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Swedish Accident Investigation Board

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Olycka med fartyget MT PROSPERO i Milford Haven, Wales, Storbritannien, 2006-12-10

Dnr S-147/06

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Statens haverikommission har i samarbete med Marine Accident Investigation Branch (MAIB), Leading State, Storbritannien, undersökt en olycka som inträffade den 10 december 2006 i/Milford Haven, Wales, Storbritannien, med fartyget MT PROSPERO.

Statens haverikommission överlämnar härmed enligt 14 § förordningen (1990:717) om undersökning av olyckor en rapport över undersökningen.

Statens haverikommission emotser besked senast 28 dagar efter mottagandet av rapporten om vilka åtgärder som har vidtagits med anledning av de i rapporten intagna rekommendationerna.
(Se bifogad skrivelse MAIB 1/1/96, 2007-12-17).

En översättning av rapporten till svenska insänds senare.

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Report on the investigation of

the loss of control of product tanker

Prospero

and her subsequent heavy contact with a jetty at the

SemLogistics terminal, Milford Haven

10 December 2006

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Report 24/2007
December 2007

This is a joint investigation report between MAIB and the Statens haverikommission - The Swedish Board of Accident Investigation (hereinafter referred to as SHK). The MAIB has taken the lead role pursuant to the IMO Code for the Investigation of Marine Casualties and Incidents (Resolution A.849(20))

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

AMS	Alarm & Monitoring System
CHIRP	Confidential Hazardous Incident Reporting Programme
CSGC	China Shipbuilding Group Corporation
DNV	Det Norske Veritas classification society
DOC	ISM - Document of Compliance
dp	Dynamic Positioning (system for maintaining vessel in geostationary position)
DPA	Designated Person Ashore
DWT	Deadweight tonnage (vessel's load displacement less lightship)
ECR	Engine Control Room
FMEA	Failure Modes and Effects Analysis
GMT	Greenwich Mean Time
HI	Human Interface
IACS	International Association of Classification Societies
IMO	International Maritime Organization
ISM Code	International Management Code for the Safe Operation of Ships and for Pollution Prevention
ISO	International Standards Organisation
Knots	Speed in nautical miles per hour
kW	kilowatt
LR	Lloyd's Register classification society
MCA	Maritime and Coastguard Agency UK (The Port State administration)
MCB	Main Circuit Breaker
MHPA	Milford Haven Port Authority
MSB	Main Switch Board
MSC	IMO Maritime Safety Committee
OLM	Optical Link Module
OOW	Officer of the Watch
P&S Unit	Power and Speed Unit: controls drive related propulsion functions
PCS	Propulsion Control System

PEC	Pilotage Exemption Certificate
PES	Programmable Electronic Systems
PMS	Planned Maintenance System
PQF	Pod Quality Forum
PSM	Permanently Excited Synchronous Motor or Permanently Excited Machine
RA	Risk Assessment
RCU	Rudder Control Unit
rpm	Revolutions per minute
Schottel	Schottel GmbH & Co.KG
SHK	Statens haverikommission – The Swedish Government Board of Accident Investigation
Siemens	Siemens AG, Marine Solutions
SMA	The Swedish Maritime Administration (The Flag State authority)
SMC	ISM - Safety Management Certificate
SMS	Safety Management System
SOLAS	The International Convention for the Safety of Life at Sea 1974 (as amended)
SSC	Siemens-Schottel Consortium (designers & manufacturers of the SSP system)
SSP	Siemens-Schottel Propulsor (the podded drive system)
Standby	The formal heightened state of readiness of a vessel's crew, machinery and equipment just before, and during, a significant operation e.g. arrival or departure from port.
STCW	International Convention on the Standards of Training Certification and Watchkeeping for Seafarers 1978 (as amended)
STW	IMO Committee on Standards of Training for Watchkeeping
T	Tonnes
TCU	Torque Control Unit; controls converter related functions
UMS	Unmanned Machinery Space
VDR	Voyage Data Recorder

All times in this report are GMT

Photograph courtesy of FotoFlite

Prospero

SYNOPSIS

At 0035 on 10 December 2006 *Prospero* was approaching No. 2 Jetty, of the SemLogistics terminal, Milford Haven, when the master suddenly and without warning lost control of the vessel's podded propulsor system. This caused the vessel to make contact with the jetty's infrastructure, resulting in material damage to both the jetty and the vessel before control was regained.

At the time of the accident, *Prospero* was nearing the end of a passage from Dublin. The master and a pilot were on the bridge; no tugs were taken. As the vessel approached the jetty, the master transferred the conning position from the centre to the port control console in preparation for berthing the vessel port side alongside.

When *Prospero* was within 100 metres of the jetty, at a speed of 1.2 knots, the control lever then moved, with no manual input, to approximately 70% of full power. As the pod had been positioned to keep the vessel's stern clear of the jetty, *Prospero* very quickly increased speed and her bow swung to port. The master attempted to pull the control lever back to zero but the power remained at 70% and *Prospero*'s stem struck the concrete deck of the jetty, shortly after which the flare of the bow made contact with the steel gantry support of the jetty's oil loading arms.

While he was unable to control the pod's power, the master still had control of its direction, and he rotated the unit to move the vessel's head to starboard and operated the bow thrust to push the vessel's bow off the jetty. This brought the vessel parallel with the jetty, but with the power still at 70%. The master attempted to regain control by transferring control back to the central console and selecting the push button power control function, but this was not successful. The master then ordered the vessel's anchor to be let go and he turned the pod towards the stern to reduce the vessel's headway.

Shortly after this, and for no apparent reason, the power returned to zero. However, while the master was still evaluating the situation the power increased again to 70% and the vessel accelerated astern towards the jetty. The master was again unable to regain control. The pilot warned the personnel on the jetty to vacate the area, shortly after which the vessel's port quarter made heavy contact with the first of the mooring dolphins to the west of the jetty. She then continued astern to make contact with the second dolphin, resulting in material damage to both the vessel and the mooring dolphins.

By transferring pod control to the engine room and back to the wheelhouse, the master was able to regain control of the pod and stabilise his vessel until tug assistance arrived and *Prospero* was moved to a nearby jetty.

When *Prospero*'s primary propulsion control system failed, the master was not alerted to the failure and did not detect that the system had automatically switched into a reversionary mode of control. In his subsequent actions he was, to some extent, fighting the control system and was unable to prevent his vessel colliding twice with the jetty; once forward and once aft.

When built, *Prospero*'s propulsion system had been innovative, and the owners had benefited from an extended warranty. These two factors resulted in the owners depending heavily on the manufacturers for all aspects of product support. The lack of in-house maintenance procedures, inadequate system knowledge by ship's officers and shore staff, and weak SMS and onboard system documentation, overlaid on a propulsion system for which, when introduced, no dedicated technical standards existed, resulted in a vessel whose resilience to defects and emergencies was significantly weakened.

Although previous accidents and incidents to *Prospero* and her sister vessel, *Bro Sincero*, had presaged a control failure in some ways similar to that which occurred in this accident, these warnings had not been identified and no pre-emptive mitigating action was taken.

Prospero has suffered two further failures of pod control since this accident and the owners, manufacturers and classification society have individually and collectively commenced a series of actions to help prevent a recurrence; these are listed at Section 4.

Nonetheless, recommendations have been made to the vessel's owners, Donsötank:

- to provide training to their vessel's deck and engineering staff on the operation and maintenance of the SSP system;
- to put in place a service and maintenance regime for their SSP fitted vessels;
- to improve onboard documentation;
- and, to co-operate with the manufacturers and classification society to complete a Failure Modes Effect Analysis, and to retrospectively assess *Prospero*'s SSP system against the current criteria for podded vessels.

While Siemens AG Marine Solutions, as senior partner of the Siemens-Schottel Consortium, has cooperated with the investigation, Schottel GmbH & Co. KG has declined to do so. The investigators, therefore, have been unable to fully resolve some of the engineering issues identified, and so cannot comment on the safety of the Schottel components of the SSP System.

On 26 October 2007, Siemens advised MAIB that the Siemens-Schottel Consortium (SSC) was no longer active, and that the two companies were investigating other means of mutual cooperation, with Siemens taking the role of sole responsible leader.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *PROSPERO* AND ACCIDENT

Vessel details

Registered owner & Technical Managers	:	Rederi AB Donsötank, Donsö, Sweden
Port of registry & flag	:	Donsö, Sweden
Type	:	Chemical and petroleum product tanker (IMO type2 – 20200m^3)
Built	:	2000 Shanghai, China
Classification Society	:	Det Norske Veritas
Construction	:	Steel, Ice class 1B. Double hull, single deck
Length overall	:	145.7 metres
Gross Tonnage and Deadweight	:	GT 11793T, DWT 16800T
Engine power and type	:	Four diesel generator sets (totalling 5290kW) operating in power station mode, supply a diesel/electric propulsion system
Propulsion system	:	Cycloconverter powered synchronous motor, mounted as a single, 360 degree azimuthing, tractor pod drive. Type SSP 7 - 5100kW at 120 rpm
Service speed	:	14.5 knots
Other relevant info	:	1 x 620kW electric bow thruster

Accident details

Time and date	:	0038, Sunday 10 December 2006
Location of incident	:	No. 2 Jetty, SemLogistics Terminal, Milford Haven, UK
Persons on board	:	14
Injuries/fatalities	:	None
Damage/Pollution	:	Material damage to both vessel and jetty; no pollution

1.2 BACKGROUND INFORMATION - OWNERS, MANAGERS AND SHIP

1.2.1 Owners and ship managers

Prospero is owned by Donsö Shipping KB and operated by Rederi AB Donsötank (effectively the same company for the purposes of this investigation and referred to as Donsötank throughout this report). The company was registered in 1953, and currently employs about 120 people in total. The majority owners of Donsötank are four families, most of them originating from the island Donsö, in the Gothenburg archipelago. Donsötank has six modern ships: four tankers and two general cargo vessels. Three of the tankers are sister ships, powered by the Siemens-Schottel propulsor (SSP) system.

The families have a long tradition in owning and operating vessels. Several members of the founding families are master mariners and marine engineers. They still play significant roles in the management of the company, and continue to sail on board their ships on occasions. While technical and personnel management of *Prospero* is the responsibility of Rederi AB Donsötank, Broström Tankers AB is the commercial operating company for *Prospero* and the other tankers in the Donsötank fleet[1].

Donsötank was a customer of the Siemens-Schottel Consortium (SSC), who provided the Siemens-Schottel Propulsor (SSP) system; there was no other business relationship between these two companies.

1.2.2 The vessel – *Prospero*

Prospero predominantly traded around the coast of northern Europe, including the Baltic during the winter season, and she was a regular visitor to UK ports. She mainly carried parcels of clean petroleum products and did not usually carry chemicals.

Prospero was one of a class of three sister vessels[2] fitted with the novel SSP system which combines the functions of propulsion, steering and stern thruster into one unit. *Prospero* was an example of the “power station concept”. Four diesel generators were available to produce all of the ship’s power requirements, which was then distributed and consumed as required. The production of propulsion, cargo handling and all other electrical power was thus integrated into one system. Power electronic systems, similar to those used for the SSP (but independent from them), were used to drive and control the cargo pumps. *Prospero* embodied several very significant innovations, she was: the first diesel-electric vessel to be operated by Donsötank; the first ship fitted with a podded propulsor to be operated by Donsötank; and, the first vessel to be fitted with the novel SSP system.

Prospero was also the first podded propulsor ship to be built by the Shanghai Edwards shipyard in the People’s Republic of China. The three sister vessels were built under separate contracts; they are close sisters but, due to continuous product development, the SSP systems vary slightly over the three ships.

The complete underwater part of *Prospero*’s SSP unit was renewed in December 2002 as a result of commercial issues arising from the acceptance sea trials.

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[1] See http://www.donsotank.se/ and http://www.brostrom.se/Page89.aspx

[2] *Prospero* (2001), *Bro Sincero* (2002) and *Evinco* (2005). All are Swedish flag and DNV class.

Prospero had an excellent Port State Control (PSC) record[3], with the previous six inspections before this accident (covering the lifetime of the ship) resulting in only one minor deficiency. She was very clean, well painted and created an excellent first impression.

1.3 ENVIRONMENTAL CONDITIONS

The weather at the time of the accident was fine and clear; it was dark.

Wind: Westerly force 2, Slight Sea.

Tide: 260° at 1.2 knots.

1.4 PRECEEDING EVENTS - PREVIOUS POD CONTROL SYSTEM FAILURE

At the time of the accident in Milford Haven, Det Norske Veritas (DNV) had issued *Prospero* with a 'condition of class' because of an earlier problem with the SSP system.

The pod control system failed on 19 September 2006, while *Prospero* was on passage in the Gulf of Finland; the crew experienced a loss of steering control, and an alarm had sounded. The crew reported the incident and SSP service engineers, together with a DNV surveyor, attended the ship.

The faulty unit (the gauss transmitter[4]) was sent ashore for repair but, because of a lack of available spares, it was necessary to effect temporary repairs to allow the vessel to continue in service. By using existing back-up arrangements and making temporary modifications to the wheelhouse control levers, service engineers adjusted the SSP control system; the result being a functional, but less versatile pod. Pod azimuth was limited to 180° either port or starboard of amidships; it was not possible to continuously rotate the pod through 360°, but power/speed control was not affected. A sea trial was made and, attending surveyors being satisfied **(Annex A)**, *Prospero* continued to trade while awaiting permanent repairs.

1.5 NARRATIVE OF THE ACCIDENT[5]

Prospero's passage from Dublin to Milford Haven had been uneventful; the engine room had been operating in unmanned machinery space (UMS) mode and the propulsion system was operating under bridge control without any problems. The chief engineer was called for standby, and pre-arrival checks were completed as normal.

At 2329 on 9 December 2006, *Prospero* embarked a pilot off Milford Haven for the passage to No. 2 Jetty at the SemLogistics' terminal where she was due to load petroleum products for the Chevron oil company. It was dark and the bridge lighting, including the lighting of the control panels and the alarm system, was dimmed down to a very low level.

Once on board, the pilot discussed the port entry plan with the master; the master in turn briefed the pilot on the vessel's particulars and provided him with a Pilot Card. No tugs were ordered for the berthing operation.

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3. See http://www.parismou.org

4. A high frequency radio link, which was used to transmit control signals to and from the rotating part of the pod, so enabling the pod to azimuth through an unlimited number of turns,

5. Footnote inserted by Statens haverikommission (SHK) as joint authors of this report: This narrative has been constructed from the documentary evidence available to investigators, and information provided by witnesses. It represents the investigators' best assessment of the sequence of events but should not be considered legally as the definitive statement of facts.

The master did not inform the pilot that the vessel's SSP unit was the subject of a 'condition of class'; the pod could not be turned through 360º, contrary to the details provided on the Pilot Card. Further, the master had also declared to the port authority that the vessel was in ballast, although approximately 220 tonnes of cargo remained on board, overcarried from a previous voyage.

Entry into the Haven proceeded to plan; the master retained the conduct of the vessel from the central control console with the pilot providing advice. The Officer of the Watch (OOW) and the chief officer remained on the bridge until the vessel was nearing its berth, leaving the bridge when the crew were called to standby at their mooring stations.

The chief engineer was on watch in the engine control room (ECR) throughout the arrival standby. Thus, with only the master and pilot on the bridge, the vessel commenced its approach towards the jetty. The master then transferred to the port control console in preparation for berthing the vessel port side alongside the jetty. The pilot moved across the bridge to assist the master and kept him informed of the vessel's distance off a crane barge which was alongside No. 1 Jetty. This was particularly important as, due to the layout of the ship, the master could not easily see the ship's side (either ahead or astern) from the manoeuvring position.

At 0035, *Prospero* was approximately 100 metres from No. 2 Jetty, proceeding at a speed of 1.2 knots with less than 10% power applied to the SSP, when the master moved the control lever to increase the speed slightly in order to bring the vessel further ahead. At this point, suddenly and without warning, the control lever appeared to move to approximately 70% of full power and, with the azimuth direction set to move the vessel's stern off the jetty, *Prospero* very quickly began to increase speed and her bow began to swing to port towards the jetty.

The master attempted to pull the control lever back to zero, but the power remained at 70%. The vessel was now so close to the jetty that impact occurred with the vessel swinging to port. *Prospero*'s stem landed heavily on the concrete decking at the head of the jetty before the flare of the bow made contact with the steel gantry supporting the oil loading arms **(Figures 1, 2, 3 and 4)**.

The master realised that, although he was unable to control the power, he still had normal azimuth control on the SSP. He therefore altered the direction of thrust to move the vessel's head to starboard and utilised the bow thrust to push the vessel's bow off the jetty.

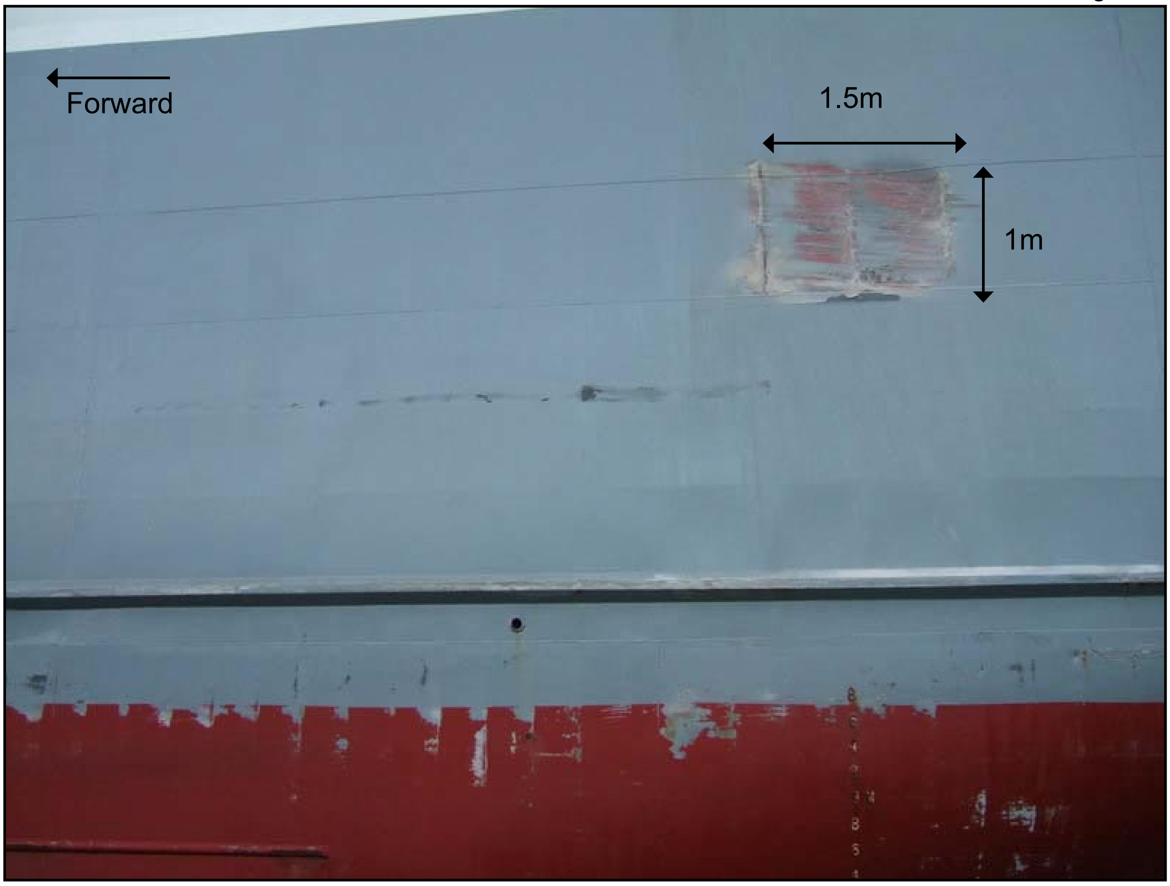
The master was thus able to succeed in moving the vessel bodily off the jetty and thrust the bow to starboard to place the vessel parallel with the jetty. However, *Prospero* was still moving ahead.

In an attempt to regain complete control of the SSP, the master transferred control back to the central control console and selected the push button back-up system, but this was not successful. At this point the master, on the pilot's advice, ordered the vessel's anchor to be let go and turned the SSP towards the stern to reduce the vessel's increasing headway. This was particularly important as there was another tanker on the berth ahead, and *Prospero* was still not under control.

Figure 1

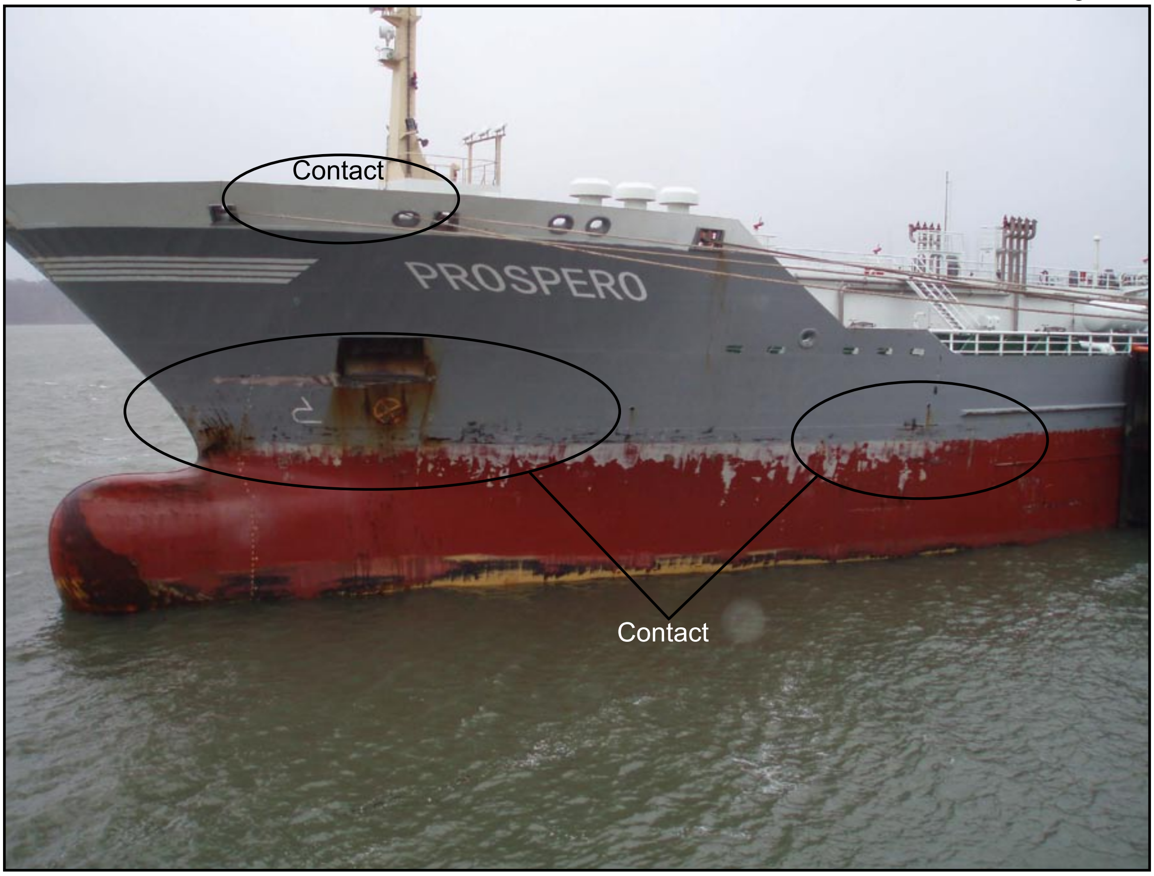
SemLogistics jetty No.2, Milford Haven

Figure 2



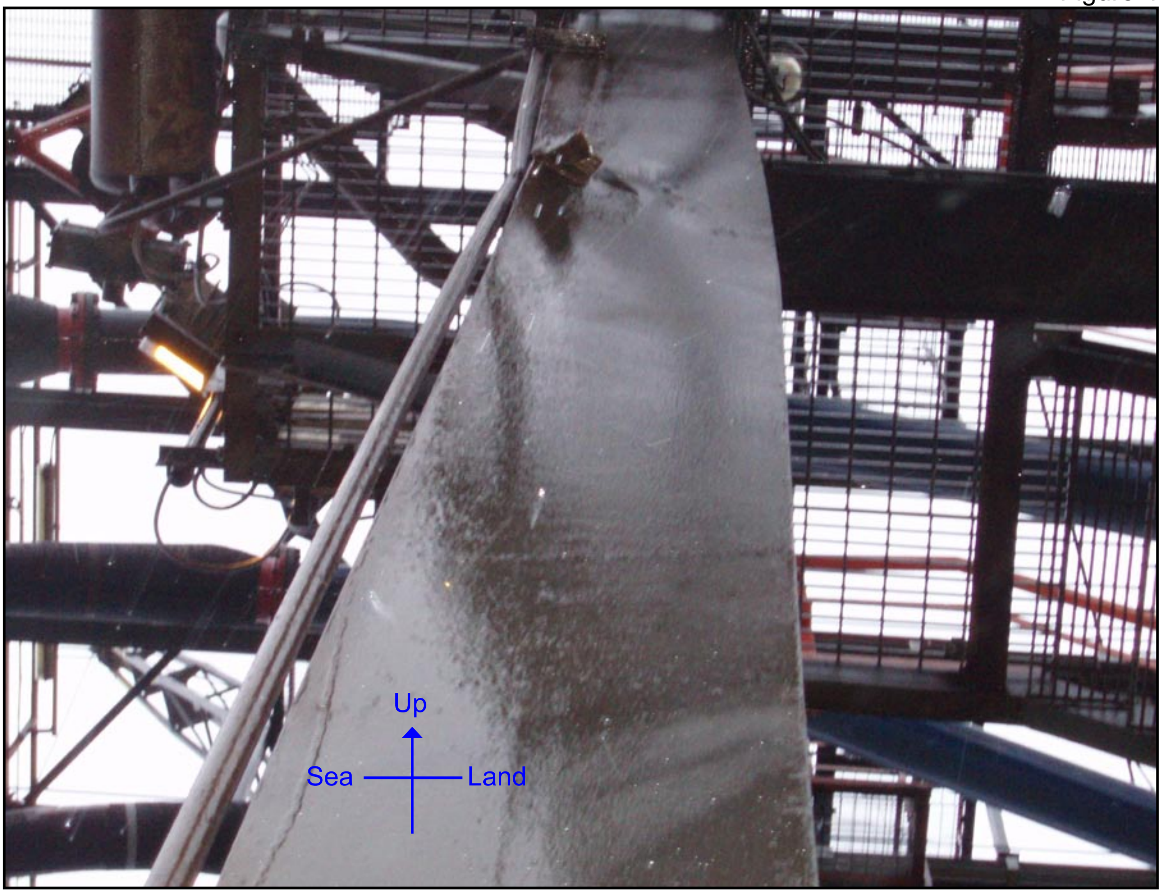
Damage to port quarter of *Prospero*, by jetty edge capping

Figure 3



Bow of *Prospero*, showing damage by jetty and gantry

Figure 4



Damage to loading arm gantry, by bow of *Prospero*

Shortly after this, the power on the system dropped to zero, although the master did not recall making any specific control inputs. However, just as the master began to evaluate the situation, and with the azimuth direction still set towards the vessel's stern, the power setting returned to 70% and the vessel quickly started to move astern towards the jetty.

The master once again attempted to reduce power by pulling back on the control lever, but to no avail, and he then tried the push button controls again, also without success. The vessel was now proceeding astern, albeit with an anchor down, but remained out of control. The pilot warned the personnel on the jetty of the situation to ensure they were clear of danger.

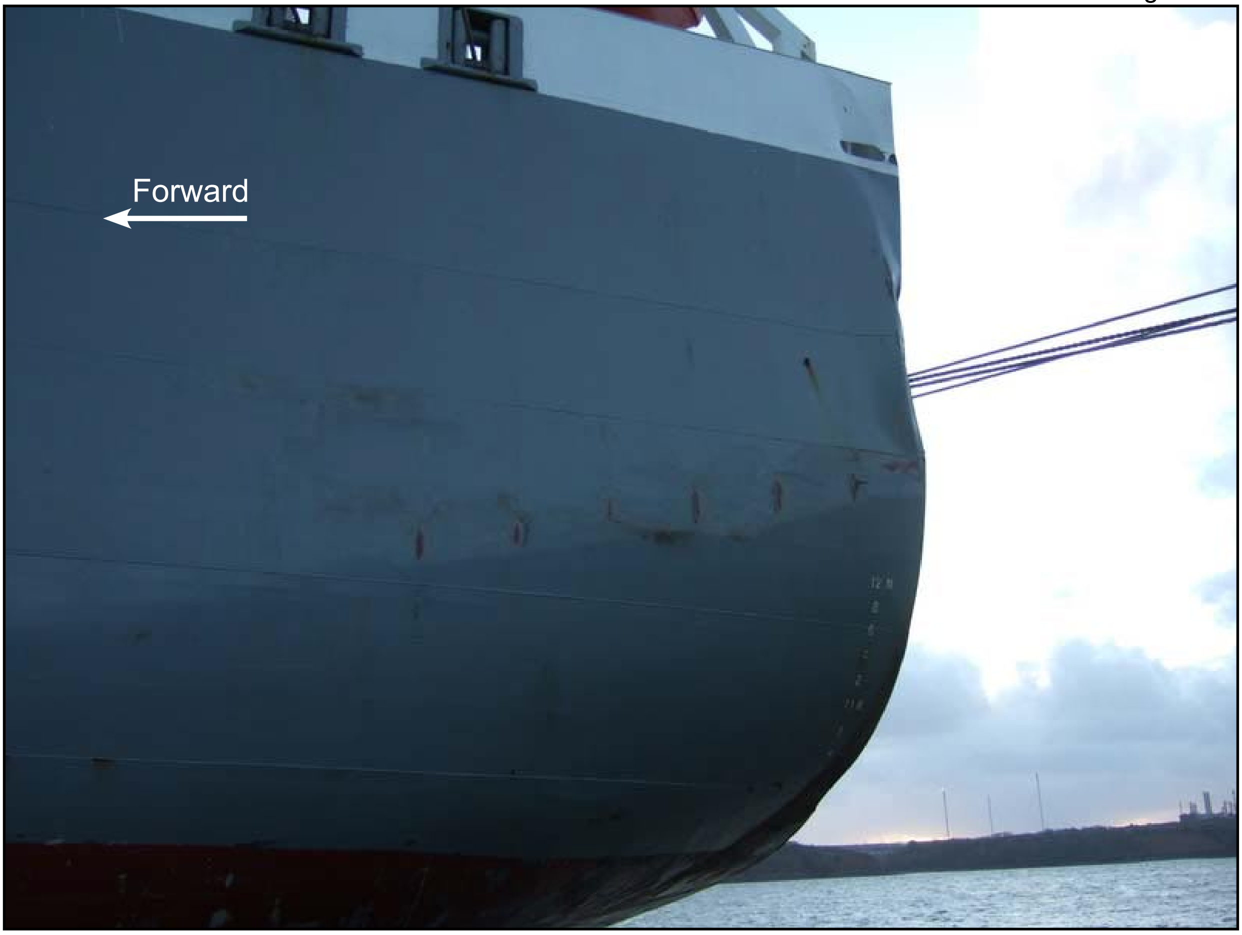
Shortly after this second, undemanded, application of power, the vessel's port quarter made heavy contact with the first of the mooring dolphins to the west of the jetty. She then continued moving astern to also make contact with the second dolphin, resulting in significant damage being caused to both the vessel and the mooring dolphins **(Figures 5a, 5b and 6)**.

Following the second collision, the master telephoned the ECR and spoke to the chief engineer. They agreed to attempt to regain control of the SSP by transferring the control position from the bridge to the ECR, and then immediately back again to the bridge in an attempt to reset the SSP control system. This was successful, and the master was then able to use the normal control levers to stop the SSP and stabilise the situation while awaiting the arrival of tugs to assist the vessel onto a suitable safe jetty. Two tugs were attached before making this move. Despite the earlier control problems, the pod was used during this move and behaved normally throughout.

Figure 5a

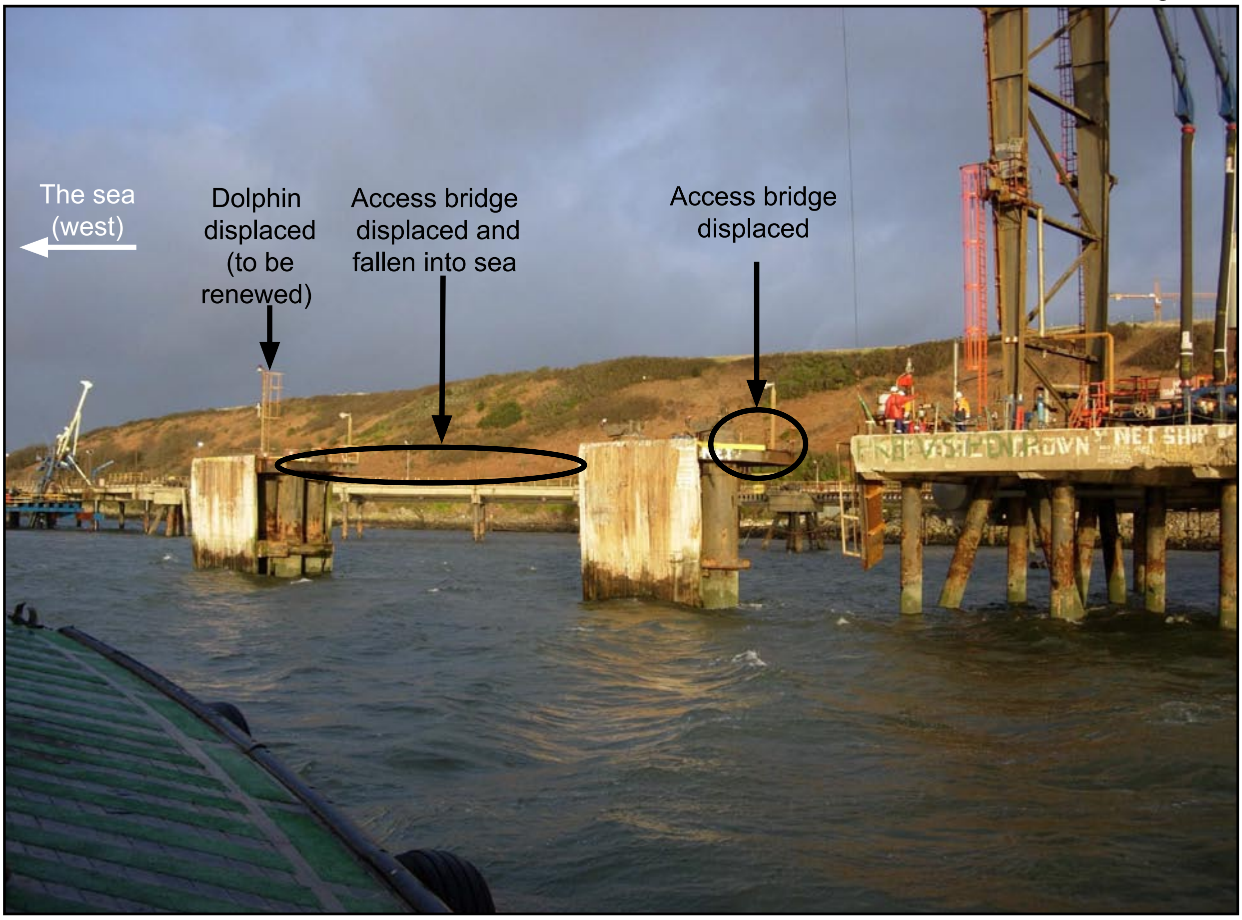
Damage to stern of *Prospero* by jetty dolphins, from aft.

Figure 5b



Damage to stern of *Prospero* by jetty dolphins, from port side.

Figure 6



Damage to jetty dolphins, one displaced but attached, the other displaced and fallen into the sea.

1.6 ACTIONS TAKEN AND EVENTS IMMEDIATELY AFTER THE ACCIDENT

1.6.1 Over-carried cargo

Two hundred and twenty tonnes of kerosene remained on board *Prospero* at the time of the accident, which had been over-carried from a previous voyage. Initially, neither the port authority nor the ship's owners/managers were aware of this cargo, although the ship's staff, commercial managers and charterers were aware it was on board, and the master and pilot had discussed the over-carried cargo during the pilotage.

The presence of the cargo delayed *Prospero*'s departure from Milford Haven as she was required to discharge it to tanks ashore before she was allowed to sail to the repair yard.

1.6.2 Owners/managers

The master activated the Donsötank emergency response procedures by telephoning the Designated Person Ashore (DPA). The shore based team immediately assembled at their offices in Donsö and established contact with all stakeholders.

The emergency response team decided that Donsötank's technical managers would not attend the vessel at Milford Haven, but would remain in the office to coordinate the response and arrange repairs; the DPA then travelled to Milford Haven to begin an internal investigation.

1.6.3 Milford Haven Port Authority

Traffic within the Haven was temporarily suspended while the incident was ongoing. Representatives of the Milford Haven Port Authority (MHPA) attended *Prospero* in order to make an assessment of the incident.

1.6.4 SemLogistics and Chevron

The SemLogistics emergency callout arrangements were initiated. Representatives of both SemLogistics and Chevron attended the incident, following which the SemLogistics No. 2 jetty was declared to be unusable and was closed for repairs.

The jetty was originally designed for vessels of up to 165,000 DWT, but due to the extent of the damage caused by the contact, it was necessary to impose a long-term restriction on this berth limiting the berth's capacity to 100,000DWT.

1.6.5 Classification Society

A surveyor representing Det Norske Veritas (DNV) attended the ship. A thorough survey of the hull damage was made, and the resulting temporary repairs were overseen. The surveyor was not experienced in the survey of podded propulsors and did not request that the propulsion system be tested or sea trials conducted.

Prospero sailed from Milford Haven with one 'condition' and three 'memoranda' of class due to the accident at Milford Haven added to her record. These memoranda covered both the pod system and the damage to the hull.

The 'memoranda of class' issued regarding the SSP system stated:

> *Bridge wing control for main propulsion pod is to be taken out of use until the control system is satisfactorily tested by manufacturers representative and malfunction cause satisfactorily identified.*

1.6.6 Port State Control - The Maritime and Coastguard Agency (MCA)

Two MCA surveyors, one of whom was a Port State Control (PSC) inspector, boarded and made a general inspection of *Prospero*, as well as a close examination of the damage and the temporary repairs. Their inspection revealed two deficiencies[6], in addition to those directly resulting from this accident. Neither MCA officer had any experience with podded propulsors. They did not require full sea trials to be conducted before *Prospero* was allowed to depart for the repair port.

1.6.7 Siemens-Schottel Consortium

Donsötank requested that a service engineer attend the vessel at Milford Haven. However, SSC advised that no one was available, and arrangements were made for the service engineer to attend the ship at the repair port.

1.7 TESTS OF THE SSP AND THE VOYAGE TO THE REPAIR YARD AT FREDERICIA

Limited function tests of the SSP were carried out with the ship alongside at Milford Haven. It was not possible to conduct a full range of tests due to restrictions at the berth. The faults which apparently caused the accident could not be replicated during these tests and the pod behaved normally throughout.

After completion of temporary repairs to the hull, it was agreed that *Prospero* would be permitted to make one, ballast only, voyage directly to a nominated repair yard at Fredericia, Denmark. After some negotiations, the cargo remaining on board was eventually discharged ashore and the ship was ready to sail. MHPA authorised *Prospero* to sail, but with tugs to remain attached until clear of the Haven.

The planned passage took *Prospero* around Land's End and via the English Channel and Dover Strait to Denmark. *Prospero* sailed on 12 December 2006, however the weather had deteriorated to such an extent that it was not possible to drop the Milford Haven pilot off once the vessel had cleared the port. Consequently, the pilot was overcarried to Falmouth, in Cornwall, where *Prospero* deviated inshore to rendezvous with a launch to put him ashore.

Thereafter, the voyage went as planned and no further problems were reported; *Prospero* arrived at Fredericia on 16 December 2006.

1.8 REPAIRS AT FREDERICIA

1.8.1 Steelwork

All steelwork repairs to the hull were completed to the satisfaction of DNV and the relevant 'conditions/memoranda of class' were deleted.

1.8.2 SSP control system

Engineers from Siemens attended *Prospero* on a break-down call-out basis, as there was no arrangement in place for routine maintenance or system "health-check" visits. They checked all of the control cables for the bridge remote control system and the manoeuvring control levers (known as the electric shaft system). The engineer's report

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[6] The PSC database recorded the deficiencies as: *Fire safety measures, means of control (opening, pumps) machinery spaces*

stated that one loose wire was found, in the connections to the control lever on the starboard bridge wing control stand. This wire provided the supply for the electric shaft line motor for this control lever. Several other connections were found to be loose.

The Siemens report stated: *All these cables are external cables and was not part of Siemens supply [sic].* This cabling was provided and installed by the shipyard.

A full power-on system test was conducted, without any apparent problem. The test included the transfer of control within the wheelhouse and manoeuvring from all wheelhouse control positions. The back-up control buttons were also tested satisfactorily.

Siemens engineers also fitted an additional data/signal recorder in the wheelhouse in order to capture command inputs to the system to aid any later investigations.

The 'memoranda of class' issued at Milford Haven, relating to the SSP system was deleted on 21 December 2006. DNV stated:

> *The bridge wing controls for the pod were thoroughly checked by two service engineers from Siemens. The complete system was found in order and any cause for the possible malfunction could not be found.*

1.8.3 Gauss signal transmitter

The gauss signal transmitter had been ashore for repairs since September 2006. It was returned to *Prospero* during the repair period and refitted by the SSP engineer. However, the transmitter was still not functioning correctly, so was again taken ashore for further repairs and the temporary arrangement was reinstated **(Figures 7a and 7b)**.

1.8.4 The Donsötank internal investigation

Donsötank completed its internal investigation on 21 December 2006. The investigation found that: there were no maintenance routines for checking the security of cable connections in the SSP system; there were no maintenance routines for the manoeuvring control levers; the master was unaware of the SSP control system failure (the alarm lamps were too dim) and that the back-up steering system (buttons) had been activated; this was due to inadequate test regimes and onboard documentation. Corrective actions were identified: maintenance routines and ISM amendments to be completed by December 2006, education and training to be completed by the end of January 2007.

Prospero was off hire for 10 days as a result of this accident.

1.9 PERSONNEL AND MANNING

1.9.1 Master

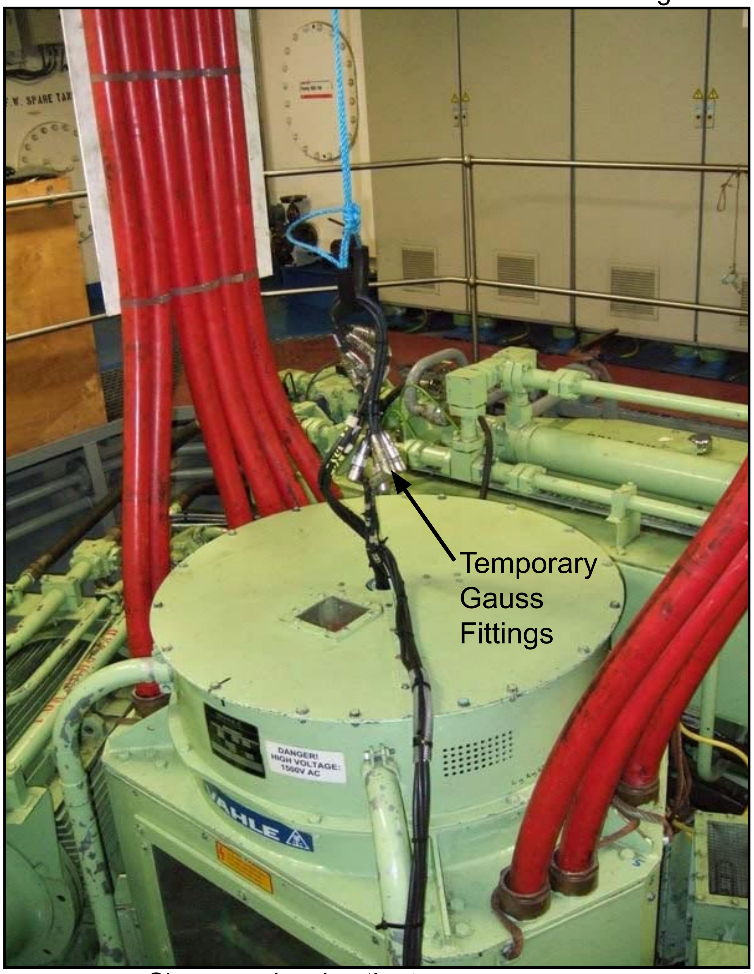
The master, a Swedish national, held a master's certificate of competency (STCW II/2 unlimited), which he had obtained in 1970. He was promoted to master in 1974, and later spent 15 years as a marine pilot in Sweden before returning to sea in 1995, as master of tankers of a similar size to *Prospero.*

The master began working for Donsötank in 2004, and first joined *Prospero* in September 2006. This was the first time he had sailed on a ship with an SSP. Before taking over command, he was allowed one week to familiarise himself with the system by shadowing the master he was relieving; during this time the vessel called at

Figure 7a

Pod room showing the temporary gauss transmitter arrangements.

Figure 7b



Close-up showing the temporary gauss transmitter arrangements.

three ports. He had received no other specialist training for ships fitted with podded propulsors. The master had joined the ship at about the same time that the gauss transmitter was removed for repairs; he was, however, generally very pleased with *Prospero*'s manoeuvrability, and he found the ship easy to handle.

The master worked a routine of 1 month on, 1 month off the vessel, and was on his second period on board, having rejoined *Prospero* on 30 November 2006. The master was familiar with the port of Milford Haven as he had previously visited there on a number of different vessels.

At the time of the accident, the master had taken 10 hours rest in the previous 24 hours.

1.9.2 Pilot

The pilot held a master's certificate of competency (STCW II/2 unlimited) which he had obtained in 1987. He was promoted to master in 1988, and became a pilot at Milford Haven in 1992; he was authorised as a first class pilot in 2000.

He had acted as pilot on *Prospero* and on similar sister vessels on more than 10 previous occasions and knew the vessel to be highly manoeuvrable. However, he had never actually operated the controls of the vessel as the various masters had always chosen to do this. He had also acted as pilot for *Prospero*'s master when he had been in command of other vessels that had called at the port. The pilot had received no specialist training for ships fitted with podded propulsors.

At the time of the accident, the pilot was on his fourth act of pilotage since commencing a 24 hour duty period at 0800 on 9 December. He had worked between 1000 and 1652 and then had 6 hours clear of duty, during which he was able to have 3.5 hours rest before returning to the pilot base at 2225 to be taken to sea to embark on *Prospero*. The pilot had been on 2 weeks leave before commencing this duty period.

1.9.3 Deck officers

The OOW for the vessel's entrance into the port was the second officer; however, as the vessel approached its berth he left the bridge and went to his designated station for mooring the vessel.

The chief officer was also on the bridge during the entrance into the port, but he too left the bridge to standby at the manifold area as the vessel approached the berth.

This was the normal bridge routine for standby on *Prospero*.

1.9.4 Engineer officers

The chief engineer officer (certificated to STCW III/2), a Swedish national, had been 9 years in rank. He had served 3 years with Donsötank, much of the time on tankers. He had been chief engineer of *Prospero* since January 2006, working a 1 month on, 1 month off routine. Although it was not a requirement for service on *Prospero*, the chief engineer had additional electrical engineering qualifications, obtained through self-study.

In common with the company's other engineer officers, the chief engineer had not received any specialist training for the SSP system; he had learnt from experience on board. This had been assimilated through combined process of hand-over from his predecessors, "look and learn" when manufacturers' service engineers attended for service calls, and information obtained during service support requests.

1.9.5 Manning arrangements

Prospero exceeded the minimum requirements of her Safe Manning Certification, as issued by the Swedish Maritime Administration[7] (SMA). She was required to have a minimum crew of 10; however there were 13 crew on board, plus 1 deck cadet.

The deck department consisted of a master, chief mate, two second mates, a bosun and two seamen. The engineering department consisted of chief, first and second engineer officers, plus a motorman. There were also two catering crew.

There was no regulatory requirement for any of the crew to have formal specialist training in podded propulsor systems, nor for any electrical engineering/electro-technical officer to form part of the ship's complement.

The predominantly Swedish officers were employees of Donsötank; the Filipino crew were employed via a manning agency.

1.10 OWNERS/MANAGERS AT DONSÖTANK

1.10.1 Designated Person Ashore

The Designated Person Ashore (DPA) for the Donsötank fleet was a qualified master mariner; he had worked on board the company's vessels in various ranks, including as master on board the SSP tankers. He had not received any formal training in the SSP system.

1.10.2 Technical management team

The technical management team at Donsötank consisted of two qualified engineer officers, both of whom had sailed on board the Donsötank fleet, though neither was an electrical engineer. They had stood-by the building of *Prospero* and had sailed on the vessel during the delivery voyage from China to Sweden, but had received no formal training regarding the SSP system.

1.11 SPECIALIST TRAINING FOR NEW TECHNOLOGY

1.11.1 Training in new technology – the IMO view

> *The introduction of new technology on board merchant ships has the potential to improve the efficiency and effectiveness of Watchkeeping and to improve the safety of operations. However, it must be recognised that this technology brings with it the inherent training requirements needed to be able to physically operate the new systems and also the training needed to allow seafarers to use the systems to make better decisions[8].*

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[7] See http://www.sjofartsverket.se/default_603.aspx

[8] IMO MSC/Circ. 1091 2003 *Issues to be Considered when Introducing new Technology on board ship*

1.11.2 Specialist training at Donsötank

The two masters and two chief officers originally assigned to *Prospero* were given specialist training relating to podded vessels in the manoeuvring simulator at Gothenburg; this training was arranged by Donsötank and was not supplied or recommended by the SSC.

These officers found that the fundamentals of manoeuvring ships with podded propulsors were quickly learnt; however, although the control joystick was the same as that fitted on *Prospero*, the simulator was not SSP type specific.

No formal external training was provided for the engineer officers. The original engineers (including the technical managers) obtained most of their knowledge from the SSP guarantee engineers who oversaw the installation, commissioning and the delivery voyage. The Donsötank engineers and the technical department learnt "on the job".

Donsötank aimed to maintain knowledge and experience by ensuring that they retained their sea-staff; they were satisfied that this approach had been successful, and so no further formal external training on the SSP system or podded drives in general had been provided for any of their newer staff. All masters and officers learnt "on the job"; a process of cascade learning from their predecessors during the normal hand-over process.

1.12 FLAG STATE – THE SWEDISH MARITIME ADMINISTRATION (SMA)

The national authority responsible for *Prospero* was the SMA. The accident was reported to them by Donsötank. Surveyors from SMA did not attend the accident in Milford Haven as, at that time, the accident was seen as a heavy contact only and they had no particular concerns regarding the SSP system.

In common with many other states (including the UK), SMA has delegated some surveys for statutory certificates to classification societies. The SMA has an agreement with five classification societies (including DNV) authorising them to issue safety construction certificates. The SMA retained responsibility for issuing safety equipment and ISM certificates.

As the SSP system was not treated as a novel propulsion arrangement, the SMA files for *Prospero* contained very little information on the SSP system. The SMA files for the ISM surveys of both the ship and the company made no specific mention of any issues related to the novel propulsion arrangements or the handling of associated safety critical equipment.

1.13 PROPULSION SYSTEM MANUFACTURE AND INSTALLATION

1.13.1 Designers and manufacturers – the Siemens-Schottel Consortium

The design and manufacture of the SSP system was a result of a Consortium consisting of Schottel GmbH & Co. KG, and Siemens AG, Marine Solutions. It was understood that the broad division of expertise was such that Siemens dealt with the power electronics and propulsion motor equipment, while Schottel was responsible for the more mechanical aspects of the pod arrangement used to mount the SSP system onto the ship, and to azimuth it. However the division of responsibilities was not entirely transparent, either to investigators or to some Donsötank employees.

In common with many complex systems, several sub-contractors supplied specialist components and expertise; for example the hydraulic steering system was supplied by Hägglunds Drives AB, and control system components by Stork Kwant BV. Documentation shows that it has been necessary for SSP engineers attending *Prospero* to then call upon specialist service engineers from both these companies.

Investigators contacted both the Siemens and Schottel offices dealing with the SSP system in order to discuss the circumstances of the accident; however, all the questions submitted to Schottel were re-directed by them to Siemens. Schottel stated that the head of this Consortium was the Siemens company, and consequently that Siemens was in charge of communication for the Consortium.

When investigators attended a meeting with the SSC at the Hamburg offices of Siemens, Schottel representatives were due to attend but cancelled at short notice. Despite several requests, no further communications from Schottel were forthcoming during this investigation.

1.13.2 Builders and installers

The contract for the propulsion system was via SSC's Norway division, to the shipbuilders, Edward Shipbuilding Co Ltd, Shanghai, People's Republic of China. This company is a Sino-German joint venture of the China Shipbuilding Group Corporation (CSGC).

The SSP system was manufactured in Germany, then fully assembled and test run before being shipped to China to be installed by the shipbuilders. Both SSC and Donsötank technical staff were in attendance throughout the commissioning and sea trials.

1.14 THE PODDED PROPULSION SYSTEM

1.14.1 Overview

A podded drive is distinct from other forms of more traditional propulsion, one definition is: *Any propulsion or manoeuvring device that is external to the normal form of the ship's hull and houses a propeller powering device*[9].

A general overview of *Prospero*'s propulsion system can be obtained from the photograph of the builder's model **(Figure 8)**.

From the initial concept and development in Finland in the late 1980's/early 90's the advantages of using electrically powered azimuthing podded propulsors, in place of conventional stern gear arrangements, has become very attractive to both ship owners and ship builders.

Early units were generally fitted to fleets with some history of operating diesel-electric propulsion systems and the problems that they experienced are widely reported[10]. These were perhaps inevitable given the rapid development of this fairly revolutionary technology.

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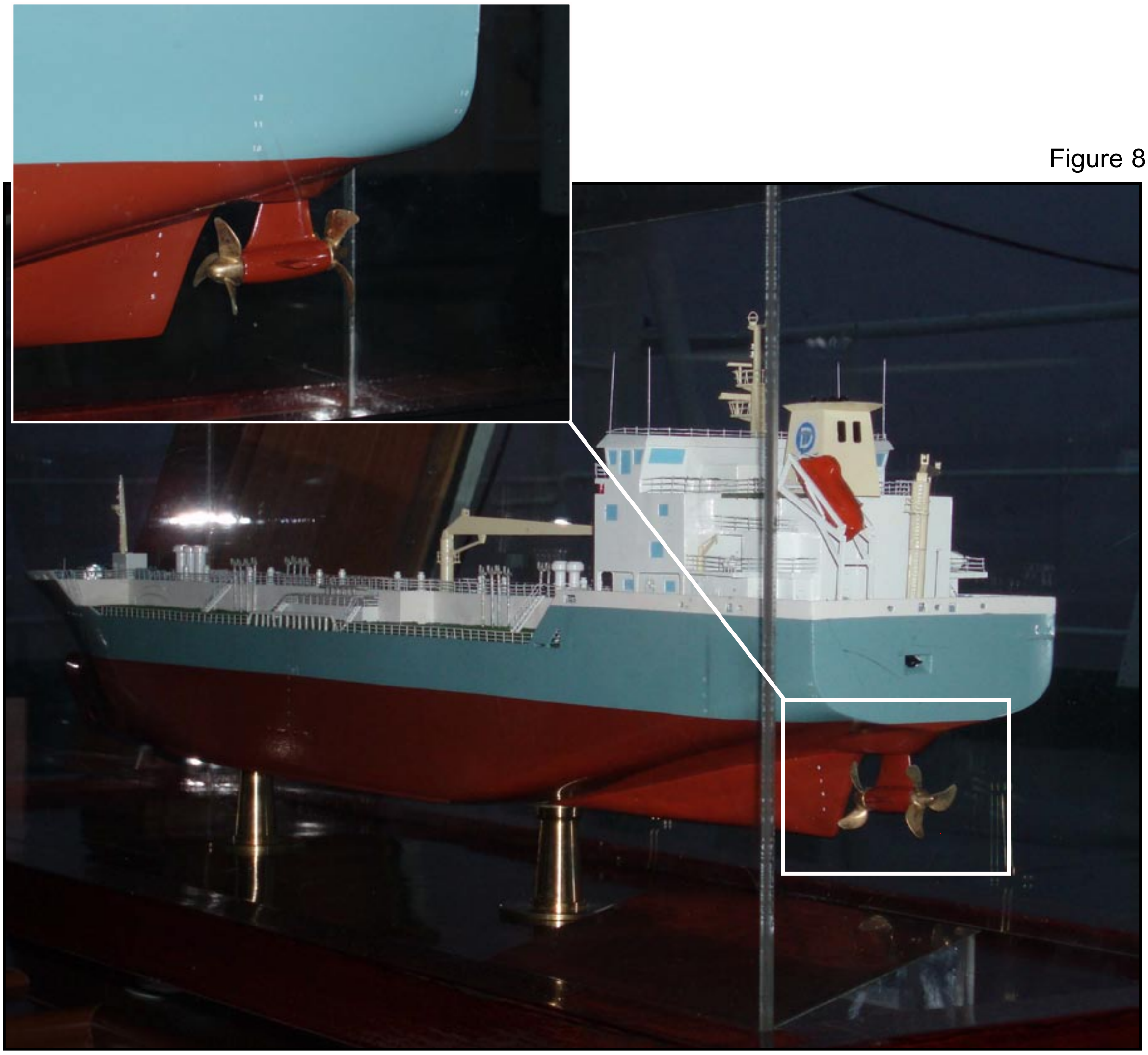
9 LR *Rules and Regulations for the Classification of ships 2006* pt 5, Ch 23, S1.1.2

10 E.g. *Experiences with electrically powered podded propulsion units on cruise ships*, JW Hopkins. And also *Podded Propulsors: Some results of Recent Research and Full Scale Experience,* JS Carlton, LR London, IMarEST 2006.

Figure 8



Builders model of *Prospero*

Prospero's SSP system consisted of a cycloconverter supplying a permanently excited synchronous motor (PSM) via slip rings. The PSM was unusual in that it utilised permanent magnets, rather than conventional electrical arrangements for its excitation. This allowed the size and weight of the pod motor to be reduced. The manufacturers claimed that the arrangement improved hydrodynamic efficiency due to the combination of twin propellers (mounted at either end of a common PSM shaft) and the compact pod motor housing. Gains in electrical efficiency were also claimed as there was no electrical excitation system and the PSM was directly cooled by the surrounding seawater instead of external air cooling.

To achieve the redundancy necessary for a single pod installation, the four main generators were located separately; two in each machinery room. The main switchboard could be electrically split into two separate systems. The main switchboard supplied two separate cycloconverter and transformer plant rooms. The PSM consisted of two independent electrical systems mounted on a common shaft, so providing a back-up motor capability.

Further details of the propulsion system can be found at the Donsötank and SSP websites[11] and in the SSP sales brochure which forms **Annex B**.

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[11] See http://www.donsotank.se/ and http://www.industry.siemens.com/broschueren/pdf/marine/siship/en/2004-04-19_134848_SSP.pdf

1.14.2 System selection by Donsötank

Donsötank selected the SSP system, attracted by SSC's claims of improved performance and economy, details of which are in **Annex B**.

1.15 THE PROPULSION CONTROL SYSTEM

1.15.1 Overview - propulsion control system

The propulsion control system (PCS) controlled the pod operating modes, and also protected it by limiting its acceleration and deceleration, according to parameters programmed into the system by the manufacturer. This was intended to maximise the capabilities of the pod, while protecting it (and the ship) from damage due to the pod being operated outside of design parameters. A diagram showing an overview of function units is at **Annex C**.

The PCS also interfaced with the power management system in order to ensure that propulsion power demand was matched to the supply available. This minimised the potential for overloading the electrical system and consequential power blackouts.

1.15.2 Normal operating modes

The PCS allowed the user to select several modes of operation, the parameters of each being configured by the manufacturers to match the operational requirements and limitations of the ship systems.

- <u>Manoeuvring mode (also known as "harbour mode")</u>. Manoeuvring mode was used when the vessel was operating at reduced speed; for example, when berthing. When manoeuvring mode was selected, two steering pumps would be running, and the pod could be rotated through 360°. In order to ensure that the pod was operated within design limits (for both the pod and the ship structure), in this mode the ship's speed was restricted to 10 knots[12], above which an alarm would sound. Selecting manoeuvring mode disabled the 'crash stop' function.
- <u>Rudder mode (also known as "sea" mode)</u>. Rudder mode was used on passage, but could be selected at any ship speed. In this mode, only one steering pump operated (either could be selected). Pod azimuth was restricted[13] - in a way similar to conventional propulsion and rudder configurations - to normal rudder limits in order to protect the pod and ship structure. The auto pilot could only be selected in rudder mode.

If the ship was operating in rudder mode and slowed down below 10 knots, manoeuvring mode had to be manually selected for the 2nd steering motor to start automatically. At slow speed, there was no alarm to warn the operator that the Pod was in rudder mode and would not turn through 360°. This arrangement was specified by Donsötank when the system was ordered.

The Donsötank SSP systems across their fleet were configured as tractor pods; the rear of the ship travelling in the direction the SSP was pointing.

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[12] This limiting speed is programmed by the manufacturers, and varies according to the referenced document.

[13] The pod azimuth limits varied according to the referenced document. The preliminary operating instructions found onboard stated +/- 20°. See later comments in the section 1.18 on documentation and manuals.

1.15.3 Emergency operating modes

The system was fitted with two emergency operating modes.

- Emergency stop mode. Emergency stop mode shut down the SSP system by opening the main supply breakers, though power was maintained to the steering system. With a manned engine room, it would be possible to recover from an emergency stop quite quickly; the system had to be re-set by passing control to the ECR, cancelling the alarms, moving the pod control levers to zero and initiating the normal re-start sequence.
- Crash stop mode. Crash stop mode was intended to stop the ship in the shortest possible distance. Following depression of the crash stop button, the system automatically reduced pod speed to zero and started the second steering pump (if not already running). The pod was then turned to face astern and the speed of the pod increased until maximum power was reached. When the ship was at a standstill, the operator was required to manually reduce the pod speed to avoid moving the vessel astern.

1.16 MANOEUVRING CONSOLES AND POD CONTROLS

1.16.1 Wheelhouse - layout

Prospero had an enclosed wheelhouse with manoeuvring control consoles in the centre and on the port and starboard sides **(Figures 9, 10 and 11)**. The centre console was the dedicated steering position which was fitted with a conventional ship's wheel and rudder angle indicator, auto pilot, and compass repeater.

Figure 9

Wheelhouse centreline console

Figure 10

Wheelhouse port side console.

Figure 11

Wheelhouse starboard side console

Visibility of the ship's side from the wheelhouse wing control consoles was restricted by the tops of the deckhouse below **(Figure 12)**, and the person controlling the ship needed to move from the control console to the side windows in order to get a better view of the ship's side. This problem has been corrected on later vessels of the class.

Figure 12

Looking forward from wheelhouse port console, showing obstructed view.

1.16.2 PCS controls

The pod controls at each console had an identical layout for ease of operation **(Figure 13)**. This figure also shows the cable ties attached to the pod control levers as a result of the gauss transmitter failure on 19 September 2006. All the pod control levers were electrically driven to match the position of the 'in-command' control lever. Control levers which were not 'in-command' provided physical feedback to the operator through increased resistance to movement and automatically returning to the 'in-command' setting when released. There was, therefore, no need to set the lever to zero before transferring control which was instead achieved by pushing a button. Transfer of control of the pod between the wheelhouse and the ECR was also achieved by the push of a button.

Additional controls and indicators were provided for the bow thruster, which was not integrated with the SSP system.

<u>Primary Control</u>

Primary control of the PCS was by the "electric shaft system", a type approved item used by several manufacturers of propulsion systems. This consisted of a combined pod azimuth and pod power/speed control lever, one on each of the three manoeuvring consoles. The direction of the pod was dictated by rotating the base of the control, so shaped as to indicate the "front" of the pod.

A handle above the base controlled the speed of the pod propellers. This lever could be moved in the “ahead” or “astern” direction, but to protect the pod, “astern” power was limited to about 30% of “ahead” power. In order to achieve full astern power, it was necessary to rotate the pod 180° so that it pulled in the aft direction, and then apply full power.

Secondary Control

A back-up system of push buttons controlling speed and azimuth was provided at each console. The buttons were hard-wired directly to the speed and steering control units, and were independent of the control signal provided by the primary control levers. When back-up was selected (either automatically or manually), the pod control lever signal was bypassed and the buttons had priority.

Alarms

On *Prospero*, the system was configured so that if a pod control lever failed, an audio and visual alarm was triggered in both the wheelhouse and ECR, and control of the PCS automatically changed over to the back-up push buttons.

While much of the alarm and control system for the propulsion system was presented as a conventional graphical display, the power electronic systems used independent alarm/fault indication panels which presented the alarms as codes. However, some codes were deliberately not included in the onboard documentation as they could only by interpreted by SSC personnel.

Figure 13

Close-up of wheelhouse console

1.16.3 Engine and pod room controls

The ECR pod control panel was similar to the wheelhouse panel but without the primary pod control lever system. The ECR display allowed the engineer to watch the azimuth movement of the pod and propeller revolutions, but there was no representation of pod control lever input, and therefore no way of checking that the pod was following bridge control commands **(Figures 14a and 14b)**.

The arrangement was therefore comparable to that found on ships fitted with conventional propulsion systems.

The emergency controls situated in the pod room allowed for emergency steering and were also very similar to the arrangements on a conventional ship.

1.16.4 Ergonomics and human factors

The alarm panel was designed so that the same lamp was used for both indication (steady state) and alarm (flashing). An audio alarm accompanied the flashing visual alarm. The flashing visual alarm could be dimmed without affecting the level of the audible alarm. However, as it was possible to dim the visual alarm to the extent that it was not visible, the alarm lamp indication did not comply with IMO[14] and DNV[15] requirements applicable at the time that *Prospero* was built.

The "critical speed" alarm for changing over from 'manoeuvring mode' to 'rudder mode' only activated when the ship's speed was increasing. It was possible, therefore, to slow down to manoeuvring speed, for example when entering port, but no alarm would sound to indicate the system was still operating in 'rudder mode'. However, DNV did not require such an alarm to be provided.

1.17 WARRANTY, SERVICE SUPPORT AND SPARE PARTS

1.17.1 Warranty and service support

As *Prospero* was the first ship of its type, Donsötank was able to secure particularly attractive warranty terms from the SSC. However, *Prospero* was out of warranty at the time of this accident and no ongoing service/support contract had been arranged.

The ship's staff generally dealt with the SSC service and support staff directly, while keeping Donsötank technical managers informed. However, there was an effective "help-line" arrangement, where queries were primarily dealt with by means of email, and some ship's staff considered that *Prospero* could not continue to function without email/telephone support.

The division of responsibilities within the SSC caused some confusion to ship's staff initially, but the support system had generally bedded-in with regular use; however, ship's staff frustration with not being able to resolve longer term problems was readily apparent.

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[14] IMO Code on Alarms and indicators 1992, Annex to resolution A.686 (17).

[15] DNV Rules 1998: Pt.6 - Special Equipment and Systems - Additional Class. Chapter 3 - Periodically unattended, Machinery Space. SECTION 2 - System Arrangement C. Alarm System. C 100 General. *The light intensity of alarm indicators on the bridge should not be reducible below the intensity necessary in normal daylight.*

Figure 14a

ECR control console.

Figure 14b

ECR control console, close up showing pod controls.

The "last resort" practice of resetting the PCS, by transferring control down to the ECR and then immediately back-up to the wheelhouse, had been learned by ship's staff observing the practices of service engineers; it was not found in any documentation. However, since the accident, the validity of this practice has been confirmed by SSC.

1.17.2 Spare parts

Siemens had no centralised stock control system for spares for the SSP system. Approximately 95% of the SSP system was made up of standard Siemens components which were available from company outlets world-wide. Siemens reported having experienced problems with the use of "equivalent" spares from the "grey market". It was not possible to determine whether any such components had been fitted to *Prospero*.

The arrangements for Schottel components are not known. Evidence was seen of problems in obtaining spares for some components; for example, the gauss signal transmitter (a Schottel item) was missing for months due to a lack of spares.

From the SSC perspective, it was highly recommended that a customer purchased a service/support contract as this ensured the plant was regularly serviced, and it enabled the consortium to underwrite the provision of maintenance spares. The SSC also found the lack of training and experience of Donsötank personnel hampered their service support staff when attempting to diagnose problems remotely.

1.18 SSP MANUALS AND DOCUMENTATION

It was the SSC's declared intention that the SSP should be simple to operate by ship's officers with reference to the onboard manuals. Most of the SSP components would be easily interchangeable should a failure occur, and with the built-in diagnostic capabilities and service-support help-line, there would be no need for in-depth training on the system.

The SSC stated that they delivered the 'as built' documentation in compliance with the contract. However, Donsötank contended that the manuals were not supplied with the ship and the manuals, as described, were not available on board *Prospero* during the investigation. The ship's chief engineer was not able to produce a schematic layout drawing of the SSP system, and no bridge operations manual, covering the use of the system by the master and deck officers, was available on board.

Such SSP documentation and manuals that were available on board *Prospero* consisted of many folders of complex electrical drawings, with few schematics and very little text to guide the ship's engineering staff. Part names, acronyms and abbreviations were not consistent throughout and contained contradictions. For example, Schottel manuals referred to the system operating in "*rudder mode*" or "*manoeuvring mode*"; Siemens manuals referred to "*sea mode*" or "*harbour mode*". In another example, the Schottel manual referred to the steering angle limits for "*rudder mode" as limited to +/- 20°"*, whereas the Siemens manual stated "*In the sea mode…the steering angle is limited to +/- 35°".* The DNV Survey Report at **Annex A** states that the *seagoing mode* is limited to *+/- 30°*.

The technical publications were required to be in the ship's official operating language, which was English. However, some system documentation was only available in German.

The engineer officers on board *Prospero* had produced their own instructions for changing some components within the cycloconverter units by recording details of the 'help-line' call and photographing the job as it was undertaken. These supplementary instructions were written in Swedish.

No evidence was seen of any systematic process for the updating of the manuals and other documents to reflect changes to either the hardware or software systems on board *Prospero.* Any service bulletins and technical service letters that might have been produced by the SSC were apparently not reaching the users onboard ship. The pod operating manual found in use on board *Prospero* some 6 years after building was stamped *"Preliminary!"* .

1.19 DATA RECORDING SYSTEMS

1.19.1 Voyage data recorder

Prospero was not required to be fitted with a voyage data recorder (VDR) and none was fitted at the time of the accident.

1.19.2 Alarm and data logging systems

The SSP plant had a dedicated alarm and data recording tool as a part of its operating system. This tool was provided for diagnostics use (generally by specialist SSC service engineers or by ship's engineers when "talked-through" remotely, via the 'help-line'), and was very heavily relied upon. After the accident, the data was downloaded by the chief engineer and sent to Siemens as it required dedicated software in order to interpret it. The data did not provide conclusive evidence for the purposes of this accident investigation.

"Telemaster", a remote diagnostics system which is available from SSC and has been fitted to other ships, was not specified by Donsötank for their fleet.

The machinery alarm system was separate from the SSP alarm system and was of a familiar design seen on other vessels. Graphical user interfaces presented conventional representations of the propulsion plant for normal operational scenarios.

1.20 THE RISKS OF COMPLEX AUTOMATED SYSTEMS

1.20.1 Marine programmable electronic systems

Many modern vessels have become highly dependent on programmable electronic systems (PES), for example, for bridge equipment, propulsion machinery, and the automation of cargo handling systems. In many cases, the PES are integrated with each other. The risk of PES failure, and the need for such a risk to be managed has been identified, as has a need to change the way that such risks have been managed in the past. The difficulties experienced in podded propulsion systems, when different layers of software are required to work together, has been the subject of an academic paper[16]. This paper describes the need for rigorous testing in order to eradicate intermittent faults which may occur during operation, sometimes with serious safety consequences.

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[16] Podded Propulsors: Some results of Recent Research and Full Scale Experience, JS Carlton, LR London, IMarEST 2006.

1.20.2 International Standards Organisation and PES

The International Standards Organisation (ISO) document 17894:2005 provides a set of mandatory principles, recommended criteria and associated guidance for the development and use of dependable PES for shipboard use:

> *Ships and marine technology - Computer applications – General principles for the development and use of programmable electronic systems in marine applications.*

The ISO document applies to any shipboard equipment containing programmable elements which may affect the safe or efficient operation of the ship. A brief introduction to this 72 page standard and the associated principles for marine PES are at **Annex D**.

Security of the PES is vital; configuration management procedures must be in place and there must be traceability of software. SSC was able to produce documentation relating to change control. However, Donsötank had no procedures in place covering traceability of operating software, and no documented system of control configuration for either software or hardware was available.

1.20.3 Mitigation of human error in automated systems

Systems become much more complex when a person interacts with a computer, which then controls a machine. Of relevance to this accident, the MCA has published the findings of research project 545: *Development of Guidance for the Mitigation of Human Error in Automated Ship-borne Systems*[17]. This is summarised as follows:

> *Given the increasing prevalence of automated systems on board ships, it is important that the human element is considered throughout their design, implementation and operational use. Automation can be beneficial to operators of complex systems in terms of a reduction in workload or the release of resources to perform other onboard duties. However, it can also potentially be detrimental to system control through increasing the risk of inadvertent human error leading to accidents and incidents at sea.*
>
> *This research identified particular issues in design, selection, installation, use, maintenance, and updating or modification of automated systems which can present problems. A range of guidance points were produced for those involved in selecting or using automated systems, throughout the lifecycle of a vessel. In particular these include the following: Shore-based company management, shipboard management, seafarers using automated systems, training providers.*

1.21 POD INDUSTRY – SPECIALIST STANDARDS

1.21.1 The Pod Quality Forum

The Pod Quality Forum (PQF) was instigated by DNV in 2003 and consisted of the three major pod manufacturers, including the SSC. DNV provided the secretariat to facilitate the forum, which had the aim of improving pod quality and operational reliability[18]. The PQF common quality instructions are in addition to classification society requirements and implemented as an industry standard by the pod manufacturers involved.

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[17] Marine Information Note 261(M), December 2006.

[18] For more information see: http://www.dnv.com

The PQF Common Quality Instructions are general, and address three phases in the life-cycle of a system:

- Production – covering manufacturing methods, main components, sub-systems, assembly and workshop installation, and workshop acceptance testing.
- Post-production – covering storage, transportation, installation, commissioning, harbour and sea trial acceptance tests.
- Operational – covering customer support, life-cycle management, training, manuals, maintenance and monitoring.

The over-arching need for quality management forms the final section of the document.

Relevant excerpts from the Common Quality Instructions[19] are at **Annex E**.

1.21.2 T-Pod conference

The first T-Pod conference in April 2004[20] gathered together pod manufacturers, shipyards, operators, designers, test facilities, classification societies, regulatory authorities, researchers and other interested parties to discuss and disseminate advances in pod propulsion technology. Topics discussed included: new technology; the need for new standards; and training and skills. The conference also considered establishing a database where problems and difficulties associated with pods could be logged, for the greater benefit of all parties. The next T-pod conference was scheduled for Japan in 2009.

1.22 FAILURE MODES AND EFFECTS ANALYSIS

Failure Modes and Effects Analysis (FMEA) aims to be a practical, realistic and documented assessment of the failure characteristics of the vessel and its component systems. It is undertaken with the aim of defining and studying the important failure conditions that may exist in a system[21]. This risk assessment technique has been applied to various craft where the experience necessary to assess the safety of operation of new types of vessels has not been available.

The SSC carried out an FMEA for *Prospero*'s podded propulsor, the first of its type. DNV stated that it was not a specific requirement in their rules (applicable at that time) that an FMEA should be submitted to DNV for approval. However, SSC has produced a copy of this document stamped as approved by DNV in October 1999.

The FMEA for the SSP system, as fitted to *Prospero*, shows that:

- Failure of the electric shaft speed set point (pod speed control) would have the effect of activating an alarm and automatic switch over to back-up speed control.
- Failure of the electric shaft rudder angle would have the effect of automatically activating emergency rudder control, but the FMEA does not state whether any alarm would be activated.
- Failure (due to component failure, missing connections or a broken wire) of the selected shaft encoder (actual speed value) showed that the effect would be a shutdown of the complete propulsion system; propulsion could only be restored by manual intervention to switch over to the other shaft encoder and restarting the propulsion system.

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[19] PQF Common Quality Instructions, V2.0 September 2004.

[20] See http://tpod.ncl.ac.uk/

[21] e.g. See the IMO High Speed Craft (HSC) Code, Annex 4 *Procedures for failure mode and effects analysis.*

The FMEA did not address the interface between the SSP system (as the most significant electrical consumer on board) and the electrical generation plant, via the power management system. For example, the main propulsion system on a diesel-electric ship would be expected to vary its demands to match the electrical power available, reducing propulsion power if there were insufficient generators available in order to reduce the risk of a blackout.

There was no requirement for the FMEA to be proven by sea trials, so no such trials were undertaken.

The FMEA document was not available on board, or at the company offices when visited by SHK shortly after the accident. Donsötank management was not fully aware of the FMEA for *Prospero.*

A similar FMEA document was prepared for *Prospero*'s sister vessel, *Bro Sincero*, and was seen on board; it was not stamped by DNV as approved. This FMEA, also, was not verified by sea trials. The FMEAs showed some important differences between the vessels. While the selection of the back-up pod control buttons on *Prospero* was automatically activated once the primary control had failed, a similar failure on *Bro Sincero* would only activate an alarm to the operator who would then have to manually select the back-up controls.

SSC stated that these changes were made as a result of the experience gained with the first plant installed on *Prospero*. These changes were required by Donsötank and approved by DNV.

1.23 TECHNICAL STANDARDS FOR PODDED PROPULSORS

1.23.1 International Maritime Organization (IMO)

The fundamental requirements for the propulsion and steering installation are derived from the SOLAS convention. This was developed from experience with conventional propulsion systems and therefore contains no specific requirements for podded propulsors. SOLAS requirements generally relate to the performance and capability of the propulsion and steering gear, and not to the manoeuvring capability of the ship.

Useful recommendations and guidance can be found in other IMO publications[22], several of which were in existence when the SSP system was designed.

1.23.2 Practical application of SOLAS standards to podded propulsion systems

A paper has been published discussing the difficulties in applying to pods the SOLAS derived requirements for the performance of conventional shaft driven propeller-rudder arrangements[23]. The paper describes the potentially damaging overload conditions that can be generated when pods are tested in accordance with these requirements.

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[22] *International Code of Safety for High-Speed Craft* 1994 (Type rating, the use of the probability concept and procedures for failure modes and effects analysis); The IMO *Code on Alarms and Indicators* (design of alarm systems)1992; MSC/Circ.891 1998 *Guidelines for the on-board use and application of computers* (fail-to-safe, system integration, user interfaces, training and testing) ; MSC/Circ.1091 2003 *Issues to be Considered when introducing new Technology on board Ship* (standardisation, simulator training, human elements).

[23] *Aspects of the Hydro-Mechanical Interaction in Relation to Podded Propulsor Loads*, JS Carlton & N Rattenbury, LR, London.

1.23.3 International Association of Classification Societies

The International Association of Classification Societies (IACS) has published a unified requirement for the on board use and application of programmable electronic systems; however they are to be applied only to new ships[24].

Not all member societies have dedicated rules for podded propulsion units. However, those recently published by Lloyds Register[25] provide an example of the bespoke requirements of some classification societies:

<u>FMEA</u>

For vessels where a single podded propulsion unit is the sole means of propulsion, an evaluation of a detailed engineering and safety justification will be conducted…This evaluation process will include the appraisal of a failure modes and effects analysis (FMEA) to verify that sufficient levels of redundancy and monitoring are incorporated into the podded propulsion unit's essential support systems and operating equipment.

The FMEA is to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

The FMEA is to:

(a). identify the equipment or sub-system and mode of operation;

(b). identify potential failure modes and their causes;

(c). evaluate the effects on the system of each failure mode;

(d). identify measures for reducing the risks associated with each failure mode;

(e). identify measures for preventing failure; and

(f). identify trials and testing necessary to prove conclusions.

Documentation

All podded propulsion units are to be supplied with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment. The manual required… is to be placed on board and is to contain the following information:

(a). Description of the podded propulsion unit with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.

(b). Identification of all components together with details of any that have a defined maximum operating life.

(c). Instructions for installation of unit(s) on board ship with details of any required specialised equipment.

(d). Instructions for commissioning at initial installation and following maintenance.

(e). Maintenance and service instructions to include inspection/renewal of bearings, seals, motors, slip rings and other major components. This is also to include component fitting procedures, special environmental arrangements, clearance and push-up measurements and lubricating oil treatment where applicable.

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[24] UR E22 (December 2006) To be applied only to such systems on new ships contracted for construction on and after 01 January 2008 by IACS Societies.
See: http://www.iacs.org.uk/document/public/Publications/Unified_requirements/PDF/UR_E_pdf150.PDF

[25] *LR* Rules *and Regulations for the Classification of Ships* 2006, Part5, Chapter 23.

(f). Actions required in the event of fault/failure conditions being detected.

(g). Precautions to be taken by personnel working during installation and maintenance.

1.24 DET NORSKE VERITAS CLASSIFICATION SOCIETY

1.24.1 DNV Rules for podded propulsors

Prospero was the first SSP ship to be classed by DNV. DNV did not have rules specifically dedicated to podded propulsor installations; their requirements for the SSP system were taken from across the full range of their rules, and applied as applicable to the particular aspect of the system under consideration.

1.24.2 Documentation

DNV had no rule requirements covering the supply of manufacturer's installation and maintenance manuals for podded propulsors; therefore this matter was not subject to class scrutiny.

1.24.3 SSP man-machine interface

At the time of construction of *Prospero*, DNV had no specific rule requirement related to the human-machine interface. Consequently, no formal assessment was made of the human interface with the SSP system.

1.25 SAFETY MANAGEMENT

1.25.1 ISM certification

The SMA retained responsibility for ISM survey and issued the Donsötank ISM Document of Compliance (DOC) on 24 May 2002, which remained valid until 10 June 2007. An intermediate survey was conducted by SMA on 01 September 2005.

Prospero's ISM Safety Management Certificate (SMC) was issued on 10 October 2005 and remained valid until 31 October 2010, subject to periodic verification and the company DOC remaining valid. The SMA conducted an ISM-intermediate inspection on 2 January 2007, some 3 weeks after the accident in Milford Haven. Three minor deficiencies were found; two in the documentary system and one procedural deficiency. None of them were relevant to this accident.

The SMA required no particular provisions within the Safety Management System (SMS) to allow for the fact that the SSP system fitted to *Prospero* was the first of its type. Records show that subsequent audits for both the DOC and SMC made no findings particularly relevant to the SSP system or this accident.

1.25.2 ISM Code requirements

The ISM Code was introduced in 1998, before *Prospero* was ordered. Much of the Code is relevant to this accident; however the following section is included here for reference:

> *10.3 The Company should establish procedures in SMS to identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of standby arrangements and equipment or technical systems that are not in continuous use.*

1.25.3 ISM findings

The Donsötank company ISM system is described in one company administrative manual (QMA) and one onboard manual (QMS) for each ship.

The QMS manual on board *Prospero* contained standard bridge routine and emergency procedures, and instructions for the conduct of navigation. Routines for the familiarisation of new personnel were well documented, and the following checklists were provided for bridge personnel: *Familiarisation bridge*, *familiarisation deck officer*, and *promotion master.* These checklists did not contain any detailed company requirements relating to operation of the SSP system, or for any verification routines to determine the actual knowledge and understanding of basic SSP system functions i.e. an understanding of the differences between the various modes of operation, such as 'crash stop' and 'emergency stop'. The operational procedures for the engine room contained more detail regarding the correct handling of blackouts. Overall, however, the QMS did not reflect the novel nature of the propulsion system, the first of its type to be operated by Donsötank.

The QMA manual stipulated a company internal requirement for risk assessment. At company level, the risk assessment was very vaguely described, but a more detailed requirement for an onboard risk assessment was contained within the QMS. This required a risk assessment to be carried out when there was a change in normal operating procedures, i.e. non-routine repairs or a potentially hazardous operation. No specific risk assessment was evident for the SSP system.

1.26 REQUIREMENTS OF MILFORD HAVEN PORT AUTHORITY

1.26.1 Milford Haven Port Authority guidelines for employing tugs

The MHPA issues guidelines[26] stating the number of tugs which vessels of specified sizes are required to use for berthing and un-berthing operations:

Tug usage for berthing:

Up to 100,000 DWT	-	*Minimum of 2 tugs.*
100,000 to 150,000 DWT	-	*Minimum of 3 tugs*
Over 150,000 DWT	-	*Minimum of 4 tugs*

It must be recognised that the above are only general guidelines and may be varied to pilots discretion, depending on weather and known ship's limitations. Tug numbers may be reduced depending on ship's equipment i.e. bow and stern thrusters, twin screw, high lift rudders, dp capability etc. Tug numbers may also be reduced for un-berthing at pilot's discretion.

For all movements over 25,000 DWT (or LPG over 20,000m3) regardless of thrusters, at least one tug to be in attendance

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26 *The Milford Haven - Entry and Departure Guidelines* (Seventh Edition 11/2006)

1.26.2 General Directions 2006

The MPHA also issued the following general direction in January 2006:

Direction 10, Bridge Manning (Annex 2)

This direction requires that vessels of 50 metres or more in length when navigating within the Haven shall have a bridge team of at least two persons on its bridge or other control position, one of whom shall be the master or Pilotage Exemption Certificate (PEC) holder and the other shall be a member of the crew capable of taking charge of the vessel or of taking and acting upon a pilot's orders when appropriate.

1.27 SIMILAR ACCIDENTS TO *PROSPERO* SINCE MILFORD HAVEN

1.27.1 Contact, following loss of pod control - Brofjorden, Sweden, 10 March 2007

Prospero was departing from Brofjorden (a refinery port in Sweden) under the control of an experienced master, and the chief officer and pilot were also in the wheelhouse. Pre-departure checks were carried out and all was normal; however, a tug had been ordered due to a bow thruster malfunction. During the pilotage, the master lost control of the ship on two occasions; one witness stated "*The pod was living its own life"*, and expressed concern at the ability of operators to effectively control the SSP system.

During un-berthing there was light contact with the quay; a more serious accident was perhaps prevented due to the intervention of the tug and the master's use of the emergency systems. As at Milford Haven, control was restored by a "re-boot" of the propulsion system.

The rudder mode was working normally when the second incident occurred; the auto pilot was connected and the pod made a 90° azimuth movement. Following this, *Prospero* sailed with the tug connected aft as an escort and went to anchor in Malmo roads to await investigations and repairs to the SSP system. There were no injuries and no pollution.

A Siemens service engineer and DNV surveyor attended the ship. After 3 days of investigations, the cause of the loss of control was found to be a spare part that had been fitted following the earlier failure of the gauss system. The uncalibrated part was carrying incorrect software settings which had resulted in the pod rotating independently of the operator's input as it lacked an accurate position reference. After re-calibration of both signal systems the SSP system worked normally.

A second problem was considered; the configuration of the pod shaft encoder system (a vital part of the pod power control system) meant that the automatic redundancy capability of the SSP system was severely compromised. The FMEA for failure of the selected shaft encoder (actual speed value) shows that the effect would be a shutdown of the complete propulsion system. Propulsion would only be restored by manual intervention, to switch over to the other shaft encoder and then restarting the propulsion system.

The gauss signal transmitter that had originally been removed in September 2006 was refitted.

DNV issued a survey memorandum and two conditions of class as a result of this incident:

- The memorandum required modifications to improve the SSP alarm system.
- The first condition of class required significant alterations to be made to parts of the SSP power control system, in order to ensure that a back-up system was readily available at all times, and to be capable of being put in to operation within 30 seconds. DNV also required that written procedures for dealing with a loss of steering and propulsion were to be established and regularly trained.
- The second condition of class suspended the class notation E0 (UMS) and so required that *Prospero's* engine room be continuously manned; valid until the first condition was deleted.

Investigation by Donsötank found the root cause of the incident to be that company SMS procedures regarding the maintenance of critical equipment had not been followed:

> *Duly qualified personnel only are allowed to handle critical equipment with regards to operation, maintenance and repair and amending parameters, such as changing alarm set points.*

Corrective actions were identified, to be completed by March 2007.

Experts attending this breakdown noted that Schottel service personnel had repaired the gauss transmitter system; they had then removed from the vessel the emergency jumper cables for the gauss system. However, these cables should have been retained on board as a part of the redundancy capability of the SSP system. They have subsequently been returned to the vessel.

The wheelhouse data recorder fitted by Siemens at Fredericia in December 2006 was not a success. Due to the low sampling rate, movements were not accurately recorded and some sampling points used were more suited to sea trials than accident investigation. In addition to this, the ship was running on four different electronic "clock times" as they had not been synchronised by the crew.

1.27.2 Grounding, following loss of pod control - St Petersburg channel 23 April 2007

After departure from St Petersburg, loaded, and with the pilot still on board, *Prospero* experienced steering problems; the symptoms were that the SSP unit was not able to hold azimuth (rudder) angle position, even with two hydraulic steering pumps running. The SSP was not following orders, either when in auto pilot or hand-steering, as a result *Prospero* grounded. There were no injuries and no pollution.

Prospero proceeded to Simrishamn roads (south east Sweden) and anchored there on 25 April, where she was boarded by representatives from the SMA, DNV, SSC and her owners. *Prospero* was placed under a "prohibition to use" order from SMA.

Service engineers from both Siemens and Schottel attended; over a period of 4 days they ran various tests on the SSP system and eventually found a fault in the hydraulic system of the azimuthing gear.

When *Prospero* had increased speed above about six knots, with manoeuvring mode selected (i.e. two steering pumps running), the hydrodynamic forces on the pod had exceeded the available capacity of the faulty steering system causing the pod to azimuth in an uncontrolled way.

Specialist hydraulic engineers from Hägglunds (the manufacturers of this sub-assembly) attended in order to make the necessary tests and repairs. A fault was found in the hydraulic pump valve block; the faulty unit was replaced by a new spare.

The Hägglunds service engineer stated that the damage could be explained by the running hours on the plant. He recommended that a spare valve block should be carried on board because "*such failures can happen suddenly after years of duty".*

Investigation by Donsötank found the root causes to be insufficient test procedures after service work conducted during an earlier repair period, and also that there were no planned maintenance routines for regularly checking the pressure in the hydraulic steering system. Corrective actions were identified, to be completed by May 2007.

1.28 SIMILAR ACCIDENT TO SISTER SHIP - *BRO SINCERO* MAY 2006

*Prospero'*s sister ship *Bro Sincero* (the second in this class of 3 tankers powered by the SSP system) was involved in a collision with the Norwegian ro-ro vessel *Elektron* in Berendrecht lock, Antwerp at 12:15 on 6 May 2006.

As this accident was not investigated by either SHK or SMA, the information below has been taken from reports by DNV, Donsötank and SSC.

1.28.1 Synopsis

While manoeuvring during the approach to the locks*, Bro Sincero* hit *Elektron* heavily from astern, pushing *Elektron* into the lock gates. There was steelwork damage to *Bro Sincero* and the lock gates and significant damage to *Elektron* **(Figures 15, 16 & 17)**. There were no injuries and no pollution; tugs were not attached to *Bro Sincero* at the time of the accident.

In summary, the master became confused as to whether the pod position indicator (equivalent to a rudder angle indicator in a conventional ship) was faulty and so not indicating the true position of the pod, or if the pod itself was not azimuthing correctly. This caused him to lose control of the SSP; no attempt was made to regain control using the back-up control buttons, the 'crash stop' facility or the 'emergency shutdown' button.

A DNV surveyor attended and carried out a hull damage survey. The damage survey report was concerned with steelwork damage; no survey or investigation of the SSP system was undertaken. At the time of this accident, DNV did not consider that this accident justified any "read-across" actions to sister vessels. In light of their later experiences with *Prospero*, the situation is now *'considered differently'* by DNV.

SSC service engineers attended and the ship was moved to Flushing anchorage while investigations were carried out; a Stork Kwant BV (manufacturers of the pod manoeuvring control levers) service engineer also attended. Failure logs indicated a failure of the pod manoeuvring control lever (the electric shaft system). A broken connection was discovered inside the electric shaft cabinet; once repaired the system was tested satisfactorily.

Figure 15

Damage to stern of *Elektron*, due to collision with bow of *Bro Sincero*

Figure 16

Damage to bow of *Elektron*, due to contact with lock gates.

Figure 17

Damage to bow of *Bro Sincero*, due to collision with stern of *Elektron.*

1.28.2 Internal investigation

This accident was subject to a joint accident investigation by the Donsötank Technical Manager and the Safety and the Marine Manager of Broström Tankers AB (the commercial managers for *Bro Sincero*); an underwriter's representative also attended the ship.

Donsötank reported the root cause of the accident to be the master's failure to use the emergency controls of the SSP system correctly. Actions to be taken to prevent recurrence were identified, but completion dates were not specified. The actions identified did not include checking similar cable connections on board sister vessels.

1.28.3 *Bro Sincero*, findings relevant to the *Prospero* case

As part of the investigation of the *Prospero* accident, investigators visited *Bro Sincero* at Falmouth during March 2007. The master was aware of both this accident to his ship and that to *Prospero* at Milford Haven. *Bro Sincero's* manning arrangements were similar to *Prospero's*, and there was no electrical engineering officer on board.

Due to continuous product development, the SSP system fitted to *Bro Sincero* was slightly different to that on *Prospero*. Most obviously, where *Prospero* used a high frequency radio link for the gauss signal transmitter, *Bro Sincero* used a second set of slip rings to transmit the control signals to/from the azimuthing part of the pod. SSC stated that this change was more cost effective and was not due to problems with radio frequency or other interference; the control system signals were robust. *Prospero* was not upgraded with this new arrangement when her gauss signal transmitter failed.

Following delivery of the vessel, *Bro Sincero* had experienced problems with the auto pilot and manual steering modes switching off automatically. These had continued for over 3 years, and caused great concern to the master; it was the subject of very many email exchanges between the ship and the Consortium. The solution initially provided by SSC was to retrofit an additional alarm to alert bridge personnel when the auto pilot switched itself off. Much later, a number of electronic cards in the control panels were changed, which apparently resolved the problem.

The alarm system lamp dimming and audible alarm arrangements were similar to those fitted to *Prospero*.

Bro Sincero's SSP manuals and system documentation were generally better than had been seen on board *Prospero*, particularly those supplied by Siemens. However, ship's staff had made attempts to obtain English language manuals from Schottel since delivery, and some of the manuals in use on board were marked as having been originally supplied to *Prospero* for her first pod. This meant that, when trying to correctly identify system components, the Schottel service department found it necessary to direct the ship's engineers to email them photographs, with engineers pointing to the relevant parts. Donsötank has no ongoing service/spares contract in place for *Bro Sincero*.

1.29 ACCIDENTS TO OTHER SHIPS, RELEVANT TO *PROSPERO*

1.29.1 *Savannah Express*

The findings of the MAIB investigation into the engine failure of the German flag container vessel *Savannah Express*, and her subsequent contact with a linkspan at Southampton docks on 19 July 2005, was published as report number 8/2006 in March 2006[27].

The accident occurred due to failures within a new type of complex electronic control system fitted to the main engine. It was not fully understood by those operating the vessel because of deficiencies in training and experience; there were also problems with availability of spare parts.

Following the investigation, the UK Maritime and Coastguard Agency was recommended[28] to:

> *Submit an appropriate information 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.*

Following the MCA's submission to IMO, the competency of electrical engineering and electronics personnel will be reviewed as part of the "Comprehensive review of the STCW Convention and the STCW Code"[29] being undertaken by the STCW Committee.

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[27] See: http://www.maib.gov.uk/publications/investigation_reports/2006/savannah_express.cfm

[28] MAIB recommendation number 2006/136.

[29] STW 38/12/4.

1.29.2 *Red Falcon*

The findings of the MAIB investigation into the contact with a linkspan by UK flag passenger vessel *Red Falcon* at Southampton on 10 March 2006, were published as report number 26/2006 in March 2006[30].

The investigation identified the following matters that are relevant to the *Prospero* case:

- The vessel's propulsion system was not being used in its normal mode of operation; a secondary mode was being used and the ship's officers were not fully familiar with this mode. The ship's officers had insufficient training and experience to operate the vessel in this secondary mode, and the SMS failed to identify and rectify this shortfall.
- The indication system provided to inform the operator that the vessel was not operating in its normal mode was not effective in alerting the operator to the mode selected; the result being that the propulsion system did not behave as anticipated.

This report did not result in recommendations as the ship managers immediately implemented the following corrective measures:

- The reporting system for all onboard drill and training exercises was changed to become a positive monthly report to the company by the vessel's senior master.
- Handover and critical operations checklists were consolidated into easy to use and readily available sheets for use by deck officers.
- The requirement to review and risk assess operations in which an equipment malfunction may impact on the safe operation of the vessel was reiterated to staff at all levels in the company. The need to monitor procedures put in place to ensure the above was also re-emphasised.
- Correct procedures governing unusual and/or critical operations were reiterated to all staff.
- An external audit of the ISM procedures on *Red Falcon*, by the MCA, was successfully conducted.
- Independent consultants were engaged to audit and benchmark the Red Funnel operation against a database of in excess of 800 vessels.
- A new senior master was appointed to *Red Falcon* to help provide impetus and leadership in the rebuilding of processes and procedures on board following the accident.
- A series of meetings was held with ships' staff to review the details of the accident to ensure appropriate lessons are learnt throughout the fleet.
- A review of the philosophy and design intent of the synchronisation/de-synchronisation control systems was undertaken in conjunction with the designers/manufacturers.

1.30 SISTER VESSEL - *EVINCO*

Investigators have not been able to visit *Evinco,* the third ship in the series, and have not received any relevant information regarding this ship. The SSP system for *Evinco* was under manufacturers' warranty until September 2007.

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30 See: http://www.maib.gov.uk/publications/investigation_reports/2006/red_falcon.cfm

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 FATIGUE

The effect of fatigue on the master, pilot and chief engineer was assessed using the MAIB fatigue assessment software tool; fatigue was considered not to be a contributory factor to this accident.

2.3 ENVIRONMENTAL CONDITIONS

The environmental conditions were not considered to be contributory to this accident.

2.4 THE ACCIDENT

The root cause of the initial failure of the pod controls has not been found; however, it is suspected that out of range signals in the PCS caused the system to automatically supplant the primary control levers with the back-up buttons.

When *Prospero*'s primary propulsion control system failed, the master was not alerted to the failure and did not detect that the system had probably switched into a reversionary mode of control automatically. In his subsequent actions he was, to some extent, fighting the control system and was unable to prevent his vessel colliding twice with the jetty; once forward and once aft.

When built, *Prospero*'s propulsion system had been innovative, and the owners had benefited from an extended warranty. These two factors resulted in the owners depending heavily on the manufacturers for all aspects of product support. The lack of in-house maintenance procedures, inadequate system knowledge by ship's officers and shore staff, and weak SMS and system documentation, overlaid on a propulsion system for which, when introduced, no dedicated technical standards existed, resulted in a vessel whose resilience to defects and emergencies was significantly weakened. Although the previous accident to *Bro Sincero* had presaged a pod control failure whose effect was similar to the one which occurred in this accident, these warnings had not been identified and no pre-emptive mitigating action was taken.

2.5 THE LOSS OF CONTROL OF THE PODDED PROPULSOR

2.5.1 The Pod Control System

While *Prospero* was berthing in Milford Haven at night, the pod primary controls failed. All the alarm lamps had been dimmed, so the master was initially unaware that a failure had occurred. The master did not have a sound working knowledge of the pod reversionary control mechanisms, and in his attempts to avert an accident he could not prevent, first, the bow of his vessel colliding with the jetty, and subsequently driving astern into the mooring dolphins aft. The master was not able effectively to use the emergency controls to stop the ship.

The causes of the two un-demanded applications of 70% ahead power during the incident at Milford Haven have not been identified. The first power increase occurred either during, or immediately after, the master changed control from the centre to the port console; no explanation for this spurious command has been determined. A further power control problem occurred when the master attempted to zero the controls from the port console, but the system re-applied the undesired 70% ahead command. This could be explained if control of the PCS had not been successfully transferred from the centre to the port console. The master believed he had azimuth control at the port console, but not power control. It is possible that system control of power had switched to the back-up push button system which was applying input, and therefore the electric shaft system was attempting to synchronise the port console lever with the unwanted 70% power command. The second undesired application of power (which resulted in the damage to the stern of *Prospero*) from zero to 70% has not been explained.

SSC has stated that the loose wires subsequently discovered in the starboard bridge wing console were not the cause of the loss of control of the SSP system at the port console. However, investigations have found that an apparently similar failure occurred on board the sister vessel, *Bro Sincero,* that also resulted in loss of control of the pod system, with comparable consequences. At the time of that accident, the attending SSC service engineer believed that the loose wires were the cause of the loss of control.

If the loose wires/broken connections discovered in the pod control lever manoeuvring cabinets on both *Prospero* (section 1.8.2) and *Bro Sincero* were not the cause of the problem, then there were other significant defects within the SSP system that have yet to be identified.

As *Prospero* was not fitted with either a VDR or a bridge movement recorder it is unlikely that the exact cause of the initial loss of control of the pod will be determined.

2.5.2 The alarm system

The lighting of the control panels and the alarm system in the wheelhouse was capable of being dimmed down to a point where they were no longer visible, and the audible alarm was not loud enough to be clearly discernible above the ambient noise. The master was not, therefore, made aware that the primary control system had failed. His confusion and consequent reactions were therefore understandable.

There is a natural tendency, at night, to minimise lighting on the bridge in order to preserve night vision. Thus, any permanent illumination would be turned down to its lowest level. By using the same lamps to indicate steady state functions and alarms, any reduction in the steady state illumination would compromise the chances of the flashing alarm indication being noticed by the watchkeeper. Further, it should not have been possible to reduce the alarm lamp illumination below the visible level so that it was difficult for the master to see the “electric shaft failure” alarm, which indicated that control of the PCS had automatically changed to the back-up, button system. Had the steady state and alarm lamps been separate, the steady state buttons alone could have been dimmed.

Donsötank responded to this problem by amending their pre-arrival checklist to require the bridge team to turn up the brightness of the alarm system lighting, so as to make it visible at all times. However, given the potential consequences of this fault and that it is present on more than one ship, a permanent solution, such as separating the lamp functions and increasing the volume of the audible alarm would be more effective.

2.6 SHIP OPERATIONS AND PILOTAGE WITH THE SSP SYSTEM

There was a very high level of reliance on the PES and the SSP hardware on board *Prospero*; when the system worked correctly it was so flattering to the operator that difficult ship manoeuvres became deceptively easy. The master was ill-equipped to react to a primary PCS failure for a number of reasons:

- The PCS controls did not facilitate an easy understanding of how the system was operating or configured.
- None of the bridge staff or engineers had received any formal training in the system and its reversionary modes of operation.
- There was no requirement laid upon the deck officers by the company to demonstrate competency in the use of reversionary modes.
- The master was the only ship's officer on the bridge when the accident occurred.
- Had the deck officers elected to teach themselves how to use the secondary systems, the documentation was not on board to facilitate this learning.
- There were no tugs attached to *Prospero* at the time of the accident.

2.6.1 PCS controls

In primary mode, the PCS was relatively simple to use, and basic competency could be achieved by an oncoming master understudying his predecessor. However, the poor functionality of the indicator lamps and the numerous modes of operation, some of which could occur automatically, made it difficult for the operator to monitor the system while focused outside the vessel on an approaching jetty. The lack of an effective audible alarm to draw his attention to a change in the pod system further reduced the chance of an operator detecting an anomaly.

It would appear that the primary system was so easy to use, that no one had focused on the difficulty an operator would have using the reversionary modes.

Ideally, the man-machine interface should be developed to make it more user-friendly. In the interim, improved training would help mitigate any deficiencies.

2.6.2 Training

STCW training focuses on conventional propulsion systems, and during training deck officers will often be lucky to receive anything more than a basic awareness of other propulsion systems.

The need for dedicated training of the deck officers on specialist or unusual types of craft has long been recognised in some areas of the marine industry, e.g. high speed craft and dynamically positioned (dp) vessels. Such training is usually focused on the master and chief officer, but encompasses the OOW to some degree.

Without structured in-depth training that included all of the SSP's capabilities and limitations (including back-up and emergency modes of operation), the master was placed in a position of total reliance on the correct operation of the propulsion system.

Operators of podded propulsor systems should assess whether the basic skills of certificated personnel need to be supplemented by specialist training for the propulsion plant which they are required to operate and, if so, ensure an appropriate training regime is implemented.

2.6.3 Practice in reversionary modes of operation

A good SMS system will require deck officers and engineers periodically to practice and drill reversionary modes of operation. As well as fully understanding the emergency functions of the system under their command, operators must have both the confidence and the competence to switch back and forth between the primary method of propulsion and steering control, and the back-up systems.

On this occasion, the master did not recognise that the system had probably automatically selected the back-up button control system, but neither, once it was evident that the system was not following his commands, did he embark upon a well drilled set of procedures to regain control of the system. Of more concern is that when he found he could not control the ship, he did not activate the 'emergency shutdown'. As soon as he had ordered the anchor to be 'let go', this action would at least have prevented the second series of collisions. In electing not to activate the 'emergency shutdown', he was influenced by the chief engineer, who was so uncertain about the effect of using the control that prior to this accident he had cautioned the captain against its use.

The "last resort" option of resetting the PCS, by handing control down to the engine room, then immediately back up to the wheelhouse similarly was not practiced or drilled.

The MAIB is becoming increasingly aware of accidents that have been caused because ship's staff have either failed to recognise that a system had automatically selected a reversionary mode of control, or who are so inexperienced in the use of reversionary modes that they have been unable to effectively control their vessel. In this respect, the similarities to the *Red Falcon* accident referred to at section 1.29.2 are striking.

The lack of any requirement in the SMS for deck and engineering officers to be trained in, and to practice, reversionary modes of control meant that when the SSP system ceased to operate in its primary mode, *Prospero*'s deck and engineering officers were unable to regain effective control of the ship.

2.6.4 Bridge manning

Notwithstanding that MHPA General Direction No.10 required the bridge team to consist of at least two people capable of taking charge of the vessel, there were no other watchkeepers on *Prospero*'s bridge at the time of the accident. The master was, therefore, alone when attempting to deal with the loss of pod control.

As was normal standby procedure on board, the OOW had proceeded to his mooring station and the chief officer had gone to the manifolds on the main deck to check the ship was berthing in position. Not only was this not the most effective use of manpower, but also a check on local rules should have prompted a change in procedure to retain a qualified OOW on the bridge.

The pilot did not have any formal training or experience of podded propulsor systems so was unable to be of direct assistance to the master, although he was able to advise and minimise the danger to others. However, pilots are engaged for their local knowledge and experience, not to drive the ship on behalf of the master. A pilot cannot be expected to be an expert on all propulsion systems, and he should not be relied upon as such by ship's staff.

Had an OOW, who was trained and experienced in the operation of the SSP system, remained in the wheelhouse with the master, it is possible that the failure of the control levers and the resulting automatic change-over from the control lever to the push buttons would have been noticed. More likely, is that appropriate emergency action to bring the vessel back under control would have been taken.

Subsequent to this accident, Donsötank has reviewed the bridge manning policy throughout its fleet to ensure that the bridge team consists of at least two competent persons for port entry and departure. This should also allow another officer to develop some experience in ship handling and berthing manoeuvres, and so become better able to assist the master or to intervene in an emergency situation.

2.6.5 Onboard documentation

From SSC's perspective, the documentation supplied to *Prospero* was probably adequate to facilitate the installation engineers during initial commissioning, and the repair engineers during the subsequent warranty period. The various SSC technical staff who did attend the ship had the detailed system documentation they needed to hand, produced in a format they were familiar with.

However, the documentation did not support ship's staff understanding of the system. There were no manuals available to the deck officers to study to gain a knowledge of the system's operating modes, and its limitations. On the engineering side, ship's staff had resorted to compiling their own manuals by documenting work done on the system.

With *Prospero* out of warranty, and with no support, servicing and maintenance contract in place, responsibility for keeping the system running fell to the ship's engineers. The failure of the hydraulic steering system on 23 April 2007, which led to the vessel grounding in the St Petersburg channel, was directly attributed to the lack of a planned maintenance routine for the system.

With its mix of languages, conflicting and, in some instances, total lack of instructions, the onboard documentation did not support the safe operation of the ship.

2.6.6 MHPA Guidelines for the use of tugs

Although MHPA guidelines refer to the need for vessels such as *Prospero* to have a minimum of two tugs, a lesser number is permitted if the vessel is considered to be highly manoeuvrable. The decision not to allocate tugs to *Prospero* on this occasion was based on her history of safe operation during previous visits, and the safety record of similar podded ships visiting the port. Even though the master had omitted to inform the pilot about *Prospero*'s 'condition of class', it is unlikely that this would have changed the pilot's view about the employment of tugs. The decision, therefore, not to allocate tugs to *Prospero* when entering Milford Haven on 10 December 2006 was not unreasonable.

However, it is a general observation that ports are heavily reliant on masters to brief them about limitations or reliability concerns that could affect their port entry and berthing, especially where these have occurred since the vessel last visited.

MHPA's current guidelines for tug use do not clearly define the process which should have been followed when considering a reduction in tug allocation for vessels such as *Prospero*. There should be unambiguous guidelines that define the process for reaching a decision to reduce the tug requirement for a specific vessel, and such decisions should be recorded and regularly reviewed.

By insisting that two tugs were employed by *Prospero* when leaving port after the accident, MHPA minimised the risks to its stakeholders.

2.7 ONBOARD ENGINEERING EXPERTISE

2.7.1 Safe Manning Certification and the engineer officers

Although the SSP system was developed with simplicity of operation in mind, it was, nonetheless, a highly complex system which required all those who operated and maintained it to have a thorough knowledge of its limitations as well as its capabilities. This knowledge was lacking in the case of the SSP system fitted to *Prospero*.

Prospero's propulsion system was innovative and complex, utilising hybrid electro-mechanical systems that would be outside the training and experience of the majority of ships' engineers. While any engineer's knowledge of such a system would have been enhanced by an equipment-specific course, the nature of *Prospero*'s plant was such that inclusion of an electro-technical officer, at least on the first of class, would have been appropriate.

Engineers and technical staff on podded vessels require a thorough understanding of the mechanical, hydraulic, electronic and electrical engineering principles used to construct and maintain the propulsion system. Such knowledge cannot be assimilated through information cascade during handovers and by watching over the shoulders of contractors' specialists. It is similarly unlikely that the basic elements of STCW training for engineer officers would equip them to operate a plant of this type.

Had *Prospero's* engineer officers received more comprehensive training, they would have been better equipped to operate, test and maintain the SSP system on a routine basis. Further, they would have been sufficiently confident in both the SSP system and their own abilities to ensure that the reversionary and emergency modes of control were regularly exercised, and would have been better able to advise the master when the PCS failed.

Attendance on a manufacturer's course, specific to the systems to be found on board, should be a standard requirement for service on vessels with novel or unusual propulsion types. Ship managers and ship's officers should carefully consider whether attendance on such a course is required for safe ship operation.

Donsötank and the SMA should reconsider the current manning arrangements for engineer officers on board similar vessels, with a view to increasing the electro-technical component of the ship's complement or, as a minimum, ensuring that ship's engineers undertake type-specific training on the SSP system.

2.7.2 The case for electro-technical officers

The increasingly complicated propulsion systems found on modern ships requires a high degree of knowledge of computer-based automation, medium voltage control equipment and electronic systems, particularly for diesel electric ships fitted with pods or conventional electric propulsion motors.

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

Following MAIB's investigation into the accident involving *Savannah Express* at Southampton on 19 June 2005, the MAIB recommended that the MCA raise this matter at IMO; that recommendation has been implemented[31]. The need for such a change has been reinforced by this accident.

2.8 LESSONS IDENTIFIED FROM PREVIOUS ACCIDENTS

While there is no direct technical link between the individual accidents discussed in this report, the accident at Milford Haven was not the first time that *Prospero* had suffered a loss of pod control, nor the first time that a Donsötank vessel had suffered damage due to loss of control of the SSP system. However, aside from immediate repairs, the lessons from these earlier incidents had not been effectively followed up by the owners, Flag State, classification society or equipment manufacturers.

Prospero has suffered two further losses of pod control since the accident on 10 December 2006 at Milford Haven, though fortunately neither resulted in serious damage.

2.8.1 *Bro Sincero* - collision at Antwerp

With hindsight, it is clear that had more attention been paid to *Bro Sincero*'s accident on 6 May 2006, the subsequent accident involving *Prospero* in Milford Haven could have been avoided, or at least, the effects minimised.

Firstly, the master was unable to regain control of the system once the pod manoeuvring control lever had failed. This should have indicated that *Bro Sincero*'s master's knowledge of emergency actions and reversionary modes of pod control was inadequate. The cause of this inadequacy could have been a lack of training in emergency response, a lack of practice in emergency response actions, or a lack of underpinning emergency response procedures. All of these were absent when *Prospero* collided with the jetty at Milford Haven, yet the 6 months between the *Bro Sincero*'s accident and *Prospero*'s in December would have been ample to plug this gap.

Secondly, that a single broken connection could apparently (according to the service reports issued by the SSC representative attending *Prospero* at that time) have such a major consequence should have rung alarm bells with the manufacturers (SSP Consortium), owners (Donsötank), and the classification society (DNV).

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[31] See section 1.29.1.

Had the Consortium investigated further, issued a product alert, and Donsötank a fleet safety notice, a vital warning to other SSP operators could have been sounded, so reducing the risks of further accidents.

Whatever the reasons for the lack of action by owners, manufacturers, and the classification society following the *Bro Sincero* collision, it nevertheless remains likely that better accident reporting and follow-up procedures on behalf of any of these parties could have prevented the subsequent accident to *Prospero*.

With regard to *Bro Sincero*'s ongoing problem with the auto pilot and steering modes randomly switching themselves off, the master's persistence in chasing SSC for an effective solution was commendable. However, Donsötank technical managers should have been dealing with this problem on the ship's behalf, and the fault should not have been allowed to persist for so long.

2.8.2 *Prospero* - pod control system failure prior to Milford Haven

As the root cause of the initial failure of the PCS has not been determined, it is not possible to be conclusive, but the earlier breakdown of the gauss signal transmitter, the temporary repairs, and the condition of class consequently imposed were probably not directly material to the accident at Milford Haven. That said, the requirement to accommodate the pod restrictions might well have added to the pressure on the master (section 2.10.4).

However, the fact that the gauss signal transmitter unit remained out of service for so long indicates problems with the owner's arrangements for ongoing product service and support.

2.8.3 Siemens-Schottel Consortium

There are SSP systems being operated by several other ship owners. The SSC must ensure that lessons identified from the operation, maintenance and repair of all SSP systems are captured and circulated to the operators of similar SSP systems.

2.9 THE DONSÖTANK SAFETY MANAGEMENT SYSTEM

Many of the shortcomings highlighted above would have been absent, or at least minimised, had the Donsötank ISM system for the operation of *Prospero* been effective, specifically:

- Resources and personnel: The ISM Code requires that masters are properly qualified for command. It is debatable whether *Prospero*'s master, without formal training in the operation of the SSP system, was properly qualified. Specifically, he was unable to react correctly or effectively to the emergency situation created when the propulsion system failed.

- Plans for shipboard operations and emergency preparedness: The Donsötank SMS was not effective in detailing responses to a foreseeable loss of control of the SSP system, or for requiring that drills and exercises for that event were carried out. The fact that drills and exercises were not being undertaken effectively was not detected by either the company or the Flag State audit process.

- Reports and analysis of accidents and hazardous occurrences: While evidence was seen of detailed analysis of individual accidents and incidents, the Donsötank SMS was not successful in its objective of improving safety across the fleet. Specifically, despite a number of other accidents and incidents with similar root causes, Donsötank had not issued any fleet-wide safety memoranda warning about the failures, or instructions to mitigate their impact.

- Maintenance of the ship and equipment: Primarily due to the poor standard of manufacturers' documentation available on board for the SSP system, Donsötank did not, or perhaps could not, ensure that the propulsion system was maintained appropriately. However the requirements at section 10.3 of the ISM Code for the regular testing of stand-by (referring to back-up or emergency systems) arrangements was within their control, yet was not effectively implemented.
- Documentation: Version and change-control for documentation relating to the SSP system was not effective. Manuals marked *Prospero* were found on board *Bro Sincero*; documentation marked "preliminary" was in use some 6 years after commissioning.

From the above list, it would appear that although Donsötank had implemented an ISM compliant SMS on board *Prospero*, and so satisfied regulatory requirements, it did not evolve in response to experience and was not wholly robust and effective.

The Donsötank ISM system should be audited, by both the company and the SMA, to confirm that it adequately addresses the operational requirements of the ships in its fleet and any deficiencies found. The ISM system must be capable of ensuring that actions to rectify any shortfalls are put in place and their ultimate close-out is recorded; an auditable methodology should be used throughout.

The Flag State ISM audit is, of necessity, a sampling process; it is commonly accepted that not all areas are checked at every survey and a complete audit of an SMS is seldom ever conducted. The shortcomings of the Donsötank SMS relating to this accident were not detected during ISM audits by SMA. However, as many of the problems directly relate to the introduction of radically new technology to the Donsötank fleet, they should have been reasonably foreseeable.

Given the number of shortcomings with the SMS not detected by earlier ISM audits, consideration should be given to a Flag State audit of the entire Donsötank company SMS, with special attention being paid to the areas highlighted in this report.

2.9.1 Over-carried cargo

The practice of retaining cargo and over-carrying to another port had developed as an informal arrangement between the charterers and the commercial operators intended to facilitate logistics operations. In this case, the cargo had remained on board due to insufficient tank space in a previous port.

While not a direct influence on the circumstances of this accident, the fact that both the owners/managers of the ship and the port authority were not aware of the cargo remaining on board had potential safety and environmental implications. After the accident, the 220 tonnes of kerosene cargo remaining on board constrained how the vessel was treated within the port, and under what conditions she was to be allowed to sail to the repair yard. Once permission had been given for *Prospero* to conduct a single, ballast only, voyage, the requirement to first discharge the remaining cargo added to the risk in the port and caused delay.

The Donsötank ISM SMS should contain appropriate instructions in order to minimise the risks arising from over-carried cargo.

2.10 THE INNOVATIVE TECHNOLOGY OF THE SSP SYSTEM

2.10.1 Managing the risks of complex systems

Over recent years, pressure to reduce costs and minimise emissions has resulted in the introduction of a number of innovative marine propulsion systems. Common themes have been: developments in diesel-electric generation and heavy power electronics; increased use of computers to control systems; and, the introduction of podded drives. The incentive to develop and introduce new technology is unlikely to abate as the global warming debate gathers pace and the carbon footprint of shipping receives political focus.

One disadvantage of adopting new technology is that decision makers have little by way of knowledge, experience or available expertise to guide them. As the technology matures, experience of its weaknesses is gained. If these are insurmountable or prohibitively expensive to cure, the product withers. If the weaknesses can be resolved, then improvements are taken forward in subsequent builds and, perhaps, retro-fitted to existing vessels. The problem for the industry is minimising the opportunity for innovative, unsafe systems to become operational.

In the case of *Prospero*, the untried, untested propulsion system initially performed well. However, as defects started to emerge, the control measures required to counter them were lacking.

2.10.2 The owners

In deciding to purchase *Prospero*, the owners, Donsötank, were heavily influenced by SSP's claims about the system **(Annex B)** and the extended warranty on offer. The owners, therefore, did not take the usual steps of developing in-house expertise and documentation on the system, establishing a service contract or regime, or setting about formally training their officers in the new technology.

The consequence was that ship's engineers liaised directly with the Consortium when technical expertise or assistance was required, and were supported either via site visits by SSC technicians, or were 'talked through' fault rectification over a telephone line. Without the engineering manuals or training, the ship's engineers learned what they could from this process by osmosis. However, the nature of this arrangement meant that instead of being at the heart of decision making, the Donsötank technical manager's involvement in 'trouble shooting' became sidelined. Without this involvement, and without a working knowledge of the SSP system, the technical manager's ability to identify trends and to read-across lessons from accidents and incidents on one vessel to others in the class was severely compromised.

Another consequence of Donsötank's limited in-house technical support capability for the SSP system and heavy reliance on the SSC service engineers was that *Prospero's* planned maintenance system for some parts of the SSP system had deteriorated to little more than breakdown driven maintenance (section 2.6.5). Specifically, Schottel ascribed the breakdown of the Gauss system to the lack of routine maintenance inspections and maintenance which would have identified the wear on the bearings. All three SSP ships operated by Donsötank will soon be out of warranty; timely and effective service and support arrangements (covering planned maintenance and system "health checks" as well as breakdown support) are required, be they from the SSC or from elsewhere. Other operators of similar systems have recognised the need for this capability, and one reason that SSC service personnel were not available to *Prospero* in Milford Haven was that they were occupied on contract service work elsewhere.

In deciding not to invest in type specific training for their deck and engineering staff, Donsötank had not adequately identified or mitigated the risks present throughout the life of their SSP vessels. While the risk based approach of ISO 17894:2005 had not been published when *Prospero* and her SSP system were being designed, the principles are valid for this case in that systems engineering methodology is used to address hazards and deliver dependable and traceable systems - throughout the plant lifecycle. The principles have now been adopted by certain classification societies and marketed as an additional service to their clients[32]; this fresh approach to complex systems assessment can be applied to both new and existing installations.

Considering the findings of this investigation, a risk based assessment should (as far as is reasonably practicable) be applied retrospectively to the PES used within the SSP systems fitted to Donsötank ships, in order to reduce risks and the consequences of the failure of the podded propulsor system.

In addition to the technical solutions that are required, the assessments should include analysis of the system lay out on the bridge and in the ECR, with special attention to both presentation and control options from a man-machine interface perspective.

2.10.3 Documentation

System documentation must be provided to guide and instruct operators and maintainers in the safe and efficient management of all aspects of the systems on board.

SSC stated that adequate documentation was delivered to all stakeholders. Whatever the reason is for the lack of SSP documentation found on board *Prospero* at the time of the accident, Donsötank overlooked the need to ensure that adequate documentation was made available on board. This requirement remains to be addressed by Donsötank, in conjunction with SSC.

The fact that both LR "pod rules" and the PQF have needed to contain specific requirements for pod manufacturers to provide adequate manuals and documentation for their systems is evidence that the problems with systems documentation faced by Donsötank are more widespread.

That the marine industry faces significant challenges and many problems with ship's manuals and documentation is well established, much has already been written on the subject[33].

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[32] E.g. Lloyd's Register (LR) "*Dependable Systems Review*" as an alternative approach to complying with some of LR classification requirements.

[33] e.g. CHIRP report: *Marine Operating and Maintenance Manuals – are they good enough?* http://www.chirp.co.uk/main/Downloads/pdfs/CHIRP%20Operating%20&%20Maintenance%20Manuals%20Final.pdf and IACS recommendation 71 *Guide for the Development of Shipboard Technical Manuals* at: http://www.iacs.org.uk/document/public/Publications/Guidelines_and_recommendations/PDF/REC_71_pdf211.pdf IMO MSC.1/Circ. 1253 Shipboard Technical Operating and Maintenance Manuals (published October 2007), see http://www.imo.org/includes/blastDataOnly.asp/data_id%3D20329/1253.pdf IMO MSC.1/Circ. 1253 Shipboard Technical Operating and Maintenance Manuals (published October 2007), see http://www.imo.org/includes/blastDataOnly.asp/data_id%3D20329/1253.pdf MCA MIN 312 Shipboard Technical Operating and Maintenance Manuals (published November 2007) see http://www.mcga.gov.uk/c4mca/312.pdf

The problems and associated risks arising from poor documentation and manuals is acknowledged to be endemic in shipping in general and is certainly not confined to the SSP system; however the significant omissions discovered in this case are highlighted as they were contributory to this accident. *Prospero's* SSP system was effectively a prototype; the documentation on board the second ship, *Bro Sincero,* was better, but still fell short of what was required for the safe and efficient operation of such complex and safety critical equipment.

The manuals on board were largely written by German English speakers, primarily to be used by Scandinavian English speakers; those officers who were able to speak German and English as well as other languages were better able to deal with the information as it was presented. In any event, this increased the likelihood of errors, either by misinterpretation of the information provided, or the process becoming so difficult and tiresome that the SSP documents were not referenced at all, so encouraging an over-reliance on email and the telephone help-line. Nevertheless, it is essential for safe and efficient operations that the ship's manuals are provided at all relevant locations in a working language understood by the crew.

2.10.4 The SSP Consortium

The SSP was, like some other podded propulsor systems, the product of a consortium. There is some evidence to suggest that, in this case, the consortium approach was less than fully effective. Specifically, the provision of SSP documentation, the length of time it took to provide a replacement part to repair the gauss transmitter, and protracted maintenance time while responsibility for defect resolution was passed between the prime contractors and on to sub-contractors.

On the subject of system documentation, it is not clear whether sufficient documentation was originally provided, and then mislaid, or if the documentation provided on board was there to support SSP technical staff and not ship's personnel. In either event, the documentation on board *Prospero* at the time of the accident was inadequate.

The protracted 'jury rig' cabling to the gauss transmitter, in lieu of the slip-ring system, constrained the pod's freedom of movement. During normal operation, the cable ties on the bridge consoles would have been sufficient to remind the deck officers not to 'wind up' the cables by continuously rotating the pod in the same direction. However, as the master was attempting to regain control of the ship, the need to consider this constraint on pod movement would only have increased the pressure he was under. The gauss transmitter failure had not been anticipated and no spare was available. A different approach to the gauss transmitter was utilized on *Bro Sincero*, but not retro-fitted to *Prospero*. In the event, instead of providing a robust alternative, the temporary repair arrangement was allowed to become a semi-permanent, but sub-standard solution.

There is some evidence that, even during the warranty period, the SSC was not equipped to provide effective product support. On a number of occasions, *Prospero*'s engineers became embroiled in protracted defect rectification by telephone and email; in effect acting as the eyes and hands of the system engineers who were apparently too heavily committed to attend the vessel in person. On other occasions, relatively simple defects took a long time to isolate because each contractor had to verify that his part of the system was clear of defects before the next part could be checked.

While this procedure might be inevitable in some sophisticated systems, in this case it was exacerbated by the arrangement of the SSC and the lack of specialist training for the engineers on board *Prospero*. This was particularly difficult for the ship's engineers, who had problems identifying the correct technical expert to consult. The investigators' experience of dealing with the Schottel partner within the SSC was less than satisfactory, with all enquiries being passed on to the lead Consortium member (Siemens) for action, even though the subject matter was within Schottel's preserve.

In defence of SSC, once the SSP warranty had expired, Donsötank did not enter into any ongoing service arrangement with the consortium. The consequence of this was a reduction of available resources for Donsötank service support.

Without a history of operation, the types and rates of failures could not be known; the fault finding protocols were not proven; and the level of spares support could not be accurately judged. However, these problems could have been anticipated, and steps taken to mitigate them.

On 26 October 2007, as this report was being prepared for publication, Siemens-Schottel Consortium was no longer active. Both companies were investigating other means of mutual cooperation, with Siemens taking the role of sole responsible leader.

2.10.5 Classification Society

The innovative nature of the SSP system caused difficulties for the vessel's classification society, DNV, as well.

The DNV surveyor attending *Prospero* at Milford Haven concentrated on the damage to the steelwork, paying little attention to the checking of the machinery systems that had precipitated the damage. Without a working knowledge of the SSP system and its potential failure modes, *Prospero* was permitted to depart for Fredericia without first conducting manoeuvring trials and then full sea trials off Milford Haven. The risk of a repeat failure had not been quantified or mitigated before *Prospero* was allowed to proceed, first to call at Falmouth, and then to continue to Denmark via the Dover Strait. It would be unreasonable for attending surveyors and inspectors to have a comprehensive knowledge of all propulsion systems they are likely to encounter. However, they should be alert to the potential for problems, and to have readily available to them a source of expert advice that can guide them in the actions they should be taking to ensure a vessel remains fit for service under classification society rules.

Although at the time *Prospero* entered service DNV did not have a composite set of rules for the classification of podded drive vessels, they did consider other equivalent standards; for example the FMEA detailed the failure of the selected shaft encoder as a possibility, with the consequence that complete loss of propulsion would result, and that manual intervention would be required to regain propulsion. However, although the problem had been identified by the original FMEA, it apparently had not been followed through and tested by DNV as part of an approvals process and, there had been no sea trials to prove the FMEA.

Failure of a shaft encoder affects the RPM control, not the Azimuth control, so failure of the selected shaft encoder was not considered as a contributing factor in *Prospero*'s accident at Milford Haven. It was not until after her subsequent accident at Brofjorden that a 'condition of class' was imposed. Full records of *Prospero*'s earlier 'control problems' could not be found, and it is possible that DNV was not aware of them. Nonetheless, *Bro Sincero* had experienced one accident, and *Prospero* two, before a condition of class was imposed and the failures in the control system investigated.

In light of recent operating experience within the Donsötank SSP tanker fleet, and as a result of the accidents discussed in this report, it is considered that the current classification society standards for ships fitted with single podded propulsor systems should be retrospectively applied to the existing SSP ships operated by Donsötank (where reasonably practicable and appropriate). There should be an evaluation of a detailed engineering and safety justification of the SSP systems. The existing FMEA should be re-visited, and its findings appraised to verify that sufficient levels of redundancy and monitoring are incorporated into the podded propulsion unit's essential support systems and operating equipment. Findings of the evaluation should be verified by means of a sea trial. This task, and the resulting documentation, should be formally approved by the appropriate classification society.

The revised FMEA documents should be complemented by an analysis of the man-machine interface with the SSP system.

2.10.6 Port State Control - MCA

The MCA surveyors who attended *Prospero* in Milford Haven were in a similar position to the classification society surveyor regarding their lack of specialist training and experience of podded propulsors, and the absence of a source of expert advice. While concentrating on the seaworthiness of the hull, the risks of a recurrence of the control problem were not fully addressed.

2.10.7 Flag State - SMA

The Flag State administration also faced significant challenges in assessing the novel SSP system. However, as they were required to assess the system for the purposes of issuing safe manning and ISM certification, their challenge arguably was greater. They were expected to consider the total integration of the technical system with its human operators and managers, without having a full understanding of the technical aspects of the SSP system. As a consequence, they had no benchmark against which to judge whether Donsötank's proposed manning was adequate (section 2.7.1). Of more concern, is that the gaps in Donsötank's SMS identified in section 2.9 went undetected. When ISM audits fail to identify weaknesses in an SMS, the usual response is that the audit is only a sampling process, which cannot and is not expected to identify every anomaly. However, the lack of onboard documentation, weakness in system knowledge, and the absence of a set of emergency procedures for dealing with machinery malfunctions should, it is argued, have been detected.

The SMA is not alone in delegating much significant technical work to classification societies. However, as the delegated work is being done on behalf of the Flag State administration, that administration needs to have sufficient in-house expertise to monitor the effectiveness of the classification society's work, and also to effectively discharge the duties it retains.

2.10.8 Development of current standards

There have been numerous technical innovations over the years, among them dp, azimuthing stern drives, and Voith-Schnieder propulsion units, that have required the industry to adapt and read across current standards to ensure that new systems are safe to operate. In some cases, it took many years for systems to mature sufficiently for full confidence to be placed in them. It is disappointing, therefore, that the new technology of podded propulsion was not subject to more rigorous standards from the outset. The PQF was not formed until 2003, and it subsequently developed standards in response to the issues emerging as experience of the new technology matured. In many cases, however, the issues were similar to those identified and addressed years ago by the mainstream propulsion sector.

Had the standards now set by the PQF been applied when the SSP system was developed, installed and commissioned, many issues that have now become problems could have been avoided. It is recognised that it would not now be either possible or appropriate to fully apply all sections of the PQF standard to existing plant. However, retrospective application of the current PQF standards to the SSP system would provide an auditable reference standard against which the operational SSP plants and their support systems could be judged.

The investigators would have expected that it would have been possible for DNV (as the secretariat of the PQF) to conduct an audit of the SSC. However, on 26 October 2007, in a letter received from Siemens as a part of the consultation process, MAIB were informed that:

"the Siemens- Schottel Consortium is no longer alive"

Clearly an audit of the Consortium will not now be possible.

During this investigation a certain reluctance to share information and experience of the operation of podded propulsors has been noted; similar problems have previously been recognised in discussions at the T-Pod conference. This is likely to be the case with new technology: there will be variations in systems; commercial advantage will need to be protected; and disclosure will be limited when contractual and legal disputes ensue. This should not, however, prevent the classification societies from developing broad guidelines that can be applied to any new or innovative system to ensure it is safe and fit for purpose. An example would be the requirement for an FMEA to be produced, that is then tested and approved. The very act of completing the FMEA would force an understanding of the new technology that would inform Flag State, classification society, and owners' decisions about manning, training and documentation, and support.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. Practical experience of the shipboard operation of the SSP system proved that the presentation of the alarms and reversionary controls on the SSP system had the potential to confuse an operator who was not fully trained on the SSP system. [2.4, 2.5, 2.6]

2. The master had received no dedicated training in the SSP system, and was insufficiently familiar with reversionary mode operation and emergency drills. [2.5, 2.6]

3. *Prospero*'s engineers had not received either general training (STCW) in podded drives, or SSP system specific training; none were specialist electro-technical officers. They were, therefore, ill-equipped to advise on system operation, or to oversee maintenance and defect rectification on the SSP system. [2.6, 2.7, 2.10]

4. The Donsötank SMS had a number of shortcomings which were not identified during routine Flag State audits. In this case, the "sampling process" did not detect the anomalies in the SMS. [2.6, 2.9]

5. Better accident and reporting procedures following *Bro Sincero*'s collision on 6 May 2006 could have prevented the subsequent accident to *Prospero*. [2.8]

6. The manuals and documentation on board *Prospero* were inadequate to support the safe operation of the ship. [2.6, 2.10]

7. Donsötank's shore staff had not received adequate training to support the operation and maintainance of the SSP system. [2.10]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. When *Prospero* was built, the standards against which she was assessed were inadequate. The improved standards and practices that are currently applied to the podded propulsor industry should be retrospectively applied to the SSP ships operated by Donsötank. [2.10]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

1. The alarm did not effectively alert the master that the primary control system had failed, or that the back-up system had been automatically selected. [2.5]

2. The lighting of the control panels and the alarm system in the wheelhouse were capable of being dimmed down to a potentially dangerous level. The audible alarm was ineffective. [2.5.2]

3. The master did not have the support of an OOW in the wheelhouse as *Prospero* was approaching her berth in Milford Haven. [2.6.4]

4. The master did not disclose to the pilot that *Propsero* had a ‘condition of class’, due to limitations in the SSP’s capabilities. [2.6.6]
5. *Prospero* was permitted to enter Milford Haven without tugs, but the reasons for this decision were not adequately recorded. [2.6.6]
6. Current STCW requirements for the general training of marine engineer officers are inadequate for this type of complex plant. [2.7.2]
7. MHPA had not been informed that *Prospero* had a significant quantity of cargo remaining on board. [2.9.1]
8. The Consortium approach to the design, manufacture and after-sales support of the SSP system had a negative impact on maintenance and defect rectification on board *Prospero*. [2.10.4]
9. The surveyors and inspectors who attended the ship, were not experienced in podded propulsion systems, and so allowed *Prospero* to depart Milford Haven without a comprehensive system check and full sea trials. [2.10.5, 2.10.6]

SECTION 4 - ACTION TAKEN

4.1 DONSÖTANK HAS:

4.1.1 As a result of the Milford Haven accident to *Prospero* (10 December 2006):

- Added twice yearly PMS routines for the regular checking and tightening of cables in the SSP manoeuvring cabinets.
- Added PMS routines for the SSP manoeuvring control levers.
- Implemented procedures within the SMS for the changeover to bridge wing control stands, to include function tests.
- Revised the pre-arrival checklist to include checking the wheelhouse alarm and control panel dimmer levels.
- Reviewed the bridge manning policy throughout its fleet to ensure that the bridge team consists of at least two competent persons for port entry and departure.
- Amended its ISM SMS to include instructions regarding the procedures required when cargo remaining on board is knowingly over-carried. These new instructions have been circulated to all of its tanker fleet.

4.1.2 As a result of the Brofjorden incident involving *Prospero* (10 March 2007):

- Distributed a company letter across the fleet, highlighting the correct procedures (detailed within the Donsötank SMS) for the operation, maintenance and repair (including amending parameters such as alarm set points) of critical equipment.
- Reviewed the company procedures for the technical supervision of critical equipment.

4.1.3 As a result of the St Petersburg Channel incident involving *Prospero* (23 April 2007):

- Reviewed test and approval procedures for critical equipment.
- Implemented, fleet wide, PMS routines regarding the testing of hydraulic steering gears; any trend of pressure drop to be reported and rectified.

4.1.4 In consultation with DNV, commissioned SSC to revise certain technical aspects of the SSP system, specifically:

- The Schottel pod system alarms are to be revised and routed to the alarm system of the PCS and the automation system; this revision is necessary to fulfil the requirements of the gauss transmitter FMEA.
- The propulsion converter controls and associated systems have been revised to ensure that if the converters shut down due to speed encoder failure, the PCS changes over to the other speed encoder automatically. This automatic changeover will be logged; however, the manual changeover function will be retained.

- The automatic changeover from pod control lever to the back-up speed control buttons (in the case of setpoint speed failure) is to be cancelled, and revised to manual changeover after an alarm has been initiated. The alarm arrangement has been revised and now includes signals to both the SSP alarm system and the main ship's automation system. The setpoint processing has been modified, the last setpoint is now stored in case of failure.

4.2 SIEMENS HAS:

- Agreed to offer Donsötank a technical training package for the SSP system.
- Prepared the technical modifications to *Prospero*'s SSP system necessary to meet current class requirements.
- Agreed to ensure that a full package of SSP system documentation is made available to Donsötank; all documentation will be available in English.
- Agreed that the PES within *Prospero*'s SSP system will be audited (as far as is reasonably practicable for a system that has already been commissioned) to the ISO document 17894:2005 or an equivalent classification society standard.
- Agreed to apply current standards to compile a revised FMEA for the SSP system on *Prospero*. The analysis of the system will include the human-machine interface. The verification process will include the trials and testing necessary to prove conclusions, to be approved by DNV.
- Agreed to circulate relevant safety critical information - "Lessons Learnt" among all owners/operators of SSP systems that are in service **(Annex F)**.

4.3 DNV HAS:

- Issued further survey memoranda and two conditions of class to *Prospero*; the memoranda required modifications to improve the SSP alarm system. The first condition of class requires significant alterations to be made to parts of the SSP power control system, in order to ensure that a back-up system is readily available at all times and to be capable of being put in to operation within 30 seconds. DNV also required that written procedures for dealing with a loss of steering and propulsion were to be established and regularly trained. The second condition of class suspended the class notation E0 (UMS) and so required that *Prospero*'s engine room be continuously manned; valid until the first condition is deleted.
- Issued an internal memorandum to its surveyors reminding them that when attending ships for the survey of casualties, they should consider all aspects of the incident within the scope of class involvement.
- Issued a memorandum detailing changes made in DNV's requirements and procedures for approval, certification and installation and testing of pods and associated control/automation systems **(Annex G)**.
- Proposed changes to their rules for the classification of ships that will improve the handling of changes to control systems on board ships in operation. Surveys of control and monitoring systems will be extended to include greater focus on how changes to control systems are handled. A "change log" will be kept by a responsible person on board the ship, the change handling process will become traceable.

- Reviewed the extensive investigation and testing on board *Prospero* off Simrisham (25 April- 1 May 2007) and consider this as a practical equivalent of an FMEA review for the vessel.

4.4 MILFORD HAVEN PORT AUTHORITY HAS:

- Reviewed its guidelines regarding tug usage for berthing and un-berthing. The revised guidelines clarify the process for tug allocation to tankers of all sizes using Milford Haven.
- Issued an operational memorandum, requiring that vessels new to the port and so not assessed previously by pilots, must be “flagged up” to the deputy harbourmaster. This will highlight visits by new-build vessels, including those using new propulsion technology.

4.5 THE CHEVRON MARINE ASSURANCE GROUP HAS:

- Declined to charter *Prospero* and her sister vessels again until this report has been published and until such time that it is content with the risk reduction measures applied to the SSP ships operated by Donsötank.

SECTION 5 - RECOMMENDATIONS

Rederei AB Donsötank is recommended to:

2007/193 Revise its current management and operating procedures to ensure:

- Specialist technical training, accredited by the manufacturers of the SSP system, is provided for all technical staff that are involved in the operation, maintenance and repair of the SSP systems operated by Donsötank.
- Specialist ship handling training, accredited by the manufacturers of the SSP system, is provided for all nautical staff that are involved in the operation of the SSP systems operated by Donsötank. The training should pay particular attention to the back-up and emergency modes of operation.
- Accurate, comprehensive manuals and documentation are available on board vessels in its fleet fitted with SSP systems.
- Clear instructions are provided with respect to actions which need to be taken by ships' staff wherever a 'condition of class' is issued. The amended procedures should include the need to brief port authorities and pilots prior to entering or leaving harbour.
- Safety critical information is promptly circulated to all vessels in its fleet. A positive feedback arrangement should be implemented to verify that safety critical information is being received by the target audience.
- Vessels in its fleet equipped with SSP systems are appropriately manned. The need to include dedicated electro-technical officers on board should be considered as part of any manning review.

2007/194 Establish formal arrangements for an on-going service-support/ maintenance package, employing suitable experts who are fully familiar with all aspects of the SSP system.

2007/195 Facilitate and cooperate in all respects with the various PES, FMEA and human-machine interface improvement and validation projects; to be undertaken with technical assistance provided by DNV and Siemens- Schottel, as detailed in section 4 above.

The Swedish Maritime Administration is recommended to:

2007/196 Review the current safe manning requirements for Donsötank vessels that operate complex, diesel-electric and podded propulsor systems, taking into consideration the need for specialist electro-technical expertise on these particular ships.

2007/197 Undertake an ISM Code audit of the Donsötank company and all of its ships fitted with the SSP system, with particular attention being paid to the matters raised in this report.

Marine Accident Investigation Branch
Statens haverikommission
December 2007

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

Annex A

Synopsis: *Prospero*’s loss of pod control, the Gulf of Finland 20th September 2006

DET NORSKE VERITAS Rev. [1]

SURVEY REPORT

DNV id. no.	Job Id.
22081	

Name of vessel	Name of owner	IMO no.
PROSPERO	Partrederiet för M/T "Prospero"	9212589

Pod control system failure

This is to confirm that the following has been carried out:

Surveys

Survey Code	Survey Name	Result
MACHDAM.O	Machinery damage occasional -	Complete

Conditions and Memoranda - Given		Due Date
CC 12	Pod control transmitting unit (gauss) to be repaired. Finding(s): **[Propulsion pod, azimuth A > Control and monitoring system A]** Malfunction	2006-12-21
MO 13	As long as the CC related to pod control is in force, the crew are to perform and log regular inspections of stoppers fitted to pod control levers and condition of control cables in the pod and in the pod room.	

Station	Place of survey	Survey started	Survey completed	Stamp
x		2006-09-20	2006-09-21	
Lead surveyor’s name	Lead surveyor’s signature			
Surveyor’s name	Surveyor’s signature			

Name of vessel	Name of owner	DNV id. no.	Job Id..
PROSPERO	**Partrederiet för M/T "Prospero"**	**22081**	

Survey Observations and Findings

Propulsion pod, azimuth A

As reported by crew, the vessel was eastbound in Gulf of Finland in early 20.09.2006, when an alarm of pod control unit fault 1&2 was raised, consequently the pod control was inoperative. Upon investigation, the fault was detected to be the device transmitting control signals from the turning pod to the control units, later called as gauss. Short emergency cables provided as spares onboard were connected in order to by-pass the gauss thus making the manoeuvering possible though limited in terms of pod steering angle. Vessel proceeded towards Hanko, last stage with tug assistance and anchored in Hanko Roads.

Vessel was attended 20.09. midnight together with two engineers from the pod maker Schottel Siemens. After investigation, the engineers agreed the fault being the defected gauss, which was dismounted and sent to the factory for inspection. Decision if it can be repaired or a new one to be produced is not yet done. New four meter long cables were fitted by-passing the gauss.

On attendance late evening 21.09. installation was finished. The pod control was tested from all positions (down inside the pod, local in pod room, ECR console, bridge console and both bridge wings). From local control at pod room was tested the pod turning full 360 degrees in both ways. Transformers local control panels 1&2 were clean of alarms. The control levers in bridge console, bridge wings and ECR console were fitted with mechanical stoppers in order to prevent the pod turning more than 180 degrees and signboards fitted besides all control positions. A short sea trial was done while pilot onboard incl. full turning the vessel. All installation and testing was satisfactory.

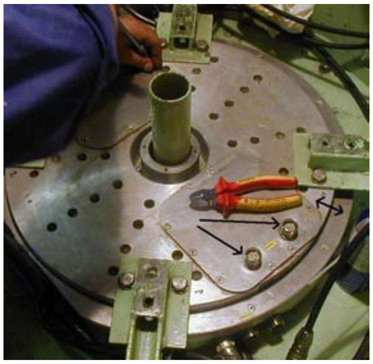
The modification done is creating a limitation to the pod operation; now the pod can not be turned around full turns 360 degrees unlimited times due to the cables being then twisted and damaged. Noted that only the manoeuvring mode is concerned, the sea going mode is limited anycase to +- 30 degrees. Since the operational way is deviating from the original design, the modification was deemed as a temporary one and a CC was issued for permanent repairs (or alternatively seeking approval of the modified system of transmitting control signals from the pod). Additionally, a MO was issued for the crew to perform and log regular inspections of the control lever stoppers and control cable condition under cover.

Findings
[Control and monitoring system A]
Malfunction
[Issued as part of CC 12]

Final assembly. Cables coming through a pipe in center and continuing to the control units.

Control lever stoppers and signboard seen in stbd bridge wing, typical for all control positions.

As original. Arrow on the right showing the control cables coming from underneath the pod and connected to the gauss. Arrow on the left showing the control cable connected to the otherside of the gauss and continuing to control units.



Indicator baseplate taken off. Arrows on the left showing the control cable plugs on the gauss fixed part. Arrow on the right showing the contact surface of the gauss turning part.

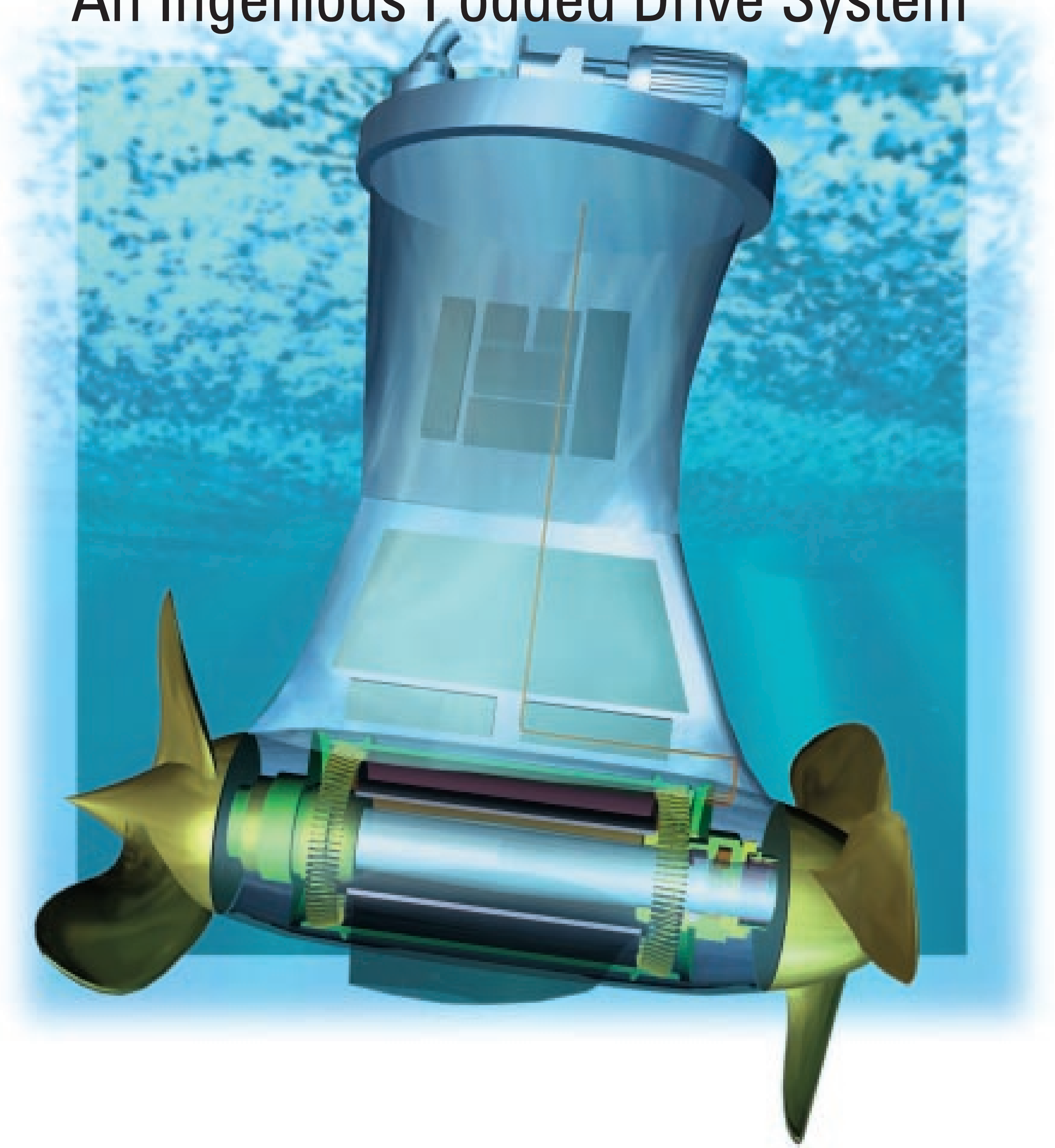
Assembly as original (cover taken off) above pod room deck.

Annex B

General details of the Siemens-Schottel propulsor system

The SSP Propulsor

An Ingenious Podded Drive System



C O N S O R T I U M S S P

SIEMENS

SCHOTTEL

The SSP Propulsor – a concept of genius,

the most efficient podded drive available

The CONSORTIUM SSP, a consortium of SCHOTTEL GmbH & Co. KG and Siemens AG, Marine Solutions, has developed a new podded azimuthing diesel-electric propulsion system for power outputs in the range of 5 to 20 MW per unit.

Thanks to optimum hydrodynamic design and the new permanently-excited propulsion motor, the **SSP Propulsor** is the first diesel-electric drive system which proves significantly more efficient than a conventional diesel-direct drive system or azimuth thruster. These benefits, combined with the proven excellent manœuvrability of an azimuthing drive, explain the new system's attraction to cost-conscious ship owners.

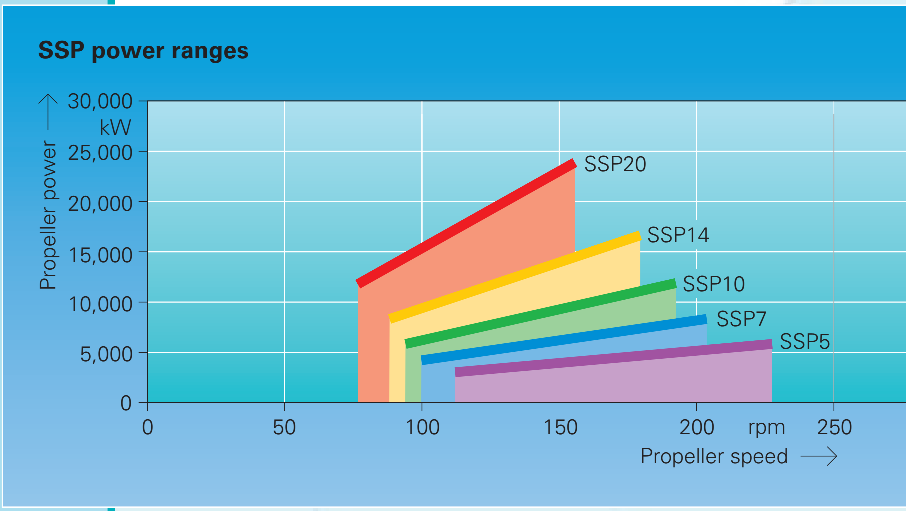
The new podded diesel-electric azimuth drive is especially suitable for all kinds of vessels requiring high electric power demands aboard and high manœuvrability. It is also suitable for vessels with frequent changes of power output, such as cruise ships, large ferries and passenger vessels, medium-sized cargo vessels (feeder container vessels and chemical tankers, for instance), ice-going vessels, offshore vessels and structures of all kinds, plus navy vessels.

As already proven by tank tests and full-scale tests, the **SSP Propulsor** can guarantee energy savings of more than 10% over conventional diesel-direct systems or azimuth thrusters.

Consider the
enormous benefits of SSP

Main benefits

- Efficiency increased up to 10% and more in optimum cases
- No external cooling necessary
- Elimination of rudder, shaftline, bossings, aft tunnel thrusters
- Suitable for a wide variety of stern hull designs
- No cooling systems or cooling air ducts and fans, which saves space and simplifies installation
- Flexible design options for stern and engine room
- Increased cargo space
- The modular design principle allows installation of the propulsion module just before the vessel is launched
- Mounting and dismounting of the propulsion module is possible while the vessel is afloat
- Optimum manœuvrability without additional stern thrusters, especially at low vessel speed
- Minimized crash stop-time
- Increased safety and easier handling of the vessel
- High on-board comfort on account of extreme low noise and vibration levels
- Low service and maintenance costs due to minimized number of parts
- Reduced exhaust gas emission at rated vessel speed as a result of lower power consumption and optimum manœuvrability



What are the differences?

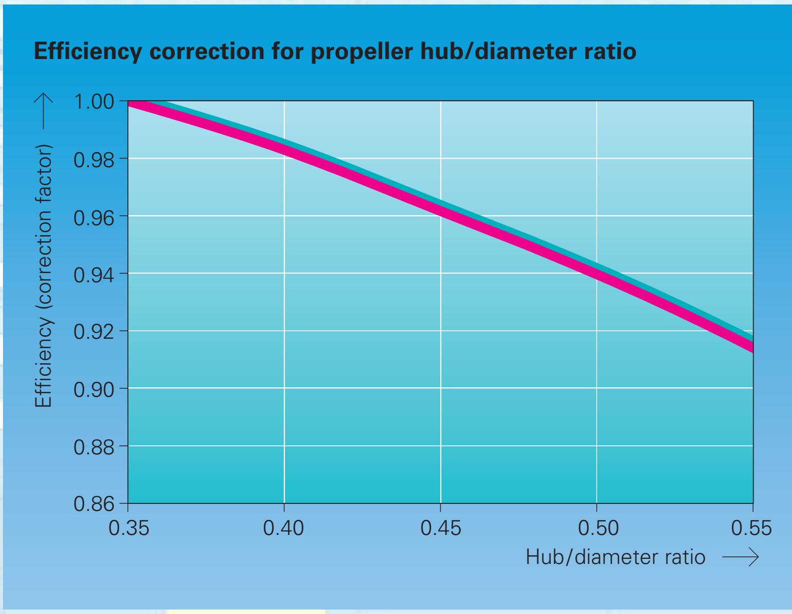
Steerable azimuth drive systems with single propeller are available with mechanically geared power transmission up to about 8 MW and, at present, with electrical power transmission up to 20 MW per unit. In general, these azimuth drives are as efficient as conventional shaft line systems.

The improved efficiency of the **SSP Propulsor** results from its twin propeller technology, combined with the hydrodynamically optimized propulsion module, and from the permanently-excited propulsion motor.

The twin propeller technology comprises two propellers on a common shaft. These two three-bladed propellers rotate in the same direction and are located in front and behind the propulsion module, which includes the permanently-excited propulsion motor. This configuration has the advantage of sharing the load between the propellers with maximum productivity from both. The two fins mounted between the propellers on the propulsion module also increase the overall efficiency, along with the propulsor's strut by gaining back the swirl energy.

The diameter and weight of the newly-developed, permanently-excited synchronous propulsion motor are significantly lower compared with conventional, electrically-excited synchronous motors. It has therefore been possible to reduce the diameter of the propulsion module that accommodates the motor. As a result, the housing/propeller diameter ratio can be reduced to 35–40%, which has a dramatic effect on the overall efficiency of the **SSP Propulsor**.

Furthermore, the permanently-excited propulsion motor itself is about 2% more efficient because there is no electrical excitation or associated equipment, and no external air-ventilation. According to its design, the motor needs no brushings, sliprings and ventilators.



Efficiency correction for propeller hub/diameter ratio

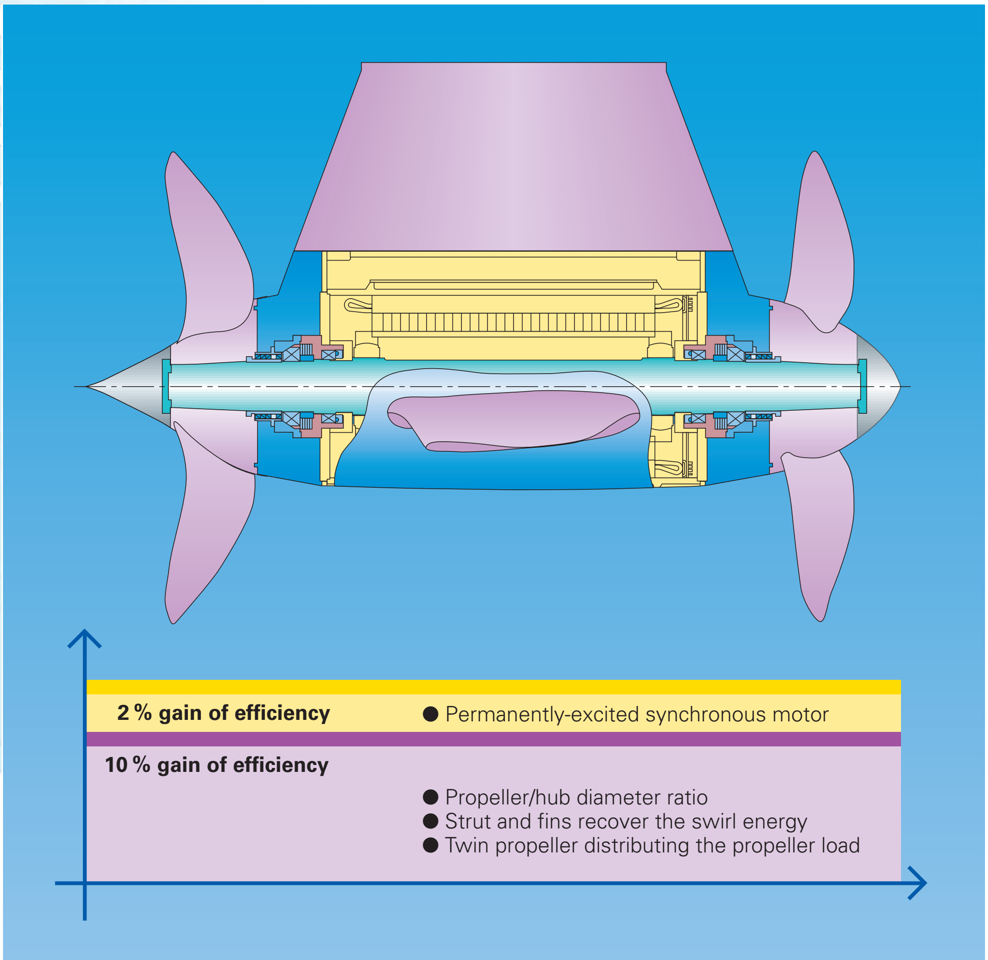
Test results

The hydrodynamic basis of the SSP is the twin propeller concept developed by SCHOTTEL.

Extensive tests are carried out in advance with various ship designs in order to prove the outstanding values of efficiency and noise inductions.

The tests comprise cruise liners in different executions as well as RoRo ferries, conventional cargo vessels and offshore applications.

The tests in general show hydrodynamic efficiency improvements of up to 10 % and more in optimum cases. The risk of cavitation and noise inductions are reduced to a minimum.



The efficiency

Mechanical
design

The **SSP Propulsor** is based on a unique modular design. Two main modules – the azimuth module and the propulsion module – are flanged together at the ship's hull line.

Azimuth module

The azimuth module consists of a cone-type support flanged onto the vessel's structure and is made from shipbuilding steel. The following items are installed in the azimuth module:

- Slipring unit to allow unlimited azimuth steering
- Electric/hydraulic azimuth steering system
- Local indicators
- Propeller shaft seal high tank
- Activation system for the emergency seals
- Hydraulic system for the blocking brake
- Bearing lubrication system
- Monitoring system.

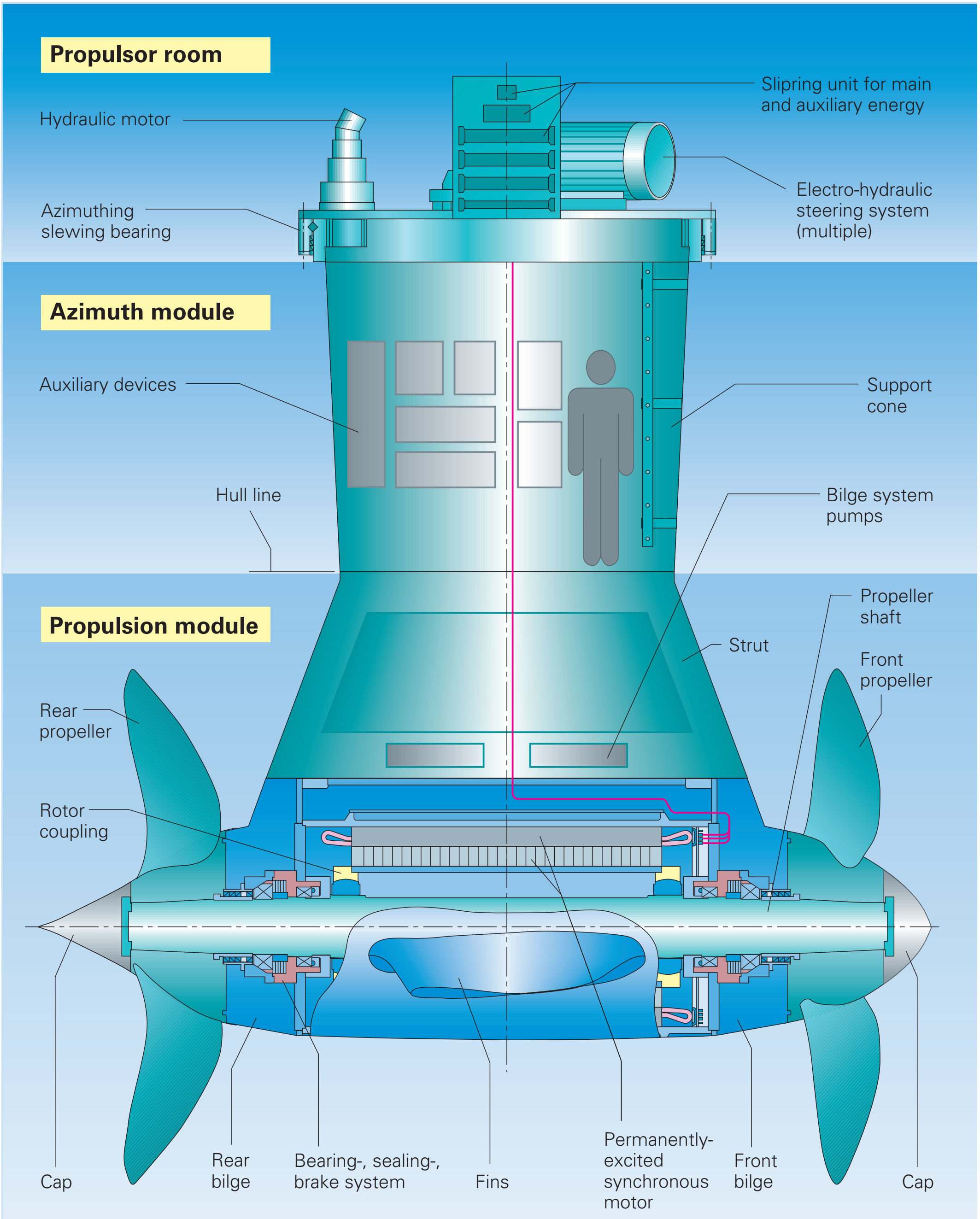
Propulsion module

The propulsion module has a cast housing. Two aeroplane-type fins are flanged onto its surface and together with the strut gain rotational energy from the forward propeller. The unit is designed in such a way to allow the mounting/dismounting of the underwater propulsion module while the vessel is afloat. Optionally, a proper underwater mounting is possible for offshore structures.

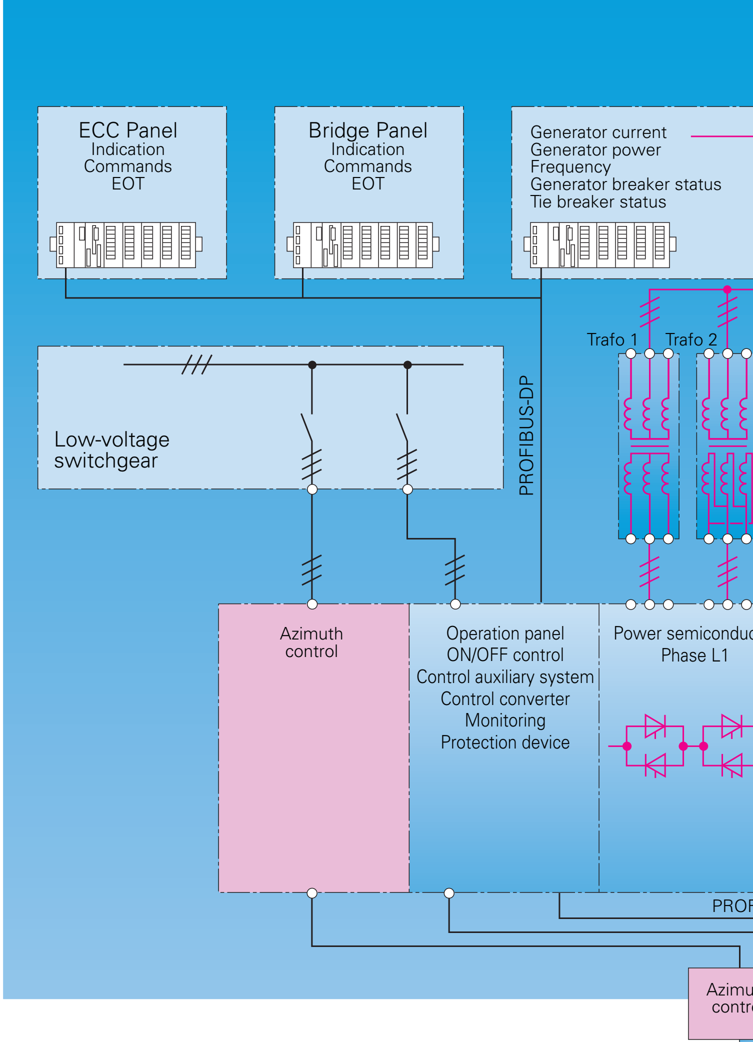
The following items are installed in the propulsion module (underwater part):

- Propeller shaft
- Shaft sealing system
- Bearing system
- Emergency sealing system
- Shaft blocking system
- Propulsion motor
- Bilge system/pumps
- Alarm and monitoring sensors for motor, bearings and sealing systems.

Steering gear plate



Electrical
drive system



Only the permanently-excited synchronous motor is capable of satisfying the rigorous technical and economic requirements placed on the drive system.

In this machine, the magnetic flux is generated by high-performance permanent magnets. These well-proven standard magnets are arranged on the rotor of the motor and take the place of conventional excitation windings and auxiliaries, such as sliprings and rectifiers. This arrangement makes it possible to significantly reduce the volume and weight of the power unit. A further advantage of the permanently-excited motor is its enhanced efficiency resulting from the elimination of core, winding and ventilation.

Continuous excitation causes the motor to behave as an under-excited synchronous machine. Self-commutated converters such as the cycloconverter have been selected for optimum economic and technical performance. To suit the given load requirements, the **SSP Propulsor** will be available with cycloconverter.

The active elements of the rotor, i.e. laminated yokes and magnetic elements, are arranged on the external surface of the hub. The rotor will be banded and completely impregnated for maximum strength.

As the working flux of the motor is constant with respect to time, small core losses are generated in the rotor surface as a result of mutual induction in direct proportion to rotor speed. These losses are dissipated by convection across the air gap, laminated stator core and housing directly to the surrounding seawater.

The entire rotor structure is mounted directly on the propeller shaft.

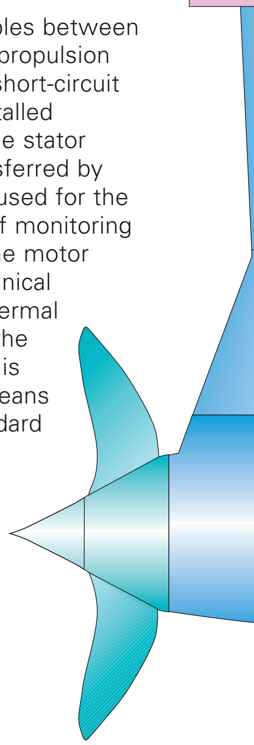
The electrically active parts of the stator do not differ significantly from those of a conventional synchronous motor. In this design, however, the stator is reduced to the laminated stator core and windings. The completely impregnated stator is shrunk directly into the lower housing for maximum heat dissipation.

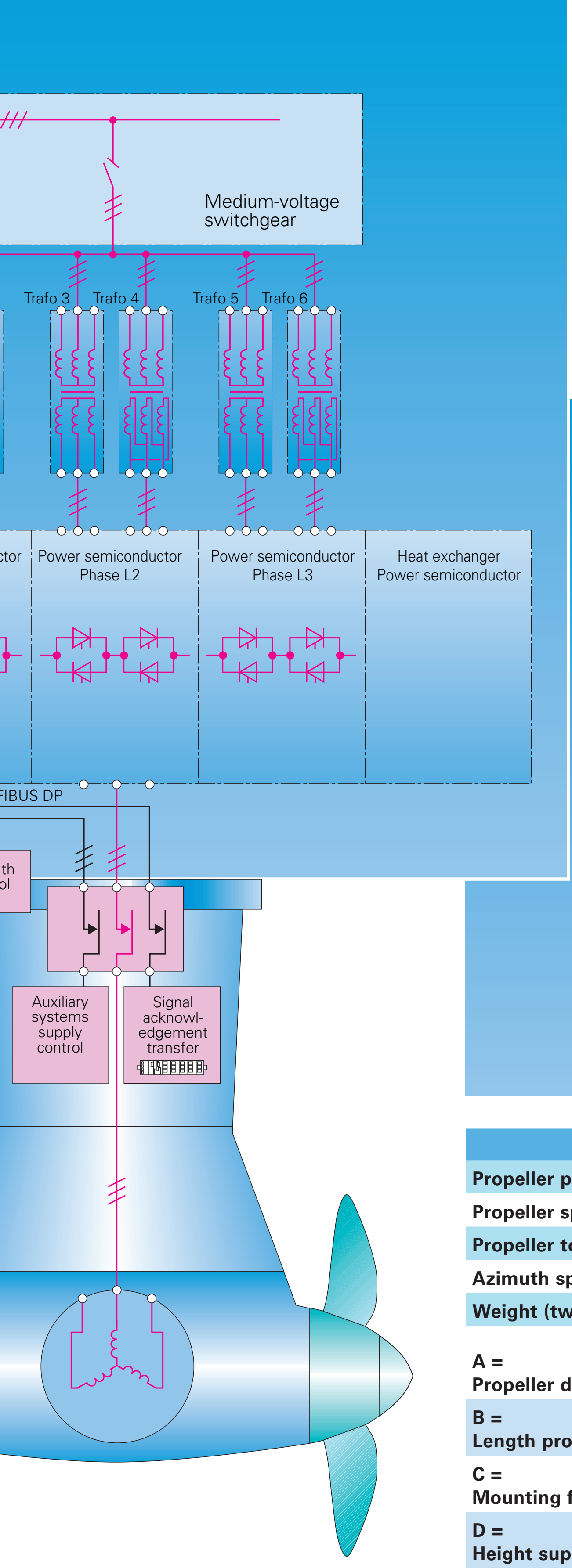
The winding overhangs of the stator windings are cast with a heat-conducting compound, so as to establish a firm mechanical connection with the lower housing and achieve low heat resistance. Here, too, all current-induced heat losses will immediately be dissipated to the surrounding seawater.

The motor will be designed with one or two independent winding systems according to the demands placed on the propulsion system. The individual system windings are finished into a star configuration. For connection of the supply cables, the remaining 3 or 6 winding ends are brought out into the stern of the lower housing via a cable duct. Terminals inside the lower housing will be avoided.

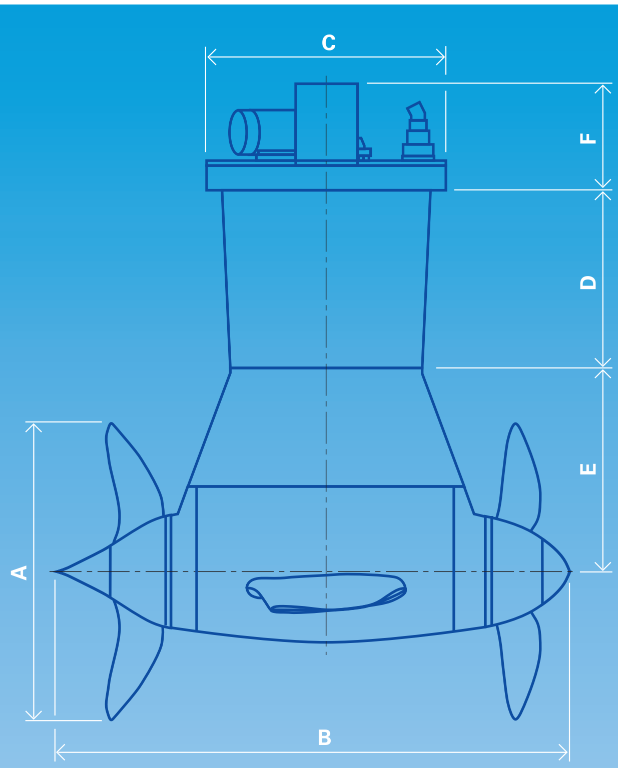
By reducing the diameter of the motor the design measures have made it possible to meet the hydrodynamic demands. In comparison to a conventional synchronous motor, the diameter of a permanently-excited motor can be reduced by 40%, without increasing the length of the active elements in the axial direction. At the same time, a weight reduction of 15% can be achieved.

The supply cables between converter and propulsion motor will be short-circuit tested and installed accordingly. The stator current is transferred by sliprings, also used for the transmission of monitoring signals from the motor and the mechanical equipment. Thermal monitoring of the stator winding is achieved by means of built-in standard resistance temperature detectors.





Technical
data



	Unit	SSP5	SSP7	SSP10	SSP14	SSP18	SSP20
Propeller power	Pp [kW]	5000	7000	10,000	14,000	18,000	20,000**
Propeller speed	np [rpm]	190	170	160	150	145	130
Propeller torque	Mp [kNm]	251	393	597	891	1185	1469
Azimuth speed	na [rpm]	2	2	2	2	2	2
Weight (twin version)	mssp [t]	95	125	170	230	280	310
A = **Propeller diameter**	[mm]	3750	4250	4750	5250	5800	6250
B = **Length propulsion module**	[mm]	6625	7500	8380	9260	10,590	11,000
C = **Mounting flange diameter**	[mm]	3000	3500	3800	4200	4800	5000
D = **Height support cone**	[mm]	2100 – 2750 (standard height 2500)					
E = **Height propulsion module***	[mm]	2100	2975	3325	3675	4000	4375
F = **Installation height propulsion room**	[mm]	1630	1675	1720	1760	1800	1850

* Valid for standard propeller diameters.

** Higher propeller power available on request. Dimensions are based on standard types. Adaptions will be made to project requirements.

The SSP Propulsor can optimize your vessel design

Drive concepts

Due to electrical characteristics identical to those of a conventional synchronous motor, the permanently-excited motor can easily be integrated into established drive system concepts without restriction. The availability improvement achieved in this way will result in significantly increased security of the entire vessel.

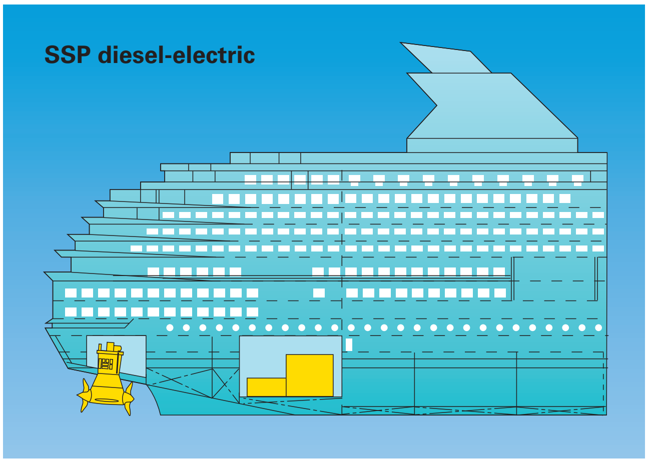
Installation

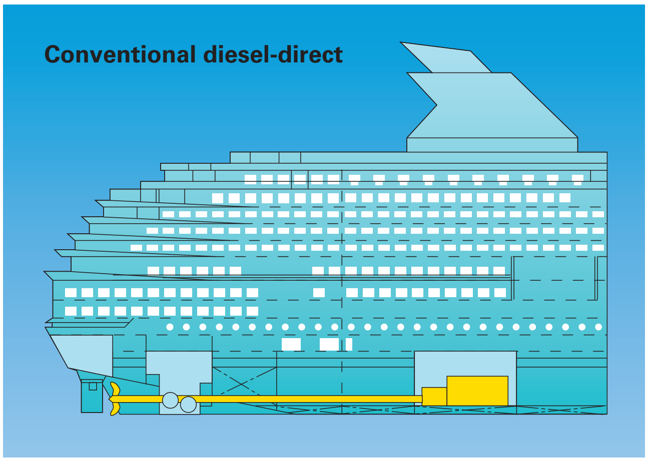
As our drawings show, **SSP Propulsor** offers major vessel design benefits.

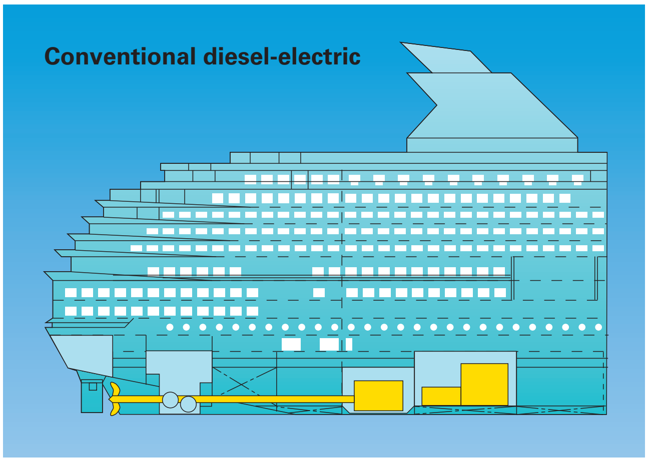
Diesel-mechanical drive systems are the most space-consuming marine propulsion systems. Because of the layout dictated by the main diesels, gears, shaft line systems, rudders and so on, all other machinery and the hull shape have to be designed accordingly.

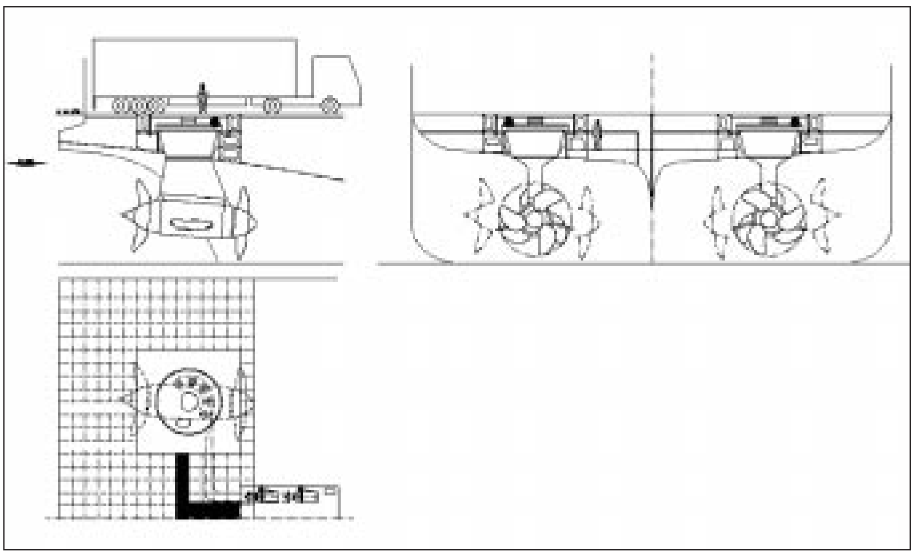
Diesel-electric drive systems allow more design flexibility because there is more latitude in the placing of the diesels in the engine room. However, the major disadvantages of shaft line systems, rudders, etc. remain and the hull shape is still largely predetermined.

Only podded azimuthing diesel-electric propulsion systems offer a maximum of flexibility of hull and engine room design, resulting either in extended cargo capacity at given vessel dimensions, or reduced vessel dimensions as compared with the alternatives already mentioned.









Convincing advantages

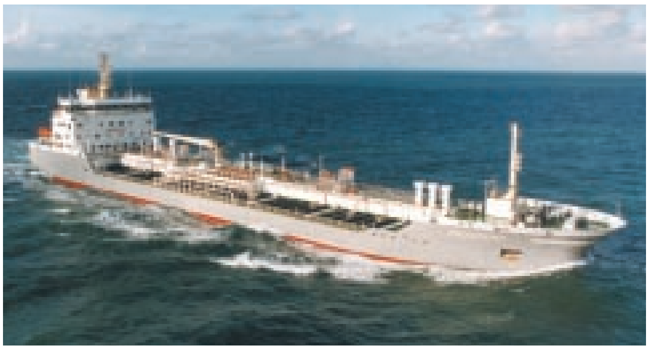
More usable aft deck space is available due to the fact that a large-scale cooling system is not necessary. No disturbing noises are emitted by cooling fans etc.

All auxiliary units are located inside or on top of the **SSP Propulsor**. Therefore the designer has a greater scope for planning the aft ship.

The system is inclined to allow optimum water flow to the propellers. The **SSP Propulsor** and the design of the aft ship are matched for optimum hydrodynamic efficiency.

References

The SSP proving its versatility
in a variety of applications:



2 chemical product tankers
For Donsø Tank Rederi AB, Sweden
1 unit SSP7 each tanker

2 RoRo ferries
For TT-Line GmbH & Co, Germany
2 units SSP10 each vessel

2 heavy lift carriers
For COSCO, P.R. of China
2 units SSP5 each vessel

International patents pending

C O N S O R T I U M   S S P

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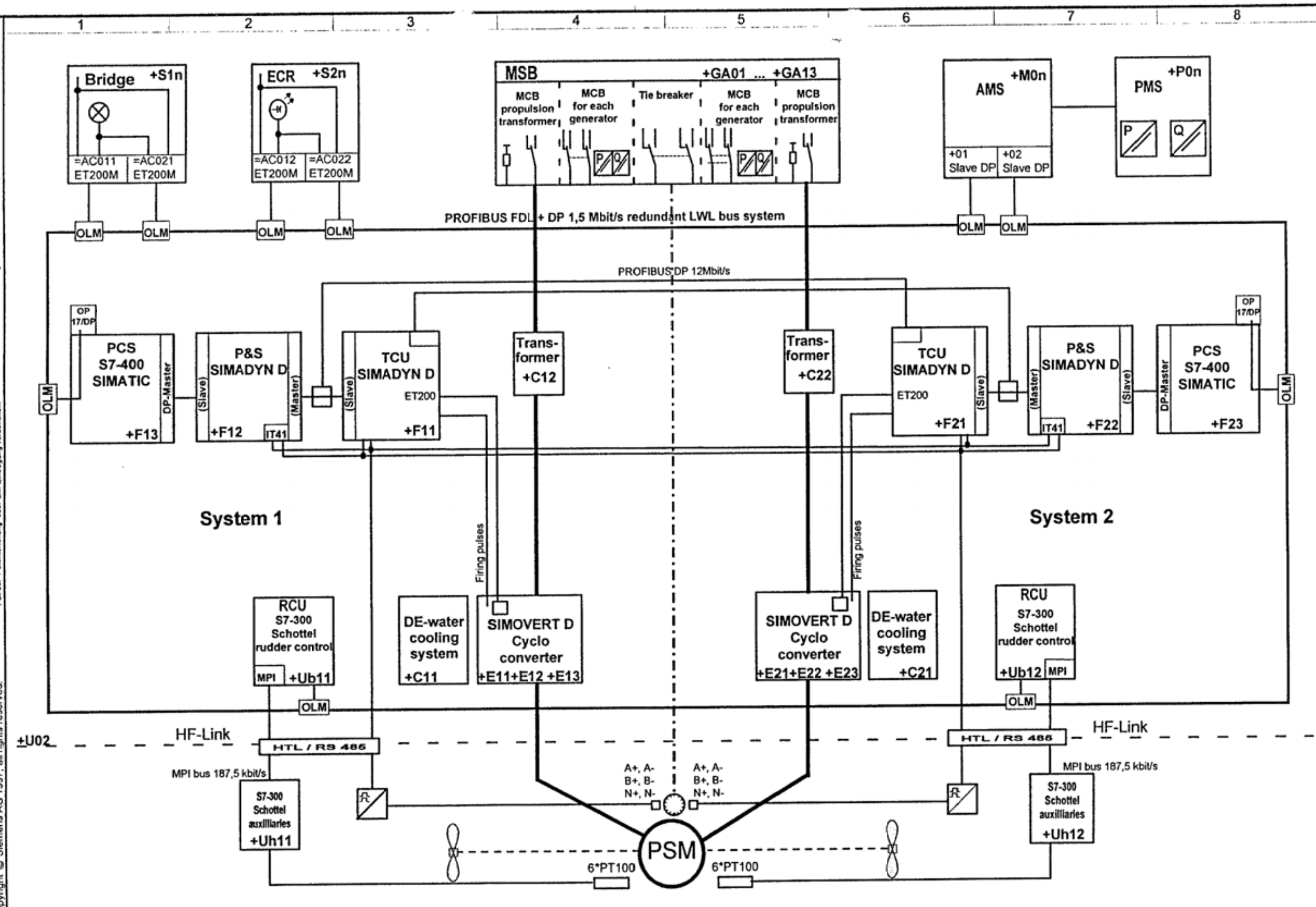
Subject to change without notice

Order No. E10001-A930-A55-V5-7600
Dispo No. 16600
174D6080 WS 10012.

Annex C

Diagram showing overview of function units



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Datum	99-09-13	SESC HULL 118 Donsoetank	Siemens AG	Overview of	
Bearb.	Wietoska	SIMAR DRIVE SSP	ATD IS 3M Hamburg	function units	ATD IS3-123575
Gepr.	Hoes				
Zustand / Änderung / Datum / Name / Norm		Urspr. / Ers. f. / Ers. d. E10231-K1016-S143 FuE Typicals 26.05.99 Wietoska			Blatt 1 Bl

Annex D

Introduction to Standards for Marine Programmable Systems

Introduction to Standards for Marine Programmable Systems

Ships and marine technology — Computer applications — General principles for the development and use of programmable electronic systems in marine applications[SR1]

Systems which include programmable electronic systems (PES) are not exact substitutes for the electromechanical systems and/or crew tasks which they replace. A new technology is involved, which can provide opportunities for integration of traditional system components (including crew tasks) and more complex behaviour. This allows increases in efficiency and safety through improved monitoring, better situational awareness on the bridge, etc. However, PES are complex products and, like all products, they can contain defects. These defects cannot be seen. Software does not respond to traditional engineering methods for the testing of soundness. The combination of complexity, replacement of a combination of mechanical and crew functions with computer hardware and software, and industry practice in developing and maintaining marine PES leads to a wide range of potential defects which cannot be guarded against by prescriptive standards.

The use of a PES in the management, monitoring or control of a ship may have several effects:

- *Potential to enhance the ability and efficiency of the crew;*
- *Changes in the organization of work through the automation of lower-level tasks;*
- *Integration of systems through use of several systems by one seafarer;*
- *Shift in the role of the crew towards the management of many linked, complex PES;*
- *Shift of the crew's perception of the ship to that presented by the interfaces of the PES;*
- *Layers of embedded and/or application software interposed between the crew and the ship;*
- *Physical interconnection of ship systems through the use of computer networks.*

The overall effect of the use of PES is that the ship becomes one total system of inter-linked PES and crew which work together to fulfil the operator's business goals for the ship. In order for this total system to be dependable, both the design of the PES and the management of its use have to support the safe and effective performance of the crew as a critical component of the total system. Such a human-centred approach has to be based on a thorough knowledge of the particular skills, working environment and tasks of the crew using the PES.

In the traditional approach to maritime safety, ship systems are built to and operated against precise, prescriptive standards. These standards were developed in response to feedback about incidents or risky behaviour of previous ship systems. This approach is appropriate for relatively simple systems in a time of slow technical innovation. However, suppliers and operators nowadays want to innovate with complex, new solutions. In addition, the base technologies for PES are evolving very quickly. The assurance of dependability in this case cannot rely on knowledge of previous systems. The solution is for the developer and operator to assess the risks from and to the particular ship, its systems, crew and its operating philosophy, and to address these specific risks in the design and operation of the PES. Components of the system can then either be redesigned or operated in such a way as to minimize these risks. The quality of construction, operation and maintenance of the system to be sure of the achievement of a required level of dependability of the PES is also defined. This International Standard is based on best practice in PES development as stated in existing marine, electrical and electronic, IT, ergonomics and safety standards. It is not intended to replace any of these standards. It presents a synoptic view of the requirements of these standards as a framework of principles for the development of dependable PES.

Product principles for marine PES[SR2]

The PES shall be demonstrably suitable for the user and the given task in a particular context of use. It shall deliver correct, timely, sufficient and unambiguous information to its users and other systems. The hardware and software of the PES shall respond correctly throughout its life cycle. This can be achieved if the following principles are fulfilled by the PES and its associated elements throughout its life.

P1 The PES shall be free from unacceptable risk of harm to persons or the environment.
P2 In the event of failure the PES shall remain in or revert to the least hazardous condition.
P3 The PES shall provide functions which meet user needs.
P4 Functions shall be appropriately allocated between users and PES.
P5 The PES shall be tolerant of faults and input errors.

P6 The PES shall maintain specified levels of accuracy, timeliness and resource utilisation when used under specified operational and environmental conditions.

P7 Unauthorised access to the PES shall be prevented.

P8 The PES shall be acceptable to the user and support effective and efficient operation under specified conditions.

P9 The operation of the PES shall be consistent and shall correspond to user expectations of the underlying process.

P10 The interaction between the PES and the user shall be controllable by the user.

P11 The PES shall support proper installation and maintenance, including repair and modification.

Life cycle principles for marine PES[SR3]

The successful realization and use of a dependable marine PES requires a systematic approach throughout the life of the PES. The key requirements for any approach which aims to meet the product principles given in above are described below.

L1 All PES lifecycle activities shall be planned and structured in a systematic manner.

L2 The required level of safety shall be realised by appropriate activities throughout the lifecycle.

L3 User centred activities shall be employed throughout the lifecycle.

L4 Verification and validation activities shall be employed throughout the lifecycle.

L5 All parties involved in lifecycle activities shall have and use a Quality Management System.

L6 Existing requirements for marine systems shall be taken into account throughout the lifecycle.

L7 Suitable documentation shall be produced to ensure all PES lifecycle activities can be performed effectively.

L8 Persons who have responsibilities for any lifecycle activities shall be competent to discharge those responsibilities.

L9 The PES configuration shall be identified and controlled throughout the lifecycle.

Annex E

Excerpts from Pod Quality Forum Document

Common Quality Instructions

Version 2.0

13 September 2004

POD QUALITY FORUM

ABB

Rolls-Royce AB

Siemens

Schottel

DNV

List of content

3.5 Harbour acceptance test

3.5.1 Pre-requirements

- In order to secure the system functionality before tests, the pod manufacturer shall establish checklists specifying the pre-requirements before the harbour acceptance test can commence.
- In order to optimise the supplier's participation, the pod manufacturer shall require that a plan (time and resources) for harbour acceptance test is established by the ship yard. This plan is to be presented to the supplier in due time prior to the test.
- In order to make the tests efficient, the roles during the tests must be clear and communicated to all involved parties. Although this is coordinated by the yard, the pod manufacturer shall actively contribute to ensure this.

3.5.2 Functional tests

- During the harbour acceptance test, a complete system functional test shall be carried out, in order to verify the systems prior to the sea trial acceptance test (see 3.6). The functional tests shall be carried out according to a procedure, specified by the pod manufacturer.

3.5.3 Oil replacement

- Debris (particles) might have entered the system during testing. Hence, lubrication oil is to be replaced after the harbour acceptance test
- If adequate means are provided to supervise the debris content, the above may be waived when supervision results provides for it.
- This is to be communicated clearly to the yard in the applicable instructions.

3.6 Sea trial acceptance test

3.6.1 Pre-requirements

- In order to secure the system functionality before tests, the pod manufacturer shall establish checklists specifying the pre-requirements before the sea trial acceptance test can commence.
- In order to optimise the supplier's participation, the pod manufacturer shall require that a plan (time and resources) for sea trial acceptance test is established by the ship yard. This plan is to be presented to the supplier in due time prior to the test.
- In order to make the tests efficient, the roles during the tests must be clear and communicated to all involved parties. Although this is coordinated by the yard, the pod manufacturer shall actively contribute to ensure this.

3.6.2 Monitoring

- The first monitoring values from the unit in operation shall be recorded during sea trials. These will be the basis for further monitoring and for adjustments during sea trial acceptance test.

- The monitoring shall be carried out according to the pod manufacturer's specification.

4 Operational phase quality requirements

4.1 Customer support

4.1.1 24-hours service

- In order to give the operators technical staff sufficient support in case of problems exceeding scope of manuals (and thereby prevent failures or unscheduled maintenance), the pod manufacturer shall have established a system for 24-hours service ("Hotline").

4.1.2 Certified service personnel

- The pod manufacturer shall ensure that certified service engineers are available within reasonable response time.
- Such personnel must be familiar with the pod specific requirements.
- The personnel shall undergo a certain amount of training, specified by the pod maker, prior to the certification.

4.2 Life cycle management

4.2.1 Contingency plan (unexpected failures)

- In order to ensure that both maker and operator are aware of possible failures, the maker shall see to that a contingency plan can be provided. Such a plan shall be in form of an agreement between maker and operator.
- In addition to possible failures, the contingency plan shall include:

    - Possible causes of failures
    - Effect of failures
    - Standard solutions to most likely or most critical problems that may arise.
    - List of necessary spare parts (see 4.2.2)

- Contingency plan is normally to be based upon a Failure Mode Effect Analysis (FMEA).
- Necessary preparations shall be done at both maker and operator with respect to the optimisation of logistics, spare parts, training, definition of responsible personnel, etc.

4.2.2 Spare parts

- A list of necessary spare parts shall be available, and preferably a part of the contingency plan.
- Pod manufacturer (including sub-suppliers) and operator shall agree upon the necessary degree of availability for all spare parts, based on expected component lifetimes and a consideration of operational profile.

4.2.3 Modernisation / upgrading

- In order to keep the pods in operation on the best technical standard and to guarantee the availability of spare parts to the operator, the pod manufacturer shall ensure that technical information regarding hardware and software updates is available.
- Pod manufacturer shall also recommend on proactive upgrading, in case of pending risks learned from other applications.

4.3 Training

4.3.1 Crew training

- In order to ensure that there are qualified people available to operate the pod system, the pod maker shall offer theoretical and practical training of the ships crew or owner/operators office staff.
- The training shall comprise function related lessons (for nautical, technical and office staff) held by manufacturers.
- Theoretical training can be given in makers or operators office, while practical training may be given directly on the system.

4.3.2 Pod maker personnel training

- In order to ensure that qualified people are available from maker on site or on phone, the pod maker shall see to that proper training of service engineers and office staff at the makers service department is carried out.
- For service engineers the training shall include product & safety aspects.

4.4 Manuals

4.4.1 Operation instructions

- Pod manufacturer shall ensure that operation and maintenance instructions are available, by means of manuals. The manuals shall aim to give the operator the best possible overview of functionality and possible malfunctions of the system.
- The manuals shall give technical personnel detailed information about:
    - The function of all systems and sub-systems
    - How to react on failures
    - How to maintain the systems
- The manuals shall give nautical personnel global information about:
    - The main function of the major systems
    - Recommendations on how to react on failures
- The manuals shall comprise graphical explanations showing what, when and how to do.

4.4.2 Safety manuals

- Safety items are of superior importance, and the pod manufacturer shall ensure that safety manuals are available on board, either as separate manuals or included in ordinary manual.
- A very compact *Bridge handbook* is recommended to be available for nautical staff, focusing on interaction of propulsion system and ship safety system. It shall give a short overview of possible consequences of possible failures, as well as recommended reactions.

4.5 Maintenance

4.5.1 Scheduled maintenance program

- The pod manufacturer shall ensure that a plan defining maintenance and exchange intervals by time (e.g. classification periods) or operation hour intervals is available on board.
- The maintenance plan is to be defined from design and operational profile.
- The maintenance plan shall clearly define what maintenance item has to be executed at what time / operation interval, as well as who is carrying it out.
- The operator must be instructed by the pod manufacturer that maintenance work shall be traceable.

4.5.2 Condition based maintenance

- In order to ensure a high availability and prevent unexpected incidents, such as failures or breakdowns, the pod manufacturer shall ensure that the maintenance plan identifies the maintenance items that are not dependent from time/ operation intervals, but from machine condition. Condition based maintenance is also connected to the monitoring program (see 4.6).

4.6 Monitoring

The intention for all the monitoring requirements is:

- Prepare data for condition based maintenance measures.
- Prevent unscheduled maintenance and breakdown.
- To allow condition-based maintenance or replacement of components.

4.6.1 Local monitoring

- The pod manufacturer shall see to that local monitoring of vital parameters is possible. E.g., such parameters are:

    - Bearing condition / bearing lubricant condition
    - Condition of propulsion motor (temperature)
    - Vibration level (bearings)
    - Leakage rate in sealings

- The values from the local monitoring system shall continuously or regularly be recorded from the automation system or by visual read-out or measuring/gauging.
- Monitoring recordings/analysis shall be evaluated against given limitations by makers' experts.

4.6.2 Monitoring by inspections

- The pod manufacturer shall provide the necessary features in order to allow monitoring of slow-changing (mainly wear related) machine condition by visual checks. Such checks could be videoscope inspection or wear gauging.

4.6.3 Approval of monitoring system

- The monitoring system is to be approved by the pod manufacturer.
- It must be clearly communicated to the yard and ship operator that no additional monitoring system must be installed inside the pod without the approval of the manufacturer.

5 Quality management

5.1 Quality system

- The quality system shall comprise description of production inspection processes, assembly check lists as well as inspection procedures and records.

5.2 Quality plan

- A project specific quality plan shall be established for each project.
- All major tests and inspections are to be carried out in own workshop or at sub-supplier shall be identified. Tests that are to be carried out during installation and commissioning shall be described as well.
- In the quality plan all main components of the pod shall be dealt with, describing the following:

    - Test methods and specifying documents
    - Where the tests shall be carried out
    - Who is responsible for each task and who shall be informed

5.3 Documentation

- The following documents shall be described in the quality plan:

    - Production check lists
    - Measurements and inspection records
    - Records of all tests
    - Classification certificates

- No document is valid without formal approval. Approval is to be clearly marked in document, including possible comments.
- Pod manufacturer is responsible for obtaining classification of the whole pod system, including components from sub-suppliers.

Annex F

Siemens Safety Critical Information for SSP
dated 8 November 2007

SIEMENS **Industrial Solutions and Services**

Rederi AB Donsötank

P.O. Box 19
430 82 Donsö
SWEDEN

Name	
Department	I&S OGM MAS LCM
Telephone	
Fax	
E-mail	
Your letter of	
Our reference	O-09300121-U-01/S1-si
Date	November 8, 2007

MT Prospero, MT Bro Sincero & MT Evinco, here: Safety Critical Information for SSP

Dear

The following bulletin refers to the operating of your SSP drives:

Due to past inducement we advise you, not to dim the lights in the bridge console of the conning stations under the visibility level since this would render alarm lights invisible.

Sincerely yours,

Siemens AG
Division: Oil, Gas, Marine Solutions
Head: Otto Soeberg, Head Business Admin.: Thomas Liegl
Group: Industrial Solutions and Services
Group Executive Management: Joergen Ole Haslestad, Group President;
Bernd Euler, Hans-Joerg Grundmann, Joachim Moeller

Postal address:
Siemens AG
I&S OGM MAS LCM
P.O. Box 10 56 09
20038 Hamburg

Office address:
Lindenplatz 2
20099 Hamburg
Tel: +49 (40) 28 89-0
Fax: +49 (40) 28 89-22 10

DNV memo MTPNO867/KRESSE/22081-J-1102
Changes made in DNV's requirements and procedures to approval,
certification and shipboard installation and testing of pods
and associated control and automation systems

MEMO TO:
Whom it may concern

MEMO NO. : MTPNO867/KRESSE/22081-J-1102
FROM : Machinery Ships in Operation
DATE : 2007-05-21
PREP. BY :

Copy:

CHANGES MADE IN DNV'S REQUIREMENTS AND PROCEDURES TO APPROVAL, CERTIFICATION AND SHIPBOARD INSTALLATION AND TESTING OF PODS AND ASSOCIATED CONTROL- AND AUTOMATION SYSTEMS

DNV has during the past years taken several steps to further evolve the classification activities related to complex machinery installations with its associated control and monitoring systems. Different measures have been initiated both in terms of work process alterations, extended training of surveyors and rule amendments as indicated below.

Work process alterations, control and monitoring

A completely revised Instructions to Surveyor, IS III D-7.2, was released in April 2004. These Instructions provide clearer assignment of responsibilities and improved quality assurance of both approval and certification of control and monitoring systems in general. The Instructions contain extensive check lists for approval and survey of control and monitoring systems. Together with amended rules they also provide guidelines on expected contents of certification survey test programme.

In addition, DNV has during the recent years turned the focus more towards multi-disciplinary handling of cases, and are currently running pilot projects on organising complex projects with a new co-ordinator position – System project manager with a specific job-instruction

Further, the ICT tools are developed and improved to facilitate rapid and stable sharing of documentation on the intranet as well as implementation of a new production system (Nauticus) providing a common electronic access to all relevant project information to the whole DNV organisation.

Training, control and monitoring

A course was developed and made mandatory in 2004 for all approval engineers and surveyors involved with approval and certification of control and monitoring systems. The main focus in the course is the work process related to certification of control and monitoring systems and experience exchange related to i.a. technical and procedural challenges.
The Veritas Qualification Scheme Class ensures that relevant personnel have undertaken necessary training related to handling control and monitoring systems.
In addition, a course covering electrical installations has been introduced and has been attended by many of the electrical surveyors.

Rule, control and monitoring

- The Rules for control and monitoring systems have been developed on several areas, and have during the recent years been (or is about to be) amended on i.a. the following areas: Quality assurance of software development and change handling
- Response to failures
- Alarm handling and presentation
- User interface / man – machine interface
- Integrated systems / network challenges
- Independency between systems and verification of back-up functions

(Some Rule References of relevance:

Pt.4 Ch.9 Sec.1
A 300Alterations and additions
Requiring a controlled and traceable way of handling SW changes during the operational phase.

Pt.4 Ch.9 Sec.1 D Tests and Pt.4 Ch.9 Sec.2 C Back – up functions (rule proposal)
Verification of emergency means of control of essential systems

Pt.4 Ch.9 Sec.3 System Design (rule proposal)
Clarified requirements for independency between safety functions and other functions

Pt.4 Ch.9 Sec.4 System Design (rule proposal)
Improved requirements for data communication links including wireless communication

Pt.4 Ch.9 Sec.6 User interface (rule proposal)
Major update of the requirements)

The steering gear requirements have been strengthened i.a. on the following issues:

- Identification of failure modes in a separate document (Pt.4 Ch.14 Sec.1A)
- Response to failure in the feedback-loop preventing unexpected rudder behaviour upon feedback failure (Pt.4 Ch.14 Sec.1A)

Rules, mechanical

Also the rules related to the mechanical aspects, given in Pt.4 Ch.5, of the pods have been subject to further evolvement as outlined below.

Jan.01

The manufacturer shall submit information about any operational limitations, design criteria and load assumptions (A200).

Leakage detection for slewing seal at hull penetration has been added (B504).

Function testing is required for all hydraulic systems (D103).

Detailed requirements with respect to static and dynamic stresses in pod stay (B501).

Extended requirements for lubricating oil systems (B800).

Azimuth thrusters shall be mounted in a watertight compartment unless the penetration through the hull is situated above the deepest loaded waterline (F104).

July 05

For single pod installations the steering gear torque capacity should be 2x100% (B402).

The thrusters/pods shall be prevented from sudden turning in the case of power failure, failure in the steering control system or any other single failure, except failure in steering column and support bearings (B404).

Sub-assemblies carried out the yard to be verified by surveyor (H103).

Extended requirements for seatrial testing (I100).

More detailed requirements for documentation for steering gear and for documentation of electrical motor control system for thrusters driven by electric motor (A200).

The following rule paragraphs where introduced:

- B103: shielding of POD internals
- B104: hydraulic components (and for piping arrangement)
- B105: cooling of podded thrusters
- B202: duplication of shaft seals for single unit installations
- B203: rope guard
- B416: control system for electro mechanical steering gear with respect to acceleration and shock load
- B417: rating for electro motor driving the steering gear

B505: bilge system for podded thrusters

B802: separate lubrication systems for installations with a limited volume of oil sump

E105: duplication of sensors not easily replaceable

F104: boundary to sea

F203: steering gear emergency power supply

Guidance note has been added covering:
B803: lubrication oil cleanliness

July. 07 (coming into force)

Under Sec.1 E300, **TMON** for podded propulsion has been withdrawn.

Rules, electro

The Rules for Electrical Propulsion in Pt.4 Ch.8 have been modified as follows:

2001:
Frequency converters certification, requirements modified:
- Added requirements to protection and monitoring in line with requirements in Pt.4 Ch.5/Pt.4 Ch.9
-Added/clarified requirements to testing of converters and scope of verification work.

- o0o -