ANNEX 4

Executive summary of model experiments

BMT SEATECH Limited

MFV GAUL
MODEL EXPERIMENTS
IN EXTREME WAVES

EXECUTIVE SUMMARY

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1 EXECUTIVE SUMMARY

Introduction

The new evidence that has been discovered by the recent MAIB underwater survey of the GAUL has raised important issues relating to the cause of the loss. For example, if the fish loading hatches had been left open, or had been opened by a build up of air pressure within the vessel, did the hatches contribute to her loss? Although the exact reasons for the loss have not been established, the MAIB have considered a number of hypotheses relating to the flooding of the factory deck and engine room, when engulfed by a succession of three abnormally large waves, on her port beam or quarter.

Model experiments in extreme waves were carried out by BMT SeaTech Limited, to test the validity of the MAIB hypotheses on the cause of loss, and to investigate other theories for the open fish hatches. These experiments would help to establish how the GAUL would have responded to a group of very large waves, in particular when the fish hatches and access doors on the trawl deck were open.

Weather Conditions

On the day that the GAUL was lost on 8th February 1974 the seas off North Cape Bank were reported to be huge by late morning. At the Formal Investigation into the loss of the GAUL, the Institute of Oceanographic Sciences estimated the significant height of the waves to be 6.7m at 10.30 hours on 8th February 1974 and 7.6m at 16.30 hours. Three particularly large waves were observed at the time that knocked the stern trawler SWANELLA off her course. The height of these waves was estimated at the Formal Investigation to be as high as 16.8m, from crest to trough. The Institute of Oceanographic Sciences estimated the wind force at the time of loss to be up to Beaufort force 9 or even 10, with intermittent snow squalls.

Review of severe waves

Dr Neil Hogben, an authority on ocean waves, made a review on the modelling of severe waves, (Annex 1), in November 1998. This gave guidance on suitable parameters of wave groups for use in the model experiments. The review confirmed that the tendency for waves to form groups, characterised by sequences of relatively high crests separated by areas of comparative calm, is a well established feature of the real sea. These wave groups are indeed a natural consequence of the 'beating' between pairs of wave trains with nearly equal frequencies that move in and out of phase. Wave groups are most pronounced in sea states corresponding to narrow banded spectra

The maximum individual wave height for a wave corresponding to the significant wave height of 7.6m at the time of loss was estimated to be 18.3m. This wave height was considered to be an extreme but not a freak wave.

The Model

A 1:46 scale model of the GAUL was constructed by the Hydrodynamic Test Centre at Haslar and completed in December 1998. Experiments with this model would establish how the vessel would have responded to a group of very large waves. The model was fitted with a superstructure, a factory deck below the trawl deck, and a number of watertight bulkheads. A number of openings were arranged in the model to correspond to the ventilator openings, access openings and hatchways, on and above the trawl deck. These openings would give rise to downflooding in the event of green water being shipped onto the trawl deck, or when the model was heeled over at large angles to starboard. Some of these openings would lead to flooding of the factory deck and others to the engine room.

Stability Condition

The stability condition selected for the model experiments was that given by the Department of Trade condition for the GAUL at the time of the Formal Investigation. This gave a trim of 2.47m by the stern and metacentric height, GM fluid, of 0.935m. The selection of this condition for the model experiments is supported by information given in the transcripts of the Formal Investigation.

Model Experiments

The model experiments were conducted in the Ship Tank at the Hydrodynamic Test Centre, Haslar, during December 1998 and January 1999. The main objectives of the experiments were firstly to determine how the GAUL would have responded to a group of three large waves. Secondly, to determine if the vessel would have been endangered if door 13 (access to factory deck from trawl deck), and door 14 (emergency escape from engine room) were left open at the time and in addition if the fish loading hatches had been left fully open.

The model was subjected to extreme regular waves with heights corresponding to 18.3m and irregular waves with similar heights. For the irregular waves a JONSWAP wave spectrum was used with a non-standard enhancement factor to generate small groups of steep waves. The heights of the individual waves within the groups ranged from between 14m and 22m, and the extreme wave steepness caused some to break.

Experiments were carried out with the model tethered beam-on and in stern quartering waves, and with the model free to drift. Manoeuvring tests were also carried out in extreme waves at various headings. A number of experiments were made in order to determine whether the GAUL would have been endangered if various openings to the factory deck and engine room were left open. For these experiments openings to the factory deck (door 13, fish loading hatches and ventilators) followed by openings to the engine room (door 14, ventilator on portside and starboard funnel ventilator) were left open.

With the model positioned in beam seas and struck by a breaking wave the model was knocked down to a roll angle of approximately 90°. The model always recovered from this position in a relatively short period of time, assisted by the buoyancy of the model's superstructure that provided large restoring moments at higher angles of heel. In less extreme waves green water was shipped onto the trawl deck and this was effectively discharged over the after bulwarks, through the freeing ports, or down the stern ramp. The largest quantities of water reaching the factory deck and engine room followed repeated knockdowns of the model.

During the initial calibration of wave groups the model was knocked down and inverted to 180°, in a breaking wave corresponding to 22m from crest to trough. However, it is considered extremely unlikely that a wave of this height would have occurred in the area of the North Cape Bank at the time of loss.

When manoeuvring in beam seas the model tended to take up a heading slightly into the waves and did not experience a knock down. These tests were carried out in the absence of wind. The effect of strong wind on the superstructure would undoubtedly have an influence on this orientation when heading up into the wind. The effect of downflooding to the factory deck would also impair steering ability at all headings.

Conclusions

The experiments on the model of the GAUL explored how the vessel would have responded to a group of very large waves in the event that access door 13 and the fish loading hatches on the trawl deck were left open.

The findings of these experiments are consistent with the previous model experiments carried out by the National Maritime Institute (a predecessor of British Maritime Technology Limited, the parent company of BMT SeaTech Limited), that the GAUL had adequate intact stability and adequate manoeuvring and seakeeping qualities. The experiments found two particular situations that could lead to the vessel to become endangered:

- The first is that of a vessel being knocked down momentarily in beam seas by a large breaking wave, the first of a group of three waves. The large roll angles and accelerations experienced in a knock-down would be sufficient to cause a cargo shift and injury to the crew on board the vessel. This would be followed by downflooding over a relatively short period of time of about 30 minutes.

- The second situation is that of progressive downflooding, over a longer time period, from water shipped onto the trawl deck flooding through door 13 and the fish loading hatches to the factory deck below.

The experiments in steep breaking waves only covered a limited range of wave heights that were considered to be representative of extreme, but not freak waves. The hydrodynamic event of a breaking wave impacting on the side of a hull and superstructure is essentially non-linear, both for the wave and the vessel's response, and consequently there may be uncertainties of scaling from model to ship. Despite these uncertainties the roll-sway characteristics experienced by the ship during a knock down will be similar to those experienced by the model.

The subsidiary conclusions of these experiments and the calculations are as follows:

(i) The manoeuvring experiments in extreme seas in head, beam and stern quartering headings, indicated that the vessel would probably have survived the extreme waves, with all openings on the trawl deck closed watertight.

(ii) The model sustained knock-downs when beam-on to the on-coming waves. This only happened when the wave was breaking, the high energy jet from the breaking crest resulting in a severe roll as it hit the topsides of the model.

(iii) The maximum roll angle following a knock-down was approximately 90°. The corresponding roll rate and acceleration for the ship was 22° per second and 16° per second^2, respectively.

(iv) The mean roll angle following a particular knock-down (Run 28) was 30° to starboard. The time taken for the vessel to return to the upright, without the effect of wind and cargo shift, would be well over a minute.

(v) The maximum air pressure acting against the underside of the fish loading hatches, assuming flooding through doors 13 and 14 was calculated to be 478 N/m^2. This pressure occurred when the vessel had sunk to a depth of 80m.

(vi) It is unlikely that a sufficient air pressure could be generated to open the fish hatches during the sinking of the vessel, if the air in the factory deck was able to exhaust through vents. If the vessel sank steeply by the stern then this would in any event, be an impossibility.

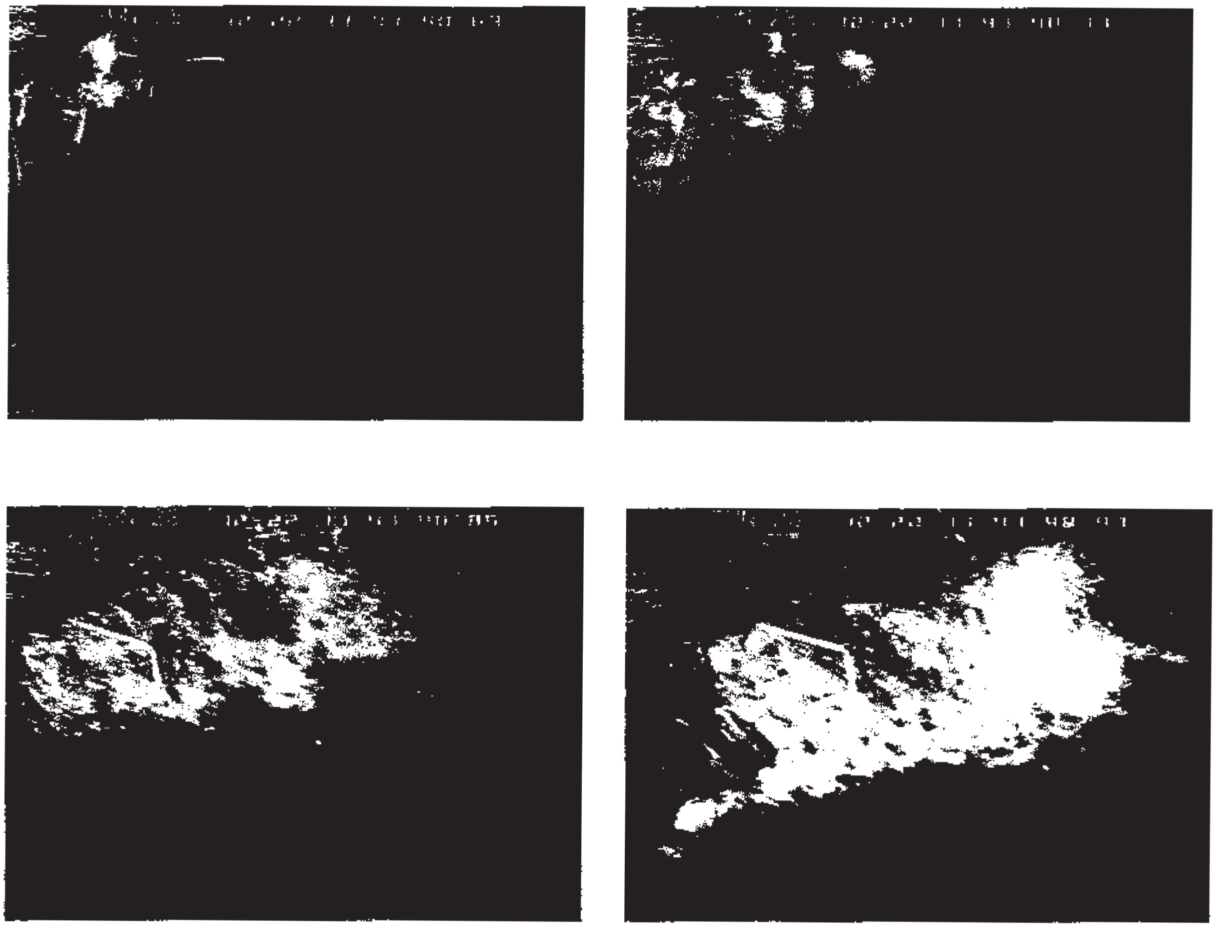
(vii) For the fish hatches to be opened during a knock-down, the local accelerations at the hatches would have had to overcome:

- the friction of the hatch system
- the grip of any locking devices
- the hydraulic system holding the hatches closed
- the gravitational forces on the hatches

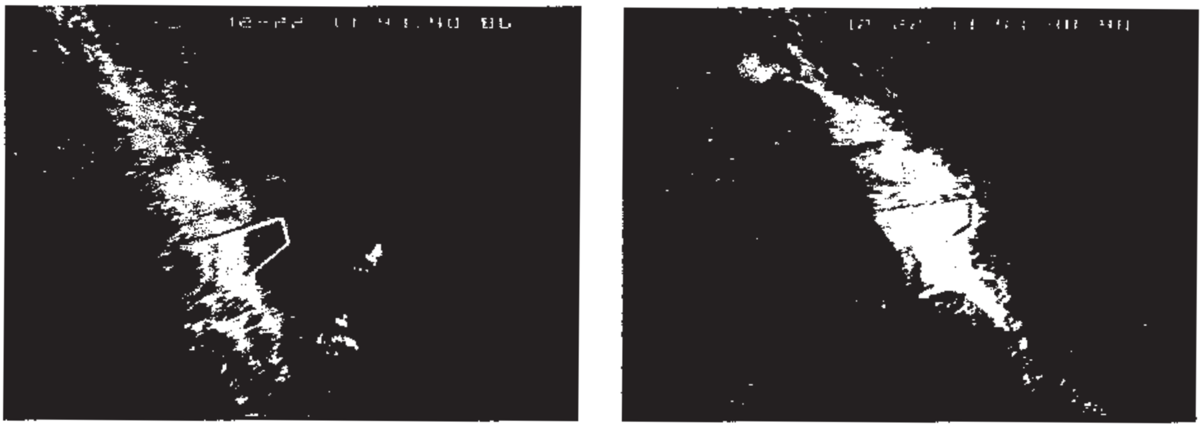
Roll velocities corresponding to 22° per second were measured on the model during a knock down. The magnitude of these velocities is unlikely to overcome gravity and open the hatches. However, if the roll angle exceeded 90° then gravity would tend to open the hatches.

(viii) The sinking test of the model confirmed that the vessel would initially heel to starboard and then sink steeply stern first, as a result of flooding through the openings in the trawl deck.

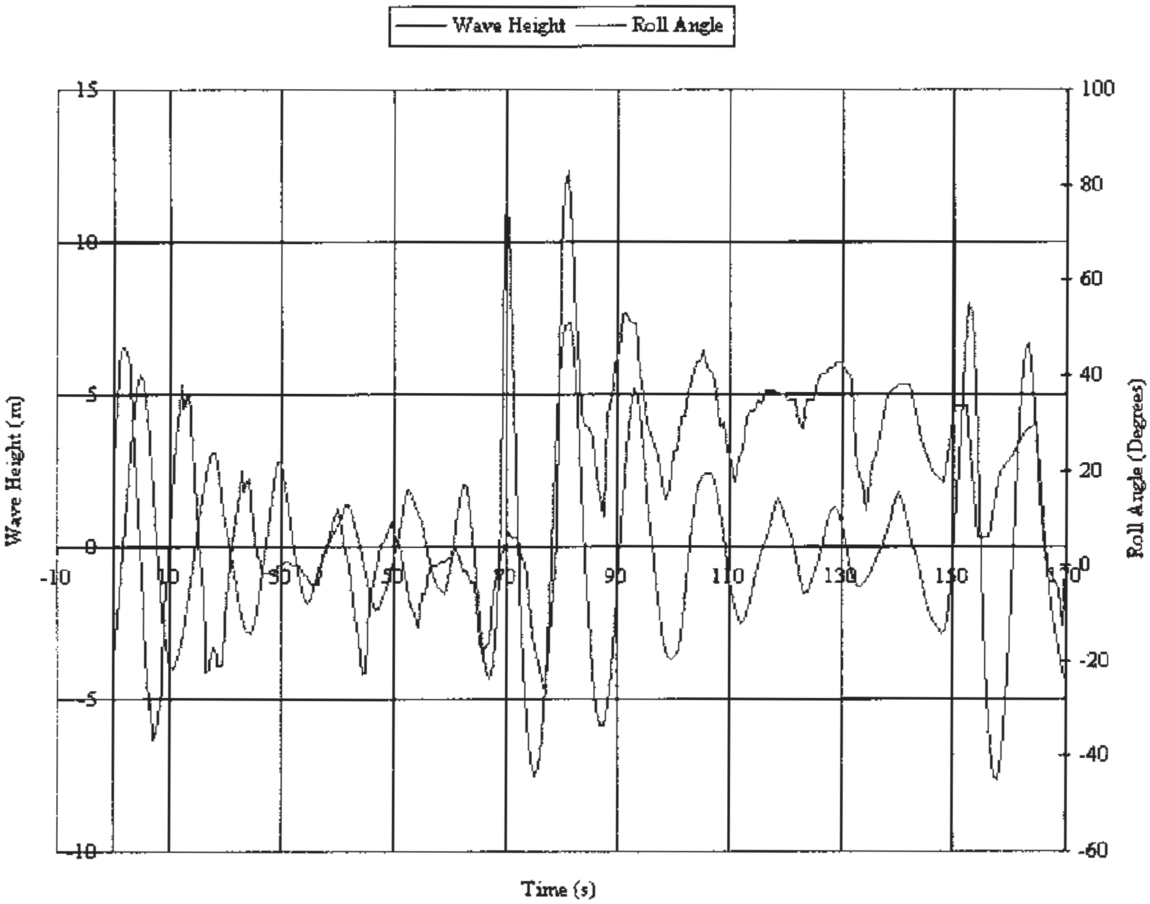
The model of the GAUL being subjected to a breaking wave



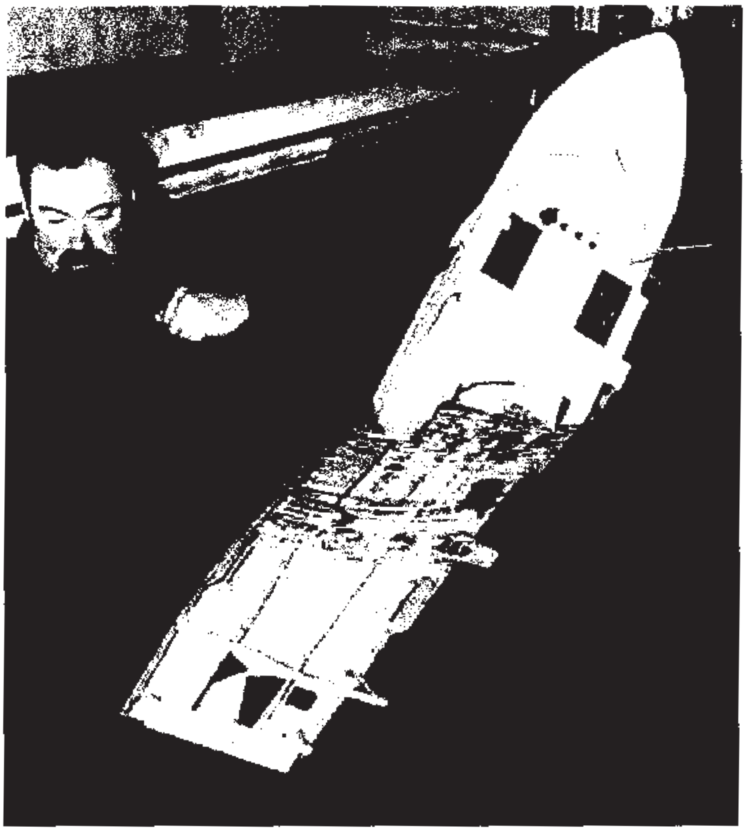
Various stages of a *knock down* experienced by the model of the GAUL in Run 28, from the moment of wave impact in the upright position to a roll angle of 90°.



The final stages of the *knock down* experience by the model of the GAUL in Run 28, viewed from a different position.



A trace of the wave heights and the roll motion of the GAUL model for Run 28, during which a *knock down* occurred. The height of the first steep wave of the wave group was 18m from crest to trough. This wave became a breaking wave and was responsible for the *knock down*. The wave trace represents the wave profile at the model's mean position at the start of the run.



The model of the GAUL sinking rapidly stern first, as a result of down flooding through doors 13 (access to factory deck) and 14 (engine room escape), the fish loading hatches, vents to factory deck and engine room, and vents in the starboard funnel.