FEBIMA

Vooruitgangstraat 56

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Belgium

Report 2018/002718

Report on the capsizing of

fv O.13 - MORGENSTER

on 7 November 2018

Part I - Investigation Report

Picture : Van Elverdinghe - VLIZ photo gallery

Federal Bureau for the Investigation of Maritime Accidents

Extract from European Directive 2009/18

(26) Since the aim of the technical safety investigation is the prevention of marine casualties and incidents, the conclusions and the safety recommendations should in no circumstances determine liability or apportion blame.

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Glossary of abbreviations and acronyms

%	Percent
°	Degree
a.o.	Amongst others
AIS	Automatic Identification System
Bft	Beaufort
BST	British Summer Time
CPA	Closest Point of Approach
E	East
EPIRB	Emergency Position Indicating Radio Beacon
etc.	Et cetera
Fv	Fishing vessel
IMO	International Maritime Organization
kg	Kilogram
km	Kilometres
kW	kiloWatt
L	Litre
Lbpp	Length Between Perpendiculars
LIANTIS	External Service for Occupational Health
m/v	Motor Vessel
m	Metres
m^2	Square Metre
m^3	Cubic Metres
mrad	Metre Radians
N	North
N°	Number
nm	Nautical miles
PREVIS	Preventie van Arbeidsongevallen aan boord van Visserijschepen (Prevention of Occupational Accidents on board Fishing Vessels)
PS	Portside
SB	Starboard
SE	South East
SW	South West
UK	United Kingdom
UTC	Universal Time Coordinated
VLIZ	Flanders Marine Institute / Vlaams Instituut voor de Zee
ZVF	Zeevissersfonds / Sea Fishery Fund

1 Marine Casualty Information

1.1 Resume

November 7th, 1537 UTC, the Belgian fishing vessel O.13-MORGENSTER capsized 22 km southeast off the coast of Eastbourne (UK).

The position of the derricks during reparations on the trawl gear combined with the influence of wind and waves reduced the stability of the vessel.

Shipping of water in this situation, due to overcoming waves, lead to the capsizing of the vessel.

All four crewmembers survived the accident. One crewmember on deck was not wearing his lifejacket, as it got inflated. The man in the wheelhouse was not wearing a lifejacket. Both fell into the water without lifejacket.

The liferaft of the fishing vessel did not come afloat.

1.2 Classification of accident

According to Resolution A.849(20) of the IMO Assembly of 27 November 1997, Code for the investigation of Marine Casualties and Incidents, a very serious marine casualty means a marine casualty involving the total loss of the ship or a death or severe damage to the environment, consequentially, the incident was classified as

VERY SERIOUS

1.3 Accident Details

Time and date	November 7, 2018, 1537 (UTC)
Location	United Kingdom, 22km SE off Eastbourne
Persons on board	4
Injured	0
Deceased	0

2 Synopsys

2.1 Narrative (UTC, unless specified)

Fishing vessel O.13 – MORGENSTER had left the port of Oostende on Sunday, November 4th, 2018, bound for fishing area VIId, south of Eastbourne. Fishing started on November 5th. The vessel capsized on November 7th, 22 km south-east of Eastbourne.

Figure 1- Fishing Divisions

O.13-MORGENSTER was fishing in division VIId- Eastern English Channel.

O.13-MORGENSTER was manned according to the regulations as stipulated in the minimum safe manning certificate.

Latest inspections and applicable certificates showed no major shortcomings. The latest flagstate inspection was in March 2018 and corrective action was taken, controlled during additional inspections and approved for most of the remarks made. In June 2018, a dry dock inspection took place.

There were two new crewmembers, with experience on similar vessels, on board. The skipper and the engineer were well familiarized with the vessel and fished in the fishing area before. Both were also owners of the vessel.

On November 7th , around 1500 , a fishing track was finished and the nets were emptied.

The weather was cloudy and a strong south-south westerly wind, 7 Beaufort, was blowing causing waves of a height of 2 meters and over. It was ebb tide with the next low water expected at 1725. Sunset was predicted for 1624.

Station 62305 - Greenwich Lightship

Owned and maintained by UK Met Office
Lightship 50.400 N 0.000 E (50°24'0" N 0°0'0" E) - 46 km south west of the place of the incident

Month	Date	TIME (BST)	Wind direction	Wind Speed kts	Wave height ft
11	07	6:00 pm	SW	28.9	7.5
11	07	5:00 pm	SSW	29.9	6.9
11	07	4:00 pm	SSW	31.1	6.9
11	07	3:00 pm	SSW	33.0	7.2
11	07	2:00 pm	SSW	35.9	6.9
11	07	1:00 pm	S	36.9	6.9

Figure 2 - Meteo Greenwich, 7 November 2018

As there were some damages to both nets (portside and starboard), it had been decided to stop the vessel and to execute the necessary repairs, before dusk.
The vessel was stopped, heading 120°, with beam waves coming in on starboard.

The portside net was first repaired. Reportedly, the repairs on portside took about 10 minutes. After the repairs, the portside derrick was topped to 20-35°from centre line, as reported by the crew. The net was lowered to the water. Reportedly, the distance between the net and ship's side was about 3m.
The bottom of the starboard net (damaged at the chain mat and cod-end) was attached to the clamps at the ship's side to bring the chain mat under tension in order to repair it. The remainder of the net was lying on deck.
Both nets were empty, and due to the different elevations of the derricks, there was a slight list over portside, see Figure 3. No manipulation of winches was ongoing.

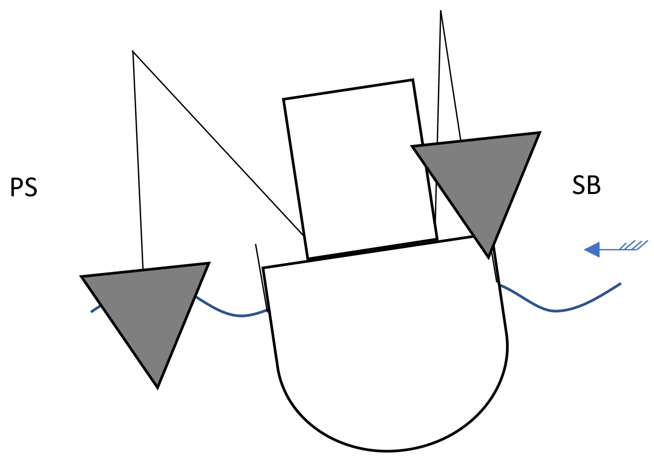


Figure 3 - Schematic drawing of initial condition of the vessel

At 1535, m/v ARKLOW BREEZE, heading 260° and a speed of 9 knots, crossed fv O.13–MORGENSTER. Fv O.13-MORGENSTER was drifting northwards with a heading of 120°. The closest point of approach (CPA) between both vessels was 0.15nm.

Reportedly, radio contact between both vessels had taken place when m/v ARKLOW BREEZE was at a distance of 0.75 nm with an initial CPA of 0.10 nm.

Figure 4 - CPA m/v ARKLOW BREEZE

CPA between m/v ARKLOW BREEZE (Dark Blue color) and O13. MORGENSTER is 0.15 nm or 278m, at 1535 UTC. (Source AIS data UK Coastguard)

Reportedly, shortly after the m/v ARKLOW BREEZE had passed, O.13-MORGENSTER came into a wave trough and a huge amount of water came on board on portside.

Immediately, the man in the wheelhouse tried to down the starboard derrick, but due to the list and the position of the derrick, it did not react.

Meanwhile a second wave of water came on board and reportedly the portside bulwark disappeared under water.

Reportedly, the portside wire was put into free running position, lowering the portside net to the bottom. This action had no apparent effect on the stability of the vessel. At the same time, the vessel rolled a little bit back from portside to starboard. Due to this movement, the starboard derrick came down, but the vessel did not regain its stability.

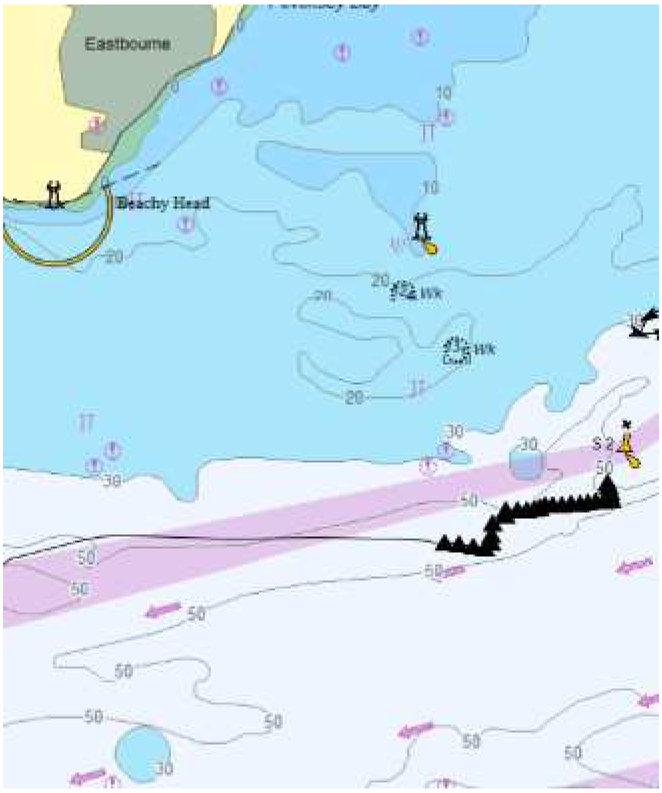


Figure 5 - Last Position

Last available position received by UK Coastguard is N 50°38' 29" E 000° 32' 7 at 15:37:06 UTC. (Source AIS data UK Coastguard)

When the vessel rolled back to portside, she rolled further than before and consequentially water entered the wheelhouse. At that moment, the helmsman left the wheelhouse and jumped overboard. He was not wearing a lifejacket.

The starboard derrick went over to portside, the vessel capsized and rolled further to upside down position.

Two of the three men working on deck managed to climb onto the hull when the vessel was rolling back from starboard to portside. Both of them were wearing a lifejacket.

The third man on deck held on to the ship's side when the vessel capsized and fell into the water. He was not wearing a lifejacket as his lifejacket got inflated during the last fishing track before the incident.

The two men in the water could grab a lifebuoy and a lifejacket that was thrown by one of the men that climbed onto the hull.

Figure 6 - Capsized vessel

Extract from video by UK Coastguard upon arrival.

The crew on board the M/v ARKLOW BREEZE witnessed the incident and turned the vessel around in order to pick up the two men from the water.

The crew of the M/v ARKLOW BREEZE also alerted the UK Coastguard. Shortly after the alert of m/v ARKLOW BREEZE, the EPIRB signal from fv O.13-MORGENSTER had been broadcasted.

Figure 7 - M/v ARKLOW BREEZE and state of the sea

Extract from video by UK Coastguard upon arrival.

A Search and Rescue helicopter of the UK coastguard picked up the two men sitting on the hull and the two crewmembers that were rescued by m/v ARKLOW BREEZE, and flew them to the Dover Coastguard Station.

At Dover Coastguard, a medical check-up was performed. Later that evening all rescued crewmembers were repatriated to Belgium by Ferry (via Calais).

The life raft, located on top of the wheelhouse, did not came afloat.

1

3 Factual information

3.1 Vessel's details

Figure 8 - O.13 - MORGENSTER

Picture: shipspotting.com

Type: Fishing vessel (Beam trawler)

Flag: Belgium

Port of registry: Oostende

Vessel-ID: 1922

Call Sign : OPAM

Shipyard : Holland Launch B.V

Year of built : 1989

Current owner since 2011:

BVBA Rederij Hollebeke

LOA: 23.94m

Lbpp: 21.14m

Beam (moulded): 6.00m

Depth (moulded): 3.00m

Gross tonnage: 94

Net tonnage: 28

Engine power: 218 kW

Engine type: Caterpillar 3408C (1997)

3.2 Beam trawling

Beam trawling was developed in England in the 19th century.

In 1950, first attempts were made to have beam trawling used in open water. Because of the successes, by 1957, most Dutch shrimpers were rigged for beam trawling. In 1959, the first two Belgian shrimpers with home port Zeebrugge were rigged for beam trawling. Today, the majority of the Belgian commercial fishing fleet is rigged for beam trawling.

Most commercial beam trawlers use two beam trawls towed from long derricks on each side of the vessel.

The target species are usually bottom-dwelling flat-fish such as plaice , sole, megrims, etc.

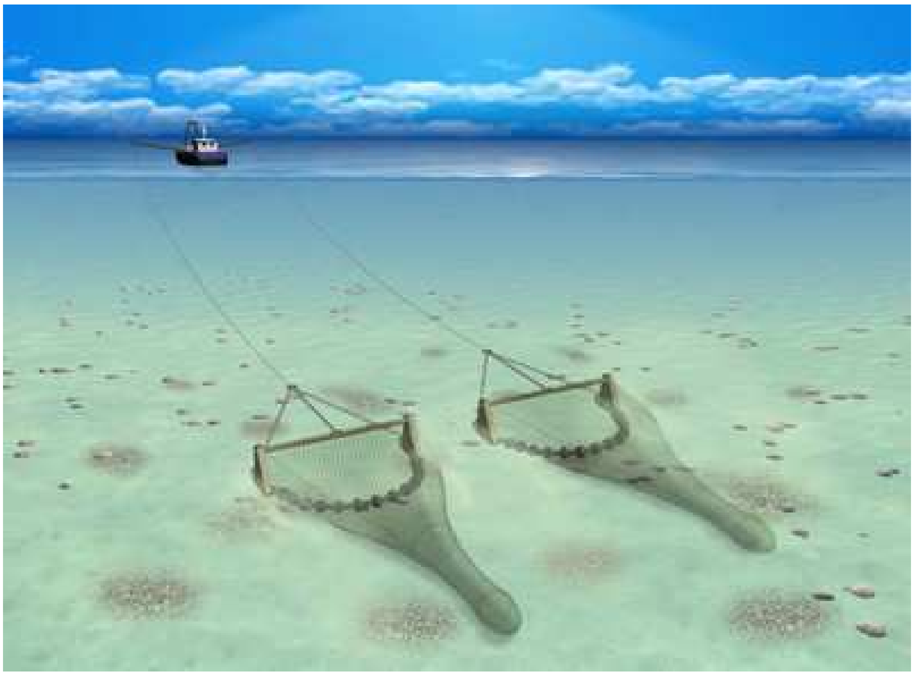


Figure 9 - Beam trawler

Impression of a fishing vessel rigged for beam trawl www.seafish.org

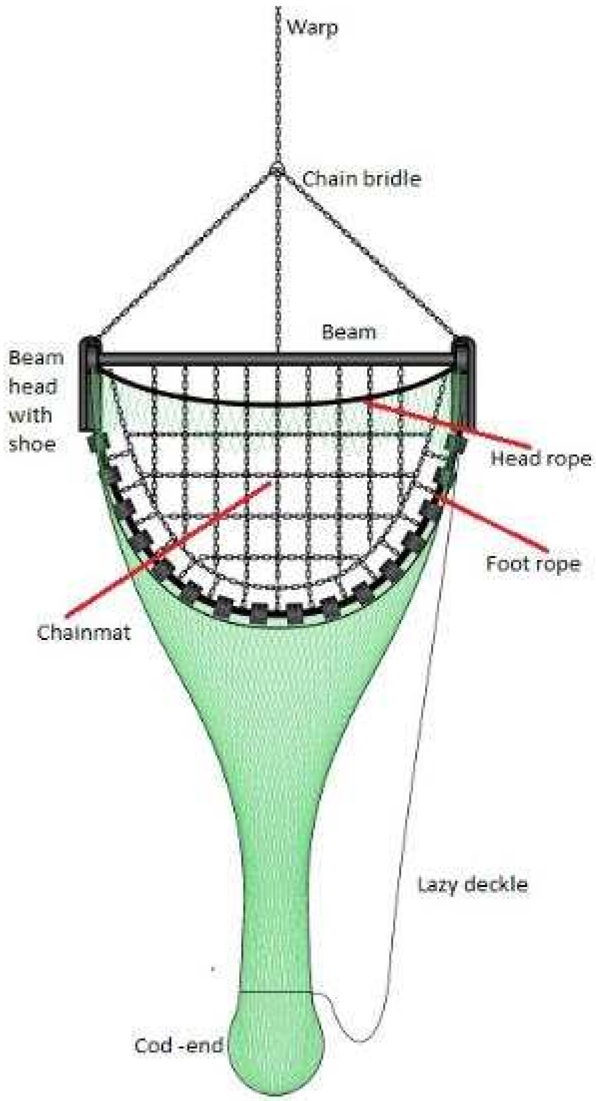


Figure 10 - Trawl Gear

The beam trawl consists of a heavy tubular steel beam supported by beam heads at each end. These beam heads have wide shoes at the bottom which slide over the seabed. The beam and beam heads form a rigid framework that keeps the mouth of the trawl open and supports the net.

The cone-shaped net is towed from this framework with the headline attached to the beam, and each end of the footrope connected to the bases of the shoes. As the gear is towed over the seabed, the footrope forms a 'U' shape curve behind the beam and shoes, with the net and cod-end behind this.

The beam is usually towed using a chain bridle arrangement from both shoes and the centre of the beam attached to the end of the trawl warp leading to the vessel.

Beam trawlers are prone to capsizing due to the nature of the activities. Although the stability conditions imposed upon fishing trawlers by the competent authorities are in most cases met, slight alterations in symmetrical load between the two fishing nets, starboard and portside, during fishing and especially during recovery of the nets can have detrimental effects on the initial stability of beam trawlers.

Figure 11 - Chain net

VLIZ Fotogallerij

4 Analyses

4.1 Stability of the vessel

The latest stability calculations (including inclining test) were approved by the Belgian maritime inspectorate according Service Regulation 15 "*Stability of fishing vessels*" (see appendix 1) on 21/04/1995.

The stability calculations took following circumstances into account:

- Inclining test as executed on 30/03/1995
- Vertical center of gravity determined with derricks at 45°
- Nets lying on deck
- Condition N° 1,Departure from port with 100% consumables
- Condition N° 2, Departure from grounds with 50% consumables and 100% catch
- Condition N° 3, Arrival at port with 10% consumables and 100% catch
- Condition N° 4 , Arrival at port with 10% consumables and 20% catch
- Wind pressure of 75kg/m² (surfaces from LL up to 5m) and 125 kg/m² (surfaces over 5m in height) for condition N°4

These calculations only indicated whether or not the fishing vessel was fulfilling the stability criteria as mentioned in Service regulation 15.

The content of today's stability criteria goes back to 1939, when the first unofficial stability criteria were developed by J. Rahola. The purpose of his investigation "*The judging of the stability of ships and the determination of the minimum amount of stability*" was to find a procedure to judge with adequate certainty the amount of stability of a certain vessel.

Especially smaller vessels had been chosen in the study as these were very vulnerable to capsizing.

Mr. Rahola used three different methods:

- Comparing stability values of capsized and not capsized vessels with comparable characteristics.
- The qualities of stability of capsized vessels were being founded as “bad stability qualities”.
- Theoretical determination by calculation the magnitude of those heeling moments to which the vessel may be subjected in the most unfavourable circumstances and make the stability qualities of the vessel such as to allow the vessel to withstand these heeling moments without risk.

In 1939, the stability theory for amongst others the impact of waves was not yet sufficiently developed to be used into calculations. In fact, the study was based on still water behaviour.

In 1968, the IMO issued the first official recommendations on stability criteria of fishing vessels. The recommendations stated minimum requirements for certain parameters of the GZ curves , as based on the stability criteria in still water developed by Mr. Rahola.

IMO Resolution A.168, Recommendations on intact stability of fishing vessels, was adopted on 28 November 1968 and superseded in 1993.

The IMO resolution encouraged individual countries to publish stability criteria for the specific type(s) of fishing vessels flying their flag, based on the method used by IMO.

Also in 1968, as a result of several incidents with beam trawlers, The Netherlands published their own stability criteria, based on the IMO criteria and they integrated an increasement of 20% for the different parameters of the GZ-curve for beam trawlers.

The 20% safety margin for beam trawlers was an arbitrary idea. No calculations justifying this 20% increasement were found.

In 1977, IMO put fishing vessel stability on the agenda again, but it was concluded that since the previous recommendations in 1968, no or little progress was made regarding the investigation of behaviour of fishing vessels in open seas.

As a result, the parameters of the GZ curve as mentioned in the 1977 IMO Safety of Fishing Vessels (or Torremolinos convention) were the same as in IMO A.168. On the other hand, IMO 1977 contained more detailed methods to calculate the influence of wind, ice, water on deck and rolling.

In the Netherlands, the new IMO 1977 criteria resulted in an update of the regulations regarding stability of fishing vessels (with the same parameters for the GZ-curve as IMO 1977). The 20% increasement for beam trawlers was still part of these regulations and a minimum GM of 0.50 m for beam trawlers was introduced.

Belgium ratified the 1977 Torremolinos convention in 1982, but the convention never came into vigour. The 20% increasement for beam trawlers was not part of this convention and the convention only applied to fishing vessel with a LOA of 24m and above.

In Belgium, Service Regulation 15 contained the requirements concerning intact stability for fishing vessels (including 20% higher requirements for beam trawlers). The Belgian Flagstate Administration was appointed to approve the stability calculations and to tighten the stability criteria when deemed necessary. Service Regulation 15 was based on the Dutch requirements and/or on IMO A.168 and 1977 IMO Safety of Fishing Vessels. It could not be determined when Service regulation 15 was published for the first time.

Today's stability criteria, as mentioned in Service regulation 15, are parameters for the design of the GZ-curve in different loading conditions:

1. The GM or the initial metacentric height should be at least 0.5m. This GM is an important parameter for the judgement of the stability at small angles of heel. Ships with a high GM can easily withstand high heeling moments (wind pressure, waves, weight shifts due to loading and unloading, etc.) and are little sensitive to eccentric loading.
   A ship with a high GM is a stiff ship: a ship with short rolling motions and fast rolling.

2. Criteria for the surface below the GZ curve : The total area under the static stability curve (GZ-curve) gives the amount of energy that the ship can absorb from external heeling forces (winds, waves, weight shifts, etc.) till it capsizes.
   This area represents the dynamical way when heeling a ship. If the dynamical way (surface below the GZ curve) is multiplied with the displacement, the dynamic stability of the vessel is known.
   Dynamic stability is the work to be done to heel a ship from a certain position, very slowly, into another position. It does not represent the stability by the impact of dynamic forces (kinetic energy such as the impact of waves) at sea.

3. Criteria regarding the righting lever or GZ: the size of the righting arm GZ is crucial to whether the vessel can straighten up and get back on an even keel. The greater the righting arm is, the better is the ability of the vessel to get back on an even keel.

The parameters were determined by the comparison of fishing vessels (same technique as Rahola applied) that were sailing in 1968. As the size and design of fishing vessels (also beam trawlers) changed through the years, it could be supposed that the criteria should be updated as well.

The increased stability requirements for beam trawlers (20%) had never been adapted, although several beam trawlers capsized over the years, with these criteria already applicable.

Stability criteria stated into Service regulation 15 were based on the static condition of the vessel and did not take operational circumstances into account.
Dynamic forces and the effect of water on deck had not been taken into account when developing the criteria.
This made the approved stability calculations not very useful to determine the actual stability of the vessel when operating at open seas.

4.1.1 Stability at the moment of capsizing

From the testimonies, four steps leading up to the capsizing could clearly be identified:

Step 1: initial condition: "The derricks were topped. PS derrick estimated between 20-35 degrees with fishing gear partly in the water. SB fishing gear attached to the ship's side."

Step 2: "The vessel came into a wave trough (possibly caused by a passing ship) and a "huge" amount of water came on board on PS side."

Step 3: "A second wave of water came on board and reportedly the PS side disappeared under water."

Step 4: "The vessel rolled to SB and back to PS, further than the last time. Water entered the wheelhouse and the SB derrick went over to PS and the vessel capsized"

The vessel was into a condition with a major influence of derrick positions, waves and water on deck. The stability booklet did not give any information about these circumstances.

Fv O.13- MORGENSTER sunk and could not be recovered for further investigation and stability tests. Some factors have not been taken into account when executing the stability calculations, as accurate data were not available, such as:

- Buoyancy effect on the partly submerged fishing gear on PS
- Effect of beam waves (see further)
- Effect of the partly submerged fishing gear to the movement of the vessel
- Mass of water absorbed by the wooden deck

Lightship

At the moment of capsizing, following masses were on board as reported by the crew:

- Fuel: 6000 L , equally spread over three tanks
- Fresh water (3 tanks): 8000L
- Hydraulic oil: 300 L
- Crew and luggage : 4 persons (part of lightship mass in latest stability calculations)
- Fish and ice: 3500 kg – in well secured boxes equally spread over port and starboard side

All other weights (spare parts, spare shackles, wires, ropes, …) were considered as part of the lightship, see Figure 12.

In 1997, an increase of 1.258 tons in the mass of the lightship had been determined by a tonnage surveyor, based on the draught. No new inclining test had taken place.

Between 1995 and 2019, it was possible that the mass of the lightship changed due to extra spares on board, extra tools and machinery on board, other types/lengths of chains and wires and ropes, other derricks, other deck flooring,… If these masses were added above the centre of gravity, there is a negative influence to the vessel's stability.

The vessel was only required to perform a new inclining test in case of a rebuild or modifications to the vessel. No modifications or rebuilds had been done, therefore the mass of the lightship, as calculated in 1995, was still used.

3.1. CONDITION : INITIAL CONDITION DURING ACCIDENT, PS DERRICK AT 20 DEGREES

Description	Filling %	Density ton/m³	Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship	-	-	148.600	2.463	9.522	0.000	-
Subtotals for group : Fuel Oil							
FO. Fr.38 SB	45.4	0.8750	1.724	1.525	15.969	1.538	0.372
FO. Fr.38 PS	45.4	0.8750	1.724	1.525	15.969	-1.538	0.372
FO. Fr.38 CL	33.5	0.8750	1.732	0.836	15.993	0.000	0.454
SUBTOTAL	40.6	0.8750	5.180	1.294	15.977	0.000	1.199
Subtotals for group : Water							
FW Fore	10.0	1.0000	0.379	0.510	18.245	0.000	0.286
FW Aft	98.0	1.0000	2.322	2.303	-0.296	0.000	0.335
SUBTOTAL	43.9	1.0000	2.701	2.052	2.304	0.000	0.621
Subtotals for group : Misc. Tanks							
IceW. Fr.18/24 SB	98.0	1.0000	2.478	0.896	8.505	2.045	0.076
IceW. Fr.18/24 PS	98.0	1.0000	2.478	0.896	8.505	-2.045	0.076
SUBTOTAL	98.0	1.0000	4.956	0.896	8.505	0.000	0.152
Subtotals for group : Fish & Ice							
Fish & Ice	-	-	3.500	1.500	12.750	0.000	-
SUBTOTAL	-	-	3.500	1.500	12.750	0.000	-
Subtotals for group : Water on deck							
Water op dek, water	0.0	1.0250	0.000	-	-	-	-
SUBTOTAL	-	-	0.000	4.000	8.817	0.000	-
Fish boxes at aft deck	-	-	0.350	3.900	0.450	0.000	-
Fishing gear SB	-	-	2.500	4.450	12.950	2.240	-
Fishing gear PS Beam @ 20deg	-	-	2.500	14.280	12.950	-4.550	-
TOTAL	-	-	**170.287**	**2.561**	**9.723**	**-0.034**	**1.971**

Figure 12 - Initial weights on board

Derricks and nets

The position of derricks and nets also affected the stability.

The centre of gravity of the derrick itself moved whenever the derrick was lifted or lowered.

The fishing gear was attached to the derrick. The centre of gravity of a suspended weight, in this case the fishing gear, could be considered to be acting at the point of suspension, as shown in Figure 13.

When the PS derrick was lifted higher, the point of suspension rose (vertical centre of gravity), but came closer to the centre of the vessel (transversal centre of gravity). When the derrick was lowered, the point of suspension descended, but moved further away from the centre of the vessel.

At the moment of capsizing, the starboard net was attached to the bulwark, the derrick was topped.

The portside derrick was at an angle between 20 and 35 degrees (step 1), as shown in Figure 13.

To calculate the stability when the vessel capsized, two calculations were performed: one with the PS derrick at 20° and another with the PS derrick at 35°.

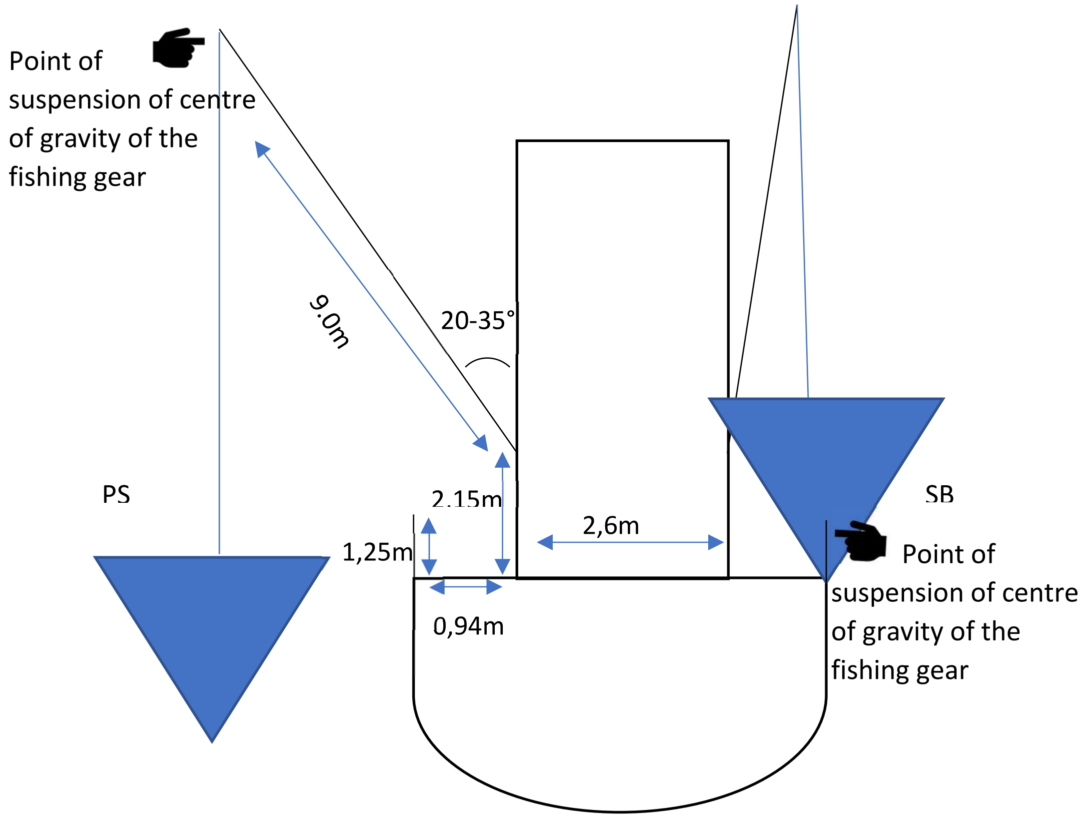


Figure 13 -Dimensions

Schematic view of distances at the time of capsizing

For beam trawlers, stability criteria of Service regulation 15 were augmented with 20% in comparison to other fishing vessels.

Stability calculations indicated that the vessel in the condition of step 1 did not comply with the stability criteria for beam trawlers (20% extra) and did not comply with the stability criteria for other non-beam trawler fishing vessels.

By hanging empty nets from the derricks and changing the position of the derricks, the stability of the vessel was decreased by more than 20%, compared to the prescribed loading conditions in Service regulation 15.

Initial condition, derrick at 20 degrees:

Stability values were less than the required values for different loading conditions in Service regulation 15. The vessel had a static angle of heel of almost 3 degrees, but had still a positive range of stability of 48 degrees. No real danger for capsizing existed.

Condition : Condition during accident, PS derrick at 20 degrees

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.293	m
Trim	-0.268	m
Statical angle of inclination	3.25	degrees PS
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

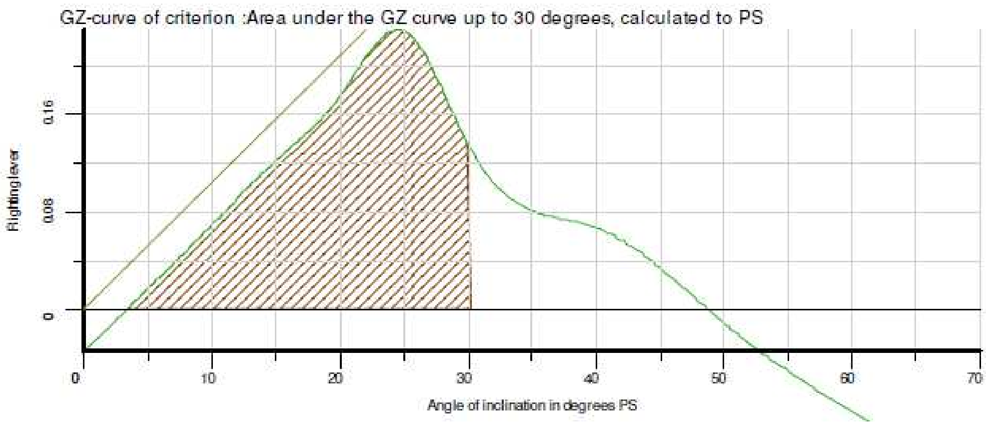
Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.598	meter
Maximum GZ at 30 degrees or more	0.240	0.135	meter
Top of the GZ curve at least at	25.000	24.522	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.060	mrad
Area under the GZ curve up to 40 degrees	0.108	0.076	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.015	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	18.561	degrees PS
---------- Additional information			
Range of positive stability	0.000	45.528	degrees
Angle of vanishing stability	0.000	48.782	degrees PS
Roll Period acc Irish authorities	0.000	5.430	sec
Roll Period acc IS 2008	1.000	6.580	sec

Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.598	meter
Maximum GZ at 30 degrees or more	0.240	0.191	meter
Top of the GZ curve at least at	25.000	24.442	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.093	mrad
Area under the GZ curve up to 40 degrees	0.108	0.117	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.024	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	11.942	degrees SB
---------- Additional information			
Range of positive stability	0.000	56.106	degrees
Angle of vanishing stability	0.000	52.852	degrees SB
Roll Period acc Irish authorities	0.000	5.430	sec
Roll Period acc IS 2008	1.000	6.580	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



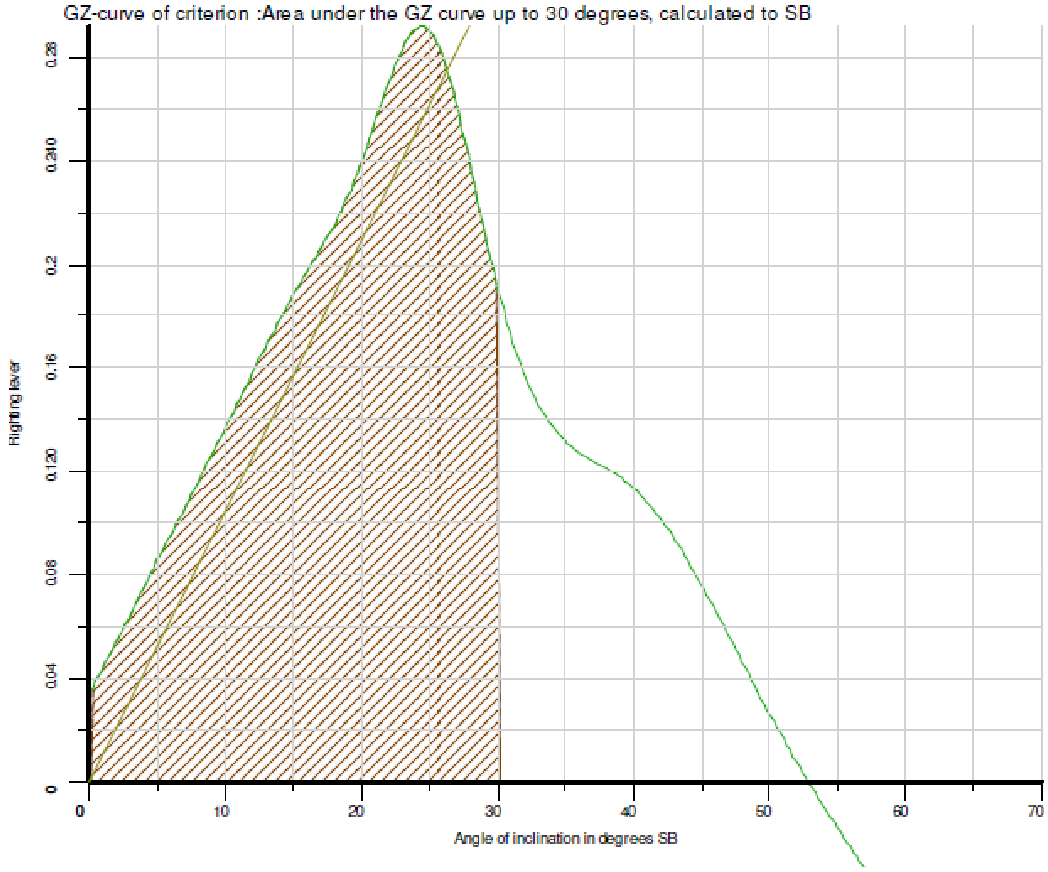


Figure 14 - Initial condition, 20°

Initial condition, derrick at 35 degrees:

Stability values were less than the required values for different loading conditions in Service regulation 15. The vessel had a static angle of heel of 5,5 degrees, but had still a positive range of stability of 44.5 degrees. No real danger for capsizing existed.

Condition : Condition during accident, PS derrick at 35 degrees

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics

Draft mld.	2.293	m
Trim	-0.268	m
Statical angle of inclination	6.18	degrees PS
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.610	meter
Maximum GZ at 30 degrees or more	0.240	0.117	meter
Top of the GZ curve at least at	25.000	24.585	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.049	mrad
Area under the GZ curve up to 40 degrees	0.108	0.062	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.013	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	20.660	degrees PS
--------- Additional information			
Range of positive stability	0.000	41.759	degrees
Angle of vanishing stability	0.000	47.935	degrees PS
Roll Period acc Irish authorities	0.000	5.377	sec
Roll Period acc IS 2008	1.000	6.516	sec

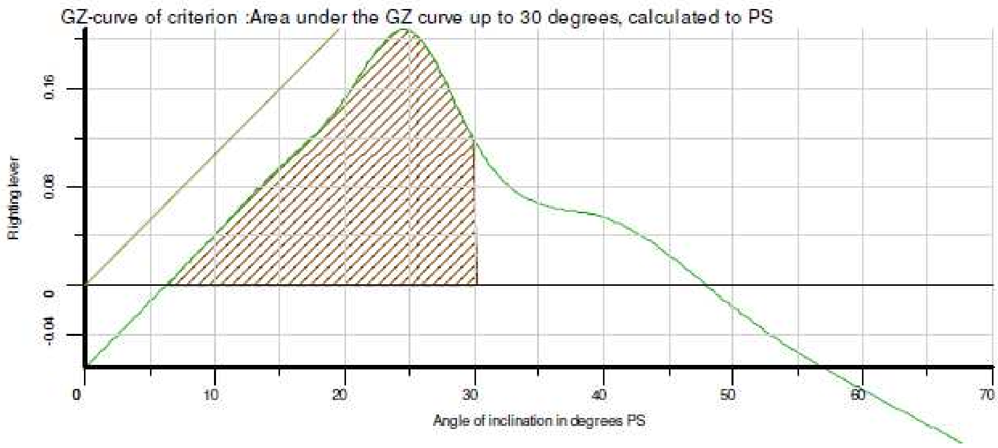
Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.610	meter
Maximum GZ at 30 degrees or more	0.240	0.225	meter
Top of the GZ curve at least at	25.000	24.429	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.111	mrad
Area under the GZ curve up to 40 degrees	0.108	0.141	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.030	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	8.656	degrees SB
--------- Additional information			
Range of positive stability	0.000	62.297	degrees
Angle of vanishing stability	0.000	56.120	degrees SB
Roll Period acc Irish authorities	0.000	5.377	sec
Roll Period acc IS 2008	1.000	6.516	sec

VCG'

A non-zero statical angle of equilibrium occurs,

No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



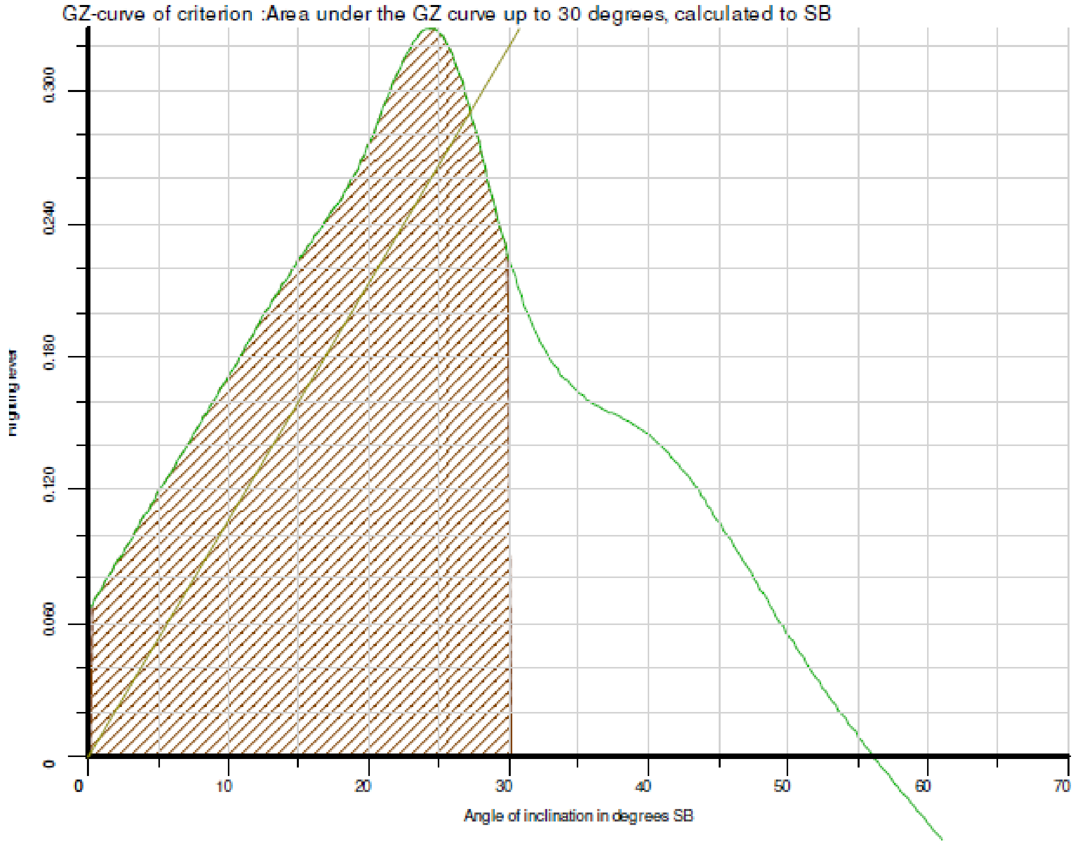


Figure 15 - Initial condition, 35°

Catch in the nets

O.13 - MORGENSTER had empty nets at the moment of capsizing.

Water on deck

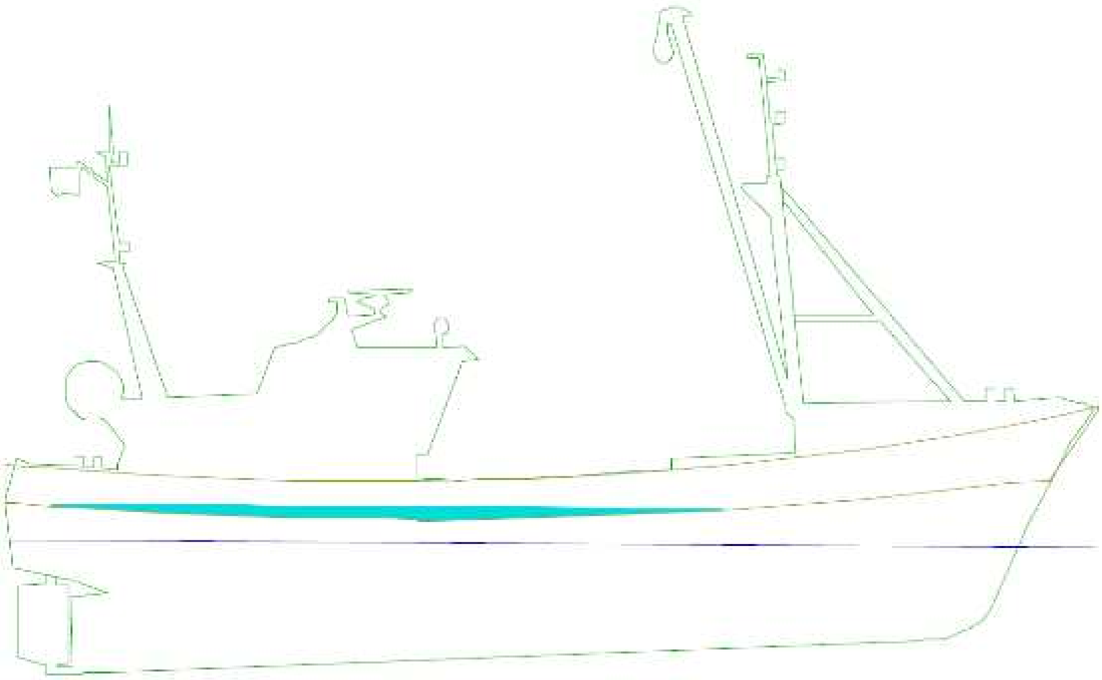
As in step 2 (see 4.1.1 Stability at the moment of capsizing) , water came on deck. The amount of water on deck was not exactly known. During investigation of the stability of the vessel, the amount of water had been increased with 5m³ by every step, as shown in Figure 16 .

Condition : Step 2, PS derrick at 20 degrees, 5 m3 water on deck

Longitudinal view, no heel, cargo liquid

Condition : Step 3, PS derrick at 20 degrees, 10 m3 water on deck

Longitudinal view, no heel, cargo liquid



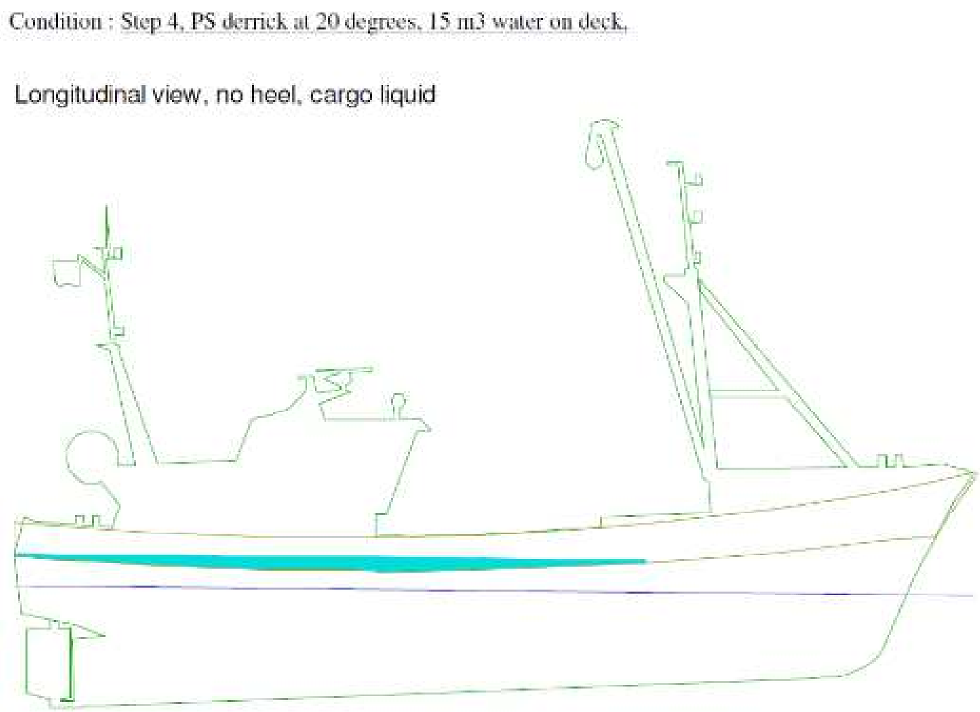


Figure 16 - Water on deck

Water on deck is a mass added to the vessel. It is a weight with a free liquid surface, thus it is easily moved by the motion of the vessel. Therefore, water on deck has a negative impact on the stability of the vessel and should be avoided as much as possible.

To prevent water on deck due to waves coming over, a minimum freeboard is required (as part of the stability requirements) and also the height of the bulwark contributes to the prevention of waves coming over.

To free the deck from water (where bulwarks on weather parts of the freeboard deck form wells), a minimum area of freeing ports is required in relation to the length and the height of the bulwark.

On board O.13 - MORGENSTER, hinged flaps covered the freeing ports, making it possible for water to escape.

Hinged covers should be well maintained. Once stuck, water will not be able to run away in time and will accumulate on deck.

The inspection of freeing ports is part of the yearly flagstate inspection. The flagstate inspection report (dated March 2018) did not mention any shortcomings related to the freeing ports.

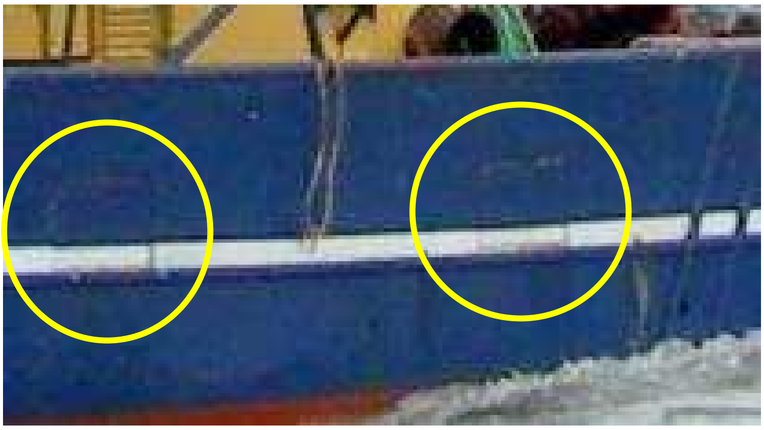


Figure 17 - Freeing ports on board O.13 - MORGENSTER

The impact of water on deck to the stability of the vessel:

Assumed amount of water on deck: 5m³

PS derrick at 20 degrees:

Stability values were almost 50% of the required values for different loading conditions in Service regulation 15. The static angle of inclination with 5m³ water on deck was 9 degrees. There was a positive range of stability of almost 42 degrees. The vessel should not have capsized, but the stability decreased significantly.

Condition : Fase 2, PS derrick at 20 degrees, 5 m3 water on deck

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics

Draft mld.	2.333	m
Trim	-0.330	m
Statical angle of inclination	10.05	degrees PS
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

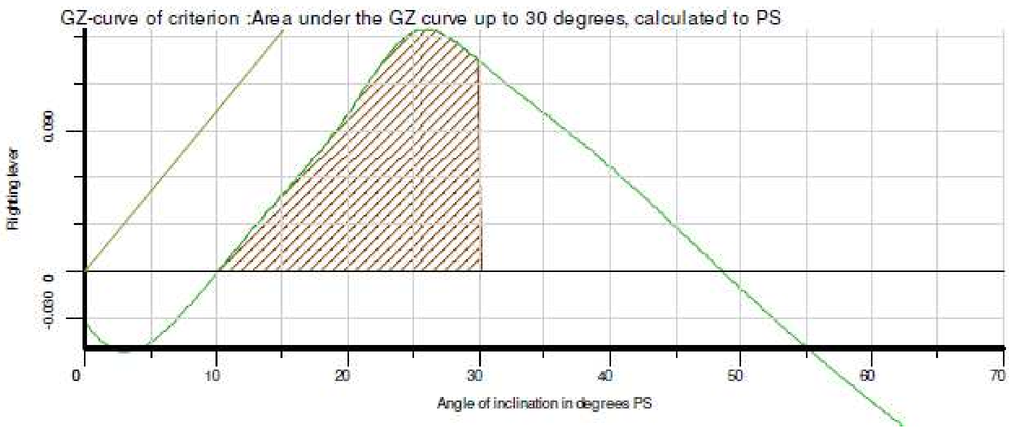
Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.588	meter
Maximum GZ at 30 degrees or more	0.240	0.135	meter
Top of the GZ curve at least at	25.000	25.924	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.033	mrad
Area under the GZ curve up to 40 degrees	0.108	0.051	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.018	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	24.405	degrees PS
--------- Additional information			
Range of positive stability	0.000	38.560	degrees
Angle of vanishing stability	0.000	48.612	degrees PS
Roll Period acc Irish authorities	0.000	5.476	sec
Roll Period acc IS 2008	1.000	6.620	sec

Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.588	meter
Maximum GZ at 30 degrees or more	0.240	0.191	meter
Top of the GZ curve at least at	25.000	25.726	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.060	mrad
Area under the GZ curve up to 40 degrees	0.108	0.086	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.027	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	18.994	degrees SB
--------- Additional information			
Range of positive stability	0.000	63.112	degrees
Angle of vanishing stability	0.000	53.060	degrees SB
Roll Period acc Irish authorities	0.000	5.476	sec
Roll Period acc IS 2008	1.000	6.620	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



Condition : <u>Fase 2, PS derrick at 20 degrees, 5 m3 water on deck</u>

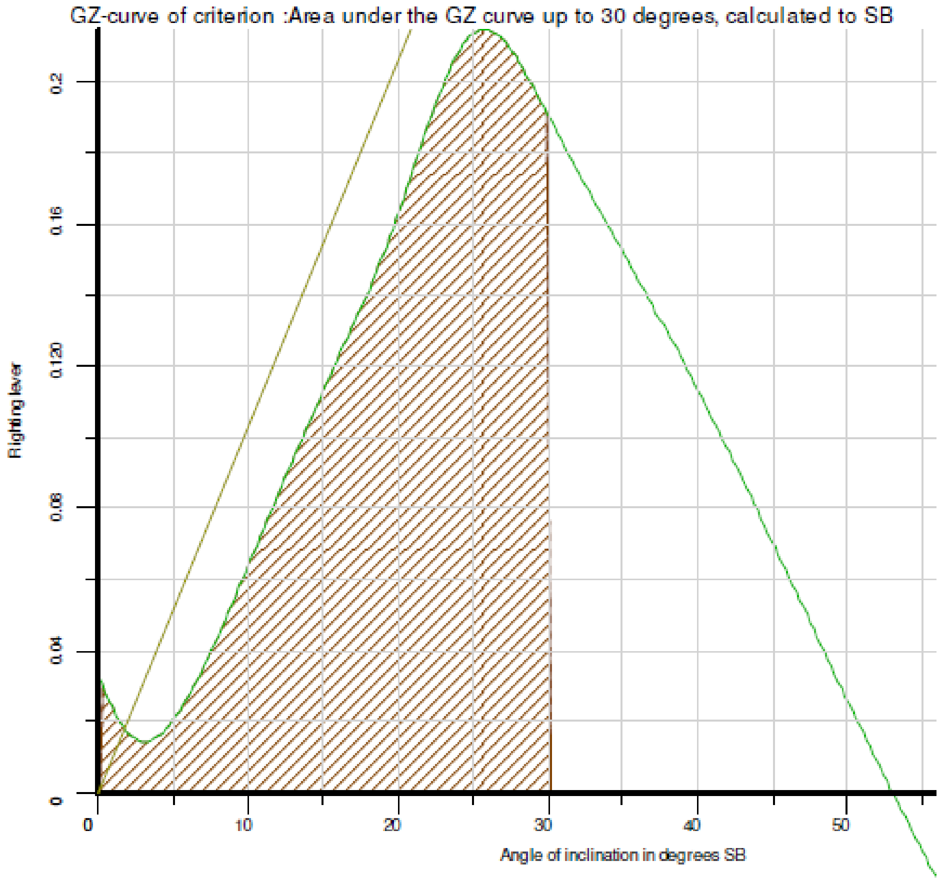


Figure 18 - Step 2, derrick 20°, 5m³ water

PS derrick at 35 degrees:

Stability values were less than 50% of the required values for different loading conditions in Service regulation 15. The static angle of inclination with 5m³ water on deck was 11,4 degrees. There was a positive range of stability of 38.5 degrees. The vessel should not have capsized, but the stability decreased significantly.

Condition : Fase 2. PS derrick at 35 degrees. 5 m3 water on deck

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.333	m
Trim	-0.330	m
Statical angle of inclination	12.70	degrees PS
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

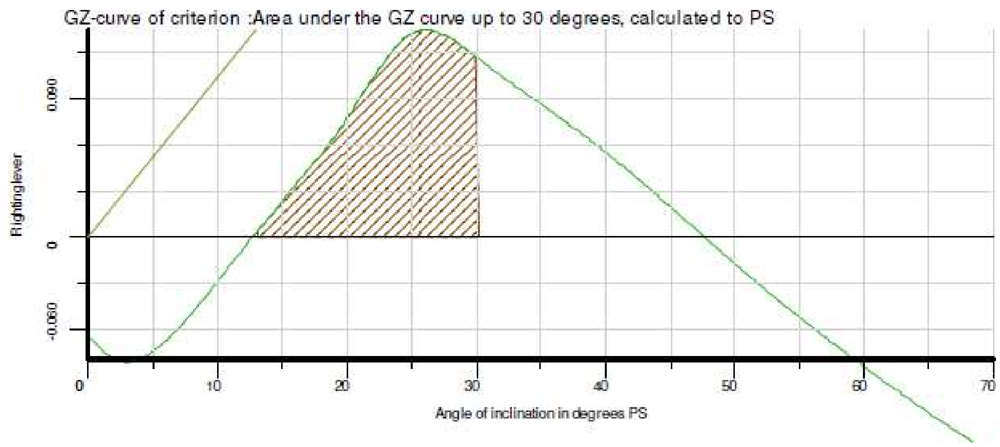
Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.598	meter
Maximum GZ at 30 degrees or more	0.240	0.117	meter
Top of the GZ curve at least at	25.000	26.087	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.025	mrad
Area under the GZ curve up to 40 degrees	0.108	0.041	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.015	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	70.000	degrees PS
---------- Additional information			
Range of positive stability	0.000	34.916	degrees
Angle of vanishing stability	0.000	47.614	degrees PS
Roll Period acc Irish authorities	0.000	5.433	sec
Roll Period acc IS 2008	1.000	6.567	sec

Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.598	meter
Maximum GZ at 30 degrees or more	0.240	0.225	meter
Top of the GZ curve at least at	25.000	25.694	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.078	mrad
Area under the GZ curve up to 40 degrees	0.108	0.110	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.032	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	15.348	degrees SB
---------- Additional information			
Range of positive stability	0.000	69.018	degrees
Angle of vanishing stability	0.000	56.319	degrees SB
Roll Period acc Irish authorities	0.000	5.433	sec
Roll Period acc IS 2008	1.000	6.567	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



Condition : Fase 2, PS derrick at 35 degrees, 5 m3 water on deck

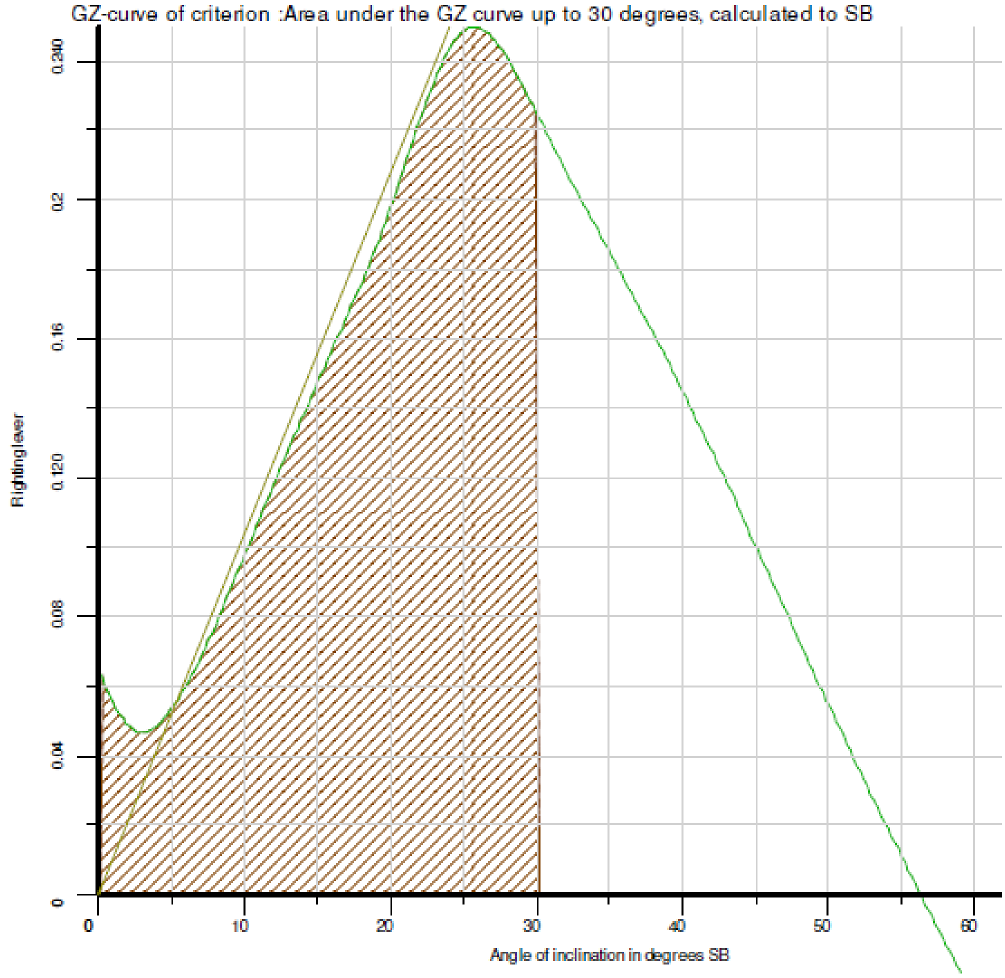


Figure 19 - Step 2 , derrick 35°, 5m³ water

Assumed amount of water on deck: 10m³

PS derrick at 20 degrees:

Stability values were 1/3 to1/2 of the required values for different loading conditions in Service regulation 15. The static angle of inclination with 10m³ water on deck was 14,5 degrees. There was a positive range of stability of 36 degrees.

The vessel should not have capsized, but the stability decreased significantly.

Condition : Fase 3, PS derrick at 20 degrees, 10 m3 water on deck

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.370	m
Trim	-0.438	m
Statical angle of inclination	16.48	degrees PS
Statical angle of inclination	9.36	degrees SB
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.512	meter
Maximum GZ at 30 degrees or more	0.240	0.136	meter
Top of the GZ curve at least at	25.000	30.524	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.018	mrad
Area under the GZ curve up to 40 degrees	0.108	0.037	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.019	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	70.000	degrees PS
--------- Additional information			
Range of positive stability	0.000	31.987	degrees
Angle of vanishing stability	0.000	48.463	degrees PS
Roll Period acc Irish authorities	0.000	5.867	sec
Roll Period acc IS 2008	1.000	7.078	sec

Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.512	meter
Maximum GZ at 30 degrees or more	0.240	0.191	meter
Top of the GZ curve at least at	25.000	30.225	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.036	mrad
Area under the GZ curve up to 40 degrees	0.108	0.064	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.028	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	24.198	degrees SB
--------- Additional information			
Range of positive stability	0.000	43.847	degrees
Angle of vanishing stability	0.000	53.208	degrees SB
Roll Period acc Irish authorities	0.000	5.867	sec
Roll Period acc IS 2008	1.000	7.078	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.

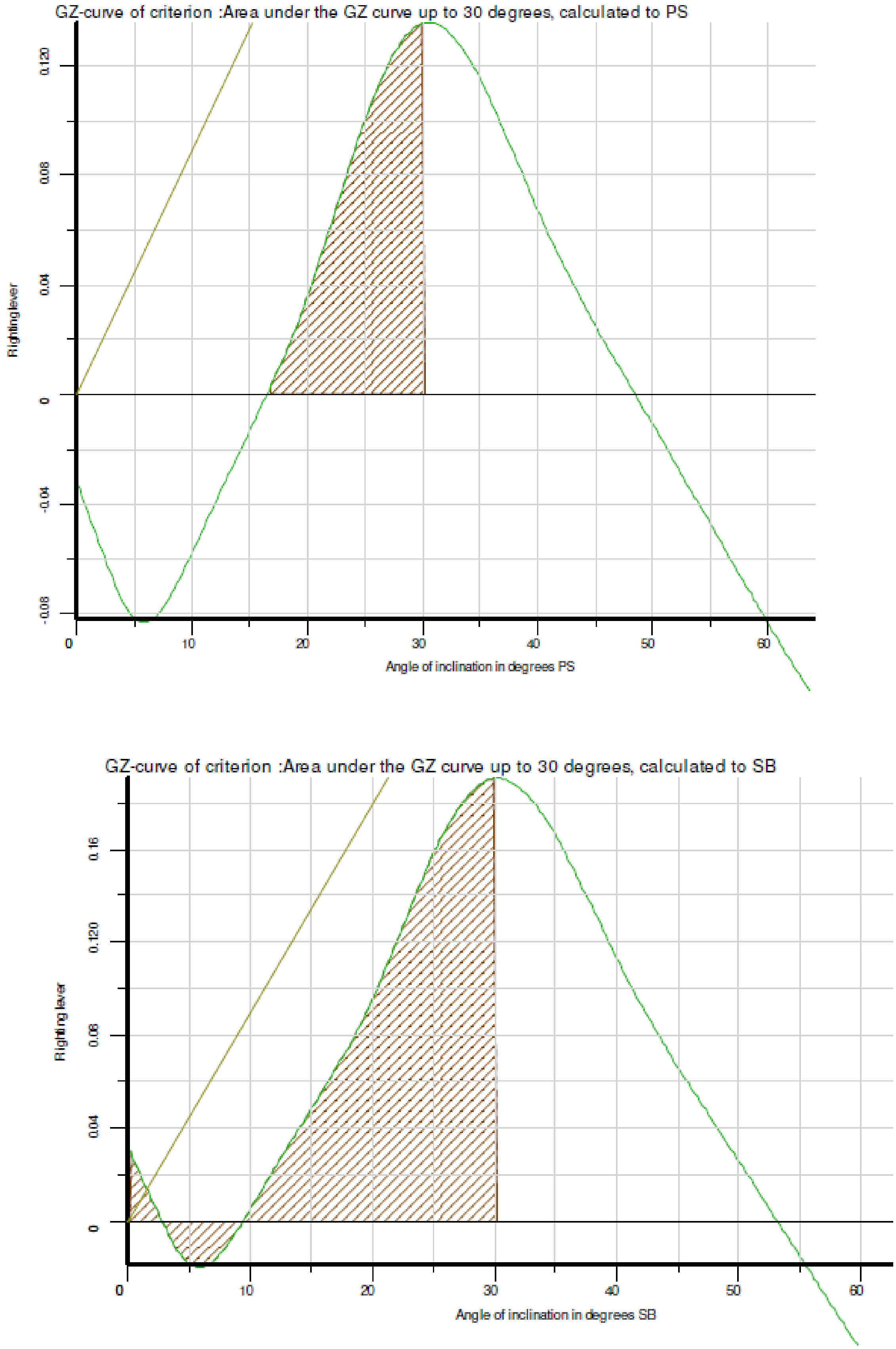


Figure 20 – Step 3, derrick 20°, 10m³ water

PS derrick at 35 degrees:

Stability values were about 1/3 to 1/2 of the required values for different loading conditions in Service regulation 15. The static angle of inclination with 10m³ water on deck was almost 17 degrees. There was a positive range of stability of almost 38.5 degrees.

The vessel should not have capsized, but the stability decreased significantly. The static angle of inclination of 17 degrees was in accordance with the reported portside of the deck disappearing under water. At that moment, the top of the bulwark was at water level.

Condition : Fase 3, PS derrick at 35 degrees, 10 m3 water on deck

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.370	m
Trim	-0.438	m
Statical angle of inclination	18.93	degrees PS
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.632	meter
Maximum GZ at 30 degrees or more	0.240	0.118	meter
Top of the GZ curve at least at	25.000	30.757	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.013	mrad
Area under the GZ curve up to 40 degrees	0.108	0.030	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.017	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	70.000	degrees PS
--------- Additional information			
Range of positive stability	0.000	28.400	degrees
Angle of vanishing stability	0.000	47.330	degrees PS
Roll Period acc Irish authorities	0.000	5.281	sec
Roll Period acc IS 2008	1.000	6.371	sec

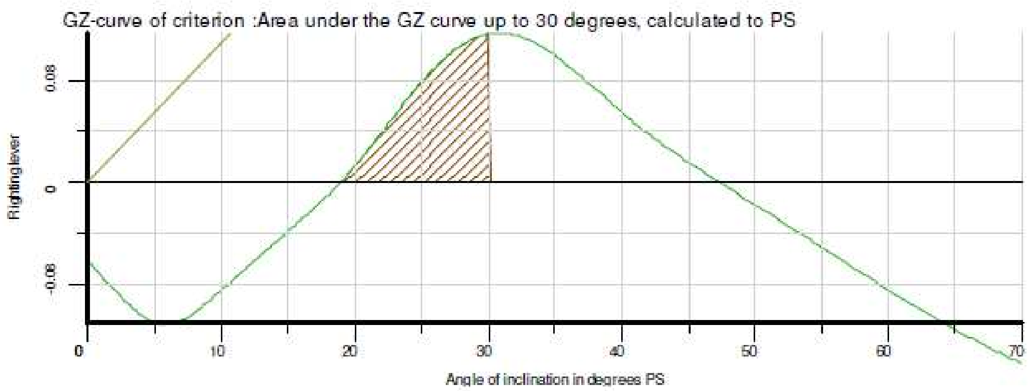
Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.632	meter
Maximum GZ at 30 degrees or more	0.240	0.225	meter
Top of the GZ curve at least at	25.000	30.166	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.052	mrad
Area under the GZ curve up to 40 degrees	0.108	0.086	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.034	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	21.502	degrees SB
--------- Additional information			
Range of positive stability	0.000	75.376	degrees
Angle of vanishing stability	0.000	56.447	degrees SB
Roll Period acc Irish authorities	0.000	5.281	sec
Roll Period acc IS 2008	1.000	6.371	sec

VCG'

A non-zero statical angle of equilibrium occurs,

No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



Condition : Fase 3, PS derrick at 35 degrees, 10 m3 water on deck

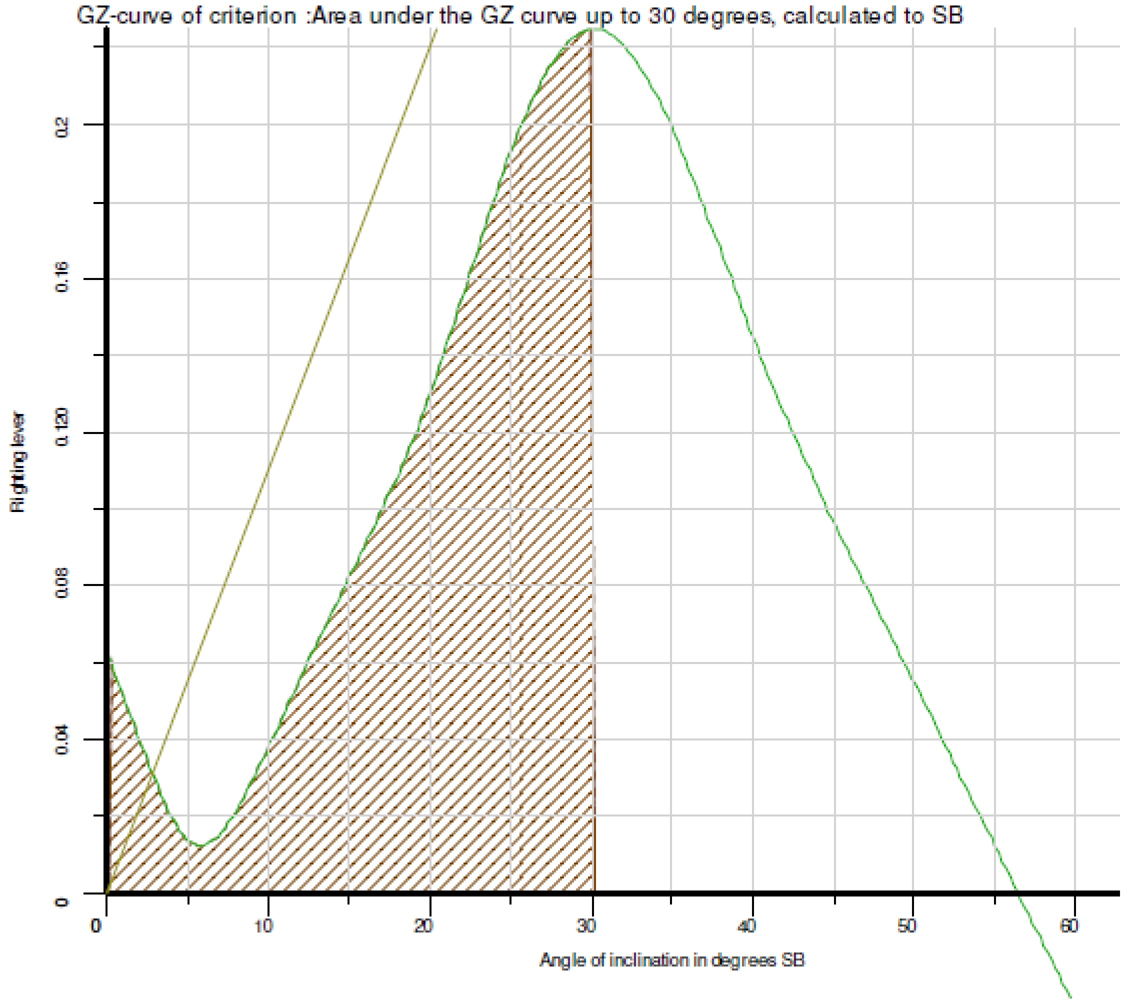


Figure 21 - Step 3, derrick 35°, 10m³ water

Assumed amount of water on deck: 15m³

PS derrick at 20 degrees:

Stability values have decreased to about 50% of the required values for different loading conditions in Service regulation 15. The static angle of inclination was 18 degrees. There was a positive range of stability of 32 degrees. The difference between 10 or 15m³ water on deck was not major because the water would have poored out/in at a certain angle. From that moment forward, the amount of water on deck was equal.

The vessel should not have capsized, but the stability decreased significantly.

Condition : Fase 4, PS derrick at 20 degrees, 15 m3 water on deck.

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.406	m
Trim	-0.541	m
Statical angle of inclination	18.93	degrees PS
Statical angle of inclination	14.06	degrees SB
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.933	meter
Maximum GZ at 30 degrees or more	0.240	0.131	meter
Top of the GZ curve at least at	25.000	30.460	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.015	mrad
Area under the GZ curve up to 40 degrees	0.108	0.034	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.018	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	70.000	degrees PS
--------- Additional information			
Range of positive stability	0.000	29.060	degrees
Angle of vanishing stability	0.000	47.990	degrees PS
Roll Period acc Irish authorities	0.000	4.349	sec
Roll Period acc IS 2008	1.000	5.235	sec

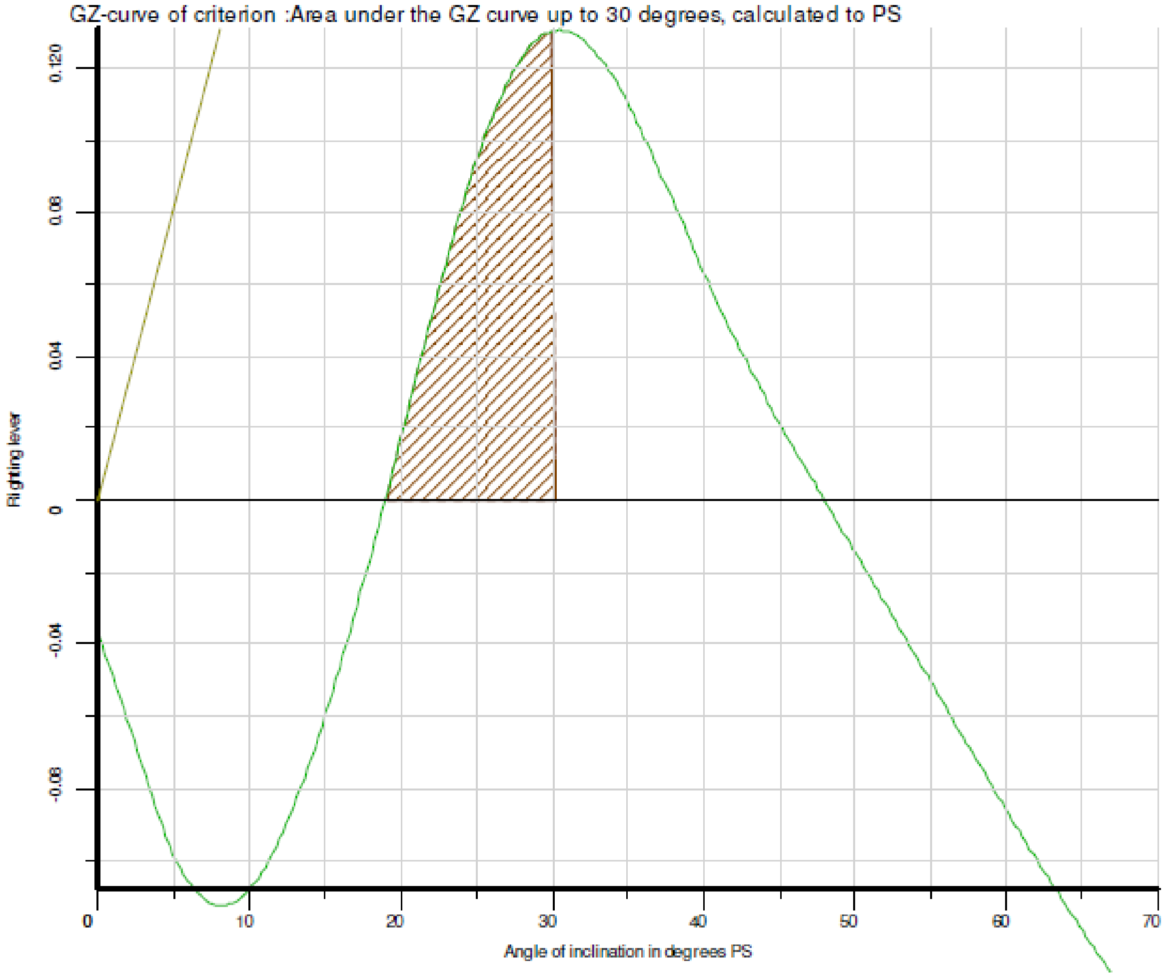
Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.933	meter
Maximum GZ at 30 degrees or more	0.240	0.196	meter
Top of the GZ curve at least at	25.000	30.101	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.032	mrad
Area under the GZ curve up to 40 degrees	0.108	0.061	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.029	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	23.699	degrees SB
--------- Additional information			
Range of positive stability	0.000	39.508	degrees
Angle of vanishing stability	0.000	53.567	degrees SB
Roll Period acc Irish authorities	0.000	4.349	sec
Roll Period acc IS 2008	1.000	5.235	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.

Condition : Fase 4, PS derrick at 20 degrees, 15 m3 water on deck.



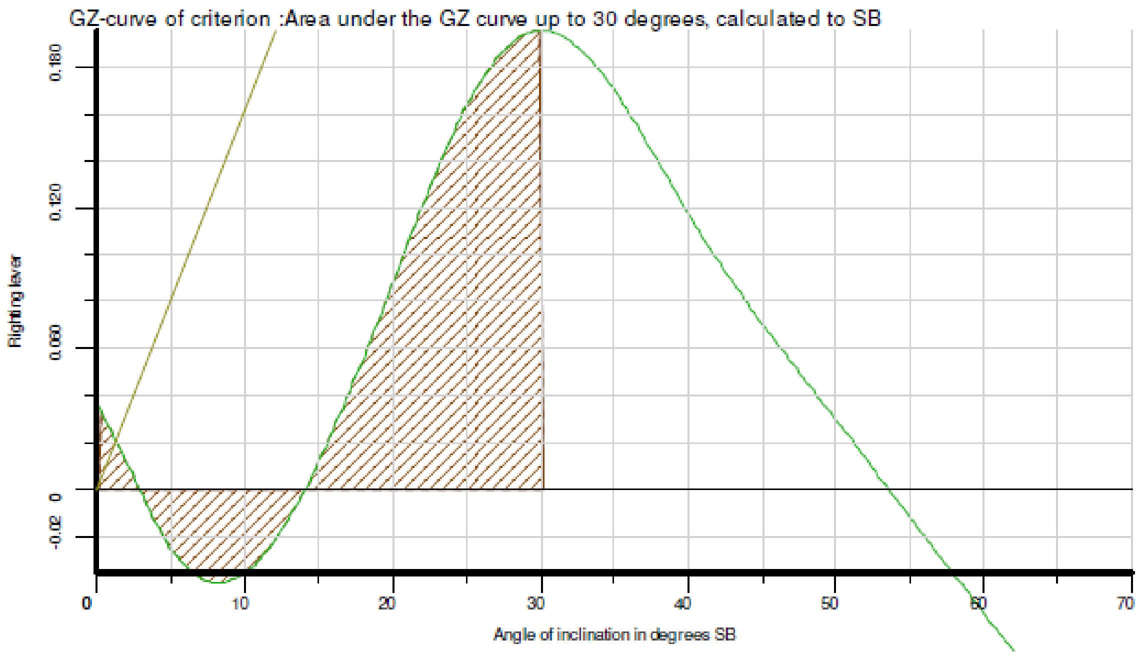


Figure 22 - Step 4, derrick 20°, 15m³ water

PS derrick at 35 degrees:

Stability values were about 1/3 of the required values for different loading conditions in Service regulation 15. The static angle of inclination was more than 19 degrees. There was a positive range of stability of only 30 degrees. Within this small positive range, the “amount” of stability was also much reduced, meaning that not a lot of energy remained to upright the vessel to its equilibrium at 19 degrees.

It was reported that water had entered the wheelhouse prior to capsizing. In calm water, water could have entered the wheelhouse at an angle of heel of approximately 58 degrees. Obviously the water was not calm and the steepness of the waves probably helped water entering the wheelhouse at a smaller angle.

Condition : Fase 4, PS derrick at 35 degrees, 15 m3 water on deck

Verification against the stability criteria "Dienstnorm 15"

Hydrostatics		
Draft mld.	2.406	m
Trim	-0.541	m
Statical angle of inclination	20.32	degrees PS
Statical angle of inclination	10.68	degrees SB
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
Minimum metacentric height G'M	0.500	0.977	meter
Maximum GZ at 30 degrees or more	0.240	0.113	meter
Top of the GZ curve at least at	25.000	30.700	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.012	mrad
Area under the GZ curve up to 40 degrees	0.108	0.027	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.016	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	70.000	degrees PS
--------- Additional information			
Range of positive stability	0.000	26.495	degrees
Angle of vanishing stability	0.000	46.814	degrees PS
Roll Period acc Irish authorities	0.000	4.249	sec
Roll Period acc IS 2008	1.000	5.115	sec

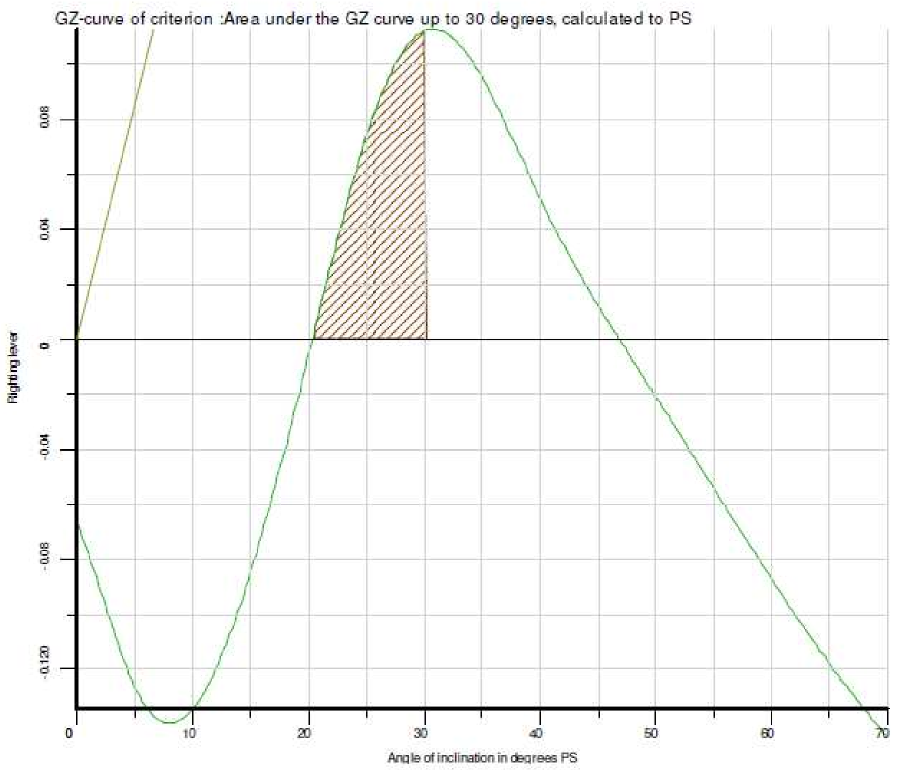
Calculated to SB	Criterion	Value	
Minimum metacentric height G'M	0.500	0.977	meter
Maximum GZ at 30 degrees or more	0.240	0.230	meter
Top of the GZ curve at least at	25.000	30.041	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.045	mrad
Area under the GZ curve up to 40 degrees	0.108	0.080	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.035	mrad
Maximum angle of inclination acc Dienstnorm 15	40.000	21.567	degrees SB
--------- Additional information			
Range of positive stability	0.000	46.083	degrees
Angle of vanishing stability	0.000	56.764	degrees SB
Roll Period acc Irish authorities	0.000	4.249	sec
Roll Period acc IS 2008	1.000	5.115	sec

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.

Condition : Fase 4, PS derrick at 35 degrees, 15 m3 water on deck



The (negative) area from 0 degrees to the static angle of equilibrium (20 degrees) is about the size of the positive (hatched) area from the static angle to the angle of vanishing stability. The area represents the "energy"of the vessel to get back to its equilibrium. This energy also causes the vessel to roll further than the static angle of equilibrium. Therefore the vessel does not calmly lay at its static angle of 20 degrees, but will roll further.
Apparently until the wheelhouse gets flooded and the vessels capsizes.

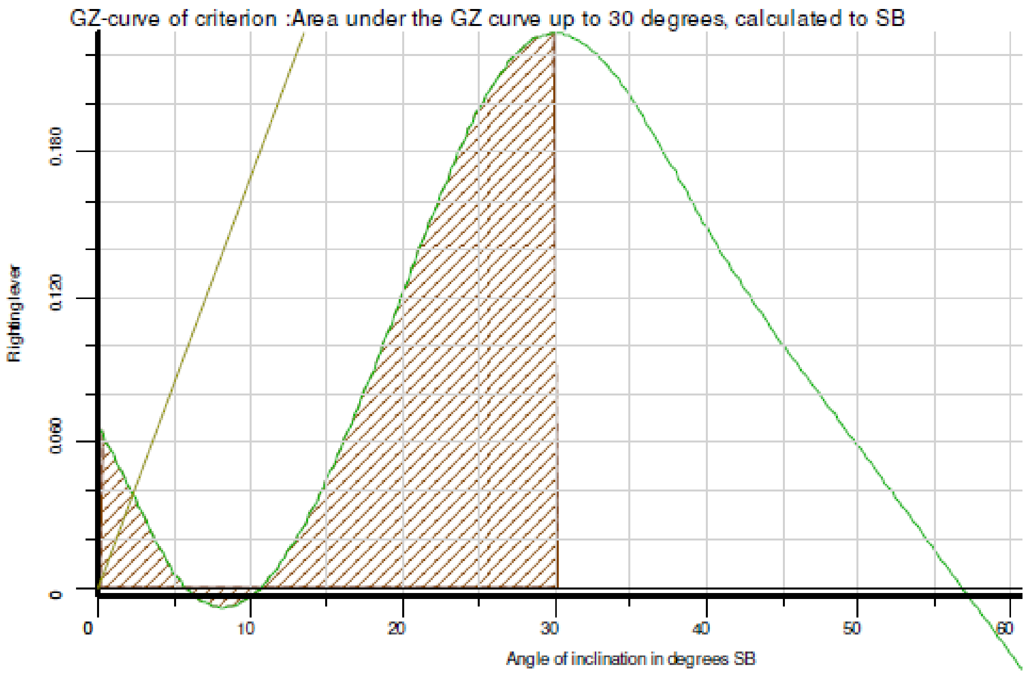


Figure 23 - Step 4, derrick 35°, 15m³ water

Wind

At the time of the accident, there was a strong south-south-westerly wind, 7 Beaufort. When this steady wind pressure (7 Bft is a wind pressure of 20kg/m2) was applied, there was a reduction of about 1/3th compared to the stability results without wind.

Figure 24 represents the condition into step 4, derricks at 35° and 15m³ of water on deck.

Condition : Fase 4, PS derrick at 35 degrees, 15 m3 water on deck

Verification against the stability criteria "Dienstnorm 15 icluding steady wind [7Bfrt]"

Hydrostatics		
Draft mld.	2.406	m
Trim	-0.541	m
Statical angle of inclination	20.32	degrees PS
Statical angle of inclination	10.68	degrees SB
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
--------Without wind			
Minimum metacentric height G'M	0.500	0.977	meter
Maximum GZ at 30 degrees or more	0.240	0.113	meter
Top of the GZ curve at least at	25.000	30.700	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.012	mrad
Area under the GZ curve up to 40 degrees	0.108	0.027	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.016	mrad
---------With wind [7Bfrt]			
Maximum GZ at 30 degrees or more	0.240	0.083	meter
Top of the GZ curve at least at	25.000	30.700	degrees PS
Area under the GZ curve up to 30 degrees	0.066	0.007	mrad
Area under the GZ curve up to 40 degrees	0.108	0.018	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.011	mrad
--------- Additional information			
Range of positive stability	0.000	20.450	degrees
Angle of vanishing stability	0.000	42.553	degrees PS
Roll Period acc Irish authorities	0.000	4.249	sec
Roll Period acc IS 2008	1.000	5.115	sec

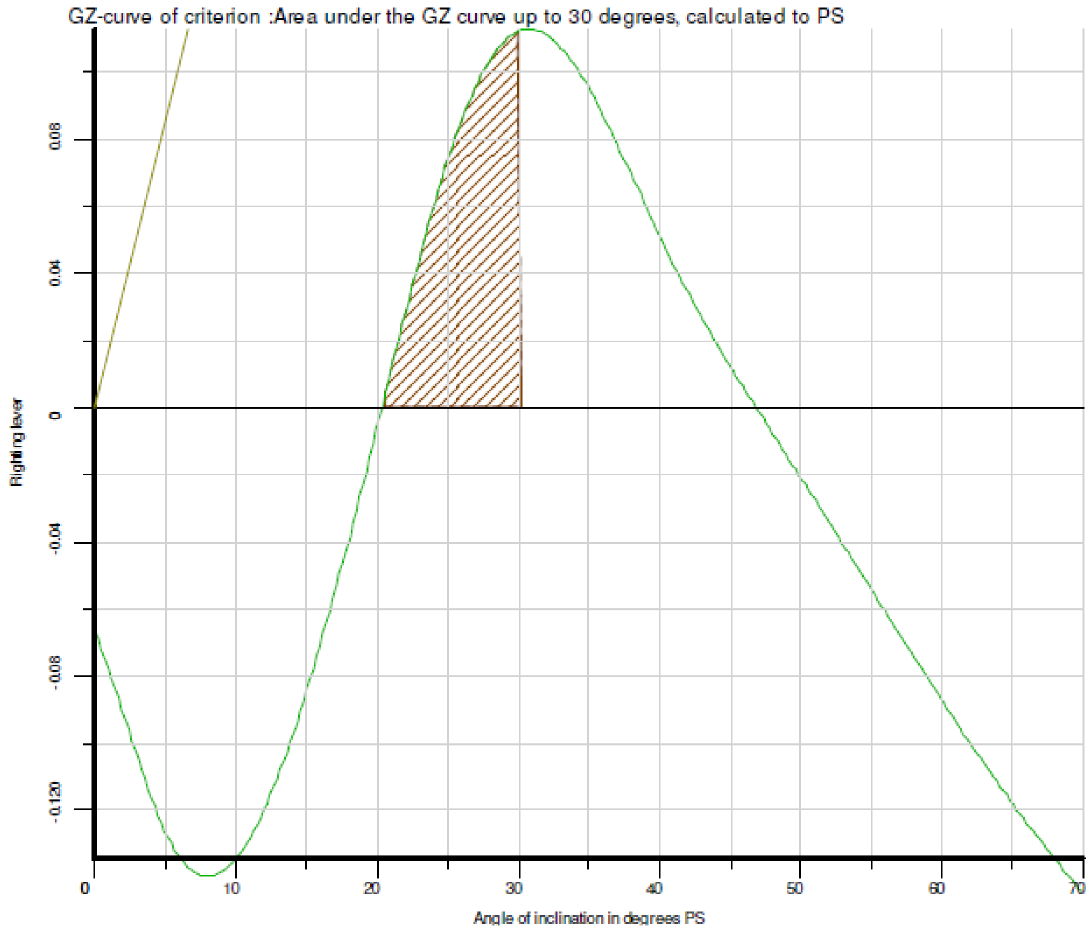
Calculated to SB	Criterion	Value	
--------Without wind			
Minimum metacentric height G'M	0.500	0.977	meter
Maximum GZ at 30 degrees or more	0.240	0.230	meter
Top of the GZ curve at least at	25.000	30.041	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.045	mrad
Area under the GZ curve up to 40 degrees	0.108	0.080	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.035	mrad
---------With wind [7Bfrt]			
Maximum GZ at 30 degrees or more	0.240	0.200	meter
Top of the GZ curve at least at	25.000	30.041	degrees SB
Area under the GZ curve up to 30 degrees	0.066	0.034	mrad
Area under the GZ curve up to 40 degrees	0.108	0.063	mrad
Area under the GZ curve between 30 and 40 degrees	0.036	0.029	mrad
--------- Additional information			
Range of positive stability	0.000	39.407	degrees
Angle of vanishing stability	0.000	53.264	degrees SB
Roll Period acc Irish authorities	0.000	4.249	sec
Roll Period acc IS 2008	1.000	5.115	sec

VCG'

A non-zero statical angle of equilibrium occurs,

No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.



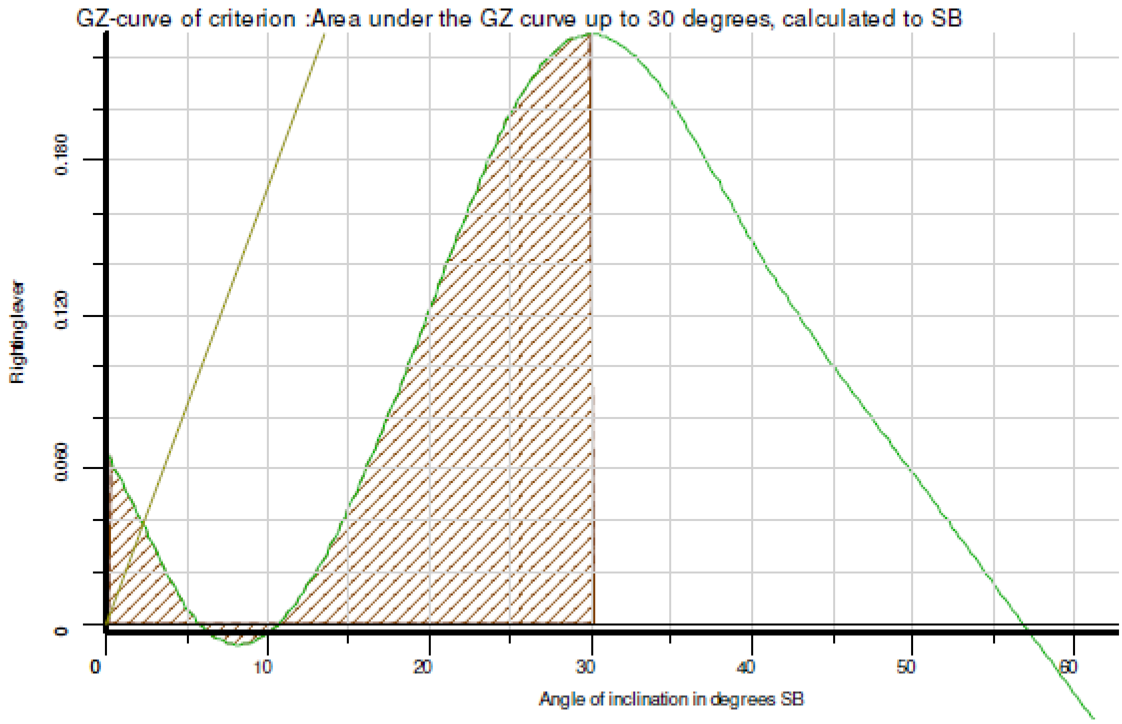


Figure 24 - Step 4, derrick 35°, with wind

Waves

Meteo station Greenwich Lightship, located at 25 nm, SW from the place of the incident, had measured waves with a height of 2,13m coming from SSW direction.
This height was the significant wave height:

- measured from top to trough,
- the mean wave height of the 33% highest waves,
- 14 % of the waves was higher,
- 3 times in 24 hours, there is a wave with a height of 4,26m.

The heading of fv O.13 - MORGENSTER was 120°. Beam waves were coming in on SB, as shown in Figure 25.

Figure 25 - Beam waves

It was not possible to determine the effect of beam waves as there was no calculation model available for beam waves.

The results of an experimental study[1] on the capsizing resistance in beam or following steep or high waves of scale models (of vessels < Lbpp 24m) in the towing tank of University of Trieste showed that capsizing due to the impact of beam waves is not very likely without any water on deck.

[1] Francescutto, A., Bulian, G., Urcia Larios, M., & Arroyo Ulloa, M. (1). Stability and dynamical effects of water on deck on the survivability of small fishing vessels. Ciencia Y tecnología De Buques, 3(5), 73-82. Retrieved from https://shipjournal.co/index.php/sst/article/view/31

The study also stressed that :

- A loaded vessel is safer than one in ballast (with corresponding GZ curves);
- The area below the GZ curve is important
- Capsizing is unlikely when the angle of vanishing stability is large (with reasonable GZ values and displacement)
- Scale models with positive GZ values extending beyond 90 degrees never capsized in waves up to 10m

In contradiction to the above, fv O.13 - MORGENSTER (Lbpp =21.14m)

- Was not fully laden (fuel oil tanks filled about 45%, fish hold filled 23%) and water was present on deck, all subject to the motion of beam waves;
- Had a reduced area below the GZ curve due to the position of the derricks, the impact of water on deck and due to wind;
- Had an angle of vanishing stability not higher than 51 degrees

The interference of the sternwave of m/v ARKLOW BREEZE with sea waves traveling in opposite directions could not be calculated. Neither was it possible to determine the impact of this combined wave to fv O.13 – MORGENSTER at a distance of 0.15nm in moderate seas.

Although there is a difference between the impact of quartering waves, following waves and beam waves, a simulation for the effect of longitudinal waves was made as represented in Figure 27.

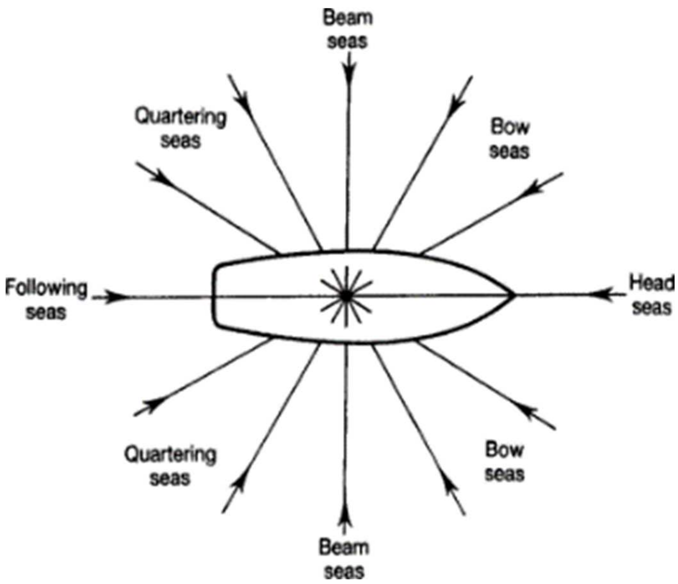


Figure 26 - Definition of seas (waves) according to direction of approach

Source : sciencedirect.com

The effect of longitudinal waves on the stability of a vessel is related to the position of the vessel on the wave: on the top of the wave, in a trough or somewhere in between.

Figure 27 does not represent the waves nor the stability values during the accident. It does however show the differences in stability that can occur between still water and being in a wave trough, top or in between..

In this example a wave amplitude of 1 m (this means a wave height of 2m) has been used and the wave length is twice the vessels length.

Loading condition Fase 4, PS derrick at 35 degrees, 15 m3 water on deck, cargo liquid

Verification against the stability criteria "Stability in waves"

Hydrostatics

Draft mld.	2.406	m
Trim	-0.541	m
Statical angle of inclination	20.32	degrees PS
Statical angle of inclination	10.68	degrees SB
Flooding angle PS	>70.00	degrees
Flooding angle SB	>70.00	degrees

Calculated to PS	Criterion	Value	
-------- Vessel in still water			
Minimum metacentric height G'M	0.150	0.977	meter
Maximum GZ at 30 degrees or more	0.200	0.113	meter
Top of the GZ curve at least at	25.000	30.701	degrees PS
Area under the GZ curve up to 30 degrees	0.055	0.012	mrad
Area under the GZ curve up to 40 degrees	0.090	0.027	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.016	mrad
-------- Vessel at wave top (1 m)			
Maximum GZ at 30 degrees or more	0.200	0.027	meter
Top of the GZ curve at least at	25.000	26.513	degrees PS
Area under the GZ curve up to 30 degrees	0.055	0.005	mrad
Area under the GZ curve up to 40 degrees	0.090	0.005	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.001	mrad
-------- Vessel in between wave top and trough			
Maximum GZ at 30 degrees or more	0.200	0.102	meter
Top of the GZ curve at least at	25.000	27.898	degrees PS
Area under the GZ curve up to 30 degrees	0.055	0.015	mrad
Area under the GZ curve up to 40 degrees	0.090	0.027	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.012	mrad
-------- Vessel in wave trough			
Maximum GZ at 30 degrees or more	0.200	0.176	meter
Top of the GZ curve at least at	25.000	29.125	degrees PS
Area under the GZ curve up to 30 degrees	0.055	0.026	mrad
Area under the GZ curve up to 40 degrees	0.090	0.052	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.026	mrad

Calculated to SB	Criterion	Value	
-------- Vessel in still water			
Minimum metacentric height G'M	0.150	0.977	meter
Maximum GZ at 30 degrees or more	0.200	0.230	meter
Top of the GZ curve at least at	25.000	30.041	degrees SB
Area under the GZ curve up to 30 degrees	0.055	0.045	mrad
Area under the GZ curve up to 40 degrees	0.090	0.080	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.035	mrad
-------- Vessel at wave top (1 m)			
Maximum GZ at 30 degrees or more	0.200	0.145	meter
Top of the GZ curve at least at	25.000	26.018	degrees SB
Area under the GZ curve up to 30 degrees	0.055	0.046	mrad
Area under the GZ curve up to 40 degrees	0.090	0.063	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.017	mrad
-------- Vessel in between wave top and trough			
Maximum GZ at 30 degrees or more	0.200	0.219	meter
Top of the GZ curve at least at	25.000	27.302	degrees SB
Area under the GZ curve up to 30 degrees	0.055	0.058	mrad
Area under the GZ curve up to 40 degrees	0.090	0.089	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.031	mrad
-------- Vessel in wave trough			
Maximum GZ at 30 degrees or more	0.200	0.293	meter
Top of the GZ curve at least at	25.000	28.459	degrees SB
Area under the GZ curve up to 30 degrees	0.055	0.070	mrad
Area under the GZ curve up to 40 degrees	0.090	0.115	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.044	mrad

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.

Loading condition DOES NOT comply with the stated criteria.

Figure 27 - Stability in longitudinal waves

The stability of the vessel was strongly reduced when is the vessel was at a wave top. In this example with longitudinal waves there was almost no positive stability anymore. In this situation only small external forces (such as wind) are enough to let the vessel capsize.

Combination of factors

Starting with an initial static angle of heel, combined with the situation of water on deck and the motions caused by wind and waves, the vessel is very likely to capsize.

The combination of these factors is important, as the vessel should not capsize by one of the factors only.

Although it was not possible to determine the exact impact of each criterium separately, the influence of water on deck could be considered as the most important factor for the capsizing of fv O.13 - MORGENSTER.

4.1.2 Stability training for skippers and watchkeepers

Fishermen engaged in watchkeeping and skippers on board were trained in the principles of stability before they received the appropriate certificate.

Stability workshops for fisherman are organized in Belgium by PREVIS. PREVIS/ZVF/LIANTIS processed general stability information into safety instruction cards with topics such as fishing and sailing in heavy weather, working in heavy weather, risks for capsizing, the risks of heavy weights in nets,…. (a.o. Cards V431, V432 ,V433, V435, V440, V441,V442, V443, V456 available on http://www.previs.be/Vissers-Vissen-Veilig.php).

The available instruction cards, trainings and workshops helped the skipper/watchkeeper to understand the consequences of his/her acts on board.

Without the availability of ship specific stability information on board, the skipper would not be able to assess the stability of the vessel with respect to the position of the derricks or with respect to the amount of water on deck, and the impact of waves.

4.2 Life raft

As the wreck of the vessel was inaccessible after capsizing and sinking, only assumptions can be made about the reason why the life raft did not come afloat.

There was one life raft on board, situated on top of the wheelhouse.

Before capsizing, the SB derrick was brought into free fall condition. When the vessel capsized, the SB derrick turned over to PS. The SB net was attached to the clamps at SB.
The vessel rolled over to upside down over PS.
The SB net was probably covering (a part of) the wheelhouse when the vessel capsized.

If we assume that the automatic release system to free the life raft under water worked well, it reacted when under water. This meant that the release had only been activated when the vessel was already turned upside down.

Probably obstructed by SB net and/or stuck under the vessel, the life raft did not come afloat.

Figure 28 - Position of the life raft on board

5 Cause of the accident

The vessel capsized due to a decrease in stability caused by an accumulation of water on deck in combination with a limited initial stability due to the position of the derricks, together with the influence of wind and the motion of beam waves.

The state of the sea, the initial heeling of the vessel and the presence of beam waves contributed to the fact that water came on deck.

6 Conclusion

6.1 Safety Issues

There is no tool or table (or other information) available on board to assist the skipper in the assessment of the stability of the vessel with respect to manipulation of the derricks, wind and wave conditions. The calculated stability conditions in the stability booklet are too limited for practical use.

No limiting operational factors based on behaviour in waves or with water on deck were set.

Service regulation 15 states stability requirements for fishing vessels, based on the comparison of vessels that sailed in the sixties. The requirements for beam trawl fishing vessels were increased with 20% and were not reviewed, even when several beam trawlers capsized.

When beam trawlers position their derricks with empty nets (regardless of any additional force), stability decreases. In case of O.13-MORGENSTER (and for all beam trawlers with a small margin to the stability requirements) , the stability even decreased below the general required stability for fishing vessels.

Calculations determining safe stability criteria for beam trawlers taking into account dynamic forces at open seas were never made. Also the effect of water on deck has not been taken into account when establishing the current stability requirements.

Latest stability calculations and inclining test of fv O.13- MORGENSTER were executed in 1995 (after repowering) and were only required to be repeated when modifications to the vessel were made (for this type of vessel).

In 1997,a tonnage surveyor stated that the lightship increased with 1.258 tons, (after a second repowering). No inclination test had taken place in 1997.

Moreover, it could not be stated that the actual mass of the lightship still corresponded with the figures of 1995, taking into account additional masses on board such as layers of paint, additional equipment, tools, spare parts, different length and diameter of wires, … . Depending on the position of these masses on board, the stability can be influenced in a positive or a negative way.

Capsizing beam trawlers tend to turn upside down. Trawl gear can cover a part of the wheelhouse when derricks turn over from one side to the other.

This leads to obstructions of life raft preventing them to become free floating after capsizing when positioned on top of the wheelhouse, which was the case in many instances.

One of the crewmembers on deck was not wearing a lifejacket as his personal lifejacket got damaged during a previous fishing trip. As the risk to damages to inflatable lifejackets is high when using them for working on deck, spare capacity should be available on board.

6.2 Actions Taken

The Belgian Maritime Inspectorate aims to achieve several safety requirements for the fishery that might among others include:

- The installation of at least two EPIRB's on board
- The installation of at least two liferafts on board
- An inclining test at least every 10 years
- An inclining test within five years after publication of the decree for each existing fishing vessel flying the Belgian flag
- Every crewmember to refresh his basic safety training every five years
- Every crewmember to follow a training to guarantee the continuity of his professional competence every five years (including operational safety and stability)
- Stability data regarding operational conditions (as determined by the Belgian Maritime Inspectorate) to be approved by the Belgian Maritime Inspectorate
- The company to provide stability data on board to enable the skipper to assess the stability of the vessel (in different operational conditions) with ease and certainty, including special instructions regarding conditions that have an unfavourable influence to the stability of the vessel.

7 Recommendations

The Belgian Maritime Inspectorate is recommended to :

1. Integrate stability data regarding the influence of water on deck, the position of the derricks (including nets) and the influence of wind and waves in the required stability data for beam trawlers provided by the company.
   Operational limits should be set for those conditions where the stability is insufficient and this information should be available on board in such a format that is easily accessible and understandable for the crew.

2. Add detailed information to the report of the inclining test regarding the on board equipment, such as:

   - Length and diameter of the derricks
   - Length, type and weight of fishing gear
   - Length and diameter of wires
   - Complete fish processing installation (conveyor belts, containers for catch, machine for sorting,…)
   - Thickness of the wooden deck
   - Spare propeller (weight and position)
   - Spare anchor (weight and position)
   - Amount and weight of spare nets

8 Appendices

Appendix 1 - Service Regulation 15 Stability of fishing vessels

(Article 13 of the Maritime Inspection Regulations).

1. Before a fishing vessel is put into service, the following data must be submitted in duplicate:

a) A calculation report of the inclining test and the calculation of the ship's mass and of the location of the centre of gravity above keel (KG), in both cases for the lightweight ready for service.

If the loading conditions that occur during operations are subject to considerable trim differences, the location of the longitudinal centre of gravity must also be calculated for the lightweight ready for service.

For fishing vessels equipped for bottom trawl fishing, the location of the centre of gravity above keel can be calculated with the booms at an angle of no less than 45° to the horizontal plane.

b) A plan of the longitudinal section of the ship, showing the various hold and tank capacities, as well as the location of the corresponding centres of gravity above keel, and, if necessary, the longitudinal centres of gravity.

In addition, this plan must show, in tabular form, the largest transverse moment of inertia of the liquid surface of each tank individually.

c) The carène diagram in tabular form including the frame surfaces (Bonjean curves) and the frame moments.
The data for the carène diagram must be calculated by means of a computer programme.
For the calculation of the carène diagram in tabular form, the line described under Appendix A must be taken as the base line.

d) The transverse curves of the static stability (KN sin φ) in tabular form for angles of heel of 2°, 5°, 10°, 20°, 30°, 40°, 50°, and 60° and for draught variations of 1 cm.
The transverse curves must be calculated by means of a computer programme.
For further data concerning the calculation of the transverse curves, see Appendix A.

e) The line plan used to determine the input data for the computer calculations and which must be certified by the computer centre for identification of the output data of the computer centre.

The full input data as part of the output data in such a manner as to permit a check of the input data.

f) The calculation of the location of the centre of gravity above keel and if necessary the longitudinal centre of gravity, as well as the calculation of the initial metacentric height and of the curves of the righting levers for the following loading conditions of the ship:

(i) Departure from port with destination fishing grounds, fully equipped with full bunkers and freshwater tanks and with ice and/or salt in the fish hold.

(ii) Departure fishing grounds with a quantity of fuel oil and freshwater corresponding to 50 percent of the available capacity of the tanks, fish hold fully filled with a homogeneous cargo with a stowage weight of 0.55 t/m^3, as well as deck cargo with a mass of 4 percent of the displacement belonging to the loading condition referred to under (i).

For ships used for bottom trawl fishing, a quantity of cargo in the fish hold that is to be considered normal for this method of fishing can be included instead of the abovementioned cargo in the fish hold and on deck.

For ships equipped both for bottom trawl fishing and for another fishing method, and on which the entire bottom trawl gear remains on board permanently, the including of the deck cargo can be omitted.

iii) Return to harbour with a residue of fuel oil and freshwater corresponding to 10 percent of the available capacity of the tanks concerned and otherwise loaded as described in (ii).

(iv) Return to harbour with a residue of fuel oil and freshwater corresponding to 10 percent of the available capacity of the tanks concerned, in the fish hold, a cargo equal to 20 percent of the cargo in the fish hold as referred to in (ii).

For ships equipped with a machine for the preparation of ice it may be calculated that a larger residue of the amount of freshwater required for the preparation of the ice will remain on board.

(v) Any other loading condition which occurs frequently and which produces considerably less favourable results than the loading conditions mentioned under (i) to (iv).

When calculating the loading conditions mentioned under (ii) to (v), the influence of free liquid surfaces in the tanks must be included (see Appendix B).

If the fishing is to be carried out in an area where the formation of ice is to be expected, the calculation of the loading conditions referred to under (i) to (v) must include the formation of ice (See Appendix C).

The influence of the wind on the vessel must be included for the loading condition that is least favourable from the point of view of windsail (See Appendix D)

g) For ships equipped for several fishing methods that will lead to different loading conditions, the loading conditions for each of these fishing methods must be submitted separately.

2. a) In each of the loading conditions mentioned in paragraph 1 under f) the following criteria must be met:

(i) The righting lever must be no less than 0.20 metres at an angle of heel of 30° or more.

(ii) The maximum value of the righting levers must preferably be reached at an angle of heel of at least 30°, but under no circumstances at an angle of heel of less than 25°.

(iii) At an angle of heel of 30°, the area under the GZ curve must not be less than 0.055 metre-radians, and not less than 0.09 metre-radians at an angle of heel of 40° or at an angle of flooding (φ f) (1) if that angle be less than 40°.

(iv) The increase of an area under the GZ curve between an angle of heel of 30° and an angle of heel of 40°, or an angle of flooding (φ f), if this be less than 40°, must not be less than 0.03 metre-radians.

(v) Except for ships equipped for bottom trawl fishing, the initial metacentric height must be at least 0.35 metres. For ships equipped for bottom trawl fishing, the initial metacentric height must be at least 0.50 metres.

(vi) If the ship is equipped for bottom trawl fishing, the righting levers mentioned under (i} and the areas under the GZ curve mentioned under (iii) and (iv), must be augmented by 20 percent.

(vii) the criteria mentioned under (i), (iii) and (iv) are only valid for ships used for bottom trawl fishing if the engine power established by the District Head of the Maritime Navigation Inspectorate and expressed in axial horsepower, is no larger than L^2 .

If the engine power is larger than L^2 the righting levers and the areas under the GZ curve must be augmented in proportion to the larger engine power.

“The length (L)” is equal to 96 percent of the total length on a water line at 85 percent of the least moulded depth measured from the top of the keel, or from the intersection of the top of the garboard strake with the bar keel if the ship has a bar keel, or equal to the length from the foreside of the stem to the axis of the rudder stock if this last length be greater.

If the ship was designed with a rake of keel, the load water line on which this line is measured must be parallel to the construction water line.

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(1) The angle of flooding (φ f) shall mean: the angle of heel at which the apertures in the hull, superstructure or deckhouses that cannot be closed watertight, are flooded. In applying this criterion, small apertures that, in the judgement of the District Head of the Maritime Navigation Inspectorate, do not allow water flowing in to penetrate further into the ship, need not be regarded as open.

2. b) The loading condition that is least favourable from the point of view of windsail must, moreover, meet the following criterion: the angle of heel that occurs as a result of the wind moment (φc) may not be more than 40° or the angle of flooding (φf) if this be less than 40°. For details concerning the calculation of the wind moment, see Appendix D.

3. Before the keel of a fishing vessel is laid, the following data must already have been submitted in duplicate:

a) the data mentioned under 1b, c and e .

b) the maximum permissible KG according to the criteria mentioned under 2 and this in the range empty ship – fully loaded ship for draught variations of 5 cm.

4. If a fishing method is used which in the judgement of the District Head of Maritime Navigation Inspections entails an increased risk with regard to stability, he is entitled to establish alternative stability criteria.

The District Head of the Maritime Navigation Inspectorate Antwerp

The District Head of the Maritime Navigation Inspectorate Ostend

Service Regulation 15 - APPENDIX A

Calculation of the transverse curves of static stability

1. The base line for the calculation must be the line parallel to the designed water line, drawn through the intersection between the moulding side frame and the centre line of the ship at the location of 1/2 Lord; all this in accordance with the NEN 3085 norm.

2. If the trim conditions that occur during operations or the shape or arrangement of the ship are such that changes of trim have a noticeable impact on the righting levers, the influence of such changes of trim must be taken into account.

3. The possible presence of wooden deck coverings may be taken into account in the calculation.

4. In relation to superstructures, deckhouses etc. the following applies:

a) Closed superstructures that comply with the provisions under b of the tenth paragraph of Article 2 of Appendix I of the Royal Decree 20.7.73 may be included.

b) Closed superstructures under the second deck above the freeboard deck that comply with the provisions under a) of the current paragraph may also be included.

c) Deckhouses on the freeboard deck may be included if they comply with the provisions under a) of the current paragraph for closed superstructures.

d) (i) If deckhouses on the freeboard deck comply with the provisions under a) of the current paragraph, with the exception of the prescribed extra exit to a higher deck, these deckhouses may not be included; however, apertures in the freeboard deck within these deckhouses may be considered to be closed, even if they are not equipped with any means of closing.

(ii) By way of derogation from the stipulations under (i) these deckhouses on small fishing vessels may be included, if the creating of the extra exit is of no practical use.

e) Deckhouses on the freeboard deck whose access routes do not have doors that comply with the provisions in Article 10 of Appendix I of the Royal Decree 20.7.73 may not be included;

apertures in the freeboard deck within these deckhouses are considered to be closed if they have adequate means of closing. With the provisions of the Articles 13, 14, 15 or 16 of the Appendix mentioned.

f) Deckhouses under the second or higher decks above the freeboard deck may not be included; however, apertures in the deck within these deckhouses may be considered to be closed.

g) Upper houses and deckhouses that do not comply with the provisions under a) of the current paragraph may be included up to the angle of heel at which the underside of the access apertures and such like becomes submerged (at this angle of heel the curve of the righting levers must show one or more leaps, while at larger angles of heel the flooded spaces are no longer considered to contribute to stability.

h) Small apertures, such as those intended for running mooring lines, anchor chains etc. through them, as well as scuppers and drainage and discharge pipes are not required to be considered to be open if they are submerged at an angle of heel of 30° or more.

If these apertures are flooded at an angle of heel of less than 30°, they must be considered to be open if they permit the entry of quantities of water that are significant in the judgement of the District Head of the Maritime Navigation Inspectorate.

i) Trunkways and hatchways may be included.
When submitting the data, those parts of the ship that have been included in the calculation of the transverse curves must be mentioned.

Influence of free liquid surfaces on stability.

1. In every loading condition of the ship, the initial metacentric height (GM) must be corrected for the influence of the free liquid surface in tanks that are not entirely full.
   All tanks that can simultaneously be "slack" in a certain loading condition must be included in this.

2. The apparent decrease of GM can be determined for each tank individually with the formula:

$$\frac{\gamma\, i}{\Delta} \text{ metre}$$

in which: γ = the specific mass of the liquid in the tank in t/m³

i = the transverse moment of inertia of the liquid surface in the tank in m^4

Δ = the displacement of the ship in the prevailing loading condition in metric tonnes.

3. The curve of the righting levers must be determined with due consideration to the apparently changed position of the height of the centre of gravity above keel (KG) as a result of the influence of the free liquid surfaces.

   In doing so, the value of KG must be increased with the calculated decrease of GM as stipulated under paragraph 2 of this Appendix.

4. If the influence of the free liquid surfaces on the stability at various angles of heel is considerable, the decrease of the righting levers at the various angles of heel can – by way of derogation from the provisions of paragraph 3 of this Appendix - be determined for each tank individually with the formula:

$$\frac{v\ b\ \gamma\ F^{1/2}}{\Delta} \text{ metre}$$

in which: v = the total content of the tank in m³.

b = the largest breadth of the tank in m.

γ = the specific mass of the liquid in the tank in t/m³

$F = \frac{v}{\text{ïbh}}$ = the coefficient of fullness of the tank: in which l, b and h are the largest length, the largest breadth and the largest height respectively of the tank

Δ = the displacement of the ship in the prevailing loading condition in tonnes of 1,000 kg; and

k = a dimensionless factor that can be determined for various angles of heel on the basis of the table belonging to this Appendix, depending on the b/h relationship of the tank; for intermediate values of b/h the factor is obtained through linear interpolation.

5. Other, equally effective methods to calculate the influence of free liquid surfaces on the righting levers are also acceptable.

6. The influence of the residual liquid normally remaining in empty tanks does not have to be included.

7. It must be clearly indicated in the calculated loading conditions which tanks have been calculated as being "slack".

TABLE FOR THE VALUES OF COEFFICIENT "K" FOR THE CALCULATION OF CORRECTIONS FOR FREE LIQUID SURFACES OF THE RIGHTING LEVERS.

$k = \frac{\sin\varphi}{12}\left(1 + \frac{\tan^2\varphi}{2}\right) \times b/h$

waar $\cot\varphi \geq b/h$

$k = \frac{\cos\varphi}{8}\left(1 + \frac{\tan\varphi}{b/h}\right) - \frac{\cos\varphi}{12(b/h)}\, 2 \left(1 + \frac{\cot^2\varphi}{2}\right)$

waar $\cot\varphi \leq b/h$

b/h \ φ	5°	10°	15°	20°	30°	40°	45°	50°	60°	70°	75°	80°	90°	b/h \ φ
20	0,11	0,12	0,12	0,12	0,11	0,10	0,09	0,09	0,07	0,05	0,04	0,03	0,01	20
10	0,07	0,11	0,12	0,12	0,11	0,10	0,09	0,09	0,07	0,05	0,04	0,03	0,01	10
5	0,04	0,07	0,10	0,11	0,11	0,10	0,10	0,10	0,08	0,07	0,06	0,05	0,03	5
3	0,02	0,04	0,07	0,09	0,11	0,11	0,11	0,10	0,09	0,08	0,07	0,06	0,04	3
2	0,01	0,03	0,04	0,06	0,09	0,11	0,11	0,11	0,10	0,09	0,09	0,08	0,06	2
1,5	0,01	0,02	0,03	0,05	0,07	0,10	0,11	0,11	0,11	0,11	0,10	0,10	0,08	1,5
1	0,01	0,01	0,02	0,03	0,05	0,07	0,09	0,10	0,12	0,13	0,13	0,13	0,13	1
0,75	0,01	0,01	0,02	0,02	0,04	0,05	0,07	0,08	0,12	0,15	0,16	0,15	0,17	0,75
0,5	0,00	0,01	0,01	0,02	0,02	0,06	0,04	0,05	0,09	0,16	0,18	0,21	0,25	0,5
0,3	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,03	0,05	0,11	0,19	0,27	0,42	0,3
0,2	0,00	0,00	0,00	0,01	0,01	0,01	0,02	0,02	0,04	0,07	0,13	0,27	0,63	0,2
0,1	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,06	0,06	0,14	1,25	0,1

Service Regulation 15 - APPENDIX C

Ice formation

1. Areas where ice formation is to be expected:

a) The area north of the parallel 65°30 N, between the meridian of 28° and the west coast of Iceland north of the north coast of Iceland north of the loxodrome between 66°N-15°W and 73°30 N-15° E, north of the parallel 73°30 N between the meridians of 15°E and 35° and east of the meridian of 35° E , as well as north of the parallel 56° N in the Baltic Sea.

b) The area north of the parallel 43° N, bordered on the west by the coast of North America and on the east by the loxodrome between the positions of 43° N-48° W and 63° N-28° W and subsequently along the meridian of 28° W.

c) All sea areas north of the North American continent west of the areas described in (a) and (b)

d) The Bering Sea and the Sea of Okhotsk as well as the Strait of Tartary during the ice season.

e) South of the parallel 60° S.

The areas listed above have been indicated on the map included in this Appendix.

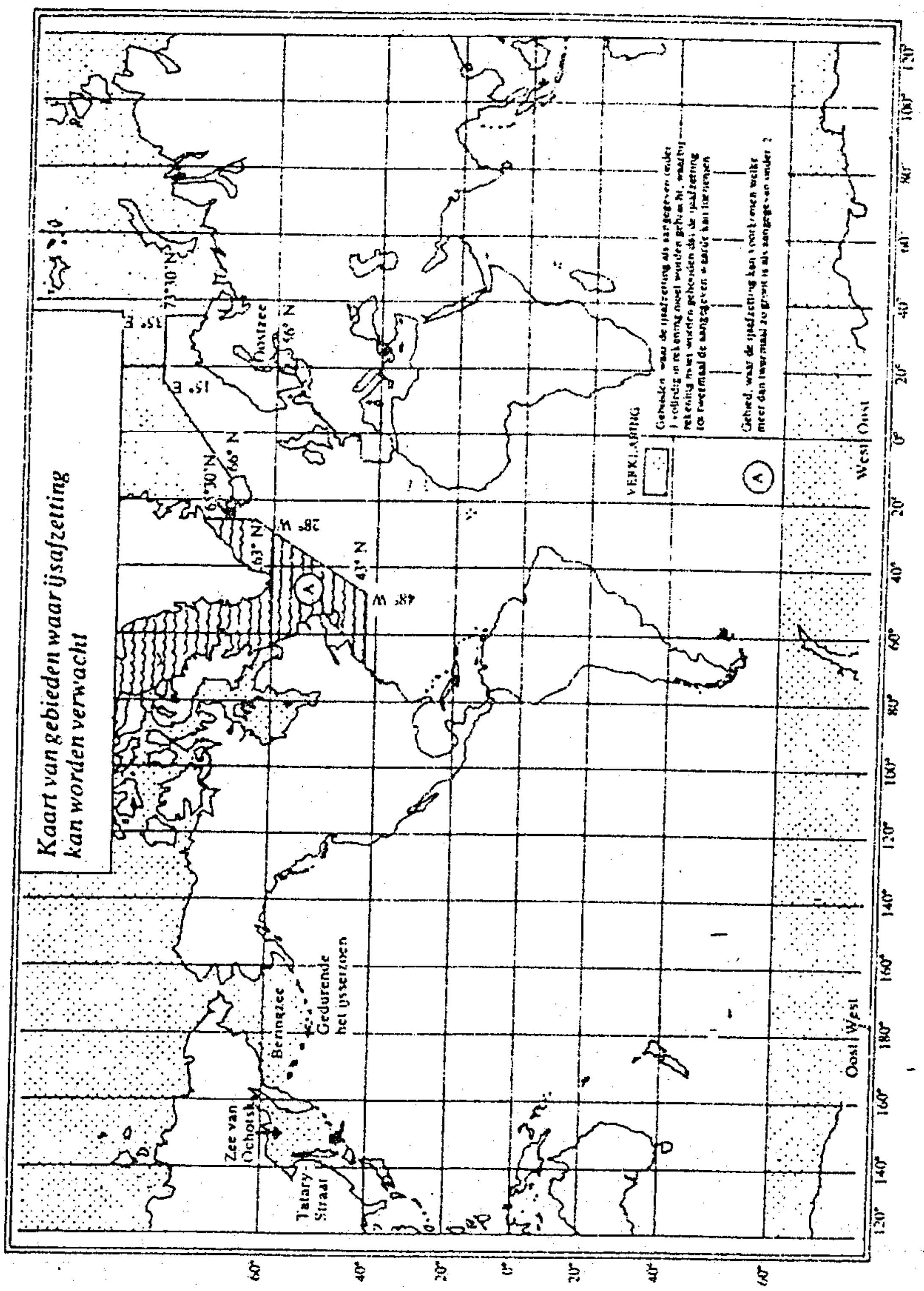
2. For fishing vessels that will be carrying out fishing in the areas listed under paragraph 1, the following ice formation must be included in the various loading conditions:

a) 30 kg per square metre for exposed decks;

b) 7.5 kg per square metre for projected lateral surface on each side of the ship above the water line;

c) the projected lateral surface of the railings, loading gear (with the exception of masts) and rigging and the projected lateral surface of other small parts must be included by increasing the total projected continuous area by 5 percent and the total static moment of this area by 10 percent.

3. Skippers of fishing vessels must nonetheless be aware that in certain parts of the areas listed in paragraph 1 larger ice formation can be expected, which can, in some parts of the areas listed under a, c, d and e, grow to twice the values mentioned in paragraph 2, and in the area mentioned under b) even more than twice the values mentioned in paragraph 2.


Kaart van gebieden waar ijsafzetting kan worden verwacht
Zee van Ochotsk
Tatary Straat
Beringzee
Gedurende het ijsseizoen
Oostzee
VERKLARING
West Oost
Oost West

Impact of the wind

In order to determine the impact of the wind on the ship, the calculation should be based on a gust of wind of long duration acting on the ship athwartships.

To this end the following must be calculated:

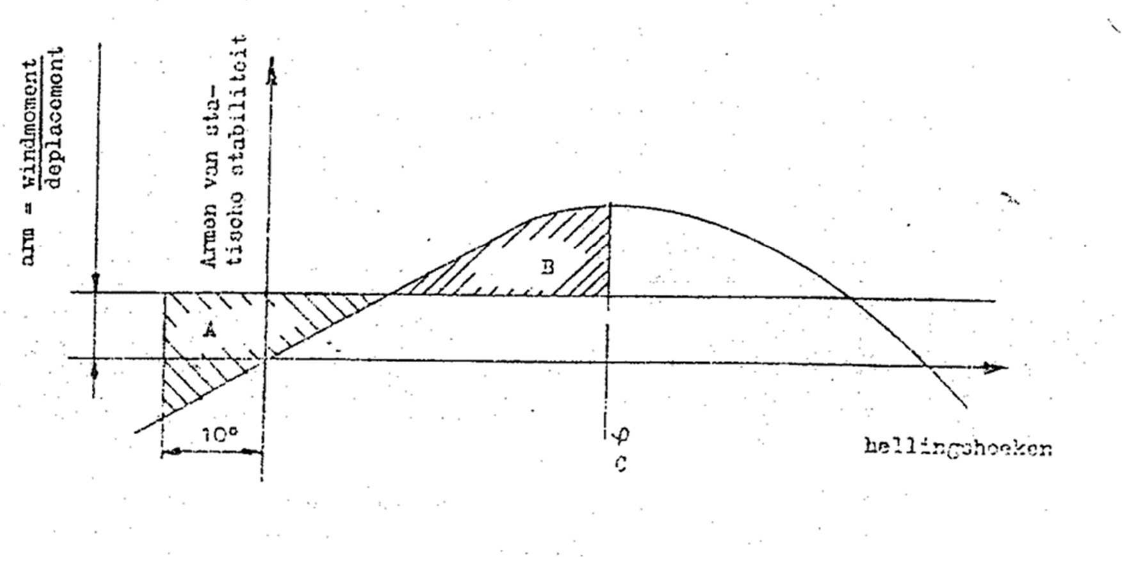
1. The lateral surface of the ship above the water line; i.e. the projected lateral surface of the hull, bulwark, superstructures, deckhouses, hatchways, masts and booms etc.;

2. The total wind pressure on the lateral surface of the ship, on the basis of a wind pressure of 75 kg/m² up to a height of 5 m above the load water line and of a wind pressure of 125 kg/m² above this height;

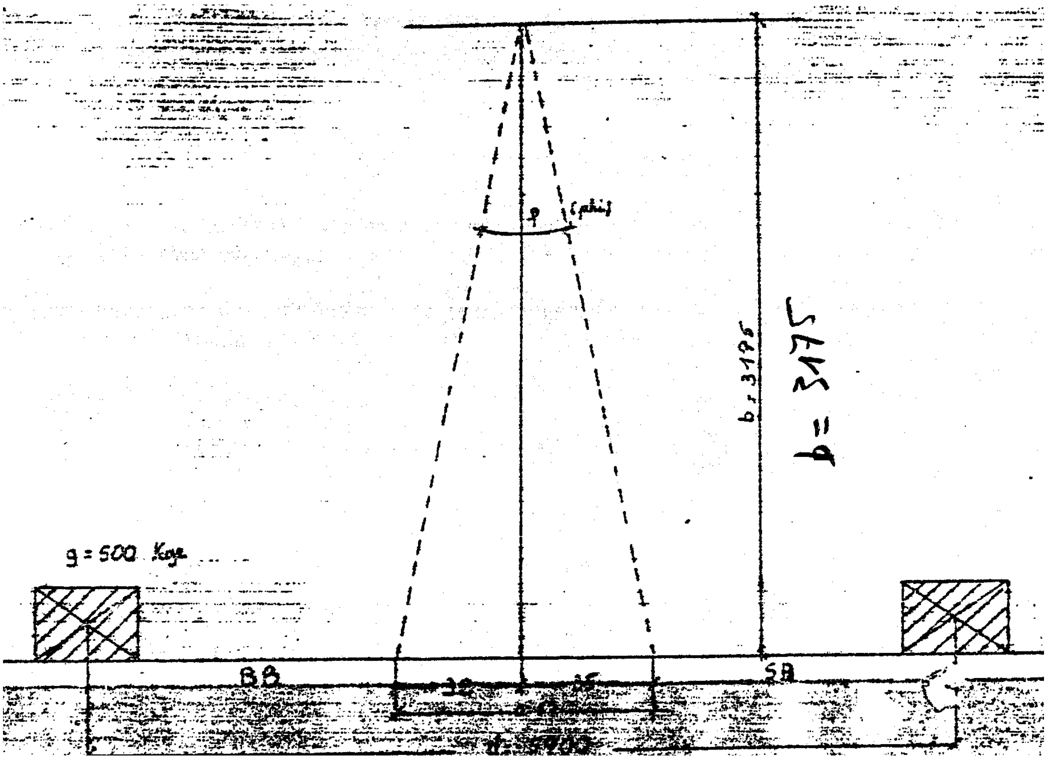
3. The wind moment, i.e. the moment of the total wind pressure calculated in relation to the centre of lateral resistance of the underwater hull;

4. The wind arm, i.e. the wind moment divided by the displacement; this wind arm must be kept equal for all angles of heel.

The calculation of the angle of heel (φ_c) caused by the wind moment should be based on a windward angle of heel of 10°; see the corresponding figure. Surface B indicated in this figure must be equal to surface A indicated.



INCLINING TEST AND PENDULUM TEST



Water displacement D = 226 m³ (obtained by calculation of the lines plan)

Heeling moment gd = 0.5 T x 5.7 m = 2.85 T/m

$$MG = \frac{gd}{D\ tg} = \frac{2.85}{226 \times 0.021} = 0.60$$

Pendulum test: example

Number of rolling periods per minute= 8.5

T = 60/8.5 = 7.05” per rolling period

If $t = \frac{0.8\ B}{MG}$ then MG is= $\frac{(0..8\ B)^2}{t^2} = \frac{(0.8 \times 6.25)^2}{7.05^2} = \frac{25}{49} = 0.51$

B = breadth of the vessel.

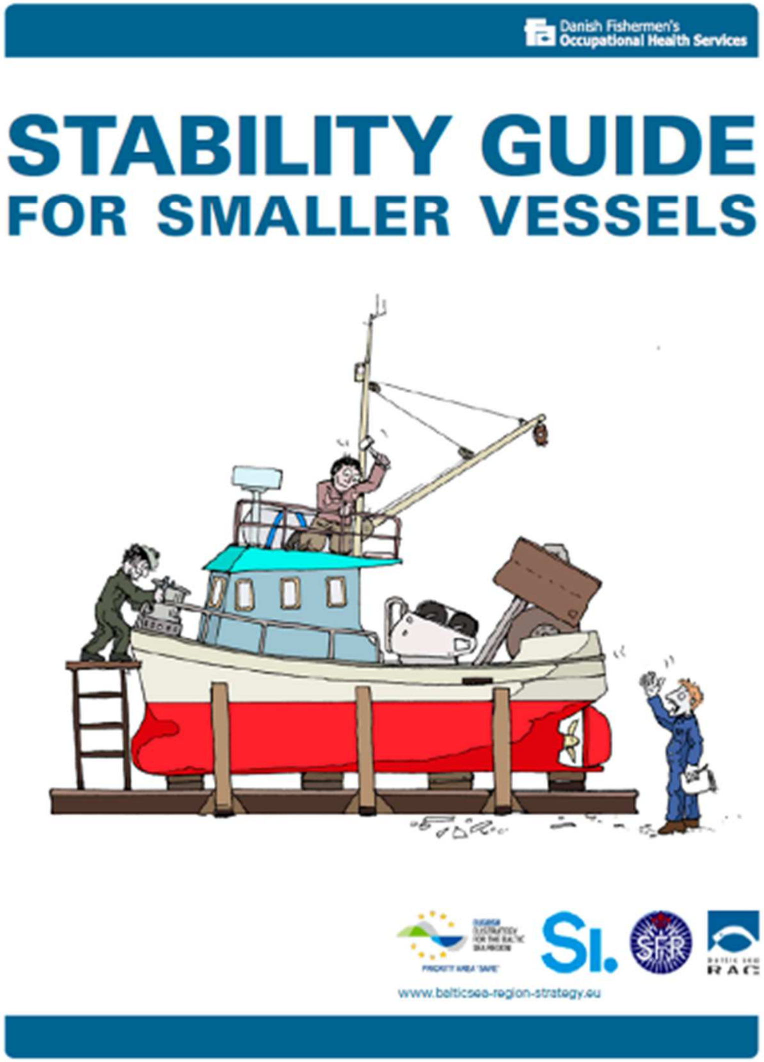
T = rolling period in seconds

Appendix 2 – Understanding the basics of ship stability

This appendix is a copy of the first pages of the Stability Guide for Smaller vessels, as issued by the Danish Fishermen Occupational Health Services.

The complete guide can be consulted at https://www.f-a.dk/english/publications.

Please be aware that the guide is written according Danish legislation.



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What is stability?

Stability is a measure of the vessel's ability to get back on an even keel after having suffered a heel.

Different factors affect a vessel's stability.

Basically it is the ratio between the centre of gravity and the distribution of a vessel's buoyancy that determines the vessel's ability to get back on an even keel.

Lightweight, deadweight and displacement

The vessel's own weight and the distribution of the weights on the vessel are essential for determining the vessel's stability.

The vessel's weight is composed as follows:

Lightweight

This is the weight of the unrigged vessel without gear, fuel oil, water, ice, boxes, crew, provisions, catch, etc.

Lightweight changes e.g. when the vessel is fitted with optional equipment, when switching engines, winches or other fixed components.

Deadweight

This is the term for all the weights the crew takes on board in order to fish or during fishing. Deadweight includes equipment, fuel oil, water, ice, boxes, crew, provisions, catch, etc.

Displacement

Displacement is the term for the vessel's total weight. That means displacement = lightweight + deadweight.

During fishing, the vessel's displacement changes constantly as a result of oil consumption and the weight of the fish caught.

A fishing vessel has a tonnage certificate that displays a certain tonnage.

This tonnage has **nothing** to do with the vessel's weight.

The tonnage on the tonnage certificate is an expression of the vessel's volume.

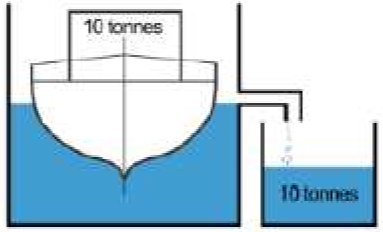
The tonnage has therefore nothing to do with the vessel's stability.

Buoyancy

A vessel floating on the water will displace an amount of water equal to the weight of the vessel (displacement).

This is illustrated by the figure to the right:

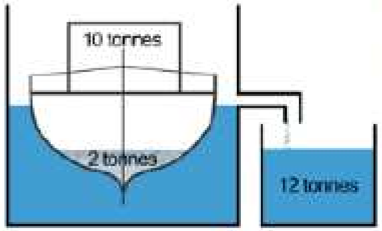
1. A large container filled with water up to an overflow.
2. A vessel with a weight of 10 tonnes is lowered into the tank.
3. Exactly 10 tonnes of water flow over the edge.



The experiment can be extended, for example by loading a vessel with 2 tonnes of fish, as illustrated in the figure to the left.

The vessel is thus 2 tonnes heavier and pushed deeper into the water.

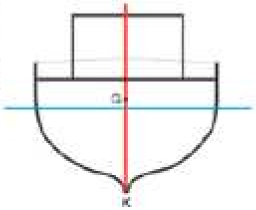
An additional 2 tonnes of water flow out of the big container, so that now the small container alongside it contains 12 tonnes of water, equal to the combined weight of the vessel and the fish.



Centre of gravity G

The centre of gravity is a rather theoretical concept. It is composed of all weights on board, including the vessel's own weight (lightweight).

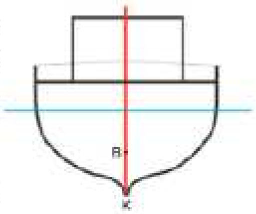
For example, if the total weight of the vessel (displacement), including deadweight such as gear, catch, etc. is 10 tonnes, all the small weights can be replaced by one total weight of 10 tonnes located in the centre of gravity. One can say that the centre of gravity is the average location of all the weights.



- For most fishing vessels, the centre of gravity is usually just above the waterline.
- Vessels may become unstable if the centre of gravity is positioned too high.
- Fish and gear on deck pull the centre of gravity up.
- Installation of new equipment on deck or in the wheelhouse pulls the centre of gravity up.
- Replacement of a heavy diesel engine with a lighter engine pulls the centre of gravity up.
- A high centre of gravity makes the vessel roll more slowly and can be a danger signal.

Centre of buoyancy B

All parts of the hull under the waterline contribute to the vessel's overall buoyancy. The total buoyancy can, just like the centre of gravity mentioned above, be merged in one single point called the centre of buoyancy and this is indicated by the letter B.

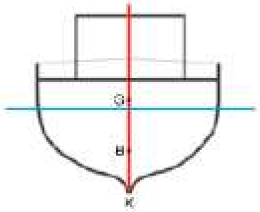


The centre of buoyancy B is the average location of the total buoyancy.

B is not fixed; it changes all the time depending on the vessel's draft, heel and trim.

The centre of buoyancy B moves when the vessel heels

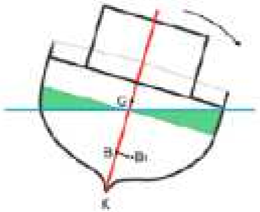
When the vessel is upright, and not tilted, the centre of gravity G is in the vessel's centre line.



In a straight line below is the centre of buoyancy B, and the vessel is in balance.

If the vessel is heeled, the buoyancy centre moves immediately off to the side of the vessel. See the adjacent illustration, where B is moved to one side and called B1.

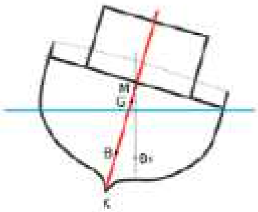
If the gear and catch are stowed away safely, there is no weight on board that can move during the roll. So the centre of gravity G remains in the same position.



Metacentric height GM

Under a light small heeling, the vertical line of buoyancy intersects with the vessel's centre line at a point called meta centre, which is indicated by the letter M.

The distance between the centre of gravity G and meta centre M is called the metacentric height GM.



The GM value is a measure of the vessel's stability under small heeling, also called initial stability.

The higher the GM value, the better the vessel's initial stability and the harder it is to get the vessel to heel.

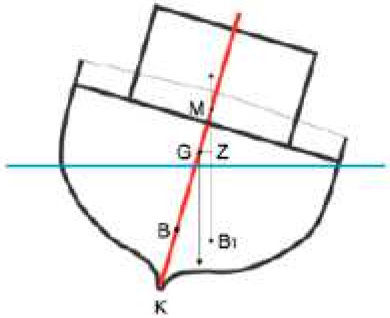
A vessel with a large GM value can be described as a rigid vessel that rolls fast on sea.

Righting arm GZ

When the vessel suffers a heel, the centre of gravity G and the centre of buoyancy B are no longer on the same vertical line above one another.

The vessel is brought out of balance.

As the figure shows, there is a distance between the vertical line that expresses the vessel's weight through the centre of gravity G and the vertical line that expresses the vessel buoyancy through the current centre of buoyancy B1.

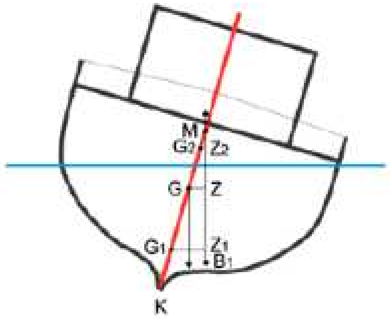


The horizontal distance between the two lines is called the righting arm GZ - and the size of the righting arm GZ is crucial to whether the vessel can straighten up and get back on an even keel. The greater the righting arm is, the better is the ability of the vessel to get back on an even keel.

The figure to the right shows how the crew can influence the size of the righting arm depending on how the vessel is loaded.

The deeper the weight is placed in the vessel, the further down is the centre of gravity G. Thus the righting arm GZ is larger. (See point G1)

Conversely, GZ is smaller if the weights are placed high up in the vessel, so that the centre of gravity G moves higher up in the vessel. (See point G2)

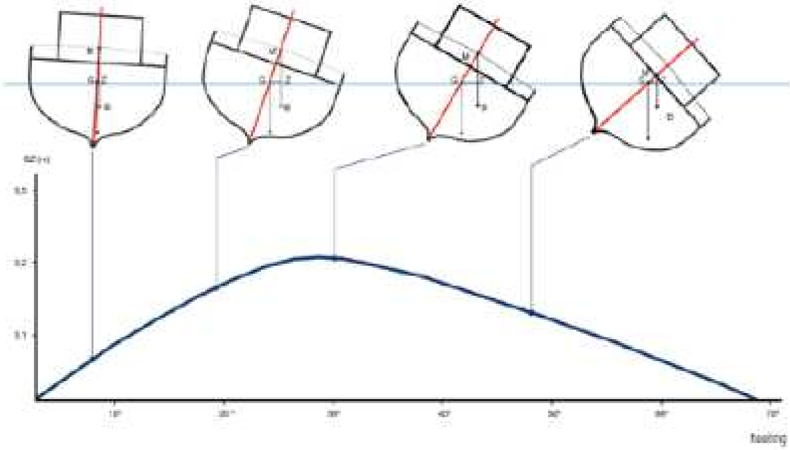


GZ curve

When the vessel heels, the part of the vessel that is under water changes behaviour. This means that the centre of buoyancy B keeps changing, depending on the heel of the vessel. The GZ value changes alongside with the heeling.

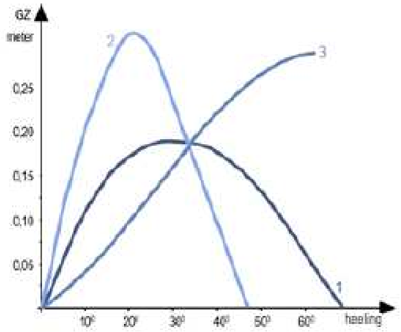
The illustration below shows how the GZ value increases, the more the vessel heels. At some point the GZ value reaches a maximum. Here the vessel has the maximum righting force. After this point the GZ value decreases. When the GZ value drops to 0, the vessel capsizes.

GZ values at different degrees of heeling can be plotted to form a curve as shown below - called a GZ curve.



GZ curves give a quick impression of the vessel and its stability. Different types of vessels have different GZ curves.

The illustration below shows 3 GZ curves for 3 different types of vessels.

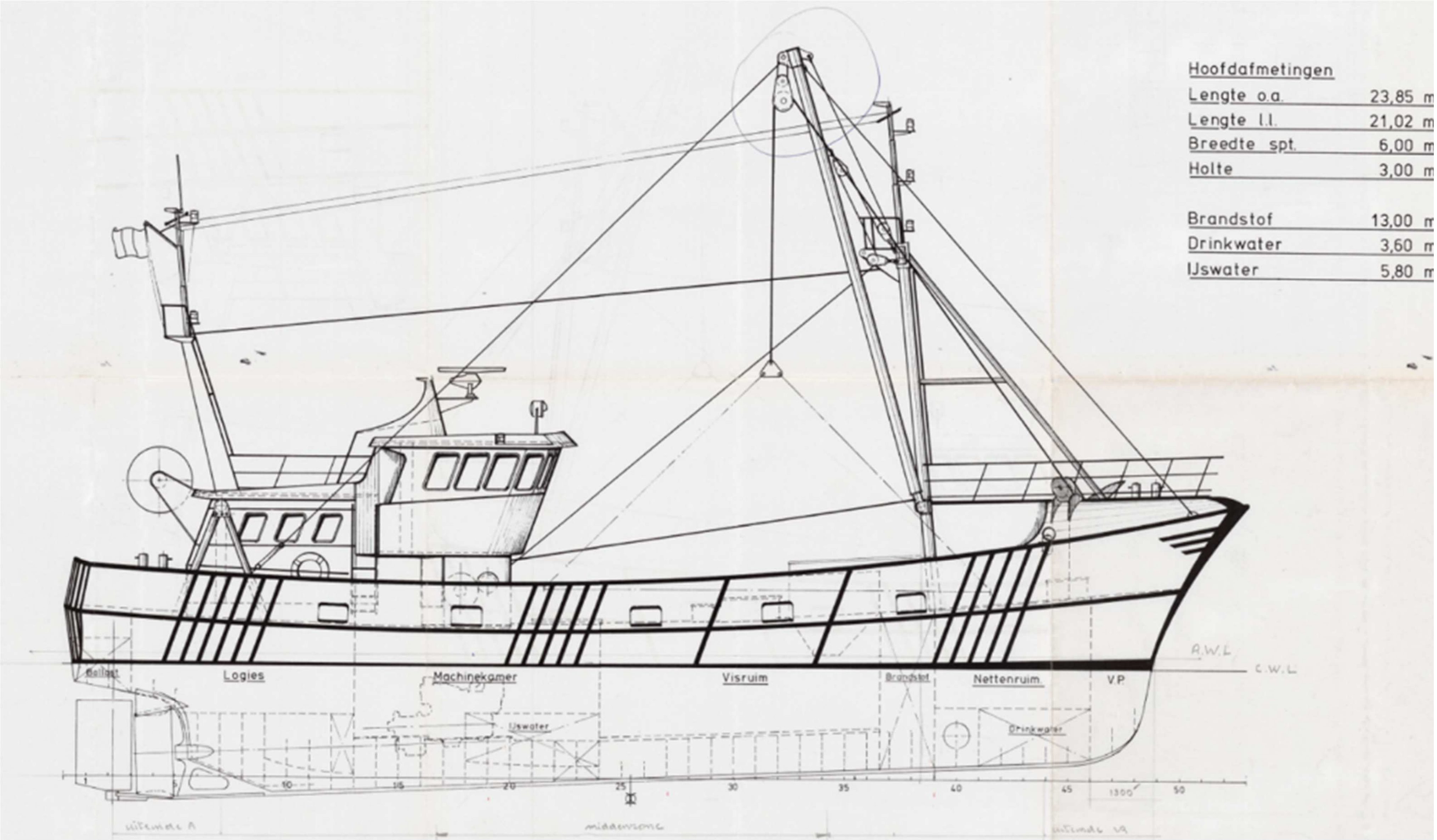


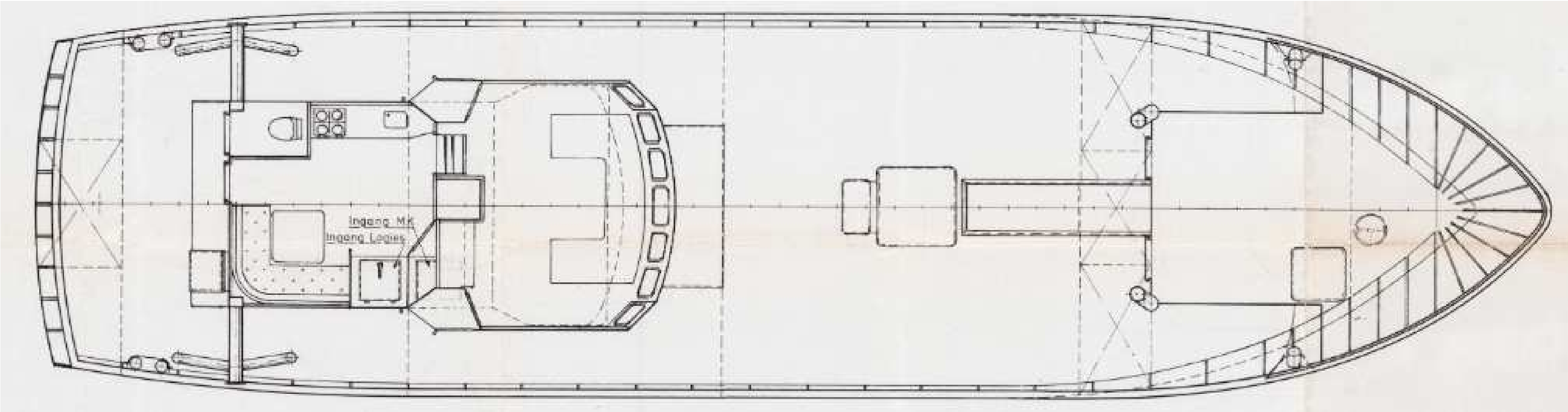
Curve 1 is for a traditional deck vessel. The curve peaks at approx. 25 degrees and extends to approx. 70 degrees.

Curve 2 is a wide flat-bottomed vessel. The curve is initially steeper than curve 1. This means that the vessel is more rigid - it has a big GM and is difficult to get to heel, but the steep curve can also be an indication that the vessel rolls faster. The vessel already reaches the maximum righting arm at a slight heel. A characteristic of these vessels is that the righting arm drops fast and the vessel cannot heel as much as a traditional deck vessel.

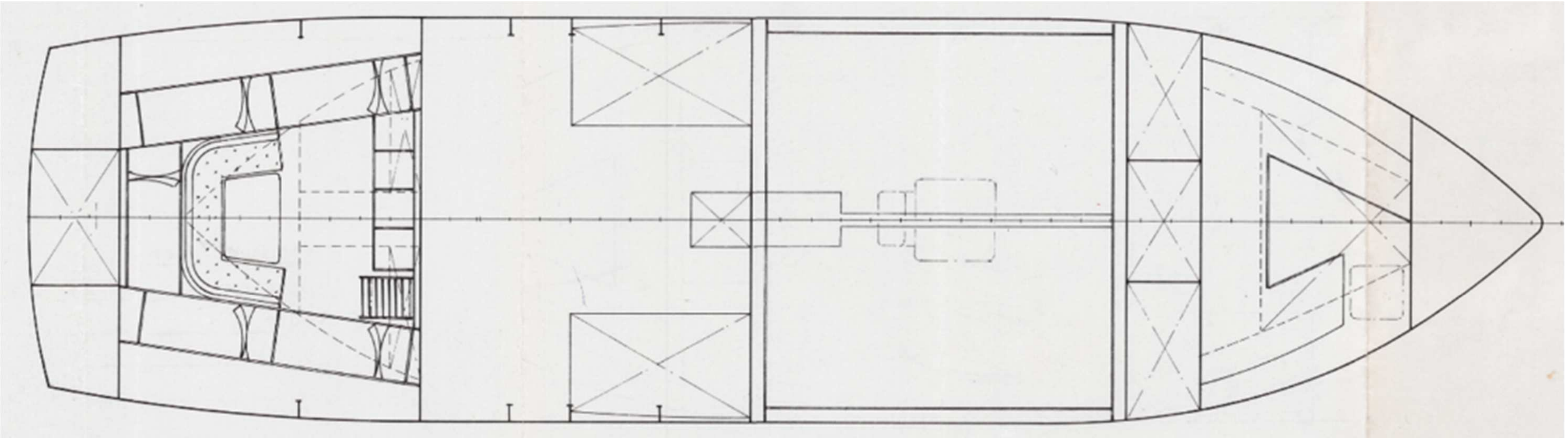
Curve 3 shows a vessel with completely different properties. The curve starts flatter. The initial stability is relatively low. The vessel heels easily, but it rolls more slowly. As the curve grows, it becomes increasingly difficult to get the vessel to heel over further. A vessel with such a curve is typically a shelter deck vessel, where the closed shelter contributes to the buoyancy and increases the vessel's freeboard considerably. A large freeboard will improve the extent of the GZ curve.

Appendix 3 – General arrangement plan





Ingang MK
Ingang Logies



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