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FIELD TRIALS OF AN INSTRUMENTED LIFEBOAT IN ICE CONDITIONS

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ABSTRACT

Emerging hazards on a ship or offshore petroleum installation can lead to an evacuation scenario. The means of independent evacuation on board must be capable of operating in the conditions that prevail at the time of the emergency. It is essential to know what to expect of evacuation systems in terms of their utility in the range of weather conditions that can reasonably be expected in a given operating region, including the presence of sea ice. It is equally important to account for the interaction of the evacuation systems and the people who have to use them.

KEY WORDS: evacuation, emergency, offshore, ice, safety, lifeboat, field trials

INTRODUCTION

This paper presents the results of field trials that investigated the performance capabilities of a small conventional lifeboat, or totally enclosed motor-propelled survival craft (TEMPSC), in natural ice conditions. The field trials were conducted in May 2007 off the north coast of Newfoundland. Ice conditions in which tests were conducted included thin level intact ice and broken pack ice. As the tests were done in spring, the first year ice was in the process of melting and was not as hard as might be expected in mid winter. Additional tests were done in heavy broken pack and rubble that was partly made up of the remnants of deteriorating icebergs. The trials were done with a manned 20-person lifeboat over a four-day period. This was the first of a series of field trials planned for the next three years with evacuation systems in ice.

We begin the paper with a brief account of the field trials, including a description of the lifeboat, instrumentation, trials site, and test plan. As space limitations prohibit a full presentation of the trials data, examples of measured results are shown to illustrate the scope of the first phase of the field program. Measured results from the trials are compared to model scale experiments done previously in an ice tank at the Institute for Ocean Technology (IOT). In addition, observations concerning human factors issues that were identified as being worth examining further in subsequent trials are reported.

FIELD TRIALS

The field trials reported here represent the first year of a three-year field campaign. A key objective of these preliminary trials was to assess the performance of the lifeboat in open water, pack and level ice, as well as work out logistical and operational requirements in advance of the remaining campaign. The trials program encompassed a day for setting up the instrumentation on site, a day for open water trials, plus two days of ice testing: one in pack ice and one in level ice. The last day was used to decommission the lifeboat. In addition to the instrumented lifeboat, there was an accompanying fast rescue boat in attendance at all times, as well as a support vessel. The support vessel was a local fishing boat chartered for the trials.

Site

The trials were done off the North East coast of Newfoundland, in the vicinity of Triton and Pilley's Island, during the first four days of May, 2007. The site was chosen due to the local ice conditions in the region, and well as the excellent logistical support available. Open water trials took place at 49°30'12.85"N, 55°43'39.68"W. Pack ice trials were conducted some 2.25 Nm miles away in the bay between Triton Shipyard and Pilley's Island harbour near 49°27'52.38"N, 55°44'6.97"W. Tests in level ice were done 2.5 Nm away in an inlet near Pilley's Island at 49°29'46.70"N, 55°41'8.17"W.

Lifeboat

The lifeboat, or Totally Enclosed Motor Propelled Survival Craft (TEMPSC), is of glass-reinforced plastic construction with the hull, inner-hull, and canopy moulded individually with poly urethane foam as the buoyant material. It was built to the requirements prescribed by the Safety of Life at Sea (SOLAS) Convention (IMO 1997) and the International Lifesaving Appliance (LSA) Code (IMO 2003). In addition, tests were done according to corresponding guidance from the International Maritime Organization (IMO 1998).

The TEMPSC is 5.28m long, 2.20m wide, 2.70m high and has a moulded depth to the gunwale of 1.10m. This size facilitates storage and transportation to the trials location in a standard cargo container, or on its own trailer. The TEMPSC is equipped with a 29 HP engine, an electric starting system, conventional propeller inside a steerable nozzle, gear shift/throttle control, wheel, magnetic compass, on/off power switches and a 24V battery, as well as safety equipment (e.g., painter, oars, sea anchor, bailer).

Prior to outfitting, the unloaded lifeboat weighed 2160 kg. It was loaded to its full complement, corresponding to 20 (75kg) people. The

actual load was comprised of three operators (coxswain, plus two crew) weighing 258.7 kg, 50 bags of sand weighing 22.7 kg each, plus 111.3 kg of instrumentation for a total of 1505 kg. The fully loaded lifeboat weighed 3665 kg. Figure 1 shows a picture of the lifeboat as outfitted and in operation.



Figure 1. Photo of trials lifeboat.

Instrumentation

The full instrumentation package fitted to the lifeboat consisted of the following elements:

- Differential global positioning system (main system) updated at 10Hz giving information on latitude-longitude and time;
- Global positioning system (back-up system), giving latitude-longitude and time;
- Inertial motion measurement system (MOTAN) unit made up of three servo accelerometers and three rate angle sensors, mounted along the centre line of the lifeboat and roughly at midships;
- Inertial motion measurement system (Min-MotionPak, or MMP): a miniaturized, low-powered inertial motion sensor unit, with surface mounted accelerometers and rates in the X-Y-Z directions, mounted along the centre line of the lifeboat and roughly at midships;
- Inertial motion measurement system (MotionPak 2) unit (3 accelerometers and 3 rates) mounted in the chest cavity of a training dummy seated in the aft portion of the lifeboat on the starboard side to measure the motions of a would-be evacuee;
- CO and CO₂ sensors to measure gas levels in parts per million and set with human safety alarm thresholds;
- Temperature sensors at the seat, shoulder and main canopy levels;
- Tachometer to measure the shaft speed;
- Yo-Yo potentiometer to measure rudder angle;
- In-line 5 kN load cell for measuring tow drag in open water and ice and for measuring bollard pull;
- Magnetic compass to measure heading;
- Sensors to measure roll and pitch independently;
- Anemometer to measure wind speed and direction;
- Data acquisition battery monitor;
- Six video cameras - two forward mounted on a transverse bar looking down on the ice at the lifeboat's shoulders, two aft on a transverse bar looking down at the ice at the steerable nozzle longitudinal position, one forward mounted on a longitudinal aluminum bar on the centerline of the lifeboat looking down at the ice at the bow, one aft mounted at the stern on the centerline looking down at the ice, one looking forward on the ice field mounted on the starboard side of the coxswain tower forward window, and one looking aft on the lifeboat track mounted at

the centerline of the coxswain tower aft window;

- Rover video camera;
- Two digital cameras (one on the support vessel, one on the fast rescue boat).

The data acquisition system used in the trials was a local area network of two laptops located in the galley of the support vessel. During the open water and pack ice trials, one laptop was running the IOT standard data acquisition server, acquiring data via one or more serial ports and making it available to client applications. The other laptop was running IOT's Windows-based acquisition client that was used to retrieve data from the server and store it in standard DAC (data acquisition and control) file format. The client laptop was also used to monitor server channels in real time and to perform online analysis of acquired data.

During the level ice trials the data acquisition system consisted of a laptop computer equipped with Bluetooth radio modems, running a stand-alone data acquisition program. The acquisition program captured the stream of data packets, which were telemetered from the embedded lifeboat systems by the radio modems connected to the computer's serial ports, and saved the raw data to disc in comma separated value (CSV) format. Real-time calibration and monitoring of 12 data channels (e.g., carbon monoxide level) were available throughout the level ice trials. Once acquired, the data was post-calibrated by a separate calibration program and transferred to IOT's main computer for analysis and archiving.

Test plan

Trials were conducted on the lifeboat in open water, level and pack ice. Open water tests were done on May 1, pack ice tests on May 2, and level ice tests on May 3. The main types of tests were speed and transit runs and turning circles. Roll decay tests and bollard pulls were done in open water. On the way to the pack ice trials, the open water towed resistance of the lifeboat was measured while the support vessel was towing it. The towed resistance in pack ice was also measured. In level ice, speed and transit runs were conducted at different concentrations. The lifeboat was also run at speed into the ice edge on several occasions. In total, 43 runs were completed: 23 in open water, 6 in pack ice, and 14 in level ice. Although there were relatively fewer runs in pack ice, they were longer compared to the runs in open water and level ice.

RESULTS

Open water

Open water trials were performed to determine the roll period and associated damping of the hull, speed and maneuverability of the lifeboat, and its open water towed resistance and bollard pull performance.

Roll decay tests showed that the lifeboat in trials condition had an average roll period of 3.56 seconds and a damping ratio of approximate 0.102 (about 10% damping). The speed trials revealed that the lifeboat as configured and ballasted for 20 occupants (75kg each) could only reach 5.23 knots in calm water at the maximum shaft rotation of 1120 rpm. Bollard tests were conducted at the dock using a 5 kN in-line load cell attached to a sacrificial link. One end of the 30 m rope was attached at the stern pull point of the lifeboat while the other end was attached to one of the dock's bollards. The throttle was adjusted for the bollard pull tests and at the adjusted maximum shaft speed of approximately 1860 rpm, the lifeboat was able to pull approximately 1100 N. While transiting open water under tow by the support vessel, the resistance of the lifeboat was measured. At the maximum tow speed of approximately 5.8 knots, the lifeboat registered a resistance of just under 1400 N. As the towed lifeboat was in the wake of the towing

vessel, there may have been some influence on the measured resistance.

Examples of measured results from the open water tests are shown in Figures 2 to 5. Figure 2 shows the relationship between the lifeboat's speed over ground and shaft speed. Figure 3 presents the bollard pull measured as a function of shaft speed. Measured values of open water towed resistance are shown in Figure 4 for four towing speeds. A turning circle test is shown in Figure 5 as an example of maneuvering performance evaluation. Pull-out tests were also done.

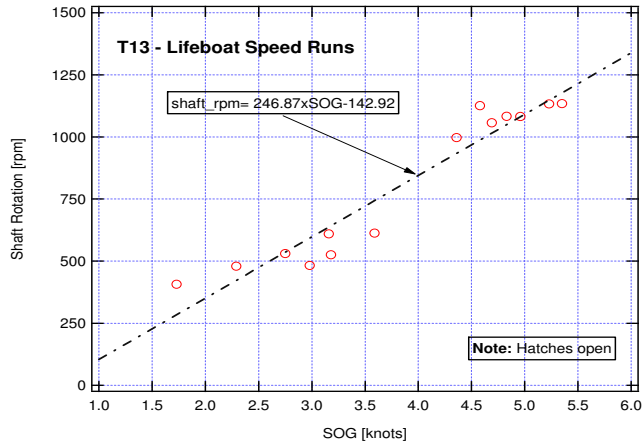


Figure 2. Shaft rotation and open water speed.

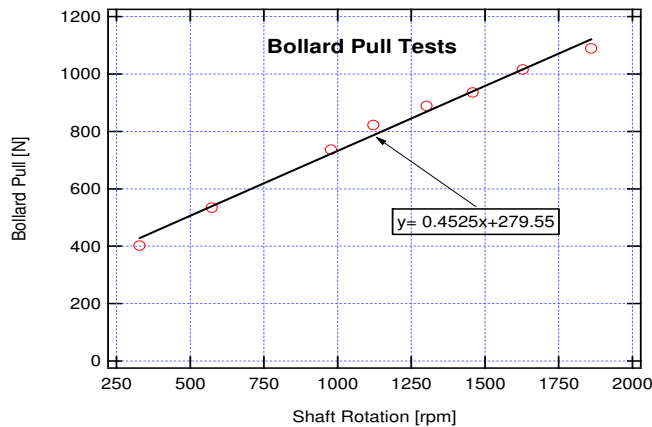


Figure 3. Bollard pull as a function of shaft speed.

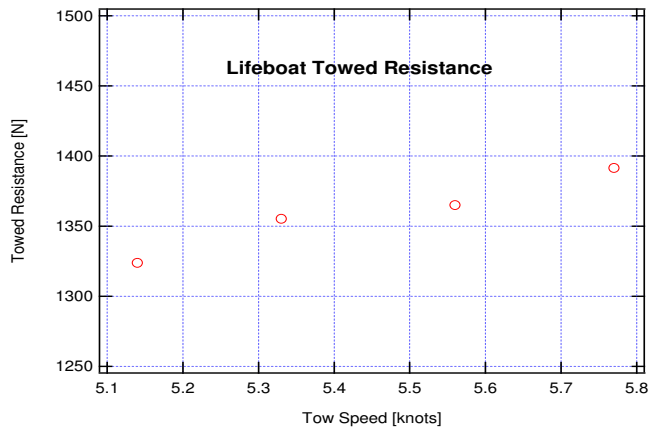


Figure 4. Open water towed resistance versus tow speed.

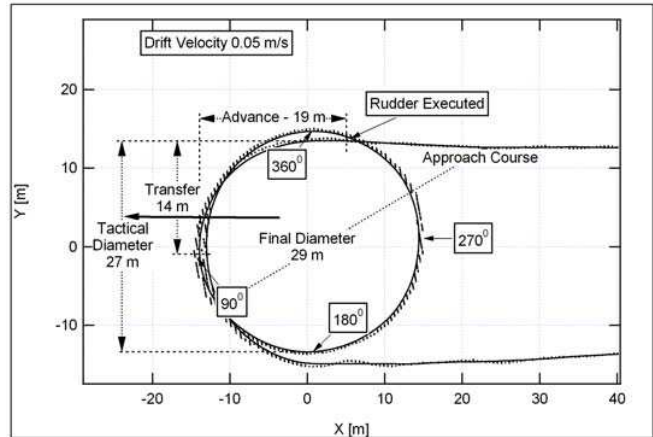


Figure 5. Open water maneuvering: turning circle test.

Pack ice

Tests in pack ice were performed to establish the lifeboat's performance in different ice concentrations and ice floe sizes, as well as its ability to make headway and maneuver.

The trials in pack ice consisted of 6 runs of various durations, from a low of 13 minutes to a high of 36 minutes. On average, the run duration was just over 23 minutes. The pack ice ranged in concentration from 5/10^{ths} to 7/10^{ths}. The crew of the lifeboat was given instructions to go to a predetermined location. In most cases, the lifeboat had to take a circuitous path through the pack in order to reach the target location. The vessel sometimes encountered ice that it was unable to push its way through and thus had to seek alternative routes. The distances traveled en route to the target location exceeded the straight path distance between the start and end points, sometimes considerably. The speeds made good were modest. The estimated impact loads reached a high of approximately 70 kN based on a lifeboat mass of almost 3700 kg and a maximum measured deceleration of approximately 20 m/s².

Examples of four separate runs are presented in Figures 6 to 9. These plots show the track of the lifeboat as it moved from its starting point to its destination. For the cases shown, the pack ice concentration was approximately 6/10^{ths} to 7/10^{ths}. The shaft speed was kept within a specified range for different runs, as indicated in the plots. Arrows indicate the position of the lifeboat at 1 minute intervals, from which it is possible to see the progress of the lifeboat, as well as places where its progress was impeded. A second set of arrows in each plot indicates a local maximum deceleration measured during the run. The numbers in the boxes are the decelerations in the longitudinal axis of the lifeboat in terms of multiples of gravitation acceleration, each corresponding to an impact with ice.

For example, in Figure 6, the lifeboat made fairly good progress for the first 14 minutes, by which time it had moved approximately 225m east of its starting point. Progress was slow for the next 4 minutes and then the vessel changed direction and soon ran into heavy ice that resulted in some significant decelerations and prevented further progress. Similar results are shown in Figure 7, where the vessel encountered difficult conditions at the start of the run and had to maneuver in the pack to find a route through the ice. In all four cases, the track was circuitous as progress was impeded by local ice conditions.

Figures 10 and 11 are also from the tests done in pack ice. These illustrate the measurements of speed over ground and shaft speed (in Figure 10) and temperature in the lifeboat and pitch and roll (in Figure 11) averaged over brief time intervals during a test run. The examples shown correspond to the test track presented in Figure 8.

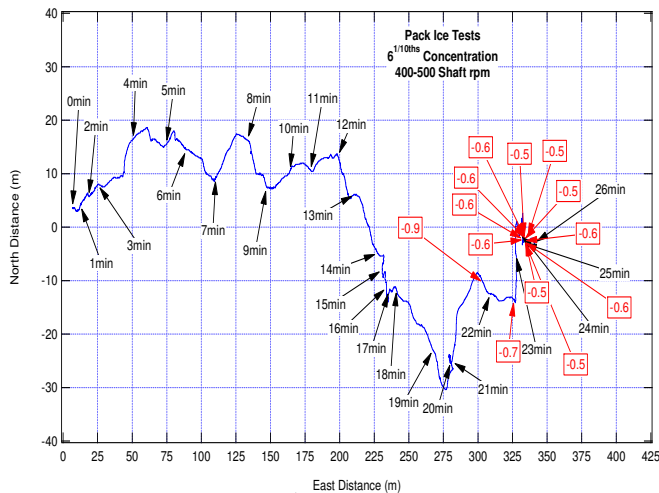


Figure 6. Track in pack of 6/10^{ths} coverage @ 400-500rpm.

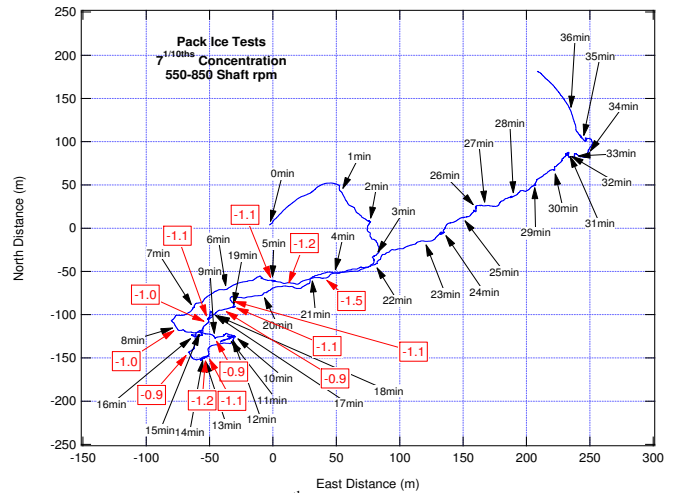


Figure 9. Track in pack of 7/10^{ths} coverage @ 550-850rpm.

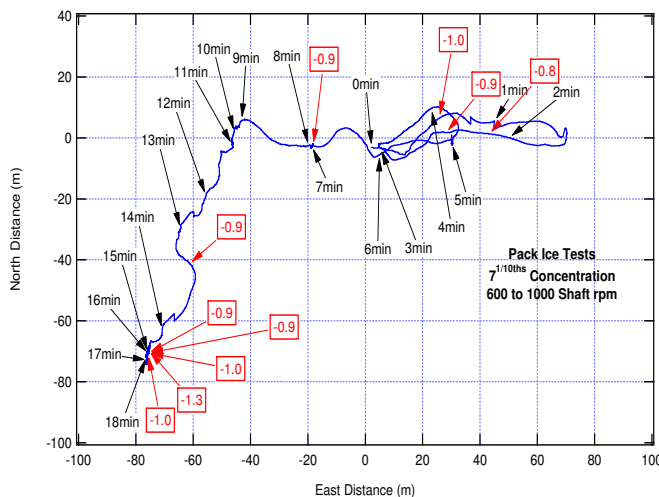


Figure 7. Track in pack of 7/10^{ths} coverage @ 600-1000rpm.

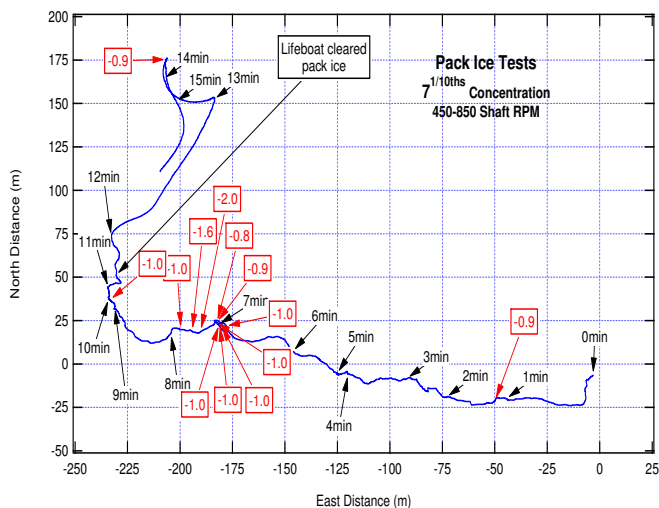


Figure 8. Track in pack of 7/10^{ths} coverage @ 450-850rpm.

Level Ice

The trials in level ice consisted of 12 runs of different durations. The flexural strength of the ice was evaluated by two simple beam tests, which indicated a strength of approximately 50 to 60 kPa. The ice was approximately 0.2 to 0.3 m thick.

The first run started with an attempt to run the lifeboat into the unbroken level ice, but it was not successful. After a few meters the lifeboat got stuck and was unable to make forward progress. The trials team then proceeded to break a channel into the level ice. All subsequent tests were done in broken level ice. The size of the pieces was not controlled and varied from small to large pieces (similar in mass to the lifeboat). An example of a run in a broken channel is presented in Figure 12. As was the case for the runs in pack ice, the average speed over ground of the lifeboat in broken level ice was low.

The duration of the broken level ice runs was typically shorter than the pack ice runs. On average the runs in level ice lasted just over 8 minutes. During these tests, the effect of having the hatches and vents open or closed on the ambient conditions inside the lifeboat was investigated. Figures 13 and 14 show the differences in two cases. When the hatches were closed (Figure 13), the air temperature and CO and CO₂ levels increased significantly, even over the short test period and even with just three personnel on board. Opening the hatches and vents mitigated these effects (Figure 14).

Turning circle tests were also made in the broken level sheet. The ice was broken up by the support vessel to cover a field, rather than a channel. The diameters of the turning circles in ice were significantly smaller than the corresponding diameters in open water, for a given lifeboat speed and rudder angle. For example, in open water, a rudder angle of about 12° resulted in a turning diameter of 29 m; in ice, a rudder angle of 15° yielded a turning diameter of just less than 17 m. The difference in rudder angle between the two tests was due to the lack of a rudder angle indicator, which meant that the coxswain had to estimate the rudder angle.

At the end of the trials program, the lifeboat was brought onshore and inspected. There was some minor surface damage to the coating of the propeller nozzle, but no other visible evidence of damage.

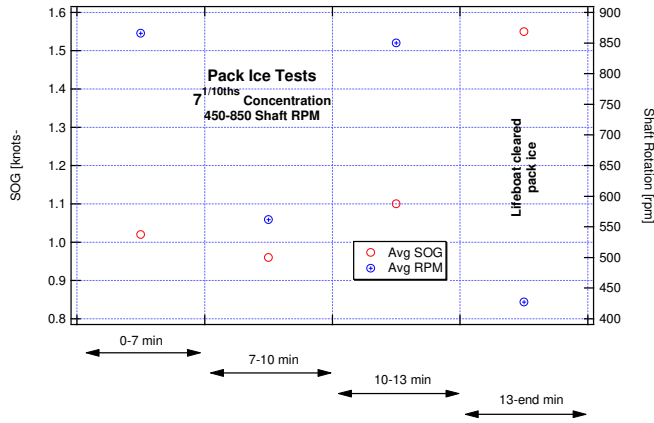


Figure 10. Average speed over ground and shaft speed over brief time intervals (pack ice test).

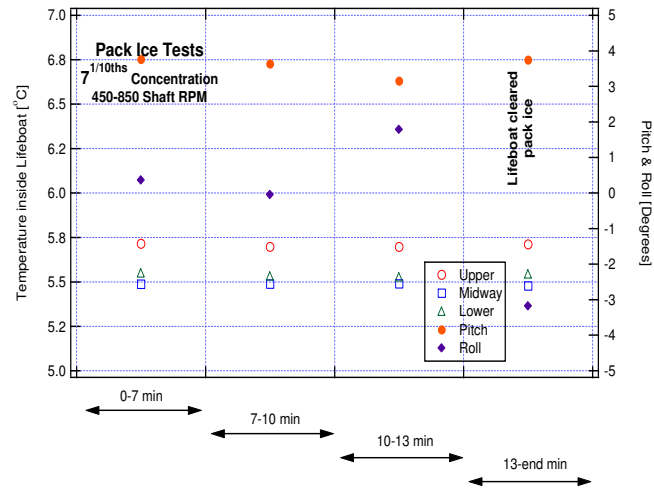


Figure 11. Temperature, pitch and roll at specified time intervals (pack ice test).

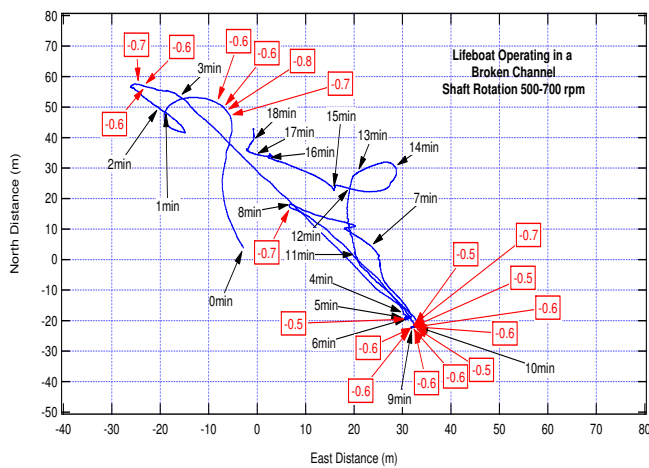


Figure 12. Track in a broken channel in level ice (level ice test).

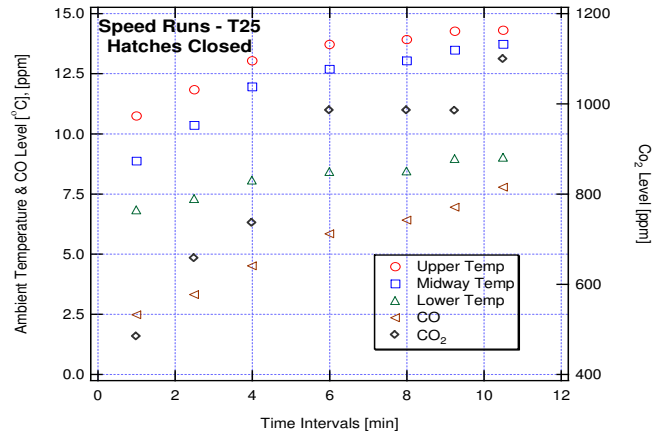


Figure 13. Measurements of conditions inside the lifeboat during a test in broken level ice with hatches and vents closed.

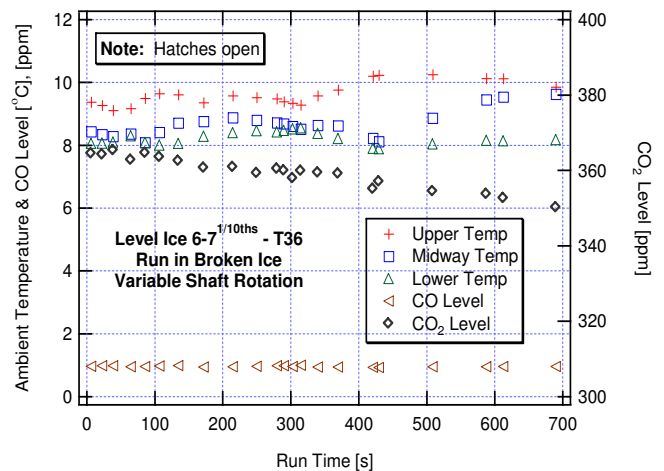


Figure 14. Measurements of conditions inside the lifeboat during a test in broken level ice with hatches and vents opened.

DISCUSSION AND FUTURE WORK

The field trials program reported here was mounted to investigate the performance of a conventional lifeboat in ice-covered waters. Tests were done in open water, in level ice and in pack ice. Measurements were made of over 40 test runs during a four-day period, providing benchmark data on the performance of a conventional lifeboat in a range of conditions. This paper introduced the trials program and presented examples of the measurements made during some typical runs. Additional results will be published in due course.

Test runs in broken level ice and pack ice with concentrations of approximately 5/10^{ths} to 7/10^{ths} provide an opportunity to compare full-scale field results with model scale experiments reported elsewhere (Simões Ré & Veitch 2007). The comparison appears quite good, although the lifeboat used in the model tests was different than the field trials lifeboat. The model test results showed that progress was possible in 5/10^{ths} cover, but often prevented in about 7/10^{ths} or higher ice cover. In the model tests, the lifeboat was unable to back and thus had less maneuverability than the full-scale vessel. Nevertheless, the field trials also indicated that progress was difficult or prevented in similar

concentrations and that at concentrations of about 5/10th, progress was much better. The performance limits are comparable in both cases. This is a rather imprecise measure of performance limits, but given the variability in ice conditions and the lack of repeated trials in the same conditions, it is difficult at this stage to be more precise.

The results reported here are for a single lifeboat so the effects of design parameters were not evaluated. One might expect that additional power, for example, would improve performance. The effects of additional power were evaluated in the model scale tests referred to above and found to have only marginal benefit in terms of the performance of the lifeboat to make way in pack ice. Additional power may very well improve the performance of lifeboats in open water, particularly in waves.

In addition to the technical performance evaluation, human factors issues were considered in the trials. The air temperature, CO and CO₂ levels in the lifeboat are examples of this. So too are factors such as the visibility from the coxswain's chair, the ergonomic layout of the coxswain's console, the access hatches and the seating arrangements. There is scope for expanding the ergonomic component of the trials in future phases.

This first phase of the field campaign was a success. In the next phase, similar tests will be done, ice conditions permitting, to continue to map the performance capabilities and boundaries of a conventional lifeboat in ice. We have since instrumented the lifeboat to measure ice loads on the structure during the next phase of the tests. We plan to operate the lifeboat remotely so that we can evaluate the performance of the lifeboat when operated very aggressively.

While evaluating the capabilities and limits of the conventional lifeboat is the focus of this work, it is important to note that in order to be able to evacuate in conditions beyond the limits of conventional lifeboat, innovation is needed.

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