hin, dass Middendorf immer von homogener Beladung mit Ausnutzung der Tragfähigkeit ausgegangen ist, und das ist insbesondere bei den Fischereifahrzeugen so nicht der Fall gewesen.

Da heute solche Schiffe fast immer keine Ladung, sondern in Ballast mit tiefem Gewichtsschwerpunkt und recht hoher Anfangsstabilität fahren, aber oft auch nicht bis zur alten Ladelinie eintauchen (eine geringere Verdrängung haben), fällt in der Gleichung

$$\varepsilon = \frac{A \cdot h}{D \cdot M_0G}$$

das Produkt im Nenner eher kleiner aus und es werden in der Regel größere Werte als bei den Typschiffen ermittelt, die Middendorf veröffentlicht hat. Das entspricht der Analyse bei historischen Fischereifahrzeugen. Für eine Anwendung zur Beurteilung von Stabilitätsverhältnissen ist von größerer Bedeutung, welcher Krängungswinkel sich bei Winddruck auf die volle Beseglung ergibt, also das Ergebnis des Produktes $\sin\varphi = \varepsilon \cdot p$. Damit eine vernünftige Grenze gefunden werden kann, sollte der Winddruck bei »5 Bft« nicht im Mittel mit 0,005 kg/mm2 sondern an der Obergrenze mit 0,007 kg/mm² angesetzt und der Krängungswinkel bis 150 zugelassen, es sollte also ε = 35 eingehalten werden. Middendorf setzt für große Rahsegler ε = 22 an. Bei 0,005 kg/mm² wären bis 70 zulässig. Die Betrachtung solcher Werte ist eine Grenzwertbetrachtung. In der Praxis muss nach den Anforderungen einer sicheren Segelführung gehandelt werden, und

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das heißt bei einer Gaffeltakelung bis auf wenige Ausnahmen, bei Bft 5 sind die Obersegel, also Flieger, Toppsegel, Stengestagsegel oder auch Bramsegel, wegzunehmen.

Damit die Segelstabilität für traditionelle Segler als Beurteilungskriterium herangezogen werden kann, muss die Anfangsstabilität bekannt sein. Wenn das M_oG nicht mit einem Betriebskrängungsversuch ermittelt wurde, kann es mit der von Dipl.-Ing. G. Weiss entwickelten Rollzeitformel

$$M_oG = \left(\frac{f\,B}{t}\right)^2 \; [m]$$

nach einem Rollversuch aus der Schiffsbreite B und der gemessenen Rollzeit t berechnet werden, wenn der Formbeiwert oder Rollkoeffizient f hinreichend bekannt ist. Dazu kann die IMO Resolution A.749(18) vom 4.November 1993 herangezogen werden (Code on intact stability for all types of ships covered by IMO instruments). In Kapitel 7 werden unter Te 7.6 Vorgaben für die Anwendung von Rollversuchen zur Ermittlung der Stabilität bei Schiffen bis 70 m Länge gemacht. In einer Tabelle sind geeignete Rollkoeffizienten für Küstenschiffe und Fischereifahrzeuge aufgeführt und darunter wird für Schiffe in Ballast f mit 0,88 angegeben. Aus neun Nachrechnungen bei Traditionsseglern, für die Stabilitätsunterlagen vorliegen, hat sich erwiesen, dass f = 0,9 ein gut passender Wert ist.

Damit steht ein Datensatz zur Verfügung, aus dem mit einfachen Instrumenten historisch gewachsene Kriterien ermittelt werden können, mit denen die Segelstabilität traditioneller Segler in guter Annäherung auf kritische Grenzen überprüft werden kann, wie sie zum Teil auch vom Germanischen Lloyd (GL) für Segelschiffe vorgegeben werden:

- Takelmaß ≤ 4
- $M_oG \geq 0{,}60$ m (GL)
- Segelstabilität nach Middendorf $\varepsilon \leq 35$
- Krängungswinkel bei Bft 5
  ($p = 0{,}007$ kg/mm² aus 10 m/sec Windgeschwindigkeit)
  mit Vollzeug am Wind
  $a \sin \varphi \leq 0{,}25$ und $\varphi \leq 15°$
  (GL 20° bzw. Ecke Seite Deck zu Wasser)

Wird eines der Kriterien nicht eingehalten, so sollten eine Überprüfung des Segelplanes und eine Stabilitätsberechnung vorgenommen werden. Werden die Kriterien eingehalten, so wird man, vor allem bei kleineren Schiffen, darauf verzichten können, mit großem Aufwand Aufmasse und Linienrisse neu zu erstellen, damit dann nach Berechnung der zugehörigen Kurvenblätter und Pantokarenen die Stabilitätsberechnungen ausgeführt werden könnten.

Mit einem Beispiel soll das vorgestellt werden. Für einen ehemaligen Lotsenschoner, Baujahr 1883, waren keine Risse mehr vorhanden. Das Fahrzeug war weitgehend unverändert erhalten geblieben, wenn man von dem Einbau einer Maschinenanlage absieht. Es war bekannt, dass der Segler eher rank ist und es bestand die Absicht, auf Tagesfahrten bis zu 50 Personen an Bord zu nehmen. Dazu war eine Risikoabschätzung erforderlich. Nach Durchführung eines Rollversuches ergab sich, dass die Anfangsstabilität und das Takelmaß eingehalten, aber die Segelstabilität mit $\varepsilon = 41{,}96$ und der Krängungswinkel mit 17° überschritten werden. Daraufhin wurden die Linien des Schiffes aufgenommen, die Berechnungsunterlagen angefertigt und ein Krängungsversuch durchgeführt. Nachstehend werden die Ergebnisse gegenübergestellt: (siehe Tabelle 1)

Es zeigt sich also, dass nach dem Aufmass auch die Segelstabilität und der Krängungswinkel nahezu eingehalten werden. Die

Schiffbau | Stabilität

Kriterium	[illegible]	[illegible]
D – Deplacement	137 t	129 t
B – Breite	5,65 m	5,65 m
A – Segelfläche	351 m²	351 m²
h – Abstand Segel ⊕ – Lateral ⊕	12 m angenommen als Abstand bis OKK	10 m
f – Rollkoeffizient	0,9	0,91 nachgerechnet
t – Rollperiode	5,96 sec	im Mittel aus 18 Perioden
M_0G	0,73 m	0,70 Ende und 0,74 m Anfang der Reise
T – Takelmaß	3,6	3,7
ε – Segelstabilität	41,96	38,5
ψ – Krängungswinkel	17°	15,5°

Tab.1

Stabilitätsrechnung hat weiterhin ergeben, dass allen Kriterien des GL gefolgt wird, auch der Anforderung an Segelyachten mit Ballastkiel über einen Stabilitätsumfang von 90°. Bei dieser Krängung zeigt die Stabilitätskurve des Schoners noch 0,4 m aufrichtenden Hebelarm.

Abschließend soll die Brauchbarkeit der Methode anhand von zwei Fällen überprüft werden, bei denen jeweils ein Schiffsuntergang untersucht wurde.

Am 1. Juli 1990 war der Segelkutter »Seekuh« vor der Schleimündung in einer Gewitterbö unter Segel auf die Seite gedrückt worden und untergegangen. Das Schiff war aus dem Rumpf eines kleinen Fischkutters als Segler aufgebaut worden. Weil keinerlei zeichnerische oder rechnerische Unterlagen vorhanden waren, bestand die Vermutung, dass das Fahrzeug nicht über ausreichende Segelstabilität verfügte. Das Oberseeamt veranlasste zur Aufklärung des Unfalles die Aufmessung des Schiffes, das Zeichnen des Linienrisses und die Berechnung der Hydrostatik sowie nach Durchführung eines Krängungsversuches die Berechnung der Stabilität durch den GL.

Mit Anwendung von Takelmaß und Segelstabilität stellt sich das Ergebnis wie in Tabelle 2 aufgeführt dar.

[illegible]	
D – Deplacement	22,14 t
B – Breite	4,65 m
A – Segelfläche	104,4 m²
h – Abstand Segel ⊕ – Lateral ⊕	5,62 m
f – Rollkoeffizient	0,9
t – Rollperiode	6,5 sec (nach gerechnet)
M_0G	0,93 m
T – Takelmaß	3,7
ε – Segelstabilität	29,45
ψ – Krängungswinkel	12°

Es wäre also auch möglich gewesen, im Vornhinein mit Takelmaß und Segelstabilität einzugrenzen, dass bei Beachtung von sicherer Segelführung und Verschlusszustand der Unfall nicht eingetreten wäre. Die Stellungnahme des GL lautete: »Die Stabilität des Schiffes ist gut. Die vom Germanischen Lloyd für Segelschiffe dieser Bauart für erforderlich gehaltenen Mindestwerte werden deutlich überschritten, so dass das Schiff bei guter Seemannschaft nicht als gefährdet anzusehen ist.« Das Bundesoberseeamt hat dann auch festgestellt, dass die mangelhafte Bedienung der Segel und der fehlende Verschlusszustand zum Untergang geführt haben.

In einem weiteren Fall war der zu einer Segelyacht umgebaute Gaffelsegler »De Hoop« am 31. Juli 2005 vor Travemünde bei südwestlichen Winden von 4–5 ft gekentert und gesunken. Das Fahrzeug war von einem Gaffelschoner zu einem hochgetakelten Stagsegelschoner (Wishbone-schooner) unter leichter Veränderung der Rumpfform umgebaut worden. Damit waren offenbar ein höherer Gewichtsschwerpunkt und eine größere Segelfläche verbunden. Die nachfolgenden Daten wurden dem Untersuchungsbericht 288/05 der Bundesstelle für Seeunfalluntersuchung entnommen. Die Analyse nach den Kriterien von Takelmaß und Segelstabilität ergibt: Das Takelmaß ist überschritten, das Schiff ist keine Yacht mit Ballastkiel. Segelstabilität und Krängungswinkel werden deutlich überschritten. Mit Takelmaß und Segelstabilität wäre es möglich gewesen zu erkennen, dass das Fahrzeug kentergefährdet war (Eine Anweisung zu dem begrenzten Segeltragvermögen war an Bord. Danach war nie ein Krängungswinkel von 150 zu überschreiten). Die Bundesstelle für Seeunfalluntersuchung hat den Unfall entsprechend auf die nicht sichere Segelführung und die unzureichende Stabilität zurückgeführt (siehe Tabelle 3).

[illegible]	
D – Deplacement	47 t
B – Breite	4,90 m
A – Segelfläche	236,4 m²
h – Abstand Segel ⊕ – Lateral ⊕	< 0,9 m
M_0G	0,87 m
T – Takelmaß	4,27
ε – Segelstabilität	52,35
ψ – Krängungswinkel	24°

Beide Beispiele machen letztendlich klar, dass es für eine sichere Segelführung auf traditionellen Seglern vor allem darauf ankommt, erkannt und erfahren zu haben, welche Segelfläche das Schiff in Abhängigkeit von der Windwirkung tragen kann. Im Wesentlichen bestimmt eine der Situation angepasste Segelführung (d.h. letztlich gute Seemannschaft) die aktuelle Krängung. Hierzu könnte für jedes Schiff ein auf Praxisbeobachtungen beruhendes Segelführungshandbuch hilfreich sein. Der Nachweis eines ausreichenden Verschlusszustands, einschließlich entsprechender Pläne mit Grenzkrängungswinkeln, sollte an Bord sein. Eine Grenzbetrachtung zu ausreichender Segelstabilität mit Hilfe von Takelmaß und maximalem Krängungswinkel ist einfach herstellbar und würde den Blick für gefahrenträchtige Betriebszustände schärfen.

Schrifttum

(1) Bundesoberseeamt Spruch zum Untergang des Segelkutters »Seekuh« vom 26.02.1992 (W 19/91) mit Stellungnahme des Germanischen Lloyd vom 18.02.1992 (Dipl.-Ing. Wagner)
(2) Bundesstelle für Seeunfalluntersuchung Kenterung der SY »De Hoop« Untersuchungsbericht 288/05 vom 1.12.2005
(3) IMO Resolution A.749(18) Code on intact stability for all types of ships covered by IMO instruments
(4) Friedrich Ludwig Middendorf Bemastung und Takelung der Schiffe (Berlin 1903 – Nachdruck Horst Hamecher Kassel 1977)
(5) G. Timmermann Vom Pfahlewer zum Motorkutter – Berlin 1957 (Schriften der Bundesforschungsanstalt für Fischerei/Hamburg)
(6) Resolution 1486(2000) Parlamentarische Versammlung des Council of Europe (www.coe.int)

☐

Verfasser
Dipl.-Ing. Michael vom Baur
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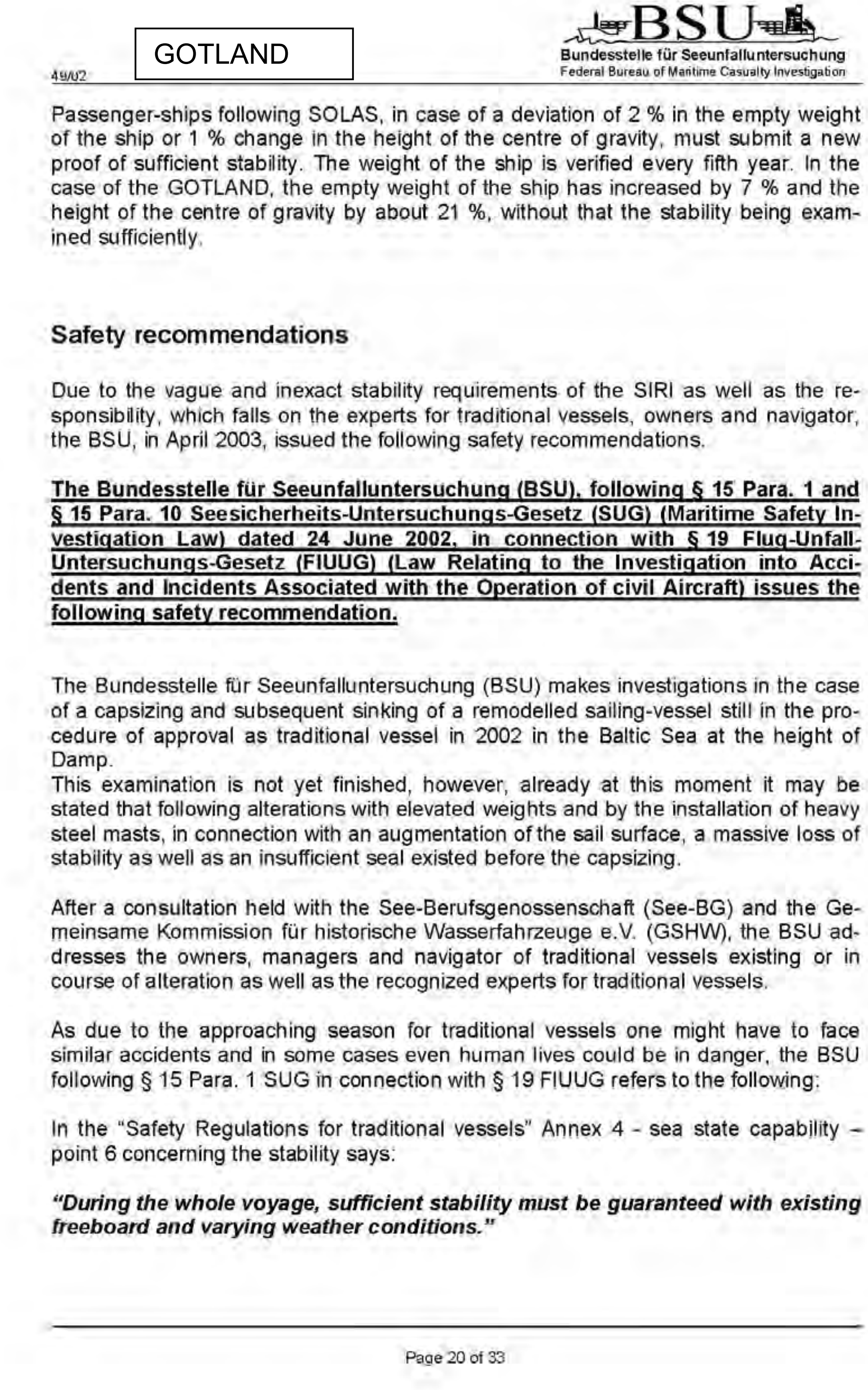
Die Autoren haben 1990 maßgeblich an der Erarbeitung der Sicherheitsrichtlinie für Traditionsschiffe durch das Bundesverkehrsministerium und die Gemeinsame Kommission für historische Wasserfahrzeuge mitgewirkt.

GOTLAND



Passenger-ships following SOLAS, in case of a deviation of 2 % in the empty weight of the ship or 1 % change in the height of the centre of gravity, must submit a new proof of sufficient stability. The weight of the ship is verified every fifth year. In the case of the GOTLAND, the empty weight of the ship has increased by 7 % and the height of the centre of gravity by about 21 %, without that the stability being examined sufficiently.

Safety recommendations

Due to the vague and inexact stability requirements of the SIRI as well as the responsibility, which falls on the experts for traditional vessels, owners and navigator, the BSU, in April 2003, issued the following safety recommendations.

The Bundesstelle für Seeunfalluntersuchung (BSU), following § 15 Para. 1 and § 15 Para. 10 Seesicherheits-Untersuchungs-Gesetz (SUG) (Maritime Safety Investigation Law) dated 24 June 2002, in connection with § 19 Flug-Unfall-Untersuchungs-Gesetz (FIUUG) (Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of civil Aircraft) issues the following safety recommendation.

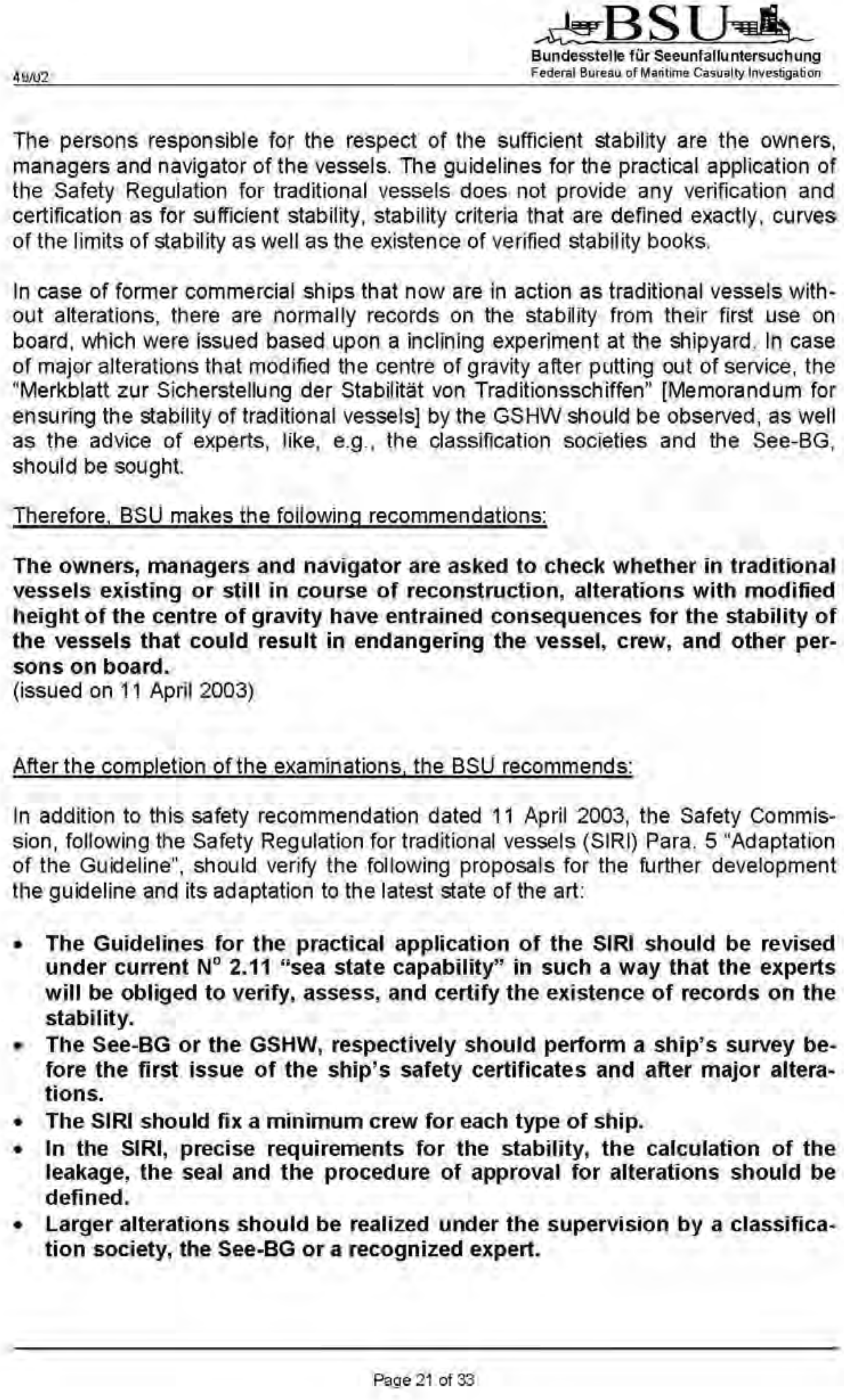
The Bundesstelle für Seeunfalluntersuchung (BSU) makes investigations in the case of a capsizing and subsequent sinking of a remodelled sailing-vessel still in the procedure of approval as traditional vessel in 2002 in the Baltic Sea at the height of Damp.
This examination is not yet finished, however, already at this moment it may be stated that following alterations with elevated weights and by the installation of heavy steel masts, in connection with an augmentation of the sail surface, a massive loss of stability as well as an insufficient seal existed before the capsizing.

After a consultation held with the See-Berufsgenossenschaft (See-BG) and the Gemeinsame Kommission für historische Wasserfahrzeuge e.V. (GSHW), the BSU addresses the owners, managers and navigator of traditional vessels existing or in course of alteration as well as the recognized experts for traditional vessels.

As due to the approaching season for traditional vessels one might have to face similar accidents and in some cases even human lives could be in danger, the BSU following § 15 Para. 1 SUG in connection with § 19 FIUUG refers to the following:

In the "Safety Regulations for traditional vessels" Annex 4 - sea state capability – point 6 concerning the stability says:

"During the whole voyage, sufficient stability must be guaranteed with existing freeboard and varying weather conditions."



49/02

BSU
Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation

The persons responsible for the respect of the sufficient stability are the owners, managers and navigator of the vessels. The guidelines for the practical application of the Safety Regulation for traditional vessels does not provide any verification and certification as for sufficient stability, stability criteria that are defined exactly, curves of the limits of stability as well as the existence of verified stability books.

In case of former commercial ships that now are in action as traditional vessels without alterations, there are normally records on the stability from their first use on board, which were issued based upon a inclining experiment at the shipyard. In case of major alterations that modified the centre of gravity after putting out of service, the "Merkblatt zur Sicherstellung der Stabilität von Traditionsschiffen" [Memorandum for ensuring the stability of traditional vessels] by the GSHW should be observed, as well as the advice of experts, like, e.g., the classification societies and the See-BG, should be sought.

Therefore, BSU makes the following recommendations:

The owners, managers and navigator are asked to check whether in traditional vessels existing or still in course of reconstruction, alterations with modified height of the centre of gravity have entrained consequences for the stability of the vessels that could result in endangering the vessel, crew, and other persons on board.
(issued on 11 April 2003)

After the completion of the examinations, the BSU recommends:

In addition to this safety recommendation dated 11 April 2003, the Safety Commission, following the Safety Regulation for traditional vessels (SIRI) Para. 5 "Adaptation of the Guideline", should verify the following proposals for the further development the guideline and its adaptation to the latest state of the art:

- **The Guidelines for the practical application of the SIRI should be revised under current N° 2.11 "sea state capability" in such a way that the experts will be obliged to verify, assess, and certify the existence of records on the stability.**
- **The See-BG or the GSHW, respectively should perform a ship's survey before the first issue of the ship's safety certificates and after major alterations.**
- **The SIRI should fix a minimum crew for each type of ship.**
- **In the SIRI, precise requirements for the stability, the calculation of the leakage, the seal and the procedure of approval for alterations should be defined.**
- **Larger alterations should be realized under the supervision by a classification society, the See-BG or a recognized expert.**

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SY DE HOOP

7 Safety recommendations

7.1 Owners, operators, and ship's commands

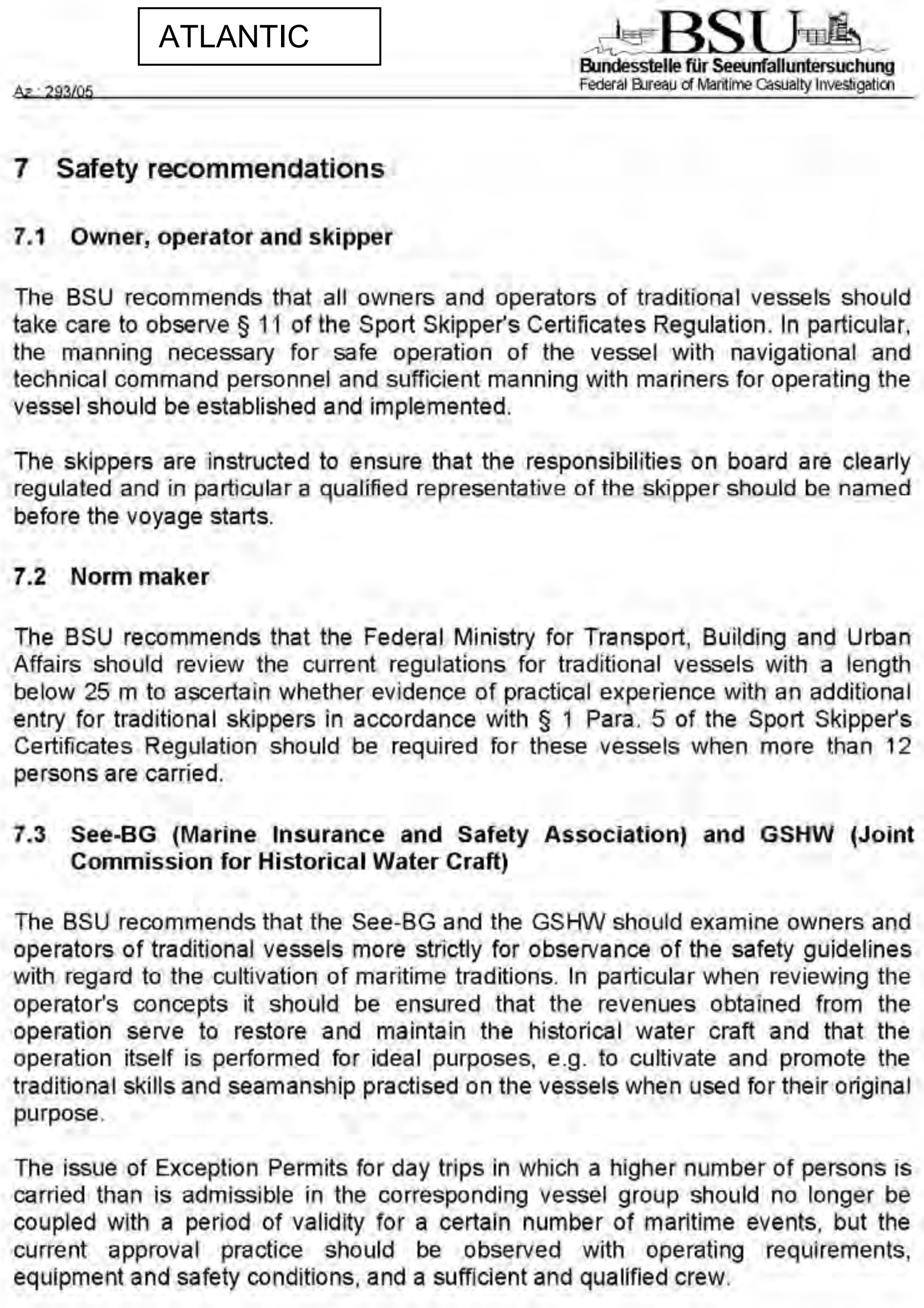
The BSU recommends that the owners and operators of sporting craft not built in accordance with the CE Directive or classification rules become sufficiently familiar with the stability behaviour of their vessels. Aside from the rules of conduct required by traffic regulations, every skipper of a sporting craft shall put into effect the ordinary practices of seamen required by customary seamanship or special circumstances of the case.
However, the ordinary practices of seamen apply not only to the conduct of traffic, but also to the navigation and safety of the vessel. One of the most important rules is that sporting craft are made ready to sail before the start of the voyage, i.e. to

- have necessary safety equipment on board and ready for use;
- check the necessary stability;
- ensure the necessary buoyancy is given, and
- establish safe water integrity is given.

7.2 Legislature

The BSU recommends that the Federal Ministry of Transport, Building and Urban Development examine whether mandatory application of the stability rules of GL for sporting craft of more than 10 m in length may be prescribed for sporting craft not operated under current rules, CE standard or other requirements.

ATLANTIC



Az.: 293/05

Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation

7 Safety recommendations

7.1 Owner, operator and skipper

The BSU recommends that all owners and operators of traditional vessels should take care to observe § 11 of the Sport Skipper's Certificates Regulation. In particular, the manning necessary for safe operation of the vessel with navigational and technical command personnel and sufficient manning with mariners for operating the vessel should be established and implemented.

The skippers are instructed to ensure that the responsibilities on board are clearly regulated and in particular a qualified representative of the skipper should be named before the voyage starts.

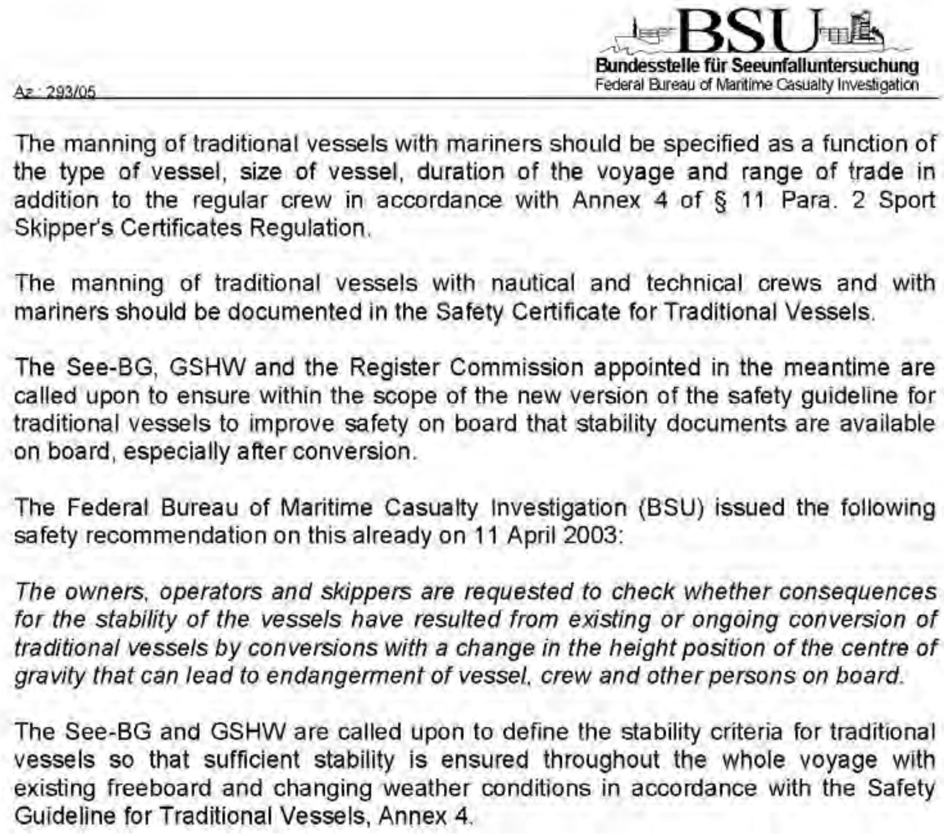
7.2 Norm maker

The BSU recommends that the Federal Ministry for Transport, Building and Urban Affairs should review the current regulations for traditional vessels with a length below 25 m to ascertain whether evidence of practical experience with an additional entry for traditional skippers in accordance with § 1 Para. 5 of the Sport Skipper's Certificates Regulation should be required for these vessels when more than 12 persons are carried.

7.3 See-BG (Marine Insurance and Safety Association) and GSHW (Joint Commission for Historical Water Craft)

The BSU recommends that the See-BG and the GSHW should examine owners and operators of traditional vessels more strictly for observance of the safety guidelines with regard to the cultivation of maritime traditions. In particular when reviewing the operator's concepts it should be ensured that the revenues obtained from the operation serve to restore and maintain the historical water craft and that the operation itself is performed for ideal purposes, e.g. to cultivate and promote the traditional skills and seamanship practised on the vessels when used for their original purpose.

The issue of Exception Permits for day trips in which a higher number of persons is carried than is admissible in the corresponding vessel group should no longer be coupled with a period of validity for a certain number of maritime events, but the current approval practice should be observed with operating requirements, equipment and safety conditions, and a sufficient and qualified crew.



The manning of traditional vessels with mariners should be specified as a function of the type of vessel, size of vessel, duration of the voyage and range of trade in addition to the regular crew in accordance with Annex 4 of § 11 Para. 2 Sport Skipper's Certificates Regulation.

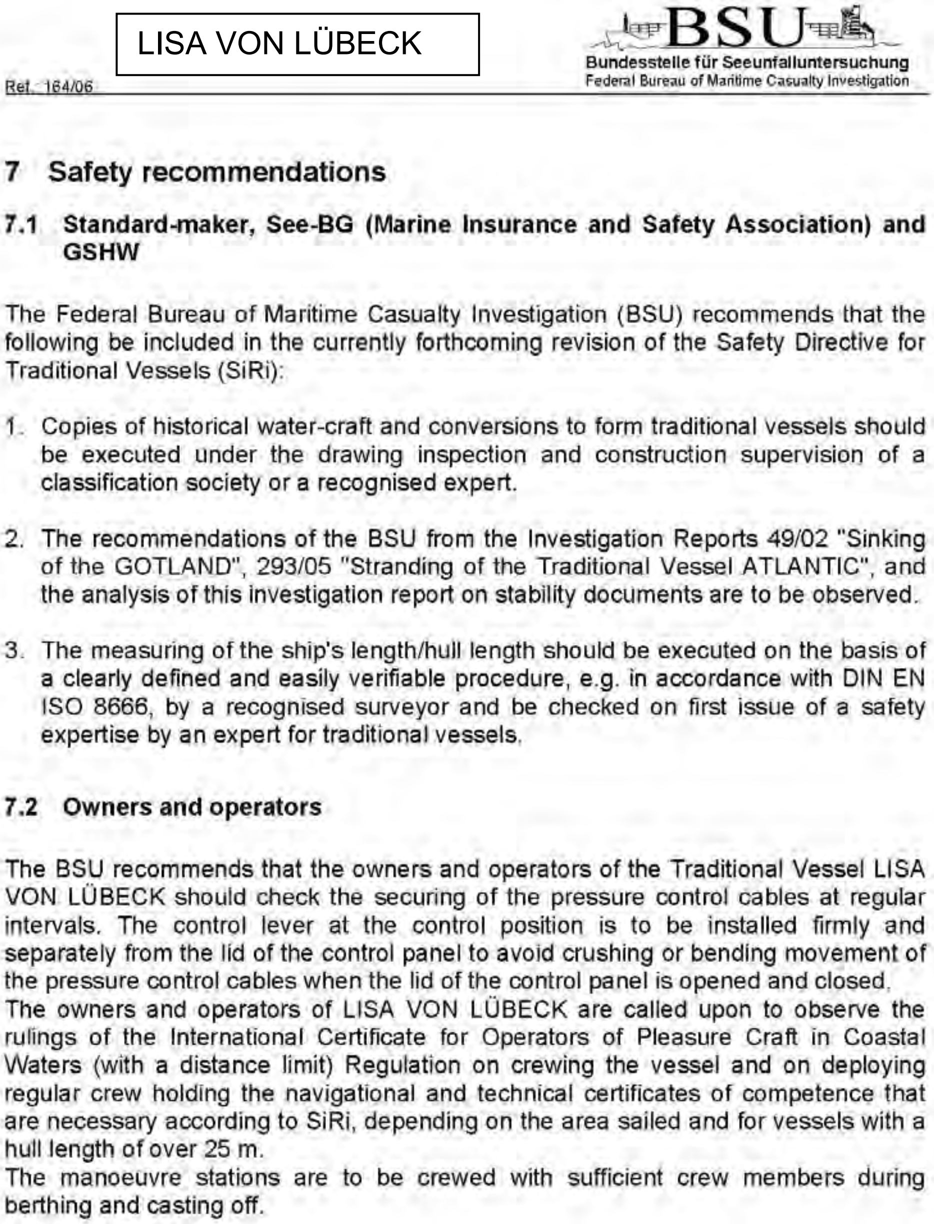
The manning of traditional vessels with nautical and technical crews and with mariners should be documented in the Safety Certificate for Traditional Vessels.

The See-BG, GSHW and the Register Commission appointed in the meantime are called upon to ensure within the scope of the new version of the safety guideline for traditional vessels to improve safety on board that stability documents are available on board, especially after conversion.

The Federal Bureau of Maritime Casualty Investigation (BSU) issued the following safety recommendation on this already on 11 April 2003:

The owners, operators and skippers are requested to check whether consequences for the stability of the vessels have resulted from existing or ongoing conversion of traditional vessels by conversions with a change in the height position of the centre of gravity that can lead to endangerment of vessel, crew and other persons on board.

The See-BG and GSHW are called upon to define the stability criteria for traditional vessels so that sufficient stability is ensured throughout the whole voyage with existing freeboard and changing weather conditions in accordance with the Safety Guideline for Traditional Vessels, Annex 4.



LISA VON LÜBECK

Ref. 164/06

Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation

7 Safety recommendations

7.1 Standard-maker, See-BG (Marine Insurance and Safety Association) and GSHW

The Federal Bureau of Maritime Casualty Investigation (BSU) recommends that the following be included in the currently forthcoming revision of the Safety Directive for Traditional Vessels (SiRi):

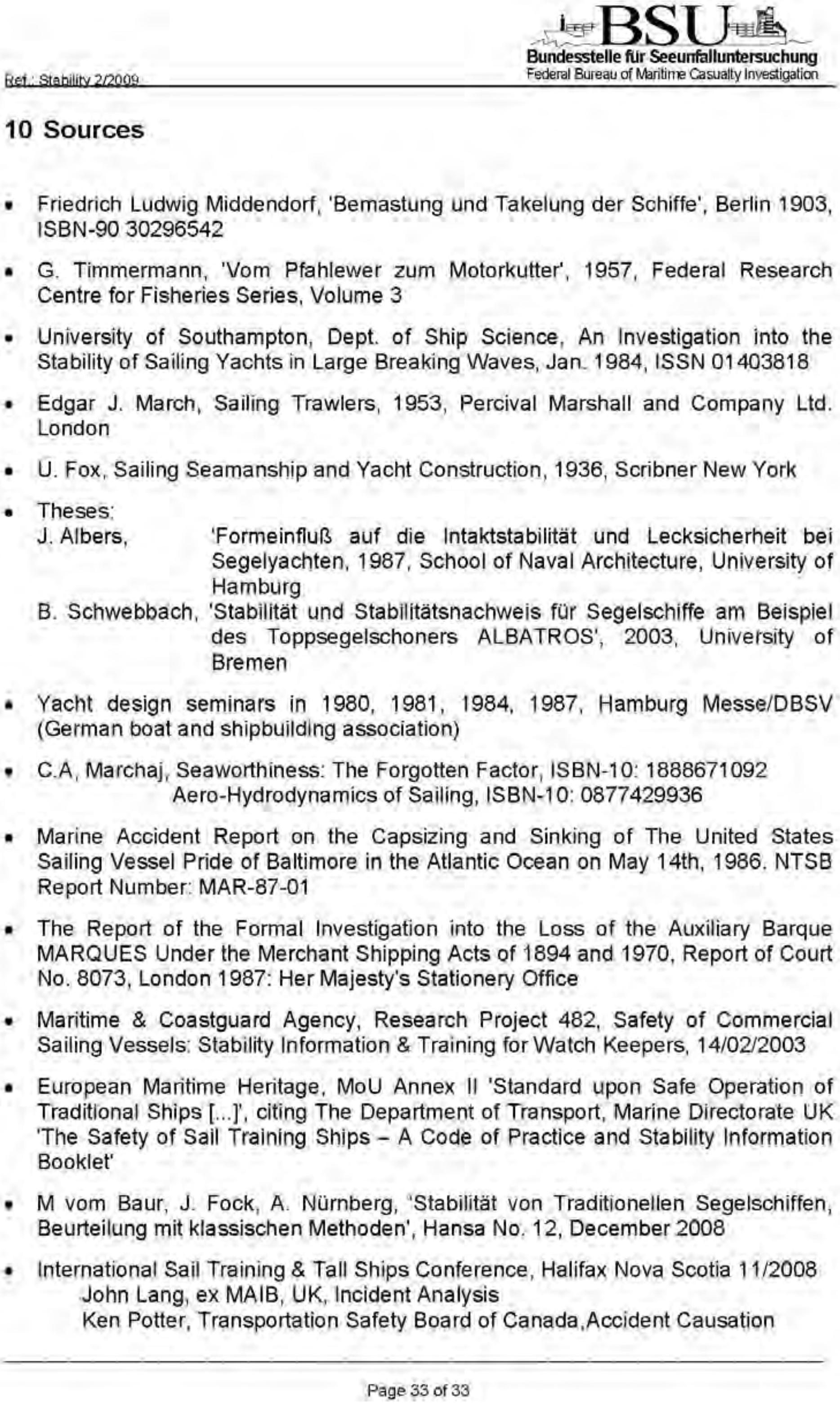
1. Copies of historical water-craft and conversions to form traditional vessels should be executed under the drawing inspection and construction supervision of a classification society or a recognised expert.

2. The recommendations of the BSU from the Investigation Reports 49/02 "Sinking of the GOTLAND", 293/05 "Stranding of the Traditional Vessel ATLANTIC", and the analysis of this investigation report on stability documents are to be observed.

3. The measuring of the ship's length/hull length should be executed on the basis of a clearly defined and easily verifiable procedure, e.g. in accordance with DIN EN ISO 8666, by a recognised surveyor and be checked on first issue of a safety expertise by an expert for traditional vessels.

7.2 Owners and operators

The BSU recommends that the owners and operators of the Traditional Vessel LISA VON LÜBECK should check the securing of the pressure control cables at regular intervals. The control lever at the control position is to be installed firmly and separately from the lid of the control panel to avoid crushing or bending movement of the pressure control cables when the lid of the control panel is opened and closed.
The owners and operators of LISA VON LÜBECK are called upon to observe the rulings of the International Certificate for Operators of Pleasure Craft in Coastal Waters (with a distance limit) Regulation on crewing the vessel and on deploying regular crew holding the navigational and technical certificates of competence that are necessary according to SiRi, depending on the area sailed and for vessels with a hull length of over 25 m.
The manoeuvre stations are to be crewed with sufficient crew members during berthing and casting off.



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