Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Marine Occurrence Investigation No. 220

Final

Independent investigation into the fires on board the Panamanian registered accommodation platform

Safe Concordia

in Bass Strait, Victoria

12 and 18 September 2005

Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Marine Occurrence Report
No. 220
Final

Independent investigation into the fires on board the Panamanian registered accommodation platform

Safe Concordia

in Bass Strait, Victoria
12 and 18 September 2005

Released in accordance with section 25 of the Transport Safety Investigation Act 2003

Published by:	Australian Transport Safety Bureau
Postal address:	PO Box 967, Civic Square ACT 2608
Office location:	15 Mort Street, Canberra City, Australian Capital Territory
Telephone:	1800 621 372; from overseas + 61 2 6274 6440
	Accident and incident notification: 1800 011 034 (24 hours)
Facsimile:	02 6247 3117; from overseas + 61 2 6247 3117
E-mail:	atsbinfo@atsb.gov.au
Internet:	www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page v.

CONTENTS

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication Date	No. of pages	ISBN	ISSN
220	29 June 2007	52	978-1-921164-85-9	1447 – 087X

Title of report
Independent investigation into the fires on board the Panamanian registered accommodation platform *Safe Concordia* in Bass Strait, Victoria on 12 and 18 September 2005.

Prepared by
Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.
Jun2007/DOTARS 50266

Acknowledgements
The chart section in this publication is reproduced by permission of The Australian Hydrographic Service. © Commonwealth of Australia 13 October 2002. All rights reserved. Other than for the purposes of copying this publication for public use, the chart information from the chart sections may not be extracted, translated, or reduced to any electronic medium or machine readable form for incorporation into a derived product, in whole or part, without the prior written consent of the Australian Hydrographic Service.

Abstract
Safe Concordia is a dynamic positioning, self propelled, semi-submersible accommodation platform that uses four electrically driven thrusters to maintain its position. The platform's construction was completed, and its delivery trials were carried out, in March 2005.

During its voyage from Singapore to Bass Strait, Australia, the platform experienced two electrical fires in its thruster power system. On 12 September 2005, after it had entered Bass Strait a fire started in the platform's number four thruster transformer. On 18 September, a fire occurred in an electrical cabinet that was providing power to the number one thruster motor.

The investigation found that the transformer fire was probably the result of an internal short circuit that occurred when the insulation failed due to overheating. The cabinet fire was the result of an electrical arc that occurred because the work bridging out of some electrical equipment was not adequately undertaken.

It was also considered that *Safe Concordia* was not fit to fulfil its charter obligations in view of the unresolved faults in the thrusters' electrical power systems and the design of the platform did not allow for effective and safe fire fighting in the thruster rooms.

The report makes several recommendations to address these issues.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, risk controls and organisational influences.

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety issues can broadly be classified in terms of their level of risk as follows:

- **Critical safety issue:** associated with an intolerable level of risk.
- **Significant safety issue:** associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.
- **Minor safety issue:** associated with a broadly acceptable level of risk.

EXECUTIVE SUMMARY

Safe Concordia is a dynamic positioning, self propelled, semi-submersible accommodation platform that uses four electrically driven thrusters to maintain its position. The platform's construction was completed, and its delivery trials were carried out, in March 2005. The platform was used operationally for its first contract in the Timor Sea before modifications were made to address various electrical problems that had occurred within its propulsion system.

On 27 July, after the modifications were completed, *Safe Concordia* sailed from Singapore with several electrical specialists still on board, bound for the Yolla gas field in Bass Strait, Australia. During the voyage, it became evident that there were still problems with the propulsion electrical system.

At 0048[1] on 12 September 2005, after the platform entered Bass Strait, a fire started the number four thruster transformer. The platform continued the voyage using its three remaining thrusters and stopped three miles[2] from the Yolla gas platform.

At 0326 on 18 September, a fire started in an electrical cabinet that was providing power to the number one thruster motor while the electrical contractors were working on the system.

After the fires, *Safe Concordia* sailed to Melbourne using its remaining two thrusters. The propulsion system could not be repaired in Melbourne. Consequently, in January 2006, the platform was taken back to Singapore, on board a heavy lift ship, for repairs to the propulsion system.

The report identifies the following safety issues and makes recommendations to address them:

- The endurance test, as required by the American Bureau of Shipping (ABS), was not successfully completed before ABS issued a certificate of class for the platform in March 2005. Consequently, unresolved faults remained in the propulsion electrical system that may have compromised the platform's DP-2 classification.
- The safety case submitted to the National Offshore Petroleum Safety Authority (NOPSA) did not take into account the problems with the propulsion electrical system that had occurred before the platform was deployed to the Yolla gas field in Bass Strait, Australia.
- While suitable materials were used for the task of bridging out a major electrical component, the task was not adequately performed, resulting in a fire in the cabinet housing the electrical equipment.
- The American Bureau of Shipping (ABS) rules do not define *Safe Concordia*'s column structure spaces, containing the propulsion electrical system, as 'Category A' machinery spaces. Therefore, the need for a fixed fire fighting extinguishing system or two means of access to the thruster machinery spaces have not been adequately addressed.

1 All times referred to in this report are local time, Coordinated Universal Time (UTC) + 10 hours.

2 A nautical mile of 1852 m.

1 FACTUAL INFORMATION

1.1 *Safe Concordia*

Safe Concordia is a Panamanian registered, self propelled, semi-submersible accommodation platform (sometimes called a floatel). It is used in the offshore industry to provide onsite accommodation for up to 390 persons and support for a variety of activities requiring extra space, equipment or personnel.

Figure 1: *Safe Concordia* at anchor in Port Phillip, Victoria

Safe Concordia, designed as an ultra-deepwater support platform based on a successful drilling platform hull design by Keppel FELS, was built at their yard in Singapore. The platform was launched in October 2004 and completed in 2005. At the time of the incidents, it was owned by a joint venture company, Joy Venture Investments, comprised of the building yard Keppel FELS and Consafe Offshore. It was managed and operated by Polycrest A/S, Norway. *Safe Concordia* was classed with American Bureau of Shipping (ABS) as ✠A1 Column Stabilised Accommodation Unit[3], ✠AMS[4], ✠DPS-2[5], and Fire Fighting Vessel Class Two.

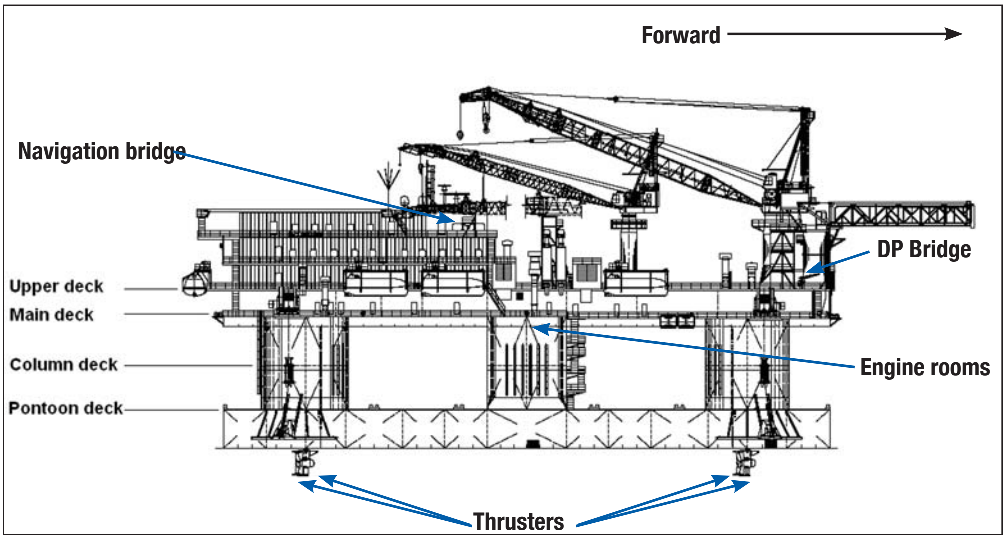
The platform has an overall length of 99.97 m, an extreme breadth of 45.22 m and a beam at the main deck level of 36.07 m. Its operational displacement is 18 000 tonnes at a draught of 16.44 m and it has a transit draught of 10.19 m (including thrusters).

3 A mobile offshore structure that was designed and built under survey by ABS and that depends upon the buoyancy of pontoons for flotation and stability or for raising and lowering the unit.

4 Machinery systems constructed and installed under ABS survey to ABS Rules.

5 Dynamic positioning system with redundancy that complies with ABS rules and includes survey of the machinery at the manufacturer's plant, during installation and during trials.

Figure 2: General arrangement profile



Safe Concordia is constructed on two parallel pontoons, each 11.59 m wide. The twin pontoons contain the 34 ballast, six fuel and four potable water tanks for the platform. Rising from each pontoon and up to the column deck are three 12.81 metre high columns. The centre columns contain pump rooms and each corner column contains the thruster machinery rooms. The columns are connected by transverse trusses that support the main and upper decks and the accommodation structure.

Safe Concordia was designed to operate on a range of operational contracts to provide accommodation, fire fighting and support services for the construction, maintenance and operation of offshore oil and gas platforms. In this role, *Safe Concordia* must maintain station, about 29 m from the drilling/production platform, using its dynamic positioning (DP) and thruster system. A hydraulically operated, telescopic gangway, mounted at the forward end of the main deck, is used for access between the two platforms.

As a fire fighting vessel, *Safe Concordia* has four fire monitors, each capable of delivering 1800 cubic metres of water per hour. The monitors can be used to direct either a spray or a solid stream of water to suppress or extinguish a fire on the adjacent platform. It also has a 120 tonne safe working load (SWL) crane on the port side of the main deck and a smaller 25 tonne SWL crane on the starboard side.

The platform has a navigation bridge located on the forward end of the top deck of the accommodation structure. It also has a DP bridge located on the port side of the upper deck, adjacent to the telescopic gangway. *Safe Concordia*'s engine rooms and the switchboard room are located on the main deck between the two centre columns.

Safe Concordia also has a four point mooring system with an anchor, cable and winch mounted on each corner column. This system is used to maintain position when the platform is 'near shore' and not on contract.

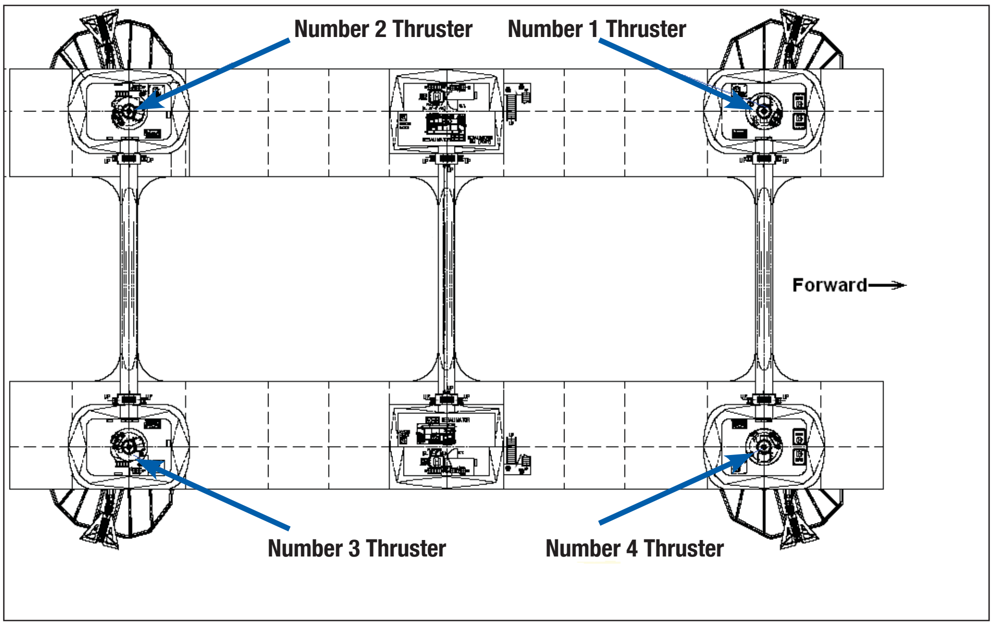
At the time of the incidents, *Safe Concordia* had 46 personnel on board. Eight of these were the Polycrest transit crew, 31 were the Australian crew for operating the platform on station in Australian waters, six were contractors engaged to fault find the propulsion system problems on board, and one was the charterer's representative.

1.2 Machinery and propulsion system

Safe Concordia is classed by ABS as a DP-2 platform. The DP-2 classification means that the platform must not experience a loss of position in the event of a single failure of any part of the dynamic positioning system. The platform's propulsion systems were designed to meet the DP-2 classification.

Safe Concordia is fitted with five Wartsila 12V26A, medium speed diesel engines, each developing 3590 kW at 900 rpm[6], providing a total power output of 17 950 kW. Each main engine drives a generator producing 5000 kVA[7] of three phase power at 6600 V and 60 Hz. All of the generators connect to a single 6600 V switchboard. A Kongsberg power management system controls the load sharing, power limiting system and the starting, stopping and synchronising of the generators.

Figure 3: Pontoon deck plan



The four corner columns contain the thruster machinery rooms (Figure 3). Within each column are two machinery rooms. The upper room, on the column deck (Figure 4), contains a variable frequency drive (VFD) cabinet, a thruster transformer and an air-conditioning plant for the transformer. The lower room, on the pontoon deck (Figure 5), contains an inductor (choke) cabinet, a thruster motor and a hydraulic power pack. Beneath each of these columns is a 360° rotatable thruster which has a fixed pitch propeller inside a nozzle. Each thruster is driven by an Alconza-Berango 2500 kW variable speed induction motor and produces approximately 50.6 tonnes of thrust at full speed.

6 Revolutions per minute.

7 Kilo Volt Ampere, a measure of apparent electrical power produced by the generator.

Figure 4: Number four column thruster transformer room (column deck) plan

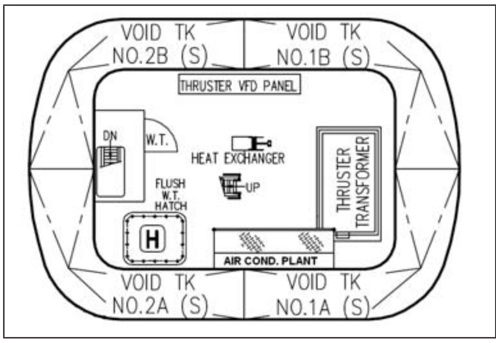
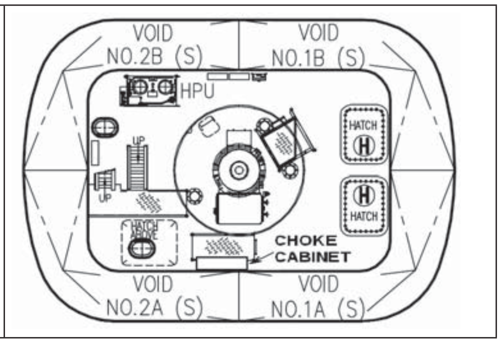


Figure 5: Number four column thruster room (pontoon deck) plan



Access to each thruster room is by a single stairway. The stairway from the main deck to the column deck is accessed from the main deck by a watertight door. Similarly, the column deck machinery room is separated from the pontoon deck thruster room by another watertight door.

1.2.1 Electrical distribution system

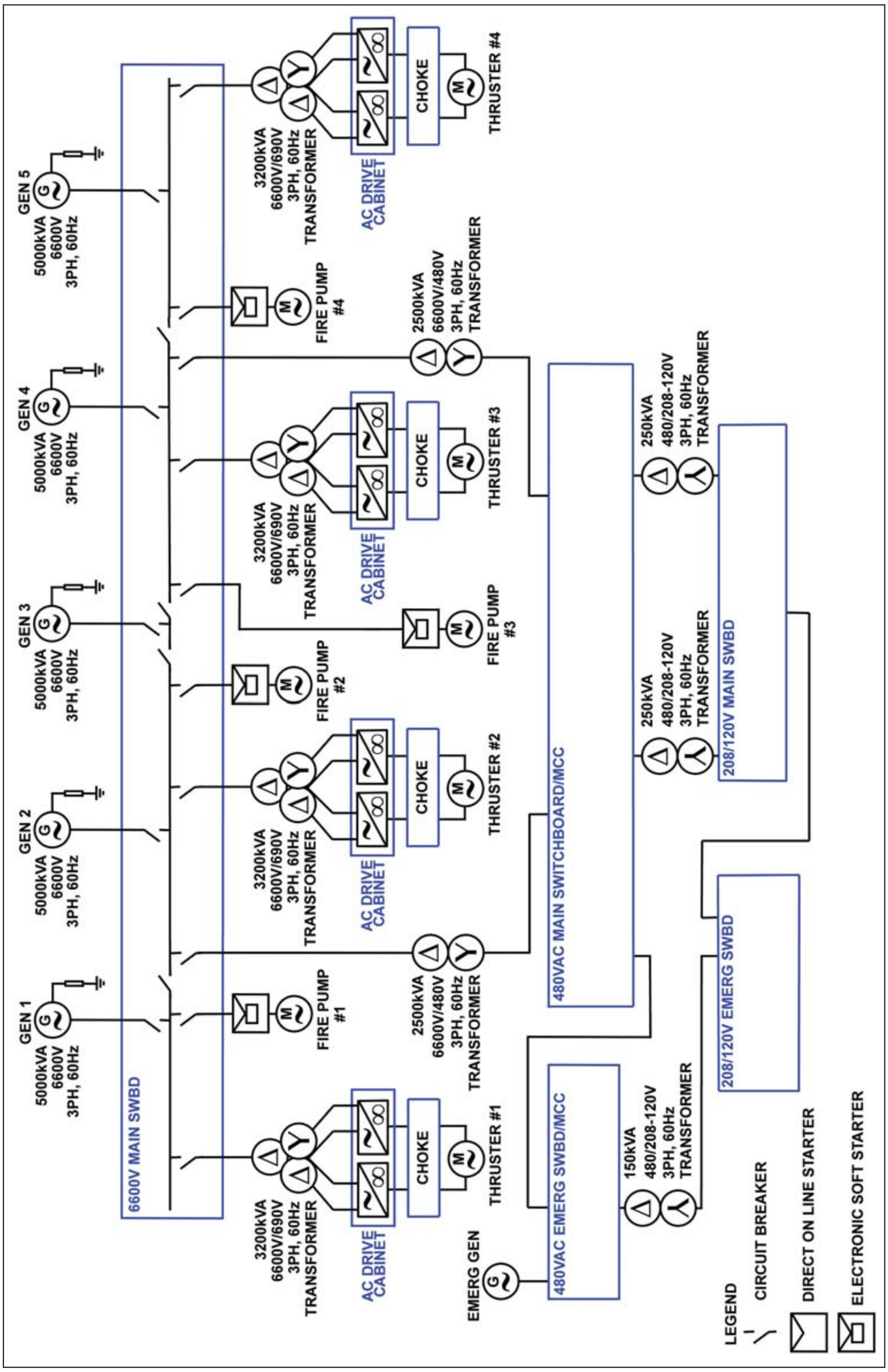
The 6600 V switchboard is divided into five sections, each section supplied from one diesel generator and separated from the others by circuit breakers (Figure 6). Sections two and four also supply the corresponding section of a 480 V switchboard via a 6600 V/480 V, 2500 kVA transformer. Each of the 6600 V switchboard sections, except for the centre section, supplies one thruster motor and one fire pump.

At the time of the incident, the 6600 V switchboard could be segregated and was designed to be used in any one of three basic configurations to maintain the platform's DP-2 classification[8]:

- 'Four split mode' with four generators on line and all four thrusters running. In this mode, each thruster was segregated from the others. In the event of the loss of one section of the switchboard, the worst case loss would be a single thruster, allowing the platform to still maintain station.
- 'Three split mode' with three generators on line and four thrusters running. The worst case failure in this mode would result in the loss of two thrusters but the platform would still be able to maintain its position.
- 'Two split mode' with two generators on line, with four thrusters running. The worst case failure in this mode would result in the loss of two thrusters but the platform would still be able to maintain its position.

8 Keppel FELS, Failure Modes and Effects Analysis of Semi Submersible Accommodation Unit "Safe Concordia".

Figure 6: Main power distribution system schematic drawing



Each thruster was supplied from the 6600 V switchboard via a 6600 V/690 V transformer rated at 3200 kVA. Each thruster transformer was built as three individual units within a single cabinet (Figure 7), with each primary coil and its associated secondary coils being wound around a common iron core.

Figure 7: Inside number four transformer cabinet

The inner coils of the transformers were the secondary windings with a lower voltage and higher current. The outer coil was the primary or high voltage winding. All of the transformer coils were made from copper wire that was insulated with Class F[9] dry resin insulation. The ratio of wire turns between the primary and secondary windings determined the transformation or voltage ratio.

The 480 V switchboard was divided into two sections, separated by a single circuit breaker, and was supplied through two transformers from the main switchboard. The 480 V switchboard provided power for various ancillary electrical services and the 208 V/120 V lighting and minor service switchboard via two further transformers.

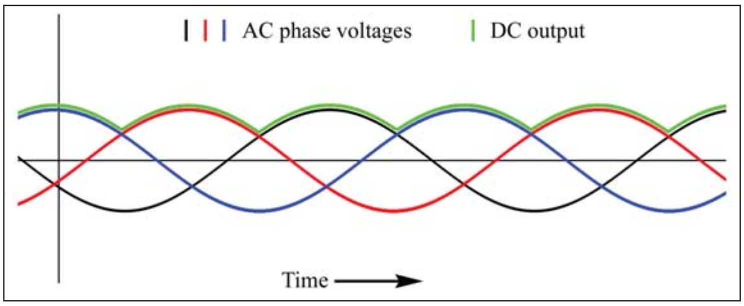
One section of the 480 V switchboard normally supplied the emergency 480 V switchboard. If the emergency switchboard lost power, an emergency generator, rated at 600 kW, was designed to start automatically and connect to the emergency switchboard.

1.2.2 Variable frequency drive

The speed of the thruster induction motors, and thereby the thrust provided by the thrusters, is altered by changing the frequency and voltage of the supplied alternating current (AC). Frequency control is achieved using a variable frequency drive (VFD). The VFD uses Pulse Width Modulation (PWM) technology to supply a near sinusoidal AC waveform at varying frequencies and voltages to the thruster motors.

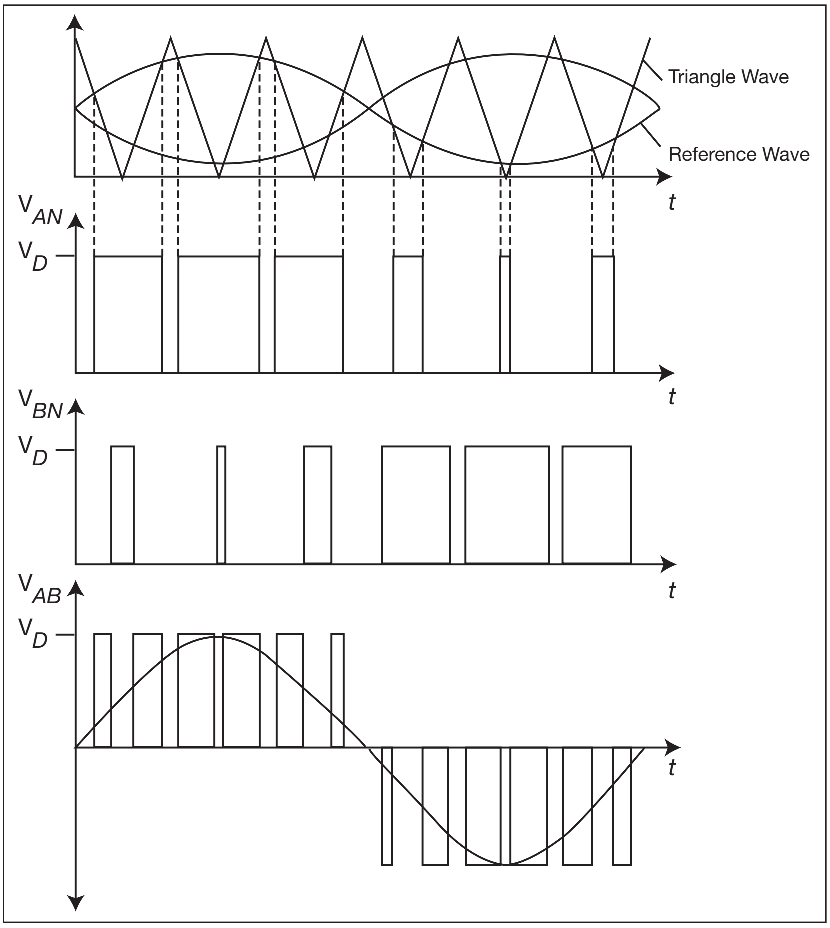
9 Class F insulation specifies a maximum operating temperature of 155°C.

Figure 8: **Typical undamped three phase rectifier output**



A VFD uses a rectifier to convert an AC input to a direct current (DC) intermediate power before converting the DC intermediate power back to AC power using an inverter circuit. The rectifier section of the VFD does not produce a perfect linear DC current (Figure 8) but a wavelike DC with a frequency that is three times the supply frequency - the third harmonic frequency. The DC busbars are linked by a capacitor to help smooth out the DC voltage output.

Figure 9: **PWM waveforms showing operating principle**[10]

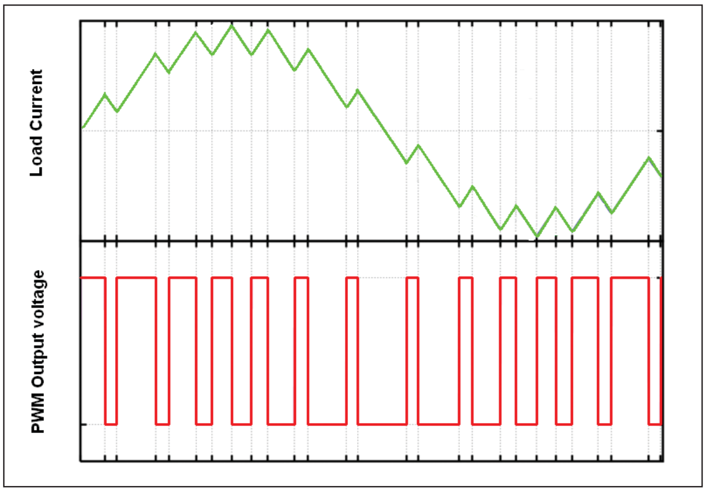


One method of controlling the voltage and frequency is by comparing a high-frequency triangular carrier wave with a three-phase sinusoidal reference wave and switching the power devices in each phase at the intersection of the sine and triangle waves (Figure 9). This produces a series of square wave voltage pulses of varying

10 ABS Guidance Notes on the Control of Harmonics in Electrical Power Systems, 2006.

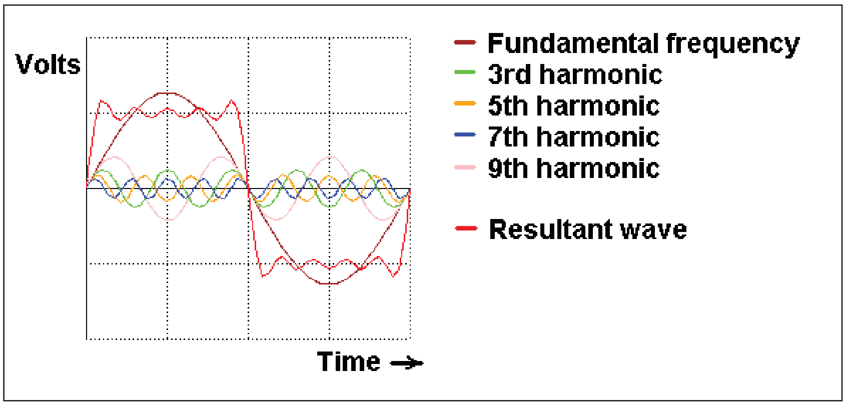
duration. These voltage pulses, when acting on the inductance of the load, produce a current flow that is nearly sinusoidal. The amplitude and frequency of the output voltage are varied by varying the amplitude and frequency of the reference sine waves respectively. A higher output voltage and frequency is created by fewer and wider pulses while a lower voltage and frequency is created by more and narrower pulses.

Figure 10: Typical single phase VFD output waveform



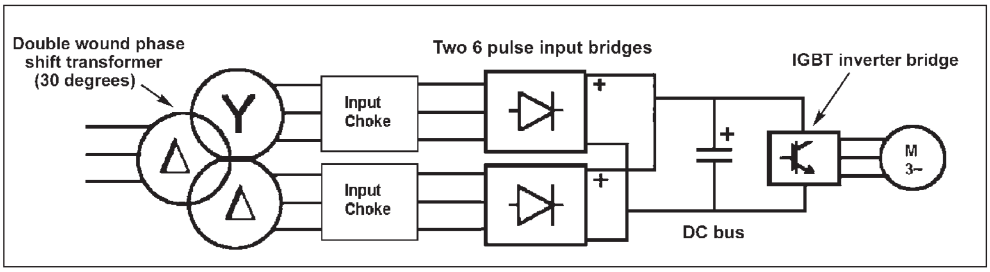
In a PWM inverter drive, the output voltage and frequency are generated by the VFD drive and the intermediate DC voltage remains approximately constant. The varying width of the output pulses produces a near-sinusoidal AC waveform (Figures 10 and 11). This AC waveform contains irregularities and spikes which can be attributed to the harmonics of the supply, the characteristics of the load and the inverter control system. The VFD creates harmonics because it draws power from the system in distinct pulses and not in the same smooth sinusoidal way that a motor does.

Figure 11: Effect of harmonics on a single sine wave



Each VFD on board *Safe Concordia* was powered through a phase shifting transformer rated at 3200 kVA. These transformers were designed to eliminate the fifth and seventh harmonics by providing a phase shift in one of the secondary coils. The transformer is equivalent to having a pair of transformers (one delta/star and one delta/delta) wound around a single iron core so that they were magnetically coupled for each phase (Figure 12). The third harmonic was also effectively eliminated if the system's three phase voltages remained balanced.

Figure 12: Typical layout for a 12 pulse PWM VFD



The harmonic currents produced by AC PWM drives are dependent on the number of pulses used and whether any additional filtering has been installed in the system. Typically, the total harmonic distortion for a twelve pulse inverter (Figure 12) is around 13%[11].

1.2.3 Dynamic positioning (DP) control system

The four thrusters mounted beneath *Safe Concordia*'s pontoons were controlled by a Kongsberg STC-400 thruster control system. The thrusters were dual purpose in that they were used for station keeping when in DP mode or for propulsion when on passage and manoeuvring. When being used for propulsion, the thrusters were controlled from a joystick using either manual or automatic heading control. The thrusters were controlled from either the navigation bridge or the DP bridge.

The heart of the DP control capability on board *Safe Concordia* is the Kongsberg SDP-22 dynamic positioning system. The SDP-22 system is a dual system designed to comply with the ABS requirements for a Class 2 redundant DP system. When the platform is maintaining station in DP mode, the SDP-22 controls the thrusters.

To achieve DP-2 classification, *Safe Concordia* used a combination of global positioning system (GPS) signals, a Fanbeam laser range finder and an active reference signal from the telescopic gangway to verify its position relative to the adjacent platform.

1.3 Fire fighting and protection

Safe Concordia had a fire detection system installed on board to monitor all of the platform's compartments. The fire detection system had alarm and indicator panels in the engine control room, the DP bridge and the navigation bridge.

The engine room and electrical distribution switchboard/transformer room on the main deck had a remotely operated, fixed carbon dioxide (CO_2) fire extinguishing system. The CO_2 cylinder store was located on the starboard side of the main deck, with release control stations located in the transformer room, purifier room, outside the emergency generator room and on the main deck outside, and adjacent to, the engine rooms.

The accommodation had an automatically activated water sprinkler system. Pressure for the system was maintained in a tank located in the service equipment room on the main deck.

11 Power Electronic Converters for Ship Propulsion Electric Motors - Damir Radan, P22.

The thruster rooms and columns had no fixed fire extinguishing system.

Each column had supply and exhaust fans built into mushroom ventilators located above the main deck which could be closed manually or by using pneumatically operated dampers. Above the door to the stairway entrance from the transformer room to the thruster motor room is a ventilation opening which can be closed with a hinged flap.

1.4 The incidents

Safe Concordia took fifteen months to construct and underwent its pre-delivery trials in Singapore in March 2005. Part of its pre-delivery trials programme was an endurance test which ensured that the propulsion system was capable of operating at full load for a minimum of four hours.

The endurance test was not fully completed because high temperature alarms occurred in the thruster transformers when the load exceeded 70%. Consequently, extraction fans and ducting were fitted to the transformer cabinets to improve the air circulation around the coils. The set point for the transformer high temperature alarms was raised, after discussions with the equipment designers and suppliers, and the thrusters were only run at 80% load for the four hours of the test.

On 16 March 2005, *Safe Concordia* sailed from Singapore to the Bayu Undan gas field in the Timor Sea for a two month contract. During the transit to Bayu Undan, system testing found that the transformer temperatures were high when the load exceeded 60%. The weather during this contract was typical of the tropical regions at that time of year, with calm to very slight seas, light winds and little or no swell. Consequently, the loads on the thrusters while in DP mode during this period did not exceed 30%. All thrusters operated satisfactorily at these low loads during the contract.

On 27 May 2005, after the Bayu Undan charter was completed, *Safe Concordia* returned to Singapore where the overheating transformer problem was studied by various electrical experts. The electrical experts concluded that the overheating was caused by harmonic currents being generated by the VFD drive and the uneven sharing of the load current between the two secondary coils of each transformer. It was decided that the best solution was to fit inductance coils (chokes) to the power supply for the main thruster motors to filter out the harmonic currents. Ducted air conditioning systems, each with two refrigeration units, were also installed to supply cold air to each of the transformer enclosures to help cool the transformer windings.

During the modification work in Singapore, the number two thruster transformer was found to have a heat damaged winding and some overheating damage to its bus-bars. A consultant was called in and he inspected the transformer and considered that the damage was the result of an arc fault at the low voltage connections of the transformer and that it had 'suffered some impairments due to the occurrence of an abnormal event'. After evaluating the transformer, he determined that it was suitable for continued operation up to full power using the new ventilation and cooling system.

After the refit, all of the thrusters were successfully tested for four hours at full load without any signs of the transformers overheating. However, during the trials the engineers noticed that the newly installed chokes had, they suspected, created a new problem with the propulsion system. The modified system now appeared to have a significant power factor[12] problem which was the result of resonance in the propulsion electrical system. The plant was operating with an indicated power factor as low as 0.49 when it should have been around 0.80. The engineers made some minor improvements in the power factor by making adjustments to the generator automatic voltage regulators (AVR).

On 27 July 2005, *Safe Concordia* left Singapore, under its own power, en route to the Yolla gas field in Bass Strait, Australia. *Safe Concordia* would make a scheduled stop at Gladstone, Queensland, during the passage to Yolla. It was decided to carry some electrical engineering specialists during the voyage to further investigate the power factor problem in the propulsion system.

On the morning of 4 August 2005, while the platform was north of Java, Indonesia, one of the ship's electricians noticed an unusual electrical smell, similar to 'burnt cable' in the vicinity of the transformer windings for the number one thruster. He also noticed that the winding temperatures had risen significantly during the night. The thruster was stopped and isolated. After a thorough inspection of the equipment, no abnormalities were observed. The thruster was then restarted without further incident.

At about the same time, the number three thruster transformer high temperature alarm activated. The sensor was changed and the unit briefly inspected. It was restarted but the temperatures did not stabilise until the air conditioning refrigeration unit was changed over to the standby unit.

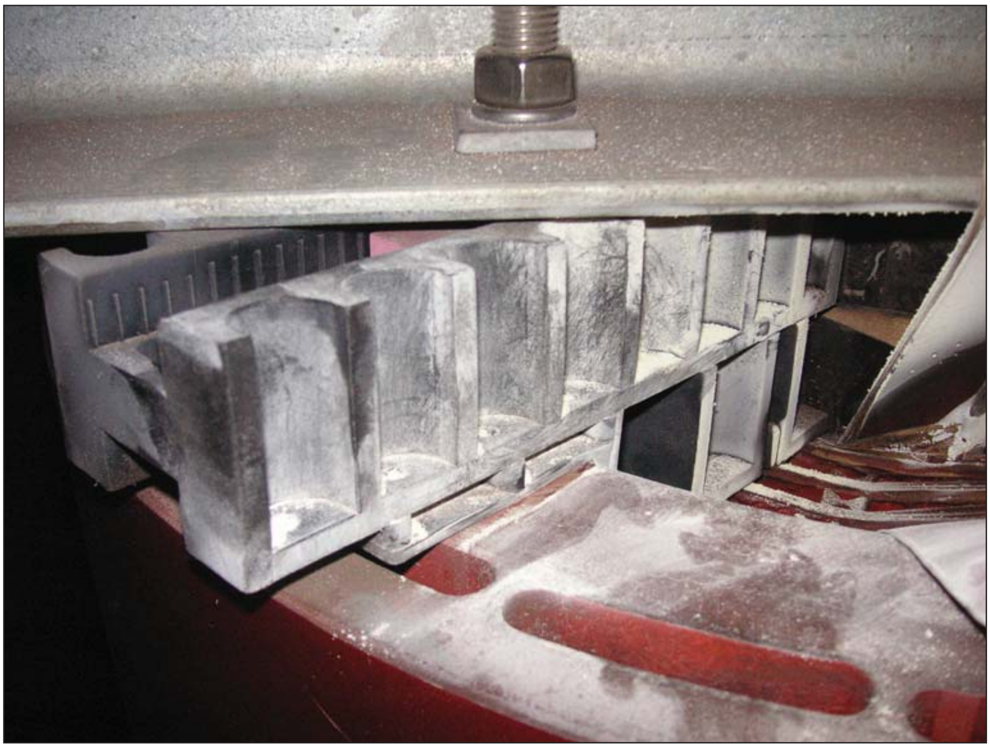
On 5 August 2005, while still north of Indonesia, *Safe Concordia* was taken in tow by the offshore support vessel *Lady Valisia* to reduce its transit time to Yolla. The platform was released from the tow on 11 August 2005.

On 11 August 2005, the number three thruster transformer again indicated a high temperature in one winding. Once again, an inspection was carried out but no problem was found. A short time later, one of the transformer cabinet exhaust fans was noticed to have tripped off, possibly leading to poor air circulation around the affected winding. The 'burnt cable' smell was evident in the transformer at this time.

On 21 August 2005, number two and number four thruster circuit breakers tripped off almost simultaneously. Number four thruster was reset and restarted without any problems although number one thruster tripped off immediately after number four was engaged. Number two thruster was found to have blown most of the fuses in the VFD. After discussions with the manufacturer, the VFD was exchanged with a spare and a transformer inspection carried out. The inspection revealed that the transformer was coated with a layer of fine grey dust that could not be explained at that time (Figure 13). The dust was removed and the thruster was returned to service.

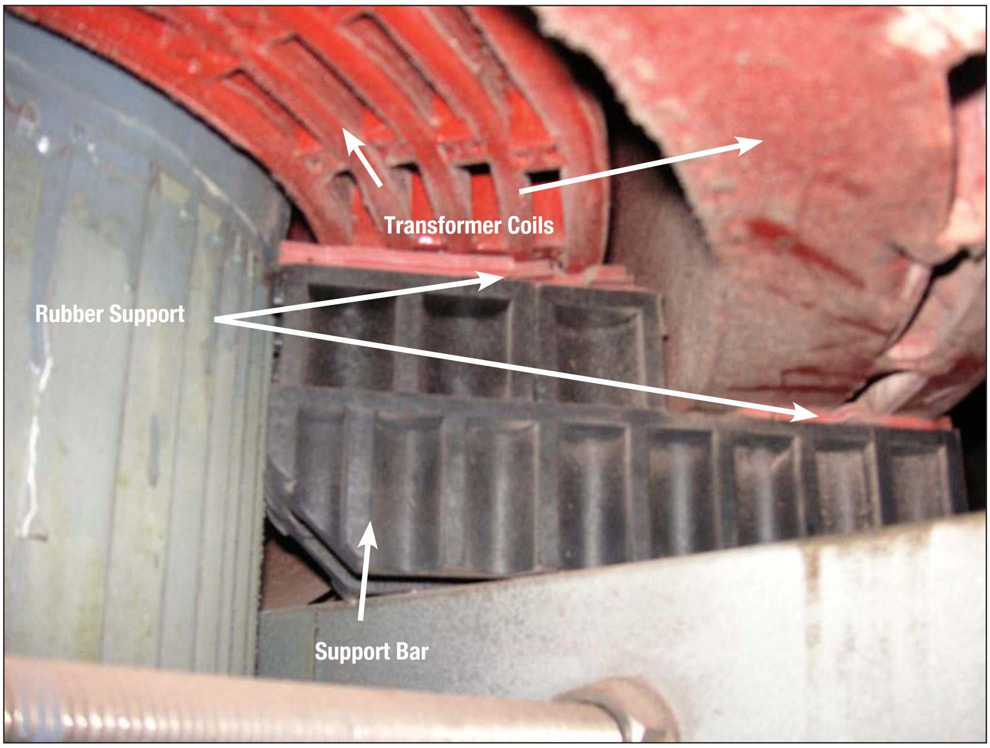
12 Power factor is the ratio between true power and apparent power. A low power factor represents a higher current flow within the system to drive a particular load.

Figure 13: Grey dust on a transformer top



The first revision of the formal safety assessment (FSA), dated 22 August 2005, was released to the National Offshore Petroleum Safety Authority (NOPSA) as part of the safety case required for *Safe Concordia*'s deployment to the Yolla gas platform in Bass Strait. The FSA did not mention any problems with the propulsion system.

Figure 14: Transformer bottom showing support bars and rubber supports

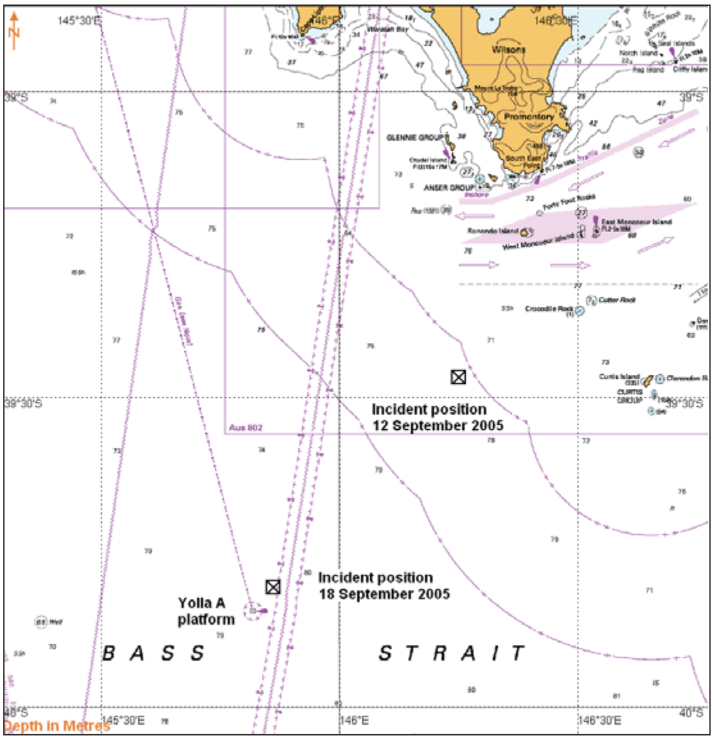


Safe Concordia arrived in Gladstone on 28 August 2005, where it loaded bunkers and cleared customs and quarantine for entry into Australia. During the stay in Gladstone, more electrical engineering specialists arrived on board to inspect the system's major components. *Safe Concordia* left Gladstone on 3 September, continuing the voyage south to Yolla.

The thruster transformers were inspected by a manufacturer's representative during the period 3 September to 5 September. All of the transformers showed some signs of overheating and signs of the grey dust, a sample of which was taken for analysis. The transformer coil support bars had also moved and some of the rubber support blocks were missing (Figure 14). All of the transformers were again cleaned and new rubber support blocks were fitted where appropriate. The transformers were electrically tested before they were re-energised.

In the early hours of 12 September, when *Safe Concordia* was nearing the end of its voyage and still 27 miles from Yolla (Figure 15), a fire detection system alarm sounded, indicating the number four thruster transformer room as the source of the alarm. The general fire alarm was sounded at 0048 and number four thruster was stopped and the transformer electrically isolated.

Figure 15: Section of navigation chart Aus 487



A breathing apparatus (BA) equipped fire party entered the space and identified the seat of the fire as the centre coil of the transformer. The remaining power to the compartment and the ventilation was isolated at 0055. The BA party made an unsuccessful attempt to extinguish the fire with a dry powder extinguisher before leaving the space. By 0105, only 36 personnel had been accounted for, so the master ordered a name check to identify the missing crew. At 0106, another BA team entered the transformer space and reported no flames at the site. At 0118, all personnel were accounted for and three crew members entered the space and discharged three portable carbon dioxide (CO_2) extinguishers into the transformer coil to ensure that the fire was extinguished. At 0151, the fire was declared extinguished.

A number of meetings were held during the next week to try to identify the cause of the short circuit in the transformer which led to the fire. However, no conclusions were reached.

Meanwhile, investigations into the power factor problem continued. It was decided that the newly installed chokes would be isolated from the system, by bridging them out, to check whether or not they were causing the power factor problem. This was to be achieved by leaving the chokes in place and fitting bridging cables around them. The procedure to be followed was agreed upon and an isolation certificate was issued.

A closed circuit television (CCTV) was fitted to monitor the choke cabinet during the test and, at about 0230 on 18 September, after the number one thruster chokes had been isolated from the system, load tests were started.

At 0326 on 18 September 2005, with the platform three nautical miles from Yolla (Figure 15), a fire detection system alarm sounded, indicating a fire in the port forward column. At the time, the contractors working on the power factor problem were in the engine control room and they saw the fire start while watching the CCTV camera that was monitoring the choke cabinet.

Electrical power to the area was isolated when the breaker for the thruster tripped. The test team members went to the number one thruster room and started closing the ventilation to the area. The muster signal was sounded at 0329 and at 0337 the first BA equipped fire party entered the thruster machinery space. By 0341, all personnel had been accounted for. At 0350, the on scene controller reported that the fire was extinguished. The crew then started ventilating the area to clear the smoke.

One crew member had inhaled smoke and fumes while he was trying to lower additional equipment down the access stairs to the thruster room. As he was not part of the BA party, but only assisting it, he was not using BA equipment at the time. He required medical treatment on board *Safe Concordia* but did not need to be landed ashore for further treatment.

At 1005 on 18 September, *Safe Concordia* departed the Yolla field for Melbourne using its remaining thrusters. On 20 September, *Safe Concordia* was assisted by tugs to transit the entrance into Port Phillip and sail to the Melbourne outer anchorage where the platform was anchored to await repairs and the supply of replacement parts for the propulsion system.

In January 2006, the platform was taken back to Singapore on board the heavy lift ship *Mighty Servant 1*. The thruster drive transformers were replaced with larger capacity units and the control software for the VFD was modified to address the harmonics and the power factor problems. The new VFD software was also designed to address the system's resonance.

Following the repairs, performance trials were successfully conducted without any sign of the previously experienced problems before *Safe Concordia* was returned to service.

2 ANALYSIS

2.1 Evidence

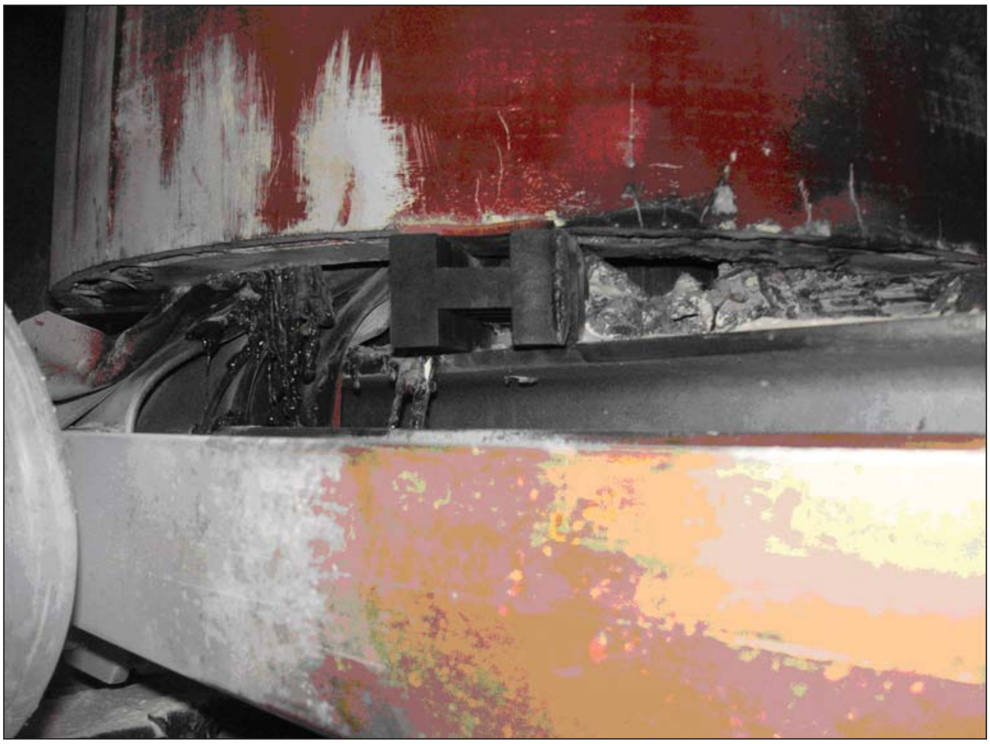
On 26 September 2005, two investigators from the Australian Transport Safety Bureau (ATSB) attended *Safe Concordia* at the Melbourne anchorage. The master, chief engineer and the other involved crew members and specialists were interviewed and provided their accounts of the incidents. Copies of relevant documents were obtained including the safety case submitted to the National Offshore Petroleum Safety Authority (NOPSA), log book entries, operations manuals, various procedures and statutory certificates. Photographs of the damage to the transformer and a forensic fire examination report were also obtained.

2.2 The fires

2.2.1 Transformer fire

At 0048 on 12 September 2005, *Safe Concordia* suffered a fire in its number four thruster transformer. The damage to the transformer was localised and this indicated that the origin of the fire, and the fault that caused it, was contained within the centre coil of the transformer (Figure 16). The fire could only have been fuelled by the resin insulation within the transformer. These materials were probably ignited by electrical arcing within the transformer coil due to the failure of the insulation.

Figure 16: Localised fire damage on number four transformer centre coil



When supplying nonlinear loads, such as variable frequency drives, transformers are particularly vulnerable to overheating and early-life failure. This occurs because of the harmonic currents in the system. The harmonic currents produce no valuable output but increase the electrical losses of the system and reduce its efficiency. Within the transformer, the harmonics increase the eddy currents[13], copper losses and magnetic losses of the transformer, resulting in greater heat than usual being generated within the transformer windings. The heat produced, if not removed, will cause the temperature of the transformer windings to rise, possibly to the point where the transformer insulation is damaged.

There are two methods normally used by designers to combat this problem; de-rating an existing transformer; or using a 'K-Rated'[14] transformer. K-rated transformers are usually preferred to de-rated transformers because they are designed to run at their rated kVA loads in the presence of harmonic currents. They are more electrically robust and are designed to minimise the generation and effect of eddy currents.

Correctly rated transformers can operate continuously without damage or loss of performance. However, if the transformer is not correctly selected or its operating conditions fall outside its rated capacity, it will, inevitably, be damaged or fail completely. All of the transformers on *Safe Concordia* had a history of overheating, suggesting that they were not correctly rated for their intended service conditions.

The presence of any electrical imbalance between the phases of the electrical system magnifies the effect of the harmonics. Load tests were conducted on board *Safe Concordia* in September 2005, after the platform had again experienced transformer overheating problems, and the tests found that the transformer phase voltages were not balanced and that the harmonic distortion was higher than expected. The voltage imbalance increased the harmonic distortion and thereby increased the electrical overload experienced by each transformer.

Given that each thruster motor was rated at 2500kW, it is possible to calculate the required rating for a thruster transformer at various power factors and harmonic loads, assuming that the load is evenly balanced between each of the phases. A transformer rated at 3200 kVA was specified for the thruster power system and this should have been suitable for the thruster motor provided that the phases were balanced, the power factor remained above 0.8 and the harmonic distortion remained below 20%.

The overheating of the transformers on board Safe Concordia suggests that they were not able to withstand the harmonic currents. Furthermore, the system resonance and the unbalanced phases were causing the transformer to become saturated, i.e. unable to develop additional magnetic flux and, therefore, unable to provide increased output when the supply is increased. These factors, in turn, suggest that the transformer specification was not sufficient for its intended service conditions. The transformers did not have a suitable 'K-rating'.

All of the transformers on board *Safe Concordia* had experienced some degree of overheating. In addition to the harmonic currents, a subsequent analysis of test results from the thruster load tests by the VFD manufacturer determined that the VFD was causing a significant DC component in the transformers that caused the transformers to saturate and overheat.

---

13 A current that swirls within a large conductor, such as a transformer core, that is induced by the moving magnetic field formed by the AC power input and causes energy to be lost as heat.

14 K-ratings reflect how well a transformer can withstand the added current and heating effects resulting from harmonic loads. A higher K-rating can withstand greater harmonic loads.

Number two transformer had shown significant signs of heat damage to the aluminium connection bars and to the insulation when it was inspected in Singapore in May 2005. The presence of an ash-like grey/white powder on the transformer coils suggests that there were partial discharges[15] occurring within the coils. The heat from these partial discharges caused a further breakdown in the insulation. The chemical analysis of the dust revealed the presence of 8 % aluminium oxide, 5% iron oxide, 3% copper oxide, 4% silicon oxide and 70% carbonate residue. These results are consistent with a breakdown of the insulation and oxidisation of the aluminium busbar connection strips and of the transformer due to heat.

The evidence suggests that the fire in the centre transformer coil of number four thruster transformer on 12 September was probably the result of an internal short circuit within the transformer. The short circuit was caused by a breakdown of the transformer insulation due to overheating of the transformer, probably due to the effect of the DC components and high harmonic currents supplied by the VFD, because the transformer was not suitably rated.

2.2.2 Choke cabinet fire

After the chokes had been fitted to the propulsion electrical system in Singapore to reduce the effects of the harmonics on the transformer, the engineers noticed a change in the propulsion system's power factor at particular thruster loads.

All AC circuits have a resonant frequency which is determined by the capacitance and inductance of the system. The impedance of a circuit, the result of its capacitance and inductance, determines the current flow in the circuit and it changes at the resonant frequency. Electrical power systems are normally designed so that the resonant frequency is not in the normal operating frequency range of the system.

The propulsion system on board *Safe Concordia* was fitted with a filtering capacitor on the DC bus of the VFD, as well as the natural capacitance of the cable runs. The wire coils of the transformers and motors provided the inductance. Analysis suggests that the introduction of a choke (additional inductance) into the thruster electrical system changed the system's resonant frequency characteristics and moved the resonant frequency to within the system's operating range. This allowed the propulsion system to become vulnerable to the effects of the changed impedance which occurred when the system was operating at the resonant frequency.

During the voyage to Bass Strait, the electrical plant's monitoring system indicated that the propulsion electrical system had a low power factor at between 45% and 55% of full load. The apparent low power factor was subsequently determined to be the result of system resonance causing very unbalanced and distorted voltages and currents within the system.

When the electricians decided to test the system characteristics without the choke in place, it was electrically removed from the system by placing a bypass bridge across it while still leaving it in the circuit. The procedure for bridging the choke was discussed and agreed to by the team of electrical specialists. The existing cables in the choke cabinet were too short to be used directly so bridging cables and connection strips were manufactured and bolted onto the choke bus connections. The bridging cable for each phase consisted of six strands of electrical cable of sufficient cross-sectional area to carry the full load current. The wiring lugs and connection strips were manufactured on board the platform out of pieces of the

15 Small electrical arcs occurring between wires in the coils as the insulation breaks down.

earth straps from the unusable number four thruster choke. The weight of the cables was supported using nylon cable ties attached to the top of the cabinet.

All of the connections were bolted together and then insulated from each other, and from the choke coils, with rubber sheeting. Due to the small size of the choke cabinet, access to the bridging cable connections within the cabinet was difficult, making it awkward to tighten the bolted connections. Furthermore, not all of these connections were checked for tightness with a spanner before the system was re-energised. An inspection of the choke cabinet after the fire by a forensic electrical specialist concluded that:

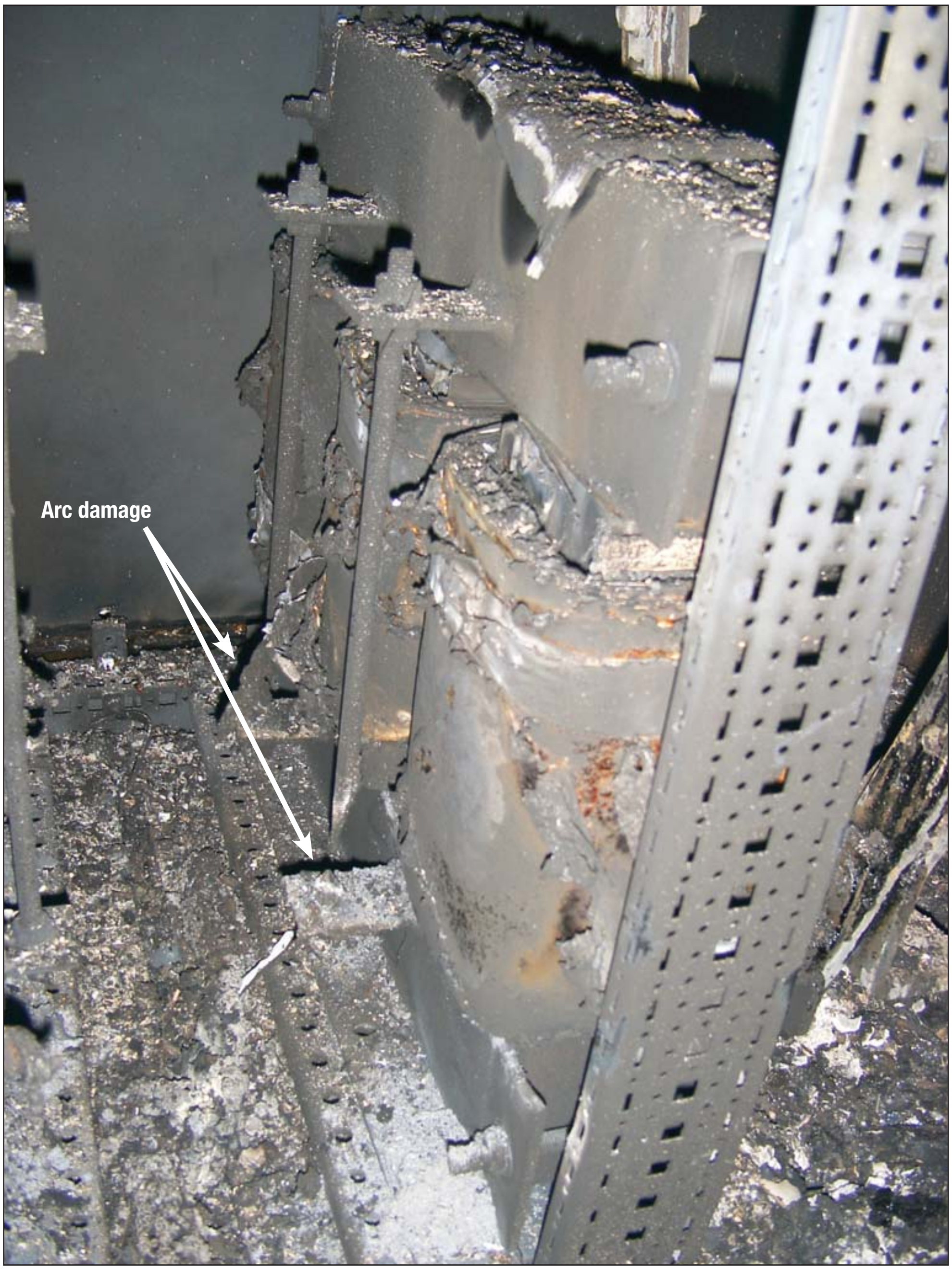
> The work appears to have been rushed. I suspect that the possibility of intermittent connections was not contemplated, and was not obvious because of the crowded conditions. Some connecting busbars were done correctly. Some were not. It appears most likely that two different tradesmen were working in the area. One was careful. The other was not.

Figure 17: Burnt out upper section of the choke cabinet showing extra cables

At 0326 on 18 September, the insulation on the cables within the choke cabinet, and the rubber sheeting, caught fire while the electrical contractors were testing the system under load.

The fire, as observed by the testing team, appeared to start near the left hand side of the lower chokes and then spread to the right hand side of the choke cabinet. A detailed examination of the cabinet revealed that the tie bolts for the lower right hand chokes, between the two lower banks of chokes, had sustained arc damage. An arc had occurred between the lower turns of the adjacent coils and these tie bolts.

Figure 18: Burnt out lower section of the choke cabinet showing arc damage



An examination of the connections between the bridging cables and the terminal strips, after the fire, revealed arc erosion damage on the lower, right hand choke's centre connection. This was consistent with it not being sufficiently tight and an arc occurring across it. The same connection also showed signs of overheating, consistent with arcing or a high resistance across the connection due to it being insufficiently tightened.

There was also evidence of arcing between the new bridging cables and the existing, lower, choke terminals. This suggests that the extra cable length and weight had caused the connections to distort in the crowded cabinet and make arcing contact with the unused choke terminals.

The most likely sequence of events was that an intermittent electrical connection to the lower, right-hand, centre choke resulted in overheating of the adjacent cable insulation which, in turn, caused a fault to earth in the lower right-hand coils. This earth fault subjected the remaining lower chokes to about 1.73 times their normal voltage to earth. A second arc then occurred to earth, followed by a phase-to-phase fault between the chokes, by way of the chassis and the tie bolts.

The duration of the entire sequence of events from the initial failure to earth to the final phase-to-phase fault which resulted in the circuit breaker tripping off would have been measured in seconds. If it had been longer then it would almost certainly have been noticed by the test team who were looking for any significant anomaly.

A subsequent review of the monitoring system showed that the phase-to-phase fault had been recorded as 14 000 Amps for approximately 60 milliseconds before the circuit breaker tripped off and isolated the power from the chokes. The heat from this second arc probably ignited the rubber sheeting that had been fitted to insulate the bridging connections and which protruded around and over the chokes.

In submission, Prosafe Productions, the new owners of *Safe Concordia*, stated that:

> A forensic team from Keppel FELS Insurance Company came onboard later and they determined that the fire had started with arcing between the terminal and the chassis or enclosure of the choke.
>
> This caused enough concern that we decided later on to subject one of the chokes to high voltage test until destruction. Arcing occurred as suspected and all of our chokes were modified and extra insulation added to prevent this happening.

The execution of the task of bridging out the number one thruster choke on 18 September was not adequate. While suitable materials were used, the terminal connections were not all tight enough to provide low resistance electrical connections and this fault was not detected before the number one thruster electrical system was re-energised and tested under load.

2.3 Human factors

The choke for number one thruster transformer was isolated from the electrical system at around 0200 on 18 September. While this decision may have met with the electrical contractors' enthusiasm and desire to locate the source of the problem, there was no external pressure on them to complete the task at that time.

When the human body is required to work at times that are incongruent with the body's biological or circadian rhythms, cognitive processing and performance may become compromised[16]. During this time, operational personnel may have more difficulty integrating information efficiently, maintaining a clear picture of the overall situation, have increased difficulty performing activities and may experience degradation of accuracy and timing.

The electrical contractors may not have effectively considered the impact of their decreased alertness on the decision making process or the execution of the task, given the time of day. The decision to isolate the chokes, and to test the effect this action would have on the system's power factor, represented a logical progression from their previous testing strategies. However, the decision to conduct the test at approximately 0200, when circadian rhythms and alertness levels are at their

16 Caldwell, J.A., & Caldwell, J.L., (2003). Fatigue in aviation: A guide to staying awake at the stick. Ashgate Publishing Company: USA

low point, was not optimal. It is therefore possible that time of day effects, and the operators pre-existing alertness levels, may have contributed to the bolted connections not being tight enough and for the fault to go undetected.

The electrical specialists had identified the risk of fire and had installed a CCTV in the cabinet for the early detection of a fault. They do not appear to have fully considered the implications for, or the ready availability of, the crew that would have to respond in the event of a fire occurring.

The decision by the electricians to isolate the chokes from the electrical system at 0200 did not consider the increased risk associated with performing the task at that time of day.

2.4 Column structure fire fighting

The fire fighting equipment fitted in the thruster rooms on board *Safe Concordia* and access to the compartments were designed in accordance with ABS rules which were based on SOLAS[17] regulations and the IMO's[18] MODU[19] Code .

The lack of a fixed fire extinguishing system in the columns, as well as a single point of access, exposed the crew to significant risks in the event of a fire in a thruster machinery room because in order to fight a thruster machinery room fire, entry to the space had to be made from above the fire.

'Category A'[20] machinery spaces are defined by ABS as those spaces that contain either internal combustion machinery used for main propulsion, internal combustion machinery used for other purposes with a total power of over 375 kW, or an oil-fired boiler or oil fuel unit. This definition reflects the risks associated with the machinery contained within a 'Category A' machinery space. ABS requires that a 'Category A' machinery space is provided with a fixed fire extinguishing system while all other machinery spaces are to be provided with a sufficient number of portable fire extinguishers, or other means of fire extinguishing, either in or adjacent to the space.

The thruster rooms on board *Safe Concordia* are not 'Category A' machinery spaces and are not required to be fitted with a fixed fire extinguishing system. A fire in a thruster room can, therefore, only be fought by isolating the compartment and using boundary cooling, difficult to achieve with a column structure, or by entering the compartment and using portable fire extinguishers or fire hoses. If a fixed fire extinguishing system was installed for the thruster machinery rooms, a fire could be effectively fought without exposing the crew to the extra risks involved in entering the compartment from above.

'Category A' machinery spaces are also required to have two means of escape, one from the upper part of the space to the open deck and another which provides a safe escape route from the lower part of the space. For other machinery spaces, ABS may accept a single access for spaces that are only accessed occasionally. *Safe Concordia*'s thruster machinery rooms do not need to be accessed regularly and only have a single access at the top of the compartment. Under normal circumstances, a single

---

17 The International Convention for the Safety of Life at Sea, 1974, as amended.

18 International Maritime Organisation.

19 The IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units, Consolidated Edition, 2001.

20 ABS Rules for Building and Classing Steel Vessels, Part 4 - Vessel Systems and Machinery, Chapter 7 Fire Safety Systems.

point of access to the thruster rooms should be adequate. However, in the event of a fire, the single access is located above the fire which exposes the crew attempting to enter the compartment to the risk of severe injury. A second, lower, access would allow the crew to enter the compartment without being exposed to the heat rising from a fire and, possibly, from below the seat of any fire.

While *Safe Concordia*'s columns contain propulsion machinery, they do not meet the requirements for a 'Category A' machinery space. The high currents drawn by the propulsion machinery and the fact that the propulsion system is running for extended periods of time means that the risk of a fire occurring in a column is higher than in other, non 'Category A' machinery spaces, such as a bow thruster room. Furthermore, the consequences of a fire occurring on board the platform, while it was stationed 29 m from an oil/gas platform are also potentially more severe.

In submission, ABS stated that:

> Note that these regulations and the ABS rules represent the minimal standard necessary for design, construction and operation of marine vessels. Flag States and Coastal States may request any additional requirements they feel are necessary; however we have no such requirement from the original flag state for this unit, Panama, nor have we received any additional requirements from the present flag state, Singapore.

It appears that the definition of a machinery space in the ABS rules does not adequately consider the fire risks associated with modern diesel-electric propulsion systems in column structures, as there is no requirement for a fixed fire fighting installation or two means of access. Furthermore, the rules do not adequately consider the hazards to which the crew would be exposed if they were fighting a fire in a thruster machinery room, risks which could be significantly reduced by either installing a fixed fire fighting extinguishing system and/or a second, lower, access to the compartment.

In response to this, ABS stated that:

> As our Rules essentially mirror the international requirements, we do not feel it necessary to make change at this time. With regard to the comment that the ABS Rules do not adequately consider the electrical systems associated with modern diesel electric propulsion in a column structure, we disagree, noting that the IMO requirements were last updated 2001.

While the IMO requirements were updated in 2001 and the ABS rules do mirror the international requirements, it is noted that the ABS Rules represent a minimum standard.

2.5 Acceptance criteria

Neither *Safe Concordia*'s endurance nor its DP-2 capability were proven at full load before the platform was deployed on its first operational contract to Bayu Undan in March 2005. The propulsion system was modified, but still remained unproven, when *Safe Concordia* sailed to the Yolla gas field in July 2005.

The ABS rules for DP systems[21] require that:

> Upon completion of the installation, performance tests are to be carried out in the presence of a Surveyor on a sea trial. This is to include but not limited to running tests at intermittent or continuous rating, variation through the design range of the magnitude and/or direction of thrust, vessel turning tests and vessel manoeuvring tests.

The ABS rules for propulsion electrical installations require that[22]:

> Complete tests are to be carried out including duration runs and maneuvering tests which should include a reversal of the vessel from full speed ahead to full speed astern, tests for operation of all protective devices and stability tests for control. All tests necessary to demonstrate that each item of plant and the system as a whole are satisfactory for duty are to be performed.

The ABS rules do not specify a time period for the endurance trial but the time for this trial is determined by agreement with all of the interested parties.

The trials programme, as agreed for *Safe Concordia*, had required the thruster system to be run at full load for four hours to meet the ABS rules for testing an electrical propulsion system but the tests were aborted because the transformer temperatures were unexpectedly high. The tests were completed at only 80 percent of full load for the required four hours.

In this instance, the endurance tests, as agreed, on the electrical propulsion system were not completed before the platform sailed from Singapore to Bayu Undan for its first charter because of the electrical problems that presented during the trials.

The decision was made to deploy *Safe Concordia* to Bayu Undan to meet contractual obligations. Even though the endurance tests had not been completed, the vessel's operator agreed to send the platform to the Bayu Undan because it was unlikely that the platform would need its thrusters at 100 percent loads in the calm tropical conditions. This decision, while made on commercial grounds, did not adequately consider all the risks associated with the fact that the propulsion system had not yet been proven as reliable and the DP-2 capability at full load, vital when working so close to another platform, had also not been proven as reliable because it had not been run at full load for the endurance tests.

Despite the fact that the platform did not complete its test regime in March, no 'condition of class' was issued by ABS for the platform before it sailed Bayu Undan and an interim certificate of class was issued on 15 March 2005.

In submission ABS stated that:

> Subsequent investigation by the system designer attributed the high temperatures to air flow restrictions caused by the placement of the transformers near the bulkhead, thus restricting air flow. Exhaust fans and ducts were installed to improve the air flow through the transformer coils subsequent to the sea trails. The attending surveyor exercised his judgement and accepted the sea trial as satisfactory.

When Safe Concordia completed its first charter, it returned to Singapore for modifications to the electrical system in an attempt to rectify the overheating problems in the thruster transformers. The modifications were made despite

21 ABS Rules for Building and Classing Steel Vessels, Part 4 - Vessel Systems and Machinery, Chapter 3 Propulsion and Maneuvering Machinery.

22 ABS Rules for Building and Classing Steel Vessels, Part 4 - Vessel Systems and Machinery, Chapter 8 Electrical Systems.

the fact that the origin of the transformer overheating problems was not fully understood.

Before sailing from Singapore on 27 July 2005, the platform conducted endurance trials at full load. *Safe Concordia* was issued with its full term certificate of class by ABS on 29 July 2005, after trials were successfully completed following the modification work in Singapore.

Safe Concordia was issued with its full term certificate of class by ABS on 29 July 2005, after trials were successfully completed following the modification work in Singapore.

Safe Concordia was deployed before propulsion system problems that were found during testing were understood and permanent, and more importantly, effective repairs were completed. The thruster system of the platform was not fully tested and proven to be reliable at full load before the platform was deployed operationally.

In response, ABS stated that:

> It is ABS opinion that the intent of the ABS Rules was met when we issued our Certificate of Classification. It is unfortunate that the vessel continued to have problems after delivery; however we do not believe this is a weakness in our Rules. This is a new one off design, the problems that this unit had are common problems that are often encountered with a new vessel design. Note that the builder, designer and owner have now rectified these issues and the vessel is now operating satisfactorily and has done so for the last fourteen months.

The failure to complete the tests was not in accordance with the ABS rules under which the platform was constructed. ABS issued a certificate of class before all of the classification requirements were met. ABS took a considerable risk when it issued a certificate of class before the platform had satisfactorily met its specified acceptance criteria. The platform was not fit for its intended duty because it had been unable to meet its agreed acceptance criteria.

2.6 Safety case

Before an offshore petroleum facility can be used in Australian waters, its operators must prepare a safety case which must be submitted to, and accepted by, the National Offshore Petroleum Safety Authority (NOPSA).

The *Safe Concordia* safety case, in particular for its use about 29 m from the Yolla gas production platform, was based on *Safe Concordia* having been designed and constructed to meet the ABS classification requirements for a DP-2 facility.

An element of the safety case is a formal safety assessment. This assessment was conducted shortly before submission of the safety case to NOPSA in August 2005. By that date, the platform had begun to experience signs that the propulsion system was flawed, despite the modifications made in Singapore. The problems, however, were not addressed in the safety case that was submitted to NOPSA.

The formal safety analysis (FSA) states that the FSA is a 'key means of verifying that the *Safe Concordia* design meets the safety goals and risk acceptance criteria'. It also states that '*Safe Concordia* was built under special survey of the American Bureau of Shipping (ABS) to the highest classification…'.

The core of the FSA is the hazard identification process which identified a number of potential hazards and major accidental events. A risk analysis was undertaken to determine the severity, frequency and degree of risk associated with each identified hazard. Of the identified hazards, three relate to the incidents which occurred on board the vessel en route to Bass Strait and need more detailed examination: DP system failure, fire in an engine room or machinery space and electrical fire.

DP failure, and a possible impact with the adjacent Yolla gas facility during positioning or maintaining station, was analysed. The measures for prevention, control and mitigation included the DP-2 system that had been approved by ABS. It was determined that the risk of DP failure was acceptable, meaning that, in the view of those conducing the assessment, that no further measures to reduce the risk were justifiable. This analysis was undertaken without any consideration of the propulsion system problems that had been occurring since the platform was built.

Electrical fires were identified in the FSA as a hazard. The potential causes included deterioration of electrical equipment, short circuits and incompatible equipment. The risk was determined as unacceptable, as a consequence of which, further assessment was undertaken to identify additional control measures that could be implemented. The prevention measures listed in the FSA included the maintenance and testing schedule and the installation of fuses. The detection, protection and recovery measures included the fire detection system and the fire extinguishing equipment. The overheating problems within the electrical system did not form part of the analysis of this hazard.

The analysis of fires in the engine rooms and machinery spaces determined that one possible consequence of such a fire was ‘smoke development and fire leading to personnel injury’. The FSA identified several factors that would limit the risks including, crew training, fire detection systems and fixed fire extinguishing systems. Despite the fire detection and protection systems fitted on board *Safe Concordia*, one crew member suffered the effects of smoke inhalation while taking part in the fire fighting operations on 18 September 2005 after the choke cabinet caught fire. There was no fixed fire extinguishing system for the thruster room, or a second means of access, so the risks to the crew were higher in the event of a fire in that area compared to other areas of the platform. In retrospect, the safety case did not sufficiently identify the fire risk in different machinery spaces.

While the safety case was used to determine the suitability and safety of *Safe Concordia* while operating at the Yolla platform in Bass Strait, it did not take into account the problems within the propulsion electrical system and did not fully consider the consequences of a fire occurring in a column structure that did not have a fixed fire extinguishing system or a second means of access.

3 FINDINGS

3.1 Context

During *Safe Concordia*'s voyage from Singapore to Bass Strait, the platform experienced two electrical fires in its thruster power system. On 12 September 2005, a fire started in the platform's number four thruster transformer and on 18 September, a fire occurred in an inductance choke cabinet that was providing power to the number one thruster motor.

From the evidence available, the following findings are made with respect to the incidents on board *Safe Concordia* and should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing safety factors

1. The thruster transformers were not adequate for the high harmonic currents and system characteristics of the propulsion electrical system on board *Safe Concordia*.
2. The endurance test, as required by the American Bureau of Shipping (ABS), was not successfully completed before ABS issued a certificate of class for the platform in March 2005. Consequently, unresolved faults remained in the propulsion electrical system that may have compromised the platform's DP-2 classification. *[Safety issue]*
3. The safety case submitted to the National Offshore Petroleum Safety Authority (NOPSA) did not take into account the problems within the propulsion electrical system that had occurred before the platform was deployed to the Yolla gas field in Bass Strait, Australia. *[Safety issue]*
4. The inductance chokes had been installed in the propulsion electrical system to reduce the harmonic currents in the transformers but the chokes probably caused a fault, that appeared as a low power factor, because the change in the system's resonance resulted in highly distorted and unbalanced voltages and currents.
5. The overheating of the transformer insulation, which resulted in the fire on 12 September 2005, was probably the result of transformer saturation that occurred because of the DC input into the transformer and the unbalanced voltages and currents in the system.
6. An arc, or a high resistance connection, which resulted in the fire on 18 September 2005, occurred when the chokes were bridged out of the electrical system for testing.
7. While suitable materials were used for the task of bridging out a major electrical component, the task was not adequately performed, resulting in a fire in the cabinet housing the electrical equipment. *[Safety issue]*

3.3 Other safety factors

1. The American Bureau of Shipping (ABS) rules do not define *Safe Concordia*'s column structure spaces, containing the propulsion electrical system, as 'Category A' machinery spaces. Therefore, the need for a fixed fire fighting extinguishing system and two means of access to the thruster machinery spaces have not been adequately addressed. *[Safety issue]*

4 SAFETY ACTIONS

4.1 Safety action taken by Keppel FELS

In January 2006, the Keppel FELS installed new transformers in *Safe Concordia's* propulsion electrical system. Instead of each thruster motor being driven through a single transformer with one primary coil and two secondary coils, two transformers were fitted for each motor. Each new transformer had the same rating as the original transformer, effectively doubling the total kVA rating of the transformers.

It was subsequently determined that the perceived low power factor, which was caused by system resonance, could be overcome by adjusting the gain on the VFD control loop and increasing the switching frequency of the VFD.

The new chokes fitted to *Safe Concordia's* propulsion system were modified to address the risk of a high voltage failure to earth.

Full load endurance tests were conducted after the new transformers were commissioned. The entire thruster system was found to operate satisfactorily without any signs of overheating.

4.2 ATSB recommendations

MR20070024

The endurance test, as required by the American Bureau of Shipping (ABS), was not successfully completed before ABS issued a certificate of class for the platform in March 2005. Consequently, unresolved faults remained in the propulsion electrical system that may have compromised the platform's DP-2 classification.

The Australian Transport Safety Bureau recommends that the American Bureau of Shipping (ABS) takes action to address this safety issue.

MR20070025

The American Bureau of Shipping (ABS) rules do not define *Safe Concordia*'s column structure spaces, containing the propulsion electrical system, as 'Category A' machinery spaces. Therefore, the need for a fixed fire fighting extinguishing system and two means of access to the thruster machinery spaces have not been adequately addressed.

The Australian Transport Safety Bureau recommends that the American Bureau of Shipping (ABS) takes action to address this safety issue.

4.3 ATSB safety advisory notices

MS20070007

While suitable materials were used for the task of bridging out a major electrical component, the task was not adequately performed, resulting in a fire in the cabinet housing the electrical equipment.

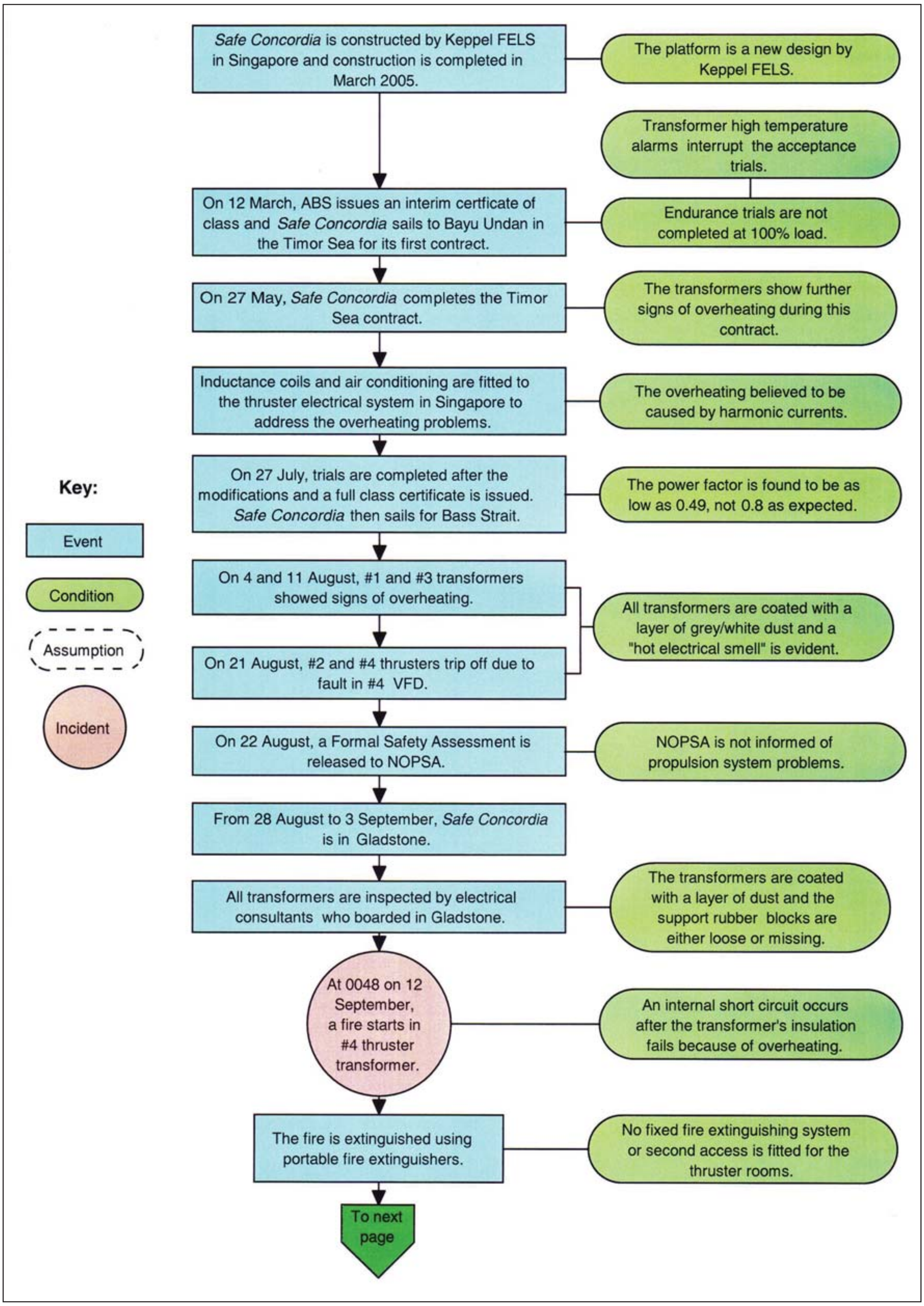
The Australian Transport Safety Bureau advises that the owners and operators of platforms consider the safety implications of this safety issue and take action when considered appropriate.

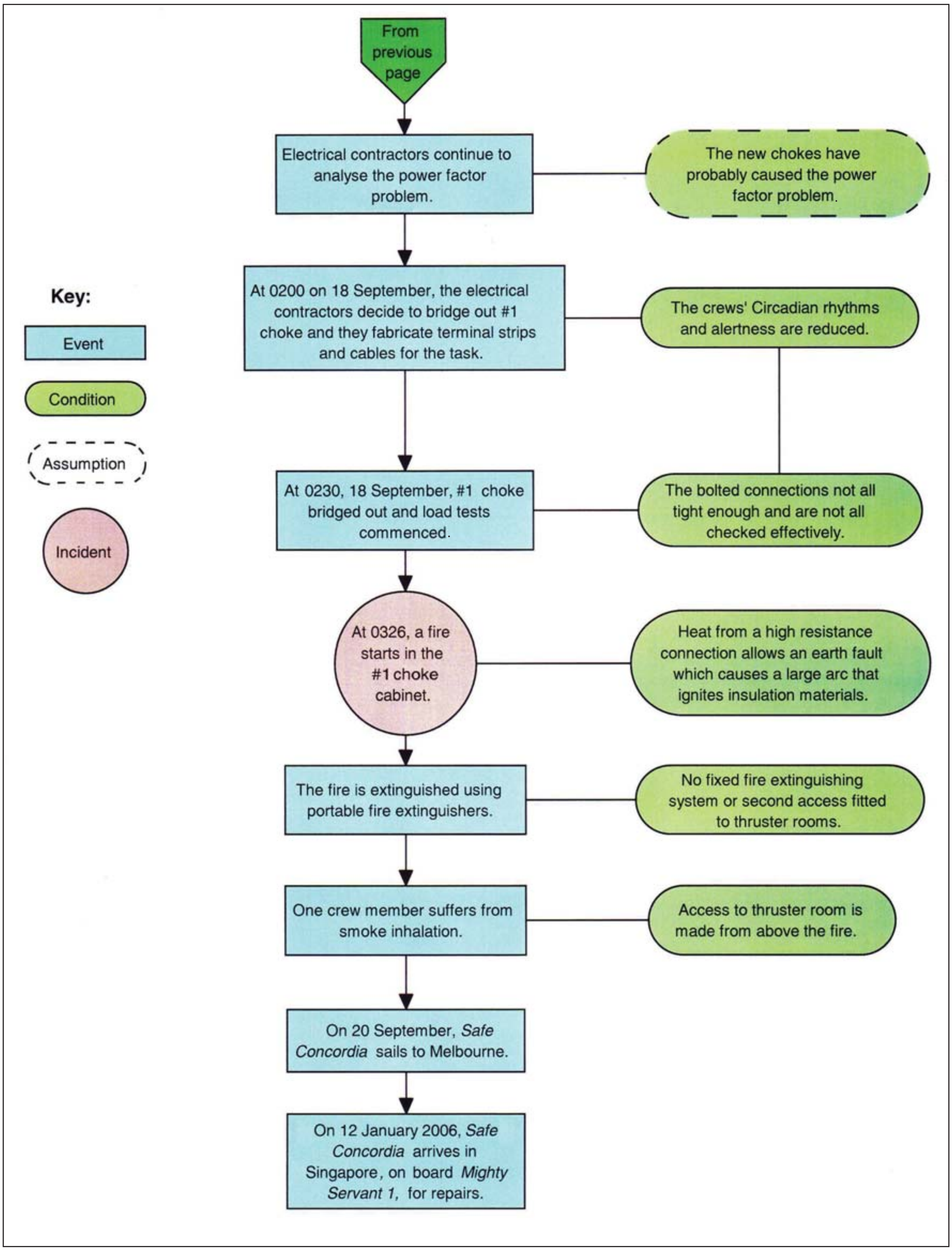
MS20070008

The safety case submitted to the National Offshore Petroleum Safety Authority (NOPSA) did not take into account the problems within the propulsion electrical system that had occurred before the platform was deployed to the Yolla gas field in Bass Strait, Australia.

The Australian Transport Safety Bureau advises that the owners and operators of platforms should consider the safety implications of this safety issue and take action when considered appropriate.

5 APPENDIX A: EVENTS AND CONDITIONS




From previous page
Electrical contractors continue to analyse the power factor problem.
The new chokes have probably caused the power factor problem.
Key:
Event
Condition
Assumption
Incident
At 0200 on 18 September, the electrical contractors decide to bridge out #1 choke and they fabricate terminal strips and cables for the task.
The crews' Circadian rhythms and alertness are reduced.
At 0230, 18 September, #1 choke bridged out and load tests commenced.
The bolted connections not all tight enough and are not all checked effectively.
At 0326, a fire starts in the #1 choke cabinet.
Heat from a high resistance connection allows an earth fault which causes a large arc that ignites insulation materials.
The fire is extinguished using portable fire extinguishers.
No fixed fire extinguishing system or second access fitted to thruster rooms.
One crew member suffers from smoke inhalation.
Access to thruster room is made from above the fire.
On 20 September, Safe Concordia sails to Melbourne.
On 12 January 2006, Safe Concordia arrives in Singapore, on board Mighty Servant 1, for repairs.

6 APPENDIX B: SHIP INFORMATION

6.1 *Safe Concordia*

IMO Number	8768127
Call sign	H99IU
Flag	Panama
Port of Registry	Panama
Classification society	ABS
Ship Type	Platform, semi-submersible
Builder	Keppel FELS, Singapore
Year built	2005
Owners	Joy Venture Investments Ltd
Ship managers	Consafe Offshore AB
Gross tonnage	16 700
Net tonnage	5010
Summer draught	5.94 m
Length overall	99.97 m
Moulded breadth	45.212 m
Moulded depth	20.11 m
Engine	5 x Wartsila 12V26A
Total power	17 950 kW

7 APPENDIX C: SOURCES AND SUBMISSIONS

7.1 Sources of information

National Offshore Petroleum Safety Authority (NOPSA).

Masters, officers and crew of *Safe Concordia*.

Various electrical specialists and consultants that were on board at the time of the incidents.

A forensic fire investigation report.

7.2 References

ABS Guidance Notes on the Control of Harmonics in Electrical Power Systems, 2006.

ABS Rules for Building and Classing Steel Vessels, Part 4 - Vessel Systems and Machinery.

Keppel FELS Drawings for *Safe Concordia*.

Keppel FELS, Failure Modes and Effects Analysis of Semi Submersible Accommodation Unit *Safe Concordia*.

'Power Electronic Converters for Ship Propulsion Electric Motors', Damir Radan

Safe Concordia - Formal Safety Assessment, Revision 1, August 2005.

Schneider Electric – Electrical Installation Guide 2005.

7.3 Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the Executive Director about the draft report.

The final draft of this report was sent to the National Offshore Petroleum Safety Authority, the Australian Maritime Safety Authority, the American Bureau of Shipping, the chief engineer on board *Safe Concordia*, the forensic fire investigator, Prosafe Production Services and the electrical specialists.

Submissions that were received from Prosafe Production Services, the National Offshore Petroleum Safety Authority, Keppel Fels, the American Bureau of Shipping and two of the electrical specialists were included and/or the text of the report was amended where appropriate.

8 APPENDIX D: MEDIA RELEASE

Bass Strait platform stopped by electrical fires

The ATSB has found that the self propelled accommodation platform *Safe Concordia* had been plagued by problems in its electrical systems since its construction and these problems had not been adequately addressed before the platform suffered two electrical fires in its propulsion system after entering Bass Strait in September 2005.

Safe Concordia is a dynamic positioning, self propelled, semi-submersible accommodation platform that uses four electrically driven thrusters to maintain its position. The platform's construction and delivery trials were completed in March 2005. The platform was used operationally for its first contract in the Timor Sea before modifications were made to address various electrical problems that had occurred within its propulsion system. After the modifications were completed, the platform sailed from Singapore, bound for Bass Strait, Australia, where it was to be positioned about 30 metres from the Yolla gas production platform.

On 12 September 2005, after the platform had entered Bass Strait, a fire started in one of the *Safe Concordia*'s thruster transformers. The Australian Transport Safety Bureau investigation found that the transformer fire was probably the result of an internal short circuit that occurred when the transformer insulation failed due to overheating. The transformers had overheated because of flaws in the design of the propulsion electrical system.

On 18 September, while still in Bass Strait, a fire occurred in an electrical cabinet that was providing power to another thruster motor. The cabinet fire was probably the result of an electrical arc that occurred when electricians had bypassed part of the electrical system to try and diagnose the ongoing problems and the execution of the task of bypassing the equipment was not adequately completed.

The ATSB report also concluded that *Safe Concordia* was not fit to fulfil its charter obligations in view of the unresolved faults in the thrusters' electrical power systems. The National Offshore and Petroleum Safety Authority had not been made aware of the problems and the design of the platform did not allow for effective and safe fire fighting in the thruster machinery rooms.

The ATSB has made several safety recommendations with the aim of preventing further incidents of this type.

Independent investigation into the fires on board
the Panamanian registered accommodation platform
Safe Concordia in Bass Strait, Victoria;
12 and 18 September 2005