

Report on the investigation of  
the engine failure of  
***Savannah Express***  
and her subsequent contact with a  
linkspan at Southampton Docks  
19 July 2005

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**Extract from**  
**The United Kingdom Merchant Shipping**  
**(Accident Reporting and Investigation)**  
**Regulations 2005 – Regulation 5:**

*“The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame.”*

**NOTE**

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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## **GLOSSARY OF ABBREVIATIONS AND ACRONYMS**

ABP	-	Associated British Ports
ACU	-	Auxiliary control unit
BPA	-	British Ports Association
CCU	-	Cylinder control unit
ECR	-	Engine control room
ECS	-	Electronic control system
ECU	-	Engine control unit
EICU	-	Engine interface control unit
FMECA	-	Failure Mode, Effects and Critical Analysis
GL	-	Germanischer Lloyd
HCU	-	Hydraulic cylinder units
HPS	-	Hydraulic power system
IHMA	-	International Harbour Masters' Association
IMO	-	International Maritime Organization
INF	-	Information
ISM	-	International Safety Management Code
kW	-	Kilowatts
LOA	-	Length overall
LOP	-	Local operating panel
MBD	-	MAN B&W Diesel
MCA	-	Maritime and Coastguard Agency
ME-C	-	Electronic control – container ship
MOP	-	Main operating panel
MPC	-	Multi purpose controller

NRS	-	Norddeutsche-Reederei H Schuldt
PMSC	-	Port Marine Safety Code
ro-ro	-	roll-on roll-off
RPM	-	Revolutions per minute
SHA	-	Statutory Harbour Authority
SMS	-	Safety Management System
STCW	-	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TDC	-	Top dead centre
TEU	-	Twenty-foot Equivalent Unit, a measurement of standard containers
UKHMA	-	United Kingdom Harbour Masters' Association
UKMPG	-	United Kingdom Major Ports Group
USB	-	Universal serial bus
UTC	-	Universal co-ordinated time
VIT	-	Variable injection timing
VTS	-	Vessel Traffic Services

## SYNOPSIS



At 1146 on 19 July 2005, one of the largest container vessels in the world, the German flagged, 94483 gross tonne *Savannah Express* made heavy contact with a linkspan at 201 berth, Southampton Docks. The vessel had lost astern engine power entering the Upper Swinging Ground where she was due to swing before going alongside.

Minor paintwork damage was sustained to the bulbous bow of the vessel, and she was able to proceed to her berth with the assistance of three tugs. The linkspan suffered extensive damage to its structure, which prevented its further use until major repair work was carried out.

Prior to the collision, two tugs had been secured to *Savannah Express*, one at each end of the vessel. They were unable to take the way off the vessel sufficiently to prevent the collision with the linkspan, partly because the tugs lacked the necessary power, and partly because there was insufficient room for them to manoeuvre. The most effective tugs available, bearing in mind the size of the vessel, its particular requirements and the characteristics of the tugs, were not allocated to *Savannah Express*.

*Savannah Express* had suffered an engine failure earlier that morning as she approached the Nab Tower and the pilotage boarding area. She anchored and carried out repairs before proceeding to Southampton. The pilot was aware the engine had been turned before leaving the anchorage, but he was unaware that the engine had only been turned on air astern. Over an hour after leaving the anchorage, the pilot was informed that the cause of the engine failure had not been positively diagnosed, but no additional precautions were put in place and the harbour authority was not told.

The large, slow speed, diesel main engine on *Savannah Express* was of a revolutionary design without the normal camshaft and mechanical timing gear. This equipment had been replaced with a computer controlled electro-hydraulic system. The system had suffered a number of technical problems since *Savannah Express* had left the builder's yard in Korea in April 2005.

At Singapore, the previous port of call, a service engineer from the engine manufacturer had attended the vessel to rectify various guarantee claims. In addition, three out of the four pressure sensors on the hydraulic system had failed during the preceding 2 months, but the service engineer was unable to provide any spares, due to a problem with supply. The chief engineer received the impression that the sensors were used for pressure indication only, and that the loss of the final sensor would not cause the engine to stop. As a consequence of this erroneous information, the chief engineer informed the master that he was content for the vessel to sail with only one sensor working.

On the morning of the accident, the final pressure sensor failed, which resulted in the failure of the main engine as the vessel approached the Nab Tower.

Without any spare sensors, and misunderstanding the displayed hydraulic pressure information, the engineers resorted to disabling an electronic control system to enable a back-up system to take-over. Unbeknown to the engineers, this resulted in insufficient hydraulic power being available to operate the engine astern. Later, when astern power was needed as the vessel entered the swinging basin before berthing, the engine failed to run.

Although the engine manufacturers provided a short training course for operators of the new engine, the chief engineer and electrical engineer on board *Savannah Express* had not attended this course. However, the course was of a superficial nature, and might not have provided them with sufficient knowledge to successfully diagnose the engine failure either at the Nab Tower or at the Upper Swinging Ground.

The engine manufacturer also provided the vessel with a 24 hour telephone hotline to give additional technical support. Unfortunately, the chief engineer, who had joined the vessel at short notice, was not aware of this.

Although the engineers on board were experienced and held appropriate STCW certificates, they were unable to correctly diagnose the reason for the engine fault at the Nab Tower and, later, at the Upper Swinging Ground. The increasing levels of electrification of engine control and propulsion systems require increased training requirements in the operation, maintenance and fault finding of these technically complex, and multi-discipline systems. The STCW training standards for ships' engineers have not been updated to account for modern system engineering requirements. The accident has also highlighted the essential need for the development of adequate type specific training.

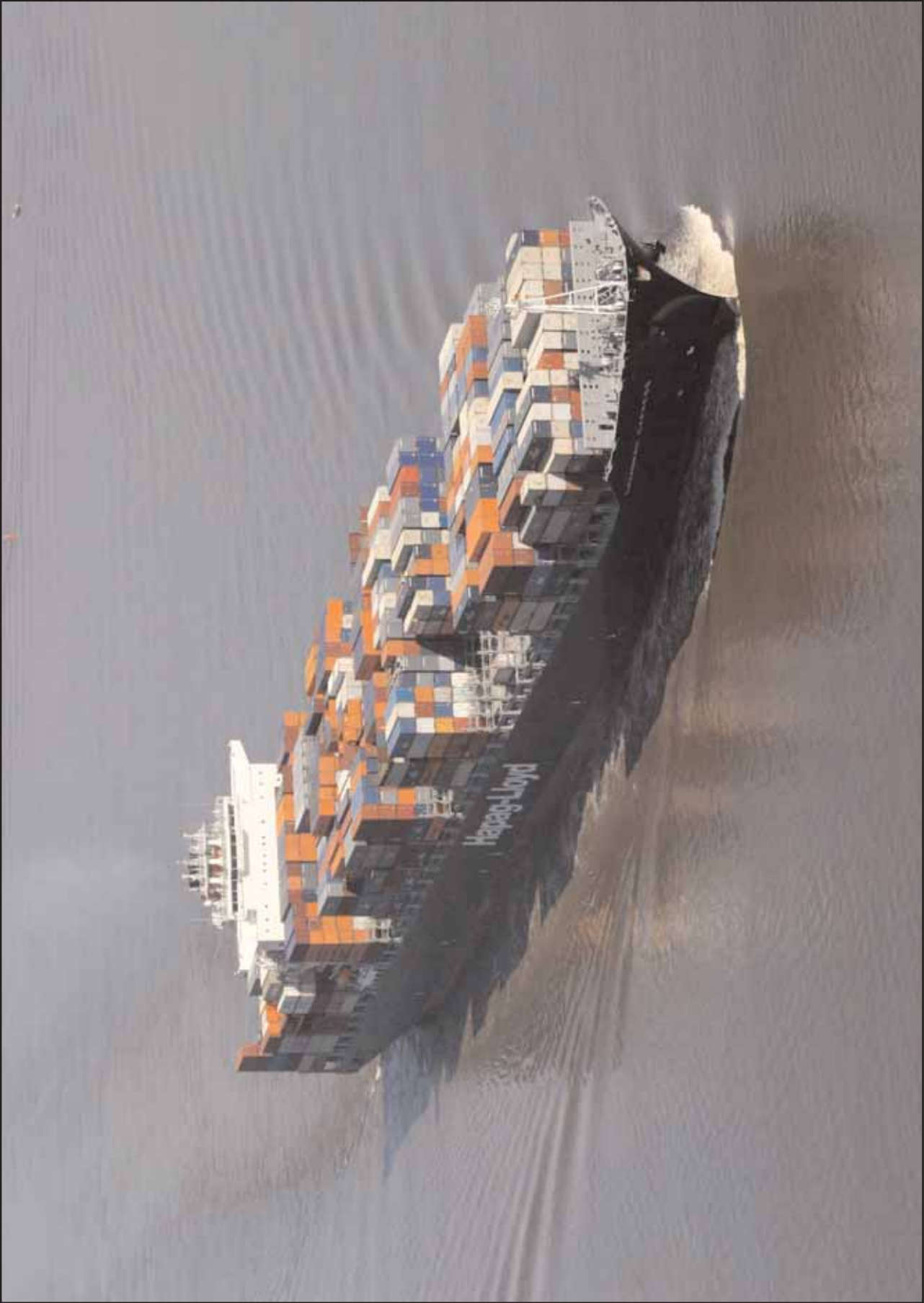
Corrective action has been taken by the ship manager of *Savannah Express*, the Statutory Harbour Authority of Southampton and the tug operating company. Additionally, the MAIB has circulated a synopsis of this accident, with the lessons to be learned, to shipowners around the world.

Specific recommendations have been addressed to the Maritime and Coastguard Agency (MCA), the ship manager of *Savannah Express* and the engine manufacturer, and UK harbour authorities with the purpose of:

- Raising at IMO the need for improved training requirements of ships' engineers and electricians;
- Improving the MAN B&W specialised training course for electronically controlled engines;
- Raising awareness of the inability of some large, powerful vessels to fully test their main propulsion systems prior to departure from the berth, due to likely mooring damage.



Figure 1



Savannah Express

## SECTION 1 - FACTUAL INFORMATION

### 1.1 PARTICULARS OF SAVANNAH EXPRESS AND ACCIDENT

#### Vessel details

Manager	:	Norddeutsche Reederei H Schuldt GmbH & Co
Charterer	:	Hapag-Lloyd Container Line GmbH
Port of registry	:	Hamburg
Flag	:	German
Type	:	Container 8411TEU
Built	:	April 2005 Daewoo Shipbuilding, Okpo, South Korea
Classification society	:	Germanischer Lloyd
Construction	:	Steel
Length overall	:	332m
Gross tonnage	:	94483
Displacement	:	105000
Draught	:	12.3m
Engine power and/or type	:	61642kW MAN B&W 12K98ME-C single diesel engine (12 cylinder - 980mm bore)
Service speed	:	25.6 knots (loaded)
Other relevant info	:	Electronic engine timing and control system

#### Accident details

Time and date	:	1246 19 July 2005
Location of incident	:	201 berth, Southampton docks
Persons on board	:	27 + pilot
Injuries/fatalities	:	None
Damage	:	Propulsion failure leading to extensive damage to a linkspan and minor paint damage to the bulbous bow of <i>Savannah Express</i>

## 1.2 VESSEL HISTORY

*Savannah Express* traded between Europe and the Far East. At the time of the incident, she was on her first complete voyage, Europe/Far East/Europe, following her maiden voyage to Hamburg from her building yard in Korea.

She was originally named *Northern Julie*, but was re-named by her managers before leaving the building yard.

At 332m LOA, and with a breadth of 43.3m and a capability of carrying 8411TEU, she was one of the largest container vessels in the world. Her slow speed diesel engine was one of the largest and most technically advanced available. It utilised electro-hydraulic controls (ME type) instead of the more conventional mechanical timing gear (MC type).

MAN B&W (MBD) instigated a short training course for engineers and ship managers who were going to be involved with operating vessels with ME engines. An MBD guarantee engineer sailed with the vessel for 1 week after she left the builders' yard.

During *Savannah Express*'s first 3 months of operation, some minor malfunctions in the main machinery controls had been experienced. Additionally, she had left Singapore for the passage to Southampton with only one of the four suction pressure sensors for the main hydraulic pumps operational.

## 1.3 NARRATIVE

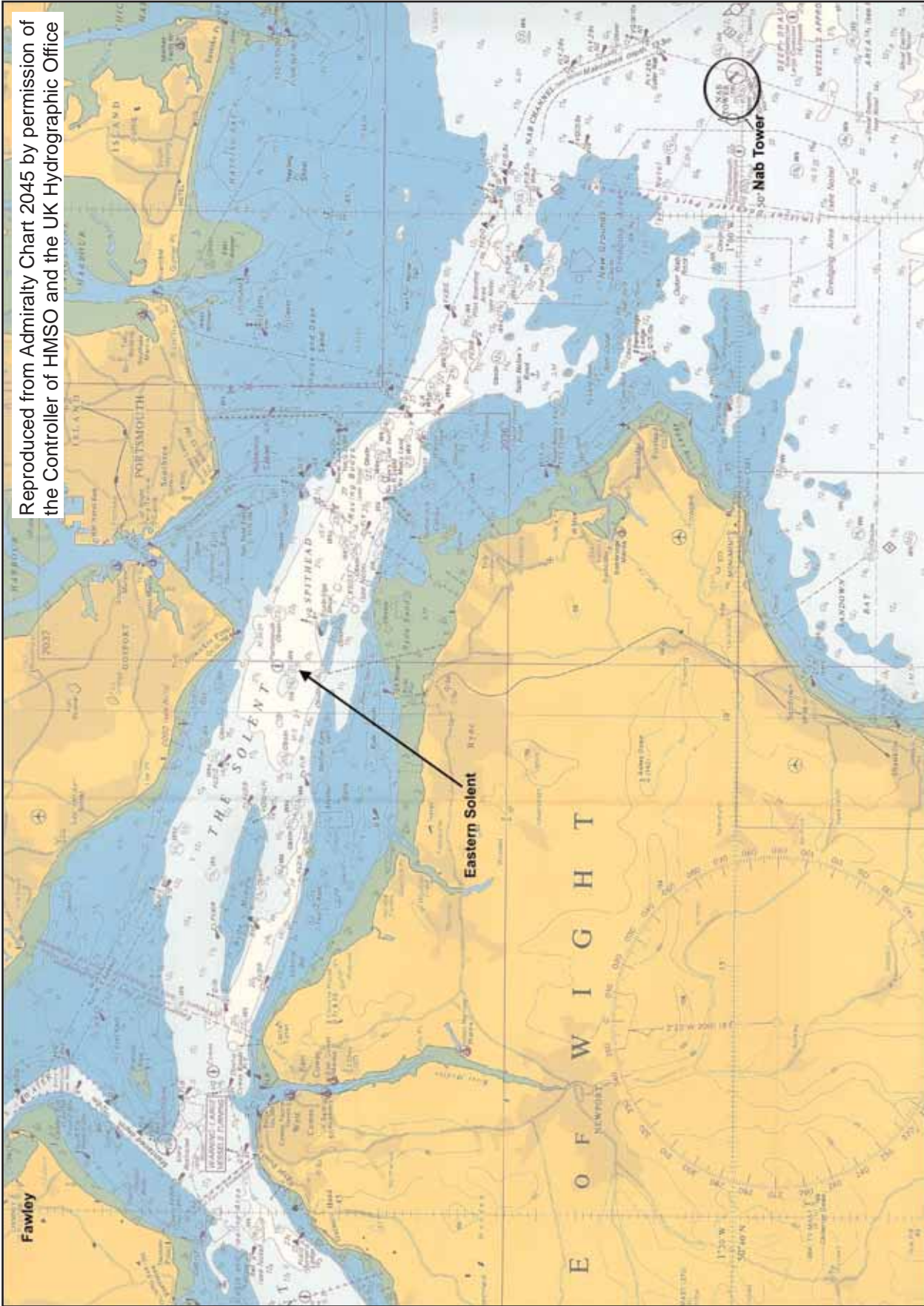
All times are UTC +1

At 0700 on the morning of 19 July 2005, *Savannah Express* approached the Nab Tower and the pilot boarding area at the eastern approaches to the Solent, bound for berth 206 of Southampton container terminal (**Figure 2**). Her last port had been Singapore, and this was the first of three scheduled ports in Northern Europe .

At 0729, with the vessel about 1.5nm south of the Nab Tower, a shutdown of the electronically controlled (ME) main engine occurred. Various hydraulic pressure and shutdown alarms occurred simultaneously.

*Savannah Express* continued under her own momentum toward the pilot boarding area. The master informed VTS of the engine failure. At 0800, the pilot boarded, and both he and the master were content to let the vessel progressively slow down.

Figure 2



Reproduced from Admiralty Chart 2045 by permission of the Controller of HMSO and the UK Hydrographic Office

Approaches to The Solent

At 0807, the master told the pilot that the engine failure was caused by an electronic fault, although the chief engineer had told the master that the exact cause was unknown at that time. Shortly after, with the vessel drifting at very slow speed, the port anchor was let go (the anchorage position was 0.7nm south of the Nab Tower).

The pilot considered the vessel's draught and the predicted tidal height, and informed the master that 1330 was the latest time that they would be able to leave the anchorage for the passage to the berth. The master and pilot also spoke in general terms about the planned passage to Southampton port, and the pilot told Southampton VTS of the situation.

By 0854, the ship's engineers had analysed the alarms, including those indicating low hydraulic pressure, but had been unable to locate and solve the immediate cause of the engine failure. They decided that Engine Control Unit A (ECU-A) could be at fault, and this unit was disabled. This enabled the engine computer system to default to the 'hot' standby ECU-B. They also fitted a 'cheat plug' or resistor to provide a false hydraulic pressure signal to the ECU. The engineers were aware that they had no back-up if further failures occurred. Further hydraulic low pressure alarms occurred during this time among the many engine room alarms.

The chief engineer informed the master, who reported to the pilot that the engine was now running on another system and it was ready to start. The pilot subsequently informed VTS that the anchor was being heaved.

At 0906, the main engine was turned ahead and astern on air before the master informed the pilot that the vessel was ready to go. The pilot had witnessed the test, and he told the master to head to the west of the Nab Tower at dead slow ahead.

At 0912 the vessel weighed anchor and began her passage to Southampton container terminal. The pilot informed VTS that they had left the anchorage. In addition to the master and pilot, the bridge complement included the duty officer and a watchman.

Over the next 5 minutes, the engine speed was gradually increased to half ahead, with the engine responding quickly and accurately to bridge orders. At 0938 the pilot requested full speed.

At 1020, when *Savannah Express* was in the Eastern Solent, the master told the pilot that the engineers had been unable to determine the cause of the engine shutdown. A brief discussion followed, on the difficulty of diagnosing faults on electronic systems, but no actions were taken as a result of this information.

The vessel passed Fawley at 1045, where the engine speed was reduced to slow ahead. It was subsequently reduced to dead slow ahead off Netley, in preparation for making fast the two tugs that had been ordered to assist in the final approach to the berth.

At 1112, the tug *Sir Bevois* was made fast centre lead forward, and tug *Lyndhurst* made fast centre lead aft. Both tugs ran out approximately 60 to 70 metres of towing line to *Savannah Express*.

As *Savannah Express* approached Cracknore Buoy at 1124, the engine was stopped to reduce headway.

At 1127, the engine was put to dead slow ahead in order to maintain steerage, and at 1128 the engine was again stopped as the vessel passed the Cracknore Buoy and turned to transit the Western Docks **(Figure 3)**.

At 1133, as the vessel passed 105 berth, the helm was put hard over to port and the engine was 'kicked' ahead. Engine control was transferred to the Port Bridge Wing in anticipation of the swing to starboard required in the Upper Swinging Ground. The vessel speed was 4 knots **(Figure 4)**.

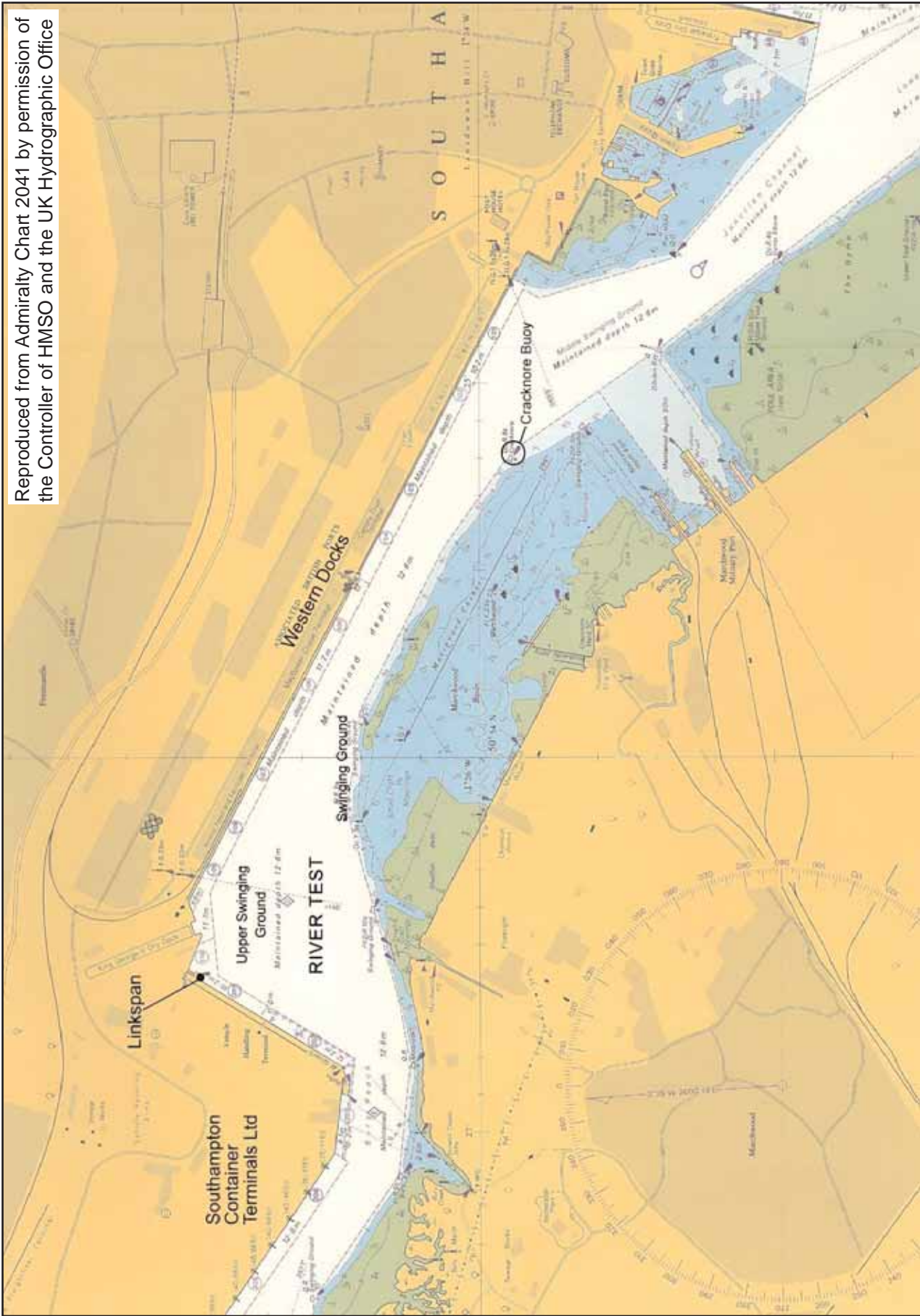
At 1136 the engine was set to dead slow astern. The engine briefly responded to the astern command and, although it reached 46 rpm, it failed to run and it stopped after about 18 seconds **(Figure 5)**. Further hydraulic low pressure alarms and ECU – A and B 'tacho failure' alarms occurred in the engine control room (ECR). Several attempts to re-start the engine in astern were made from the bridge wing before control was transferred to Bridge Control, and then to the ECR.

The master informed the pilot that main engine failure had occurred. The experienced pilot knew that without engine power, the two tugs would be unable to stop the vessel from striking the dock wall, at berths 201/202, which was immediately ahead. Pilot simulator training of this scenario had shown him that turning a vessel within the swinging ground was the quickest way to reduce vessel speed, in addition to giving more time to stop the vessel.

The pilot informed the tugs that the vessel had lost engine power and that they should continue to assist to swing her to starboard, as originally planned. *Sir Bevois* was requested to pull to starboard and *Lyndhurst* to port. The bow thruster of *Savannah Express* was set to provide full thrust to starboard.

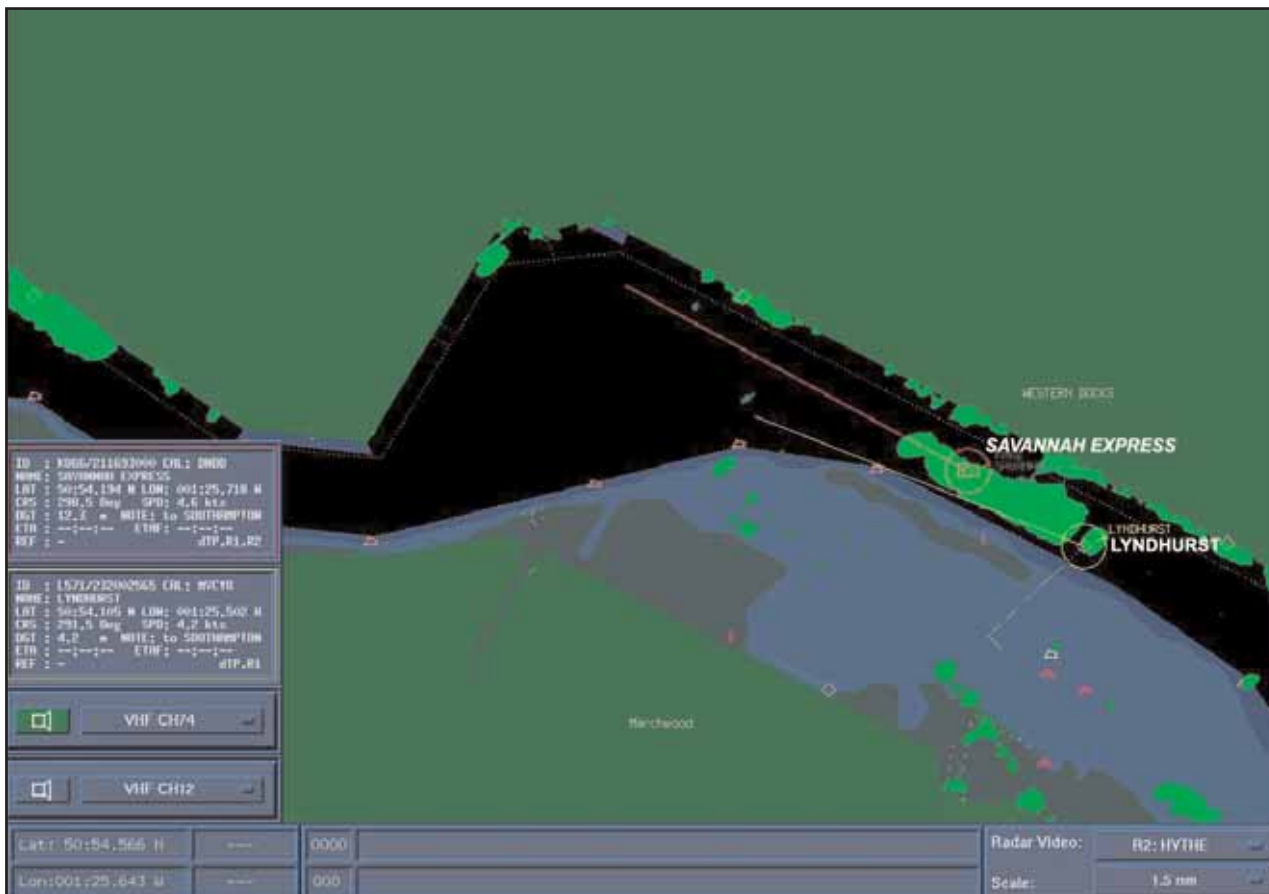
The size of *Savannah Express* meant that *Lyndhurst* had very limited space to pass between the port quarter of the vessel, and the buoy which marks the edge of the swinging ground on the opposite side of the river.

Figure 3



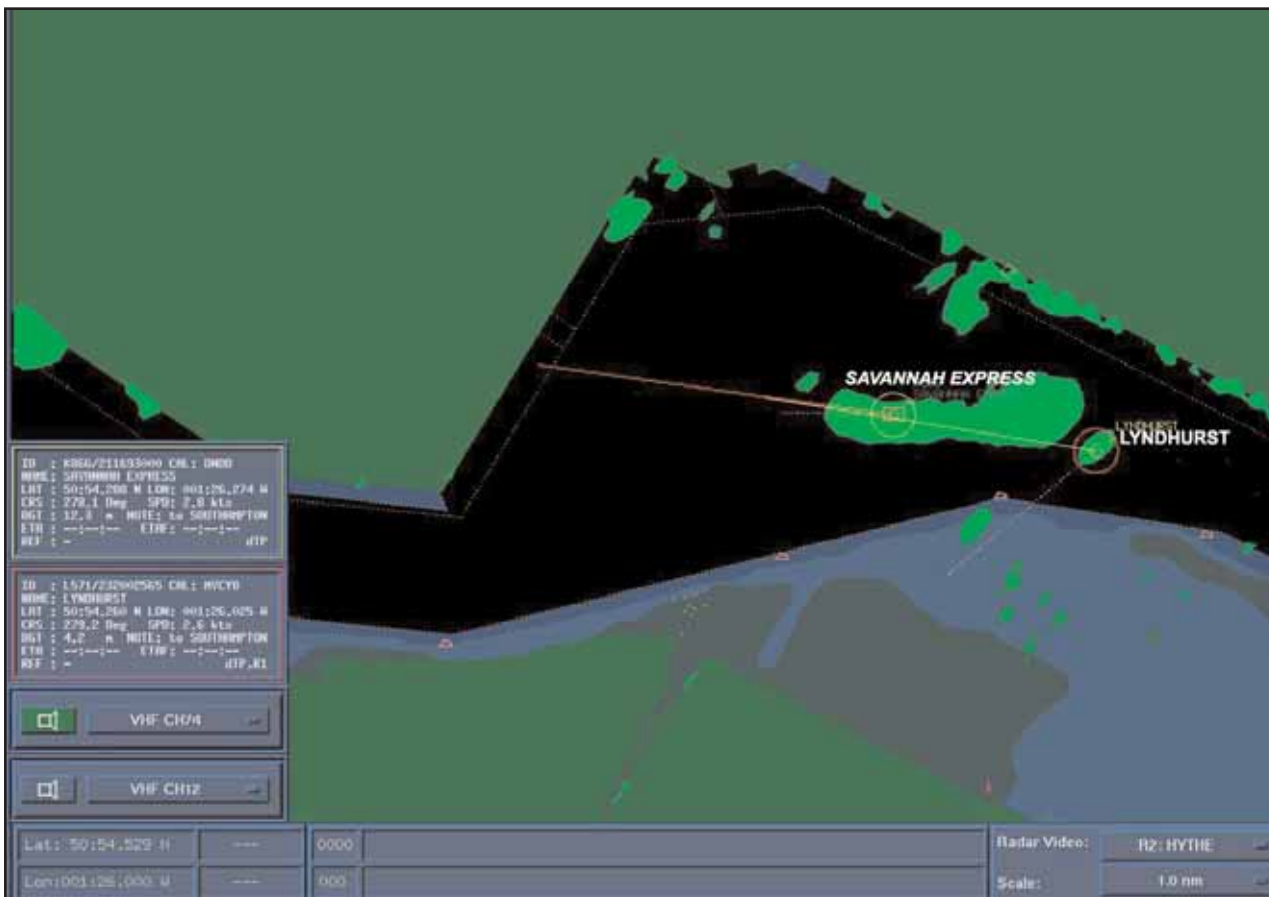
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Upper swinging ground and approaches



Radar recording from Southampton VTS of *Savannah Express* passing Western Docks

Figure 5



Radar recording from Southampton VTS showing *Savannah Express* beginning to swing to starboard



During the next few minutes, as the ship continued her slow swing to starboard, further attempts were made to start the main engine from the LOP (**Figure 6**), until low air pressure meant no more attempts could be made. The master informed the pilot that the main engine would not be available. At 1142, with the bow at about 20 – 30 metres off the quayside and with the vessel speed at about 2 knots, the master gave the order for the port anchor to be let go to reduce the headway. At about the same time, the pilot requested *Lyndhurst* to move right astern of *Savannah Express* and apply full power to further reduce headway.

At 1146, with *Savannah Express*'s bow heading towards the corner of the Upper Swinging Ground, she made heavy contact with the pontoons of the linkspan at 201 berth, at a speed of just under 2 knots (**Figure 7**).

As she slowly continued her swing to starboard, the linkspan was severely damaged. The vessel then scraped the laid up ro-ro ferry, *Bergen Castle*, before coming to a halt (**Figures 8 and 9**).

At 1152, the tug *Hamtun*, which had made her way to assist *Savannah Express* after listening to the collision on VHF, was secured to the starboard quarter. The master of *Savannah Express* agreed that the vessel should be treated as a dead ship, and she was towed to berth 206 to be secured port side to at 1300.

#### **1.4 ENVIRONMENTAL CONDITIONS**

The weather on the morning of the incident was fine and clear with a moderate westerly wind of 10 to 15 knots, gusting to 18 knots. Visibility was good and there were only low wind waves in the sheltered Upper Swinging Ground (**Figures 10a and b**).

The tide was between springs and neaps, with predicted high water occurring at 0932 and low water occurring at 1527. At the time and location of the accident, there was a slight southerly flowing tidal stream.

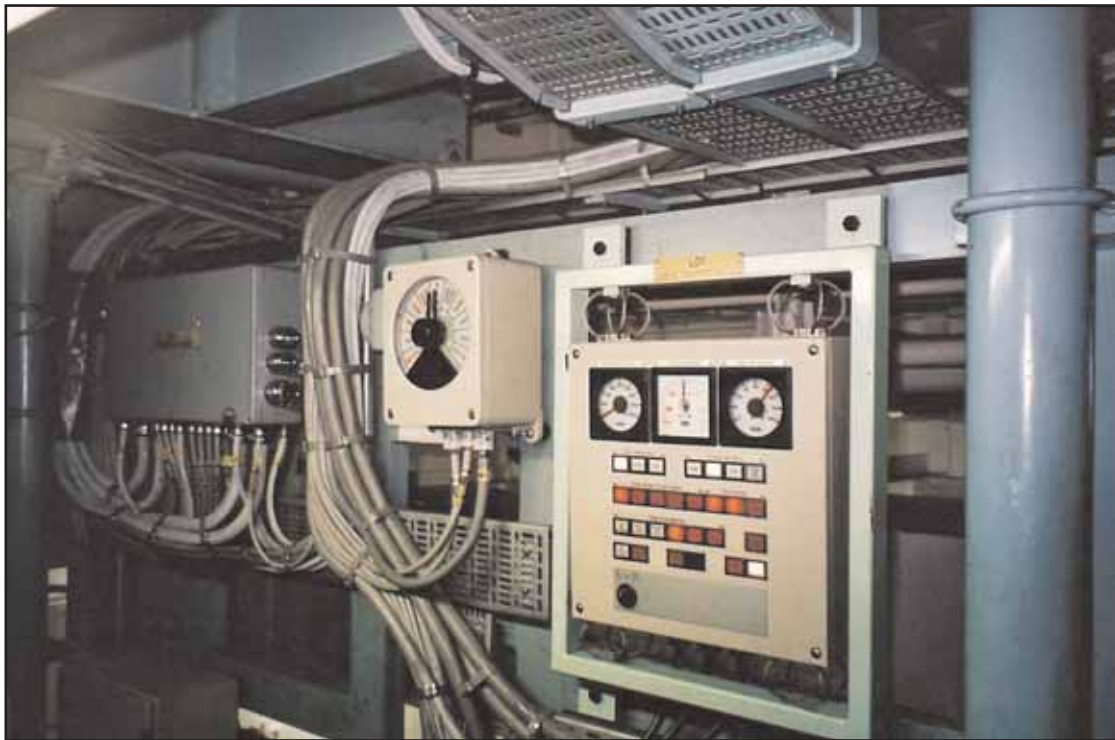
#### **1.5 VESSEL CREW**

Of the 27 crew on board *Savannah Express*, the master, chief engineer and chief officer were German nationals, the second engineer was Ukrainian and the electrician was Hungarian. The remaining complement was from Germany or Myanmar.

There were five officers in the engineering department: chief, second and third engineers, an electrician and a cadet.

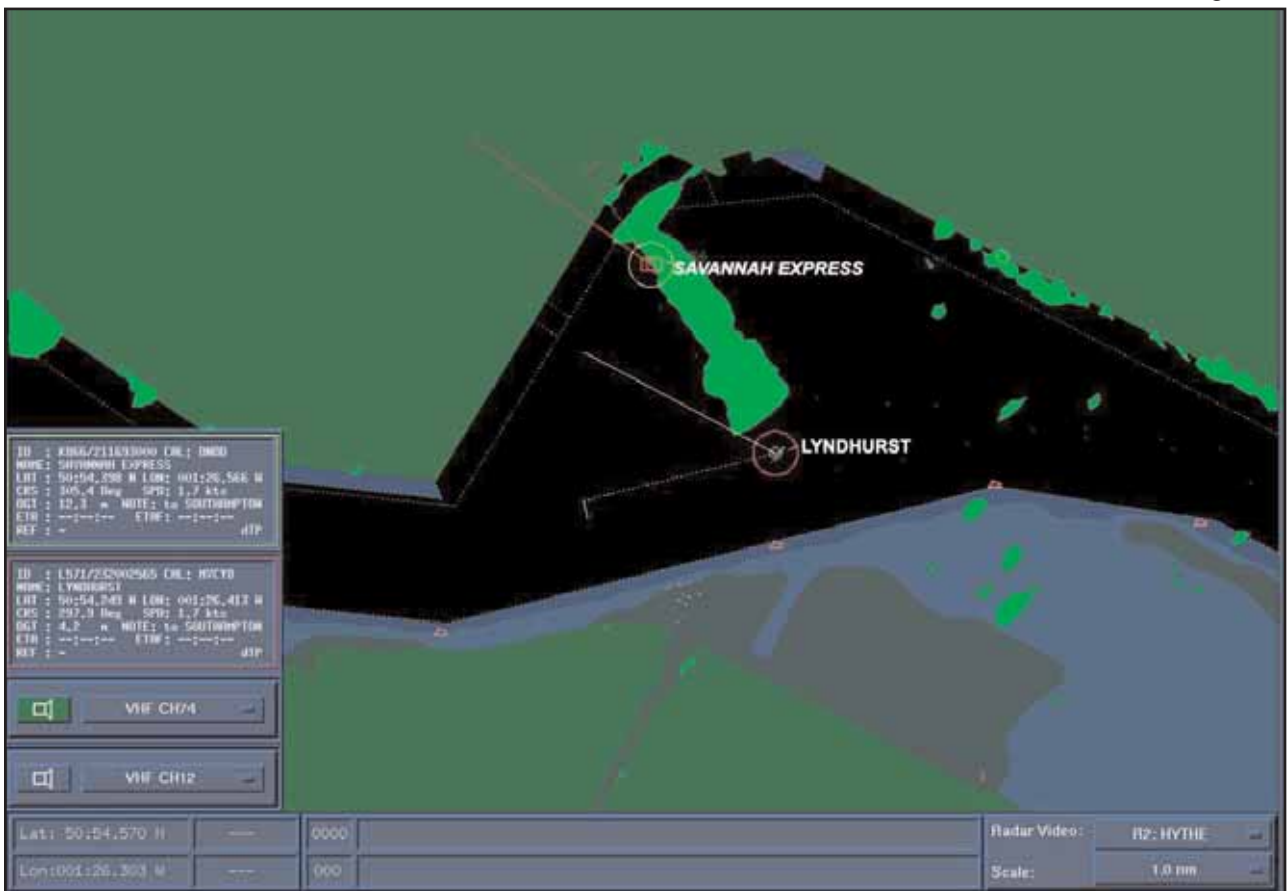
The master had joined *Savannah Express* in May 2005, at Hamburg, at the end of her maiden passage. He had been master with Norddeutsche-Reederei H Schuldt (NRS) since 1998. He had previously served as master with various shipping companies since 1975.

Figure 6



Local Operating Panel (LOP)

Figure 7



Radar recording from Southampton VTS showing *Savannah Express* making contact with the linkspan

Figure 8 and 9



Linkspan damage

Figure 10a



Figure 10b



Panorama of Upper Swinging Ground including *Bergen Castle*

The chief engineer had joined the vessel on 22 June 2005, in Hong Kong. The chief engineer had been requested to join *Savannah Express* at short notice due to a health problem with the designated, ME engine trained chief engineer. The new chief engineer had 3 days handover between Hong Kong and Shanghai to learn about the ME engine. In addition to the ME engine operation manual, the departing chief engineer left his personal ME engine training manual on board as additional reference.

The second engineer had been onboard since delivery of the vessel in April 2005, and both he and the electrician had stood by the vessel in the shipyard and were also on board during her sea trials. Neither of them had attended MBD's ME engine training course.

The electrical engineer had been employed by the same crewing agency for over 10 years, on a variety of ships. He was qualified as an electrical engineering officer under Hungarian regulations, which allowed him to serve on a vessel with any electrical installation (no upper power limit). There are no certification requirements within STCW for electrical or electronic engineers.

## 1.6 DESCRIPTION OF THE 12K98ME-C ENGINE (Figure 11)

### 1.6.1 History

Camshafts have been used as the standard method of timing fuel injection and exhaust valve cycles to control diesel engines from the early beginnings of reciprocating machinery. However, despite ongoing development, the fixed camshaft has its limitations, and alternative means to provide finer control of fuel injection pressure, and pressure variation over the load range have been explored by various engine manufacturers.



Engine upper level

One alternative offered the additional flexibility required to meet the demands of ship operators for reduced fuel and cylinder oil consumption and the lower air pollution demands of the regulators. This was a computer controlled hydraulic-mechanical system for the activation of the fuel injection, exhaust valves and the associated equipment.

MAN B&W has been developing its ME (electronic) engine concept since 1993. Its prototype MC/ME engine (a combined camshaft and electronically controlled, hydraulically operated engine with the camshaft roller guides lifted) started tests at sea in 2003 on the Odfjell owned chemical tanker *Bow Cecil*. This has since been supplemented with the first wholly electronically controlled (ME) engine on the chemical tanker *Bow Firda*.

This ME engine was designed and built without a camshaft, and those functions associated with a camshaft have been taken over by a fully integrated and computer controlled electro-hydraulic system.

The MAN B&W Diesel Annual Report of 2004 states that more than 130 electronically controlled ME engines had been sold and, in the same year, the engine types 12K98ME and 12K98ME-C were built for the first time. Since then, larger engines up to a 14K108ME, destined for container ships with a loading capacity exceeding 9000 TEU, have been developed.

## 1.6.2 ME engine components

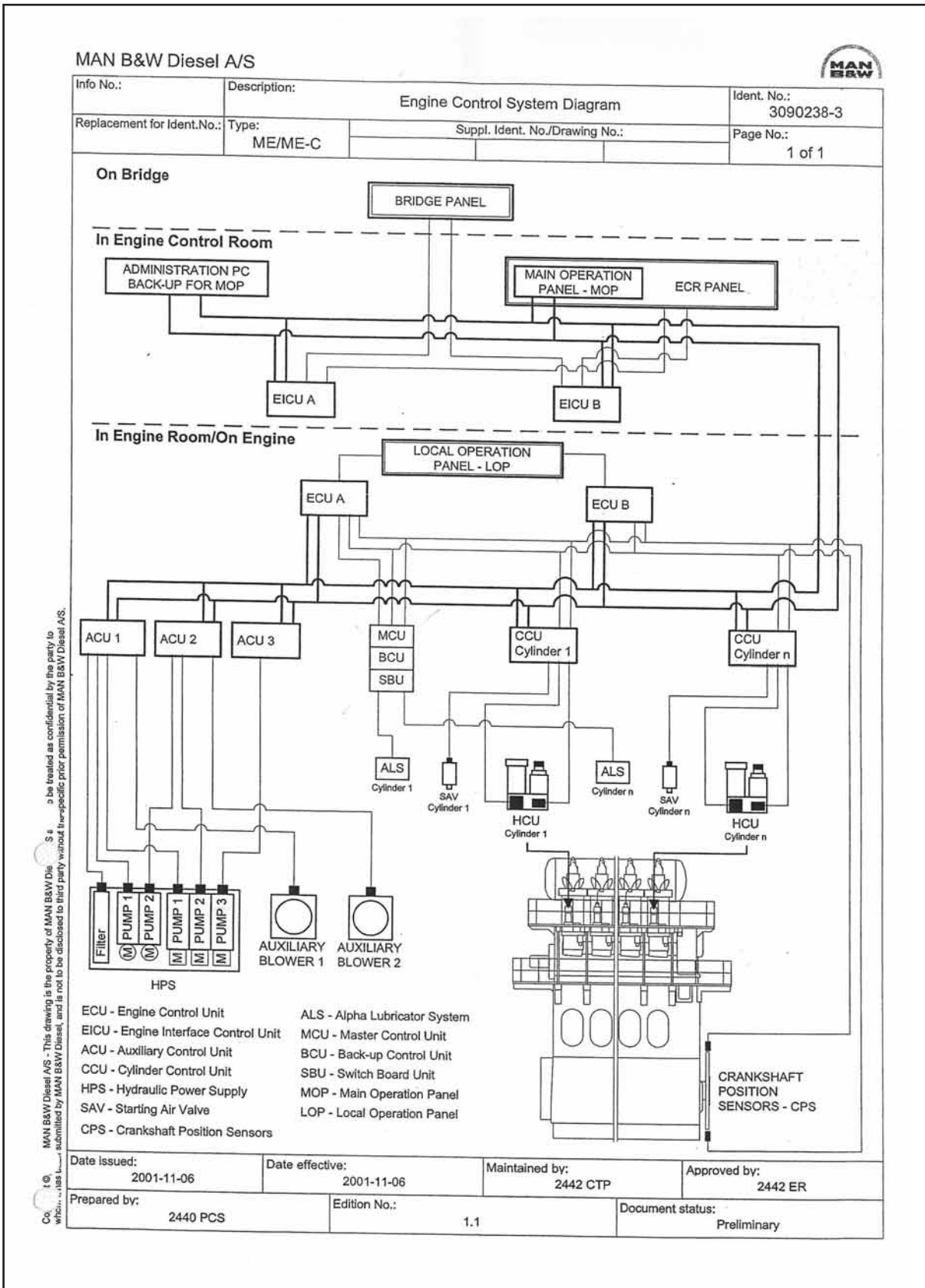
The ECS system controls the timing of the fuel injection and exhaust valve opening through close monitoring of the crankshaft position via a tachometer and encoder. This provides a more accurate and responsive system of control, resulting in fuel and oil consumption efficiency savings, while also providing improvements in manoeuvrability control. The ECS therefore provides a fully integrated control of all functions.

Electronically controlled hydraulic actuators carry out the functions of the mechanical components of the camshaft controlled engine (MC). The following components of the MC engine have been replaced:

- Chain drive for camshaft
- Camshaft with fuel cams, exhaust cams and indicator cams
- Fuel pump actuating gear, including roller guides and reversing mechanism
- Conventional fuel injection pumps and variable injection timing (VIT) system
- Exhaust valve actuating gear and roller guides
- Engine driven starting air distributor
- Electronic governor with actuator
- Regulating shaft
- Engine side control console
- Mechanical cylinder lubricators.

These components have been replaced on the ME engine with the following **(Figure 12)**:

- Control units (19 on the 12K98ME) comprising:
  - Two engine interface control units (EICU) – interface to external systems
  - Two engine control units (ECU A/B) – engine control functions: engine speed (governor), running modes and start sequence
  - Three auxiliary control units (ACU) – hydraulic power supply and auxiliary blowers
  - One per cylinder, cylinder control unit (CCU) – controlling the fuel injection, exhaust valve and starting air activators.
- Hydraulic power supply (HPS) unit – four engine driven pumps (12K98ME engine) and two electrically driven start-up pumps



ECS

Note: System shown has three main engine driven pumps

- Hydraulic cylinder units (HCU), including:
  - Electronically controlled fuel injection, and
  - Electronically controlled exhaust valve actuation
- Electronically controlled starting air valves
- Electronically controlled auxiliary blowers
- Integrated electronic governor functions
- Tacho system – including crankshaft position sensing system
- Electronically controlled cylinder lubrication
- Local operating panel (LOP) – has highest priority in an emergency.

### 1.6.3 Hydraulic operating system (**Figure 13**)

The hydraulic operating system uses the engine lubricating oil as the transmission medium via the main lube oil pump, and this is filtered and further pressurised by the HPS. The HPS comprises four engine driven pumps and two electrically driven start-up pumps.

Before an engine start can begin, the hydraulic pressure required for hydraulic actuator control is generated by the 2 x 175 bar start-up pumps. Once a minimum of 150 bar pressure is available, the ECS allows the engine start sequence to begin. After engine start-up, the engine driven hydraulic pumps take over the generation of the hydraulic power, and the start-up pumps automatically stop.

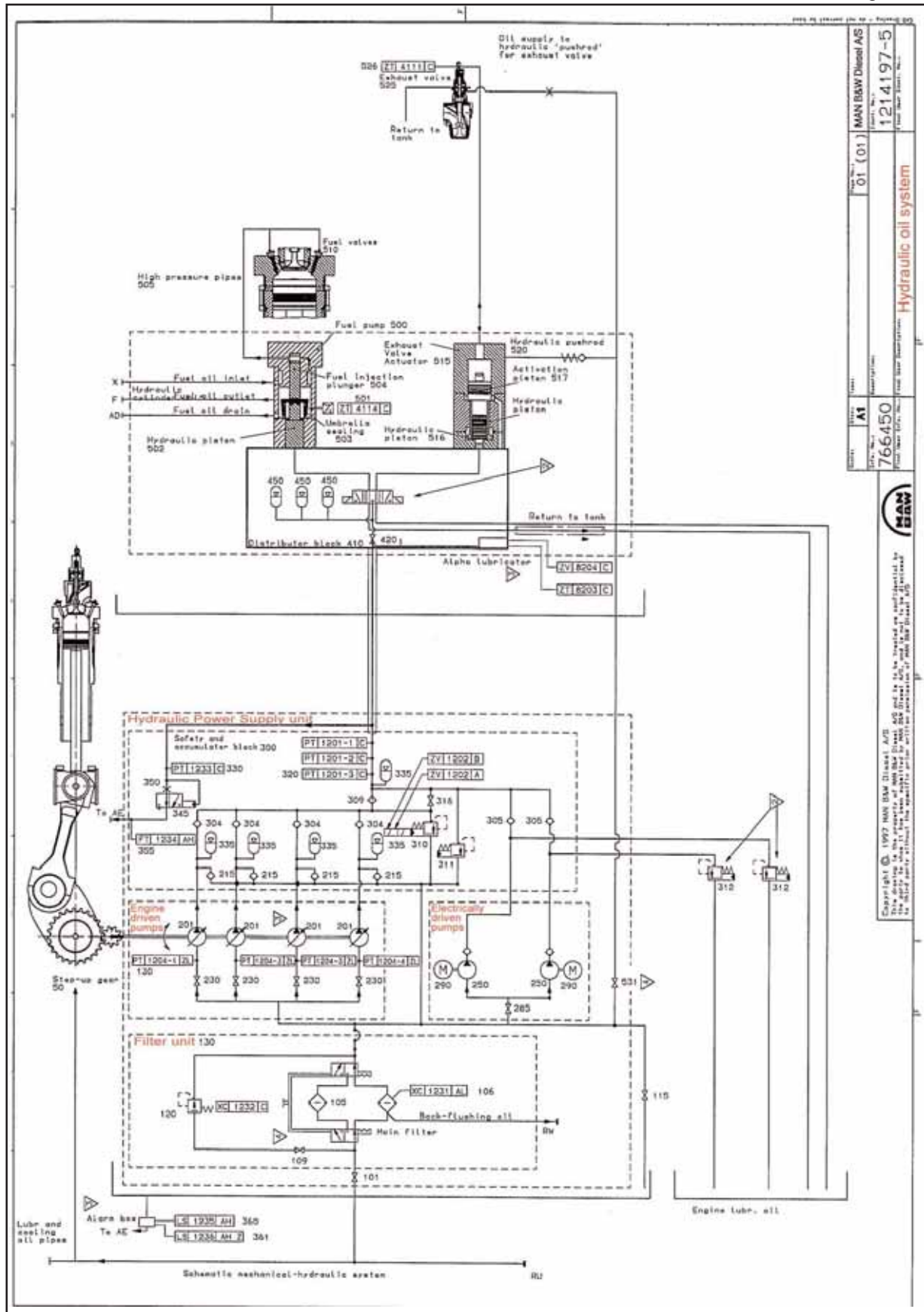
The main engine driven, 250 bar, hydraulic pumps are uni-directional axial piston pumps, with flow controlled by a swash plate via a position feedback sensor. A safety feature causes the swash plate to move to the 100% ahead position should the feedback sensor fail.

The engine driven pumps operate in 'control' and 'follow-up' modes. One pump is designated as the control pump, while the others are set as follow-up.

The follow-up pumps operate at 100% load while the control pump output varies, via operation of the swash plate, around a load setting of 50% while maintaining the hydraulic system pressure set point, nominally 250 bar. The set point can vary with engine load.

A minimum of three engine driven pumps is required to provide the 12K98ME engine with sufficient hydraulic power to operate, either ahead or astern. However, the start-up pumps can be set to manual and run in parallel with the engine driven pumps. This can provide sufficient power to run the engine, either ahead or astern, with some reduction in engine load, depending on the configuration of the engine driven pumps.





MAN B38L Diesel AS
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Hydraulic oil system
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Hydraulic operating system

Each engine driven pump unit has a hydraulic pressure sensor, or transmitter, situated on the suction side of the pump. These protect the pumps in case of loss of oil supply, via alarm indication on the Main Operating Panel (**Figure 14**) and, if all four sensors indicate loss of oil pressure, initiate an engine shutdown.

Another set of sensors on the pressure side of the pumps, provides pressure indication and feedback control for the swash plate to adjust the pump displacement. The exception is pump number four which is set up as an on/off pump providing maximum displacement. An average hydraulic pressure reading from these sensors is also provided on the MOP screen. If hydraulic pressure, or pressure indication, drops below 150 bar, an engine shutdown can occur.

Main engine driven pumps one to three are controlled by ECU-A or ECU-B via ACUs one to three, while pump four is controlled by ECU-A only.

#### 1.6.4 Electronic system

The ME engine control system is designed with the principle that no single failure of any component will render the engine inoperative. Therefore, all essential computers operate with a 'hot' standby, ready to take control immediately a fault occurs in the 'in use' system.

All the computers in the system (EICU, ECU, CCU, and ACU) use the same type of electronic card, or Multi-Purpose Controller (MPC), which can be quickly interchanged between computers. The card is configured for each control unit with the use of an ID key (dongle) which gives the card its new identity.

Figure 14



Main Operating Panel (MOP)

The LOP, which has the highest priority in an emergency and can be used to take over command at any time (forced takeover), has two separate, independent computers.

In normal operation, ECU-A will be in operation running its associated equipment. If a failure of ECU-A occurs, then ECU-B should take control and run with its associated equipment.

Cabling between control units, and to the engine for the operating and 'hot' standby systems, is run separately where possible, to ensure maximum redundancy in the event of cable damage. Critical system cables are continuously supervised, and alarms advise the ship's engineers if a cable fault occurs.

Critical system sensor fault alarms can be disabled electronically on the MOP, akin to 'pulling a card', to enable the 'faulty' systems to continue to run. The hydraulic pump suction pressure sensors and associated cabling are not listed as a critical system.

#### 1.6.5 Measurement of rotational speed and crankshaft position

The tacho system uses two self-contained angle encoders, mounted externally, at the forward end of the crankshaft to measure rotational speed and crankshaft position. They are connected axially, and operate within bellows to protect the encoders against vibration and any slight misalignment. The bellows are protected by a steel enclosure (**Figure 15**).

Figure 15



Angle Encoders

The two encoders measure crankshaft position from the 0° position and the 45° position respectively. A single reference sensor at the flywheel provides a signal to ECU-A of the top dead centre (TDC) position of number one piston. This provides crankshaft position redundancy in case of failure or shaft slippage of either of the encoders.

When operating at low speed, or during manoeuvring when ahead and astern operations are likely, tacho failure alarms, which can result in an engine failure, are inhibited. This process is carried out automatically by the ECS when in manoeuvring mode.

During pre-departure testing, engine commissioning, or after replacement of the tacho encoders (when the electronic system will not have the information to locate the angular position of the crankshaft), the engine can be rotated on compressed air only, without fuel being admitted. This is known as an 'air run' and is used to prevent overloading of the moorings, resetting of tacho faults or to provide the reference signal for the ECS to allow an engine start. The 'air run' uses large amounts of compressed air, more than a conventional diesel engine would require when 'blowing over on air', and can quickly deplete the compressed air reserves.

## **1.7 ALARM SYSTEM AND EVENT LOG (Figure 16)**

The computer system is based on a Microsoft Windows operating system, to allow eventual upgrades to the system. It is a standalone system, to prevent inappropriate software being installed and thus creating operating problems.

Alarms are logged chronologically on the MOP, and in addition to displaying the latest alarms, the earliest acknowledged alarm is also visible. Any disabled channels are visible on the MOP screen and are logged on the main computer alarm system event log.

As not all alarms provide enough information for efficient fault finding, the engineers are assisted by an information page for each alarm. This gives a description, a cause, an effect and suggested action to be taken.

The system indicates the number of current alarms, disabled alarms and those which have been muted but not cleared.

The alarm system has a large hard drive, which can store a comprehensive alarm history and can be downloaded to an external computer via a USB connection or floppy drive. Due to the large storage capacity and the number of alarms that can be listed, a filtering capability can be used to list only specific alarms or a range of dates or times. Times can be set as either UTC or local.

```

2005-07-19 06:29:13',73,'ACU2','1204-204',1,32,'Suprv. Ch32,1204-2,Lube oil pressur',0,'2005-07-19
06:29:15','2005-07-19 07:29:15');
INSERT INTO event_recorder VALUES (118881,'2005-07-19 06:29:15',824,'ACU2','1204-204',0,32,'Suprv.
Ch32,1204-2,Lube oil pressur',0,'2005-07-19 06:29:17','2005-07-19 07:29:17');
INSERT INTO event_recorder VALUES (118882,'2005-07-19 06:29:20',327,'ACU2','1204-204',1,32,'Suprv.
Ch32,1204-2,Lube oil pressur',0,'2005-07-19 06:29:22','2005-07-19 07:29:22');
INSERT INTO event_recorder VALUES (118883,'2005-07-19 06:29:21',998,'ACU2','0711',1,40,'Inlet pump 4
pressure deviation',0,'2005-07-19 06:29:23','2005-07-19 07:29:23');
INSERT INTO event_recorder VALUES (118884,'2005-07-19 06:29:22',658,'ECUA','5121',1,32,'Pump inlet
press. low',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118885,'2005-07-19 06:29:22',928,'ACU1','070119',0,40,'Pump ctrl
failure',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118886,'2005-07-19 06:29:23',148,'CCU5','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118887,'2005-07-19 06:29:23',168,'CCU11','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118888,'2005-07-19 06:29:23',178,'CCU2','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118889,'2005-07-19 06:29:23',229,'CCU3','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118890,'2005-07-19 06:29:23',239,'CCU6','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118891,'2005-07-19 06:29:23',249,'CCU9','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:24','2005-07-19 07:29:24');
INSERT INTO event_recorder VALUES (118892,'2005-07-19 06:29:23',299,'CCU7','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118893,'2005-07-19 06:29:23',319,'CCU1','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118894,'2005-07-19 06:29:23',319,'CCU10','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118895,'2005-07-19 06:29:23',389,'CCU8','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118896,'2005-07-19 06:29:23',469,'CCU12','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118897,'2005-07-19 06:29:23',549,'CCU4','0109A',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118898,'2005-07-19 06:29:23',589,'ECUB','02010214',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118899,'2005-07-19 06:29:23',689,'ECUA','02010214',1,32,'Shut
Down',0,'2005-07-19 06:29:25','2005-07-19 07:29:25');
INSERT INTO event_recorder VALUES (118900,'2005-07-19 06:29:25',450,'ECUB','0202020709',1,32,'Low
Hydraulic Pressure',0,'2005-07-19 06:29:27','2005-07-19 07:29:27');
INSERT INTO event_recorder VALUES (118901,'2005-07-19 06:29:25',710,'ECUA','0202020709',1,32,'Low
Hydraulic Pressure',0,'2005-07-19 06:29:27','2005-07-19 07:29:27');
INSERT INTO event_recorder VALUES (118902,'2005-07-19 06:29:27',331,'ECUB','5131',1,32,'Hyd. press.
deviates from setpoint',0,'2005-07-19 06:29:29','2005-07-19 07:29:29');
INSERT INTO event_recorder VALUES (118903,'2005-07-19 06:29:27',411,'ECUA','5131',1,32,'Hyd. press.
deviates from setpoint',0,'2005-07-19 06:29:29','2005-07-19 07:29:29');
INSERT INTO event_recorder VALUES (118904,'2005-07-19 06:29:31',413,'CCU5','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118905,'2005-07-19 06:29:31',663,'CCU7','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118906,'2005-07-19 06:29:31',794,'CCU11','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118907,'2005-07-19 06:29:31',914,'CCU6','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118908,'2005-07-19 06:29:32',44,'CCU1','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118909,'2005-07-19 06:29:32',164,'CCU8','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118910,'2005-07-19 06:29:32',284,'CCU12','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:33','2005-07-19 07:29:33');
INSERT INTO event_recorder VALUES (118911,'2005-07-19 06:29:32',404,'CCU4','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:34','2005-07-19 07:29:34');
INSERT INTO event_recorder VALUES (118912,'2005-07-19 06:29:32',534,'CCU2','03023209',1,32,'Exhaust
Valve Open Stroke Low',0,'2005-07-19 06:29:34','2005-07-19 07:29:34');

```

First 19 seconds of Event Log alarms after failure of the suction pressure sensor of number four hydraulic pump

## 1.8 ENGINEERING TRAINING

### 1.8.1 ME engine training

The intention of MBD is that the ECS should be simple to operate by marine engineers with the assistance of the onboard operation manuals, but without the need for in-depth training. Most of the ECS components should be easily interchangeable when a failure occurs and, therefore, considerable knowledge of the system is not required. As the system matures, its operation is expected to become easier.

However, as part of the introduction of the new engine design, the manufacturers, MBD, offer 3 and 5 day training courses on the ME engine control system in Copenhagen for marine engineers and ship managers. These courses provide an introduction to the operation and maintenance using a classroom simulator and engine test bed.

The simulator gives the students an opportunity to operate and, to a limited extent, fault find on the simulator. Access to the system designers, via the lecturer, is also possible to clarify technical issues.

The chief engineer and electrician on board *Savannah Express* had not attended this course before they joined the vessel, although the chief engineer was booked to attend the course in August 2005.

MBD also provide a 24 hour telephone hotline for use by ship staff and the technical department to assist with fault finding on MBD engines.

### 1.8.2 General training in modern technology

The engine control system of the ME engine is not the only area of advancing technology in the marine industry. Many cruise ships have been operating with diesel-electric propulsion systems for a number of years; systems which, invariably, use medium voltage generation of 6.6kV or 11kV, high frequency load sharing systems. The complicated electronic systems involved, require a high degree of knowledge of computer-based automation, medium voltage control equipment and electronic systems which have become a fundamental part of the operation of the propulsion system. Traditionally, the training of marine engineers has been in the generation of low voltage, commonly 440V.

A result of this trend towards increasing technology has been a demand from cruise vessel operators in particular, for specially trained electro-technical officers capable of both operation and fault diagnosis. Various training establishments have responded to this demand, however, there is no common standard of training for these officers, or a requirement within STCW for any electrical bias in the training of engineers.

## 1.9 PRECEDING EVENTS

A service engineer from MBD visited *Savannah Express* during her visit to Singapore on 3 July 2005, to carry out follow-up work, including guarantee claims on the main engine.

Under the 'Pending guarantee claims' section, the following were included:

6) – *Low pressure sensors – Three (3) out of four (4) sensors are presently not working. MBD will arrange delivery of correct sensor type in Europe, and in addition we will arrange re-location of sensors to a more protected location.*

7) – *Swash plate feed-back sensor [for] ACU-1 is out of order. Confirmed by inter-changing between ACU1 and ACU2. MBD will arrange delivery and installation in Europe.*

The chief engineer was aware of the faulty sensors after he had joined the vessel in Hong Kong, and was under the impression that they had failed due to engine vibration. He understood from the MBD service engineer in Singapore that they were for pressure indication only, and that a shutdown would not occur if the fourth sensor failed. The chief engineer informed the master that it was safe for the vessel to sail in this condition.

The guarantee claims were processed through the operating company, and, in parallel with the shipyard, to the equipment supplier. Main engine claims were also sent to the MBD Hamburg office and MBD head office in Copenhagen. *Savannah Express* had many guarantee claims during her maiden voyage; this is not unusual for a new vessel.

### 1.9.1 Previous engine slowdowns

*Savannah Express* had suffered from approximately eight engine shutdowns or slowdowns before her visit to Singapore on 3 July, and another eight between Singapore and Southampton (including the two on 19 July) (**Figure 17**).

The majority had been quite short in duration and had resulted from faults in the electro-hydraulic or mechanical systems.

## 1.10 ACTIONS TAKEN AFTER THE ACCIDENT

Another MBD service engineer visited *Savannah Express* the day after the accident. This was a pre-planned visit to re-supply the vessel with new hydraulic pressure sensors. In the event, the replacement sensors were lost with the service engineer's luggage while in transit.

<b>MV "Savannah Express"</b>						
<b>Shut- and Slow Downs</b>						
Date	time	hrs	description	reason	caused by	remarks
19.7.	11.36	1550	shut down	ECS	unknown	Southampton
19.07.	7.42	1546	shut down	ECS	low hydr press, sensor	Southampton
17.07		1504	man slow down	oil leak	c5 exh valve hydr pipe	slow down for repair, M 039
13.7.	10.38	1428	slow down	exhaust gas deviation	sensor failure	E 018
12.7.	19.01		slow down	cyl 7 lub fail	lubricator	
12.7.	11.18	1392	slow down	exhaust gas deviation	c9 fwd fo valve	stopped for repair, M 035
11.07		1367	man slow down	broken fixing screws	c8 exh vlv hydr pipe	reduced for repair
7.7.	16.02	1273	slow down	exhaust gas deviation	c3 sensor fail	E 013
Total stops, shut or slow downs					8	
shut or slow downs due to fuel valve failure					1	
shut or slow down due to cylinder lubrication failure					1	
shut or slow downs due to sensor failure					2	
shut or slow downs due to hydraulic problems					2	
shut or slow downs due to electronic failure					2	(Southampton)
shut or slow downs due to other					0	

History of shut and slow downs 7 July - 19 July

The service engineer's completed timesheet provided some information as to his views on the likely cause of the engine failures, as follows:

*Pressure Transmitter: Shut down was experienced on arrival to Southampton due to failure on pressure sensor on hydraulic pump suction side. Three (3) was [sic] damaged previously, and hereby the last was damaged, which leads to engine Shut Down. Crew managed to start again installing a 'cheat plug' with a resistor in ACU 1 terminal 32.*

Replacement pressure sensors had been lost in transit. The service engineer fitted a second 'cheat plug', the manufacturer's accepted method to inhibit low hydraulic pressure indication, which allowed the vessel to sail with the agreement of the Classification Society, Germanischer Lloyd (GL). New pressure sensors were to be delivered to Hamburg, the next port of call.

The timesheet also indicated the possible cause of the second engine failure, as follows:

*Tacho failure: Engine stop due to tacho failure, was also experienced during arrival to Southampton, without crew being able to restart from Bridge, ECR or LOP. The vessel was hereafter tugged in.*

*All connections were checked by MBD, as well as timing of TDC to TDA A+B and trigger pulses to all ECU and CCU's. This was found correct and within limits. Afterwards an air run was made, and all tacho failure resets except 'CCU 1 Tacho failure B'. All connections were checked again and CCU 1 reset. Alarm*



*disappeared, but during next air run, same alarm arises. It was decided to change MCU on CCU 1 and make an air run again. None tachometer failure was observed during several air run [SIC].*

*It was concluded that, tachometer failure was caused by this failing MPC. MAN B&W Diesel A/S agreed on this and found it safe to continue towards Hamburg. Classification Society (GL) agreed as well and Southampton Port Authorities was informed. Hereby the vessel was cleared to leave towards Hamburg [SIC].*

A Condition of Class for the engine control system was imposed by the Classification Society on 20 July. This required that all four 'hydraulic pump suction shutdown devices' be reinstated, and the swash plate position indicator be repaired prior to the vessel's departure from Hamburg, or not later than 25 July 2005.

On 16 August 2005, MBD produced a "Summary of events leading to the accident on 2005-07-19". This summary, based on the information available to MBD at the time, listed the sensor faults (suction pressure and number one pump swash plate) in existence prior to 19 July, and the failure of the fourth sensor which led to the shutdown at the Nab Tower.

The summary then mentioned that this shutdown had been resolved by disabling ECU-A.

The consequences of the fourth sensor failure, and the measures taken by the engineers, were listed as:

- *Pump #1 cannot be controlled. The pump will deliver 100% flow in AH (ahead) direction but cannot be reversed, and it will not deliver hydraulic oil in AS (astern) direction. The remaining three pumps are sufficient for AS operation.*
- *The shut down function for low hydraulic oil inlet pressure is based on four sensors. The function works correctly as long as one sensor is in operation. When the last sensor failed, the system generated a shut down (we expect that the system has locked the sensor value to the last 'valid' but wrong pressure – below the shut down level).*
- *By disabling ECU-A, the control of #4 hydraulic pump was lost. The pump will deliver normally in AH direction and without control it cannot be reversed and cannot deliver in AS direction. In combination with the failure of pump #1, only two pumps were available for AS running and as this gives too low capacity for operation, the AS manoeuvre failed due to the missing hydraulic power.*

The summary went on further to explain that “*the indicated tachometer failures are a consequence of the unexpected stop due to lack of hydraulic pressure, and these failures can be cleared by an air run...*”.

Finally, the summary stated that the system worked normally after the pressure sensors had been replaced.

## **1.11 HARBOUR TUGS**

### **1.11.1 Tugs serving the Port of Southampton**

The tug *Lyndhurst* was built in 1996, has an LOA of 30 metres, an installed power of 2995kW, two Voith Schneider propulsion units and a designed bollard pull of 43 tonnes. The tug *Sir Bevois* was built in 1985, has an LOA of 29.37 metres, an installed power of 1822kW, two Schottel propellers and a bollard pull of 34 tonnes. Both vessels are owned by Adsteam UK Limited, and their port of registry is Southampton.

Adsteam UK Ltd operates tugs in a number of UK ports. They have seven tugs in Southampton and stand by and assist approximately 12 container vessels each week. The seven available tugs have bollard pulls of between 34 and 61 tonnes and various propulsion methods and capabilities.

### **1.11.2 Call-out arrangements**

The tugs operated by Adsteam UK Ltd in Southampton operate on a rota system, and are contracted to provide services to inbound and outbound vessels, often at short notice.

The tug crews work a 12 hour day during their week on-call. On 19 July 2005, *Savannah Express* was the first call-out that *Sir Bevois* and *Lyndhurst* attended at the beginning of the crews' on-call week.

The number of tugs allocated to a particular vessel depends on the vessel characteristics and the requirements of the vessel's agent, as well as environmental conditions. In the case of *Savannah Express*, with a working bow thruster, two tugs were considered sufficient.

### **1.11.3 Crew training**

The skipper of *Sir Bevois* had been a relief and permanent tug skipper for over 17 years, and had been the skipper on *Sir Bevois* for 2½ years. His experience had been gained mostly in and around Southampton, and he had attended the STCW training courses. During his time with a previous tug company, approximately 15 years ago, he had accompanied pilots and had stood on the bridge of various ships entering Southampton to gain a better understanding of the problems encountered in manoeuvring large vessels in restricted waterways.

The skipper of *Lyndhurst* had served 21 years as relief and permanent tug skipper, and had been skipper on *Lyndhurst* for 5 years. He had also attended various training courses, including STCW. He had previously worked on all the Southampton, Adsteam owned tugs.

Both tug skippers had provided advice to Southampton pilots on tug operations on board their tugs, as part of pilot training.

In the past, tug crews had made familiarisation visits to ships under pilotage, but this practice had not occurred for many years. Although this subject had been raised during meetings between the port authority and the towage company, little progress had been made towards reinstating the practice.

#### 1.11.4 Southampton towage guidelines

Towage guidelines are contained in a publication entitled 'Southampton VTS – Towage Guidelines'.

This states that, for container vessels over 240m LOA and intending to berth at berths 204 – 207, three tugs are required if a swing is intended, or two tugs if not. The minimum bollard pull for each tug must be 30 tonnes. The minimum number of tugs could be reduced by one if the vessel had a bow thruster of over 2000HP (1492kW).

Pilots in Southampton have been concerned for some years regarding the allocation of existing tugs to increasingly large vessels. Regular discussions within the port's Navigation Risk Assessment group have been held, in order to develop the Towage Guidelines for the port and ensure the Port Users Information and Navigational Guidelines remained valid.

In 2002, an incident, involving *Hamburg Express* (100,000DWT), occurred as she entered the Upper Swinging Ground when the stern tug was not powerful enough to slow the ship down sufficiently, necessitating half astern on the ship's engines.

Southampton port risk assessment meetings of 2002 have highlighted the need for higher bollard pull tugs in the port, with recommendations to that effect. In a 2002 meeting between pilots and tug crews, a consensus indicated that more powerful tugs, in the region of 55 tonne bollard pull, with Voith Schneider propulsion, would be desirable.

The formal risk assessment required to be carried out by the Statutory Harbour Authority (SHA), under the Port Marine Safety Code (PMSA), includes the need for tugs. The Towage Guidelines were developed from this risk assessment. In addition to taking account of the physical conditions of the harbour, and the characteristics of the vessels using it, an assessment should also take into account the capacity of available tugs.

As ABP is the SHA for Southampton, and has responsibility for towage guidelines under the PMSC, the Towage Guidelines were amended in May 2003. They now include the requirement that vessels of over 60,000DWT must have at least one tug of 40 tonnes bollard pull.

In June 2005, the issue of tug allocation to the latest 8500 TEU vessels was again raised in a meeting between the SHA and pilots. During this meeting, an incident was noted, in which *Lyndhurst*, acting as the stern tug, appeared to have difficulties when requested to slow a vessel in the swinging ground.

On 19 July, at the time of the incident involving *Savannah Express, Lady Madeleine*, a 61 tonne bollard pull tug, operated by Adsteam UK Ltd in Southampton, was assisting a significantly smaller vessel in the Western Docks.

#### 1.11.5 MAIB Safety Bulletin

In 2005, after three significant collisions involving tugs, the MAIB issued Safety Bulletin (2/2005) – *Collisions and contacts between tugs and vessels under tow or escort in United Kingdom ports*.

The bulletin contained two safety lessons, the second of which stated:

- *All harbour authorities, pilots and tug operators regularly review the capabilities and limitations of their harbour tugs and their crews, to ensure a common understanding of each tug's strengths and weaknesses. This should be supplemented for each towing task with a local appraisal of the intended operation to ensure the "tug to task" allocation is appropriate before the tow or move begins.*

### 1.12 CLASS REQUIREMENTS

#### 1.12.1 General rules

The design changes that were carried out to change a camshaft controlled (MC) engine to an electro-hydraulically controlled (ME) engine had to comply with the Classification Society rules regarding control, monitoring and ships' safety systems.

Class Societies' rules comply with SOLAS guidelines with respect to one failure criterion: essentially, a single component failure should not cause a vessel to lose critical systems.

As part of Germanischer Lloyd's (GL) approach to the introduction of electro-hydraulic controlled engines, they required MBD to carry out a Failure Modes, Effects and Critical Analysis (FMECA) to determine the weak links in the system.

FMECA is a method of identifying a hazardous event, the cause, the method of control and the corrective action.

As not every conceivable combination of faults could be tested, GL concentrated on the effectiveness of the back-up systems, and selected specific system faults. These tests met the SOLAS requirements.

Various paragraphs within GL's rules apply SOLAS requirements regarding the single failure criterion, including:

- Section 9 (3.1) Design and Construction

*Machinery alarm systems, protection and safety systems, together with open and closed loop control systems for essential equipment shall be constructed in such a way that faults and malfunctions affect only the directly involved function.*

- Section 2 (6.1.3) Electronic components and systems

*For main propulsion engines one failure of an electronic control system shall not result in a total loss or sudden change of the propulsion power. In individual cases, GL may approve other failure conditions, whereby it is ensured that no increase of ship's speed occurs.*

#### 1.12.2 Rules with respect to spares

The carriage of certain specified spare parts is a Classification Society requirement to ensure that the vessel can carry out repairs in the event of machinery failure. The spare parts listed in class rules are mainly generic (such as piston, main bearing etc), but some are more ship specific.

For *Savannah Express*, in addition to the usual spares for the main engine and ancillary equipment specified by GL, spare ECS components were also listed, along with their quantities.

Within the listing for the HPS, one pressure transducer (or sensor) for the system pressure surveillance was included. No spare reference sensor for the tacho system, or spare tacho encoders, was required.

Although the FMECA was used to determine the level of spares to be carried, the overriding decision was based on the manufacturer's experience.

Although not required by the Classification Society, MBD has advised that additional spares for the main engine were carried on board for easier maintenance and increased security in operation. This additional spares list did not include any pressure sensors for the HPS.

## 1.13 INTERNATIONAL SAFETY MANAGEMENT CODE

The ISM Code is concerned with procedures whereby the safety and pollution prevention aspects of a ship are managed, both onboard and ashore, rather than laying down specific rules for the technical condition of the ship itself. The ISM Code requires the Safety Management System (SMS) on board to be structured so that all relevant rules and regulations are complied with. This includes STCW.

Effective recruiting, vetting, familiarisation, training and renewal of knowledge and skills are prerequisites to ensuring that the crew operate the vessel to the best possible standards, and the systems in place are demonstrable.

### 1.13.1 ISM Code requirements

The ISM Code promotes preventive measures and one concept is contained in objective 1.2.2(.2) which states '*Establish safeguards against an identified risk*'. This philosophy for the prevention of safety and environmental hazards, through pro-active measures, is intended to ensure appropriate precautions are identified and put in place rather than reacting to a problem after the event.

## **SECTION 2 - ANALYSIS**

### **2.1 AIM**

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

### **2.2 ANALYSIS OF ENGINE EVENTS PRIOR TO THE CONTACT**

#### **2.2.1 Prior to Singapore**

The swash plate feedback sensor for number one hydraulic pump had already failed before *Savannah Express* reached Singapore. This prevented the pump from providing any hydraulic power to operate the engine in astern. Three suction pressure sensors for the main engine driven hydraulic pumps were also out of action, having failed between 27 May and 3 July due to hydraulic pressure fluctuations or pulses, and were logged as engine guarantee claims. This left one remaining, on number four pump. The chief engineer was aware of these faults and the limitation imposed by the swash plate feedback sensor.

#### **2.2.2 At Singapore**

Although the MBD service engineer was unaware of the failed suction pressure sensors before visiting the vessel, the information he gave the chief engineer gave the impression that the sensors only provided pressure indication, and their failure would not cause an engine shutdown. Probably due to insufficient knowledge of the ECS to disagree with, or question, the service engineer, the ship's engineers accepted the operational guidance. This information underpinned the chief engineer's thinking during the engine failures on 19 July.

Although MBD was aware that the failure of all four pressure sensors would result in engine shutdown, delays in processing the many guarantee claims, and because the sensors failed within a relatively short time, meant that no warning was provided to the vessel operator.

Based on the information provided by the service engineer, the vessel sailed from Singapore without any spare sensors, although this was a Class requirement both in terms of minimum spares to be carried and the SOLAS 'one failure' criterion. No checks appear to have been made directly with MBD on the implications of operating with only one sensor.

Had this information been obtained, the necessary advice on how to overcome any potential shutdown, with the agreement of the Class Society, could have been provided, and the shutdown at the Nab Tower probably avoided.

### 2.2.3 At the Nab Tower

As *Savannah Express* approached the Nab Tower on 19 July, the fourth, and last working hydraulic suction pressure sensor, on number four hydraulic pump, failed. Without feedback from the sensors, the ECS generated an engine shutdown signal to protect the hydraulic pumps from damage due to indicated loss of hydraulic oil. As the hydraulic system pressure was the operating medium for the mechanical components on the engine, without it, the engine would not run.

The engineers' attempts to locate the cause of the lost pressure signal failed, as they presumed that the average pressure reading on the MOP was an actual sensor. However, they eventually decided to fit a 'cheat plug' to provide a false pressure signal in the control panel for number one pump. This resolved the pressure signal loss, even though they did not consider the loss of the suction pressure signal to be the cause of the failure. In the meantime, the chief engineer believed the fault might lay with ECU-A, so he disabled this control unit. The engine subsequently started under the control of ECU-B, which supported his belief.

The inadequate information provided in the MBD instruction manuals, on the consequences of disabling an ECU, and the lack of comprehensive training, meant the engineers were unaware that disabling ECU-A caused a loss of swash plate control to number four hydraulic pump, which reverted to providing 100% full ahead power only. Hence, astern hydraulic power, from pump number four was, like pump number one, no longer available.

Prior to departing from the anchorage position at the Nab Tower, the main engine was only turned astern on air and not run on fuel astern. Had an attempt been made to restart the engine after fitting the 'cheat plug', the engineers would probably have realised where the shutdown fault lay. Unfortunately, due to a possible misunderstanding of the comments of the MBD service engineer in Singapore, they were under the impression that the suction pressure sensors would not cause a shut down, and the actual fault lay elsewhere.

There was no company procedure on testing of the engine with fuel prior to departure from a port or anchorage or, specifically, after an engine shutdown. Had an attempt been made to start the engine astern on fuel, its failure to start would have alerted the engineers that a fault still existed, and that more diagnostic work needed to be undertaken before *Savannah Express* was put at risk. As numbers one and four pumps no longer operated in astern, the remaining two pumps were insufficient, on their own, to provide the required hydraulic power.

If the chief engineer had been aware of the 24 hour telephone hotline to MBD, it is conceivable that he would have made use of it, and would have effectively resolved the shutdown. He was not provided with the information on this link to MBD, although he had no prior working knowledge of the ECS and had joined the vessel unplanned and at short notice.



## 2.2.4 At the Upper Turning Ground

As *Savannah Express* reached the Upper Turning Ground, her engine was stopped and then given an astern command. The engine turned on air but did not start, which prompted tacho failure alarms. The chief engineer probably believed that there was a genuine tacho fault and, due to his limited understanding of the ECS, further believed that the tacho fault could be cleared by carrying out an 'air run'. Several 'air runs' were carried out, depleting the compressed air reserves dramatically, resulting in low air pressure and preventing any further attempts to start the engine.

The tacho failure alarms occurred due to low hydraulic pressure generated by the only two hydraulic pumps (two and three) which provided astern power. Numbers one and four hydraulic pumps were no longer controllable, and had defaulted to providing 100% ahead power only. Although the electrically driven automatic start-up pumps initially produced enough hydraulic pressure to turn the engine, there was inadequate power from the two, engine driven pumps, for the engine to continue turning once the auto start-up pumps had cut out. Although low hydraulic pressure alarms had occurred, the chief engineer was confident that hydraulic pressure was present (as indicated by the pressure indication from the pressure side of the pump). Because of the chief engineer's conviction that inadequate hydraulic power was not the cause of the failure, he did not consider, or was unaware of, the possible option of switching the electrically driven start-up pumps to manual and running them in parallel with the engine driven pumps. This option might have supplied just enough hydraulic power for the engine to run astern at low revolutions.

## 2.3 ALARM EVENT LOG (Figure 17)

### 2.3.1 Analysis of the individual alarms

After the incident, the main engine event log was downloaded. From this log, three separate groups of alarms have been selected and analysed from the large number that were displayed. They are as follows:

1. Alarms when arriving at the Nab Tower

All times UTC + 1

#### 07:29:15 – Lub oil pressure

The relevant guidance information provided for this alarm is as follows:

*Cause: Most probably a failure in the cabling to the sensor or a failure of the sensor, or missing sensor power supply ....*

*Effect: Reduced supervision quality; One sensor out of three is unavailable.*

Although this information gives the correct direction in which to begin fault finding, it also effectively supports the advice given to the chief engineer by the MBD service engineer in Singapore, and does not indicate that an engine shutdown could occur as a result of sensor failure. The chief engineer was

aware that three suction pressure sensors had already failed, which had not caused any operating problems. As such, this information provided by the alarm system was probably not considered to be relevant for locating the cause of the shutdown.

It should be noted that the alarm information only makes reference to three sensors, and not four. It is probable that this information page was not updated to reflect the requirements of the larger 12K98ME engine.

#### 07:29:21 – Inlet pump 4 and pressure deviation

The relevant guidance information provided for this alarm is as follows:

*Effect: no effect*

As with the previous alarm, the engineers were aware of the three pre-existing failed suction pressure sensors which had no detrimental effect on the operation of the system. However, this alarm does specify pump number four, which had the remaining working pressure sensor and should have prompted the engineers to consider the possibility of this sensor failure being the cause of the shutdown. The limited guidance information indicates that this alarm will not cause any problems, and clearly does not indicate that an engine shutdown could be imminent.

#### 07:29:22 – Pump inlet pressure low

The relevant guidance information provided for this alarm is as follows:

*Effect: If lub oil pressure further decreases, a non-cancellable shutdown could be carried out to protect engine driven pumps from cavitation.*

This alarm does provide the indication that a shutdown could occur as a result of low oil pressure. Unfortunately, the guidance appears not to have been acted upon, especially when taking the previous alarms into account. This alarm occurred about 7 seconds after the initial warning that there was a fault on the hydraulic system.

#### 07:29:23 – Shutdown

This was the signal to each of the twelve CCUs to stop fuel injection as a result of low hydraulic control pressure.

#### 07:29:27 – Hydraulic pressure deviation from set point ECU- B/A

The relevant guidance information provided for this alarm is as follows:

*Cause: ...Another possibility is that it could be caused by either one or more malfunctioning engine driven pumps .....*

*Effect: If hydraulic pressure is lower than ECS computerised setpoint and continues to decrease, hydraulic pumps cannot deliver enough oil to maintain pressure. If pressure drops below 145 – 150 bar, ECS likely to carry out a shutdown.*

*Suggested action: Check hydraulic pressure on MOP.*

This guidance clearly states that a shutdown could occur if the pressure drops below a certain point. However, a shutdown had already started by this stage of the alarm list.

The engineers were aware that the hydraulic pumps' suction pressure indication had been lost, and they had begun looking for a faulty sensor. Their limited knowledge of the control system led them to believe that the pressure reading on the MOP screen was derived from a single specific pressure sensor. They were not aware that it recorded an average from the four suction pressure sensors. Attempts to locate this non-existent sensor failed, and their attention turned to ways to bypass the fault conditions.

Although a 'cheat plug' was eventually installed to overcome the low pressure signal, the engine was not re-started until after control was changed from ECU-A to ECU-B.

## 2. Alarms when changing over from ECU-A to ECU-B

### 08:53:04 – No command from ECU-A

Indicates a failed MPC as ECU-A is set to test mode.

There was no warning that full duplication of the system would not occur. ECU-B did not carry out all the functions of ECU-A as it was unable to control number four hydraulic pump. This lack of information was critical because the chief engineer might have considered alternative options to disabling ECU-A.

### 08:53:06 – Pump control failure

The relevant guidance information provided for this alarm is as follows:

*Description: The engine driven swash plate pump that delivers the high hydraulic pressure cannot be controlled by the MPC.*

*Effect: The pump will try to swivel its swashplate to deliver full flow in the engine AH direction... In case of reversing the engine, this pump cannot contribute with flow to the HPS. This corresponds to loss of one pump.*

This clearly states that control has been lost on a pump, and that it cannot deliver astern hydraulic power, but it does not specify which pump, or that it was caused by changing control to ECU-B. This information also appears not to have been acted upon to determine which pump was no longer controllable. If the engineers had located the control failure as being from number four pump, they might have realised that without control on two pumps, which fail safe to the 100% ahead position, the engine would be unable to operate in astern.

### 3. Initial alarms after first astern command at the Upper Swinging Ground

#### 11:36:40 – Low hydraulic pressure

The relevant guidance information provided for this alarm is as follows:

*Description: The hydraulic supply pressure has dropped to a level where it was necessary to reduce maximum allowed fuel index to less than 100%.*

*Cause: Pump failure, hydraulic leakage or faulty bypass valves in hydraulic supply system.*

*Effect: If the pressure at some point drops too far a shutdown is carried out.*

*Suggested action: Check for hydraulic pump related alarms...*

The information warns of inadequate hydraulic supply pressure, possibly as a result of a pump related fault, and could be the basis on which to discover that more than one pump is set to 100% ahead, especially if earlier alarms (in particular 08:53:06 – Pump control failure) are also taken into account.

#### 11:36:51 – Tacho set A failure

The relevant guidance information provided for this alarm is as follows:

*Description: Inconsistent or missing tacho signals recorded.*

*Effect: The MPC had to change active set of tacho sensors. If both sensors set A and B fail on one CCU, control of injection, exhaust and start air valves are stopped.*

*Suggested action: Check tacho sensor power OK.*

The information advises that, as a result of an unreliable tacho sensor signal, the controlling computer switched to the back-up sensor. It further advises that if a Cylinder Control Unit did not receive a signal from either tacho sensor, then operation of the air start fuel injection and exhaust valve, to that cylinder, would be stopped.

No alternative reasons for these tacho alarms are provided, even though MBD was aware that “*the indicated tacho failures are a consequence of the unexpected stop due to lack of hydraulic pressure...*” as stated in its summary of events (see section: “Actions taken after the accident”).

### 2.3.2 Conclusions

In general, the individual alarm information ‘assumes’ that no other system faults have occurred and, therefore, the information pages cannot provide complete advice on alternative fault scenarios. This is not possible without carrying out a full FMECA of all possible combinations of failure. As such, there is a possibility that the advice given can lead the engineers in the wrong direction and, as occurred when ECU-A was disabled, to actually make the situation worse.

The limited number of relevant alarms that have been highlighted above, are among a large number occurring in a very short space of time (**see Figure 16**). Considerable time can be spent scrolling through them all in an attempt to identify the critical alarm, or alarms, which will enable the fault to be located. Even when a particular alarm is identified as being the main suspect, the guidance provided can, as has already been stated, be inadequate or detrimental to the fault finding process.

The magnitude and speed at which the alarms are delivered can quickly overwhelm those unfamiliar with the system. It is clear, however, that with a good working knowledge of the control system, irrelevant alarms could be quickly dismissed, leaving only a few for more detailed investigation. The information to diagnose the two shutdowns, was provided within the alarm information pages, and the engineers correctly resolved the first engine failure by fitting the 'cheat plug'. However, they also disabled a working system (ECU-A), which reduced the operational capabilities of the engine.

Because of the engineers' consistent belief that inadequate, or low indicated, hydraulic pressure was not the cause of the engine shutdown, they did not take full account of the hydraulic alarms. Repeated attempts to clear the tacho faults by using the 'air run' system were ineffective, as the indicated tacho faults were not the root cause of the engine failure. Using the 'air run' also substantially reduced the compressed air available.

The engineers on *Savannah Express* did not have a good working knowledge of the ME alarm system due to a lack of specific training (in the case of the chief engineer), and a limited understanding of the system gained during the vessel build and subsequent sea trials (in the case of the electrician). Furthermore, the engineers' general engineering knowledge, gained through many years' experience, appears to have been insufficient for them to understand and make use of the alarm information provided.

## **2.4 TRAINING AND KNOWLEDGE OF THE ECS**

### **2.4.1 Chief engineer**

The STCW certificated chief engineer was experienced and highly regarded for his knowledge of general marine engineering and practical operation of the MAN B&W MC (camshaft) engine. However, it is apparent that he did not have sufficient knowledge, or specific systems engineering training, to effectively fault find on the electro-hydraulic system of the ME engine.

He was not the designated chief engineer for *Savannah Express*, and neither he, nor the other senior engineers, had attended the ME training course prior to joining. His only type specific training comprised a 3-day handover, the ME engine operation manual and the ME training manual left by the previous chief engineer. However, the ME training manual only provided an overview of the system, and the operation manual was insufficient for the needs of the engineers.

The chief engineer had gained some knowledge of the ECS during his time on board. For example, he understood that the faulty swash plate sensor on number one pump would prevent that pump from delivering hydraulic power astern, and that only the minimum of three pumps were available for astern power. However, his working knowledge of the system was highlighted during the morning of the accident, as follows:

1. The failure of the last suction pressure sensor was not considered to be the cause of the shutdown at the Nab Tower, even though the alarms indicated that it was. The chief engineer's conclusions would have been affected by his understanding of the advice received from the MBD service engineer in Singapore.
2. The decision to disable ECU-A. The chief engineer understood the engine control system to be fully duplicated, so that when ECU-A was disabled, ECU-B would take over all the functions of ECU-A. This was not the case, and the decision to not take full account of the hydraulic system pressure alarms, and to disable ECU-A, effectively prevented the vessel from operating in astern. This problem could have been recognised had a full engine test been carried out prior to departure from the Nab Tower.
3. The next misunderstanding of the ECS occurred at the Upper Swinging Ground, when the engine failed when put astern. Again, the hydraulic alarms did provide some indication that the fault was hydraulically related, and that a shutdown could result. However, the occurrence of the tacho failure alarms, and the engineer's conviction that full hydraulic power was available, meant that a proper investigation of the fault was not undertaken. Attempts to override the failure centred around using the 'air run' mode to reset the tacho alarms.

#### 2.4.2 Electrician

The experienced electrician had attended *Savannah Express* while she was being built in Korea, and had sailed on the following sea trials and her maiden voyage. He had not attended the ME training course prior to sailing on the vessel. Attendance at this training course might have provided enough additional knowledge for the engine shutdown at the Nab Tower to be effectively diagnosed.

He was qualified as an electrical engineering officer under Hungarian regulations to allow him to serve on any vessel. Under STCW, there is no specific training requirement for electrical engineering officers on board ships, and therefore no internationally agreed standard of training against which shipping companies and flag states can effectively assess electrical and electronic engineering knowledge. Standards of training currently differ considerably between countries.

### 2.4.3 MBD training

Although the ECS was developed with simplicity of operation in mind, it is a complex system which requires engineers to have a thorough knowledge of mechanical, hydraulic, electronic and electrical engineering principles. For the same reason that the FMECA did not test every possible combination of faults on the system, such as all four suction pressure sensors failing, the alarm information pages will not provide the answers to all possible fault conditions. The engineers will require, therefore, sufficient knowledge to be aware of the implications of faults before they might cause a shutdown, and be capable of overcoming these faults when they occur. Engineers also need sufficient knowledge to be able to question the advice provided by the service engineers, and to recognise their own limitations.

Evaluation of MBD's ME training code has indicated that it does not cover fault finding in sufficient depth to provide engineers with an adequate knowledge of this subject.

### 2.4.4 Training – general conclusions

The engineers were not provided with sufficient information (through suitable training and in the engine operation manual), or the means to gain that information (via the hotline), prior to, or during the voyage, to enable them to fully diagnose the cause of the engine shutdowns. An MBD guarantee engineer only sailed with the vessel for the first 2 weeks after she left the builders' yard.

The chief and electrical engineer's theoretical knowledge, gained from attending standard STCW and Flag State courses (which includes electrical theory and practical training), and the practical knowledge gained over a number of years' experience, appear to have been insufficient to effectively diagnose the cause of the engine shutdowns and deal adequately with the situation that occurred on 19 July.

It is questionable whether the existing MBD ME training course would have provided enough information for the chief or electrical engineer to diagnose the engine shutdown, as it effectively provides only an overview of the engine control system. However, attendance on a maker's engine specific course should be a standard requirement for service on vessels with novel engine types. Ship managers and ship's officers should use the risk assessment procedures to establish where attendance on such a course should be required for safe ship operation.

Modern vessels increasingly rely on complex, integrated control and operating systems. Often these systems cannot be separated to enable operation of the equipment in a 'limp home' mode. The rapid introduction of such technology has placed ever-increasing demands on the shipboard engineers, who have often not had the requisite training with which to equip them to safely operate, maintain and fault find on this complex equipment.

STCW95 has only the basic generic requirements for competence in the operation of electrical and electronic control equipment. In reality, individual shipping companies are requesting maritime training establishments to provide specific technology training courses to supplement the basic training given to marine engineers at the STCW level.

Unfortunately, it is likely that not all shipping companies which manage vessels using complex integrated technology, recognise a training deficit for their engineers and expect that the STCW95 requirements are sufficient to cope with the developing technology. The inability to effectively diagnose faults in these complex systems can put vessels, their crews, and the environment at considerable risk.

It is possible that the present generic training requirements of STCW95 are insufficient to cope with the 'system engineering' aspects of complex, integrated engine control and operating systems like that of the MBD ME engine. It is considered that these training requirements should be reviewed to determine their present and future effectiveness.

Despite rigorous testing prior to delivery, experience shows that incidents will occur as the system matures, on the vessel. In the meantime, the ECS is being fitted to numerous vessels which have the capability of causing considerable damage after a propulsion failure. The necessary safety barriers, such as a longer period of supervision by guarantee engineers, should be put in place during the development of a new safety critical piece of equipment, such as a main engine control system.

## **2.5 THE ROLE OF THE MBD SERVICE ENGINEERS**

It is disconcerting to note that both MBD service engineers who visited the vessel, one at Singapore and one at Southampton, appear not to have had full operational knowledge of the ECS, or did not effectively convey their knowledge to the shipboard engineers.

### **2.5.1 At Singapore**

The first service engineer left the chief engineer with an incorrect impression of the importance of the remaining working sensor, which led to *Savannah Express* sailing without any spares for a component which, when it did eventually fail, caused an engine shutdown. In this respect, when the vessel sailed, she inadvertently did not meet the Classification Society requirement for 'one failure criterion'. The incorrect advice also influenced the chief engineer's thinking, and the actions that he took after the engine failure.

### **2.5.2 At Southampton**

The second service engineer noted, in his report, that the engine failure at the Upper Turning Ground was due to tacho failure. This was incorrect. He subsequently noted that 'air runs' were carried out during his visit, which failed to



clear the fault. This was the same method employed by the engineers prior to the contact with the linkspan, and which also had failed. This was a clear indication that the tachos were not at fault, but were responding to an engine 'failure to start' due to the inadequate hydraulic pressure. The fact that the engineers had disabled ECU-A was not noted in the report. The engine 'failure to start' was eventually attributed to an MPC within CCU-1. This was also incorrect.

### 2.5.3 The MBD Summary Report

The report generally clarified the causes and consequences of the two incidents of engine failure. This report, however, was produced nearly a month after the contact with the linkspan. In the meantime, *Savannah Express* continued to operate with the engineers unclear about the cause of the incidents, aside from the flawed analysis which had been received from the service engineer.

### 2.5.4 Conclusion

MBD should review the training and level of knowledge of its service engineers, who are its 'front line' staff, and on whom the ships' engineers rely for operational advice. This advice needs to be concise if further accidents are to be avoided.

## 2.6 TUG OPERATIONS

### 2.6.1 Tug allocation

Because of the nature of the rota system employed by Adsteam UK Ltd, the allocation of tugs to vessels means that the least powerful tugs might be employed to assist some of the largest vessels.

Although *Savannah Express* is one of the largest vessels to berth at Southampton Container Port, she was not allocated the largest tug available which, at the time of the incident, was providing assistance to a much smaller vessel.

*Lyndhurst* and *Sir Bevois* are adequately powered to assist a large vessel within the confines of the port. However, in an emergency when, for example, the vessel has a propulsion failure while underway, the lower powered tugs would find it difficult to reduce the headway to a sufficient amount in the space and time available.

It is clear that the most effective use of available tug resources has been under discussion by the pilots and harbour authority for a number of years, as the size of vessels entering the port has increased. However, the only action taken to address this issue has been the requirement for a 40 tonne bollard pull tug to be provided for vessels in excess of 60,000DWT. Although this occurred with *Savannah Express*, this tug was still unable to slow the vessel adequately in the space and distance available.

As ABP Southampton is the SHA and, under the PMSC, is required to review and update the port Towage Guidelines as appropriate, it should, in light of this incident, consider reviewing the present guidelines for both tug allocation and tug bollard pull within the port.

The contents of the MAIB Safety Bulletin (2/2005) should be taken into account during any review.

#### 2.6.2 Tug crew training

The tug masters were very experienced, and had operated tugs in Southampton for many years. However, they were, to some extent, unaware of the problems faced by, and the operational procedures adopted by the pilots in connection with the manoeuvring of very large container ships.

The tug masters had been on familiarisation visits to ships under pilotage to gain a better appreciation of the difficulties of manoeuvring a large vessel in the confines of a port. Unfortunately, this training exercise had not been undertaken for many years.

Adsteam UK Ltd should, in consultation with ABP Southampton and the port pilots, review tug master training, to ensure that it is appropriate to meet the requirements of the increasing size of vessels entering the port of Southampton.

### 2.7 COMMUNICATIONS AND THE DECISION TO ENTER HARBOUR

After the engine was started, the master was informed that the engine failure had been resolved by swapping to another engine control system; he was aware that the 'hot' standby ECU-B was now in operation and, implicit in this knowledge, that no other back-up system was available. This important piece of information was not passed on to the pilot. It is the master's responsibility to ensure that he has the necessary information with which to advise a pilot of any factors which may affect the operation of his vessel. It might be considered that the number of slowdowns etc that had been experienced on *Savannah Express*, warranted the port being given prior warning about the engine's unreliability prior to her arrival. That sort of information, coupled with the known fact that she had an unexpected shutdown when approaching the pilot station, should have been enough to trigger a new risk assessment of the pilotage.

Over an hour after leaving the anchorage, the pilot was informed that the cause of the engine failure had not been positively diagnosed. This should have prompted the pilot to advise the Harbour Authority for additional precautions to be put in place.

During the investigation, it came to MAIB's attention that vessels operating with large, modern, slow speed diesel engines might be unwilling or unable to test their engines before departure from a berth. This is due to the considerable power that the engines develop, even at dead slow ahead, and which can

quickly and easily overload the moorings. As a result, engine manufacturers have developed methods of pre-departure testing these engines, without fuel being admitted for combustion. In the case of the ME engine, this testing method is the 'air run' system. Such a system does not test the engines to the same degree as the traditional fuelled runs.

This inability to fully test the main propulsion system may not be generally appreciated by harbour authorities and pilots, who may gain the impression that the normal requirements of testing the critical propulsion and manoeuvring systems of a vessel, prior to departure, have been complied with. Port authority risk assessments should take this fact into account.

## **2.8 ADEQUACY OF SPARES**

The Classification Society requirement to carry one hydraulic suction pressure sensor, as described in Section 1.12, not only met the SOLAS 'one failure criterion', but actually exceeded it. As stated, there were four sensors in the system, and a propulsion failure would not occur until all four had failed.

MBD had realised that the main engine on *Savannah Express* had a design problem, and were evaluating changes to the engine's pipework and the durability and availability of the sensors at the time of the accident. The rate of failure of the suction pressure sensors, coupled with the rate at which guarantee claims were processed, meant that the three failed sensors were not replaced and *Savannah Express* sailed from Singapore with only one sensor operational and no spare on board.

The chief engineer, the master and the vessel operator were under the impression that failure of the remaining suction pressure sensor would not have a critical impact on the safe operation of the main engine. They were therefore content for *Savannah Express* to sail from Singapore without taking further remedial action. Because they were blind to the potential for an engine shutdown if the remaining pressure sensor failed, no contingency plan was considered for that scenario. They were consequently also unaware that the vessel no longer met the Classification Society requirements with respect to its 'one failure criterion'.

## **2.9 THE EFFECTIVENESS OF THE SMS**

If the owners of *Savannah Express* had fully considered the risks of placing a chief engineer on board who was inexperienced and untrained in the operation of the ECS, then additional safety barriers might have been put in place.

These include, but are not limited to, requesting the departing chief engineer to remain on board for longer, requesting MBD to provide a service engineer to sail with the vessel or requesting the shipyard to provide another guarantee engineer who was familiar with the system.

Effective use of the ISM Code and, in particular, the SMS within the company, should have highlighted the issue of training prior to the chief engineer joining the vessel.

It is unclear if the necessary mechanisms were in place within the company to ask the relevant questions regarding the potential gaps in the joining chief engineer's training, and the means to correct any knowledge gap.

Although the chief engineer discussed with the master the method used to overcome the engine shutdown at the Nab Tower, the discussion was not effective in evaluating the hazard of further unplanned breakdowns. In analysing this hazard, the possible causes should have been considered, and measures implemented to mitigate them. In this case, a judgment was made on the significance of the hazard based on incomplete knowledge of the ECS.

## **2.10 FATIGUE**

The work/rest routines of the pilot, master and chief engineer were analysed and it was concluded that fatigue was not a contributory factor in this accident.

## SECTION 3 - CONCLUSIONS

### 3.1 SAFETY ISSUES

The following are the safety issues which have been identified as a result of the MAIB's investigation. They are not listed in order of priority, but in the order in which they appear in Section 2.

1. Three out of four suction pressure sensors for the four main hydraulic pumps had failed before *Savannah Express* reached Singapore, due to hydraulic pressure fluctuations, or pulses. Only one spare sensor had been carried, and the availability of further sensors was limited due to supply problems. [2.2.1]
2. The chief engineer had been informed by the engine manufacturer's service engineer in Singapore that the loss of all four sensors would not cause an engine shutdown. He was therefore content for the vessel to sail with only one operational sensor. [2.2.2]
3. As *Savannah Express* approached the Nab Tower, number four hydraulic pump suction pressure sensor failed. Without any suction pressure indication, the ECS caused the engine to shutdown to protect the pumps from potential damage. [2.2.3]
4. The chief engineer had limited understanding of the ECS. [2.2.3]
5. The engineers were unaware that disabling ECU-A would cause loss of control of number four hydraulic pump, which defaulted to the 100% ahead position, and that this, along with another existing fault, meant that the engine would not run astern. [2.2.3]
6. An astern test was only carried out on the engine as an "air run" prior to leaving the Nab Tower. Had an astern test been carried out using fuel, the problem would have been discovered before the ship was put at risk. [2.2.3]
7. The inability to go astern at the Upper Swinging Ground was caused by inadequate hydraulic power as numbers one and four hydraulic pumps were no longer controllable, and had defaulted to providing 100% ahead power only. [2.2.4]
8. The chief engineer considered that the tacho failure alarms at the Upper Swinging Ground represented a fault with the tacho system, and resorted to carrying out a number of 'air runs' to reset the ECS. This was ineffective, as the indicated tacho faults were not the root cause of the engine failure. Due to their insufficient understanding of the ECS, the engineers did not recognise the association of the tacho alarms with the hydraulic pressure alarms. [2.2.4]

9. Necessary safety barriers, such as a longer period of supervision by guarantee engineers, should be put in place during the introduction of a new safety critical piece of equipment, such as a main engine control system. [2.4.4]
10. The ship's engineers did not have a sufficiently good knowledge of the main engine control system or specific system engineering training to successfully diagnose faults. [2.3.2]
11. The chief engineer was not the designated chief engineer for *Savannah Express* but was transferred at short notice. He had not received any specific training in the operation of the ECS components of an ME engine, apart from what could be conveyed during a 3-day handover with the former chief engineer. [2.4.1]
12. None of the ship's technical staff had received any formal training in the operation, testing, maintenance or fault finding of the complex ECS. They were also not aware of the 24 hour telephone hotline to MBD. [2.4.4]
13. It is possible that the present generic training requirements of STCW are insufficient to cope with the system engineering aspects of complex integrated engine control systems like that of the MBD ME engine. [2.4.4]
14. It is questionable whether the existing MBD training course for the ME engine is sufficient to enable efficient fault finding and diagnosis. [2.4.4]
15. The MBD service engineers who visited the vessel, one at Singapore and one at Southampton, appear not to have full operational knowledge of the ECS, or effectively conveyed that knowledge to the shipboard engineers. [2.5]
16. Without any spare hydraulic suction pressure sensors, *Savannah Express* did not meet Classification Society requirements, regarding the 'one failure criterion', between Singapore and Southampton. [2.5.1]
17. The tugs allocated to *Savannah Express* were unable to slow and halt the vessel's ahead movement. A more powerful tug had been available, but the system by which tugs were allotted jobs did not have the flexibility to match vessel need to tug capability. [2.6.1]
18. The master informed the pilot that the engine fault had not been positively diagnosed about an hour after leaving the Nab Tower. This should have prompted the pilot to inform the Harbour Authority so that additional precautions could be put in place. [2.7]

19. The pilot was aware that the engine had been tested before leaving the Nab Tower. However, he was unaware that it had only been run “on air” and that a full test with fuel had not been carried out. [2.7]
20. Had the port been aware that the vessel had a history of engine slowdowns, this, coupled with the unexpected shutdown when approaching the pilot station, could have been sufficient to trigger a review of the risk assessment associated with the vessel’s passage to Southampton Container Terminal. [2.7]
21. During the investigation, the MAIB became aware that large ships may be unwilling or unable to effectively test their engines while alongside, prior to departure, due to the risk of mooring failure, and that this may not be widely appreciated by harbour authorities and pilots. [2.7]
22. The number of working suction pressure sensors had been reduced due to the rate of sensor failure, lack of onboard spares and supply problems. [2.8]
23. The company SMS was not used effectively to recognise the risks associated with the chief engineer’s limited understanding of the ECS. [2.9]

## SECTION 4 - ACTION TAKEN

### MAN B&W has:

- Fitted an extension pipe and orifice plate for the hydraulic pump suction pressure sensors to remove the pressure pulses, and has replaced the sensors with a more robust, and readily available, type;
- Looked at the possibility of altering the ECS to transfer control of the fourth hydraulic pump from ECU-A to an ACU, as per the other hydraulic pumps, to provide 100% redundancy if failure of ECU-A occurs;
- Improved the ME training course to include the consequences of disabling an ECU;
- Planned a new software release, intended to reduce the number of alarms generated and make it easier to find the essential ones.
- Planned to introduce further ME engine simulators in China and Korea.

### ABP Southampton has:

- Initiated further discussions with Adsteam UK regarding the introduction of more powerful tugs for Southampton, and the allocation of high bollard pull tugs to the larger vessels entering Southampton;
- Engaged with Adsteam (UK) Ltd for joint simulator training for pilots and tug masters;
- Planned a simulation of the *Savannah Express* incident to assist in reviewing its Port User and Information Guidelines.

### Adsteam UK (Limited) has:

- Arranged with ABP for ship visits with a pilot as part of further tug master training;
- Arranged for tug masters to participate in simulator training courses alongside pilots, focussing on large container vessel movements;
- Discussed the possibility of informal meetings between pilots and tug masters to improve communications in general;
- Obtained a strain gauge to carry out routine bollard pull tests;
- Amended its rota system to enable the most powerful tugs to be allocated to vessels exceeding 95,000 DWT and allocate *Lady Madeleine* to vessels in excess of 320m in length;
- Implemented a tug replacement programme as part of its review of tug assets in the UK ports where they operate.



**Norddeutsche-Reederei has:**

- Advised its crews operating with ME engines, of the incident, and directed them to critically observe the existence of hydraulic pressure to ensure the engine is available during manoeuvring;
- Improved and extended the training of engineers, including the attendance of second and electrical engineer officers at the ME engine training course;
- Improved the pre-arrival (engine) checklist to include an astern test.

**The MAIB has written a 2-page summary of this report, which emphasizes the need for shipowners to ensure that:**

- The most effective type specific training is provided for engineers who are required to serve on vessels with novel engine types.
- Other safety barriers, such as a longer period of supervision by guarantee engineers, are put in place during the development of a new safety critical piece of equipment like a main engine control system.

The summary has been circulated by e-mail to shipowners worldwide.

## SECTION 5 - RECOMMENDATIONS

**The Maritime and Coastguard Agency** is recommended to:

2006/136 Submit an appropriate INF paper to IMO's Sub-Committee on Standards of Training and Watchkeeping so as to facilitate a review of the training requirements for marine engineers within STCW. This should take account of continuing developments in propulsion technology, particularly where main propulsion systems employ integrated combinations of mechanical, electrical, electronic and hydraulic systems essential to the proper and continued functioning of the overall system.

**MAN B&W Diesel, as manufacturer of the main engine,** is recommended to:

2006/137 Review and consider improvements in its ME engine training course, to equip the attending trainees with sufficient knowledge to enable them to adequately fault find a range of system faults which could occur. The syllabus should include a review of case studies reported by their service engineers.

**The International Harbour Masters' Association (IHMA), United Kingdom Harbour Masters' Association (UKHMA), United Kingdom Major Ports Group (UKMPG) and the British Ports Association (BPA)** are recommended to:

2006/M138 Ensure their members are aware that the crew of some large, powerful vessels may be unwilling or unable to effectively test main propulsion systems when alongside, prior to departure, due to the potential for mooring rope failure. Local port risk assessments need to reflect this change in modus operandi.

**Marine Accident Investigation Branch  
March 2006**

Safety recommendations shall in no case create a presumption of blame or liability