INCIDENT REPORT

SHETLAND ISLANDS COUNCIL
PORTS & HARBOURS OPERATIONS

INCIDENT REPORT

REPORT ON INVESTIGATION OF THE COLLISION BETWEEN THE TANKER "LOCH RANNOCH" AND TUG "SOLAN" ON 20 DECEMBER 2011

The investigation of the incident has taken many months as input has been sought from manufacturers' representatives, etc. The initial investigation was undertaken without full data from the Voyage Data Recorder (VDR) which inhibited the ability of the Examination Panel to reach a definitive conclusion. Work undertaken for another purpose revealed that most VDR data had been recorded and was available. This has been used to provide further information to the Examination Panel.

The main findings of the Examination Panel are:

1. At delivery the tug had an underlying directional stability issue. Following trials, the builder installed a system of electronically vectoring the propeller thrust to try to counter this. It was achieved by installing two modes of operation, one using vectoring, one not. The default mode was to vector the thrusts.
2. The consequence of vectoring the propeller thrust as a method of correcting the vessel's inherent directional instability introduced a handling characteristic that was not identified. Trials have subsequently shown that "splitting the sticks" on this vessel results in the opposite reaction than expected with other vessels. both Voith and conventional screws.
3. The operational issues associated with the towing winch were a distraction for the bridge team and a contributory factor to the incident.
4. The Master (who was in the 'winch control' role) was probably distracted by the recurrent winch issues and hence his 'steering' supervisory role was compromised.
5. The Mate (who was in the 'steering' role under the supervision of the Master) was in the early stages of the training programme for the tug but did have experience from similar towing operations on "Solan" and Bonxie" as well as other Sullom Voe tugs.
6. Darkness, and the layout and poor illumination / labelling of the engine speed control buttons on each side of the conning position probably led to incorrect buttons being pressed.
7. There is no evidence of any propulsion, mechanical or electrical control problems and the tug was responding to the commands from the wheelhouse at all times.
8. There was significant evidence of the effects of EMI on the alarm and indicator systems, however no actual effect on control function was identified during test and investigations.
9. Contrary to the technical report from TMS, both modes are usable at the discretion of the Master. For good reasons there is no definitive "correct mode", but the vectoring mode is set as the default. At the time of the incident, most Tugmasters preferred to use vectoring mode at all times.
10. Whilst differing power levels on each thruster may have exacerbated the sheer, the prime reason for the incident is believed to be the effect of vectoring.

Recommendations

1. Work should continue to resolve and rectify the underlying cause of the directional instability.
2. Improve the labeling of the engine speed control buttons and consider a more effective layout
3. Prior to re-introduction to service, a comprehensive training programme to be put in place.

SHUTTLE TANKER “LOCH RANNOCH”

Port of Registry	Lerwick, UK
Official Number	901255
Class	Lloyds Register
Built	1998
Vessel Type	Shuttle Tanker
Gross Tonnage	75,526
Deadweight	130,031
Length Overall	269.73m

The Loch Rannoch is fitted with two MAN-B&W engines producing a total of 19,960 kW (27,138hp) connected to two controllable pitch propellers. The tanker is also fitted with two thwart ship thrusters with controllable pitch propellers.

TUG “SOLAN”

Port of Registry	Lerwick, UK
IMO Number	9449003
Class	Lloyds Register
Built	2010
Vessel Type	Voith Tug
Gross Tonnage	852
Deadweight	540
Length Overall	40
Bollard Pull	87.9 Tonnes

Although not compulsory, as recently built vessels the Voith tugs “Solan” and “Bonxie” are fitted with a Voyage Data Recorder (VDR).

The “Solan” is operated with a crew of 4 (Master, Mate, Chief Engineer and 2nd Engineer / GPR) whilst within harbour limits. This is in compliance with the Safe Manning Document.

The tugs “Solan” and “Bonxie” have an electronic propulsion and direction control system. The older tugs in the fleet are controlled by mechanical linkage.

The new tugs “Solan” and “Bonxie” suffer from directional instability. This has been an ongoing problem which has persisted since the vessels were built and is believed to be design related. In March 2013 the propulsion manufacturers Voith undertook tank testing of relatively minor hull modifications which they believe will cure the directional instability issue. This work is planned for the near future.

Appendix 9 details the directional instability problem more comprehensively. However in the normally installed configuration of the propulsion system, the vessels are challenging to control. The shipbuilder developed an electronic control based modification in order to improve the vessels' steering characteristics. This modification, termed the 'Free Running' mode, applies correctional thrust to allow for a heading to be maintained without excessive corrective input from the steering wheel. The conventional mode has no corrective thrust.

SULLOM VOE PORT

TECHNICAL WORKING GROUP

The Sullom Voe Port Safety Management System defines the role, composition and function of the Technical Working Group (TWG). The TWG is composed of members of the port management, the Designated Person, representatives from each service area within Port Operations, a representative from Sullom Voe Terminal, a representative of the port users and third party members as required.

One of the functions of the group is to review reports and recommendations from the Examination Panel and to promulgate onwards any recommendations or findings to the appropriate bodies, including the Duty Holder.

EXAMINATION PANEL

A sub group of the Technical Working Group, the Examination Panel is chaired by the Harbourmaster.

Under the Port's Safety Management System the Examination Panel are charged with conducting investigations "into any incident involving vessels within the Sullom Voe Harbour Area or the approaches".

Reports and recommendations from this panel are passed to the Technical Working Group. The members of the Examination Panel for this incident were as follows.

Member	**Position**	**Qualification**
Roger Moore	Harbour Master (until June 2012)	Master Mariner
Colin Reeves	Harbour Master (from June 2012	Master Mariner
Bill Cameron	Marine Pilot	Master Mariner
Stuart Polson	Marine Pilot	Master Mariner
Michael Jamieson	Tugmaster	Master Mariner
John Halcrow	Tug Chief Engineer	Chief Engineer

INCIDENT SUMMARY

1. On 20 December 2011, the Shuttle Tanker “Loch Rannoch” departed from Jetty Number 3 at the Port of Sullom Voe under pilotage and with the aid of two tugs, “Solan” and “Dunter”.

2. The “Loch Rannoch” was berthed Starboard side to. This is the preferred berthing format and allows vessels to depart the port with the minimum amount of manoeuvres and without having to“swing” the vessel.

3. The “Loch Rannoch” is a regular visitor to the port operating as a shuttle tanker between the Floating Production Storage and Offloading (FPSO) facility at the Schiehallion oilfield and the port and oil terminal at Sullom Voe.

4. Normal departure practice for the “Loch Rannoch” is for two tugs to assist in un-berthing.

5. On 20 December 2011 the tug “Solan” was made fast on the port bow of the “Loch Rannoch” and the tug “Dunter” was made fast to the tanker through the tanker’s centre lead aft. As is normal practice, both tugs used their own lines.

6. The towing winch on “Solan” “tripped out” on a number of occasions whilst making fast to the tanker “Loch Rannoch”.

7. Weather at the time was good – wind 290^0 at 10kts (gust 15 kts); dark with good visibility; no precipitation.

8. Onboard the “Solan” both the Master and Mate were on the bridge. The Mate was controlling the tug under the supervision of the Master. The Master was also operating the winch.

9. The “Loch Rannoch” sailed from Jetty Number 3 at 19:42 and made her way past Jetty Number 4 outbound.

10. At approximately 20:01 the “Loch Rannoch” was in the vicinity of Number 3 buoy. The pilot onboard the “Loch Rannoch” requested that the tug “Solan” shorten up in preparation for letting go.

11. At 20:03 the Master of the tug “Solan” reported on the VHF radio that they had “lost power”. The tug “Solan” passed in an uncontrolled manner from the port bow to the starboard side of the “Loch Rannoch”.

12. The pilot onboard the “Loch Rannoch” immediately requested that her engines be put full astern. During this time the tug paid out on the winch to slacken the tow rope.

13. At 20:03.29 the Master on the “Solan” reported that he had “got her back again”.

14. Continual problems with the towing winch, which required a number of restarts, caused the crew problems in operating the winch to let go. It was not until 20:07 that, as a result of manoeuvring the tug, enough slack on the tow line was available to allow the crew of the “Loch Rannoch” to release the tug.

15. Once clear of the “Loch Rannoch” the crew on the “Solan” managed to regain operational control of the towing winch and retrieved the tow line before proceeding safely back to the tug jetty.

16. The sister tug, “Bonxie”, took over the duties of “Solan” and the tanker “Loch Rannoch” resumed her departure from port.

17. There were no reported injuries, structural damage or pollution on either vessel as a result of the incident. The “Loch Rannoch” did sustain some marks from Solan’s fender rubbing on the starboard side.

18. Prior to, during and after the incident no alarms were recorded from the Solan’s main engines, auxiliaries, propulsion or control systems. A warning buzzer was heard from the towing winch control panel at 20:02:40.

POST INCIDENT

1. The incident was reported to the Duty Harbourmaster by telephone with reports from Master, Mate and Pilot written on 21 December 2012 and submitted to the Harbourmaster.
2. Both tugs “Solan” and “Bonxie” were removed from service pending the result of an investigation into the incident.
3. The Marine Accident Investigation Branch (MAIB) and the Classification Society (LR) were informed.
4. The Engineering Manager investigated on the morning of 21st December but failed to find any evidence of malfunction of propulsion systems or controls.
5. Some information was retrieved from the Voyage Data Recorder (VDR) on 28th December.
6. The initial view of the Master was that Solan had suffered a control systems failure. An independent incident investigation was commissioned from Trident Marine Services (TMS), specialists in control systems.
7. Due to the holiday season, TMS did not attend until week commencing 9 January 2012.
8. A series of trials and interviews were carried out by TMS and an initial report produced on 23 January 2012.
9. The Examination Panel convened to scrutinise and evaluate the report. This small professional group chaired by the Harbourmaster included representatives from the tugs and pilots
10. A number of questions and theories were raised and over the following months these were investigated by the Examination Panel.
    a. TMS were invited to assist in this process.
    b. MAN, Voith, Bosch Rexroth (VBR), Ibercisa and Siemens were all contacted and various questions set and information requested. It was confirmed that neither MAN or VBR systems on these vessels were designed to record information.
    c. Voith and Bosch Rexroth technicians visited the vessels and undertook a series of tests.
    d. The Examination Panel went onboard the tugs and various trials were undertaken to try and replicate the sequence of events.
11. At this stage, the Examination Panel could not agree with the conclusions reached by TMS. As no technological faults had been identified TMS favoured a "human error" conclusion. The Examination Panel furnished with the same information and evidence made available to TMS could find no definitive evidence of human error. Further, it transpired that TMS had assumed that the content of the Voith training manuals (which had never been distributed to Tugmasters) were correct. However, experience of

operating these vessels has called into question some of the detail of the training manuals (see para 20).

12. The Examination Panel concentrated their efforts on attempting to identify why there appeared, at that stage, to be an apparent temporary loss of control function on the “Solan”. The Examination Panel were also made aware of an uncorroborated similar apparent loss of control function on the “Solan”, which had not previously been reported by the crew. This information may not have been available to TMS.

13. During the months whilst the tugs “Solan” and “Bonxie” remained out of service and the Examination Panel attempted to identify what technical issues could have caused the apparent loss of control function a considerable level of maintenance, inspections and testing was undertaken. It was believed that this may have made it more difficult to replicate a loss of control function.

14. In June 2012 a technician fitted new digital input modules to replace faulty modules removed from both Solan and the sister vessel, Bonxie in August 2011 – before the incident. During this installation process the technician was able to establish that most VDR data from the incident was still present in it’s raw format, but that the graphical interface element of the playback software was faulty, falsely indicating that no data was present.

15. VDR data not present was confined to the VBR NMEA data from the Starboard propulsion system and the elements relating to the newly fitted module (primarily watertight door information).

16. Accordingly the remaining data was extracted and the most relevant 3 minute period of the incident from 20.01.20 to 20.04.20 was shown as a graphical timeline diagram which is exhibited as Appendix 11.

17. This timeline diagram together with the raw data was passed to both TMS and VBR. As a result, TMS reviewed their report of 23 January 2012 and produced an updated report dated 12 September 2012 which is attached as Appendix 5.

18. In September VBR confirmed that the time line data extract accurately represented the raw data recorded on the VDR.

19. Accordingly the Examination Panel was reconvened to study the new graphical evidence and the updated TMS report.

20. Owing to the incorrect initial belief that the cause was a control failure, TMS were employed to provide an independent report. However, it should be noted that their expertise is in control systems and not ship-handling. Accordingly their ship-handling conclusions in their report need to be treated with caution and based against those of the experienced Master Mariners on the Examination Panel.

FINDINGS AND CONCLUSIONS

Having considered all the available data the panel were of the view that the most likely scenario is as detailed below:

1. The “Loch Rannoch” sailed from Jetty Number 3 at 19:42 with the assistance of tugs “Solan” and “Dunter”.

2. Analysis of the available data indicates that at 19.42 both Main Engines on Solan were at 675 RPM.

3. At 19.44 the Mate selected 800 RPM on the Port Main Engine and 500 RPM on the Starboard Main Engine. The view of the Examination Panel was that this selection was in error and that the Mate had been seeking to set both engines at the 800 RPM setting. From the voice recording of the conversation at 19:28 the Master can be heard instructing the Mate to move to the “top one” for the actual pull.

4. The Examination Panel are of the view that the most probable explanation for the asymmetric engine settings (Port 800 RPM and Starboard 500RPM) was as a result of a misinterpretation of the symmetry in the ergonomic layout of the engine speed settings as shown in Figure 1 below. The engine control buttons are mounted with other buttons and equipment in controls panels on either side of the conning position – as shown in Figure 2. The view of the Examination Panel is that the Mate would appear to have interpreted the buttons as being slower speeds to the inside and higher speeds to the outside. The VDR data shows that the Mate selected the two outer power settings (L1 and R4) rather than the far right setting on each bank of controls (L4 and R4).

Figure 1: Aft control position

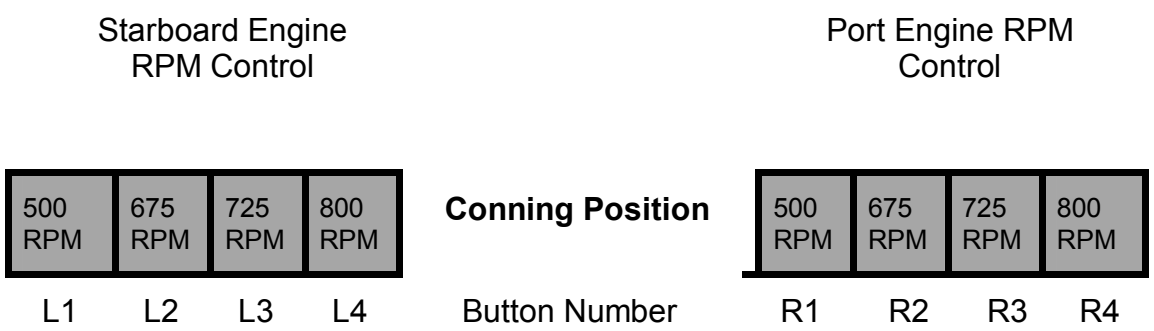

Figure 2

5. The vessel continues towing on these settings (P800, S500) for six minutes.

6. At 19.50 the Port Main Engine was reduced to 725 RPM and the Starboard Main Engine was increased to 675 RPM. This selection of the second outer buttons would appear to confirm the Mate's apparent confusion over the sequencing of the engine speed command buttons. From the voice recording it would appear that the Mate was trying to reduce power to one step below full RPM having pulled the vessel off the berth and been instructed by the Pilot on Loch Rannoch to "Ease back and work your way ahead". The recording of the conversation between the Master and Mate also shows that they were seeking to maintain tension on the towing rope.

7. The VDR data shows that the Mate has pushed L2 and R3 which would reinforce the view that the Mate believed that the power setting buttons were symmetrical about the conning position. In retrospect the Examination Panel can see how this confusion could have arisen.

8. The Vessel continued on the above settings (P725, S675) for 11 minutes.

9. At 20:00:56 the voice recording of the VHF radio traffic records the Pilot on Loch Rannoch ordering "Solan, if you'd shorten up & I'll let you go".

10. At 20:01 the VDR data would suggest that the Mate may have attempted to select 800 RPM for both engines. At this time the voice recording has the

Master instructing the Mate to “gee her more steam ….gee her the top one”. However, the pressing of the correct button, L4, for 800RPM on the starboard engine is contrary to the previous interpretation that the Mate believed the engine speed command buttons were symmetric around the Conning Position.

11. There are a series of engine speed changes:

    a. At 20:01:41 the VDR data shows that 800 RPM was selected for the Port engine;

    b. At 20:01:42 both engines are accelerating towards 800 RPM;

    c. By 20:01:45 the Starboard engine is running at 800 RPM. However, the Port engine is back down to 725 RPM;

    d. At 20:01:54 the Starboard engine is at 800 RPM but the Port engine is accelerating again only to fallback again. The Port VBR system was recording the button commands at 2 second intervals. It is believed that the most probable reason was that the 800 RPM button had been pressed shortly followed by the 725 RPM button causing the engine to accelerate and then fall back.

12. At 20:01:50 the VDR data shows the rate of turn to Starboard of “Solan” can be seen to increase gently from the compass heading and Rate of Turn trace. This could be as a result of two effects.

13. Firstly the effect of the bow wave from the “Loch Ranoch” pushing on the starboard rear quarter of “Solan” which would not be an unexpected event.

14. Secondly, as a result of the vectored thrust introduced by “free running” mode. Prior to this incident neither Masters nor management appreciated the potential full effects of the thrust vectoring, an electronic “fix” which had been introduced by the shipbuilder to overcome what would appear to be a hull design fault that was causing course instability. These thrust vectoring effects with asymmetric engine settings only became clear during the sea trials undertaken with TMS post incident and are described on page 17 of the TMS report. These sea trials showed that when the vessel is in “Free Running” mode the effect of more starboard power is to induce a turn to Starboard rather than to port as would be expected by an experienced mariner.

15. This effect will have been exacerbated by the fact that the port engine was at 725 RPM whilst the Starboard Engine was at 800 RPM and as such the combination of power setting and vectored thrust would have also induced a turn to Starboard thus amplifying the effect of the “Loch Rannoch” bow wave on the “Solan”

16. At 20:02:06 the VHF recording shows that “Solan” called “Loch Rannoch” and advised they were ready to be let go. “Loch Rannoch” acknowledges.

17. At 20:02:16 the “Solan” voice recording has the Master warning the Mate to “be on stand-by to catch”. The Examination Panel noted that the bridge team

were communicating correctly with each other and were properly alerted to be ready to respond if necessary.

18. At 20:02:22 the VDR data suggests that the Mate would appear to have perceived the change in rate of turn as the compass heading shows the vessel's heading had changed from 28^0 to 38^0 between 20:02:00 and 20:02:22. The data shows that at this point the Mate pulled back on the Port Ahead/Astern lever to the "no power or neutral" position presumably in anticipation that reducing thrust from the Port Engine would correct the rate of turn to Starboard and bring the vessel back on course. However, as described above the vectored thrust introduced by the "Free Running" mode meant that the vessel did not react as would normally be expected and turn gently back to Port. On "Solan" in the "Free Running" mode this action was subsequently shown to have the opposite effect to that expected and increase the rate of turn to Starboard.

19. At around this time there was contact between the vessels and "Solan" was pushed around from the Port Bow to the Starboard Bow of "Loch Rannoch" and made contact with the rubber fendering leaving a black mark on the tanker's hull as can be seen from the vessels compass heading which changed from 38^0 at 20:02:22 to 72^0 at 20:02:50.

20. Shortly after 20:02:50 the Master took control of the vessel from the Mate and the Port Engine was set to 800 RPM at 20:02:52 and at 20:03:13 the vessel which was now facing in the opposite direction on the Starboard side of the "Loch Rannoch" was put into Astern Thrust as the Master regained control to allow the "Loch Rannoch" to let go.

21. Having considered the data in detail the Examination Panel are of the opinion that although errors were made in power selection by the Mate, this was probably as a result of inexperience on this particular vessel and his interpretation of the engine controls on this vessel. Notwithstanding the incorrect power settings selected by the Mate the Examination Panel considered that the Mate's action of reducing power from the Port engine to counteract the effect of the "Loch Rannoch" bow wave would have been correct on most vessels and the manner in which the vessel reacted was the opposite of what could reasonably have been expected. See Appendix 11.

The VDR raw data shows that the Voith propulsion units and the MAN engines worked in accordance with demands from the bridge controls.

The Examination Panel did not concur with the investigation findings by TMS in regard to the mode setting. [Ref. TMS Report - Critical Factor 1]. The "normal" preferred mode of operation by all masters is "Free Running". Experience with the vessels has shown that the directional instability is such that "Pull" mode would only be used when maximum bollard pull was required.

When engines are initially started alongside the default mode is "Free Running", the "Pull" mode has to be specifically selected.

The engine speeds (rpm), although displayed on a number of systems, are only recorded via NMEA outputs to the VDR.

The rpm displays are operated by a signal generated from a frequency converter. It was found that this signal is not connected to the control systems, and only outputs to the indicators.

The difficulties in operating the towing winch contributed to the levels of concentration and frustration experienced by the Master in the period leading up to the incident. It is noted in the TMC report that both the Master and Mate, at different times, tried to get the winch operating again by switching off and on, no mention was made of the use of the reset switch which should have reduced the winch start up period. The towing winch did have a tendency to “trip-out” which was subsequently witnessed by members of the Examination Panel. (Further details of winch problems is included in Appendix 7.)

The knowledge and understanding of all the operational characteristics of the new tugs, “Solan” and “Bonxie” has developed over time. When the Voith Training Master produced his reports (21/2-6/3/11 & 3-9/4/11)), the full effects of utilising the “Free Running” mode, as a means of countering the directional instability, was not fully understood by either the Voith Training Master or crews. The method of operating the vessels in regard to the selection of operating modes contradicts the findings and recommendations in the training reports produced by the Voith Training Master. It is noted that there is no evidence that the Voith Training Master’s report was ever distributed to the vessel Masters. It is also noted that the duty Master at the time of the incident had been involved in the training given by Voith on 22/23 February and 6 April 2011.The management did not issue any direct instruction to the Master’s of the tugs on which mode of operation to use when manoeuvring the tugs. This is in accordance with "Regulation 34-1" of "SOLAS Chapter V", which states:

> “ The owner, the charterer, the company operating the ship as defined in regulation IX/1, or any other person shall not prevent or restrict the master of the ship from taking or executing any decision which, in the master's professional judgement, is necessary for safety of life at sea and protection of the marine environment. “

Consequently the Masters were free to use which mode they felt most appropriate for the prevailing circumstances and conditions. It was noted, by the Examination Panel, that most Masters preferred to use the “Free Running” mode. It was felt by the panel that the “Free Running” mode was indeed the default as most Masters considered the underlying directional instability excessive without its application.

A training programme was put in place in March 2011 shortly after the arrival of the new tugs. The staff at that that time undertook this training. The Mate on duty at the time of the incident was not employed in the towage service until May 2011. However, the Mate was undertaking the established training programme, as outlined in the company Mates to Masters training book (see appendix 10) and had manoeuvred the tug once before, when it was made fast on the bow, without incident. In addition he had done the same manoeuvre once with the sister tug, “Bonxie”, also on the bow. One of these was after dark, the other in daylight.

It is not possible to entirely rule out the possibility of electromagnetic interference having a contributory factor in this incident. Interference was seen on some of the displays on the bridge. However despite a number tests and the inspection of the control systems by both Voith and Bosch Rexroth technicians, there was no proof

or indication of any interference in the control systems of the tugs engines or propulsion systems. However, the EMI issue had been rectified by work undertaken to cabling routing and shrouding prior to their visit.

The remedial, improvement and maintenance work on the tugs “Solan” and “Bonxie”, whilst undoubtedly improved their operation, unfortunately may have led to difficulties in replicating the incident and proving or disproving various theories. The Examination Panel sought to ensure the relevant manufacturers technicians responded urgently to the request to investigate the incident, and requested that remedial work on “Solan” be put on hold pending their arrival. However, it was many weeks from the incident before they all fully responded, in which time remedial / improvement works had already been instigated on the towing winch.

The ergonomics and design of the monitoring and control systems on the bridge may have led to confusion. Specifically:

- The layout of the engine rpm command buttons is counter intuitive in that the left hand button on each console has the same function such that the buttons ramp up from left to right. Conversely a layout where control buttons ramped up from the inner to the outer could be confusing. Lastly, on the older tugs in the fleet there is only one set of engine rpm command buttons which controls both engines in parallel making an asymmetric setting impossible.
- Labelling of the control buttons was considered both small and not visible in poor light. This was highlighted as Critical Factor 3 in the report presented by TMS;
- Positioning of dials and readouts (for example the engine rpm tachometers) which can be difficult to see when operating the tug close to other vessels;
- Controls for operating the winch.

The Examination Panel believe that the actions of the Master in regaining control of the tug undoubtedly helped to minimise any harm to the vessel, the environment and crew.

No person deliberately endangered the vessel and crew.

Weather was not a factor in this incident.

Crew onboard the tug all held the appropriate mandatory certification.

Crew were all adequately rested and within Hours of Rest limits.

ACTIONS

	Action	Due By	Progress
1	Directional stability issue to be resolved	asap	Ongoing
2	Improve the power supply and control of the winch.		Completed
3	Fit new Universal Frequency Transducers		Completed
4	Labelling of engine RPM settings on bridge consoles to be improved		Completed
5	Investigate and if possible fit one set of engine rpm control buttons to control both engines		see below
6	Improve the ergonomic layout of the controls by way of the conning station (speed buttons)	asap	Ongoing
7	Improve the ergonomic layout of the displays by way of the conning station (Tachometers)		Completed
8	Investigate and improve screening and routing of electrical cables		Completed
9	Review training procedures.		Ongoing
10	VDR equipment to be fully functional		Completed
11	Induction and training to be undertaken by crews prior to re-introduction to service.	Prior to re-entry into service	Ongoing

Item 5 – advised by VBR that this was not possible.

LIST OF ABREVIATIONS

CFD	Computational Fluid Dynamics
EMI	Electro Magnetic Interference
FPSO	Floating Production Storage and Offloading
MAIB	Marine Accident Investigation Branch
NMEA	National Marine Electronic Association It is a combined electrical and data specification for communication between marine electronic devices such as echo sounder, sonars, anemometer, gyrocompass, autopilot, GPS receivers and many other types of instruments.
RPM	Revolutions Per Minute
TMS	Trident Marine Services
VDR	Voyage Data Recorder

LIST OF APPENDICES

1. SMSF 1004 Incident / Accident Report
2. Copy of Incident Report from Master
3. Copy of Incident Report from Mate
4. Copy of MAIB report
5. Copy of TMS Report complete with appendices
6. Copy of VOITH service report
7. Ongoing Maintenance and Improvements
8. Information on Universal Frequency Transducer MCR-f-UI-DC
9. Directional instability
10. Mate's Training Book
11. "Split sticks" trial data, Solan, Tystie and Tirrick
12. Time line of critical period around the time of the collision