Class A Accident Report

Superflyte

Fire/Evacuation

Vessel bearing 130° (T) x 0.5 nautical miles from Otahuhu Point, Motutapu Island on 22 August 2004

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REPORT NO: 04 3534

VESSEL NAME: SUPERFLYTE

Ship Type:	Commercial Passenger Ferry
Certified Operating Limit:	Inshore
Port of Registry:	Auckland
Flag:	New Zealand
MSA No.:	106157
Built:	1996
Construction Material:	Aluminium
Length Overall (m):	41.00
Registered Breadth (m):	12.01
Gross Tonnage:	578
Net Tonnage:	230
Registered Owner:	Fullers Group Ltd
SSM Company:	Dunsford Marine
Accident Investigator:	Ian Clarke

KEY EVENTS

1.1 On Sunday 22 August at 1530 hours NZST (New Zealand Standard Time), the Master and crew boarded ***Superflyte*** and proceeded to take over the operation of the vessel from the previous Master and crew. Some cargo was loaded and passengers embarked for the trip from Auckland to Waiheke Island.

1.2 At 1600 hours, ***Superflyte*** left Auckland. During the passage to Waiheke Island, the Engineer made rounds of both engine rooms and did a visual inspection of the machinery. He found nothing out of order.

1.3 At 1635 hours, ***Superflyte*** arrived at Waiheke Island. Passengers were disembarked and cargo discharged, after which 311 passengers and some cargo were taken on board for the return trip to Auckland.

1.4 At the time of departure, the Master was in the wheelhouse at the helm and engine controls. The Engineer was at the bow and the Service Supervisor at the stern to handle the mooring lines. Three 'On Board Service Crew' were stationed in the passenger saloons; one on the upper deck and two on the lower deck (*See Appendix 1 – Photograph 1 -* ***Superflyte*** *- alongside Fuller's wharf in Auckland, Photograph 2 - Lower Passenger Saloon & Figure 1 - General Arrangement Plan)*.

1.5 At 1702 hours, ***Superflyte*** left the wharf at Matiatia Bay, Waiheke Island and headed towards the Motuihe Channel (*See Appendix 2 – Chart NZ 532 Approaches to Auckland*). Soon after departure, the Services Supervisor made an announcement over the public address system, welcoming passengers on board, giving information about the voyage and advising them that lifejackets were stowed under their seats in the main saloons and in containers located around the vessel. Passengers were told that in the unlikely event of an emergency, they should follow the crew's instructions. After making the announcement, he went to the bridge to tell the Master how many passengers were on board and to advise Fullers office by radio about passenger numbers.

1.6 At 1708 hours, the On Board Service Assistant, stationed in the café in the upper passenger saloon, noticed smoke in the vicinity of the port funnel. She immediately went to the bridge and informed the Master.

1.7 The Master looked at the engine-room closed circuit television (CCTV) monitor, located to the port side of his chair, which showed, alternately, the views from CCTV cameras located in the fore parts of both the port and starboard engine rooms. As the monitor switched from the starboard to port engine room, the Master saw flames rising up from the top of the port main engine. The fire detector panel indicated that there was a fire in Zone 11, the port engine room (*See Appendix 3 – Photograph 3 – Steering Console*). At about the same time, fire alarm bells, situated in the passenger saloons, started to ring.

1.8 Realizing that the port engine was on fire, the Master operated the selector switch on the panel in front of him to stop the fans and to close the fire dampers for the port engine-room. The port engine stopped immediately.

1.9 The Engineer, who had just returned to the bridge from his station at the bow, went below to check on the fire and to activate the fuel shut-off lever, located at the top of the stairway leading down to the port engine room (*See Appendix 3 – Photograph 4 – Fuel shut off to starboard engine room*). The Services Supervisor went with him to assist.

1.10 The Master made the following announcement on the public address system: *"Emergency Stations. Emergency Stations. Please go to Emergency Stations as we have a fire in the port engine room. Would you please get your lifejacket from under your seat and put your lifejacket on"*. The Services Supervisor and On Board Service Crew helped some passengers who were having difficulty donning their lifejackets.

1.11 The Master then activated the fixed fire installation carbon dioxide (CO_2) release control that was located on the bridge, thereby releasing CO_2 into the port engine room. After the release, he could still see flames above the port engine and realised that the fire had not been extinguished. A few seconds later the picture on the engine room monitor disappeared as the fire destroyed the CCTV camera (*See Appendix 4 – Photograph 6 – Port Engine Room. The CCTV camera was mounted on top of the instrument panel seen in the centre of the photograph. For comparison, Photograph 5 – Starboard Engine Room, shows a similar view of the undamaged engine room*).

1.12 Soon after the Engineer had activated the fuel shut-off lever, he heard a bang and saw a cloud of white vapour through the window of the saloon door leading to the after deck. This was followed by a movement of passengers towards the starboard side of the saloon.

1.13 At 1711 hours, the Master put out a distress call and message on VHF radio Channel 16, advising all stations that there was a fire in the port engine room and that the vessel was off the Motuihe Channel. The distress call was acknowledged by Auckland Maritime Radio, the Coastguard and several boats in the vicinity. Auckland Maritime Radio asked how many people were on board and for the vessel's position, to which the Master replied that there were 311 passengers on board and they were off Tamaki Point Beacon *(See Appendix 2 – Chart NZ 532 – Approaches to Auckland – the position is marked with a cross)*. He also told the caller that there were sufficient liferafts on board for all persons; that the passengers were putting on lifejackets; the vessel was making way on one engine; the fire may have been smothered and that he was about to release a second bank of CO_2 into the port engine room.

1.14 At 1712 hours, Auckland Coastguard rescue vessels ***Markylla***, ***Rescue Alpha*** and ***Kyrenia*** were proceeding towards ***Superflyte*** and expected to be there within 15 minutes.

1.15 When the Engineer returned to the bridge, the Master told him that the fire may not be out and that he should release the second bank of CO_2 cylinders. The Engineer went to the CO_2 locker, but on seeing that its entrance door had been blown open and that the sheet of steel lining inside the door had been bent, he decided not to activate the second bank of CO_2.

1.16 The starboard engine was still running. The Master reduced speed to half ahead and ***Superflyte*** entered the Motuihe Channel.

1.17 At 1714 hours, ***Harbour Cat*** reported that it was 1 mile from ***Superflyte*** and was requested to keep heading towards them.

1.18 At 1715 hours, the Pine Harbour ferry reported that it was 8 minutes from ***Superflyte*** and was requested to keep heading towards them.

1.19 At 1717 hours, ***Kyrenia*** reported that it was immediately astern of ***Superflyte*** and was asked to check the port quarter for signs of fire or of the vessel taking a list.

1.20 At 1718 hours, ***Kyrenia*** advised that there was no smoke but there was a strong smell of burning rubber.

1.21 At 1718 hours, the pilot launch ***Waitemata*** reported that it was heading towards ***Superflyte*** and expected to be there in 15 to 20 minutes.

1.22 At about 1719 hours, the Master told the Engineer to check if the fire was out. With the help of some passengers, the Service Supervisor gathered the breathing apparatus and some portable fire extinguishers near the entrance of the port engine room and prepared to enter the compartment. The generator at the after end of the port engine room was still running at this time and, after starting the generator in the starboard engine room, the Engineer instructed him to turn it off as a precaution.

1.23 Acting on the Engineer's instructions, the Services Supervisor put on the self contained breathing apparatus and, very slowly, opened the door to the forward end of the port engine room. Flames were flaring up from the top of the engine so he closed it immediately. Opening the door again, he saw a steady fire, which he thought looked like insulation burning. Standing just inside the door, he managed to put it out using a CO_2 fire extinguisher. He then entered the engine room, intending to stop the generator, which was abaft the main engine. As he made his way past the engine towards the generator, the fire re-ignited and he put it out again, using up most of the CO_2 in the extinguisher. He tried to reach the generator but the Engineer, who was stationed by at the entrance, signalled for him to come out.

1.24 At 1720 hours, the clutch to the starboard engine disengaged. Although the engine continued running at idling speed, the Master could not re-engage the clutch. Without engines, he had no directional control of the vessel and decided to drop anchor. Since the crew were not at their normal seagoing stations, he used the public address system to call for them to prepare to let go the anchor.

1.25 Two On Board Service Crew and the Engineer went forward to clear the anchor, leaving a Police Officer from Waiheke, who was on board as a passenger, at the engine room entrance with the Service Supervisor.

1.26 At 1724 hours, the Master made an all-stations broadcast to advise that the fire was still burning and that they intended to attack it with hoses. He asked Auckland Maritime Radio whether the Fire Department was on its way. Auckland Coastguard advised that the Lions Rescue boat would be bringing them shortly.

1.27 ***Superflyte*** anchored approximately one mile to the east of Iliomama Rock, south-west of Rangitoto Island *(See Appendix 2 – Chart NZ 532 – Approaches to Auckland)*.

1.28 ***Superflyte*** requested ***Harbour Cat***, ***Starflyte*** and ***Seaflyte*** to come alongside to take off passengers. The Master used the public address system to advise passengers to proceed to evacuation stations and asked male passengers to assist them to board.

1.29 At 1729 hours, ***Superflyte*** started to transfer passengers to other Fullers Group vessels.

1.30 ***Starflyte*** was made fast to the starboard side of ***Superflyte*** and 198 passengers were transferred from ***Superflyte*** to ***Starflyte***. During the transfer, the weather conditions remained favourable with a slight chop on the sea surface and good visibility.

1.31 ***Harbour Cat*** approached ***Superflyte*** and, at the request of ***Superflyte's*** Master, put a line on ***Superflyte's*** port quarter to carry out boundary cooling with fire hoses. While carrying out boundary cooling, one of ***Harbour Cat's*** wheelhouse windows made contact with ***Superflyte's*** belting and was broken. ***Harbour Cat*** then moved to the starboard quarter of ***Superflyte*** and embarked passengers.

1.32 ***Seaflyte*** approached ***Superflyte*** and stood off with hoses ready to carry out boundary cooling if necessary. ***Seaflyte*** then came alongside ***Superflyte*** and took on board 58 passengers. While lying alongside ***Superflyte***, five windows on the port side of ***Seaflyte*** were broken by contact with ***Superflyte's*** belting.

1.33 At 1740 hours, Fire Service officers boarded ***Superflyte*** and took over from the Services Supervisor at the scene of the fire. They used CO_2 and dry power fire extinguishers on the fire and water hoses for cooling.

1.34 At 1746 hours, ***Superflyte*** advised Auckland Maritime Radio that the flames were out but were reigniting easily.

1.35 By 1754 hours, all passengers had disembarked from ***Superflyte*** and the fire was out. The vessel's crew and Fire Service officers carried out boundary cooling and monitored the engine room and its surrounding areas in case of re-ignition.

1.36 At 1820 hours, at the request of the Police, Auckland Maritime Radio cancelled the distress. ***Superflyte's*** crew made a thorough search of the vessel to ensure there were no passengers remaining on board.

1.37 At 1916 hours, the tug ***Mana*** arrived at the scene and was made fast to ***Superflyte***.

1.38 At 1920 hours, ***Superflyte*** weighed anchor and was towed to Auckland.

1.39 At 2025 hours, ***Superflyte*** berthed at Fullers wharf in Auckland.

1.40 At 2145 hours, Fire Service staff disembarked from the vessel.

1.41 At 2200 hours, the crew handed over the vessel to Fullers shore staff. Fullers stationed a security guard on site to secure the site until investigators arrived the following morning.

KEY CONDITIONS

2.1 *Superflyte* is an aluminium alloy twin-screw passenger catamaran with the following particulars:

- **MSA Number:** 106157
- **Overall Length (m):** 41.00
- **Registered Length (m):** 38.03
- **Breadth (m):** 12.01
- **Depth (m):** 3.70
- **Gross Tonnage:** 578
- **Service Speed:** 27 knots

2.2 *Superflyte* was built in 1996 by Wavemaster International Pty Ltd in Henderson, Western Australia under survey by Bureau Veritas to the following service notification: Special Service/Fast Passenger Ship/Catamaran. The navigation notation was: Coastal Waters. Plan approvals for hull and machinery were carried out by Bureau Veritas and the machinery was inspected by Bureau Veritas during construction and trials.

2.3 Between 26 and 28 November 1969, Bureau Veritas carried out the initial survey on ***Superflyte*** and on 2 December 1996 issued an interim certificate of survey for the vessel to carry 639 passengers in Auckland River Limits and 450 passengers in Auckland Extended River Limits. On 6 May 1997, on receipt of a declaration of survey from Bureau Veritas, the Maritime Safety Authority issued a New Zealand Certificate of Survey valid until 31 January 1998, for the vessel to carry 651 passengers in Auckland River Limits and 450 passengers in Auckland Extended River Limits. This Certificate was issued in accordance with the transitional Part X of the Maritime Transport Act 1994, which terminated on 31 January 1998 and thereafter the vessel was required to enter the Safe Ship Management (SSM) System. Initially, the vessel operated under Fullers own SSM system. In 2000 the vessel's SSM was transferred to M&I Safety Management Systems and in October 2003 to Dunsford Marine Ltd. After ***Superflyte*** entered the SSM system, Bureau Veritas was responsible for issuing the International Load Line Certificate and the Classification Certificate to cover hull and machinery and the SSM company was responsible for safety equipment and the safety management of the vessel.

2.4 *Superflyte* had a New Zealand Safe Ship Management (SSM) Certificate No. 1105, to operate as a Restricted Limit Passenger Ship, issued by Dunsford Marine Ltd on 2 May 2003, which was valid until 30 June 2006. The vessel was certified to carry up to 450 passengers within Auckland, Barrier, Northland and Bay of Plenty Inshore Limits and 651 passengers in all Enclosed Water Limits, within the Inshore Limits specified above.

2.5 Ownership and Management

2.5.1 *Superflyte* was owned and operated by Fullers Group Limited, Auckland. The Fullers group of companies emerged from the progressive amalgamation of a number of maritime transport and marine engineering companies based on the Waitemata Harbour and Haruaki Gulf, to provide waterborne transport services. In 1987, a new purpose-built vessel, capable of carrying 650 passengers, commenced service between Waiheke and Auckland. Subsequently the fleet was expanded and rationalized with the purchase of 6 more modern vessels and the sale of older vessels until it reached its present configuration of 9 vessels. These now transport over 3.9 million passengers; a total of 46.6 million passenger kilometres each year on scheduled services.

2.6 Propulsion Machinery

2.6.1 *Superflyte* was powered by two Deutz TBD 620 V16 high-speed four-stroke diesel engines, each rated at 1 820 kW at 1800 revolutions per minute (RPM). These drove two fixed pitch propellers through a reduction gear box. At the time the fire started, the starboard engine was running at 1 720 rpm and the port engine at 1 700 rpm. There was one engine located in each of the two catamaran hulls.

2.6.2 Both engines had 16 cylinders in ‘V’ formation. Each cylinder had a separate cylinder head, secured by four stud bolts and nuts. Above the engines were pipes for the main engine cooling water supply and air ducts and filters made of combustible material (*See Appendix 5 - Fire Engineer’s Report – the air ducts and filters in the starboard engine room are shown in the first two photographs*). Immediately forward of each engine was a control and instrumentation panel, above which was mounted a CCTV camera. Abaft each engine was another control panel and an independently driven diesel electrical generator. The engines were originally fitted with data logger and alarm systems. The data logger however, was removed after encountering difficulties with its operation, and since then the engines have been monitored manually as described in paragraph **2.15.5** of this report. Fullers reported that the servo-data-logger gave continuous problems from the time the vessel left Australia, causing the vessel to be off the service. The back-up service was poor with only one service person available worldwide. Fullers endeavoured to deal with the service agent by phone and he attended to the system several times during visits to New Zealand. In the end, Fullers decided that the system was more of a detriment than a benefit to the vessel. Accordingly, the data logger was removed and a new manual alarm system *i* installed, which included alarms and safety trips to stop the main engine in the event of it operating outside set parameters. Alarms and safety trips were tested at each annual classification survey.

2.6.3 Routine maintenance was carried out by Fullers Maintenance Department under the supervision of the company's Maintenance Manager. In conjunction with the vessel's Safe Ship Management company, Fullers Group had developed a planned maintenance programme based on a 4 year cycle for each of the 9 vessels in its fleet.

2.6.4 The engine manufacturer initially recommended the overhaul of cylinder heads every 8 000 running hours, but with provision to be able to extend this period, by inspecting cylinder valves with an endoscope[1], together with the random removal and inspection of cylinder heads. Fullers Maintenance Department had serviced similar cylinder heads on Motoren Werke Manheim (MWM) and Deutz 604 and 620 engines for 18 years and their experience had shown that the cylinder head servicing interval could be extended beyond 16 000 hours without any problem. They were currently overhauling TBD 620 cylinder heads every 16 000 hours.

2.6.5 It was estimated that ***Superflyte's*** engines ran for about 4 000 hours in a year and that the port engine had run for approximately 12 000 hours since its last major overhaul. The cylinder head bolts had been re-used after the overhaul.

2.7 Failure of Cylinder Head Stud Bolts

2.7.1 The fire resulted from the failure of the two stud bolts on the upper side of No. 6 inboard cylinder (cylinder B6) of the port engine. Failure of the bolts allowed combustion gasses, lubricating oil and unburnt fuel, at high pressure within the cylinder, to escape by forcing the cylinder head away from its seating. Cracks in the air intake manifold attached to the cylinder heads are evidence of the considerable bending moments acting on the side of the cylinder heads opposite the broken bolts. The hot gasses, lubricating oil and unburnt fuel were then ejected upwards and would have ignited on contact with the main engine exhaust manifold.

[1] Endoscope – an instrument for internal examination of enclosed cavities machinery. It usually incorporates two flexible fibre-optic cables, one to introduce light into the cavity and the other, fitted with a lens system, to transmit the image to a viewing device. The flexible cables can be inserted through a small opening, thus eliminating the necessity to open up machinery.

2.7.2 Metal Test Ltd of Penrose, Auckland, in conjunction with R&D Consultancy Ltd of Christchurch, both of whom were appointed as experts to assist the MSA in its investigation, carried out an investigation of the stud bolt failure and concluded that it was initiated by localised corrosion of the threaded area of the bolt where it emerged through the top of the cylinder head (*See Appendix 6 - Report by Metal Test Ltd*). The process of corrosion fatigue may be summarised as follows:

- Surface corrosion caused pitting of the threads
- Pitting relieved compressive stresses built into the outer hardened layer of steel during the manufacture of the threads which led to stress concentrations in the bottoms of the pits
- This caused microscopic cracks that weakened the bolts and allowed them to stretch
- Stretching of the bolts enabled the alternating forces of combustion in the cylinder heads to cause small cyclical movements
- Over a period of time the cyclical movements eventually caused corrosion fatigue in the bolts.

2.7.3 The Manager of the Deutz AG branch in Australia, advised that numerous Deutz 620 engines were operating in his area, fitted with well over 3 000 cylinder head studs, and to his knowledge there had been only one other instance where a bolt had failed in a vessel fitted with two TBD 620 V16 engines. Analysis and material examination carried out by the manufacturer, and independently by the user, had identified corrosion as the cause of this failure.

2.7.4 In 1992, Deutz issued a Service Bulletin dealing with the problem, which they attributed to microscopic drops of coolant leaking from plugs in the cylinder heads (*See Appendix 7 - Deutz Service Bulletin 0122 – 99 - 6360 en, issued 12.03.2002*). To avoid corrosion, the Bulletin recommended new locking plugs be inserted with a specified securing compound and for the length of stud inserted in the crankcase to be coated with a specified sealing compound. New sealing plates were also introduced to protect the parts of the bolts that passed between the crankcase and the cylinder head. The Bulletin recommended the replacement of only those bolts that showed signs of corrosion (*See Appendix 8 – Figure 2 - Arrangement of Cylinder Head Stud Bolt)*.

2.7.5 ***Superflyte's*** stud bolts failed about 12mm above the last thread of the top threaded section, which was approximately where the bolts emerged at the top of the cylinder heads. Absence of corrosion below this level suggested that moisture did not migrate up the bolts, contrary to the above mentioned Deutz Service Bulletin, and pointed to the likelihood of moisture entering from outside the main engine assembly; for example, condensation, due to alternate heating and cooling of the engine room. Fullers Maintenance Manager however, found crystalline deposits on the bolts as evidence that the liquid was engine coolant, which had a green inhibiter added, and hence supporting the views set out in the Bulletin.

2.7.6 Fullers records showed failure of the following cylinder head stud bolts in ***Superflyte's*** port engine:

5 January 2004	–	cylinder B1
28 March 2004	–	cylinder B3
14 June 2004	–	cylinder B7

2.7.7 On each occasion a juddering noise from the affected cylinder alerted the ship's crew. All stud bolts that failed were located on the top left hand side of the port engine, as were those that failed on 22 August 2004. Visual examination had found no sign of pitting or water damage. Before 22 August 2004, the stud bolts had failed only one at a time, which did not allow the cylinder heads to be forced apart from the frame to be able to release hot gasses, as occurred in this accident.

2.7.8 All the different types of engines used within the Fullers fleet had, at one time or other, sustained broken cylinder head stud bolts. When the third stud bolt on ***Superflyte's*** port engine broke, they realized that there was a problem. On 21 June 2004, after the third stud bolt failure the Fullers Maintenance Manager wrote to the engine manufacturer seeking advice about the broken stud bolts. The above mentioned manufacturer responded a short time later with a copy of Service Bulletin 0122 – 99 - 6360 en, which, until that time, Fullers had not received. Fullers did not report the broken cylinder head stud bolts to Dunsford Marine as it appeared that the Deutz Bulletin was recommending the remedial action that Fullers were already proposing to take. Fullers had decided that at the next engine overhaul, due in 2005, all stud bolts, plugs and gaskets would be renewed. Prior to receipt of the Bulletin, Fullers had replaced the three broken studs on each cylinder head. These were not, however, replaced in accordance with the guidelines set out in the Deutz Bulletin.

2.7.9 The cylinder head stud bolts had the following materials specification[2]:

- 42 Cr Mo 4n. K+V n. TL WN 812
- Property class: 10.9 n DIN ISO 898
- Thread after hardening and tempering rolled Zinc-iron-layer according to delivery specification: LV 0161 02238.

2.7.10 The report prepared by R&D Consultancy Ltd in Christchurch for Metal Test Limited *(Appendix 6)*, contained the following salient points:

"The failure (of the stud bolts) resulted from corrosion-fatigue cracking. These bolts were of a high strength and quality, with roll- formed threads for their ability to resist fatigue crack initiation as a consequence of the increased surface hardness, polishing and the residual compressive stress condition of the surface material. The bolts would have been installed with a sufficiently large longitudinal applied static load (by stretching the bolt typically to between 60 and 80% of its yield strength) adequate to prevent the application of fluctuating, normal operating service loads to engender fatigue failure. The long service life before the onset of failure suggests that the initial bolt installation had been adequate for the purpose." In commenting further on the broken stud bolts, R&D Consultancy Limited stated that..."the fatigue crack arrest markings were very clear on the fracture surfaces, suggesting wide spacing… the clarity of the fatigue crack arrest markings would have resulted from a combination of the tension in the studs keeping the crack faces from fretting and also the environmental conditions staining the arrest markings, presumably during periods when the main engine was not in use. Multiple fatigue crack initiation sites are normally a feature of high stress conditions, the stress being magnified at the corrosion pitting as a consequence of stress concentration and fatigue initiated at many of the corrosion pits. Another effect of corrosion is to accelerate fatigue crack growth rates once cracking has initiated."

"Fatigue crack propagation over 70-80% of the fracture surface is typical of many bolts and studs, the final failure being simply the result of the last application of load, causing the remaining intact ligament to fail as a consequence of overload (fast) fracture, as the fatigue crack reaches the critical flaw size."

[2] Internationally accepted engineering standards specifying the properties of materials used for particular applications.

"The parts would therefore have remained intact for their very long life as a consequence of the static load, in excess of the fluctuating loads due to the detonation of the fuel in the cylinder, so that the stud did not experience fluctuating loads. Combined with the residual compression due to cold rolling of the threads and the avoidance of significant stress concentrations at surface discontinuities (rolling smoothes the surfaces) they could not suffer fatigue. The situation changed over time with the onset of corrosion pitting causing deterioration of the surface, stress concentration at the pits, and eventually the initiation of fatigue cracking at these sites."

"Corrosion fatigue is the conjoint action of both a corrosive environment on the exposed surface and the effects of fatigue due to fluctuating loads. Initially, the effect of corrosion may be to cause pitting and hence stress concentration that may initiate fatigue cracking… once cracking is underway the movement within the crack induces flows of fresh corrodent into the crack (stimulating the corrosion processes) and also causes the corrosion products to wedge the crack open, which may assist the development of the crack or, under other conditions, the effect of premature crack face contact during closure may be to slow down the rate of fatigue crack growth due to reduced crack opening displacements. The effect is to reduce, or even destroy, the fatigue limit (the minimum stress at which fluctuating loads cause cracking) and may enhance the rate of fatigue crack growth"

"It is likely that the location of the engine in a seagoing vessel would make it more liable to condensation and the accumulation of salts over a period of time, the water evaporating when the engine was in use, but rapidly returning (particularly with salt accumulation) when the engine cools, to enable continuation of the corrosive reactions. Invisible films of water are quite adequate to cause severe corrosion."

"Conclusions:

a) Failure resulted from the service conditions which allowed corrosion pitting to occur on the threads of the head bolts.

b) The corrosion pitting, which ensued, allowed the initiation of fatigue cracking and crack growth by a corrosion- fatigue mechanism until failure.

c) No metallurgical defects in the parts were identified (See Appendix 6 - Report by Metal Test Ltd)."

2.7.11 *In commenting further on the previous failures of similar bolts, and to corrosion being attributed by the engine manufacturer and Fullers to microscopic drops of engine coolant leaking from the plugs in the cylinder heads, R&D Consultancy Limited stated that whilst such a possibility could not be excluded, their own examination of the bolts from this accident "…did not reveal any green coloured crystalline material (see Photographs, 6, 9, 10 and 12 of their report)." All that they were able to observe "…was a mixture of "rust" and a white coloured corrosion product that would have derived from the zinc galvanised coating on the bolts."*

"A considerable amount of corrosion products was found around the fracture sites, but no green coloured deposits. Some staining was found on the plain portion of the studs (see Photographs 3, 4, and 5 of their report) but it appears to have been the result of draining down, leaving streaks of staining, rather than the all round corrosion that might be expected if engine coolant had travelled outwards and upwards. Water would be required to cause corrosion and when the engine is in service the part would be hot (and hence dry) so the corrosion that was observed would have had to occur during stand down periods. This would also be the time when the engine coolant system would not be pressurised and leaks would be least likely."

"The oxygen content of the coolant is also likely to be quite low in engine coolant solutions that are regularly heated. If this solution were to leak, during an engine's operation then, unless the leak was severe, the water would evaporate leaving the "package" of chemicals at the free surface to be available for later solution, should external water become available. The likelihood of these solutions causing, or allowing, severe corrosion is not great although they may become less able to inhibit under the external conditions. Chloride salts are particularly aggressive towards metals and the inhibitor packages would be adequate to control such corrosion with only the ubiquitous (low) levels of chlorides found in fresh waters (or a little higher due to evaporation of the coolant and consequent make-up) and would probably not be totally effective against sea water."

It is the opinion of R&D Consultancy Limited that "…corrosion from leaking coolant is far less likely than that caused by condensation and salt atmosphere damage where, over time, the seawater salts would concentrate, being dried down whilst the engine was operative and re-dissolved when cold."

2.7.12 *R&D Consultancy Limited was surprised that Deutz AG in their Bulletin would suggest replacement of "only those bolts which showed signs of corrosion". This was because the photographs of the bolts show that the actual corrosion sites, causing the onset of corrosion fatigue, were very small and much smaller than might be observed by the un-aided eye of an untrained observer under indeterminate lighting conditions. The bolts had a very thin layer of zinc that would serve only to prevent corrosion during storage prior to use. Under the crevice conditions found at threads, the zinc is not able to act as an effective deterrent to corrosion due to lack of adequate carbon-dioxide to maintain the passive film on zinc. There would also be issues around the re-use of studs that had previously been used, even if not corroded, if a torque wrench were to be employed to tension them because of the change to the friction coefficient with used threads.*

2.8 Lifesaving Appliances

2.8.1 ***Superflyte*** was equipped with one six-person rescue boat, eight 65-person open inflatable liferafts, nine lifebuoys, 741 adult lifejackets and 60 child lifejackets. The latter was 5 below the statutory minimum for child lifejackets namely, the requirement for "at least 10% of the total number of persons or such greater number as required", which, in this instance, was 10% of 651 passengers= 65 (Maritime Rule Part 40A – Design, Construction and Equipment – Passenger Ships which are not SOLAS Ships). During the emergency only the lifejackets were used. Adult lifejackets were located under passenger seats in the upper and lower passenger saloons and in containers on deck. Child lifejackets were in containers located about the vessel. They were shown on the plans and the containers were marked. The Investigator recommended that the crew point them out to passengers with children (*See Appendix 9 - Safety Equipment Checklist and Appendix 10 – Photograph 7 – Underseat stowage for lifejackets, Photograph 8 – Stowage of Children's lifejackets and Photograph 9 – Hutchwilco Coastal Lifejacket*).

2.8.2 The adult lifejackets, which were coloured orange, were Hutchwilco Coastal lifejackets, certified as meeting New Zealand Standard NZS 5823:1989 *Specification for Buoyancy Aids and Marine Safety Harnesses and Lines*. Posters of lifejacket donning instructions were displayed on the bulkheads of the passenger saloons (*See Appendix 10 – Photograph 10 - Lifejacket donning instructions*). There were 8 lifejackets for the ship's crew, seven of which were yellow and one orange in colour. They were all fitted with reflective tape on the back and marked with the word "Crew".

2.9 Fire Protection

2.9.1 ***Superflyte*** was divided into 13 fire detection zones, each monitored by heat and smoke detectors. The fire detection panel was located to the port side of the Master's seat at the helm position (*See Appendix 3 – Photograph 3 – Steering Console*). The smoke detectors activated klaxon fire alarms in the engine rooms and fire alarm bells in the passenger saloons. Both port and starboard engine rooms were fire-insulated, watertight compartments, protected by a fixed CO_2 installation. CCTV cameras were located forward of each main engine, feeding to a monitor above the fire detection panel on the bridge. ***Superflyte*** was fitted with a fire detection system throughout the vessel; a fire main and hydrant, and equipped with fire hoses with dual-purpose nozzles, foam generators, portable fire extinguishers, fire blankets and a fireman's outfit with self contained breathing apparatus (*See Appendix 11 - Fire Control Plan and Appendix 9 - Safety Equipment Checklist*). The above exceeded the requirements of Maritime Rule Part 40A.

2.9.2 The fixed fire installation comprised four CO_2 cylinders fitted in a purpose-built locker located at the after end of the lower passenger saloon. The locker was accessible only from the after deck. The cylinders were ganged in pairs, one pair ready for immediate discharge, the other as a reserve, in case a second discharge of CO_2 was needed. The initial discharge was activated from the bridge and the follow-up discharge was to be activated from the CO_2 locker. Operating instructions were posted on the bridge and in the CO_2 locker, and the crew had been trained in its use (*See Appendix 12 – Photograph 11 – Fixed CO_2 Installation*).

2.9.3 Fullers had contracted a fire servicing company, UNITOR, to carry out annual maintenance and inspection of the fixed fire installation, including testing the lines with compressed air and checking the level of CO_2 in the cylinders.

2.9.4 When the Master activated the fixed fire installation there was an explosion which blew open the door to the CO_2 locker. From the lower passenger saloon the Engineer and Services Supervisor heard a loud noise followed by a hissing sound. Looking out through the window in the door to the after deck, they saw a cloud of white vapour near the CO_2 locker.

2.9.5 CO_2 passed from the cylinders through high-pressure hoses into double-inlet transfer valves, which directed it to the pipelines to the engine compartments. In the configuration used in ***Superflyte's*** fixed fire installation, only one inlet port of each double-inlet transfer valve was used. The other inlet port should have been blanked with a purpose-made, screw-in plug. Dust valves had been fitted in all open ports for shipment from the manufacturer in the UK and these should have been removed and replaced with the correct screw-in plugs. This was not done. Although the dust plugs were sufficient to resist the low-pressure air used to verify that pipelines and fittings were clear, the pressure on release of CO_2 at 57 Bar blew them all out, thus releasing gas into the locker. Vents in the locker must have been insufficient to handle the sudden build up of pressure and the locker door was blown open.

2.10 Damage

2.10.1 Fire damage in the port engine room was extensive with melted wiring looms, air filters, an aluminium girder and insulation material. Damage in the passenger areas was limited to smoke damage.

2.11 Crewing requirements

2.11.1 The number of crew and their qualifications required on board ***Superflyte*** were specified in the vessel's Minimum Safe Crewing Document issued by the Maritime Safety Authority (*See Appendix 13 – Minimum Safe Crewing Document*). This was dependent on passenger numbers and the limits within which the vessel was operating on a particular voyage. At the time of the fire, ***Superflyte*** had 311 passengers on board. The route between Matiatia Bay and the Fullers wharf in Auckland, through Motuihe Channel, lay within Enclosed Water Limits. For 290 to 379 passengers in Enclosed Water Limits, the minimum crew required was 5 namely, a Master with an Inshore Launch Master (ILM) Certificate, an Engineer with a Certificate as Marine Engineer Class 5, a Deckhand holding an Advanced Deckhand's Certificate and two additional crewmembers for whom no maritime qualifications were specified. The document permitted the Advanced Deckhand to be replaced by a 'suitably trained person' who had been employed within the Fullers Group.

2.11.2 At the time of the accident ***Superflyte*** had 6 crew on board, made up of the Master, Engineer, Service Supervisor and three On Board Service Crew. The Engineer's qualifications did not satisfy the requirement of the vessel's Minimum Safe Crewing Document (*See Paragraph* **2.15.1** *of this report*).

2.12 Training and Drills

2.12.1 All crew were required to participate in the company's programme of training and drills. New On Board Services Crew were given induction training, supervised by a senior member of the crew, which included:

- Familiarization with the vessel
- Location of the Safe Ship Management System and Quality Manual
- Location of safety and rescue equipment

As part of their induction each new crewmember was required to participate in at least two emergency drills

In addition, crew were given General Shipboard Training, which included being shown the location of fire equipment, participating in fire drills and receiving instruction about types of fire, and the use and care of fire equipment.

2.12.2 Emergency drills were carried out least once every month. ***Superflyte's*** logbook recorded the following drills:

- 24 June 2004 Man overboard and fire drill
- 1 July 2004 Lifejacket demonstrations
- 8 July 2004 Man overboard, fire drill and simulated broadcasting of an urgency message
- 3 August 2004 Emergency drill

The Master stated that he also held a fire drill in the engine room 14 days before the incident, which included a comprehensive training exercise, but the drill was not recorded in the ship's logbook.

2.12.3 The crew who were on board ***Superflyte*** at the time of the fire had participated in the fire and evacuation drill held on 24 June 2004.

2.13 Hours of Work

2.13.1 The crew worked a roster of 5 days out of 7. Their hours of duty, which began on Thursday 19 August 2004, were as follows:

Thursday	–	1530 to 2230 hours (7 hours)
Friday	–	1530 to 0130 hours the following morning (10 hours)
Saturday	–	1530 to 0130 hours the following morning (10 hours)
Sunday	–	1530 to 2330 hours. (7 hours)

2.14 The Master's Evidence

2.14.1 The Master first went to sea in 1960 with the Royal New Zealand Navy. He served in frigates for 10 years, followed by 10 years in fisheries protection and hydrographic vessels. From 1980 to mid-1981, he was Mate and Relieving Master on board the ***Spirit of Adventure***. In 1981 he joined Fullers and worked as Master of ***Kestrel*** and other ferries in Auckland harbour for 5 years, after which he transferred to the Auckland to Waiheke service. In 1997, he travelled to Western Australia to serve as Master for the commissioning of ***Superflyte***. He was one of 10 Masters rostered between the vessels ***Superflyte***, ***Quickcat*** and ***Jet Raider*** which provide passenger and cargo services between Auckland and Waiheke Island. He held a Certificate of Competency No. 76 as Master of Small Home Trade Ship, issued on 20 June 1977, and Certificate of Competency No. 3147 as Engineer of a Restricted Limit Motor Ship, issued on 14 May 1981. *(Master of Small Home Trade Ship is an acceptable equivalent to an Inshore Launchmaster (ILM) Certificate in accordance with Table 1 of Maritime Rule Part 31B.)*

2.14.2 The Master had participated in the staff training programme which had been developed and expanded over his years with Fullers. He had attended a fire training course conducted by the New Zealand Fire Service in 1988. Each boat under his command had carried out fire and safety drills at least once every month. Training in evacuation procedures was carried out by instructing crew in their duties.

2.14.3 The Master's responsibility and authority were set down in Section 4.1 of the vessel's Safe Ship Management Manual. He had overriding authority for all matters concerning navigation and safety on board. While ***Superflyte*** was under way, the Master was stationed in the wheelhouse, at the helm and engine controls, and carried out communication to the passengers and crew and external communication by radio. During the emergency he was fully occupied with the tasks of handling the ship and communications and was reliant on the crew to advise him about the situation in the passenger and machinery spaces.

2.15 The Engineer's Evidence

2.15.1 The Engineer first went to sea in 1988 as a Junior Engineer in foreign going cargo ships. He held Certificate No. E06 0075 as Marine Engineer Class 6, issued on 21 February 2002. He also presented a copy of Certificate No. 30043 as Chief Engineer Officer on ships with an output power of 3 000 kW or more. This was issued by the Republic of Honduras on 7 March 2003, and was due to expire on 7 March 2008. He had applied to the Director of Maritime Safety for recognition of this Honduran Certificate. On 26 October 2001, the MSA issued a letter of temporary approval for him to be employed in any position requiring the holder of Marine Engineer Class 5, while the recognition process was being carried out. On 19 July 2003, the Honduran authorities advised that they could not authenticate his Chief Engineer Officer's Certificate and this temporary approval was withdrawn. The Engineer also presented a copy of a letter from the MSA, dated 23 September 2003, giving temporary approval to be employed in any position requiring the holder of Marine Engineer Class 3. During this investigation, it transpired that the letter of temporary approval dated 23 September and his Honduras Certificates may have been forgeries. The Engineer was stood down from duty and matter referred to New Zealand Police for further investigation, the results of which are still awaited.

2.15.2 The Engineer held certificates of completion for the following courses at the New Zealand Maritime School in Auckland:

- International Safety Management (ISM) Code - completed on 15 November 2001. Proficiency in Survival Craft and Rescue Boats and Rescue Boats - completed on 7 June 2002.

- Competence in Fire Prevention, Fire Fighting and Damage Control - completed on 12 July 2002.

- Competence in Advanced Fire Fighting - completed on 19 July 2002.

2.15.3 The Engineer had worked for Fullers Group for three years, first on their Auckland to Devonport ferries, then as a member of the crew roster for ***Superflyte***, ***Quick Cat*** and ***Seaflyte***.

2.15.4 The Engineer's responsibilities were to operate and monitor the ship's propulsion and auxiliary machinery, assist with loading and unloading of cargo and to keep a navigational lookout. He was stationed at the bow when coming alongside and leaving berth.

2.15.5 When the Engineer boarded ***Superflyte*** and took over from the Engineer on duty during the morning shift, he was told that everything was in order. This was in accordance with the hand-over procedure in Section 3 of the vessel's Safe Ship Management manual. He assisted with cargo operations and then went to his station for departure to let go the forward mooring line. After ***Superflyte*** left Auckland for Waiheke, he reported to the Master on the bridge and then made his rounds of the ship's machinery, as was his usual routine. He checked both engine rooms, first the port engine room then the starboard one, entering through the forward watertight doors, checking the control panels forward and abaft each main engine and the oil pressures and the oil, water and exhaust gas temperatures. It was the practice to check pressures and temperatures during the passages from Auckland to Waiheke and to check and record them on the return voyages. He continued past the gearbox and generators and looked inside the tiller flats situated immediately abaft the engine rooms. He stated that when he left each engine room, both the forward and the after watertight doors were closed. On completing his rounds, he went to the bridge to keep the navigational lookout and to monitor the vessel's machinery by means of the instrumentation and the CCTV display.

2.15.6 On arrival at Waiheke, the Engineer handled the forward mooring line then assisted with cargo and the counting of passengers who were coming on board. On ***Superflyte's*** departure from Waiheke, he stowed the forward mooring lines then reported to the bridge, intending to start the next round of inspection of machinery. He reached the bridge just as the On Board Service Crewmember was reporting to the Master that there was smoke coming from the funnel.

2.16 The Services Supervisor's Evidence

2.16.1 The Service Supervisor had been employed on Fullers Group ferries for four years. He had worked for about one year on the larger ferries between Auckland and Waiheke Island. He held no maritime qualifications.

2.16.2 The Service Supervisor was responsible for the On Board Service Crew. He was stationed aft when coming alongside and leaving berth. His duties included making the welcoming and safety announcements to passengers over the public address system, monitoring how many passengers were on board, updating emergency posters, writing the ship's log and keeping the Master and Fullers office informed about passengers' requirements. He was on the bridge, writing the log when the On Board Services Crewmember reported the fire.

2.17 The On Board Service Crew's Evidence

2.17.1 Crew Member 1 had worked at sea in foreign going cargo ships since 1978. He held Certificate No. CoC0011739 as Master, issued by the United Kingdom Maritime and Coastguard Agency with an International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW) its endorsement, issued by the Government of the United Kingdom of Great Britain and Northern Ireland on 14 May 2001, and due to expire on 14 May 2006. He had worked for Fullers Group since November 2003 and on board ***Superflyte*** since June 2004. He stated that on each new boat he was assigned to with Fullers, he spent the first week undergoing training and drills. This included familiarization with the vessel's layout, fire drill, anchor handling, abandon ship, flooding and man overboard. After each drill, a review was conducted by the Master.

2.17.2 On 22 August 2004, he was stationed in the lower passenger saloon. On hearing the fire alarm and the Master's announcement, he started to help passengers to put on their lifejackets and to direct them to the after deck. The Engineer instructed him and another On Board Services Crewmember to rig fire hoses and to bring fire extinguishers to the entrance of the port engine room. By then most of the passengers were out of the saloon. He waited by the engine room while the Services Supervisor made preparations to enter. The Engineer then told him to go forward to prepare the anchor for letting go, after which he stationed himself, first at the fore deck and then the after deck disembarking points to assist passengers who were transferring to other vessels. When the passengers had disembarked, he and the other On Board Services Crew searched ***Superflyte***, gathered up passenger baggage to take it to the storage area and tidied up the saloons.

2.17.3 Crew member 2 joined Fullers Group as a Marine and General Hand after leaving university about one and a half years ago. He had participated in the training programme under the instruction of more experienced crew. On 22 August 2004, he was stationed in the lower passenger saloon. Hearing the Mater's announcement he put on his lifejacket. He then went to help passengers with their lifejackets. He then helped rig fire hoses, assisted with preparing the anchor for letting go and stood-by to assist passengers transferring to the other vessels.

2.17.4 Crew member 3 had worked for Fullers Group for one month and had participated in Fullers training programme on board ***Superflyte*** and three other vessels. On 22 August 2004, she was stationed at the café in the upper passenger saloon and was serving a customer when she noticed smoke coming from the port funnel. She immediately went to the wheelhouse and informed the Master. There were between 100 and 120 passengers on the upper deck and she guided them outside and helped some with their lifejackets. There were about five children on the top deck, some of whom were vomiting in fright. She remarked that most of the passengers were very calm and cooperative but that some were reluctant to put on their lifejackets. It took about 15 minutes to disembark the passengers, by which time the fire service was on board and had taken control of fire fighting operations.

2.18 The Passengers' Evidence

2.18.1 Passengers were contacted and asked to make comments either over the telephone or in writing. A total of 17 replies were received by letter, e-mail or over the telephone. Reactions ranged from several passengers who were unhappy about safety procedures to those who wished to compliment the company and its crew on their professional approach.

2.18.2 The most frequent criticism concerned lifejackets. A few passengers had difficulty getting their lifejackets out from the under-seat stowage. Many had difficulty putting them on correctly and several observed that everyone seemed to have their lifejackets on in a different way, which they found not at all reassuring.

2.18.3 Passengers with children did not know where the children's lifejackets were stored. As a consequence some very young children were put into adult lifejackets that would have been ineffective for keeping them afloat and potentially dangerous if they had had to jump into the water.

2.18.4 The next most frequent criticism was lack of direction or assistance from the crew. Several passengers said that, after the Master told them to put on their lifejackets and go to emergency stations, they received no information about what was happening. Passengers crowded the stairways and were not well organized to evacuate in an orderly manner. The absence of crew to reassure passengers and to inform them about what was going on added to their anxiety. In contrast to this, a few passengers stated that the crew were calm and professional, went about their job of fighting the fire, assisted passengers with their lifejackets, guided passengers out and helped them off ***Superflyte*** and onto the other Fullers Group ferries that came to assist.

2.18.5 Several passengers considered the safety announcements inadequate and few could remember what they were told at the start of the voyage. Some said the announcements were unclear, especially when they were outside waiting to be evacuated. Continuous sounding of the alarm bells added to the confusion.

2.18.6 Other experiences found alarming by the passengers were:

- The explosion when the door to the CO_2 locker burst open.
- The Master's use of the public address system to communicate with the crew.
- Water was pouring onto the after deck from a fire hydrant.
- Another ferry approached from astern with fire hoses spraying water.
- Other ferries sustained damage when they came alongside ***Superflyte***.
- An exit from the passenger saloon to the foredeck was difficult to open.
- Passengers were evacuated to the after deck, which put them near the seat of the fire.

2.19 Weather

2.19.1 At the time of the fire, the weather was fine, with good visibility and a north west wind of between 15 and 18 knots. ***Superflyte*** was in the lee of Motatapu Island.

FINDINGS

3.1 There had been three previous instances of cylinder head stud bolts breaking on ***Superflyte's*** port engine.

3.2 Although the ship's Engineer had checked the engines and exhaust temperatures during the passage from Auckland to Waiheke, there had been no warning of the impending failure of the cylinder head stud bolts.

3.3 The failure of the stud bolts resulted from corrosion fatigue cracking, with corrosion a critical factor to the said failure.

3.4 Failure of two stud bolts allowed hot gasses, lubricating oil and unburnt fuel to escape and start a fire in the port engine room.

3.5 Apart from smoke damage in the passenger areas, damage from the fire was contained in the engine room, which was insulated.

3.6 Incorrect installation of a valve in the fixed fire fighting system resulted in less than the full charge of CO_2 being released into the engine room. Escaping CO_2 gas blew out the door to the CO_2 cabinet.

3.7 The CCTV camera in the port engine room was damaged by the fire so that the Master could not tell whether the fire had been extinguished. At this point, he told the Engineer to release the second bank of CO_2.

3.8 When the Engineer saw the damage to the CO_2 cabinet door, he decided not to release the second bank of CO_2. The fire was eventually put out using portable fire extinguishers and hoses.

3.9 The fire in the port engine room damaged the control system for the starboard engine and left the ship without propulsion. Although the starboard engine was still capable of being operated from the local control in engine room, the crew were fully occupied with fighting the fire and looking after passengers and this was not done.

3.10 The Master told passengers to put on lifejackets and proceed to evacuation stations. Passengers had not been given a lifejacket demonstration and some had difficulty putting them on correctly.

3.11 Some passengers responsible for children did not know where the childrens' lifejackets were stowed.

3.12 Notwithstanding the long hours worked by the crew, fatigue was not considered to be a factor in the accident.

Conclusions & Action Taken

4.1 Based on the comments noted in paragraphs **2.7.10** and **2.7.11** of this report, it is concluded that the cylinder head bolts that failed in the port engine of ***Superflyte*** were of good quality and had been correctly installed, and that the failure was due to corrosion fatigue initiated by environmental condensation and salt water atmosphere damage.

4.2 Subsequent to the fire, the cylinder head bolts on the four Deutz TBD 620 engines on board ***Superflyte*** and ***Starflyte*** were replaced with a modified type provided by the manufacturer. Also fitted were new cylinder head gaskets of a modified type and new water plugs in the cylinder heads. Deutz AG, which have recently passed on their marine engine business to Wartsila, supplied all new parts and have since provided updates of Service Bulletins of those issued between 21 June and 22 August 2004 namely:

- Special Service Tooling
- Fuel Pump Drive Sealing
- Heat Exchanger Reserve Cooling

Fullers Maintenance Department are currently monitoring both main engines for crystalline coolant deposits near the cylinder head bolts, which could indicate the likelihood of future corrosion problems.

4.3 After the accident, Fullers Group modified the engine control system to ensure that the port and starboard engine controls are independent of each other so that propulsion can be maintained in the event of an emergency.

4.4 The fixed fire installation has been reinstated and tested by Fullers Group. The CO_2 distribution system has been changed to use single-port valves, which do not require plugs.

4.5 Since the accident, Fullers Group has changed the bag release mechanism for lifejackets stowed beneath seats from the bar type to Velcro. This should eliminate any difficulty in taking out lifejackets.

4.6 All exits from passenger saloons have been checked to ensure doors open freely at all times.

4.7 A switch has been installed so that alarm bells may be silenced when no longer needed.

4.8 After discovering that the Engineer's qualifications did not meet the requirements of ***Superflyte's*** Minimum Safe Crewing Document, Fullers Group has instigated a procedure to verify the validity of qualifications presented by new employees.

SAFETY RECOMMENDATIONS

5.1 It is recommended that Fullers Group, in conjunction with their SSM company, consult with Wartsila, whom it is understood will continue to supply spare parts for existing Deutz engines, with a view to determining whether it would be possible to develop a formalised programme to monitor cylinder head stud bolts to prevent further failures. *Note: Fullers are currently in discussion with Deutz in regard to recommendations of when cylinder head stud bolts need to be replaced. Deutz are in the process of a change of ownership to Wartsila.*

5.1.1 Such a programme should take account of the running hours at which previous stud bolt failures occurred and from this, document an agreed period when stud replacement should occur, irrespective of the condition of the bolts.

5.2 Most of the passengers' concerns were attributable to the low ratio between the number of passengers and crew. During the emergency the Master, Engineer and Services Supervisor were fully occupied with handling the ship, fighting the fire and involved with external communication. One of the On Board Services crew also spent part of his time assisting the Engineer and Services Supervisor, leaving two crewmembers to evacuate 311 passengers. The minimum number and qualification of crew was arrived at through analysis and discussion between the company and Maritime Safety Authority and was considered to be adequate. MSA has a procedure for determining the safe crewing of vessels in consultation with industry and there is also a review procedure. In the light of this accident it is recommended the MSA, in conjunction with Fullers, critically review the current minimum manning levels of their vessels, having regard to the safe evacuation of passengers in an emergency. It is further recommended that Fullers improve crew visibility by marking with reflective tape all crew lifejackets, both on the front and back, with the word "CREW" clearly visible. *Note: MSA is carrying out a review of the crewing levels on board* ***Superflyte*** *and Fullers are investigating ways to make crews more identifiable in emergencies.*

5.3 It is recommended that Fullers Group provide a safety briefing to passengers at the start of each voyage, pointing out where both adult and children's lifejackets are stowed and the proper method of putting them on. If a pre-recorded video briefing is made, a prior announcement should be made to bring it to the attention of passengers who may not be within range of a display unit. Safety briefings must comply with the requirements of Maritime Rule Part 23.27. *Note: Fullers are printing cards with safety instructions, which will be positioned at every entry and exit. A boat specific safety briefing is being developed which will be posted on the bridge for the Master or crew to announce at the commencement of every voyage.*

5.4 It is also recommended that Fullers provide further practical training for ship's crews so that they become more effective in an emergency (the advice or assistance of the New Zealand Maritime School and the New Zealand Fire Service in this regard may prove helpful); the lessons learned from this training to be documented in all ships SSM manuals. This should include:

- Giving clear announcements that should be understood by passengers whose comprehension of English is limited
- Making themselves known to passengers
- Reassuring passengers and controlling them for an orderly evacuation

Note: Fullers are endeavouring to set up a fire training course or briefing by an outside organization, such as the Fire Service, Navy or Nova.

5.5 It is recommended that Fullers Group in conjunction with Dunsford Marine develop a procedure, which is to be documented in ships SSM manuals, that in addition to the safety briefing, the crew ensure that each adult who is responsible for a child knows where the children's lifejackets are stowed.

5.6 It is recommended that Fullers Group provide appropriate equipment for the Master and crew of all their vessels, who may not be at their usual stations, to be able to communicate directly, without recourse to the public address system. *Note: Fullers are investigating ways to increase the number of communication stations around the vessel.*

5.7 It is recommended that copies of this report are made available to companies that manufacture, install or service fixed CO_2 fire installations, and that they be advised to check that the necessary plugs have been inserted in CO_2 distribution systems. The shipbuilders who originally installed the system have ceased to trade.

5.8 SOLAS does not specifically require that crew lifejackets be marked with the word CREW. However, under MSC/Circ.681 " Guidelines for Passenger Safety Instructions on Roll on – Roll off Passenger Ships," ships crew are required to be distinguishable in an emergency situation. In this regard it is recommended that the MSA conduct a cost benefit analysis to drafting an amendment to Maritime Rule Part 42A – Safety Equipment – Life Saving Appliances, Performance, Maintenance and Servicing that requires all crew members on passenger vessels be readily distinguishable in an emergency.

5.9 It is recommended that a copy of the final report on this accident be sent to all Safe Ship Management Companies.