Report of the Investigation

into the grounding of the tanker

BORGA

at Milford Haven

on 29 October 1995

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The fundamental purpose of investigating an accident under these Regulations is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

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1. SUMMARY

During the morning of 29 October 1995 the Norwegian motor tanker BORGA ran aground in Milford Haven whilst under pilotage. The weather was good with a south-easterly force 3 wind and clear visibility.

At the time of the accident the vessel was loaded with 112,180 tonnes of crude oil, but although the vessel's hull was damaged the cargo tanks remained intact and there was no oil pollution. She is not a "double hull" tanker but is constructed with segregated ballast and double bottom tanks.

Two attempts were made to pull the vessel off using tugs, but both were unsuccessful. A third attempt after the vessel had been lightened by 8,500 tonnes of cargo was successful and she refloated. BORGA eventually discharged her remaining cargo at Milford Haven before proceeding to Hamburg for repairs.

The bottom hull plating and framing suffered varying degrees of torn plating and scraping damage on both sides of the bow. Additional damage, including minor plate tears, was found on the port side in way of the bulkhead separating Nos 2 and 3 double bottom ballast tanks.

The cause of the grounding was due to a failure to compensate quickly enough for the vessel's rate of turn to port by applying sufficient starboard helm following an alteration of course. The helm was put hard-to-starboard as soon as it was realised that the vessel's head was continuing to turn to port. Also astern propeller pitch was applied, bow and stern thrusters were activated, and both anchors were let go. Despite all these actions the vessel ran aground at 0755 hrs.

BORGA had the manoeuvring characteristic that, although her head turned to port when her propeller pitch was at full speed astern, her head turned to starboard at slow speed astern.

Recommendations have been made with a view to ensuring that the provisions of the International Chamber of Shipping's Bridge Procedures Guide are more closely followed, and for consideration to be given to extending the existing steering gear electrical power failure alarm required by SOLAS to include a low hydraulic pressure alarm.

PART I FACTUAL ACCOUNT

2. PARTICULARS OF VESSEL AND CREW

2.1

Type	:	Motor Tanker
Name	:	BORGA
Built	:	1992 Astilleros Espanoles, Bilbao, Spain
Port of Registry	:	Bergen, Norway
Gross tonnage	:	66,671
Deadweight	:	123,665 tonnes
Length overall	:	264.45 metres
Breadth	:	42.53 metres
Maximum Draught	:	15.218 metres
Main Engine	:	B & W Type 6S70MC 2 stroke 6 cylinder driving a single controllable pitch propeller
Propulsion power	:	14728 kW
Steering gear	:	Porsgrunn, Rotary Vane Type 650-250/2-IMO, Electro-hydraulic.
Rudder	:	Becker (max angle 60°)
Thrusters Bow	:	2 x 1618 kW
Thruster Stern	:	1 x 1029 kW
Owners/Managers	:	A/S J Ludwig Mowinckels Rederi Bergen, Norway
Classification	:	Det Norske Veritas (DNV)

The vessel has 16 cargo tanks, 8 double bottom and 4 segregated ballast water wing tanks. She is not a "double hull" tanker. The engine room, accommodation and bridge are aft with the pump room immediately forward of the accommodation block. A cargo loading facility is built forward for connection to a Single Buoy Mooring (SBM).

2.2 There was a total crew of 24 which included the Master, Chief, First and Second Officers, Chief, First and Second Engineer Officers and an Electrician. All officers were experienced in tanker operations and were certificated as required for their positions of authority on board.

2.3 All the vessel's International Safety Certificates were valid.

2.4 **Steering System**

The rotary vane steering gear system is of Norwegian manufacture, and is of the electro-hydraulic type. Steering control is via a 110v dc system which is brought into action by movement of the steering wheel. Movement of the wheel causes an electrical signal to be sent aft to a solenoid valve controlling the flow of high pressure hydraulic oil. The hydraulic system consists of two electrically driven screw pumps supplying oil under pressure to a rotary vane steering actuator fitted directly onto the rudder stock. The hydraulic pumps can be started either locally in the steering gear room aft or from the bridge console. Each pump and its associated hydraulic system can be operated either independently or in parallel. On this vessel, control of the operating mode can be, and usually is, made from the bridge console.

Alarms are fitted to cover an overload situation, partial electrical failure of a drive motor, loss of steering control (electrical failure), valve block failure, and low oil level. The steering system can be started either locally in the steering gear flat aft or from the bridge. An auto-start or standby facility is fitted. A duplicate alarm panel is fitted in the engine control room. A non follow-up steering control lever is fitted to the starter boxes in the steering flat.

The steering console on the bridge is on the centre line of the vessel, set back approximately 1.5 metres from the wheelhouse windows, and gives the helmsman a good, wide arc of visibility forward. The console is fitted with a small diameter steering wheel, rudder angle indicator, gyro-compass repeater, and a combined ship's head and digital gyro repeater box. The steering wheel movement is limited to 60° either way. Rudder angle indicators are fitted on the bridge wings, and amidships on the deckhead above the wheelhouse windows. A "rate of turn" indicator and a main engine speed indicator are also fitted on the deckhead amidships.

2.5 **The Rudder**

The rudder is a Becker type, 6 metres long overall with a 1.5 metre movable fin on the trailing edge and approximately 9 metres in height. The rudder has an area of 55 m^2 and was designed for a vessel operating speed of 14.5 knots. The maximum angle to which the main rudder can be put is 60° either way.

The fin is secured to the trailing edge of the main rudder at three hinge points and is operated by means of a sliding arm arrangement between a fixed pivot point on the hull and a box structure fitted on the top edge of the fin. The fixed pivot point is 1260 mm aft of the centre line of the rudder post. On the main rudder moving off centre, the sliding arm rotates about its pivot point and by reason of the sliding arm being restrained by the box structure, exerts a turning movement on the fin relative to the main rudder. The angle of the fin is approximately twice that of the main rudder resulting in better lift characteristics (see Figures 2 and 3).

The Becker rudder, with its ability to offer a 60° rudder angle, has particular advantages over more conventional rudders when the vessel is operating at low or zero speed. This low speed manoeuvring characteristic is a very desirable feature when the vessel is approaching or at an SBM facility. At higher speeds, the vessel response is most effective with maximum rudder angles of 30° to 40°.

3. NARRATIVE

All times are Universal Co-ordinated Time

3.1 At 1940 hrs on 24 October 1995 BORGA completed loading a cargo of 112,180 tonnes of crude oil from a Single Buoy Mooring in the Draugen Oil Field in the Norwegian sector of the North Sea, and she sailed for her port of discharge, Milford Haven.

The vessel sailed south, passing to the north of Scotland and through the Irish Sea. At 0900 hrs on 25 October, the vessel's speed was reduced due to the onset of bad weather, a south westerly wind of force 8 to 9 with gusts up to force 10. This weather continued throughout the next two days until the wind moderated to force 5 during the evening of the 27 October. The pitch of the propeller was adjusted as necessary during this period of bad weather.

3.2 On 28 October, the Chief Engineer noticed during his rounds of the engineering spaces, that small amounts of metallic dust and oil were present round the base of the starboard steering gear electric motor. As this was not considered to be unusual a more detailed inspection was not carried out. With the vessel's arrival off Milford Haven expected early the following morning, the standard EEC Tanker Check List, Ship/Shore Safety Check List and company vessel pre-arrival checks were started. At 2155 hrs, the Master contacted Milford Haven signal station on VHF Channel 12 and was advised that BORGA should remain outside the port until the Pilot boarded at about 0730 hrs on 29 October.

At midnight, the statistical end of passage was declared, the vessel at that time being in a position with The Smalls Lighthouse bearing 339°(T) at a distance of 8.5 miles. For the next few hours, the vessel maintained a position about 4 miles off the coast, and about 10 miles from St Ann's Head, using the starboard steering gear on autopilot. Whilst the vessel was waiting until the agreed pilot boarding time, the engine control room was manned by the duty Engineer and a rating. During the night the weather had moderated further to south easterly force 3 with a visibility of about 6 miles.

At 0600 hrs, the second or port steering motor was started and steering changed over to manual. All four generators were then placed on line and the three transverse thruster motors started.

3.3 With the helmsman on the wheel and the daywatch turned to, the anchors were cleared away ready for port entry. At 0700 hrs, the signal station was contacted and the vessel turned towards the pilot boat, course and speed being adjusted as necessary to make the 0730 hrs rendezvous.

The Chief Officer came on the bridge at 0700 hrs, checked and completed the pre-arrival check lists as well as plotting the vessel's position on the chart. At 0730 hrs, the Pilot boarded the vessel and arrived on the bridge at 0732 hrs. At that time the vessel was on a heading of 032°(T) with the propeller pitch on 30% ahead.

During pilotage, it was the usual practice on BORGA for the Master to operate the main engine controls and for the Chief Officer to record the engine movements in the Bridge Bell Book.

3.4 The Pilot, after receiving confirmation from the Master that the vessel had no defects, asked for "Full Ahead", and a minimum of 10 knots for passing between the buoys. The Master increased the pitch to 60% and the vessel slowly increased speed on a heading of 036° (T) towards the entrance channel to Milford Haven. At 0735 hrs, the vessel's speed was in the order of 5 knots and still increasing, the pitch having been increased to 80%. The Chief Officer ascertained the position of the vessel at this time using a manual radar bearing and range of Turbot Bank buoy and plotted the position on the chart. At 0740 hrs, another position was plotted on the chart with the vessel still on a heading of 036°(T); the course was then adjusted to 027°(T). At 0745 hrs, with the vessel on a heading of 026°(T), a further position was obtained using Middle Channel Rock.

At 0746 hrs, as the vessel was entering West Channel with speed of 9.12 knots over the ground, the Pilot ordered a starboard alteration of course to 040°(T). As the vessel came onto the new heading the helmsman applied about 5° of port rudder to stop the vessel swinging as she steadied on the new heading. The Master, who was standing by the engine controls, noted the new heading and that the helmsman had responded correctly to the Pilot's instructions, the vessel taking up the new heading without any apparent difficulty.

3.5 After they had been on the new course for about two minutes, the vessel suddenly started to turn to port causing the helmsman to apply between 5° and 10° starboard helm to correct the vessel's swing. The Chief Officer had fixed the position of the vessel at 0749 hrs using a manual radar range and bearing of Middle Channel Rock and was plotting the position on the chart. The Pilot asked the helmsman if he was coming to port and instructed him to apply starboard helm, to which the helmsman replied that starboard rudder was already on. The Master, hearing this, noted that the rate of turn indicator showed a high rate of turn to port. He was of the opinion that the bow was moving rapidly towards Mill Bay buoy although the rudder indicator was showing between 40° and 50° to starboard. As a precautionary measure he applied 60% astern propeller pitch.

The Master checked the rudder indicator on the steering console and increased the starboard helm to 60°. At the same time, he observed a decrease in the rate of turn to port, watched it steady and then again increase to port. While the Pilot was calling the signal station on his VHF and informing them that the vessel had "a complete loss of steering...", the Master, using a portable VHF set, called the First Officer and told him to go forward immediately and let go the anchors. The Pilot ordered hard to starboard.

3.6 The vessel continued to swing to port despite the fact that 60° of starboard helm was being applied. The Pilot ordered full astern. The Master put the forward transverse thrusters full to starboard, the stern transverse thruster to port and at the same time, pulled the main engine control back to full astern. At 0753 hrs the Pilot told the signal station that the vessel was about to go aground. The First Officer having arrived on the forecastle, let go the port anchor first, followed by the starboard anchor. The weather at this time was still force 3 with a northerly tidal stream of about 0.6 knots. At 0755 hrs a further call was made reporting that the vessel was aground. The Pilot also asked for the Marine Pollution Control Unit to be advised of the situation.

3.7 The vessel's speed prior to the apparent steering malfunction had been in the order of 10 knots but at the time of grounding the speed was in the order of 4 to 5 knots. The vessel initially settled on a heading of 308°(T) and took a slight list to port. The port anchor held at 9 shackles and the starboard anchor at 4 shackles. No alarms sounded on the bridge either before or after the apparent steering failure.

3.8 The Chief Engineer, who had been in the engine control room during the channel transit, first became aware that something was wrong when he heard the Master on the portable VHF telling the First Officer to go forward and let go the anchors. He immediately checked the main engine gauges, saw that the main engine was operating correctly and that the pitch indicator was moving from half astern to full astern. The rudder indicator was showing full starboard helm. The Chief Engineer, together with the Electrician, immediately went aft into the steering gear room to check the system. The manual indicator fitted directly onto the stern post showed 60° to starboard, the pointer being hard up against the stop. The electric motors driving the hydraulic motors were checked and found to be running and everything seemed satisfactory. They then returned to the engine control room and felt nothing unusual until the vessel took a slight list to port.

3.9 After grounding, the propeller pitch was set to zero and the main engines and the three transverse thrusters were stopped and shut down. The Master ordered soundings to be taken on board the vessel to assess the damage.

3.10 The fore peak was found to be holed together with hull plate damage to Nos 2 and 3 port double bottom ballast tanks. There was no pollution.

3.11 The Harbour Authorities, having been alerted by the Pilot, took charge of the salvage operation and organised four tugs and two oil reclamation vessels to attend the vessel. The first attempt to pull BORGA off at 0822 hrs was unsuccessful and the attempt was abandoned. On the arrival of the port authority vessel SEA TRUCK, the Pilot arranged for soundings to be taken around the vessel. With high water due at 0930 hrs, a further attempt to pull the vessel off was made but this was also unsuccessful.

3.12 Arrangements were made with various coastal oil tankers and a lightening operation started at 1018 hrs on 29 October and continued throughout that day and the next morning. The last lightening vessel left BORGA at 0920 hrs on 30 October when about 8,500 tonnes of crude oil had been offloaded.

The four original tugs plus a fifth, ANGLIAN EARL, had been made fast to BORGA earlier that morning and at 0923 hrs another attempt was made to pull her free. At 0924 hrs the vessel was refloated with draughts of 13.7m forward and 14.85m aft. The starboard anchor was recovered but the port one remained caught on the sea bed and its cable was let go and buoyed for retrieval at a later stage.

Once back in the channel, the vessel proceeded to the Herbrandston No 2 berth, Milford Haven, under her own power but with tugs in attendance. The vessel was all fast alongside at 1200 hrs on 30 October. Discharging started later that day and continued for two days.

3.13 Concerned at a possible recurrence of the apparent steering failure during BORGA's transit of the Channel Traffic Separation Scheme, The Coastguard Agency insisted that the vessel was provided with an escort tug when she sailed for Hamburg after completing discharge on 2 November.

3.14 BORGA arrived in Hamburg on 6 November and entered drydock during the early hours of 7 November.

(A chartlet indicating the track and positions of the vessel is at Figure 4)

PART II CONSIDERATION OF POSSIBLE FACTORS

4. EXTENT OF DAMAGE

4.1 Damage to vessel caused by grounding

The hull inspection carried out in Hamburg on 7 November confirmed that grounding damage was restricted to the fore end of the vessel. There was no damage to either the rudder or propeller, indeed generally the paint work on the bottom and sides of the hull was undamaged and in good condition.

General grounding damage ran from the underside of the bulbous bow aft along to the transverse bulkhead between the forepeak and No 1 tank on the port side and to just abaft the transverse bulkhead between Nos 1 and 2 tanks on the starboard side. A major tank penetration was present on the starboard side near the after end of the forepeak and to a lesser extent on the port side mid length of the forepeak.

There was additional damage on the port side, a short scrape with plating set up in the region of the transverse bulkhead between Nos 1 and 2 tanks, with a more serious indentation in the region of the transverse bulkhead between Nos 2 and 3 tanks. This latter damage was at the turn of the bilge and just forward of the start of the port bilge keel.

A significant damage line could be seen in the area of the bulbous bow running from port to starboard. This damage was roughly semi-circular in shape and ran at an angle of about 70° to the keel line from the port side, just under and forward of the forward bow thrust unit, to the starboard side, under and just aft of the after bow thrust unit (see Figures 5 and 6).

5. STEERING SYSTEM FAILURE

5.1 During the lightening operation on the afternoon of 29 October, the Chief Engineer discovered that the mechanical coupling between the electric motor and the hydraulic pump on the starboard steering gear had sheared.

It is not known at which point it had sheared because the alarm system fitted to the hydraulic system is activated by an electrical failure, not by individual pump outlet pressure. In this case, the electric motor continued to run, giving the impression both on the bridge and in the engine control room, that the steering gear was functioning correctly.

Both steering gear motors must have been operating at the time of the coupling failure as it was only at approximately 0600 hrs that morning that the port steering gear was switched on. Prior to that, the starboard steering gear had been in use during the passage south to Milford Haven. It follows that it is probable that both steering gear pumps were in operation when BORGA entered the channel.

5.2 Initially the investigation into BORGA's grounding centred on the sheared coupling of the starboard steering motor and the possibility that its failure had precipitated the vessel's sudden shear to port.

The steering gear manufacturer's engineers attended and carried out a thorough examination and operational check of both the mechanical and electrical parts of the steering system. Apart from the obvious failure of the starboard coupling, no mechanical or electrical defects were found in either the port or starboard steering systems.

An examination of the broken coupling showed that it had experienced considerable wear over a relatively short period of time - the electric motor bearings having been renewed in July 1995 when the coupling was reported to be in a good condition. Further discussion with the manufacturers established that this high wear rate was indicative of mis-alignment between hydraulic pump and electric motor drive. With the coupling being screened by a protective cover, the mis-alignment and high wear rate had not been observed by the engineering staff.

5.3 A new coupling was fitted to the starboard pump and, as a precaution, a new flexible coupling element (spider) was fitted on the port pump.

The steering system was tested operationally using first one pump, then both pumps, against time of operation and accuracy between actual rudder angle and indicators in the engine control room and on the bridge. No significant differences were found. The steering gear alarm system was also tested and found to be functioning correctly. It is reasonable therefore to state that, although a failure of the starboard steering gear drive coupling would have affected the speed of response, this in itself would not have been a contributory factor in the grounding of the vessel.

5.4 The steering gear system as installed complied with the requirements of the 1974 SOLAS Convention and the 1978 Protocol, Chapter II-I, Part C, Regulations 29 and 30, and in particular Regulation 29, paragraph 8, section 8.4, which states:

> *"in the event of a failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigating bridge";*

Despite the fact that the vessel complied with the requirements of the 1974 SOLAS Convention and the 1978 Protocol, the current requirements for minimising the risk under a single failure regime cannot be considered satisfactory. The failure of a coupling could lead to a situation whereby the rudder control system is disabled without any warning being transmitted to the bridge. Given that the essential feature of any hydraulic system is its pressure, the fitting of a hydraulic pressure sensor on the outflow side of each pump should be considered. This sensor should either be in lieu of, or additional to, the electrical failure alarm.

6. NAVIGATION AND PILOTAGE

6.1 The possibility of an error on the approach to, and transit of, West Channel has been considered on the basis of the evidence gathered from the chart in use at the time of the grounding, from observations made by those on the bridge, and from evidence obtained from the course recorder trace.

6.2 In a position one mile outside the entrance to West Channel, a westerly tidal stream was predicted to begin at 0805 hrs. However, it is possible that the vessel was influenced to some extent by the start of the westerly tidal stream and by the prevailing light south-easterly wind prior to her entering West Channel. This is supported by the recorded headings of 026°(T) and 027°(T), which were required to be steered in order to make good a course of 023°(T).

Although the vessel was reported by the Pilot to have been on the 022°(T) leads at the time of boarding, the charted positions indicate that the vessel was, in fact, to the west of the leading line prior to 0740 hrs. This is supported by the recorded alteration of heading from 036°(T) to 027°(T) at 0740 hrs.

6.3 At 0746 hrs, with the entrance buoys abeam, the Pilot ordered the helmsman to steer 040°(T). The early helm order correctly anticipated an advance of the vessel, due to a combination of her speed and the time required to alter her heading, so as to be on the 040°(T) leads at 0747 hrs.

From the available evidence, it is apparent that no further helm orders were given prior to the incident. However, the course recorder trace indicates that the heading progressively altered from 040°(T) to 043°(T) between 0747 hrs and 0749 hrs.

6.4 The predicted tidal stream in West Channel for 0749 hrs was 021°(T) x 0.6 knots. Between 0747 hrs and 0749 hrs, it is probable that the combined effect of the tidal stream and the prevailing wind caused the vessel to be set to the north of the 040°(T) leading line. This is supported by the charted position for 0749 hrs.

At 0749 hrs, the heading and approximate speed of the vessel were 043°(T) and 10 knots respectively. It was then that the vessel rapidly and unexpectedly started turning to port.

6.5 A hydrographic survey of the area was carried out after the incident and did not identify any uncharted obstructions. The vessel was clear of all other vessels and charted obstructions and was in an appropriate position within West Channel. The depth of water was approximately twice the draught of the vessel and it is unlikely that the rapid turn to port was initiated in any way by the effect of hydrodynamic interaction. However, it is probable that hydrodynamic interaction had an increasingly significant effect after the vessel moved out of the channel and entered the relatively shallow water of Mill Bay prior to running aground.

6.6 Between 0747 hrs and 0749 hrs, it is possible that the helmsman inadvertently allowed the heading to alter to starboard of the required course and then took action to regain the 040°(T) by applying port helm.

Although the helmsman probably intended to remove the port helm as soon as the vessel started to swing to port, it is possible that he inadvertently delayed his action causing the vessel to overshoot the required heading and to continue to turn to port at an increasing rate.

The helmsman then applied starboard helm in order to arrest the turn to port. However, the inherently delayed response of the rudder and vessel to the starboard helm prevented an immediate reduction in the rate of turn.

6.7 The course recorder trace (see Figure 7) indicates that the rate of turn to port initially increased rapidly and started to decrease when the vessel reached a heading of about 030°(T). This suggests that the amount of initial port helm was significant. It also suggests that starboard helm was applied before the vessel reached a heading of 030°(T) and this is supported by witness evidence to the effect that Mill Bay buoy was still seen on the port bow after starboard helm had been applied.

As shown on the course recorder trace, the rate of turn started to increase again when the vessel reached a heading of about 025°(T). Witness evidence suggests that the helm was 60° to starboard at that time and that the propeller pitch was not put to full astern until after the rate of turn had started to increase. However, it is probable that the propeller pitch was put astern before the vessel reached a heading of 025°(T). This is supported both by the Bridge Bell Book entry for 0749 hrs, which indicates that 60% astern pitch was applied at that time, and also by the Chief Officer's evidence that the Master put astern propeller pitch on before the rate of turn started to increase again.

6.8 This led the Inspectors to believe that the increased rate of turn to port might have been related to the fact that the propeller had been put into astern pitch. The investigation therefore concentrated on the manoeuvring characteristics of the vessel.

7. MANOEUVRING CHARACTERISTICS OF BORGA

7.1 The combined effect of a controllable pitch propeller and a Becker rudder on this vessel produces differing manoeuvring characteristics depending on the vessel's speed. Sea trials undertaken when the builders delivered BORGA showed that once the vessel had attained a speed of 11.3 knots a simple change to zero pitch resulted in the vessel turning to port through 170° if no corrective helm was applied.

7.2 Further analysis of the trial data shows that at slow speed (5.0 knots and under) the vessel turned to starboard when astern pitch was applied. However, when the vessel's speed was increased to approximately 11.4 knots ahead, reversal of the pitch into the astern mode resulted in the vessel turning to port. This latter characteristic is accentuated at limited levels of astern pitch, eg 40%. A précis of the trial results illustrating the above characteristics is given in Figure 8.

7.3 An examination of a recent zig-zag test carried out on the vessel when in ballast at 12.0 knots showed that the "overshoot" between change of rudder angle and change of vessel's heading was in the order of 8° with a time delay of about 15 seconds between opposite rudder angle and the point of change of vessel's heading (see Figure 9).

7.4 With BORGA in the loaded condition with both steering motors on and maintaining a speed of 13.0 knots, application of maximum rudder angle results in a turning circle of 657 metres to port and 620 metres to starboard.

7.5 The characteristic that at higher speeds the vessel turns to port when the propeller pitch is reversed into the astern mode appeared to account for the fact that the rate of turn to port by BORGA increased prior to grounding.

8. SIMULATION EXERCISE

8.1 Having established from BORGA's official trial results that the vessel's manoeuvring characteristics could have been a significant factor in the cause of the grounding, it was decided to try to simulate the incident. Discussions were held with the owners and their consultants, the Ship Manoeuvring Simulator Centre (SMS) in Trondheim, with a view to examining these in more detail on the Trondheim simulator. Accurate mathematical models developed from BORGA's design plans and trial results were already available on the simulator. SMS subsequently visited Milford Haven with MAIB Inspectors and obtained additional details on the topography of the area so that "true" simulation exercises could be carried out.

8.2 A number of possible scenarios were simulated at SMS on 4 and 5 May 1996. For these scenarios the following assumptions were made:

(a) at 0749 hrs, the vessel was in a position with Middle Channel Rock Lighthouse bearing 182° (T) x 0.34 mile (as indicated on the chart in use);

(b) at 0749 hrs, the heading of the vessel was 043° (T) (as indicated on the course recorder trace);

(c) the height of tide was 5.8 metres (as predicted); and

(d) the tidal stream was 021° (T) x 0.6 knot (as predicted).

Although each simulation generally followed the interpreted sequence of events, variations were introduced into the timing of those events in an attempt to replicate as closely as possible what happened on the morning of 29 October.

The following parameters were among those recorded throughout each simulation at intervals of 4 or 5 seconds:

(a) rudder angle;

(b) rate of turn;

(c) heading; and

(d) ground speed.

8.3 A total of 23 scenarios were simulated, all of which supported the theory that the application of the astern propeller pitch was a significant factor in the course of the grounding. However, one set of timings did produce the most likely chain of events which led to the grounding. The details of that scenario are as follows:

- only one hydraulic steering pump was operational at the time and that, at 0749 hrs, the vessel was proceeding at a ground speed of 10 knots.

- in order to turn the vessel promptly from 043°(T) to 040°(T), it would have been reasonable for the helmsman to have applied 15° port helm initially and then to have reduced it to 10°.

- the simulation assumes that approximately 30 seconds before the Chief Officer ascertained the 0749 hrs position, the helmsman applied 15° port helm and that he then reduced the port helm to 10° approximately 10 seconds later.

  NB The time of initial application of port helm is designated as "P" in the following events:

- at 0749 hrs (P + 40 secs), the vessel was on the heading of 040°(T) but turning to port at a rate of 13°/minute. The rate of turn to port continued to increase until 8 seconds after the helmsman applied 10° of starboard helm in order to stop the turn to port and to steady the vessel on the 040°(T) leading line.

- the maximum rate of turn of 14°/minute occurred when the vessel was on a heading of 038°(T). It is assumed that at this stage the Pilot realised that the vessel was turning to port and confirmed with the helmsman that starboard helm had been applied. Appreciating that further action was necessary, it is assumed that the helmsman then increased the starboard helm from 10° to 50°.

- at P + 58 secs, the vessel's head was 035°(T) and still turning to port at 12°/minute with a starboard rudder angle of 11°. The Master could not understand why the starboard helm was having no significant effect in reducing the rate of turn to port and at this stage he applied 60% astern pitch in order to reduce or eliminate the consequences of a possible grounding.

- at 0750 hrs (P + 1 min 24 secs), the vessel was on a heading of 031°(T) and turning to port at a rate of 6°/minute with a starboard rudder angle of 50°. It is assumed that the Master then increased the starboard helm to 60° in an attempt to reduce the rate of turn to port. However, the effect of the transverse thrust of the propeller caused an increase rate of turn to port.

- at P + 1 min 32 secs, the vessel's head was 031°(T) and turning to port at a rate of 7°/minute with a starboard rudder angle of 60°. It is assumed that the Master then applied full astern propulsion in an attempt to further reduce or eliminate the consequences of a possible grounding.

- at 0751 hrs (P + 2 mins 04 secs), the vessel was on a heading of 025°(T) and turning to port at a rate of 15°/minute with a ground speed of 9 knots.

- at 0754 hrs (P + 4 mins 20 secs), the vessel ran aground heading 341°(T) with a ground speed of 5.7 knots.

8.4 This scenario takes no account of the use of the transverse thrusters and anchors. The precise time at which the anchors were let go is uncertain. However, it is probable that the effect of the anchors would have overridden any countering effect of the thrusters and would have caused a further reduction in speed and an increase in the rate of turn to port during the period immediately prior to the vessel grounding.

(A chartlet indicating the track of the vessel from the above simulation is at Figure 10)

PART III FURTHER COMMENT AND DISCUSSION

9. ACTIONS TAKEN BY KEY PERSONNEL

9.1 The Helmsman

The helmsman had served at sea for approximately 10 years. He had worked on board BORGA for about one year and was experienced in steering the vessel in and out of port.

Having appreciated his delay in removing the port helm, the helmsman took action to correct the resultant swing to port. However, his initial application of 5° to 10° starboard helm was significantly less than that required to effectively reduce the rate of turn.

Realising that further action was necessary, he applied 40° to 50° starboard helm, which reduced the rate of turn to port. If the helm had been maintained and the propeller pitch had not been put into the astern mode it is possible that the vessel might then have turned to starboard in sufficient time to regain the channel, and so prevent the grounding.

9.2 The Master

The Master had 10 years command experience including five years on large tankers. Before joining BORGA in May 1994, he had attended simulator training at the Ship Manoeuvring Simulator Centre in Trondheim, Norway.

He became aware that the vessel was turning to port only after the helmsman had applied starboard helm. He was unaware of what had caused the vessel to turn and could not understand why the starboard helm was apparently having no significant effect in reducing the rate of turn to port. He gave no thought to the possibility that the turn had been initiated inadvertently by the helmsman and that the application of starboard helm had not yet had time to take effect.

Because the Master was unaware of what had initiated the turn, he was concerned as to whether or not the vessel would be able to turn to starboard in sufficient time to prevent her from grounding. His immediate reaction was to try to reduce the speed of the vessel by putting the propeller into astern pitch mode. However, in doing this, he should have been aware that on BORGA the rate of turn to port, towards the danger, was likely to increase as a consequence of engaging astern propulsion at high speed.

Nevertheless, in view of the closeness of the land and the speed at which the vessel was approaching it, to engage astern propulsion in an attempt to reduce the speed and to lessen the consequences of a possible grounding, was a reasonable action for him to take.

Also, the use of the anchors to assist in reducing the speed of the vessel in conjunction with astern propulsion was reasonable. However if the appropriate people had been stationed forward in readiness to drop the anchors immediately, instead of having to be called to go forward, it is possible that more effective use could have been made of them.

After applying 60% astern propeller pitch, he increased the starboard helm from between 40° and 50° to 60°. The increased angle would have lessened the effectiveness of the rudder response by reducing the side thrust.

9.3 The Pilot

The Pilot had been a pilot for 22 years at Milford Haven and had piloted vessels of the type and size of BORGA for the last 18 years.

When he became aware that the vessel was turning to port, he instructed the helmsman to apply starboard helm. The rate of turn then started to decrease. Mill Bay buoy was virtually dead ahead and the Pilot estimated that, with continued starboard helm, the vessel would eventually turn to starboard and either clear the buoy to port or leave it fine to starboard.

When the rate of turn to port then started to increase again the Pilot, with good reason, ordered full astern in an attempt to reduce or eliminate the consequences of a possible grounding. He was unaware that the Master had already engaged astern propulsion and that it was the effect of the transverse thrust of the propeller, due to the manoeuvring characteristics of the vessel, which had caused the rate of turn to increase.

10. BRIDGE PROCEDURES GUIDE

10.1 The Bridge Procedures Guide is published by the International Chamber of Shipping. Its purpose is to provide Masters and navigating officers with a summary of day-to-day bridge procedures recommended as good practice for ensuring the safety of the vessel, its personnel and cargo and its efficient operation at sea. The following are extracts:

> "*1.1.2 In order to achieve a sound and efficient bridge organisation, procedures should be established to:*
>
> *(a) minimise the risk that an error by one person will have disastrous and irreversible consequences.*"

> "*1.1.3 Clear instructions should be issued in writing by the master. These should include such matters as:*
>
> *(h) the provision of additional watchkeeping personnel in special circumstances, eg heavy traffic, narrow passages or restricted visibility.*"

> "*2.2.1 The contribution which pilots make to the safety of navigation in confined waters and port approaches of which they have up-to-date knowledge, requires no emphasis; but it should be stressed that responsibility for the ship's navigation is not transferred to the pilot and the officer of the watch retains all his duties.*"

> "*2.2.2 After his arrival on board, the pilot, in addition to being advised by the master of the manoeuvring characteristics and basic details of the vessel for its present condition of loading, should indicate the passage plan he intends to follow. The general aim of the master should be to ensure that the plan is safe and the expertise of the pilot is fully supported by the ship's bridge personnel.*"

> "*3.2.1 The officer of the watch is responsible for the maintenance of a continuous and alert watch. This is one of the most important considerations in the avoidance of collisions, strandings and other casualties.*
>
> *In order to keep an efficient watch the officer of the watch should ensure the following:*
>
> *(d) close monitoring that the course is being steered accurately and that wheel orders are correctly executed.*"

10.2 With regard to the recommendation that procedures should be in place to minimise the risk that an error by one person will have disastrous and irreversible consequences, it is apparent that in this incident the helmsman was not being monitored closely enough to enable his error to be detected and corrected in sufficient time to prevent the rapid turn to port.

Although the Master and the Chief Officer may have been able to adequately monitor the execution of specific helm orders, their additional responsibilities in monitoring the actions of the Pilot and the track of the vessel respectively would have prohibited them from being able to monitor continuously the helmsman.

10.3 An additional bridge watchkeeper in these restricted waters would have enabled the helmsman's actions to be monitored continuously and might at least have enabled his error to be recognised and reported. The Master would then have been alerted to the cause of the rapid turn to port and may have realised that there was a strong possibility that the eventual application of between 40° and 50° starboard helm without astern propulsion being applied would have turned the vessel to starboard in sufficient time to prevent her from grounding.

10.4 It is essential that the consequences of human error are carefully assessed against the manoeuvring characteristics of a particular vessel and the restrictive nature of the area through which the vessel is to be navigated. If the risk that an error by one person will have disastrous and irreversible consequences cannot be adequately minimised using on-board resources, consideration should be given to ensuring that suitable external resources, such as escort tugs, are immediately available and are capable of adequately minimising the risk.

11. THE PILOT CARD

11.1 The details provided on BORGA's Pilot Card were in accordance with established recommended practice. The Card indicated that the vessel was fitted with a Becker rudder and that the maximum rudder angle was 60°. Although it was not specifically stated that the vessel was also fitted with a controllable pitch propeller, that information was conveyed to the reader by way of a statement to the effect that astern power was equivalent to 100% ahead power. There was one error on the Card in that pictorially the vessel was shown to be fitted with twin propellers whereas, in fact, she had a single propeller.

No details were provided on the Pilot Card with respect to the natural reaction of the vessel to astern propulsion. The vessel's trial results show that the vessel turns to starboard at low speed and to port at high speed (Figure 8). Nor did the Pilot Card give any indication of the maximum rudder angle for the most effective vessel response at high and low vessel speeds. The provision of such manoeuvring data on the Pilot Card would ensure that the Master and officers remain fully aware of the handling characteristics of the vessel and that such information is readily available to pilots for the purpose of manoeuvring and contingency planning.

PART IV CONCLUSIONS

12. FINDINGS

12.1 The primary cause of the grounding was the delayed removal of port helm which the helmsman had applied in order to return the vessel to the required heading and of which the Pilot, the Master and the Chief Officer were all unaware.

12.2 The amount of port helm applied by the helmsman may have been reasonable in the circumstances. However, the manoeuvring characteristics of BORGA were such that even a short delay in removing the port helm required a significant amount of starboard helm to effectively reduce the rate of turn to port.

12.3 It is possible that the helmsman failed to appreciate his delay in removing the port helm and considered that his application of 10° starboard helm after a course alteration of possibly only 3° would be sufficient to effectively arrest the turn to port.

12.4 By putting the propeller pitch in the astern mode the rate of turn to port increased due to the manoeuvring characteristics of the vessel.

12.5 It was reasonable for the Master to engage astern propulsion to reduce speed due to the closeness of the land and the speed at which it was being approached.

12.6 Although the Master attempted to reduce the rate of turn to port by increasing the starboard helm, the increased angle would have lessened the effectiveness of the rudder response by reducing the side thrust.

12.7 The Pilot correctly ordered starboard helm after the vessel had started turning to port.

12.8 When the rate of turn to port then started to increase again the Pilot, with good reason, ordered full astern in an attempt to reduce or eliminate the consequences of a possible grounding.

12.9 It is unlikely that the rapid turn to port was initiated in any way by the effect of hydrodynamic interaction.

12.10 The appointment of an additional bridge watchkeeper would have permitted continuous close monitoring that the required course was being steered accurately, in accordance with the ICS Bridge Procedures Guide, and might have enabled the delayed removal of port helm to be recognised and reported.

12.11 It is possible that more effective use could have been made of the anchors in reducing the speed of the vessel had appropriate personnel been stationed forward in readiness to drop the anchors immediately if required.

12.12 The effect of the starboard steering gear drive coupling failure was to reduce the speed of rudder response, it was not in itself a contributory factor in the grounding of the vessel.

12.13 Although the steering gear alarm system as installed complied with SOLAS requirements, it did not detect the failure of the drive coupling between the electric motor and the hydraulic pump.

12.14 BORGA's manoeuvring characteristic of her head turning to starboard on slow speed astern, and turning to port on full speed astern, were not noted on the Pilot Card. Neither did it give an indication of the maximum rudder angle for the most effective vessel response at high and low vessel speeds.

13. RECOMMENDATIONS

13.1 BORGA's Owner, A/S J Ludwig Mowinckels Rederei, is recommended to:

1. Ensure that procedures are in place so as to adequately minimise the risk of an error by one person having disastrous and irreversible consequences, in accordance with the provisions of the International Chamber of Shipping Bridge Procedures Guide.

2. Amend BORGA's Pilot Card to include the natural reaction of the vessel to astern propulsion at high and low speeds, the maximum rudder angles for the most effective vessel response at high and low speeds, and to pictorially show that the vessel is fitted with a single controllable pitch propeller.

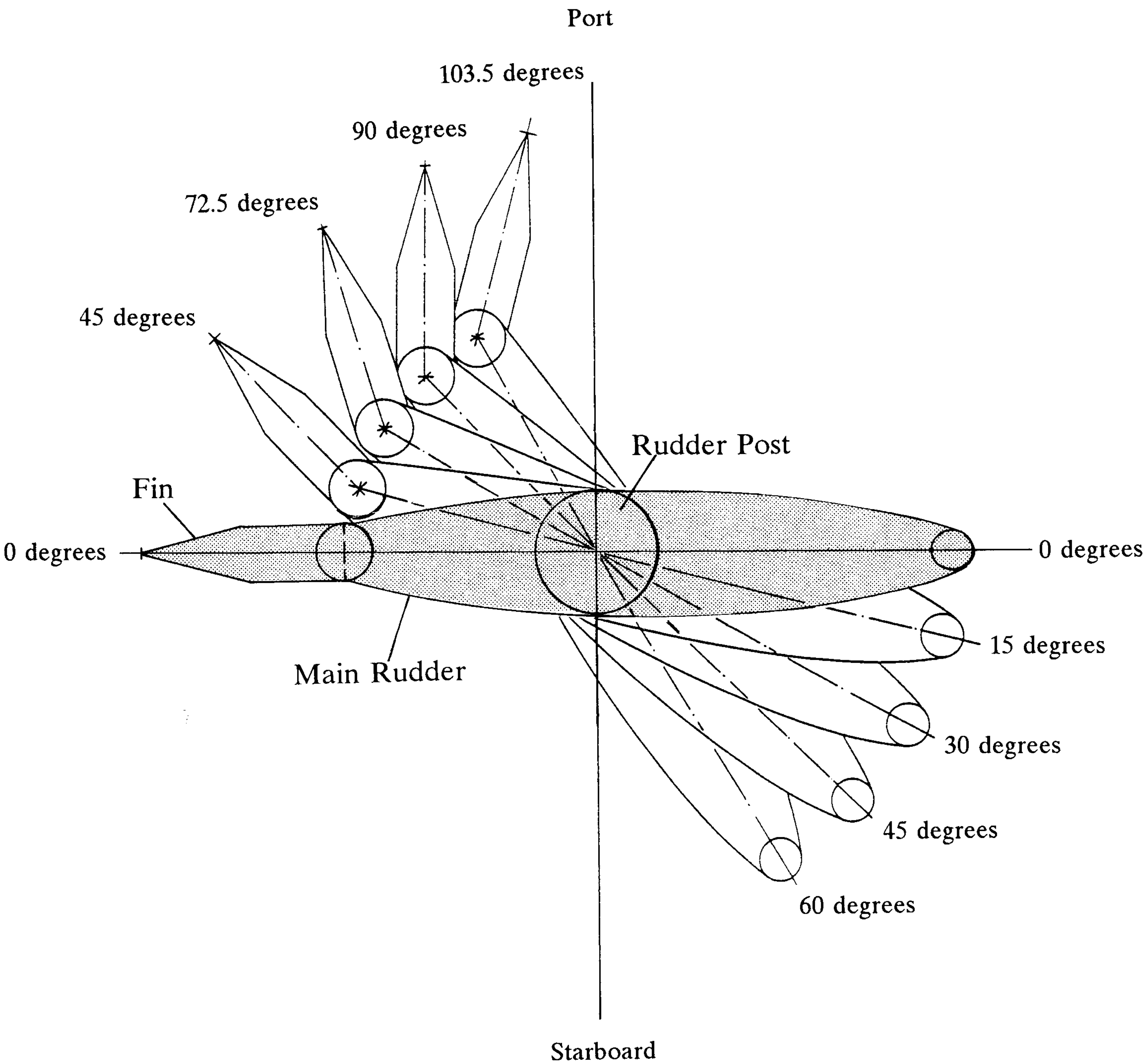
3. Consider the placing of a notice adjacent to the steering console on the bridge setting out the maximum rudder angles for the most effective vessel response at high and low speeds.

4. Extend the existing steering gear alarm system to include a low hydraulic pressure sensor alarm on the outflow from each hydraulic pump.

13.2 The Marine Safety Agency is recommended to

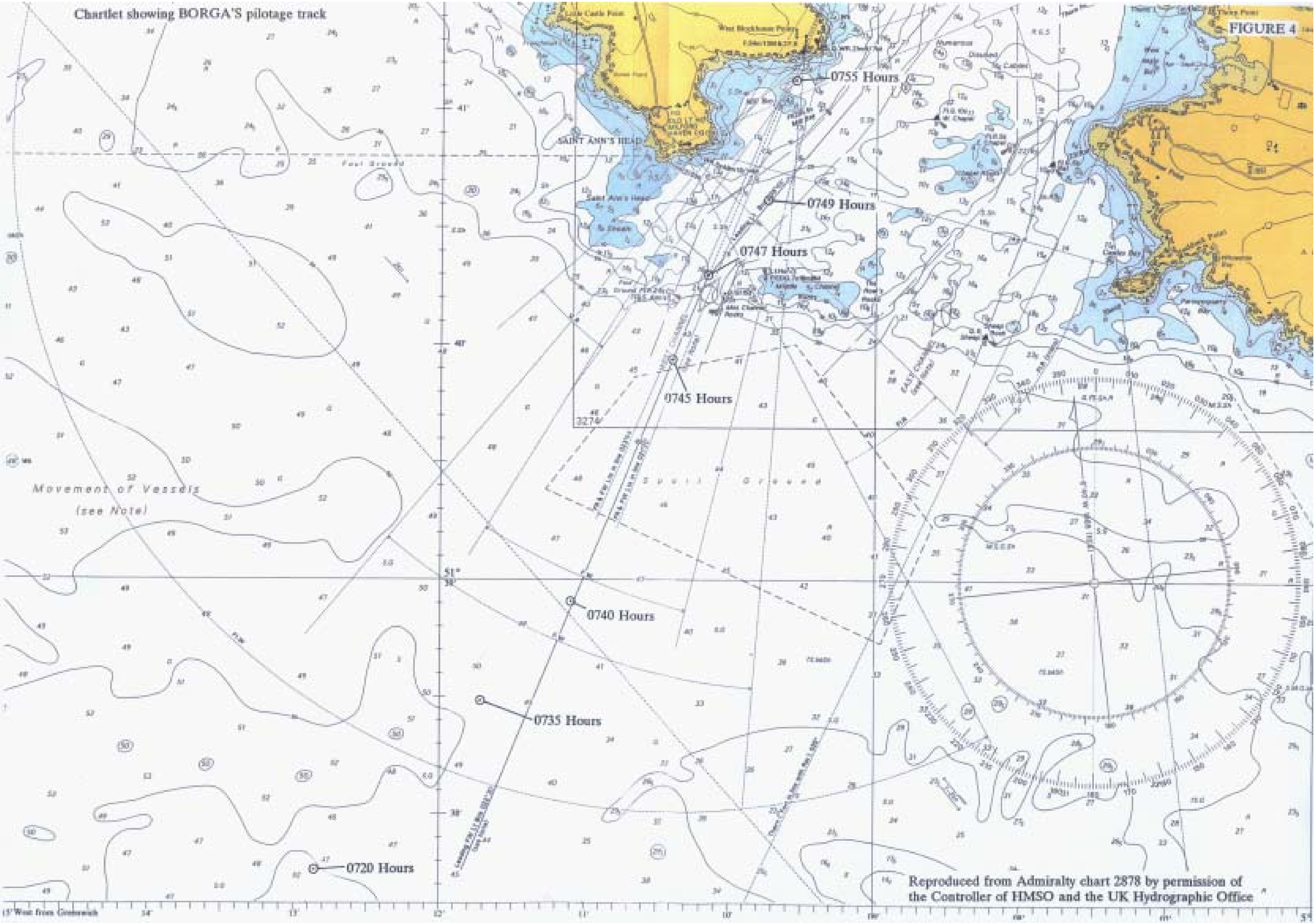
1. Give consideration to proposing to the appropriate International Maritime Organization's sub-committee that the steering gear alarm system requirements of the 1974 SOLAS Convention and the 1978 Protocol, Chapter II-I, Part C, Regulation 29, paragraph 8, section 8.4, should be extended to include a low hydraulic pressure sensor alarm in lieu of, or in addition to, the electrical power supply failure alarm.

General View of BORGA whilst alongside at Milford Haven



Becker Rudder diagram

General view of rudder and propeller from starboard side



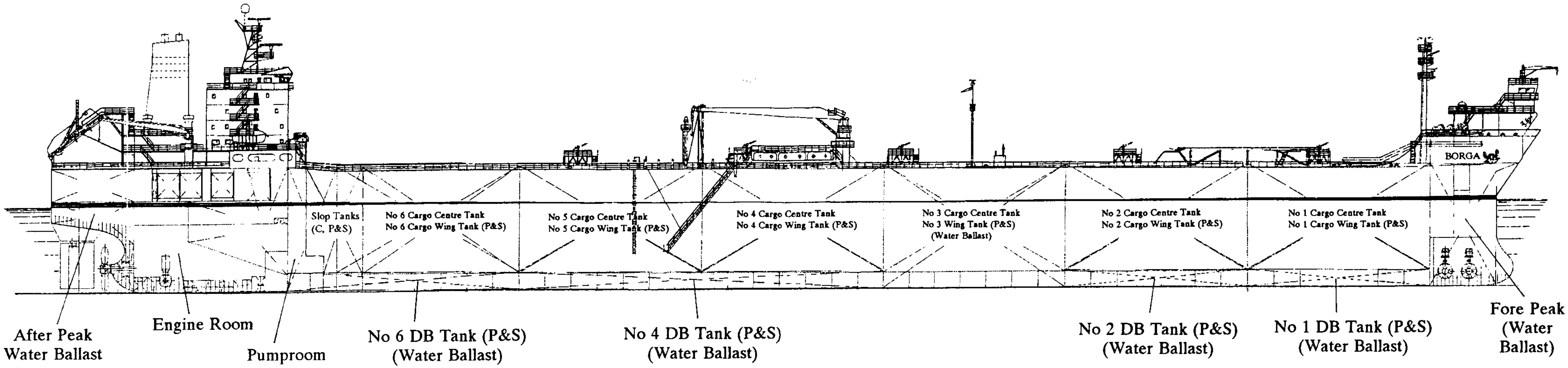
Chartlet showing BORGA'S pilotage track
FIGURE 4
0755 Hours
0749 Hours
0747 Hours
0745 Hours
0740 Hours
0735 Hours
0720 Hours
SAINT ANN'S HEAD
Movement of Vessels
(see Note)
Foul Ground
Reproduced from Admiralty chart 2878 by permission of
the Controller of HMSO and the UK Hydrographic Office

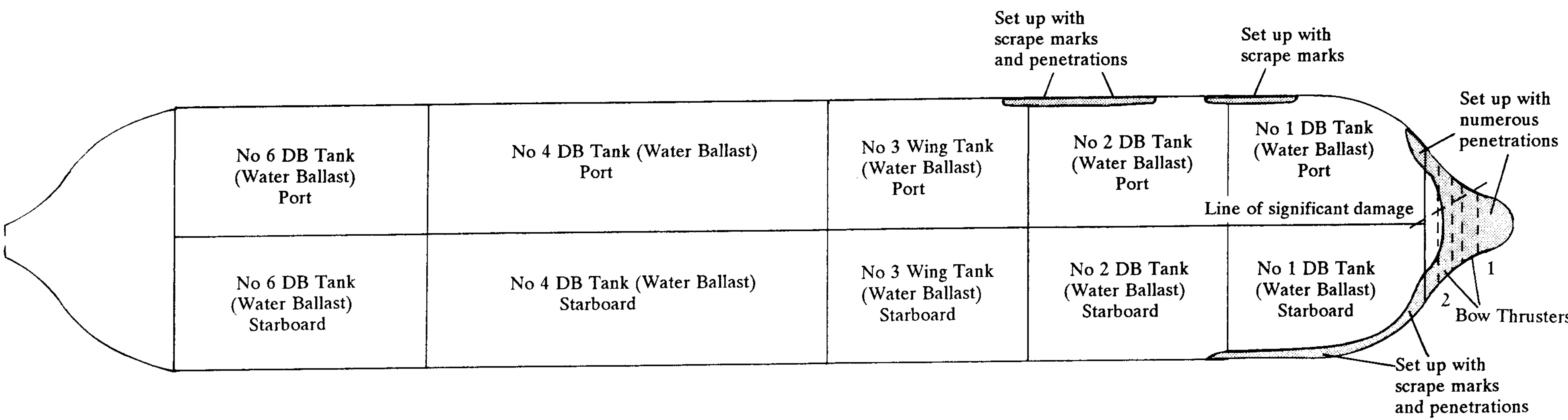
FIGURE 5

General view from starboard side forward
showing extent of bottom damage on this side

FIGURE 6

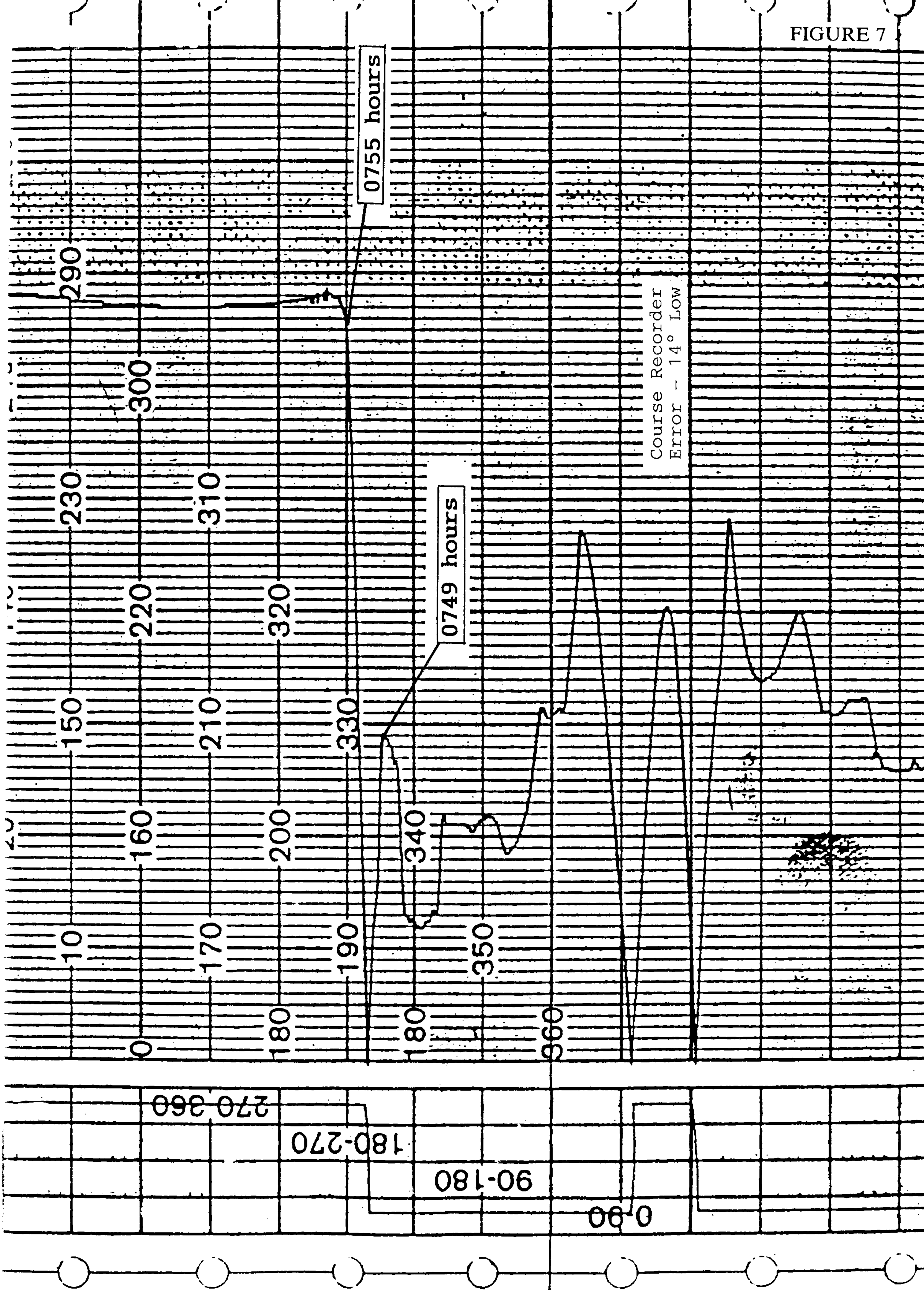
BORGA





Plan Showing Grounding Damage

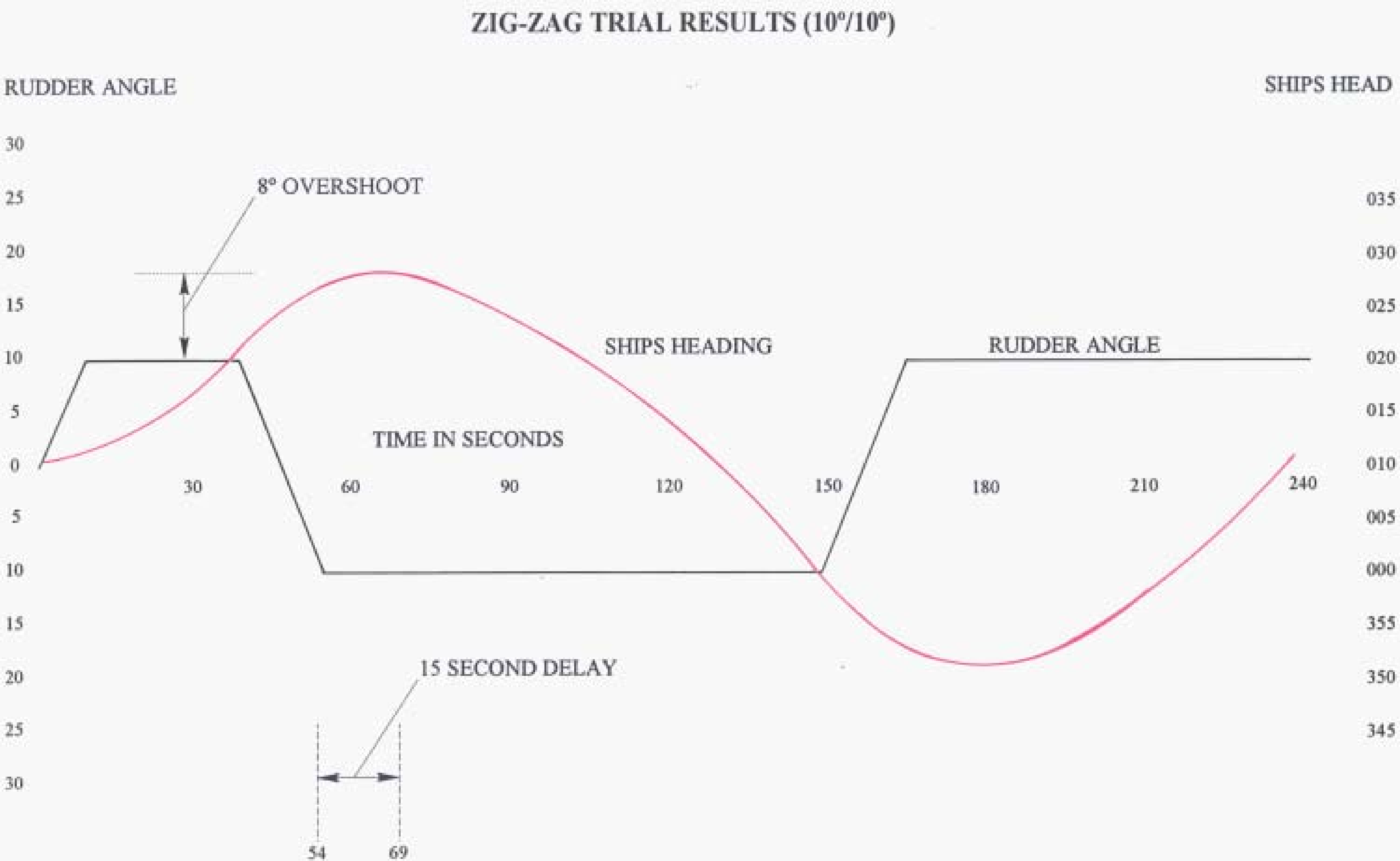
FIGURE 7



Course Recorder Trace

Table of Original Manoeuvrability Trials - "BORGA"

V_s Start knots	2.0	3.0	5.0	11.3	11.3	11.5	11.4
V_s Stop knots	0.0	0.0	0.0	3.09	0.0	0.0	0.95
% Pitch Ahead	100	20	80	100	100	100	100
% Pitch Astern	100	100	100	0	100	60	40
Distance nm	0.16	??	0.265	1.194	0.54	0.764	0.88
Time secs	292	313	382	900	379	582	900
Angle of turn	10°	11°	29°	170°	148°	149°	205°
Port/Starboard	Star	Star	Star	Port	Port	Port	Port



Ballast Condition V_s = 12 Knots

M.V."BORGA"

FIGURE 9

FIGURE 10

Chartlet of simulated track of BORGA