**Report 06-207, restricted limit passenger vessel, *Milford Sovereign*,**
**engine failure and impact with rock wall, Milford Sound, 31 October 2006**

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The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

# Report 06-207

## restricted limit passenger vessel

## *Milford Sovereign*

## engine failure and impact with rock wall

## Milford Sound

## 31 October 2006


## Abstract

On 31 October 2006, the restricted limit passenger vessel *Milford Sovereign* was on a cruise of Milford Sound with a master, 9 crew and 181 passengers on board. Shortly after rounding Dale Point at about 1400, the master slowed the vessel in order that the passengers could view some penguins. As the master put the engines astern they both stalled, and before he was able to restart them the bow of the vessel struck the rock wall. The underwater hull was not penetrated so the master resumed the cruise.

Soon after, as the vessel approached Seal Rock, another area of interest for passengers, the engines again stalled when astern was engaged. On this occasion, the master was able to restart the port engine and avert a collision with the shore or a nearby vessel.

Thereafter the master returned the vessel to Fresh Water Basin without any further incidents.

There were no injuries and the vessel damage was limited to the loss of the head of the anchor and minor localised plate damage in way of the hawse pipe.

Safety issues identified were:

- The loss of the starboard propulsion engine resulted in the loss of hydraulic steering;
- the vessels sea trials being less vigorous than optimal;
- the engine stalling issue not being previously addressed; and
- the master operating in isolation.

A safety recommendation was made to the Director of Maritime New Zealand that she ensure that the engine stalling issue be suitably addressed.


**The *Milford Sovereign***

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## Abbreviations

| | |
|---|---|
| ADH | advanced deckhand |
| ECU | electronic control unit |
| GPS | global positioning system |
| kW | kilowatt(s) |
| m | metre(s) |
| mm | millimetre(s) |
| Nm | Newton metre(s) |
| PA | public address system |
| psi | pounds per square inch |
| RPM | revolutions per minute |
| UTC | co-ordinated universal time |
| VHF | very high frequency |

## Glossary

| | |
|---|---|
| hawse pipe | hole in a ship's side through which the anchor cable passes |
| shank | shaft of an anchor |

## Data Summary

**Vessel particulars:**

| | |
|---|---|
| Name: | *Milford Sovereign* |
| Type: | restricted limit passenger |
| Safe ship management company: | Real Journeys Limited (Real Journeys) |
| Limits: | enclosed area |
| Length: | 40 metres (m) |
| Breadth: | 8.60 m |
| Gross tonnage: | 483.423 |
| Built: | 2003 at Bluff |
| Propulsion: | 2 Volvo Penta TAMD 165A 6-cylinder in-line diesel engines driving, through Twin Disc MG-516 Model XA7470G gearboxes, 2 fixed-pitch, 4-bladed propellers |
| Service speed: | 11.5 knots |
| Owner/Operator: | Real Journeys |
| Port of registry: | Invercargill |
| Crew: | 11 |

| | |
|---|---|
| **Date and time:** | 31 October 2006 at about 1400[1] |
| **Location:** | 100 m west of Penguin Cove, Milford Sound |
| **Persons on board:** | crew: 9<br>passengers: 181 |
| **Injuries:** | crew: nil<br>passengers: nil |
| **Damage:** | minor dents in hull in way of bow anchor, broken shank on anchor |
| **Investigator-in-charge:** | Captain Doug Monks |

[1] Times in this report are New Zealand Daylight Time (UTC + 13 hours) and are expressed in the 24-hour mode

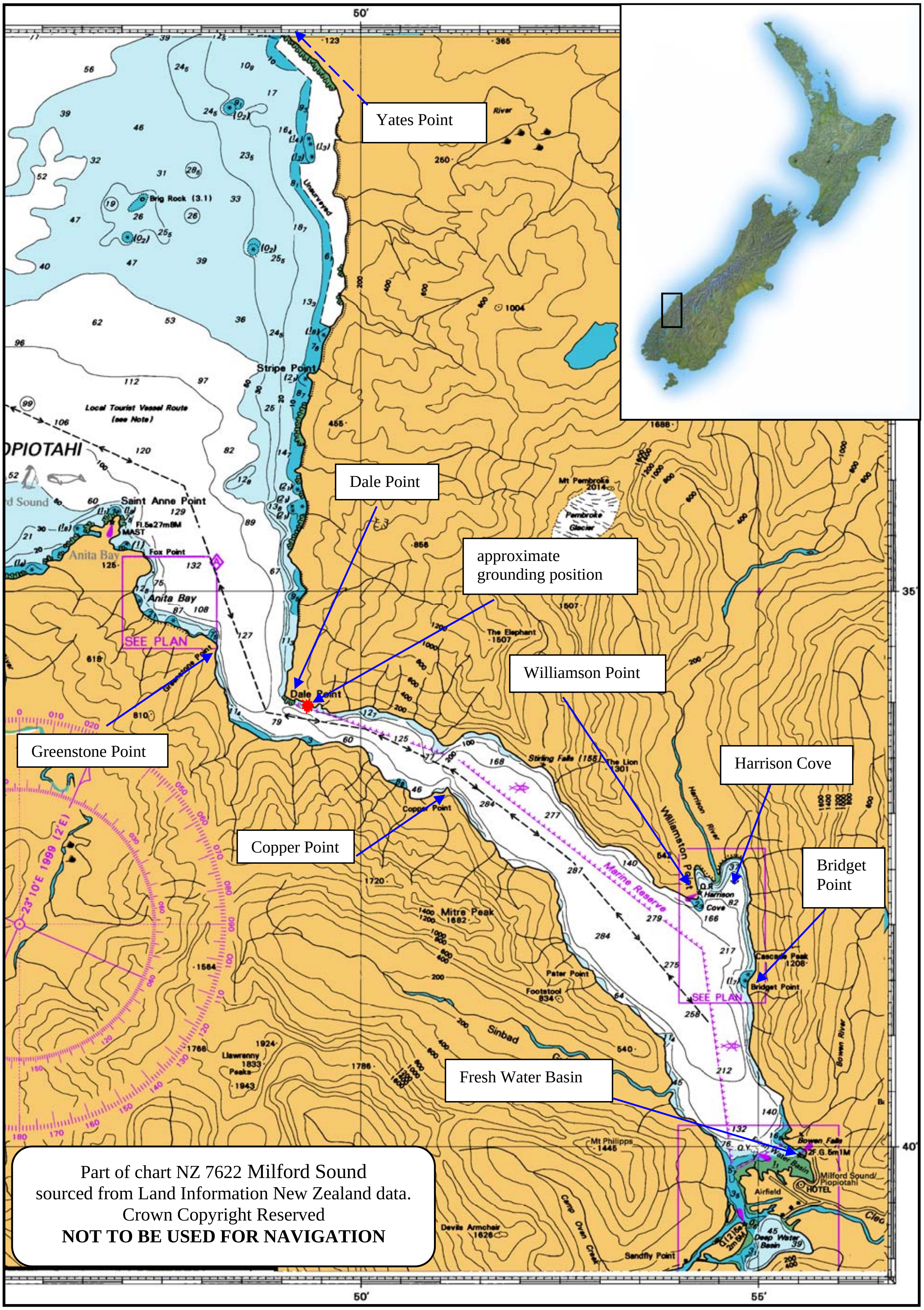


**Figure 1**
**Chart of Milford Sound**

# 1 Factual Information

## 1.1 Narrative

1.1.1 At around 1240 on Tuesday 31 October 2006, the restricted limit passenger vessel *Milford Sovereign* berthed at Fresh Water Basin in Milford Sound after a scenic cruise (see Figure 1). The crew prepared the vessel for the next cruise, then embarked the passengers.

1.1.2 At about 1300 the *Milford Sovereign*, with the master, 9 crew and 181 passengers on board, left its berth to start its second scenic cruise of the day around Milford Sound. During the cruise the master gave a commentary on the wildlife, the topography and the history of the area over a public address system (PA). Following the master's commentary in English, 3 crew members from Korea, Japan and China translated it into their own languages for passengers from those countries.

1.1.3 The vessel followed the standard clockwise route for Milford Sound tourist vessels, passing up the western side of the Sound before turning to the east inside Greenstone Point, and closing with the eastern shore to return back down the Sound along that side (see Figure 2).

1.1.4 As planned, shortly before 1400 the *Milford Sovereign* reached the extent of its outward passage and turned across the Sound, joining the east coast just outside Dale Point to start its inward passage. As the vessel passed Dale Point the master spotted 2 penguins on the shore, approximately 250 m ahead of the vessel. To allow the passengers to view the penguins the master slowed the vessel by adjusting the engine controls, first to slow ahead and then to neutral. The master told the passengers over the PA that penguins could be seen on the port side of the vessel; on hearing that announcement the translators made their way to the bridge to relay the additional commentary.

1.1.5 As the vessel approached the penguins, the master put both engine controls astern to take the way off the vessel. However, almost immediately both engines stalled. Despite numerous attempts the master was unable to restart the engines.

1.1.6 Without propulsion, the vessel carried its way forward and under the influence of the tide and wind, turned towards the rock wall on the north-eastern side of the Sound. The hydraulic steering gear was driven off the starboard main engine, so was not functioning. Having failed to restart the engines from the centre console, the master tried, also without success, to restart the engines from the starboard and port bridge wing control stations. The master said that he contemplated going to the engine room to start the engines locally, but decided against such an action given the distance to the engine room and the proximity of the vessel to the rock wall.

1.1.7 As the bow of the vessel approached the shore, the master told the translators to warn the passengers over the PA of the impending impact. At about 1405, at a speed estimated to be around 3 to 4 knots, the bow struck, and came to rest against, the rock wall. At about the same time as the grounding the master succeeded in starting both engines from the centre console, but elected to hold the vessel against the shore for a short time until he was able to confirm that the hull had not been breached. Once the crew confirmed that the vessel was intact, the master reversed the vessel into open water. The master of the *Milford Wanderer*, another vessel belonging to Real Journeys that was also heading into the Sound saw the grounding and stood by to assist. Also returning into the Sound was the *Milford Adventurer*, a tourist vessel belonging to another operator; the crew of that vessel saw the *Milford Sovereign* against the rocks with the *Milford Wanderer* in attendance, but thinking that they were looking at penguins or seals its master elected to pass the other vessels and carry on its cruise.

1.1.8 Once clear of the rocks, the master of the *Milford Sovereign* told the company's Milford Sound office of the incident. He continued the planned course down the Sound towards the next point of interest, the appropriately named Seal Rock, which was a common place to view New Zealand fur seals. The *Milford Wanderer* stayed in attendance but remained slightly further off the shore in order that it could bypass Seal Rock. During the short passage towards Seal Rock, the *Milford Wanderer* was operating at its service speed of about 9 knots, during which time the *Milford Sovereign* was easing ahead. The *Milford Adventurer* had already stopped at Seal Rock, so in order to allow that vessel to clear the area, the master of the *Milford Sovereign* slowed down then put both engines astern. Once again both engines stalled leaving the vessel drifting towards Seal Rock and the *Milford Adventurer*. After a short period the master managed to restart the port engine then the starboard one, enabling him to stop the *Milford Sovereign* before it collided with the rock or the other vessel.

1.1.9 The *Milford Wanderer* had maintained its position behind the *Milford Sovereign* and when its master noticed that the *Milford Sovereign* had again stalled he sounded his whistle to warn the *Milford Adventurer,* whose master was already aware of the developing situation and had started manoeuvring clear of the area. The master of the *Milford Wanderer* had his crew ready a tow line for the *Milford Sovereign*, but this proved unnecessary when its engines restarted.

1.1.10 The master of the *Milford Mariner,* another Real Journeys vessel that was outward bound in the vicinity of Copper Point, had heard on the very high frequency (VHF) radio that the *Milford Sovereign* was having problems, so he had his crew launch their tender to escort the *Milford Sovereign* back to the berth at Fresh Water Basin.

1.1.11 Once he had regained control of the engines, the master of the *Milford Sovereign* headed towards Fresh Water Basin staying near the centre of the Sound. Without stalling, they stopped briefly off Stirling Falls for a photo opportunity, but remained a conservative distance off.

1.1.12 At about 1515 the *Milford Sovereign* berthed safely at Fresh Water Basin.

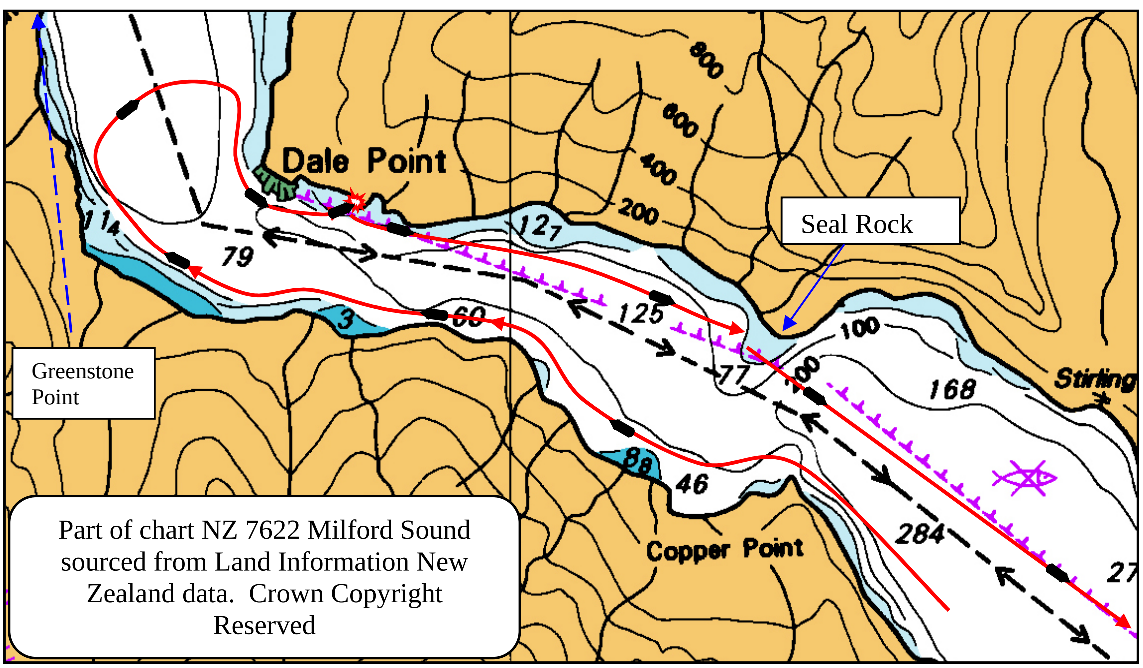


**Figure 2**
**Chart showing approximate track of the *Milford Sovereign***

## 1.2 Damage

1.2.1 The anchor located at the stem of the vessel took the brunt of the impact with the rock wall, causing the shank to fracture behind the head and the head to be lost in the water. There was slight indentation to the hull plating in way of the hawse pipe (see Figure 3).

**Figure 3**
**Bow of the *Milford Sovereign* with fractured anchor shank superimposed**

## 1.3 Vessel and company information

1.3.1 The *Milford Sovereign* was operated by Real Journeys, the trading arm of the parent company and owner of the vessel, Fiordland Travel Limited (Fiordland Travel). Real Journeys had many tourist operations, including coach services, air services, cruise boats and general attractions, throughout Otago and Southland; mainly Fiordland, Queenstown and Stewart Island. In total the company operated more than 20 vessels. The Milford Sound marine operation was divided into 2 main parts, daytime (or scenic) cruises and overnight cruises, however the overnight vessels also undertook day cruises. The scenic boats were the *Milford Sovereign*, *Milford Monarch* and *Milford Haven*, and the overnight boats were the *Milford Mariner, Milford Wanderer* and *Friendship*.

1.3.2 The *Milford Sovereign* was the newest vessel in Real Journeys Milford Sound fleet. It was a monohulled vessel that was purpose built for the Fiordland tourism industry and had a similar design and construction to that of the *Milford Monarch*, a vessel that had been launched in 1994. The *Milford Sovereign* had been constructed under the direct control of a Real Journeys' company representative, and had been launched on 24 September 2003 from a boat-building facility in Bluff, Southland.

1.3.3 The *Milford Sovereign* held a safe ship management certificate issued by Fiordland Travel on 21 January 2004, which, subject to periodic audits and inspections was valid until 27 September 2007. As part of an independent overview of the Fiordland Travel safe ship management system, the *Milford Sovereign* had been inspected and declared to be fit for its intended purpose by SGS M&I, a safe ship management and survey company, on 21 June 2005. The safe ship management certificate allowed up to 400 passengers to be carried in the enclosed water area.

1.3.4 The drive train for the vessel comprised 2 Volvo Penta TAMD 165A 16-litre 6-cylinder in-line diesel engines that each produced 389 kilowatts (kW) at the crankshaft at 1600 revolutions per minute (RPM), sufficient to propel the vessel at 11.5 knots. The engine was almost identical to the TAMD 163A on the *Milford Mariner* and *Fiordland Navigator*. The *Milford Sovereign* was fitted with Twin Disc gearboxes with a ratio of 3.06 to 1 to transfer the power to the propellers. The *Milford Mariner* and *Fiordland Navigator* were fitted with ZF gearboxes with a ratio of 3.6 to 1.

1.3.5 The propellers for the *Milford Sovereign* were manufactured by Veem Engineering Group Proprietary Limited of Western Australia; they were registered under the proprietary name of Veemstar and were a skewed design. They were 4-bladed propellers of 1200 millimetres (mm) in diameter, 940 mm pitch and a blade area ratio of 80%. The 2 propellers were outward turning with a balanced flat plate rudder immediately behind each propeller.

1.3.6 The components of the drive train had been supplied to and fitted by Real Journeys during the construction of the vessel. The manager of Southern Viking, the Christchurch Volvo Penta agent that supplied the engines and gearboxes, had attended the vessel after it had been launched and checked the installation of the engines. During the several days during which he made himself available for engine trials, the vessel had been unavailable. Instead, he had left the engine trial paperwork with the Real Journeys Supervisor of Maintenance for Bluff, to complete when the trials took place on 24 September 2003 (see Appendix 1).


**Figure 4**
**The *Milford Sovereign* bridge console**

1.3.7 The vessel was fitted with the following navigation equipment:

- a Simrad CE42 depth sounder/global positioning system (GPS) plotter
- a JRC JMA-2244 radar
- a Twin Disc Commander EC 200 engine control system
- an ICOM VHF radio.


**Figure 5**
**EC 200 main controller with illuminated station select and neutral lights**

1.3.8 The GPS plotter could be used to display the speed of the vessel, but the averaging used in the course and speed calculations caused the indicated speed to lag behind the actual speed. There was no other speed indicator on the bridge.

1.3.9 The engine control was a Twin Disc Commander EC 200 (see Figures 4 and 5) that used a single lever to control both the throttle and the transmission of each engine. There was an engine control unit at each of the 3 bridge control stations: the centre console, and port and starboard bridge wings. The master usually conned the vessel from the central console, which had the main controls within easy reach, but when manoeuvring he used the bridge wing control stations. The engine control units were electrically linked to electronic control units (ECUs) in the engine room; these ECUs were connected by cable to throttle and transmission actuators for the 2 main engines. Only one of the 3 engine control units could be active at any one time, with control being transferred between each of the engine control stations using the station select button at the desired engine control station. A red indicator light on each engine control unit was lit when that station was active (see Figure 5). A yellow light indicated when neutral was selected. A switch allowed the operator to select from 3 preset idle speeds, a useful function when manoeuvring in close situations where selective increased speed was required. The preset engine speeds for the idle settings were:

| | |
|---|---|
| Setting 1 | 650 RPM |
| Setting 2 | 885 RPM |
| Setting 3 | 1050 RPM |

1.3.10 The ignition key switch (see Figure 6) had a built-in restart inhibitor, which, once the engine had been started, deactivated the start function of the ignition key switch until it had been returned to the off position. This was a safety feature to prevent possible damage to the starter motor if an operator tried to start an engine that was already running. At each engine ignition control board there were gauges to indicate engine temperature, oil pressure, engine voltage and engine revolutions.  There were also warning lights to indicate when the engine was in alarm state and needed immediate attention.

1.3.11 Engine cooling water overboard discharge warning lights and alarms had been retrofitted to warn when the discharge of cooling water stopped.  If an engine stopped, for example if it stalled, the overboard discharge alarm was one of the first alarms to sound.

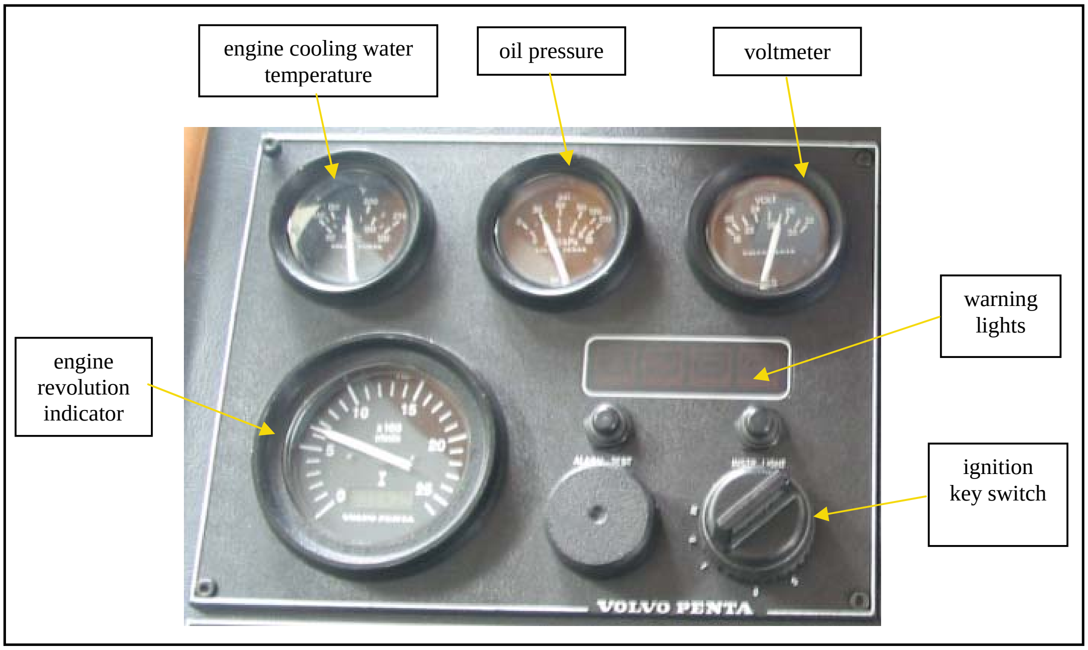


**Figure 6**
**Engine ignition control board**

1.3.12 Soon after the *Milford Mariner* had been launched, the masters of that vessel noticed that it had a tendency to stall when the engines were put astern, particularly when it was moving ahead at more than 6.5 knots.  On one occasion, the engines had stalled while the *Milford Mariner* was approaching the wharf at the Milford Deep Underwater Observatory, causing the vessel to collide with, and damage, the wharf and a building on the wharf.  At that time it was only possible to start the engines from the central console, so when the engines stalled with the master at the port control station he had to go to the central console to restart them.  The engines stalled most often when the vessel was manoeuvring close to dangers, which was when the master would be at the wing stations.  So, to improve the restart response time hot start buttons were installed at the port control station to allow the engines to be restarted at that station after a stall.  The hot start buttons were always live and would activate the starter motors irrespective of whether the engine was running or not.  Hot buttons were also fitted to the bridge wing consoles of the *Milford Sovereign* and *Fiordland Navigator*.

1.3.13 On 27 April 2006, the Commission approved for publication occurrence report 05-210 into the restricted limit passenger vessel *Milford Mariner*'s engines' stall that resulted in grounding in Harrison Cove, Milford Sound on 18 September 2005.  On 5 April 2006 as a result of that report, the Commission recommended to the Chief Executive Officer of Real Journeys that he:

> In conjunction with the engine control manufacturer, ensure that each of the company's vessels is configured for optimum operation by checking its engine control systems.

In response to that recommendation, Real Journeys employed a Twin Disc technician to check and adjust the set-up of the ECUs on all the vessels using the Commander EC 200 system in the Real Journeys fleet.  Because the vessels were large and heavy for the power available, the technician decided to set the dipswitches in the ECU to the maximum delay.  A vessel travelling at a consistent speed for longer than 60 seconds would experience the maximum delay of between 9.4 and 10.6 seconds when going from ahead to astern. However, for a manoeuvring vessel "low throttle speeds and short term transmission engagements do not produce such delays"[2].

1.3.14 Also in response to the *Milford Mariner* occurrence on 18 September 2005, the company elected to standardise the starting sequence on the Volvo Penta powered vessels. On 20 April 2006, the General Manager Maintenance and Supply sent an email to, among others, the safe ship systems manager/chief launchmaster and the senior launchmaster at Milford Sound outlining the need to standardise the starting sequence and requesting feedback before a modified system was put in place. It is unclear what, if any, the form of the discussions surrounding the modifications was, but arrangements were made to make the necessary modifications during that years survey periods.

1.3.15 In July and August 2006, the modifications to the engine starting equipment were made to the *Milford Mariner*, *Milford Sovereign* and *Fiordland Navigator*. The principal change was for the existing hot start buttons to be converted to have a normal starting function, with additional sets of buttons being installed at the control stations that had not previously had hot start buttons. After the changes the engine starting sequence was:

- the ignition key switch was turned to the on position (or remained in that position after a stall)
- the throttle was put to the neutral position
- press the station select button (the red and yellow light were illuminated)
- press the start button for 1 or 2 seconds until the engine started.

This sequence needed to be done in strict order otherwise the engine would not start.

1.3.16 Before the modifications had been made, the starting sequence for the *Milford Mariner* was:

- turn the ignition key switch to the on position. However, if the operator was restarting the engine after a stall, the ignition key needed to be turned to the off position to overcome the restart inhibitor before being returned to the on position
- ensure the engine control lever was in the neutral position
- press the station select button on the Commander EC 200 (red and yellow lights illuminated)
- turn the ignition key switch clockwise against its spring to activate the starter motor
- once the engine started, allow the spring-loaded ignition key switch to return to the on position.

The starting sequence for the *Milford Sovereign* was similar to that above, except that its engine could be started irrespective of whether the Commander EC 200 was active or not. Additionally, the Commander EC 200 could be activated using the station select button irrespective of the position of the control lever. So, the engines could be started in gear or, if the engine was already running, it was possible to activate the Commander EC 200 with the control lever in the ahead or astern position, whereupon the control system would engage gear and match the throttle setting. This facility was removed as part of the modifications, requiring that the new standardised starting sequence be followed.

1.3.17 After the modifications had been made the operating instructions were not changed, nor was there any formal training given to the masters to reinforce the revised operating procedure. Consequently, the master reported that although he was aware that modifications had been made

[2] Twin Disc EC 200 manual Section 8 - shift delay adjustment

to the starting system and procedures, he was unsure what those changes were. Additionally, the ignition key switches were still operational, so it was possible to start the engines using them rather than the start buttons. Not having been instructed otherwise the master had continued to use the ignition key switches to start the engines and still thought of the buttons as hot keys rather than start buttons.

1.3.18 At the beginning of each day the usual practice was for the master to start the engines at the control panel in the engine room, then leave them running until the end of the day. It was unusual for him to stop the engines during the day, but if he did so he used the ignition key switches in the wheelhouse to restart the engines. Another master said that he routinely started and stopped the engines using the ignition key switches, but should he stall the engines, he used the start buttons to restart the engines.

1.3.19 The master was standing at the central console when the engines stalled and his first reaction was to put the control levers to neutral then try, without success, to start the engines on the ignition switch keys. He then used what he thought were the emergency start buttons at the central control position, but again the engines did not start. He then moved to the starboard and port consoles where he was still unable to start the engines on the start buttons at those stations. He finally managed to restart the engines at the centre console by going through the full start sequence and using the ignition switch keys. After the second engine stall he also restarted them from the centre console using the ignition switch keys. Initially only the port engine started so the master used that to bring the vessel to a standstill before he successfully restarted the starboard engine.

1.3.20 Similar to the ignition on a car, both the ignition switch keys and the start buttons were required to be operated for several seconds before the engine would fire.

1.3.21 On 2 March 2006 the fuel injectors in the port main engine were replaced. The original type of injector had been discontinued and an alternative, higher-pressure injector was recommended and supplied by Volvo Penta. Almost immediately after the new injectors had been fitted to the port engine the masters on the vessel noticed that it had become unresponsive and slow to reach operating speed. On 23 March, despite the poor performance of the port engine, the new types of injector were fitted to the starboard engine. During this period the masters logged that the engines stalled frequently, and they adapted their operation to allow for this. Attempts were made to address this by improving the engine power by increasing both the no-load maximum revolutions setting and the idle speed, but with little success. By 27 April, the old fuel injectors had been refurbished and were reinstalled into each of the engines. At about this time Real Journeys enquired of the Volvo Penta representative in Auckland and through him the Volvo Penta head office in Sweden, about the fuel pump settings necessary to operate the new injectors. New fuel pump settings were supplied and during the annual survey of the vessel the fuel pumps were sent to a fuel injection specialist for recalibration.

1.3.22 The torque curve for the engine fitted with new type of fuel injector was similar but marginally different from that fitted with the old injectors. With the exception of a slight dip between 900 and 1100 RPM, the engine fitted with the new injectors produced more torque than when fitted with the original injectors (see Figure 7). However, improved performance was not achieved until the fuel pump was recalibrated.

1.3.23 On a number of occasions, both before and after the accident under investigation, the engines on the *Milford Mariner* and *Milford Sovereign* stalled when put astern with the vessel still moving ahead. One of the masters said that he stalled the starboard engine of the *Milford Sovereign* almost every day, but had learnt to minimise the consequences by ensuring that the vessel was turning away from a hazard before he made an astern movement.

1.3.24 In addition to the above occurrences there were at least 2 occasions when the starboard engine stopped while the vessel was laying alongside, out of gear, waiting to sail.

1.3.25 The main hydraulic steering system was driven by a hydraulic pump off the starboard main engine. On the bridge there was a steering control at each of the 3 control stations. A steering selector switch at the central console determined which steering control was active.

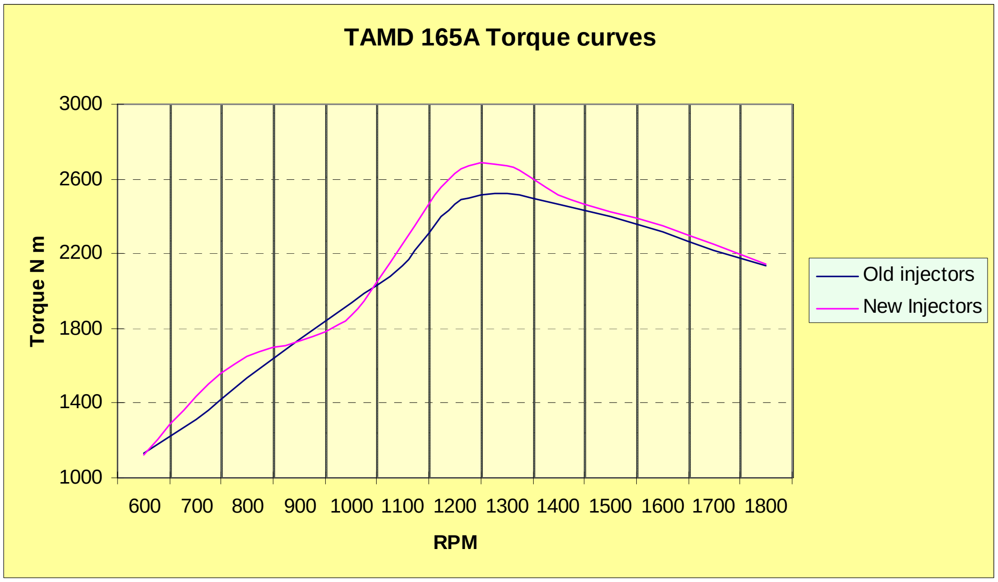


**Figure 7**
**TAMD 165A torque curves**

1.3.26 An alternative 400-volt electric/hydraulic steering system could be selected with a switch on the central control station on the bridge. However, bypass hydraulic valves in the engine room needed to be operated before the alternative steering could be used. A 24-volt independent steering control or joystick on the central console was used to steer using this system.

## 1.4 Design, construction and survey

1.4.1 Maritime Rules Part 40A Design, Construction & Equipment - Non-SOLAS Passenger Ships laid down the requirements for the structure and equipment necessary for restricted limit passenger vessels

1.4.2 The process for designing, building and certifying a vessel was as follows:

- the operational characteristics of the vessel were decided between the owner and the design architect
- the design architect designed the vessel in ongoing consultation with the owner
- after the design had been agreed, plans were prepared and submitted to a recognised surveyor, who had to be a naval architect, for design approval
- the vessel was constructed under the supervision of a recognised surveyor
- the initial fit-for-purpose survey was carried out by the supervising surveyor
- sea trials were conducted as part of the fit-for-purpose survey and to determine that the vessel met its design parameters
- vessel entered service under a safe ship management exemption certificate (or provisional safe ship management certificate)
- within 3 months, the vessel was required to submit to an initial vessel audit, which was a systems audit to ensure the safe ship management system was working.

- On successful completion of the initial vessel audit, a full safe ship management certificate was issued.

1.4.3 Maritime Rules Part 40A.7(1)(a) required that design approval be given by a surveyor authorised by the Director of Maritime New Zealand, which in part stated:

> the ship's design is approved[2] by a surveyor recognised by the Director for that purpose under rule 46.29 as -
>
> (i) fit for its intended service and intended operating limits; and
>
> (ii) complying with all the applicable maritime and marine protection rules
>
> [2] Approval of the ship's design does not guarantee any performance of the ship's design other than in respect of the sufficiency and compliance with maritime and marine protection rules of those elements included in the definition of ship design in rule 40C.2.
> ["Ship's design" includes the ship's structural integrity, watertightness and weathertightness, safe means of egress and access, intact stability and reserve of buoyancy, the ship's compliance with any damage stability and buoyancy requirements, and the provision of machinery and other installed systems and equipment necessary for the safe working of the ship]

Authorised surveyors for design approval were required to be experienced naval architects. They inspected the submitted detailed plans of the vessel, and ensured that they met all the requirements of the Maritime Rules for hull strength, machinery, electrical installation and other ancillary parts. The design of the *Milford Sovereign* was approved by an authorised naval architect from SGS M&I, who said that he had checked the vessel plans, where applicable, against the Maritime Rules or Lloyd's Classification Society Rules, which were equal to or exceeded the Maritime Rules.

1.4.4 The design approval process for the *Milford Sovereign* was started in October 2002 when plans were submitted to the naval architect at SGS M&I. A series of approval letters followed as information on the specific parts of the vessel's construction became available. The last letter of approval, which referred to the stability booklet, was issued on 21 October 2003. Collectively the letters of approval specified the criteria that the vessel had to meet for design approval. There was no letter of complete design approval to confirm that all design criteria had been met; instead that function was intended to be fulfilled by the initial survey and the issuing of the fit-for-purpose certificate under Maritime Rules Part 21.13.

1.4.5 The management of Real Journeys and the SGS M&I surveyor from Invercargill confirmed that sea trials on the new vessel had been completed on 24 September 2003. The master and crew were accompanied on the sea trials by the Real Journeys Company Engineer, the Real Journeys Supervisor of Maintenance for Bluff, a fitter and a contractor, but neither the SSM surveyor nor the engine supplier had been present. The only documentation that was available from the sea trial was an engine sea trial form completed by the Real Journeys Supervisor of Maintenance for Bluff (see Appendix 1). Although manoeuvring trials were reported to have been undertaken, no documentation was available, consequently there was no benchmark of the vessel's manoeuvring ability.

1.4.6 Maritime Rules Part 40A.8 specified that a surveyor should not issue a fit-for-purpose certificate unless the surveyor was satisfied that the design had been approved and that it complied fully with the relevant Maritime Rules. For a surveyor to be able to issue such a certificate, it was necessary to monitor and supervise the construction of the vessel. On this occasion the SGS M&I surveyor from Invercargill oversaw the building of the *Milford Sovereign*, and on 1 October 2003 he carried out the initial fit-for-purpose survey. As part of the survey, he completed an 8-part checklist on the status of the vessel and its equipment with respect to the Maritime Rules.

1.4.7 On 8 January 2004 the SGS M&I surveyor from Invercargill conducted the initial vessel audit to confirm that the safe ship management system and in particular the documentation were in order.

1.4.8 As part of a change in its policy, Maritime New Zealand decided in September 2005 to reassume immediately the responsibility for conducting the initial audit on vessels entering the safe ship management system, so instead of an authorised surveyor conducting the audit a Maritime Safety Inspector from Maritime New Zealand conducted it. Once a vessel had passed the audit, Maritime New Zealand informed the relevant safe ship management company, which was then able to issue the full safe ship management certificate.

1.4.9 The *Milford Sovereign* was substantially similar to the older vessel the *Milford Monarch.* The propulsion on the older vessel was delivered by 2 Cummins NTA-855-M diesel engines that each produced 261 kW at 1800 RPM. The engines were coupled through a Twin Disc gearbox with a ratio of 3.5 to 1 to more conventional 3-bladed propellers of 1067 mm diameter with a pitch of 965 mm. There had not been any reported incidences of stalling on the *Milford Monarch*.

1.4.10 As described in section 1.2, the vessel was designed to operate out of Fresh Water Basin, Milford Sound, being able to operate in depths of less than 3 m and manoeuvre in a turning basin with a diameter of less than 80 m. Consequently, the vessel was designed to be shallow drafted and highly manoeuvrable. Spacing the 2 propellers far apart horizontally and making them the maximum diameter that the hull configuration would allow optimised the manoeuvrability of the vessel. Real Journeys elected to use similar engines and drive train components to those on the *Milford Mariner* and *Fiordland Navigator*, and from that configuration the design naval architect calculated the propeller size necessary to provide the vessel with its required operating speed at its design displacement. The vessel and engine specifications were sent to the propeller manufacturer for them to calculate independently the appropriate propeller size. The design naval architect and the propeller manufacturer concurred on the diameter, pitch and blade area ratio.

1.4.11 When Real Journeys decided to install Volvo Penta engines in the *Milford Sovereign, Milford Mariner* and *Fiordland Navigator*, it elected for economic and passenger comfort reasons to limit the maximum speed to 1600 RPM rather than the manufacturer's specification of 1800 RPM. Volvo Penta did warn the company that the engines would be less efficient at the lower maximum speed. When ordering the propellers, the design naval architect requested that they be optimised to operate at 1600 RPM.

1.4.12 On 24 July 2007, the Commission approved for publication occurrence report 05-212 into the restricted limit passenger vessel *Milford Sovereign*'s loss of directional control in Milford Sound on 20 November 2005. On 2 April 2007, that report found, among other things, that the design approval process and the initial fit-for-purpose survey had not identified the limitations of the handling of the vessel in severe winds. It was also determined that the safe ship management system was less than optimal and a recommendation was made to the Director of Maritime New Zealand for her to undertake a full review of the national safe ship management system and make changes to ensure the system promotes and effectively regulates a safe and sustainable maritime industry consistently throughout New Zealand. This work was being undertaken at the time of writing of this report.

1.4.13 The maritime legislation covering the design and construction of domestic passenger vessels was Maritime Rules Part 40A - Design, Construction & Equipment - Non-SOLAS Passenger Ships. Section 32 (1) of that Part required that:

> (1) A ship with a propulsion motor of more than 5 kW shaft power must have sufficient astern power to provide for manoeuvrability of the ship under all normal operating conditions.

1.4.14 In the United Kingdom the statutory instrument (SI 1998 No. 2515) that prescribed the construction of passenger vessels of similar size and service to the *Milford Sovereign* required that:

> **Means of manoeuvring and going astern**
> 51 -(1) Every ship shall have sufficient power for going astern to secure proper control of the ship in all normal circumstances. The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest from maximum ahead service speed shall be demonstrated and recorded.

## 1.5 Stalling of marine diesel engines

1.5.1 A marine diesel engines is susceptible to stalling when the load on the engine exceeds the torque available; this effect is more pronounced when that load is rapidly applied. One occasion when an engine is subjected to rapid increase in load is when an operator attempts to slow a vessel by engaging reverse propulsion. Torque is a force that either produces or tends to produce rotation. For example in an engine torque is produced when the vertical action of the piston is transferred to the rotational action of the crankshaft. The torque of an engine can be determined by dividing its power by its revolutions (and multiplying by a constant, 9549 for metric units); consequently the torque will change throughout the speed range of the engine.

1.5.2 A flywheel is a heavy disc attached to the crankshaft of an engine, having most of its weight concentrated at the circumference. The power of an internal combustion engine occurs in cycles, so a flywheel is used to smooth that power and maintain a constant speed. The inertia of the flywheel absorbs power during the peak power period and releases it during the troughs, thus maintaining consistent speed. The heavier a flywheel, the more able it is to overcome intermittent loads on the engine; conversely a lighter flywheel has less capacity to maintain constant speed.

1.5.3 Conventional slower-speed diesel engines had heavy flywheels and more substantial moving parts that were able to maintain high inertia and thus reduce their tendency to stall. However, such engines were generally much larger than modern medium to high speed diesel engines, such as the Volvo Penta TAMD series, which owing to their compact physical size were often more convenient in vessels with limited space.

1.5.4 The single control lever of the Twin Disc Commander EC 200 controlled both the throttle and the transmission of each engine; the operation was such that when the control lever was in the neutral position the gearbox was in neutral and the engine was at idle speed. As the control lever was shifted from neutral to either forward or reverse, the gears engaged at the idle speed, then as the lever was advanced further the engine speed progressively increased.

1.5.5 Following the accident, Real Journeys investigated the cause of the engine stalling and proposed several options to improve the response of the engines and so minimise the probability of stalling. While it was investigating the possible mechanical remedies, Real Journeys put in place a procedure that required the masters to increase the idle speed to 1050 RPM, idle setting 3 on the Twin Disc Commander EC 200 idle speed control, when operating at speeds of more than 7.5 knots. This increased the torque that was available when the gears engaged.

1.5.6 As part of its post accident investigation, the company commissioned the design naval architects to prepare a technical report on the cause of the engine stalling and to provide recommendations on mechanical remedy options. The complete report, dated 29 April 2008 has been included at Appendix 3, but a summary of the findings and recommendations was:

- no single cause for the predisposition of the engines to stall was determined, but 2 of the principal causes were:
    - vessel displacement – the *Milford Sovereign* and *Milford Mariner* had high displacements compared to other vessels with similar length. The displacement

in the form of momentum contributed between 80% and 96% of the torque requirement in manoeuvring.

- propeller pitch – the designed maximum operating speed was 1600 RPM and the propellers were designed to operate efficiently at that speed. Had the propellers been designed to operate efficiently at 1800 RPM, their pitch would have been less and the torque demand would have been proportionally lower throughout the whole revolution range.

In addition, the report went on to discuss the effect the above conditions had on the power requirements of the engine.

- Torque demand – To bring a vessel to a stop using reverse power required that the engines produce a combined force equal to the forward resistance force of the vessel combined with the forward momentum of the vessel. Parameters for the performance of the vessel were selected, namely that the stopping time would be 10 seconds and there would be a delay of 5 seconds as the control passed through neutral. From this information the design naval architects calculated that the total torque required to stop the *Milford Sovereign* from 6 knots was 5059 Nm or 2529.5 Newton metres (Nm) per engine. When this requirement was superimposed on the propeller demand and engine torque curves it could be seen that the required torque exceeded the torque available at 750 RPM (see Figure 8). In discussions, they commented that the most significant variable in the required torque calculation was the time taken before reverse propulsion was engaged i.e. the longer the delay the more the momentum would erode and therefore the less torque required.

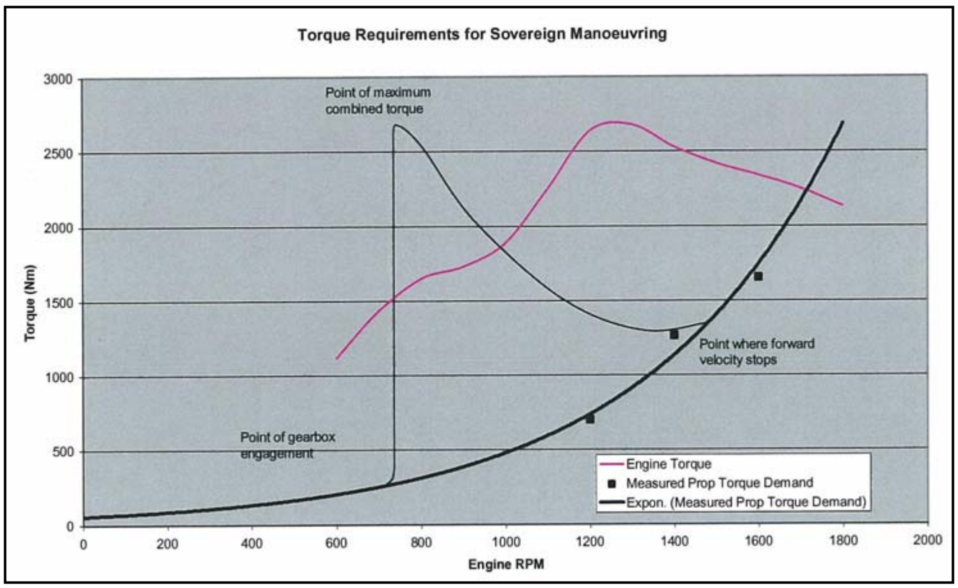


**Figure 8**
**Design naval architect's diagram indicating calculated torque demand**

- The report considered 5 alternative mechanical improvements to the propulsion system:
  - larger engines – to produce sufficient torque at idle engine speeds to overcome the combined force on the propeller would require engines of such a physical size that would be greater than the space available in the engine room. The cost would also be a major factor
  - shaft brakes – would stop the propeller wind milling when neutral was engaged. This would improve the reduction of vessel speed by causing the propellers to drag through the water. The propeller shaft being stopped when astern power

was engaged would reduce the required torque by minimising the effect from the forward momentum of the vessel

- reduction in propeller diameter – would reduce the effect from the forward momentum on the propeller, but for efficiency would necessitate an increased engine speed that would require changes to the gear ratio
- slipping gearboxes – are similar to an automatic gearbox on a car in that they progressively apply the engine power to the propeller shaft thereby minimising the risk of stalling.  They do tend to increase response time, which would require familiarisation on the part of operators.  The overall effect on the efficiency of the power train would have to be evaluated, but could be expected to be less economical than conventional gearboxes.
- controllable pitch propeller – operated by the pitch on the blades being adjusted to provide forward or reverse propulsion, which minimises the risk of stalling.  It has the disadvantage that the propeller is more vulnerable to damage owing to contact with objects, floating or fixed.  Additionally, there may not be sufficient space at the inboard end of the propeller shaft in which to install the necessary machinery.

The report discussed the benefits and disadvantages of each of the options and also the status quo.  The options most likely to minimise the risk of stalling were the controllable pitch propeller, a slipping gearbox and a shaft brake.  The larger engine and the reduced diameter propellers would be expensive and unlikely to improve significantly the required power to torque demand position.

At the time of writing Real Journeys was in discussion with a shaft brake manufacturer to determine whether such equipment would be effective and if there was sufficient space between the gearbox and stern gland for them to be fitted to the vessels.

## 1.6 Personnel information

1.6.1 The master had spent most of his seagoing career fishing.  He had gone to sea in 1973 and gained his coastal master certificate in 1977, going on to gain his mate of a deep-sea fishing boat and second-class diesel trawler engineer qualifications in 1982 and 1983 respectively.  In 2003 he joined Real Journeys, and had since been master on vessels operating in Milford Sound and Lake Manapouri.

1.6.2 The tourist operations at Milford Sound were of a seasonal nature, with a high season between 1 October and 30 May and a low season in the remainder of the year.  The staff were contracted for the high season, and in the low season could choose to work either in the maintenance departments or on other vessels, or take leave.  In mid-August, in preparation for the new high season, new and established staff assembled at Milford Sound to take part in pre-season training and familiarisation.

1.6.3 Between September 2005 and May 2006, the master had been permanent master of the *Milford Monarch*, but had spent some time on the *Milford Sovereign* during that season, including 3 coastal passages to Bluff for survey or repair of the vessel.  He had commenced his *Milford Sovereign* familiarisation training on 22 August 2005 and had been issued with a final clearance on 13 September 2005.  He was assigned as permanent master on the *Milford Sovereign* for the 2006/2007 season.

1.6.4 The masters of the scenic vessels worked a week-on and week-off roster that started on Monday morning.  During their week on the vessel the scenic cruise staff stayed in dedicated accommodation in Milford Sound.  Because he lived several hours' drive from Milford Sound, this master usually drove there on the Sunday afternoon so that he was rested and ready to start the first of his rostered days the next morning.  The accident occurred on Tuesday, the second day of his roster.  Owing to other commitments, such as coastal trips to Bluff on other vessels, the master had missed some of the pre-season training and several days of each of the first 2 rosters on the *Milford Sovereign.*

1.6.5 Masters of vessels over 100 gross tonnage were required, under the Southland navigational bylaws, to hold a pilotage exemption certificate to operate in the internal waters of Fiordland without employing a pilot. The *Milford Sovereign* was over 100 gross tons and Milford Sound was an internal waterway. This master was granted a pilotage exemption certificate by the Director of Maritime New Zealand on 13 April 2004.

1.6.6 In addition to the master, there were 9 crew members and one independent Japanese tourist guide on the vessel at the time of the accident. Four of the crew were cooks and galley hands who prepared a proportion of the daily menu for all the Real Journeys Milford Sound vessels. The 5 other crew members were primarily there as passenger hosts and their duties were based around tending to the comfort and needs of the passengers. All the crew members had taken part in the company's training programme that covered the operation of the specific vessel and emergency procedures. It was usual practice for the foreign national crew to act as translators; they repeated the tour commentary of the master in their native language. The nationalities of the deck crew on the *Milford Sovereign* at the time of the accident were 2 Japanese, one of whom was the passenger services supervisor, one Korean, one Chinese and one New Zealander. The galley crew were from Australia, Brazil, New Zealand and Malaysia. None of the crew had any maritime experience prior to joining Real Journeys.

1.6.7 On 17 November 2003, the *Milford Sovereign* had been issued with a Minimum Safe Crewing Document (Appendix 2) that required, when operating in enclosed waters, a master with a minimum qualification of inshore launchmaster, and an advanced deckhand (ADH). The minimum total number of crew was proportional to the number of passengers carried:

1 to 199 passengers required a crew of 5

200 to 299 passengers required a crew of 6

300 to 400 passengers required a crew of 7

1.6.8 When it was introduced, the ADH certificate met with resistance from the restricted limit passenger vessel sector and candidates found it difficult to get appropriate training. The resultant lack of properly qualified personnel made it impossible for operators to crew their vessels correctly. In order to mitigate the problem the then Director of Maritime Safety allowed that:

> If a crew member had been a deckhand aboard a particular vessel for 2 years or more he/she can be considered to be equivalent to an ADH under Part 31B.5(b) for that vessel only, or for similar vessels in a company fleet; provided he/she is signed off by that company's internal training system.

The minimum safe crewing document for majority of the vessels in the Real Journeys fleet required the provision of at least one ADH certified person, to meet that requirement Real Journeys had utilised the exemption to supplement crew members that held an ADH certificate. All Real Journey's staff were required to undergo pre-season and ongoing training, consequently any staff member that had been with the company for more that 2 years could be considered to be qualified to the equivalent of an ADH certificate.

1.6.9 In this case, the passenger services supervisor had been with Real Journeys since January 2004, and had spent most of the time on the *Milford Sovereign*. The company considered, and Maritime New Zealand had confirmed its acceptance that she was able to act in the capacity of an ADH. However, she was unaware of that qualification, and was concerned that she had not had realistic emergency exercises or been trained in crowd control.

### 1.7 Climatic conditions

1.7.1 The weather on the day was fine and sunny. In the morning it was calm rising to about 10 knots of day breeze blowing into the Sound in the early afternoon.

1.7.2 The tides on the day of the accident were quoted for Anita Bay:

| high water | | low water | |
|---|---|---|---|
| time NZDT | height (m) | time NZDT | height (m) |
| 0659 | 2.0 | 1309 | 0.8 |
| 1929 | 2.0 | | |

The tidal cycle was nearing neaps, so the tidal flow would have been close to its minimum. The accident occurred shortly after 1400, the early part of the flood tide, which would have caused a flow into the sound.

## 2 Analysis

2.1 Since they had been launched, the 3 vessels powered by Volvo Penta diesel engines and driven by the Veemstar propellers had been prone to stall if astern was engaged when the vessels were still moving ahead, particularly at speeds above 7.5 knots. The installation of the hot keys indicated that management had recognised that there was a problem, but until this accident there had been no in-depth investigation and analysis of the root cause. Rather, the skill of the masters to work around the problem was relied upon.

2.2 When engaging astern while the vessel was moving ahead, the engine had to produce sufficient torque to overcome the nominal propeller torque demand together with the torque exerted on the propeller by the momentum of the vessel. In his report, the design naval architect estimated that the total torque exerted on the propeller when the *Milford Sovereign* was put astern from 6 knots ahead was almost twice that available at the instant that the engines were engaged astern at an idle speed of 750 RPM. This calculation was dependent on the time that it would take for the vessel to stop; as the time increased the momentum of the vessel decreased and therefore the required torque was reduced. Sea trial data indicated that the vessels rarely stalled at speeds of less than 7.5 knots, indicating that the actual time delay was almost certainly longer than that used in the calculations and thus the torque demand would have been less. Notwithstanding the variation of calculated versus actual, the reasoning behind the cause of the stalling holds true, indicating that the power train struggled to overcome the torque applied to it during an ahead-to-astern manoeuvre at speeds above 7.5 knots.

2.3 The single engine-and-transmission control lever was simple and convenient for an operator to use. However, when reverse engine power was used to slow a vessel, the reverse gear was engaged at idle speed, the instant when the torque load on the propeller shaft was at its highest. Load coming onto the engine caused a drop in engine speed, which could be sufficient to stall the engine.

2.4 The vessel was designed to carry 400 passengers with a draft of less than 2 metres in the loaded condition. As part of the design criteria the propulsion system was required to be able to propel the vessel at 12 knots economically, while enabling it to be manoeuvred in the close confines of Fresh Water Basin. The medium- to high-speed Volvo Penta TAMD engine provided sufficient power for the propellers through the 3.06 to 1 gearbox to be efficient when free running and was also capable of manoeuvring at low speed. The widely spaced twin propellers of relatively coarse pitch provided good manoeuvring. However the design criteria did not require the vessel to be able to go astern in all normal operating conditions, as required by the Maritime Rules.

2.5 As part of the quality control of a vessel during construction, a surveyor was employed to check that the materials and workmanship met acceptable standards. Once the vessel had been completed and launched the surveyor needed to be satisfied that it met the design criteria and all the requirements of the relevant legislation; only then should a fit-for-purpose certificate have been issued. Sea trials were a vital part of the process to ensure a vessel was fit-for-purpose and could be expected to identify any short-comings. The limited sea trials that were undertaken after the launch of the *Milford Sovereign* were not attended by either the surveyor or a representative of the engine manufacturer, nor did they include specific turning or stopping manoeuvres. Consequently, the tendency to stall was not identified for that specific vessel.

2.6 All vessels should be able to manoeuvre effectively throughout their entire operating range and in particular they should be able to perform an emergency stop. The New Zealand Maritime Rules and by comparison the United Kingdom rules require that there should be sufficient power to provide effective astern propulsion. The United Kingdom rules require that ability to be demonstrated and recorded. While the New Zealand Maritime Rules did not specify testing of astern propulsion, there was an expectation that as part of the fit-for-purpose inspection, the sea trials would include a demonstration that the vessel could perform appropriately.

2.7 The tendency of the Volvo Penta TAMD engines fitted to the *Milford Mariner* and *Fiordland Navigator* to stall ought to have alerted the company to a potential operating problem on the *Milford Sovereign.* An opportunity to quantify the extent of the problem and put in place strategies to correct or minimise it was lost by not conducting comprehensive sea trials. The *Milford Monarch*, which was substantially similar to the *Milford Sovereign* but had a different power train, was not known to stall.

2.8 Since the vessel had been launched the tendency of the engines to stall had not been formally recorded in the vessel's safe ship management or hazard identification systems. Consequently, it had not been raised as a concern during the fit-for-purpose surveys. As a result, no formal mitigating procedures or contingency plans had been enacted before the accident under investigation. Had the stalling issue received early positive attention and been identified as having the potential for serious consequences, the actions that were taken after this accident may have been in place in time to prevent or mitigate this accident.

2.9 Had the safe ship management system at the time been more robust, measures could have been taken to identify and address the engine stalling issues before they became a problem during operation. However, the safe ship management system was examined in depth by the Commission's investigation and report 05-212 into the loss of directional control of the *Milford Sovereign* at Milford Sound on 20 November 2005, and Maritime New Zealand was taking action to identify and correct the deficiencies.

2.10 When the vessel was built, the Twin Disc Commander EC 200 engine control system had not been commissioned by Twin Disc technicians, so had remained at the factory default setting. Following the *Milford Mariner* stalling incident in 2005, Real Journeys engaged a Twin Disc technician to check and recalibrate the control systems on each vessel with that control system. Therefore, at the time of the accident the control system would have been set to its optimum configuration for the vessel, which amongst other things allowed the maximum delay when reversing the direction of propulsion, so that part of the power train would have been set to minimise the risk of stalling.

2.11 The Real Journeys post-accident procedural change, which required idle setting 3 to be selected when operating above 7 knots, resulted in the transmission engaging astern at the higher 1050 RPM at which speed there was 1884 Nm of torque compared with 1147 Nm of torque that was available at 650 RPM, idle setting 1. Since this procedure had been established there had been no reported incidences of stalling.

2.12 The starboard engines on each of the vessels have proven to be more prone to stalling than the port ones. It has not been possible to identify the cause of this phenomenon. One possible contributory factor may have been the primary hydraulic steering pump being driven off the starboard main engines, increasing the power demand on them. However, that additional demand was less than one kilowatt and thus would not be expected to be causal of earlier stalling even when it occurred at the lower end of the torque curve.

2.13 When the starboard engine stopped, the main hydraulic steering pump was lost. The auxiliary electric/hydraulic steering system might have been used to steer the vessel away from the land, but before the steering could be changed over, one of the crew needed to go to the after engine room bulkhead where the changeover valves were located. Had the entire changeover process been accessible from the bridge, the master might have considered using the auxiliary steering to head the vessel into safe water immediately the engines stalled. That option was not available to him, so he did not consider changing to auxiliary steering during either of the stalling incidents. Safety action 4.7 refers to modifications in the changeover system for the alternative steering that have been made by Real Journeys since the accident.

2.14 The master was aware that there had been changes to the starting sequence during August 2006, but in the absence of any formal training, instructions or documented procedures he was unsure what those changes were. Having not used the hot start buttons since he had returned to the vessel after the winter recess, he wrongly considered that they still fulfilled the hot starts function rather the normal start button function to which they had been changed. The ignition key switches operated in almost the same way as they had done prior to the change in starting sequence and it was still possible to start the engines using them. On the rare occasions that he did start the engines from the bridge, this master had continued to use the old starting sequence and so had not become practised in using the start buttons. Other masters said that they used both the ignition key switches and the start buttons at different times, indicating an absence of standardised operating procedures.

2.15 When the engines stalled the master would have been under significant stress. At such times people can revert to long established practices. For either the old or the new starting sequence to be successful a number of actions had to be carried out. Using parts or a combination of the 2 sequences could inevitably lead to an engine failing to start. Under the old restarting sequence following a stalled engine the master could have ignored the engine lever position and been able to start the engine on the ignition key switches. However since the changes to the starting sequence the engines could not start unless the engine control lever was in neutral. This is a possible explanation why the engines did not start when the master initially tried to restart them using the ignition key switches.

2.16 Normally an operator would hold a start button or ignition key switch until they heard or felt an engine start, but on this vessel the distance of the engine from the bridge deprived the operator of those immediate sensory cues. Visual and audible alarms and gauges for the engine were provided, but these may not have been obvious to the master due to the urgency of the situation.

2.17 It was unclear what position the switches and levers were in during the various attempts the master made to start the engines nor is it known whether the starter motors were engaged for sufficient time for the engines to start. In any event the engines did not start immediately. The engines did eventually start but not before the vessel collided with the rock wall.

2.18 With the exception of the masters, the majority of the crew operating the vessels in Milford spoke English as a second language. The emphasis of their duties was on hospitality, passenger support and translation, rather than on the day-to-day running of the vessel. At the commencement of each season, the crews underwent a full training programme that was largely aimed at the hospitality side of the business, but did include training in emergency response. So, while they had trained for and may well have been competent to react to a full emergency situation, such as fire or abandonment of the vessel, they would have been less prepared to assist a master in an adverse mechanical or navigational situation. Because the crew were able to communicate in the passengers' own languages, they were better placed to reassure and comfort the passengers following the collision.

2.19 The passenger services supervisor, who was a Japanese national, had been with the company for more than 2 years and, under an exemption from Maritime New Zealand, the company considered her to be capable to act as the equivalent to a crew member holding an ADH certificate. Through her position she oversaw the crew, but was unaware that she held the equivalent to an ADH qualification or that it was part of the statutory requirement for the manning of the vessel. She had received no crowd control training and was concerned that if the vessel had been damaged to the extent that abandonment was necessary, she would not have been as well prepared as she might have been.

2.20 None of the crew was specifically assigned to assist the master, so he was operating in isolation. However, after the vessel had collided with the rock the master did assign a number of the crew to check for damage, while others were employed reassuring the passengers.

2.21 The wind was light and from the westerly quarter, but together with the momentum of the vessel and the tidal flow, it was sufficient to turn it so that it struck the rock wall bow on. The angle of impact minimised the damage to the vessel and prevented the underwater hull from being penetrated, a real possibility had the vessel struck a glancing blow on the rock wall that could have had serious consequences. The low-impact speed of the collision and the warnings from the crew resulted in no injuries being sustained by any of the passengers or crew. Those standing at the time reported that they did not lose their footing, further supporting the proposition that the speed was low at the time of the collision.

2.22 After the initial grounding, the master's intention of resuming the normal routine was understandable, but to place his vessel in a situation where he needed to engage astern to avoid a collision or grounding was imprudent. He was fortunate in being able to restart one of the engines and so stop his vessel's forward progress, but there was a real risk of further damage. His subsequent decision to head directly back to Fresh Water Basin while remaining in the centre of the fiord, only stopping to view Stirling Falls from a safe distance, was appropriate.

2.23 The number of vessels operating in Milford Sound did allow assistance to be available when it became apparent that the *Milford Sovereign* was operating with difficulty. The support from the *Milford Wanderer*, and the *Milford Mariner* and its tender, was timely and appropriate.

# 3 Findings

3.1 The *Milford Sovereign* engines stalled when the torque demand on the drive train exceeded that which the engines were able to deliver at idle speed.

3.2 The incidence of stalling in earlier, similarly powered vessels to the *Milford Sovereign* had not been effectively investigated nor had a technical remedy been sought; thus a chance to prevent the latent stalling issue in the *Milford Sovereign* during its design and construction had been lost.

3.3 As found in the Commission's occurrence report 05-212 into the loss of directional control of the *Milford Sovereign* the safe ship management system surrounding the fit-for-purpose and commissioning sea trials was less vigorous than it could have been. Had the system at the time been more robust it should have identified the engine stalling problem and required that measures were taken to mitigate it.

3.4 Because stalling had not been identified in the vessel's hazard identification system, it had not been picked up in subsequent fit-for-purpose inspections or audits.

3.5 Had the stalling issue been addressed, and the post-accident action of imposing stringent operating procedures in regard to the use of the idle speed control been put in place earlier, it is probable that this accident would not have occurred.

3.6 The use of the starboard engine to provide power to the main steering hydraulic pump, together with the provision of an alternative electrically driven system, provided redundancy. However, with the vessels operating continuously close to land and other vessels, the need to change remote hydraulic valves in the engine room made the system less effective than it could have been and, as in this case, too slow to enable a master or crew member to change over to steer the vessel out of danger.

3.7 In regard to the navigation of the vessel, the master was effectively operating alone. Such an operation required effective system automation and redundancy, together with the ability to operate systems from the central control position. Good ergonomics can assist in the effective operation of a vessel, and are particularly important to vessels operating in confined waters.

3.8 The change to the starting sequence of the engines to standardise it across the fleet could have prevented the possible confusion when masters moved between vessels. However, the effectiveness was lost because the masters were neither informed about nor trained in the new system. Consequently when an urgent situation occurred the operator reverted to the old system.

3.9 The environmental conditions at the time were benign and played no part in the stalling of the engines. After the engines stalled on the first occasion, the vessel rounded up towards the shore, most probably because of the effect of the westerly quarter wind on the port quarter of the superstructure coupled with the flood tide. There may also have been a small amount of residual helm on the rudder when the steering gear became inoperative.

3.10 After the first stalling incident and grounding, the master would have been prudent to ensure the vessel maintained a safe distance off the shore and not relied upon the reverse propulsion to stop the vessel, at least until he and technical staff had been able to determine the cause of the stalling.

## 4 Safety Actions

4.1 On 2 November 2006, Real Journeys' management sent a memo to its masters informing them of the new starting sequence that had been instigated on the vessels (Appendix 4).

4.2 In March 2007, Real Journeys' management put in place a procedure to reduce the possibility of engines stalling by operating at the highest idle speed (position 3) when the vessel was travelling at speeds above 7.5 knots. A copy of the memorandum to masters of the *Milford Sovereign* is contained at Appendix 5. Since this procedure was established there have been no reported stalling incidents.

4.3 In May 2007, a representative of Twin Disc, the gearbox manufacturer, attended the *Milford Sovereign* and noted the port gearbox had an operating pressure of 235 pounds per square inch (psi) and the starboard one was 185 psi. Each gearbox was adjusted so that it had an operating pressure of 250 psi. Sea trials were conducted after this adjustment and it was noted that there was little improvement in the performance of the vessel and that it continued to stall as it had done before the modification.

4.4 Real Journeys addressed the issue of the masters operating in isolation by appointing a member of each crew to assist the master. A specialised training programme was introduced and now each vessel has a master's assistant.

4.5 The *Milford Sovereign* was the last vessel that Real Journeys had designed and built in-house, but it still had an ongoing new vessel programme. To improve the effectiveness of the commissioning process it compiled a sea trial checklist to be completed before a new vessel was accepted. The sea trial checklist was also used to record the performance of a vessel after survey work or modification.

4.6 Following the recommendation arising from the Commission's occurrence report 05-212, Maritime New Zealand put in place a work programme to review and improve the safe ship management system.

4.7 During the survey period in 2008, Real Journeys modified the alternative steering system in the *Milford Sovereign* and similarly equipped vessels in the fleet, so that it could be engaged from the bridge.

## 5 Safety Recommendation

5.1 On 21 November 2008 the Commission recommended to the Director of Maritime New Zealand that she address the following safety issue:

> Take action to address the following safety issue **-** the engines on 3 Real Journey vessels operating in Milford Sound and Doubtful Sound that manoeuvre close to the shoreline and other features during the normal daily operation were prone to stalling when placed from ahead to astern at speeds over 7 knots, which raises some doubt as to their fitness for purpose. The operational procedures that the operator has put in place to mitigate the risk of stalling have not addressed the core design issue concerning the original drive train. (032/08)

5.2 On 21 November 2008 the Director of Maritime New Zealand replied:

> Maritime New Zealand accepts this recommendation and notes that Real Journeys are currently investigating technical options to mitigate the risk of engines stalling when placed from ahead to astern at speeds over 7 knots. MNZ will write to Real Journeys requiring them to report any instances of vessel engines stalling in these circumstances; to keep the Director informed of progress regarding technical solutions to this problem, and to carry out manoeuvring trials to the satisfaction of the Director and a Recognised Surveyor when technical solutions have been implemented. (032/08)

Approved on 28 November 2008 for publication

Hon W P Jeffries
**Chief Commissioner**

## Appendix 1: Engine sea trial form

VOLVO PENTA

# ENGINE SEA TRIAL

| | | | |
|---|---|---|---|
| Date | 24-9-03 | Engine Type | TAMD165A |
| Location | BLUFF | Serial No Starboard | 110106126 /46162 |
| Vessel Type | TOURIST BOAT | PORT | 110106068 |
| Vessel Name | MILFORD SOVEREIGN | Port - | - Starboard |
| Owners Name | REAL JOURNEYS | Gearbox Type | TDMG 516 |
| Total engine Hours | — | Ratio | 3·06-1 |
| | | Gearbox Serial No | PORT 5H4089/STBD 5C235 |

| RPM Tacho Indicated | RPM (Measured) | Oil Pressure | Exhaust Temp °C | Exhaust Back Pressure | Coolant Temp °C | Boost Pressure KPA | Engine Room Temp |
|---|---|---|---|---|---|---|---|
| IDLE Port 585<br>Stbd 585 | 585<br>585 | | | | | | |
| 1200 | 1197<br>1210 | 70<br>70 | | | 78<br>79 | 3<br>3 | 20 |
| 1400 | 1385<br>1397 | 70<br>70 | | | 78<br>79 | 8<br>7 | 20 |
| 1500 | 1500<br>1481 | 70<br>70 | | | 78<br>79 | 14<br>14 | 23 |
| 1600 | 1568<br>1579 | 70<br>70 | 259<br>256 | | 78<br>79 | 18<br>17 | 23 |
| 1700 | | 70<br>70 | | | 78<br>79 | | 24 |
| MAXIMUM 1775 | 1775<br>1774 | 70<br>70 | | | 78<br>79 | 28<br>28 | 26 |

Comments: Gearbox oil Pressure Port 300 Starboard 230 Sea Temp 13
Gearbox Temps Port 50 61 Starboard 47 60

Signed: [signature]

## Appendix 2: Minimum safe crewing document

MINIMUM SAFE CREWING DOCUMENT
(Issued pursuant to maritime rule 31B.7)
Issued by/on behalf of the Director of Maritime Safety

Name of Vessel : MILFORD SOVEREIGN    Vessel Type: PASSENGER

MSA Number: 130848    Home Port: INVERCARGILL

Owner / Operator: FIORDLAND TRAVEL LIMITED

Length Overall: 40.0 mts    Number of Passengers: 400

The vessel is to carry the following minimum crewing in the ENCLOSED area: -

Master 1 Qualification ILM or equivalent as per maritime rule 31B.5

ADH 1

Passenger numbers 1-199 total safe crewing complement 5 persons
Passenger numbers 200-299 total safe crewing complement 6 persons
Passenger numbers 300-400 total safe crewing complement 7 persons

Conditions:
This document is not valid unless a valid Safe Ship Management Certificate is:
1. In force for the vessel.
2. The owner/operator, operating limits and all other conditions and limitations of the Safe Ship Management Certificate remain the same.
3. The effectiveness of the permitted minimum crewing must be continually monitored.

Additional Operational Limitations:

*Dated at Wellington this 17 day of November 2003*

Russell Kilvington
Director of Maritime Safety

*Note also the additional requirement in maritime rule 31B.6(1) to have on board the number of crew necessary to operate the vessel safely at all times.*

## Appendix 3: Technical report on the cause of engine stalling

Duffill Watts
Consulting Group

# Real Journeys Ltd

Review of Sovereign/Mariner Propulsion

Duffill Watts Consulting Group

# Real Journeys Ltd
# Review of Sovereign/Mariner Propulsion

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# 1.0 INTRODUCTION

The intent of this report is to present to Real Journeys Limited (RJL) a concise technical report on the cause of stalling on some of the vessels within their Fiordland Fleet. This report will detail the forces exerted on the propellers and engines and the response of the engine to the forces. This report will outline available options in reducing or eliminating stalling while manoeuvring and their impact on the general performance of the vessels.

For ease and verity we have only examined the MV Milford Mariner (Mariner) and MV Milford Sovereign (Sovereign), recognising that MV Fiordland Navigator is substantially similar to Mariner and uses the same engines and MV Milford Monarch is similar to Sovereign but uses different engines but similar power. This Report will not comment on cost of any remediation except where incurred due to inefficiencies in the proposed option.

# 2.0 BACKGROUND

RJL operates 6 vessels within Milford Sound and another 2 vessels in Doubtful Sound. All vessels are large and are designed to carry passengers both in overnight and day cruises. Five of the eight vessels were designed by Duffill Watts in conjunction with RJL and were built by RJL utilising fabricators and contractors from the Southland region. The vessels were launched at RJ's maintenance facility on Island Harbour in Bluff.

All vessels had remained incident free (minor incidents excluded) until the first report in loss of control on Sovereign in February 2004. Subsequent investigations by RJL, Maritime New Zealand (MNZ) and Transport Accident Investigation Commission (TAIC) have lead to fitting of plate bar keels to the two vessels that did not have them fitted when built. The directional control and transverse stability have been reported on by independent naval architects and only minor changes have been made to directional control based off those reports.

On 18 September 2005 an incident occurred in which Mariner was grounded in Harrison Cove, Milford Sound. One of the circumstances surrounding the grounding was that the engines stalled during manoeuvring procedure, which was due the inexperience of the operator, going astern when they thought the vessel was in neutral.

During the survey period (winter) 2006 when Navigator was out of the water, as a measure to reducing the likelihood of stalling, a portion of the tip of each blade of the propellers was cut off, reducing the overall propeller diameter. In the survey period of 2007 the propellers where replaced with a new set as specified by Veem and are the set currently on the vessel. Response to the new propellers would indicate that the circumstances conducive to stalling have been reduced.

The new propellers are a finer pitch which allows the engine to 'rev more'. It should be noted that due to the fiord being wider and the vessel not doing as much slow speed manoeuvring in Doubtful Sound, the likely occurrence of stalling is reduced compared to Milford Sound.

## 3.0 INVESTIGATION

The specifications of the vessels covered in this report are as below:

| | **Milford Mariner** | **Milford Sovereign** |
|---|---|---|
| Year Launched | 2001 | 2003 |
| Engine | Volvo TAMD163AA | Volvo TAMD165AA |
| Hours | 15,747 | 7,400 |
| Power @ 1600rpm | 389 | 389 |
| Power @ 1800rpm | 404 | 404 |
| | | |
| Gearboxes | ZF BW161 | Twin Disc MG516 |
| Ratio | 3.6:1 | 3.06:1 |
| Propellers | 1300x1250, 4 blade, 1.045m blade area | 1300x1250, 4 blade, 0.8m blade area |
| | | |
| Length (OL) | 40 | 40 |
| Length (BP) | 35.5 | 34.68 |
| Beam (Mld) | 10 | 8.6 |
| Depth (Mld) | 3.75 | 3.25 |
| Draught (to base) | 1.92 | 1.8 |
| Depth of keel below base | 0.182 | 0.1 |
| | | |
| Gross Tonnage | 693 | 483 |
| Nett/Reg Tonnage | 265 | 177 |
| Full Departure Displacement | 379.3 | 295.6 |

Based on written data collected and supplied by RJL and verbal reports of stalling of the engines, the outlined procedure for our investigation was as follows:

A literature review was undertaken to ensure that any method used was current and a valid practice in analysing the handling of vessels in stopping and reversing. Most literature indicated that the system is complex and analysing these issues required simplification of the performance parameters to enable calculation. Most calculations require coefficients of handling which must be obtained by measuring vessel movements and also require detailed propeller characteristics from the manufacturer.

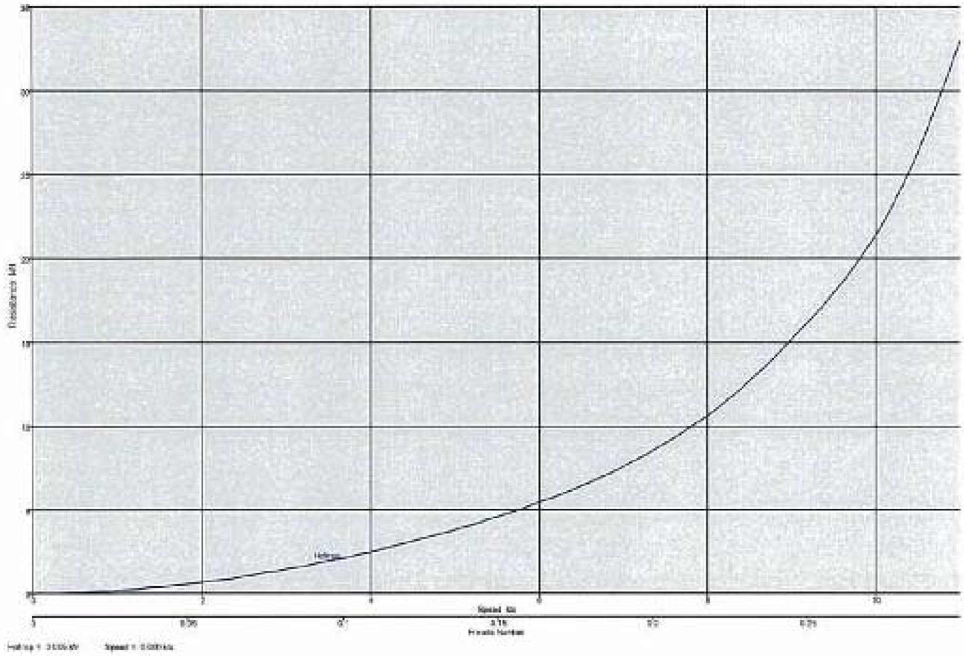

*Figure 1: Calm water resistance of Sovereign*

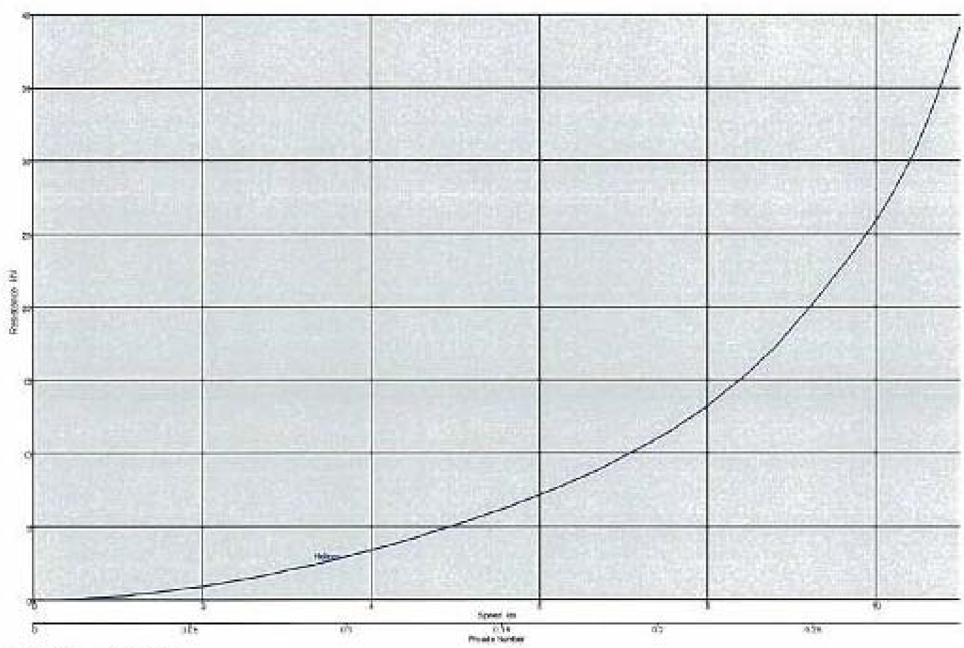

*Figure 2: Calm water resistance of Mariner*

For each vessel we used a speed range of between 0 to 11 knots and used Holtrop's resistance formula to determine water resistance (Figure 1: Calm water resistance of Sovereign, Figure 2: Calm water resistance of Mariner). We assumed that the vessel has a forward velocity and hence, the force that the propeller must produce to stop the vessel is equal to the forward resistance force. The vessel also has a momentum component that adds to the required force for the propellers to produce. To simplify the model, we assumed a set period of time that the vessel will take to come to a complete halt. For the information presented, we have used 10 seconds to halt forward velocity which for the higher velocities is a short time to stop the vessel, but also for the lower speeds, is far too long. This time can be changed in the model but for comparisons sake it will be used as a benchmark. This model also used the engine manufacturer's data on rpm vs power and torque, the gearbox ratio, propeller rpm and vessel particulars derived from design data.

(1) $$\text{Power Required} = \frac{(\text{Thrust} + \text{Disp} \times (\text{initial velocity/stopping time})) \times \text{initial velocity}}{1{,}000}$$

(2) $$\text{Torque Required} = 3916.416 \times \frac{\text{Power Required} \times \text{Ratio}}{\text{Engine RPM}}$$

*Where:*

- *Thrust is based on Holtrop's regression formulation*
- *Displacement is the design mass of the vessel*
- *Initial Velocity is the speed that the vessel was travelling at the time of manoeuvring*
- *Stopping Time is the time taken to come to a complete halt*
- *Ratio is the reduction in shaft speed that the gearbox makes between engine and propeller*

As mentioned above, characteristics of propeller behaviour have been excluded for simplification. Other simplifications or assumptions include:

- Making assumption of consistent propeller efficiency over the entire rev range.
- Discounting any cavitation produced by rotating propellers in highly turbulent water when manoeuvring.
- Assume that co-efficient of advance in reverse is 1 due to near perfect flow onto propeller if rudders are straight ahead, and hence, discounting any influence the rudders have on the propellers.
- Assuming that engine will engage reverse thrust at the moment of control operation (no latency due rev down and rev up).
- There are no other environmental influences on the model (wind, wave action).

Given that response of the engines is not immediate, a second curve (see fig 4) has been created to take into account the delay in response from the engine. We have assumed a 5 second delay in neutral (which is again, a medium value) in which the propellers windmill, causing no additional resistance to that of the hull moving through the water.

(3) *Vessel deceleration* = $\frac{\text{Hull Resistance}}{\text{Hull Displacement}}$

(4) *Speed after period of time* ($V_n$) = *Initial Velocity – (deceleration x time to decelerate)*

*Where:*

- *Hull Resistance is based on Holtrop's regression formulation*
- *Hull Displacement is the design mass of the vessel*
- *Initial Velocity is the speed that the vessel was travelling at the time of manoeuvring*
- *Deceleration Time is the time given to slowing the vessel before reverse thrust is applied*
- *Ratio is the reduction in shaft speed that the gearbox makes between engine and propeller*

Resistance at new speed is based on regression analysis of speed vs resistance using a trendline polynomial to the power of 4 we get:

(5) *Resistance at new speed* = $0.1266xV_n^4 - 1.0249V_n^3 + 3.2801V_n^2 - 1.8274V_n + 0.1794$

The formulae from the non-delayed (as detailed above) situation are then applied.

To ascertain the influence this torque has on the engines whilst transitioning from the neutral to the reverse direction the torque that the engine produces at given engine rpm has been used.

Data collected from sea trials on the Sovereign by Geoff Young and on the Mariner by Jim Young have been used to create the propeller demand curve. Some of the data is incomplete and in some cases missing, an exponential trendline has been added to indicate the likely curve this data creates. This method has been validated on the Mariner, as the intersection of the propeller demand and the available engine torque correlate well with the speeds and RPM of the vessel travelling full speed ahead.

Exponential curves are commonly used by engine manufactures to indicate likely propeller torque demand. The data provided by Geoff Young on the sea trials of Sovereign was small in sample size and the ship speed of the final engine RPM causes the curve to skew and give inaccurate results. Because of this the ship speed at 1700rpm has been left off the graph.

The propeller torque demand was calculated using the resistance curves from Figure 1 and 2 to establish required power. An efficiency factor of 60% was added to account for energy losses in the propellers and drive gear. Equation 2 was then used to establish the propeller torque at the given RPM.

## 3.1 Wind Milling

When the vessel is in neutral, the windmilling is equal to:

(6) *RPM* = $\frac{\text{fwd velocity x coefficient of advance x 60}}{\text{Pitch}}$

*Where:*

- *Fwd Velocity is the speed at which the vessel is travelling forward*
- *Coefficient of Advance is a coefficient reducing water speed onto the propellers based on the vessel hull form (0.4)*
- *Pitch is the pitch of the propellers (1250mm)*

Since the propellers are disengaged from the engine, no rotational force or torque is transferred to the engine and the propeller speed is as shown in Figure 3.

However if the engine is engaged and returned to revs that are less than the revs exerted by the forward velocity on the propellers, then the engine will provide braking and the propellers will slow the rate at which engine revs drop. This braking effect will be lost if the Master puts the vessel straight into neutral.

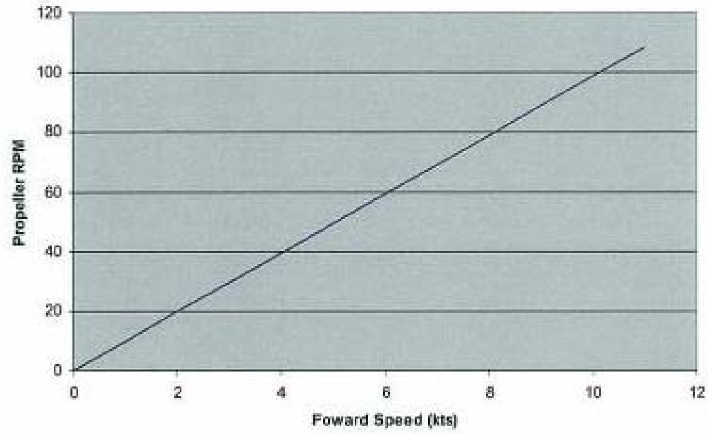


*Figure 3*

### 3.2 Current Engines

Both vessels currently have 6 cylinders, turbocharged Volvo Penta Engines. Mariner has a pair of Volvo Penta TAMD163A engines where Sovereign has a pair of Volvo Penta TAMD165A. The TAMD163A engines went out of production in 1998, with the TAMD165A (which utilises the same block) replacing it. The TAMD165A is now also out of production but both engines where substantially similar that for this report we will assume they are the same. Both engines produce 1100Nm at 600rpm (the speed that the gearbox engages) and a maximum torque of around 2,680Nm at 1,250rpm.

### 3.3 Powering Assessment

Using the maximum torque of 5,360Nm for two engines and transferring onto Figure 4, we get the following:

**Mariner**
Will allow an initial fwd velocity of 3.8 knots for a 10 second stopping time, or 4.0 knots if there is a 5 second delay during shifting.

**Sovereign**
Will allow an initial fwd velocity of 6.1 knots for a 10 second stopping time, or 6.4 knots if there is a 5 second delay during shifting.

These initial speeds are lower than actually experienced for two reasons:

1. The propellers will cavitate, reducing the torque on the engines but also increase time for the vessel to come to rest.

2. When the engines are reduced from initial fwd velocity to the idle ahead position, there is a quicker reduction in speed due to engine braking as outlined in the above section.

Figure 4, shows the difference a further 5 second delay on the torque required to stop the vessel. It can be seen that the more time that the vessel can slow before reverse thrust is applied the greater the reduction in the risk of stalling. Figure 4 also shows that if the vessel is in a situation that reverse thrust is required for stopping quickly the vessel should not have a forward speed greater than an average of 5 knots.

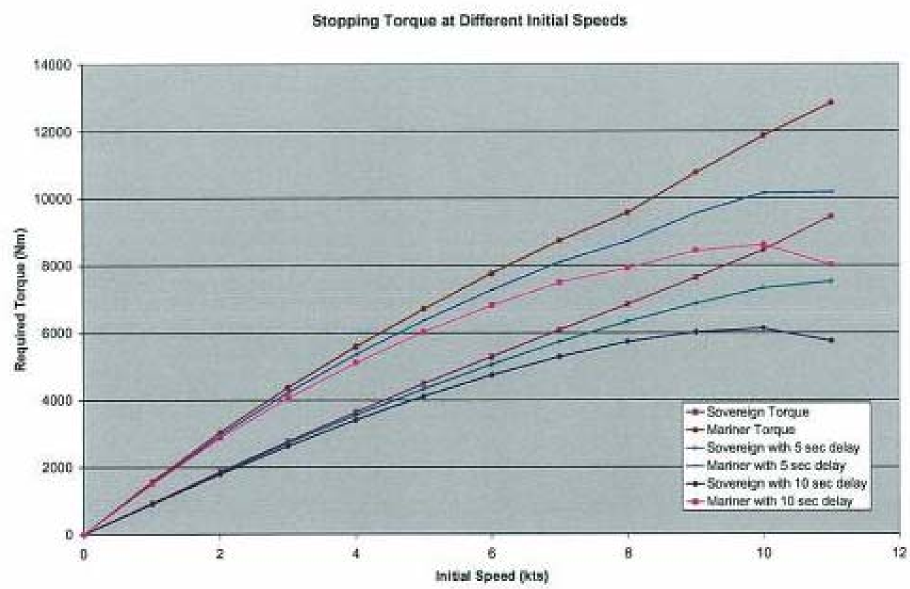


*Figure 4*

When looking at the engine torque required by the propeller throughout the rev range (Figures 5 and 6), it can be seen that the engine has sufficient torque for forward motion up until 1700rpm on both vessels. The reason that the propeller demand is greater than the torque that can be supplied by the engine is due to the propellers being pitched for a cruising speed of 1600rpm.

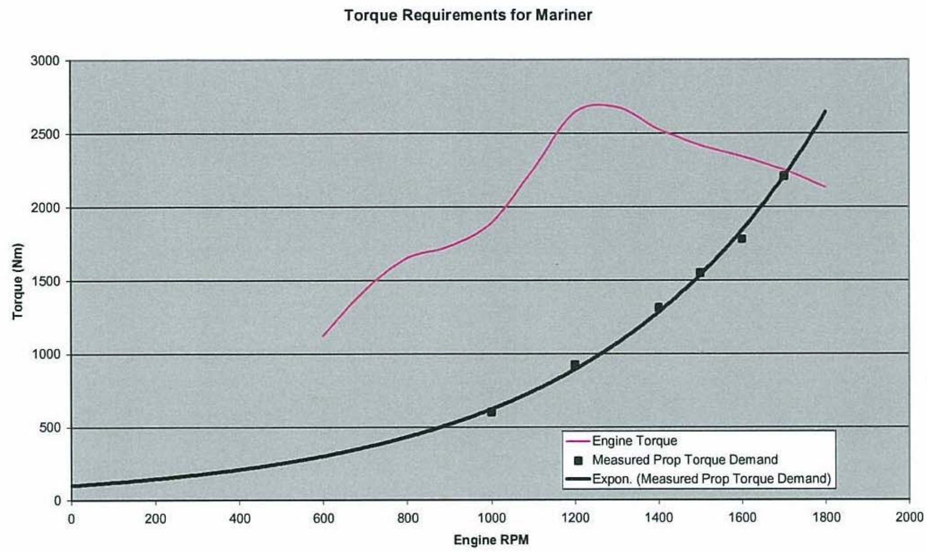


*Figure 5*

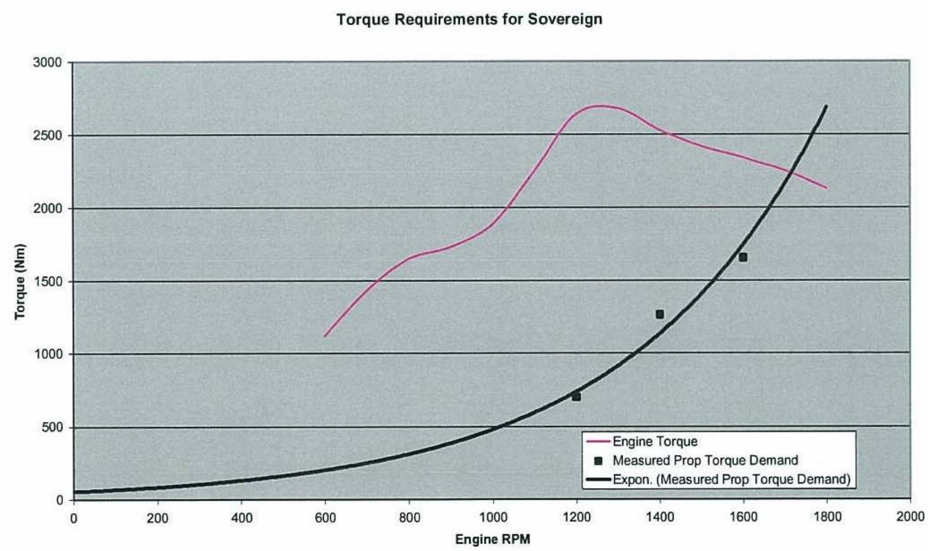


*Figure 6*

To show typical torque requirements when the vessel is put in reverse from a forward velocity, an example will be used as detailed below.

The Sovereign is travelling at 6 knots ahead and is put in reverse to slow the vessel. The selector on the gearbox is set to engage the clutch at 750rpm. The stopping time will be 10 seconds with a 5 second delay to take into account deceleration and a small rest in the neutral position before engaging reverse. Using Figure 4, the torque required to stop the vessel in these conditions is 5059Nm for both engines or 2529.5Nm if each engine is loaded equally. This additional torque load when superimposed onto the propeller demand curve exceeds the available torque from the engine as shown in Figure 7.

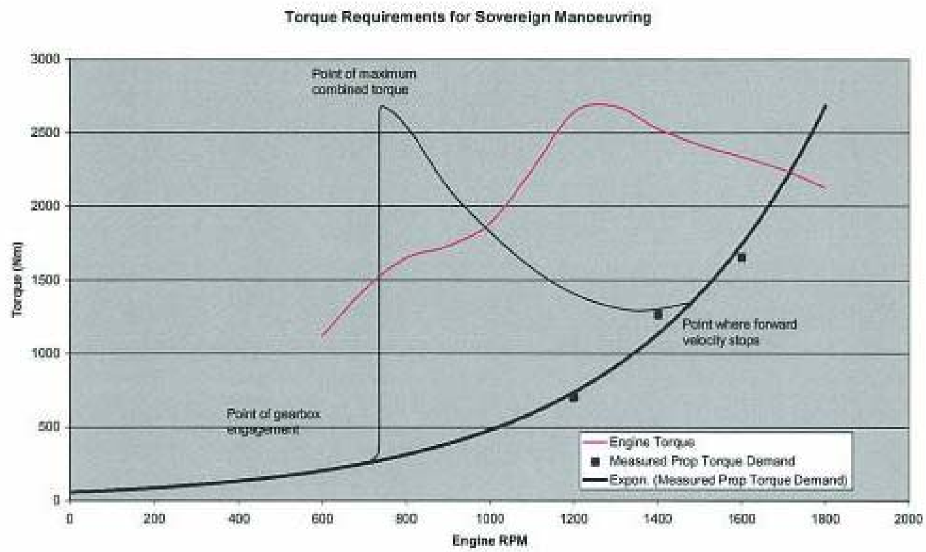


*Figure 7*

As can be seen from Figure 7 the torque required exceeds the torque the engine can produce at the instant the gearbox engages. As the vessel slows due to the reverse thrust the torque requirement reduces to the level that is required by the propeller to travel in the reverse direction.

> **Note**
> The superposition on the line in Figure 7 is correct in location and magnitude of the vertical line (as calculated), however after the initial peak torque the line is indicative to show there is a reduction as the vessels forward velocity slows.
>
> This graph in Figure 7, showing peak torque is for the given example. In general the peak for the Mariner is greater than Sovereign. The peak will be smaller for both vessels if the vessel is allowed to slow before engaging reverse and the peak will be further left or right in the rev range if the gearbox selector is set to 650 and 900rpm respectively.

The Mariner underwent a crash stop trial on 21 April 2007. From this trial the master and workshop manager were able to stop the vessel using reverse thrust and appropriate de-acceleration with initial speeds up to 7.4 knots. No time to stop or distance to stop was recorded during this experiment, nor was the level of de-acceleration recorded. However, it was the greatest speed reduction the Master felt the vessel could withstand without stalling.

The information from the experiment doesn't help to calibrate the calculations as presented in this Report. However, the unknown areas of propeller cavitation and engine braking due to manual de-acceleration should reduce the torque required to the levels that are in line with that calculated.

## 3.4 Cause

There is no single factor that causes the vessels to stall during manoeuvring there are several factors that contribute to the system and increase the likelihood of stalling. Two of the main factors are discussed below.

**Vessel Displacement**

Both vessels analysed in this report have very high displacements compared to other vessels of similar length. This is because of the wide beam and high superstructure and the robust steel hull. The vessel displacement in the form of momentum contributes 80 - 96% to the torque requirement in manoeuvring. A good example of this is the difference between Mariner and Sovereign which are similar length vessels but due to the 84 tonne difference in displacement the Sovereign will stop more effectively, see Figure 4.

**Propeller Pitch**

Monarch was the first of the high displacement, large passenger number vessel that RJL had built specifically for the Fiordland National Park Fiords. During sea trials a vibration was detected in the stern part of the main deck caused by the engines operating at 1800rpm. This vibration disappeared when the engines were reduced to 1600rpm. Real Journeys made the decision to reduce operating speed to 1600rpm because of the vibration and for a reduction in engine wear. RJL requested all the subsequent vessels (Mariner, Navigator and Sovereign) have propellers designed to operate efficiently at 1600rpm. This can be seen in Figures 5 and 6 which shows that the pitch creates a propeller demand curve that exceeds the torque that the engine can provide above 1700rpm. If the propeller was pitched for cruise efficiency at 1800rpm the propeller demand curves will drop so that the propeller demand matches the available engine torque at 1800rpm and have a lower propeller torque demand along the entire rev range.

# 4.0 ALTERNATIVES

## 4.1 General

The following options have been examined as possible measures to reduce the likelihood of engines stalling when manoeuvring the vessel ahead/astern

.

## 4.2 Larger Engines

One of the options to stalling is to consider using larger engines. This involves replacing the existing engines with larger engines which are more able to produce the torque required. This will probably require a gearbox, shaft and propeller change as well. However, assuming these remain the same, the effects will be as follows:

- Larger engines will increase the displacement of the vessel and give greater momentum. However, this will be minor due to the current displacement of the vessels.
- A larger engine will be required to produce a larger torque not just greater power
- Mariner has to increase torque to 4,500Nm per engine, and Sovereign has to increase torque to 3,500Nm per engine to stop in 10 seconds at an initial speed of 11 knots.

The following tables illustrate the effect that would result from fitting larger engines.

**Similar Sized Engines to the TAMD165A (350-400kW)**

| Make | Model | Rating | Continuous RPM | Power @ RPM (kW) | Torque @ 1000rpm (Nm) | Max Torque (Nm) | Fuel Consumption (l/hr) |
|---|---|---|---|---|---|---|---|
| Volvo Penta | TAMD165A | Continuous | 1800 | 404 | 1870 | 2680 | 101.9 |
| Lugger | L6140A2 | Medium | 1800 | 370 | 2106 | 2240 | 91.0 |
| Volvo Penta | D16 MH | Continuous | 1800 | 368 | 2600 | 2780 | 92.0 |
| Caterpillar | C18 | Continuous | 1800 | 339 | 2379 | 2694 | 82.2 |
| Yanmar | 6SY-STP | Continuous | 2100 | 404 | 1450 | 2650 | 110.0 |
| Scania | DL16 42M | Continuous | 1800 | 386 | <2190 | 2480 | 95.2 |
| Cummins | KTA19-M3 | Continuous | 1800 | 373 | 1466 | 2242 | 96.0 |

**Larger Sized Engines (450-500kW)**

| Make | Model | Rating | Continuous RPM | Power @ RPM (kW) | Torque @ 1000rpm (Nm) | Max Torque (Nm) | Fuel Consumption (l/hr) |
|---|---|---|---|---|---|---|---|
| Lugger | L6170A | Continuous | 1800 | 518 | 2019 | 2820 | 122.0 |
| Caterpillar | C32 | Continuous | 1800 | 474 | 2389 | 2512 | 122.5 |
| Yanmar | 8SY-STP | Continuous | 2100 | 503 | 1600 | 3010 | 134.0 |
| Scania | DL16 52M | Continuous | 1800 | 469 | <2190 | 2488 | 120.6 |
| Cummins | KTA19-M3 | Heavy Duty | 1800 | 477 | 1813 | 2812 | 119.9 |

The tables show that an increase in power is not proportional to increase the increase in torque available to the propellers. However, the fuel consumption and mass (not listed) increase. To have any measurable difference on stalling, the engines would have to be larger than those listed above and would require a increase in torque of about 1.5 times the current installation. This estimate on the increase in torque required is based off Figure 7, taking into account the inefficiencies and cavitation that gives an effective torque reduction. Gearboxes and propellers and shafts will need to be changed to match the new engines.

It is generally recognised that heavier slow speed diesel engines are less prone to stalling than high speed engines, the mass of the moving components being the primary reason for this.

Low speed diesels are invariably heavy and expensive and both of these factors mitigate against their popularity in the lower horse-power range. For this reason, the choice of engines to replace the existing Volvo-Pentas is extremely limited and the few that are available are 4 to 5 times the weight. Also, their dimensions are such that major structural changes would be required to fit them in the hulls. Trim and displacement would also be adversely affected.

## 4.3 Shaft Brake

This proposal involves installing a brake on the shaft line to stop the propellers "windmilling" whilst in neutral. The shaft brake will act as a brake by causing the propellers to drag in the water.

Using the drag on a disk, the additional drag force is:

(7) *F drag* = $\frac{1}{2}\rho \times V^2 \times A \times Cd$

*Where Cd* = *1.1 for a flat disk*

*A* = $\frac{\pi d^2}{4} = 1.327m^2$

*P* = *density of salt water* = $1{,}025 kg/m^3$

*Therefore, F drag* = $748.096\ V^2$

As can be seen on the graph, Figure 8; *Torque Reduction due to Shaft Brake*, for Sovereign, a 5 second delay with shaft brake engaged followed with 10 seconds astern will bring the vessel to a halt in 15 seconds from its maximum forward speed. In theory, the overall time to stop will be less than 15 seconds however due to cavitation and efficiency changes it could be longer than this. Mariner will still stall, but the shaft brake does increase the "no-stall" initial speed to around 6 knots.

In an emergency crash stop situation, the action of the shaft brake is effectively limited to reducing the rotational momentum of the propeller. The braking effect of the stationary propeller is only momentary. Furthermore, as soon as the shaft brake releases when astern gear is engaged, the conditions are no different to those with no shaft brake, i.e., the forward motion of the vessel will load the propeller against the direction the engine is trying to turn.

Overall, the shaft brake decreases stopping time by 20-30% as shown below, but will be less effective if the operator does not allow the vessel to slow before engaging astern.

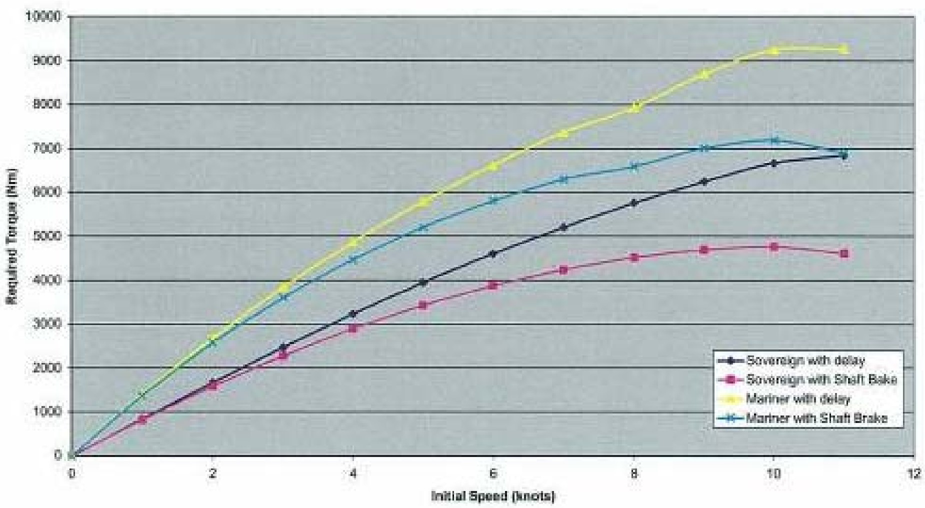


*Figure 8*

### 4.4 Reduction in Propeller Diameter/Increase Propeller RPM

Reducing the propeller diameter will reduce stalling through the increase in propeller RPM. To retain the same thrust and an acceptable efficiency, a smaller diameter propeller will have to be spun faster. This will, not only, require new propellers but new gearbox ratios to suit. Larger, slower turning propellers are the most efficient, therefore a reduction in diameter will reduce vessel top speed or require larger engines to achieve the same speed.

$$\text{(8)} \quad \textit{Torque Required} = \frac{\textit{3916.416 x Power Required x Gearbox Ratio}}{\textit{Engine RPM}}$$

This can be achieved by retaining Engine RPM and reducing gearbox ratio. For a 25% torque reduction in Sovereign, the ratio will need to be at least 1:2.3. Using a Twin Disc gearbox MG-5145 SC will give a ratio of 1:2.5.

A simple calculation gives a propeller rpm of 720 and using the smallest p/d ratio of 0.6 allows diameter of 1,160mm and pitch of 700mm.

This gives efficiency of around 43% as compared to the current efficiency of 60%.

### 4.5 Slipping Gearboxes

Slipping gearboxes like the Quick-Shift gearboxes by Twin Disc use fluid to progressively introduce transmission between the engine and propeller. This transmission integration is electronically controlled and can be varied to suit each vessel and its particular characteristics. Given that the power uptake is progressive and not instantaneous, response time is increased and can be greater than the time taken by an experienced operator controlling de-acceleration and reverse acceleration by the usual manual process.

The Quick-Shift gearboxes do not have the same higher gear ratio options although the existing propellers on Sovereign may be able to be used as the difference in ratios – 1:3.06 and 1:3 is minor. However, the difference on Mariner is greater (1:3.6 and 1:3) and, therefore, the propellers will require replacement to smaller diameter, higher pitch. See section above.

This option will increase engine response due to a smaller diameter propeller, but will reduce overall propeller response due to the progressive electronic response that minimises the risk of stalling.

## 4.6 Status Quo

Both Sovereign and Mariner were designed as displacement vessels with adequate superstructure to accommodate the specified passenger numbers and vessel layout. Both vessels are constructed from steel and have aluminium superstructures. Both vessels use Volvo Penta engines which were chosen, amongst other reasons, because of their high torque for the power required. The gearboxes and propellers were chosen to give the best efficiency and minimise cavitation. This included using high gear ratios to slow the propellers down and using the largest propellers that would fit into the available space. This combination increases the torque demand on the engines but also gives the best available handling. The propellers were designed and verified by Veem to meet these criteria as outlined above and utilise Veems proprietary Veemstar blade profile.

Overtime, research and development by propeller designers will give an advantage by using the latest propeller profiles. In this case, Sovereign had new propellers when built in 2003 and Navigator had new propellers in 2006 when the existing trimmed propellers were replaced. Therefore, there would be little advantage in replacing these propellers. Retaining the status quo will require that the operators are aware of the requirement to operate the gear shift/engine speed controls in a manner that will minimise the risk of stalling when manoeuvring.

In this respect, it is notable that the reported incidents of stalling have occurred while the vessels have been cruising in the fiords. There have been no incidents reported to us in which an engine has stalled during berthing or departure manoeuvres. With the high frequency of such manoeuvres and the consequent opportunities for stalling, it is a reasonable conclusion that the skippers are operating the engine controls correctly in these conditions, within restricted confines.

This option will not eliminate stalling.

## 4.7 Controllable Pitch Propeller

Controllable Pitch Propellers (CPP) are a propeller with a means of mechanically altering the pitch of the blades. This allows the blades to be set to the most efficient pitch throughout the rev range. Conversely, this will give better pitches for slowing the vessel and the acceleration in reverse. This can be electronically set up to constantly change the angle of the blades to ensure that the engines are never overloaded and stalling can be eliminated. A CPP will eliminate the need for a reverse gear as the engine can remain at a constant rotational speed while the blades change angle. However for this vessel and engines a step gearbox will be required. The CPP will require an additional hydraulic or mechanical system to control the blades and the bridge will require additional controls and master training to use a system that changes the traditional method of operation. The fiords have the greater occurrence of flotsam usually caused by trees slipping off the steep side during rainfall. The incidence of log strikes is common and care has always been taken to protect the propellers. Introducing a propulsion system that is complex will increase the out of service time for repair and incur a greater maintenance cost.

CPP, however, does introduce considerable greater complexity to the propulsion machinery and introduces considerably greater risk of costly repair when a log strikes the propeller.

## 5.0 SUMMARY

The table below summarises the available options:

| Option | Benefits | Disadvantages | Eliminate Stalling |
|---|---|---|---|
| Status Quo | Simple method to give good manoeuvring response. | Has greatest likelihood of stalling | No |
| Larger Engines | Greater power and torque to assist response. Possibly retain existing propellers. | Greater fuel burn. Increase weight on vessel. Engine needs to be substantially larger to influence manoeuvring. | Possibly |
| Shaft Brake | Effective at slowing vessel. Retain complete existing propulsion equipment. | Requires time to slow to be of benefit in manoeuvring. Not effective in emergency stopping. | Possibly |
| Reduce Propeller Diameter | No additional benefit to reducing stalling. | Replace propellers and gearboxes, decrease efficiency of vessel. Greater fuel burn. Reduced manoeuvring. | Possibly |
| Slipping Gearboxes | Option to use or not as use slipping capability. | Constant lag in response. Replace propellers on Mariner. | Yes (if used) |
| Controllable Pitch Propeller | Gives excellent manoeuvring. Gives best efficiency. | Vulnerable to log strikes. Complicated. Higher level of operator skill required. | Yes |

Each option has an influence on the likelihood of stalling, manoeuvring and fuel efficiency. These have been ranked in order of benefit, with 1 being of most benefit and 5 being of least.

| Option | Stalling Reduction | Handling | Fuel Efficiency |
|---|---|---|---|
| Status Quo | 5 | 2 | 1 |
| Larger Engines | 2 | 2 | 5 |
| Shaft Brake | 2 | 1 | 1 |
| Reduce Propeller Diameter | 2 | 5 | 4 |
| Slipping Gearboxes | 1 | 3 | 3 |
| Controllable Pitch Propeller | 1 | 2 | 1 |

Summarising the different options from the table above the shaft brake gives the best combinations of characteristics.

## 6.0 CONCLUSION

Our investigations have confirmed that the engines, gearboxes and propellers as presently installed in the four vessels, fully meet the operational requirements for high efficiency in respect of providing adequate power for the required hull speed within the limits of acceptable levels of fuel consumption. However during manoeuvring procedures the available torque is less than what is required to bring the vessel to a timely stop for the 5 - 9 knot initial speed range.

Given that the vessels are currently undertaking multiple manoeuvring procedures per cruise, Duffill Watts supports any modification which reduces stalling without compromising manoeuvrability.

The option to install a shaft brake gives the best characteristics required by RJL. Shaft brake systems are not common on vessels operating in New Zealand and therefore Duffill Watts recommends that further investigation is undertaken to ensure suitability for RJL's vessels.

As a secondary option Duffill Watts would endorse a move to replace the existing gearboxes with Quickshift gearboxes. Duffill Watts would recommend that a range of propeller manufactures are consulted to compare the varying options available for propeller gearbox combinations.

www.duffillwatts.com

## Appendix 4: Vessel starting procedures

Vessel Starting Procedures 2.11.06

In light of recent events in Milford it has become timely to readdress the starting procedures on the larger vessels ( Monarch, Sovereign, Mariner, Wanderer & Navigator)

During the latest event at Milford there seems to have been some confusion over the starting sequence after stalling.

Now that we have start buttons fitted to each helm station, using the keys to start the engines is a habit we should get away from, so that in an emergency or pressured situation the instinct is to use the buttons rather than the keys.

The logic behind this is that to use the keys to restart after a stall, the throttles need to be in the neutral position, the keys have to be rotated back through the 'Off' position and then rotated to t ... osition, the station select button pushed, then the keys rotated further to start the e ... It is important to note that using this method, if the keys are not turned back to the ... ition the vessel will not start.

T ... ler method is:

1. Throttles to neutral position (don't touch the keys, they will already be on)
2. Press 'Station Select' and ensure all four indicator lights are lit,
3. Press start buttons for 1-2 seconds until engine starts.

... t in to the habit of using this method when starting every time, hopefully it will become ... nature and avoid confusion in the event of a stalled engine.

Peter Bl...

Chief La...

## Appendix 5: Revised operating procedures

**REVISED OPERATING PROCEDURES NOTIFICATION**

**'MILFORD SOVEREIGN'**

**Company best practice when cruising or manoeuvring at speeds in excess of 7 knots shall be to have the idle speed on the Power Commander unit on setting 3.**

**When travelling at speeds below 7 knots, Masters shall apply discretionary situational awareness, having regard to wind, tide, other traffic, and proximity to shore. The recommended idle speed setting is '3', however a slower speed setting may be selected if the master deems it appropriate.**

**FOR EMERGENCY SITUATIONS REQUIRING MANOEUVRING OR CRASH STOPS FROM FULL AHEAD TO FULL ASTERN GEARBOX MOVEMENT, THE IDLE SPEED SETTING MUST BE ON '3'**

**It should be noted that current Navigational Bylaws restrict speed to 5 knots within 200m of the shore.**

**<u>Sovereign Masters as at 2.3.07</u>**

**I have read this Procedure change notice and understand the specified operating conditions.**

| | | |
|---|---|---|
| **Kim Cormack** | **Signature.............................** | **Date..........** |
| **James King-Turner** | **Signature.............................** | **Date..........** |
| **Dean Thompson** | **Signature.............................** | **Date..........** |
| **John Conrad** | **Signature.............................** | **Date..........** |
| **Peter Bloxham** | **Signature.............................** | **Date..........** |

**Peter Bloxham**
**Safe Ship Manager**

**Recent Marine Occurrence Reports published by the Transport Accident Investigation Commission (most recent at top of list)**

| | |
|---|---|
| 06-204 | fishing vessel "Kotuku", capsized, Foveaux Strait, 13 May 2006 |
| 07-201 | charter catamaran, *Cruise Cat*, collision with navigational mark, Waikato River entrance, Lake Taupo, 22 February 2007 |
| 06-208 | fishing vessel *Santa Maria II*, engine room fire, L'Esperance Rock, Kermadec Islands, 10 December 2006 |
| 05-212 Incorporating | restricted limit passenger vessel *Milford Sovereign,* loss of directional control, Milford Sound, 20 November 2005 incorporating: |
| 06-206 | restricted limit passenger vessel *Fiordland Navigator,* heel due extreme wind gust in Milford Sound, 8 July 2006 |
| 06-201 | passenger freight ferry *Aratere*, Heavy weather incident resulting in cargo shift, Cook Strait, 3 March 2006 |
| 06-205 | fishing vessel, *Lady Luck*, collision and subsequent foundering, Motiti Island, Bay of Plenty, 23 June 2006 |
| 06-203 | fishing vessel *Venture*, grounding, Tipi Bay, Tory Channel, 19 April 2006 |
| 05-211 | container ship *Spirit of Resolution*, collision with bridge, Onehunga, 8 October 2005 |
| 05-210 | restricted limit passenger vessel *Milford Mariner*, engines' stall resulting in grounding, Harrison Cove, Milford Sound, 18 September 2005 |
| 05-208 | passenger freight ferry *Santa Regina*, near grounding, Tory Channel eastern entrance, 9 June 2005 |
| 05-207 | freight and passenger ferry *Santa Regina* and private launch *Timeless*, collision, off Picton Point, Queen Charlotte Sound, 2 May 2005 |
| 05-206 | passenger/freight ferry *Arahura*, loss of propulsion, Cook Strait, 24 April 2005 |
| 05-205 | restricted limit passenger vessel *Black Cat*, control cable failure and collision with rock wall Seal Bay, Akaroa Harbour, 17 April 2005 |
| 05-202/204 | passenger freight ferry *Aratere*, steering malfunctions, Wellington Harbour and Queen Charlotte Sound, 9 February and 20 February 2005 |
| 05-201 | passenger ferry *Quickcat* and restricted passenger vessel *Doctor Hook*, collision, Motuihe Channel, 4 January 2005 |

Price $38.00 ISSN 0112-6962