Annex A

Ocean Way – extract of Stability Booklet

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STABILITY BOOKLET

FOR MFV

COPIOUS

BF 237

OCEAN WAY
LK 207

JUNE 2002

MACDUFF SHIP DESIGN LTD.
4 LAING ST., MACDUFF, GRAMPIAN
AB44 1RB

DATE OF ISSUE:- 25/6/02

BY:- [redacted]

Registered in Scotland: No. 143359
Registered Office: Johnstone House, 52-54 Rose Street, Aberdeen, AB10 1UD

INDEX

GENERAL PARTICULARS

Vessel's Name:	**"COPIOUS" BF 237**
Port of Registry:	**BANFF**
Owners Name & Address:	Copious Fishing Company Denholm Fishselling Ltd 22 Commercial Road BUCKIE AB56 1UQ
Builders Name & Address:	Buckie Shipyards Ltd Commercial Road BUCKIE
Yard No:	108
Year of Build:	1996
Principal Dimensions:	
LOA	24.30 metres
LBP	22.00 metres
B MLD	7.90 metres
D EXT	4.73 metres
Registered Dimensions:	
Length:	23.22 metres
Breadth:	7.90 metres
Depth:	4.80 metres
RSS Number:	B14623
Tonnage:	268 GT and 138.83 NT
Maximum Service Displacement:	486.081 in Condition No 2
Corresponding Full Draught Aft:	5.247m to USK at AP
With Minimum Freeboard:	1.036m to Deck at AP

GENERAL ARRANGEMENT DRAWING

MFV 'Copious' BF 237.

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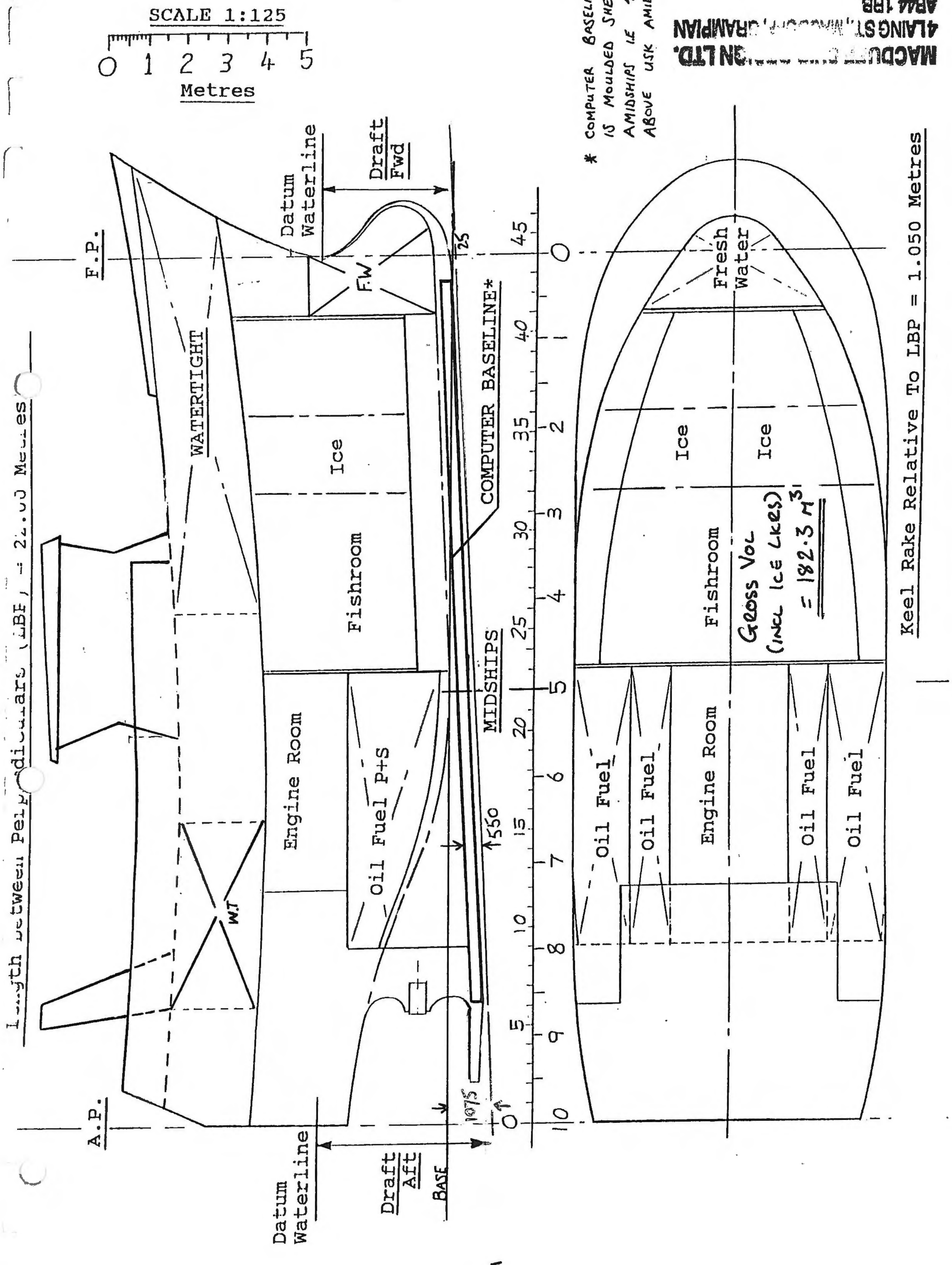


MINIMUM STABILITY REQUIREMENTS - FISHING VESSELS (SAFETY PROVISIONS) RULES 1975

The vessel is required to have a level of stability, at all times, not less than the following legal minima:-

Initial GM to be not less than 0.35 metres.
Area under righting lever curve to be not less than the following:-

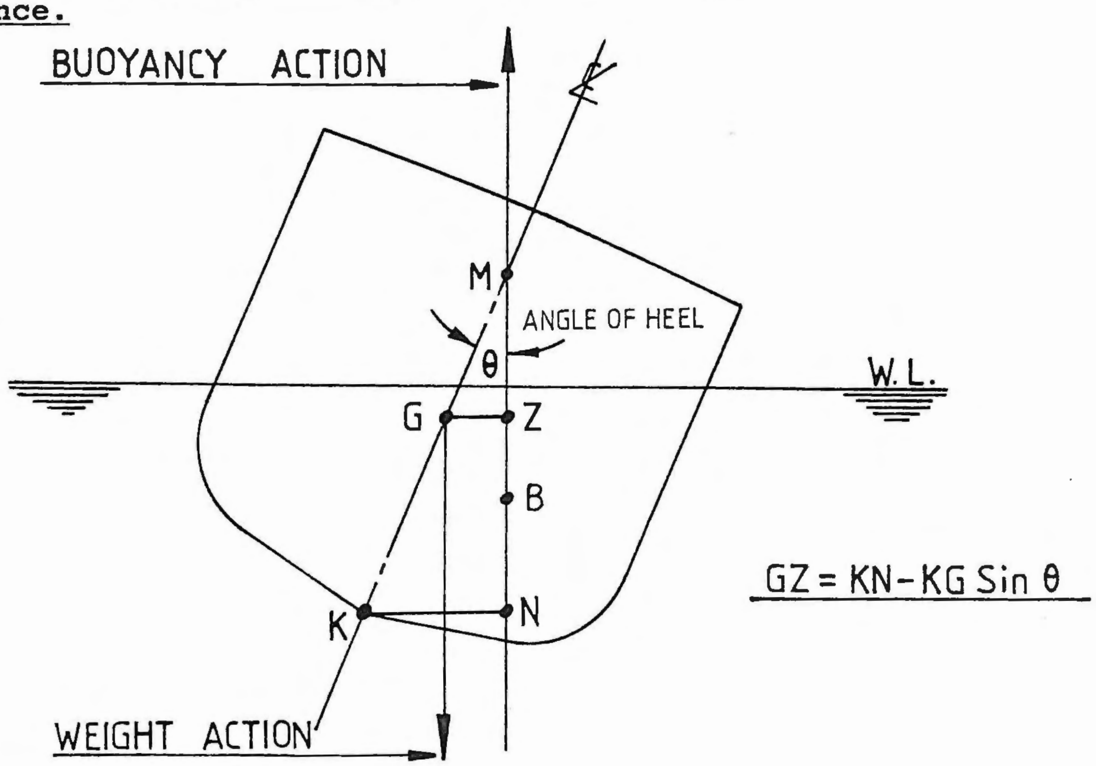
From 0° up to 30° of heel - 0.055 metre radians
From 0° up to 40° of heel - 0.090 metre radians
Between 30/40° - 0.030 metre radians

The Righting Lever (GZ) to be not less than 0.20 metres at an angle of heel equal to or greater than 30°.

Maximum righting lever shall occur at an angle of heel not less than 25°.

THE RIGHTING LEVER - GZ

The righting lever GZ is the horizontal distance between the vertical line of action of the weight of the vessel and the corresponding vertical line of action of the buoyancy of the vessel. For positive stability on any angle of heel the buoyancy line must be outboard of the line of action of weight - see figure. To ensure that G remains in the position calculated while the vessel is in motion, all items comprising the vessels load should be secured against movement. The calculated position of B will only remain valid if care is taken to maintain the watertight integrity of the hull & superstructure. **The closure of all openings in heavy weather is therefore of great importance.**



NOTICE TO SKIPPER

VESSELS STABILITY - THE LOADING CONDITIONS SHOWN IN THIS BOOK ARE TYPICAL FOR MOST OPERATIONS LIKELY TO BE CARRIED OUT. THEY ALSO PROVIDE A BASIS FOR ANY ADDITIONAL CONDITIONS, NOT INCLUDED, THAT THE SKIPPER MAY REQUIRE.

IN SEVERE WEATHER SUFFICIENT STABILITY CAN ONLY BE MAINTAINED IF THE HULL AND DECKHOUSES ARE KEPT WEATHERTIGHT. IT IS ALSO OF THE UTMOST IMPORTANCE FOR THE SKIPPER TO FOLLOW THE LOADING ARRANGEMENTS AND KEEP THE QUANTITY OF FISH STORED ON DECK, ESPECIALLY AT THE SIDE OF THE VESSEL, TO A MINIMUM AT ALL TIMES.

AREA OF OPERATION - THE VESSEL MUST ONLY OPERATE FROM 1ST NOVEMBER TO 30TH APRIL IN AREAS WHERE NO ICING ALLOWANCE IS APPLICABLE. THAT IS SOUTH OF LATITUDE 61 deg NORTH BETWEEN NORWEGIAN COAST AND LONGITUDE 28 deg WEST AND SOUTH OF LATITUDE 45 deg NORTH BETWEEN CANADIAN COAST AND LONGITUDE 28 deg WEST.

NOTES ON THE USE OF FREE SURFACE MOMENTS

PARTLY FILLED TANKS:- PROVIDED THAT A TANK IS COMPLETELY FILLED WITH LIQUID, NO MOVEMENT OF THE LIQUID IS POSSIBLE AND THE EFFECT ON THE SHIP'S STABILITY IS PRECISELY THE SAME AS IF THE TANK CONTAINED SOLID MATERIAL.

IMMEDIATELY A QUANTITY OF LIQUID IS TAKEN FROM THE TANK, THE SITUATION CHANGES COMPLETELY AND THE STABILITY OF THE SHIP IS ADVERSELY AFFECTED BY WHAT IS KNOWN AS THE"FREE SURFACE EFFECT". THIS ADVERSE EFFECT ON THE STABILITY CAN BE CONSIDERED AS EITHER A "LOSS IN GM" OR A "VIRTUAL RISE IN KG", AND IS CALCULATED AS FOLLOWS:-

$$\text{LOSS IN GM DUE TO FREE SURFACE} = \frac{\text{FREE SURFACE MOMENT x SG}}{\text{DISPLACEMENT OF VESSEL}}$$

THE FREE SURFACE MOMENT FOR EACH TANK IS LISTED IN THE LAST COLUMN OF THE CAPACITY TABLE. THE TOTAL FOR ALL TANKS SHOULD BE TAKEN INTO ACCOUNT IN BOTH ARRIVAL AND DEPARTURE CONDITIONS, BUT MAY BE IGNORED IF LESS THAN 0.01 x DISPLACEMENT.

NOTE: FSM'S GIVEN IN TABLE ON PAGE 18 ARE CORRECTED FOR SG OF TANK CONTENTS.

GUIDE TO SKIPPER ON HOW TO CALCULATE GZ'S

FOR ANY SAILING CONDITION

The first step is to calculate the displacement of the vessel adding the various items of deadweight to the known Lightship figures.

After the displacement and centres of gravity have been arrived at the KN's are lifted from the tabulated KN's at the appropriate trim.

The Righting Lever GZ is then calculated as follows:-

$$GZ = KN - KGf \sin \varnothing$$

Where KN = Cross Curve ordinate from tables.

KGf = The vertical centre of gravity corrected for free surface, measured from the base line which is 0.55m above the underside of keel.

Ø = Angle of inclination.

Then by using the GZ values obtained a Statical Stability Curve can be drawn for the ship at the displacement and KG used, as per pages 10, 11, 12 & 13.

After the curve has been drawn, the various criteria can be lifted off to ensure that the required minimum items are met.

NOTE:- The trims used in this book are as follows:-
1.0m by Stern Relative to Horizontal Base
0.5m by Stern Relative to Horizontal Base
Level ie with Waterline Parallel to Horizontal Base
0.5m by Bow Relative to Horizontal Base
1.0m by Bow Relative to Horizontal Base

EXAMPLE:-
Draft Aft = 5.218 m USK
Draft Fwd = 4.438 m USK
Trim = 0.780 m by STERN
Rake of Keel = 1.050m
Actual trim by HEAD relative to horizontal base
= 0.780 - 1.050 = 0.270m

VOYAGE CYCLE & WORKING INSTRUCTIONS

1. The voyage duration has been taken as 8 days comprising 2 days out to grounds, 4 days fishing and 2 days returning to port.

2. The vessel is assumed to depart with 38.86 tonnes of oil fuel (98%) in engine room tanks, and to arrive in port with 3.97 tonnes (10%).

3. The vessel is assumed to depart with 7.42 tonnes of fresh water (100%) and to arrive in port with 0.74 tonnes (10%).

4. 15 tonnes of ice is carried in the hold on departure for fishing. The melting rate of unused ice is taken a 2% by weight per day and of ice mixed with fish as 2% by weight per day.

5. 600 plastic boxes of fish and ice will be carried. The vessel will not be bulking fish. The weight of boxed fish and ice is calculated by taking 55 kgs per box of fish and ice, with one empty plastic box weighing 4.5 kgs.

6. All conditions comply with MCA Minimum Freeboards Rules for a vessel with L = 21.23 m (96% x WL @ 0.85D)
   Minimum Freeboard Aft to top of deck at AP = 1.008m
   Corresponding Maximum draft aft to USK at AP = 5.247m
   Minimum freeboard forward HB to top of shelter = 2.327m
   Corresponding maximum draft fwd to USK at FP = 5.638m
   (HB is used for all conditions)

7. The fishing gear aboard at time of incline is detailed in inclining report. The gear included in conditions is detailed in table on page 22.

8. It is extremely important that no alterations are carried out to the vessel or fishing gear until the effects on stability have been calculated.

9. All openings into watertight shelter spaces to be kept shut and securely fastened at sea when not in use.

CAPACITIES AND CENTRES OF COMPARTMENTS & ITEMS

ITEM	LITRES	TONNES 100%	VCG	LCG	FSM MAX
OF Outboard FR 9-23 Port	11796	10.026	1.871	8.645	1.447
OF Outboard FR 9-23 Stbd	11796	10.026	1.871	8.645	1.447
OF Inboard FR 9-23 Port	11529	9.799	1.677	8.541	0.499
OF Inboard FR 9-23 Stbd	11529	9.799	1.677	8.541	0.499
Oil Fuel Daily Service	1000	0.850	3.550	6.400	0.080
Hydraulic Oil	1000	0.850	3.850	11.100	0.040
Lubricating Oil	1000	0.850	3.850	11.100	0.040
Fresh Water Tank in Bulb	7422	7.422	1.776	21.395	1.346
Crew & Stores	-	1.500	6.300	11.000	-
Fishing Gear - see over	-	29.000	6.726	9.169	-
Ice	-	15.000	3.150	17.000	-
600 Empty Plastic Boxes	-	2.700	2.950	17.000	-
600 Boxes Fish/Ice	-	33.000	2.750	14.500	-
20% Boxed Catch	-	6.600	2.000	13.000	-

NOTES: VERTICAL CENTRE OF GRAVITY - VCG IS MEASURED ABOVE BASE LINE IN METRES.
LONGITUDINAL CENTRE OF GRAVITY - LCG - IS MEASURED FROM AP IN METRES.
SPECIFIC GRAVITY OF FUEL, HYD & LUB OIL = 0.85.

FREE SURFACE MOMENT - TO OBTAIN FSM FOR ANY TANK:- $\frac{1}{12} LB^3$ WHERE

L = LENGTH OF TANK B = MEAN BREADTH OF TANK

FREE SURFACE CORRECTION:- FSC

$$= \frac{\text{FREE SURFACE MOMENT (FSM)}}{\text{DISPLACEMENT}}$$

NOTES ON UNITS USED IN THIS BOOK

DIMENSIONS: METRES
WEIGHT AND DISPLACEMENT: TONNES

Annex B

The European Guide for Risk Prevention in Small Fishing Vessels – Flooding Checklist

5.4 ACTION CHECKLIST FOR EMERGENCY SITUATIONS

This section provides a checklist of basic actions for the most likely emergency situations on small vessels. The checklists may well assist in the preparation of the drill and debrief.

5.4.1 MAN-OVER-BOARD

Take precautions to reduce the risk of falls overboard but be prepared for a successful recovery operation. Know what to do and develop a suitable plan for your particular boat. Procedures for the recovery of a man overboard shall consider the following actions and provisions:

- ☐ **Raise the alarm:** shout 'man over board'
- ☐ **Appoint a look-out:** keep sight of the man in the water
- ☐ **Throw a lifebuoy:** to mark the position.
- ☐ **Turn the boat:** return to reciprocal course.
- ☐ **Distress signal:** call on the radio for assistance.
- ☐ **Retrieval:** rig a means of getting the man back onboard.
- ☐ **Organise:** have suitable means of retrieval, such as a basket, ladder, lifting strop or other.
- ☐ **First aid/medical attention:** have a suitable first aid kit and training to counter hypothermia.

5.4.2 FLOODING

On decked boats, flooding can occur at any time while at sea or in the harbour. Flooding is preventable but if not prevented, in most cases it can be controlled. If discovered early, leaking pipes can be isolated and the flooding controlled by pumping out the affected space. Flooding can also be rapid and late discovery leaves no time to treat the cause. An efficient bilge alarm can be critical in providing early warning of flooding.
To reduce the risk of flooding or the damage from flooding, always maintain watertight compartments and check that all spaces below deck are serviced and maintained in good working order. Should flooding occur on your vessel:

- ☐ Raise the alarm
- ☐ Start pumps, check suction is working effectively
- ☐ Wheelhouse watch keeper to send a radio message to nearby vessels and coast guard.
- ☐ Turn vessel towards shallower water or port. Consider beaching the vessel
- ☐ Attempt to stem the flow of water by shutting valves, or blocking the hole.
- ☐ If pumps are out of action get out and seal the compartment.
- ☐ Close doors, hatches and ports to prevent down flooding.
- ☐ Leave scuppers or freeing ports open to drain excess water.
- ☐ Erect dummy bulkheads using pound boards or fish bins tied across the compartment.
- ☐ Look for holes leaking into adjoining compartments.
- ☐ Consider stability effects of flooded compartment.
- ☐ Use a fothering sheet to block the ingress.
- ☐ Prepare to abandon the vessel. Remain on the vessel for as long as it is safe to do so.
- ☐ Only abandon the vessel on the command of the skipper.
- ☐ Do not wear PFDs or immersion suits while inside the vessel (enclosed spaces) because their buoyancy may hamper escape during a sudden capsizing. However, have them broken out as to be readily available.

Report on aspects of the flooding that led to the loss of *Ocean Way*

Report on aspects of the flooding which led to loss of FV 'Ocean Way' Marine Accident Investigation Branch

April 2017

Index

Appendices

Diagrams

Report on aspects of the flooding which led to the loss of FV 'Ocean Way'

1. Introduction

The fishing boat FV Ocean Way sank off the East coast of the Shetlands on 3rd March 2017. It is reported that the loss was caused by seawater flooding into the aft peak/accommodation area. The objectives of this report are:

a. to model the vessel's draughts, trim and stability at stages throughout the flooding process up to the point where loss became inevitable;
b. to estimate the volume of floodwater in the aft peak required to make the loss inevitable;
c. to estimate the breach hole size;
d. to calculate the time to loss inevitability if no pump had been used;
e. to assess the effect of the submersible pump used after flooding commenced;
f. to assess the capacity of a larger pump that might have prevented the loss;
g. to determine the consequential flow rate of water into the engine room if the drain valve in the aft engine room bulkhead had been left open;
h. to evaluate the effect on loss inevitability of allowing floodwater into the engine room, ie leaving the drain valve open, so that both the engine room pump and the submersible pump could be used to reduce floodwater volume.

Section 2 details the vessel's principal dimensions. Section 3 illustrates the hull sections used for the analysis, outlines the arrangement of the aft peak and identifies the extent of flooding that was assumed for the purpose of the report. Section 4 details the vessel's equilibrium state when intact and at six aft peak floodwater volumes prior to loss inevitability. Data for a seventh state beyond the point of loss inevitability is also included. Section 5 is comprised of an assessment of the rate at which the aft peak flooded and section 6 draws on this information to make projections on the size of the breach in the hull. An estimate of the size of pump that would have been required to prevent the loss forms Section 7 and Section 8 examines the potential effect on the outcome if the main bilge or deckwash pumps had been used in addition to the submersible pump. The report's conclusions form Section 9.

2. Principal dimensions

The vessel's principal dimensions are as follows:

Length Overall (LOA)............................:	24.30 metres
Length Between Perpendiculars (LBP).:	22.00 metres
Moulded Beam (B MLD).......................:	7.90 metres
Depth (D)...:	4.73 metres
Keel rake...:	1.078 metres over LBP (1.05m in inclining report)
Lightship displacement.........................:	392.887 tonnes (source: 13/06/02 inclining report)

3. Hull and compartment layout and computer definition

The computer model used for the production of the vessel's stability booklet was utilised for the analysis in this report. The original model was considered adequate for the production of general stability data but required some additional sections fore and aft to improve section area integration at the high trim angles evident during the course of the accident. Compartment models were derived from the hull model for the aft peak/accommodation and engine room bilge. External appendages for which there was sufficient information were also modelled. These included the nozzle, propeller, rudder and rudder skeg. Diagram 1 at the head of the next page is a plot of the hull sections (including the nozzle). Plots of the hull and compartment sections used in the analysis comprise Appendix 1.

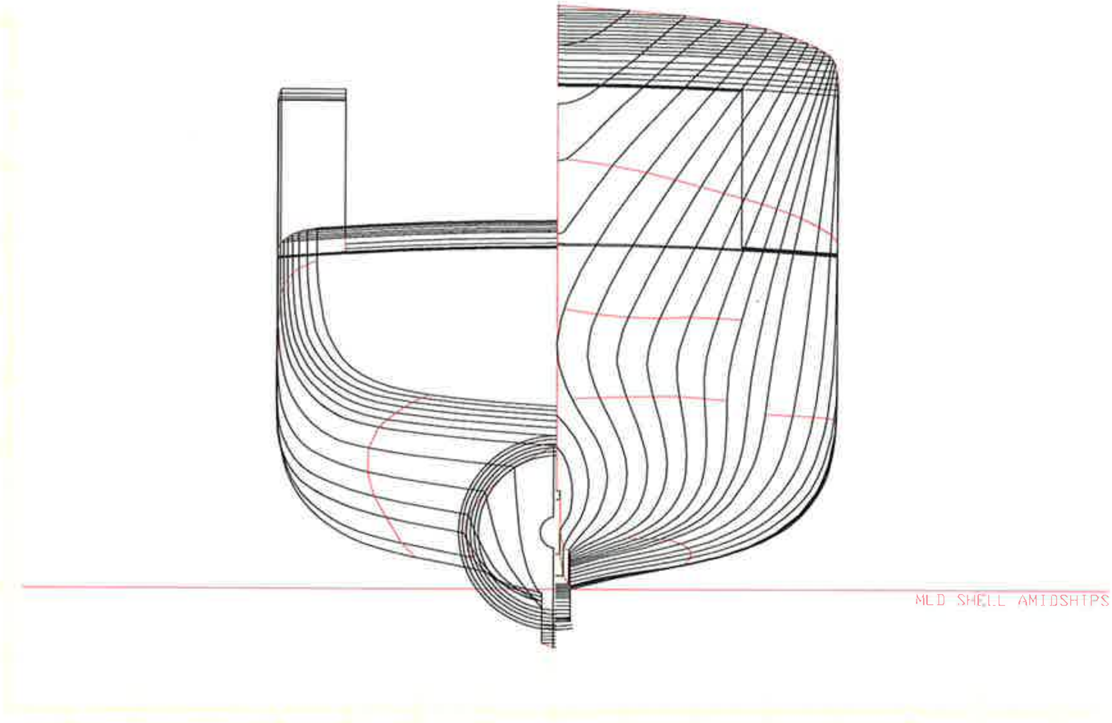


Diagram 1 – Hull sections

All longitudinal dimensions are taken about an Aft Perpendicular (AP) located at the transom and all vertical dimensions with the exception of draughts are about a Base Line passing through the moulded shell line at midships on the LBP as shown in the general arrangement drawing below.

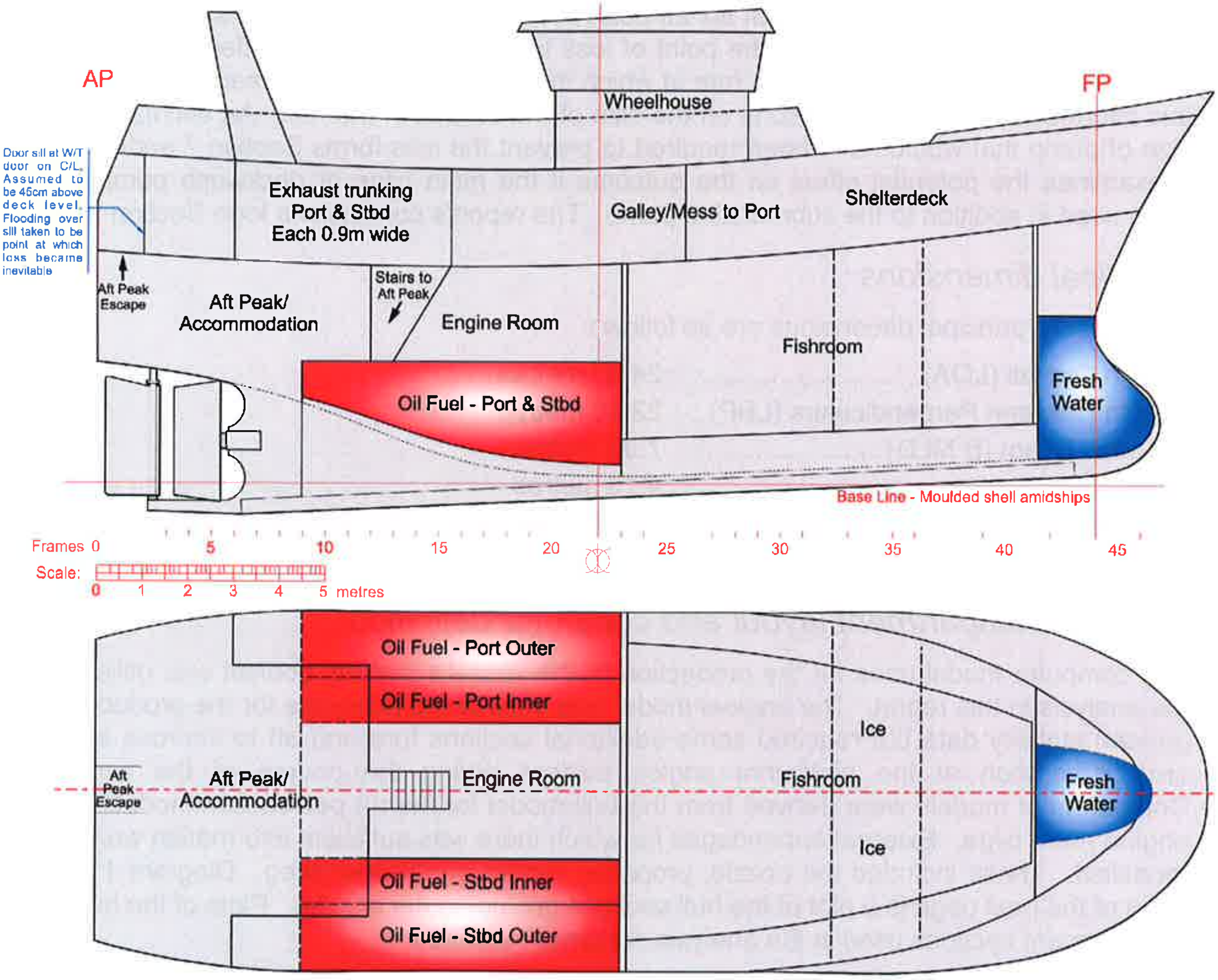


Diagram 2 – General Arrangement

Longitudinal dimensions are positive forward, negative aft of the AP and vertical dimensions are positive above the Base Line, negative below. Draughts are taken about the underside of keel extended in the intact state and about the Base Line in all flooded states. Transverse dimensions are about the centreline and are positive to Port, negative to Starboard. These axes and value signs were used for the original stability booklet.

Volumes included in the intact stability calculations are shown in the diagram below.

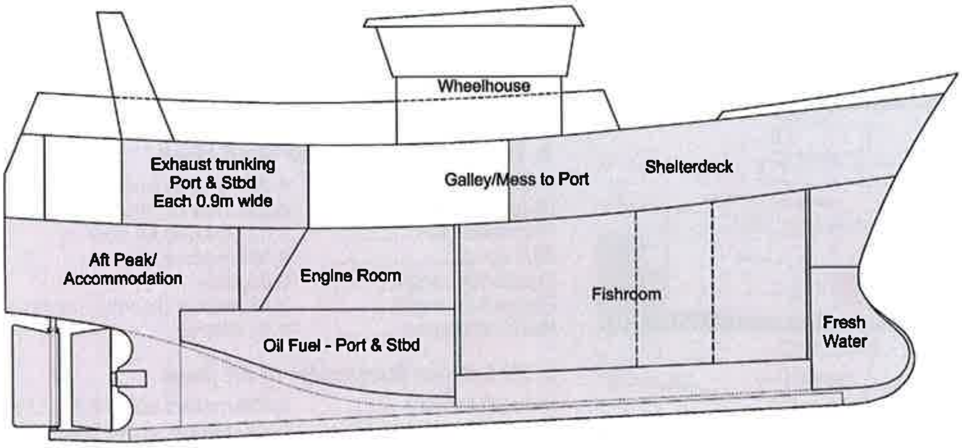


Diagram 3 – Volumes making a positive contribution to intact state

The same volumes were included for the production of the stability information booklet data.

For the purposes of this report, it has been considered that loss became inevitable once the seawater level had reached the door sill above the aft peak escape hatch on the centreline (see diagram 2). After this event, flooding into the aft peak increased dramatically and the rapidly increasing angle of equilibrium (see data for snapshot No. 8 in Section 4) that resulted would inevitably immerse other apertures into compartments further forward.

The area coloured light green in the diagram below show the contours of the aft peak/ accommodation used in the damaged state calculations, the results of which comprise Section 4. The dark green area shows the extent of the engine room bilge which is also assumed to have partially flooded for the analysis in Section 8. All other volumes were considered to remain intact until loss became inevitable.

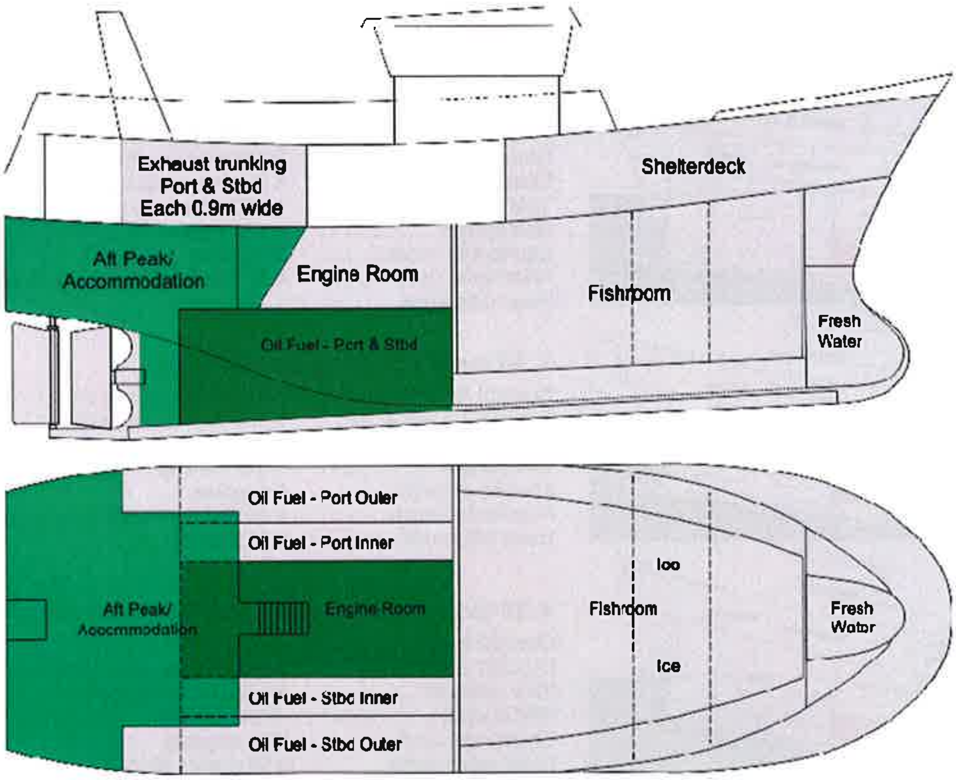


Diagram 4 – Configuration of volumes considered to flood

4. *Evaluation of vessel's trim and stability with aft peak flooding*

The diagrams below are snapshots of the aft peak flooding with related trim and stability data at 10 tonne floodwater increments from 0-70 tonnes. Appendix 3 lists the analysis data.

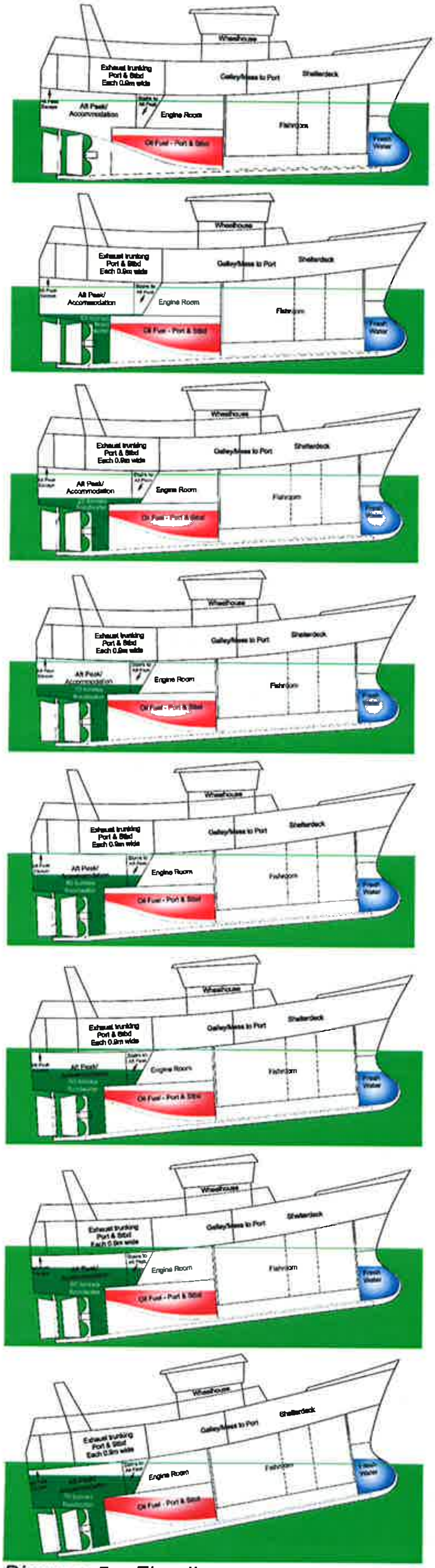


Diagram 5 – Flooding sequence

1. Condition prior to accident

Draught forward .....: 4.364 metres about keel line
Draught t AP ....: 5.138 metres about keel line
Trim over LBP ....: 0.276 metres by bow
GMf upright............: 0.599 metres
Equilibrium angle ...: 0 degrees
Floodwater depth ...: 0 metres

2. 10 tonnes floodwater in aft peak

Draught forward ....: 4.251 metres about Base Line
Draught 1m fwd of AP..: 4.231 metres about Base Line
Trim over LBP..............: 0.021 metres by bow
GMf upright..................: 0.524 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 3.48 metres (flooding via breach only)
Head difference ....: 1.71 metres

3. 20 tonnes floodwater in aft peak

Draught forward ....: 4.156 metres about Base Line
Draught 1m fwd of AP..: 4.399 metres about Base Line
Trim over LBP..............: 0.254 metres by stern
GMf upright..................: 0.483 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 3.75 metres (flooding via breach only)
Head difference............: 1.50 metres

4. 30 tonnes floodwater in aft peak

Draught forward ....: 4.048 metres about Base Line
Draught 1m fwd of AP..: 4.578 metres about Base Line
Trim over LBP..............: 0.556 metres by stern
GMf upright..................: 0.381 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 4.01 metres (flooding via breach only)
Head difference ....: 1.42 metres

5. 40 tonnes floodwater in aft peak

Draught forward ....: 3.913 metres about Base Line
Draught 1m fwd of AP..: 4.768 metres about Base Line
Trim over LBP..............: 0.897 metres by stern
GMf upright..................: 0.291 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 4.26 metres (flooding via breach only)
Head difference ....: 1.35 metres

6. 50 tonnes floodwater in aft peak

Draught forward ....: 3.765 metres about Base Line
Draught 1m fwd of AP..: 5.010 metres about Base Line
Trim over LBP..............: 1.306 metres by stern
GMf upright..................: 0.170 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 4.51 metres (flooding via breach only)
Head difference ....: 1.30 metres

7. 60 tonnes floodwater in aft peak

Draught forward ....: 3.582 metres about Base Line
Draught 1m fwd of AP..: 5.339 metres about Base Line
Trim over LBP..............: 1.848 metres by stern
GMf upright..................: 0.015 metres
Equilibrium angle ....: 0 degrees
Floodwater depth ....: 4.74 metres (flooding via breach only)
Head difference ....: 1.31 metres

8. 70 tonnes floodwater in aft peak (open escape hatch immersed)

Draught forward ....: 2.100 metres about Base Line
Draught 1m fwd of AP..: 5.642 metres about Base Line
Trim over LBP..............: 3.178 metres by stern
GMf upright..................: -0.241 metres
Equilibrium angle ....: 50.4 degrees
Floodwater depth ....: 4.98 metres (flooding via breach and escape hatch)
Head difference ....: 0.81 metres

The stability of the vessel in the flooded states listed on the previous page is summarised in the righting lever curves shown in diagram 6 below.

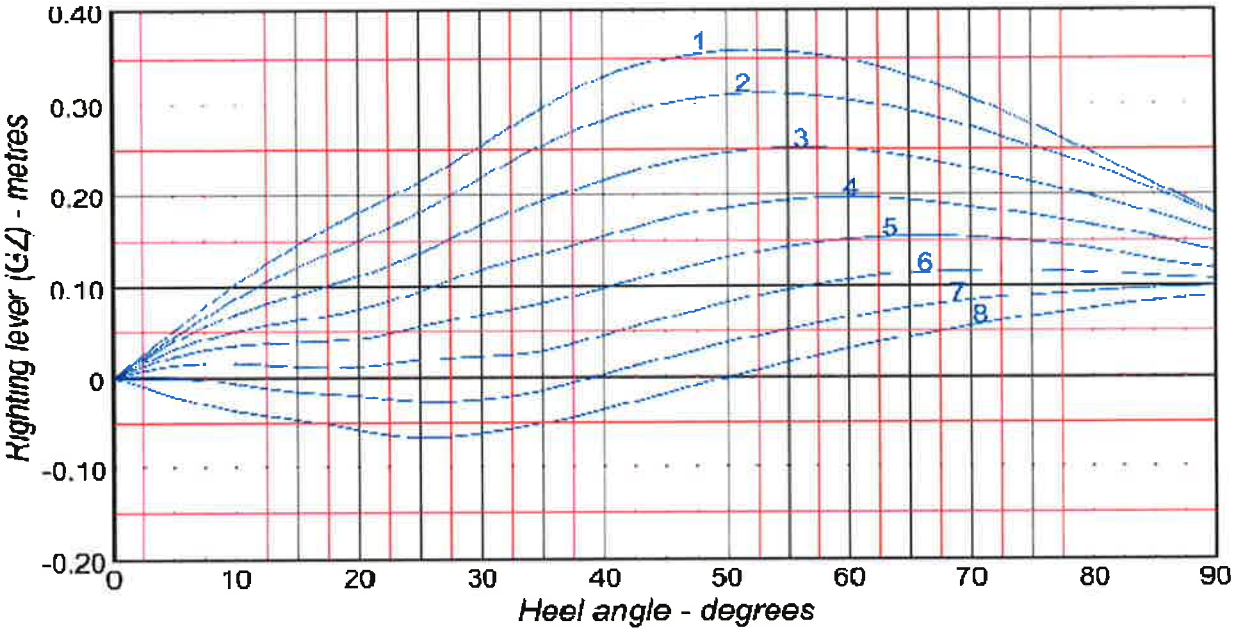


Diagram 6 – Righting lever curves at 10 tonne floodwater increments

It should be noted that the accuracy of these curves is reliant in large part on the precision of the lightship figures (displacement weight and centre of gravity location) recorded at the 2002 inclining trial and on the assumptions that flooding was symmetrical and that the transverse centre of gravity was on the centreline. It should be noted in this context that if the centre of gravity had been, for example, 25mm off the centreline, the vessel would not have been upright with 50 tonnes of floodwater aboard (see data for snapshot 6 on the previous page) but would have had an angle of heel at equilibrium of over 24 degrees.

These considerations may have had an influence on the rate of flooding into the aft peak. If the vessel was heeling before the accident a breach in the hull would have moved significantly further below the water surface (thereby increasing the rate of flooding) as the vessel heeled in response to a negative GM (upright) than otherwise.

5. *Calculation of aft peak flooding rate*

It is understood that the accident timeline ran approximately as follows:

Time(GMT)	*Elapsed time*	*Event*
0635	0 mins	Trawl door impact on hull
0640	5 mins	Initial flooding detected (bilge alarm)
0650-0700	15-25 mins	Submersible pump started through aft peak escape hatch
0745	70 mins	Vessel Gerda Saele arrives, submersible pump replaced
0810	95 mins	RNLI arrive – exterior seawater level at aft peak escape hatch sill
0830	115 mins	Vessel sinks

The analysis in section 4 indicates that the aft peak contained approximately 61 tonnes of seawater (around 60,000 litres) when the exterior sea level reached the aft peak escape hatch sill which was reported to coincide with the lifeboat's arrival.

The specification for the Makita PF1110 submersible pump used initially by the crew in the attempt to stem the floodwater states that it has a maximum capacity of 250 litres per minute. The pump was replaced by one of similar capacity at 0745. It is unlikely, therefore, that pumping was consistently at the maximum capacity, particularly as it was stopped on several occasions for detritus to be cleared from the suction head. Assuming it was working at its maximum and that pumping started 15 minutes after the breach occurred, it would have cleared about 20,000 litres of seawater in 80 minutes of running time but more realistically in view of the blockages the figure was closer to 10,000 litres. On this basis, between 70,000 and 80,000 litres of seawater flooded into the aft peak in the 95 minutes from hull breach to loss inevitability, an average flooding rate of about 790 litres per minute (13.2 litres per second). Similarly, a minimum of 11,850 litres and a maximum of 19,750 litres of sea water came aboard in the 15/25 minutes after flooding was detected and before pumping started.

If no pumping had been undertaken, loss inevitability would have come about 12 to 25 minutes earlier (between 0745hrs and 0758hrs), the time taken for the average flooding rate to fill the maximum 20,000 litres, minimum 10,000 litres cleared by the pump, respectively.

Note that the use of an average flow rate for calculations such as those that follow is an approximation. Flow rate is proportional to the 'head difference' which is the vertical distance between exterior seawater and interior floodwater levels. While the surface of floodwater inside a compartment remains below the breach, the head difference and thereby the flow rate increases only by the amount that the vessel settles in the water due to the added mass of the floodwater. However, assuming the vessel is still afloat, once the interior floodwater level reaches the breach, the head difference and consequently the flow rate will start to reduce as interior and exterior water levels converge, albeit that the vessel continues to settle in the water. In other words, flow rate may fluctuate significantly as a compartment fills.

6. *Assessment of breach size*

Examination of the hull sections in diagram 1 suggests it is likely that hull damage from a trawl door sufficient to cause such major flooding would probably occur longitudinally in the vicinity of the trawl blocks some 3 metres forward of the AP. It would seem likely that any damage would be sustained vertically between the inflexion points at the top and bottom of the turn of bilge (i.e. between the two curved red lines on the sections to the left of the centreline in diagram 1) which were close to and 1.8 metres below the waterline respectively before the damage occurred.

The formula below is used to establish flow rate through a submerged orifice:

$Q = 0.6A\sqrt{2gH}$ where Q = Flow rate in metres^3 per second
A = Orifice area in metres^2
g = Acceleration due to gravity (9.81 metres/second^2)
H = Head difference in metres

The formula may be rewritten to calculate orifice area from flow rate and head difference:

$A = Q / (0.6\sqrt{2gH})$

If the damage occurred at the proposed maximum 1.8 metres below the waterline and the flow rate was 790 litres per minute, the breach area was approximately 37cm^2 in area. Assuming the damage was at half that depth (i.e. 0.9 metres) with the same flow rate, the breach area would increase to about 52cm^2. Had the damage been sustained just below the waterline, for example 0.2 metres below, the area would increase to about 111cm^2. The diagram below plots breach area against depth below waterline at 790 litres/minute flow rate:

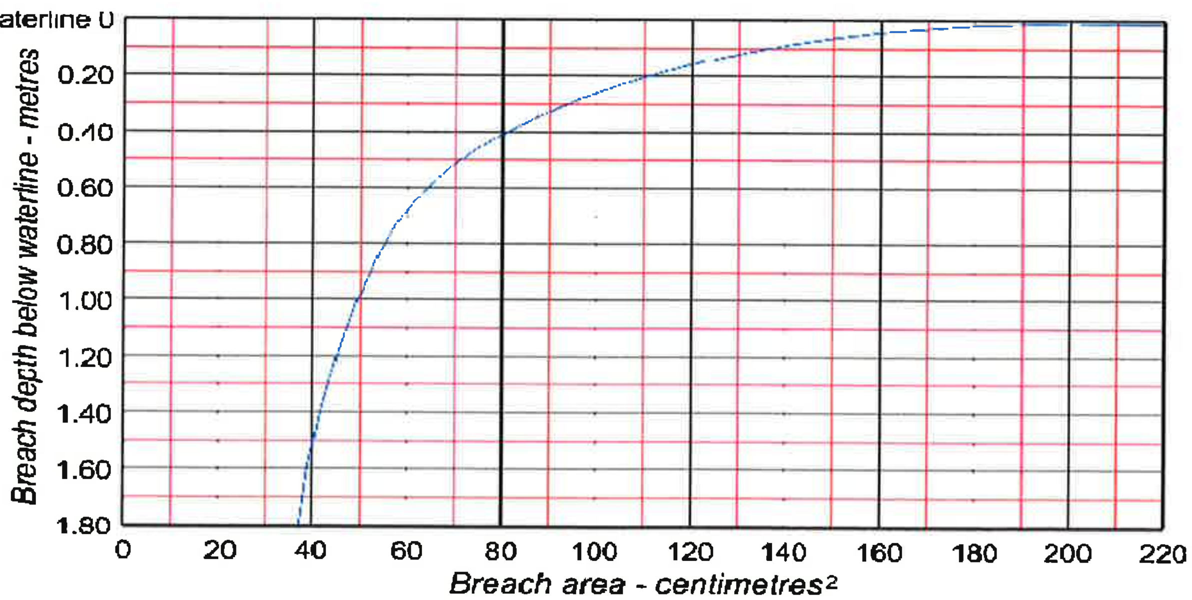


Diagram 7 – Plot of breach depth against area

7. Assessment of pump size required to prevent loss

Even if it had been working at its maximum, the 250 litres per minute capacity of the Makita PF1110 submersible pump was clearly insufficient to handle an inflow that was at least three times greater at about 790 litres per minute. On the face of it, a pump of at least the same flow rate would be required to stem the flow.

However, as the aft peak filled, the head difference between exterior seawater and interior floodwater levels decreased thereby reducing the flooding rate. The difference reached its minimum of approximately 1.3 metres with about 50 tonnes of floodwater aboard. Assuming the breach area was about 37cm^2 (see section 6) the flooding rate would have been about 680 litres per minute at this point implying that a pump with a capacity some 14% less than 790 litres per minute unit might have kept the vessel afloat, albeit lower in the water. In other words, because it would be capable of maintaining a greater head difference the larger pump would have to discharge a greater volume of water in stemming the flow than the 680 litre per minute unit.

8. Effect of using main bilge and/or deckwash pumps in addition to submersible pump

The 50mm diameter drain valve between the aft peak and the engine room, located in the vicinity of the propeller shaft, was kept closed for most of the accident duration. The following notes assess the effect of leaving this valve open, thereby potentially making it possible to augment the submersible pump with the main bilge and/or deckwash pumps discharging from the engine room bilge. These pumps had capacities of 70 and 35 cubic metres per hour respectively (1,166 litres per minute and 583 litres per minute).

When the breach first occurred, the flow rate through the open bulkhead valve would have been low reflecting the small head difference between the bilges in the aft peak and engine room. However, water flowing into the small volume of the keel blister (between frames 7 and 9 under the aft peak, about 1.4 cubic metres) at around 790 litres per minute would have filled this space in less than 2 minutes increasing the head difference between the floodwater in the aft peak and engine room to at least 1.2 metres. Flow rate through the 19.6 cm^2 drain would thus have rapidly increased to about 5.8 litres per second (348 litres per minute). This was well within the capacity of either the bilge or the deckwash pump.

Assuming that the first 20 minutes of flooding into the engine room would not be sufficient to get a satisfactory draw from the bilge pump strum, there would still have been 75 minutes pumping time to the arrival of the lifeboat. Assuming there were no blockages, either of the two pumps in the engine room could have removed about 26,000 litres of floodwater (26.65 tonnes) in that time, allowing for stoppages to ensure a sufficient head of water at the bilge strum. In other words, when the lifeboat arrived, there would have been a reduced total of about 35 tonnes of floodwater aboard, about 43% less than the 61 tonnes projected in Section 5 above.

The data in appendix 5 indicates that the vessel would have remained upright and stable with 30 tonnes of floodwater in the aft peak and 5 tonnes floodwater in the engine room bilge.

9. Conclusion

The trim and stability data coupled with the timeline indicates that flooding into the aft peak had an average flow rate of about 790 litres per minute (13.2 litres per second), varying considerably as the compartment filled and the vessel sank deeper in the water. The location of the damage is not known but given that it was caused by a trawl door, it is reasonable to assume that it was on the turn of bilge in the vicinity of the trawl blocks, i.e. approximately 3 metres forward of the AP and between the waterline and 1.8 metres below the waterline. The resultant breach area is estimated to range from more than 111cm^2 to 37cm^2, respectively.

The submersible pump had a maximum capacity of 250 litres per minute which was less than a third of the inflow rate. If the drain valve in the aft peak bulkhead had been left open and the engine room bilge pump had been used to augment the submersible pump, the 61 tonnes of seawater estimated to be aboard when the lifeboat arrived would have been reduced to about 35 tonnes, the vessel remaining stable with both compartments partially flooded.

MAIB Safety Flyer to the Fishing Industry

MARINE ACCIDENT INVESTIGATION BRANCH

SAFETY FLYER TO THE FISHING INDUSTRY

Flooding and foundering of the trawler *Ocean Way* on 3 March 2017

Image courtesy of the RNLI

Ocean Way listing to port and trimmed by the stern just prior to foundering

Narrative

At 0834 on 3 March 2017, the twin-rigged stern trawler *Ocean Way* foundered 18 nautical miles north-east of Lerwick, Scotland. *Ocean Way*'s crew was rescued uninjured and returned to shore by the Lerwick lifeboat. *Ocean Way* was lost because of an uncontrolled flood in the aft compartment; the source of the flood was almost certainly hull damage caused during the recovery of the port trawl door after the nets had been fouled on an obstruction.

Ocean Way's aft compartment was separated from the engine room by a watertight bulkhead. There was no bilge suction or bilge alarm in the aft compartment; however, when the flood started, water initially poured into the engine room bilge via a drain valve through the bulkhead. After the engine room bilge alarm sounded, the crew discovered floodwater filling the engine room bilges.

The crew attempted to control the flood using the fixed bilge pumps in the engine room and portable submersible pumps via the aft compartment escape hatch. As the flooding took hold in the aft compartment, *Ocean Way* adopted a bow up trim that rendered the pumping from the engine room ineffective. In addition, the portable pumps were susceptible to blockages by debris in the aft compartment and the flood was never brought under control. *Ocean Way* was lost when the aft compartment escape hatch submerged, resulting in overwhelming downflooding.

Safety lessons

The crew of *Ocean Way* could not have done a great deal more to save their vessel. However, post event analysis has shown that there were other possible options to consider. These included potentially increasing the portable pumping effort by early embarkation of the coastguard helicopter's salvage pump, or containment of the flood by shutting off the compartment. However, it is uncertain that either of these actions would have saved the vessel.

Onboard training and drills had not prepared the crew of *Ocean Way* for the scale of flooding they faced on the day of the accident. Flooding presents an immediate and potentially overwhelming risk to fishing vessels – it should be considered as dangerous as a fire. Industry guidance is clear that when a flood is detected, the crew's top priority must be to bring the situation under control ahead of other considerations. Every effort must be made to control the flood by maximising pumping, keeping suctions clear and considering all available options.

The only way crews can be as prepared as possible to deal with foreseeable emergencies is to conduct regular, realistic drills. Use these as an opportunity to develop and then practise potential coping strategies in the event of major flooding. Discussing the scenarios and the response plans before the drill can be a good way of embedding best practice. Conducting a wash-up after the drill will also help crews to gain a shared understanding of how to respond to an emergency and develop the knowledge and skills needed to give them the best chance of saving the boat and/or preventing loss of life.

This flyer and the MAIB's investigation report are available on our website: www.gov.uk/maib

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