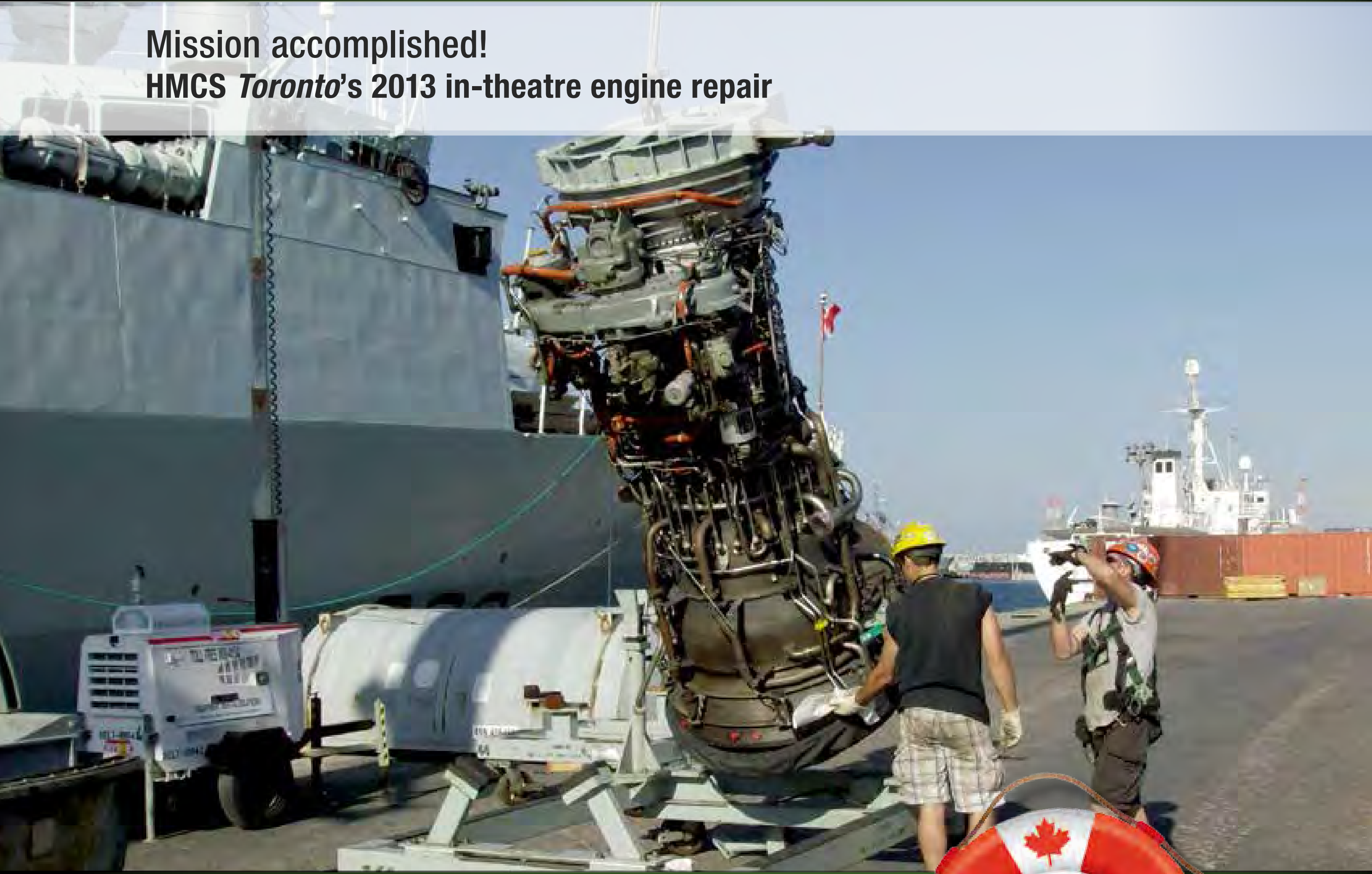
National Defence Défense nationale

# Maritime Engineering Journal

74
Since 1982

Canada's Naval Technical Forum

Summer 2014



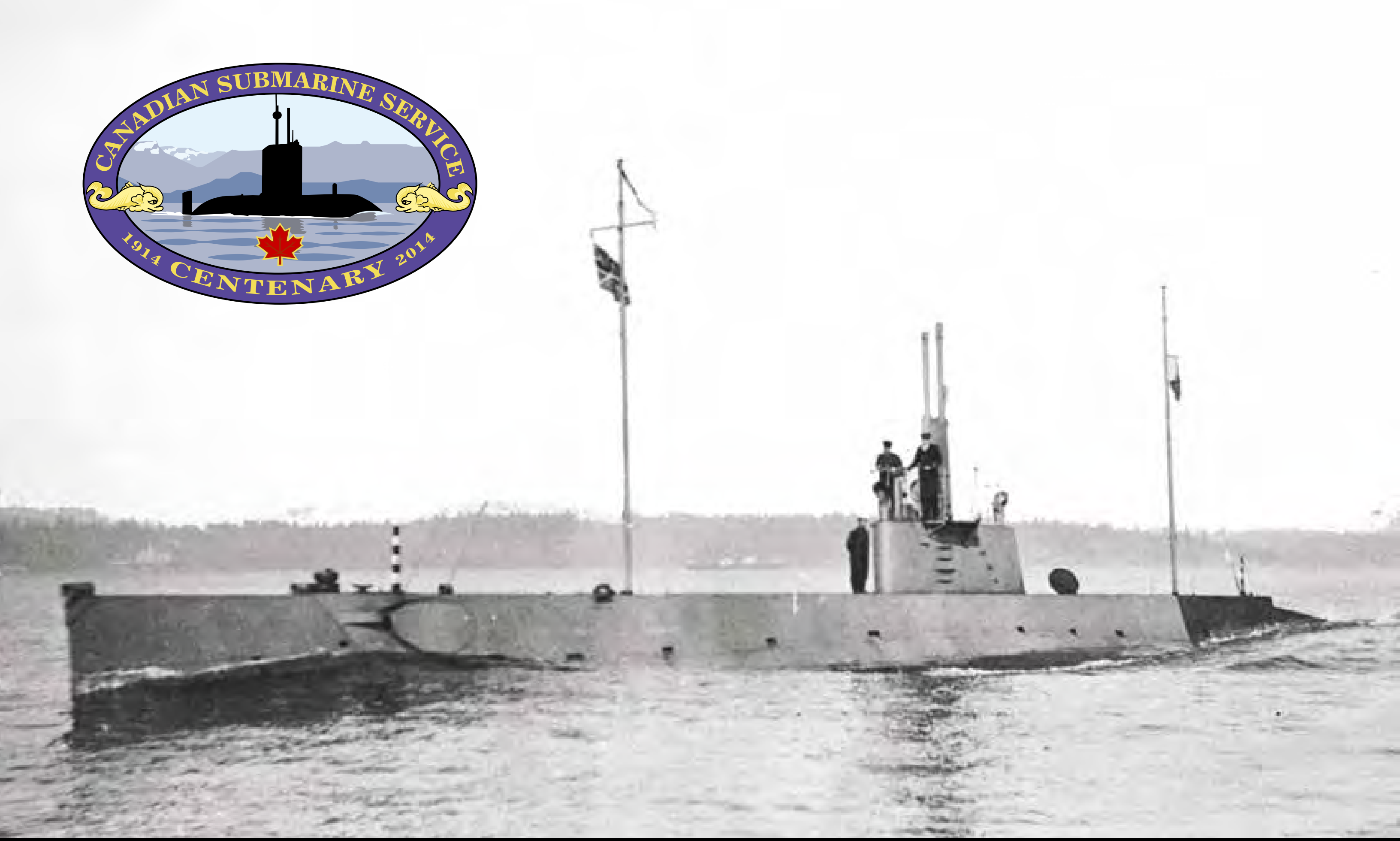
## Mission accomplished!
### HMCS *Toronto*'s 2013 in-theatre engine repair

CNTHA News Inside!

## Also in this Issue:

- Forum: Innovation is Alive and Well in the RCN's Naval Training System
- Supercavitation and Torpedo Defence
- *CNTHA News*: HMCS *Provider* Vibration Problem

# Congratulations on 100 years of Canadian Submarine Service!



*CC2* in transit to Esquimalt, BC, August 1914

***(Dolphin 72A – Very well done!)***

*Logo and images courtesy Submariners Association of Canada*

# Maritime Engineering Journal

*(Established 1982)*
**Summer 2014**

**Director General Maritime Equipment Program Management**

Commodore Marcel Hallé, OMM, CD

## Commodore's Corner

## Forum

## Feature Articles

## Book Reviews

## News Briefs

## CNTHA News

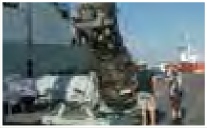
**Senior Editor**
Capt(N) Simon Page
Chief of Staff MEPM

**Project Manager**
Lt(N) Peter O'Hagan

**Production Editor/Enquiries**
Brian McCullough
**brightstar.communications@sympatico.ca**
Tel. (613) 831-4932

**Associate Editor**
Tom Douglas

**Graphic Design and Production Services**
d2k Marketing Communications
**www.d2k.ca**
Tel. (819) 771-5710



A full change-out of HMCS *Toronto*'s port gas-turbine propulsion system in Dubai, UAE was anything but 'another day at the office.'

Photo courtesy Bob Steeb, FMF Cape Scott

**The *Journal* is available on line at the website of the Canadian Naval Technical History Association – www.cntha.ca**

The *Maritime Engineering Journal* (ISSN 0713-0058) is an unofficial publication of the Canadian Armed Forces published by the Director General Maritime Equipment Program Management. Views expressed are those of the writers and do not necessarily reflect official opinion or policy. Mail and requests for free subscriptions may be sent to: **The Editor, Maritime Engineering Journal, DGMEPM, NDHQ, 101 Colonel By Drive, Ottawa, Ontario, Canada, K1A 0K2.** The editor reserves the right to reject or edit any editorial material. While every effort is made to return artwork and photos in good condition, the *Journal* assumes no responsibility for this. **Unless otherwise stated, *Journal* articles may be reprinted with proper credit. A courtesy copy of the reprinted article would be appreciated.**

# Commodore's Corner

By Commodore Marcel Hallé, OMM, CD

## The future of in-service support

In my previous (Spring 2014) Commodore's Corner, I focused on the Naval Materiel Management System (NaMMS) and the significance of changing 'maintenance' to 'materiel' in the acronym. Subtle, but profound, this change redefines NaMMS as the single integrated naval materiel acquisition and support system that underpins the Naval Materiel Enterprise. Embedded within this is in-service support, one of its key subsystems. The Royal Canadian Navy is at an important crossroad as it prepares to accept the modernized *Halifax*-class frigates into the fleet, nears achieving steady state with the *Victoria*-class submarines and readies for the transition to future fleets. Critical to our success will be getting the future of in-service support right. As demand continues to exceed the resources required to fully execute the materiel program, and as the complexity of our fleets continues to grow, managing the ongoing fiscal challenges associated with in-service support will be easier said than done. However, the environment is apt for us to collectively shape it to ensure this support is optimized and fully integrated. Doing this will require a focused effort, a sound plan, being innovative and leveraging the work of others who have had success in this area.

> *"The RCN is at an important crossroad as it prepares to accept the modernized* Halifax*-class frigates into the fleet, nears achieving steady state with the* Victoria*-class submarines and readies for the transition to future fleets."*

The Defence Procurement Strategy (DPS) announced by the Department of National Defence and the Department of Public Works and Government Services in February, and the DND Defence Renewal initiative launched by the Chief of the Defence Staff and Deputy Minister in mid-2013 are looked on as two high-level enablers to help us get there. Specifically, as part of the change management programs embedded within both the RCN and the Assistant Deputy Minister (Materiel) organizations, a Future of In-Service Support (FISS) initiative has been stood up that is being championed by Alanna Jorgensen in DGMEPM. Holistic in approach, FISS is bigger than just dealing with in-service support contracts. It encompasses the full spectrum of design, management, training and execution of all engineering and maintenance activity, ranging from what is done on board ships and submarines at the first level, to the delivery of second- and third-level work done by the Fleet Maintenance Facilities (FMFs), to the work done by industry at the third level. FISS will also play an important part in shaping what the FMFs look like – ensuring critical capabilities are retained within the RCN, as well as enabling the establishment of strategic relationships that leverage the integration of skill sets and infrastructure between the Crown and industry.

The FISS initiative touches everyone within the Naval Materiel Enterprise. Whether you are an RCN technician maintaining equipment aboard a vessel, working in a Fleet Maintenance Facility, employed within ADM (Mat), or providing industry support to the Navy's program, each of you has an opportunity to channel input through your respective chains of command back to the FISS team. Success in delivering on the future of in-service support is predicated on how we collectively choose to shape it. The time is now, the challenge is great, but the importance of achieving the desired outcome to ensure Canada continues to have a viable and operationally effective Navy in the future is even greater.

FORUM

# Innovation is Alive and Well in the RCN's Naval Training System

By Cdr David Benoit, Commandant Canadian Forces Naval Engineering School Halifax

*[Note: Cdr Benoit has just taken up a new post in the office of the Deputy Minister of National Defence in Ottawa.]*

First off, let me congratulate the editorial team on the publication of numerous years of outstanding *Maritime Engineering Journals*. Thanks to your efforts and the support of the senior engineering leadership we are able to keep connected with the engineering branch and keep abreast of the work of our colleagues, regardless of their labours.

Secondly, after reading the *CNTHA News* article titled "Where have all the innovators gone?" by Cdr RCN (Ret.) Pat Barnhouse, in the *Journal*'s Summer 2013 edition (No. 71), I thought I would put keyboard to screen and provide a likely incomplete and inadequate reply to his question.

> *"Innovation still abounds in all aspects of the current naval technical environment as we work every day to meet the operational demands of the organization with seemingly diminishing resources."*

While I would admit that the innovative changes we see today might *appear* to be less prominent than some of those cited by Cdr Barnhouse from the heady, well-funded decades of the 1940s through the 1990s, today's achievements are neither less prevalent nor less significant. Innovation still abounds in all aspects of the current naval technical environment as we work every day to meet the operational demands of the organization with seemingly diminishing resources.

Photos by Brian McCullough

Ships' personnel learn the operation of the Battle Damage Control System, a subsystem of the Integrated Platform Management System, in a modern classroom at Damage Control Training Facility Kootenay in Purcell's Cove, NS. Group and team play continue to be effective training enablers.

Acknowledging the obvious continuing efforts on the part of Defence Research and Development Canada (DRDC) to lead the way on a technological front to improve and advance the war-fighting capability of the RCN, I would like to focus on my own area of endeavour within the Naval Training System (NTS), now renamed the Naval Personnel Training Group (NPTG). Even in my seventh year as a manager and leader within this system the level of innovative effort continues to astound me, and the future promises to be even more enlightening. Consider a few examples:

The **Naval Training System Transformation** initiative launched by the commandants and DNTE leadership in the fall of 2012 with the support of RAdm John Newton, then the Director General Naval Personnel, actually had its roots in the Future Training Strategy initiated by Capt(N) Simon Page (COS MEPM) in 2010/11 while he was Director Naval Training and Education (DNTE). This initiative continues to be on track to deliver a flexible,

## *Halifax naval training facilities tour*

When Cdr Dave Benoit's spirited Forum article arrived at the *Journal* last December, I knew it would be good to meet face-to-face with some of the people he was writing about – the training developers, the instructors and the students who are working the leading edge of Canadian naval training. I wanted to see and hear from them how the mix of computer-based learning and practical hands-on instruction is being used to meet the needs of a fleet in transition.

My chance came last March when I was given extraordinary access to the East Coast naval training facilities. CFNES coordinator Lt(N) Dale Molenaar arranged an outstanding schedule of site visits, and over three whirlwind days he and I toured equipment demonstration labs, operator and equipment procedures trainers, state-of-the-art classrooms, and virtual ships: it was an impressive display of the powerful and flexible training capability that is in the hands of some very dedicated and very talented people. The men and women who briefed us were enthusiastic about their work, and articulate in interpreting how their activity fits into the larger picture of training and fleet readiness. There was no mixed messaging on this trip.

Typical was RCAF Capt. Scott Leslie, the Navy Learning Support Centre project manager for all virtual training on the East Coast, as he described the computerized Canadian Virtual Naval Fleet: "Trainees can enter a virtual space and see the console they will run their (on-the-job training packages) on," he said. "We are trying to make the content accessible anywhere so they can use it when it is convenient. We're reducing the pressure on the fleet."

My thanks to Cdr Dave Benoit for offering the hospitality of his home and office to me, and to Lt(N) Dale Molenaar for his helpful professional commentary as we moved from site to site. Most of all, my deep gratitude to the many people, professionals every one, who spent time carefully explaining to me exactly what it is they do, and why.
***— Brian McCullough***

innovative and responsive system that will maintain our world-class training and education system as the RCN transforms itself to meet future commitments. The work developed by teams across NPTG and the RCN, under the direction of commandants acting as 'thrust champions', and under the overall coordination of Cdr Martin Drews, Commandant Canadian Forces Fleet School Esquimalt, resulted in nine thrusts or areas for exploration and development. This first spiral recently concluded with the submission of a comprehensive report to Capt(N) Michael Knippel, Commander NPTG, who has decided to commence the second spiral to group these nine thrusts into three lines of operation. The initiative, while still in development, has already begun delivering new capability within the new paradigm to the Naval Personnel Training Group.


The Canadian Virtual Naval Fleet was developed by the Navy Learning Support Centre on a shoestring budget, but pays off big time in the way it allows trainees to walk their own avatar throughout faithfully rendered copies of various navy platforms. A 'coach mode' can be used to guide trainees toward specific training objectives, including accessing onboard equipment consoles.

One of these new capabilities is the computer-based **Canadian Virtual Naval Fleet** (CVNF) – developed by the Naval Learning Support Centre – that enables individual and collective training to be conducted 'on board' faithfully rendered virtual copies of the navy's various platforms. A study conducted by DRDC found that an experimental group of personnel exposed to a virtual submarine familiarization training environment were approximately five times more spatially aware than the control group who did the same training aboard an actual submarine. Clearly, exploiting this innovation will have a dramatic effect on initial and refresher training, crew competency and overall performance support.

In January 2013, faced with personnel shortages and knowledge loss through retirements, the Canadian Forces Naval Engineering School (CFNES) and Canadian Forces Fleet School Esquimalt (CFFS(E)) set up a *virtual* classroom over the Defence Wide Area Network to deliver quality interactive education to students on the West Coast with an instructor working from Halifax.

Along the same lines, the **Universal Classroom** – currently installed in CFFS(E), CFFS (Quebec) and the CF Naval Operations School – enables the delivery of training across the country (and potentially around the world) in a real-time, interactive, instructor-led, user-friendly environment. It allows classrooms in various locations to be controlled remotely over the internet so that teaching aids can be shared simultaneously with students across the network.

Finally, when it becomes fully functional, the **Defence Learning Network** will provide an enterprise-wide training highway across the Canadian Armed Forces, offering access, cooperation and synergy to personnel throughout the navy, air force and army.

Beyond these specific examples the NPTG continues to determine how it can best bring synergy to the collective naval training system. In 2010 the training establishments were formed under a single command in DNTE to bring unity of command and to ensure they meet the future training demands of the RCN. While the HQ for this new group has shifted to MARPAC, there is still much work ongoing to articulate and define this new entity. It is clear that this transformation will be realized through the empowerment of our workforce to consider new ways of delivering training, and on our ability to implement technological solutions.

> *"From my perspective our newest sailors, those whom I have had the privilege to lead while at the school, have the ideas, drive and motivation to make a success of this sea change of opportunity..."*

Key initiatives such as the National Shipbuilding Procurement Strategy will shape the development of the NPTG. We will likely have ships delivered where the onboard technology, equipment, and systems will vary between ships of the same class. The NPTG will need to be agile and flexible enough to plan for and accommodate these variances. This will take some serious work, discussion and forethought today to achieve this flexibility in the future as these ships are delivered. The current model of training for every single piece of equipment is rapidly becoming untenable. More than ever the RCN will need technicians, not just maintainers, but *technicians* who come with the education and training to work the endless technical variations that will be found in the fleet.

Photos by Brian McCullough

Weapons engineering-armament technician LS Mitchell Sheppard runs a fault-finding exercise on the 57-mm gun through a Maintenance Procedural Trainer workstation at the Naval Armament Depot in Dartmouth, NS. Computer-based learning coupled with hands-on instruction offers the navy a significant degree of flexibility in the way it delivers training.

This is not to say that the use of any technology will replace the need to have practical hands-on experience. In a controlled environment like that which is found in the current training establishments, applications courses can provide hands-on training that will ensure our technicians are safe, competent and effective as soon as they join their ships. However, practice in a well-simulated virtual environment such as the Maintenance Procedural Trainer will ensure they have lots of opportunity to learn before they get to the fleet.

In addition, the organization will have to balance the need for tech savvy solutions with the need to ensure security. Our newest sailors want these solutions, want to use their mobile devices and want to connect to our networks to learn their occupations. They want the freedom to learn at their own pace so that they can progress their qualifications in a timely manner.

The notion of a 'wireless tech', or enabling a sailor to use a mobile device for both training and maintenance, should be guiding our solutions. To provide a vision, perhaps in the future a technician, having already been notified through this mobile device about the priority of maintenance in the queue, will scan a piece of equipment and instantly see on the screen the maintenance history, most recent performance data, and equipment operating parameters. Navigating to another page the technician can obtain information about how this piece of equipment fits into the larger system. If the tech is uncertain how to conduct a certain maintenance routine the process is brought up on screen with the click of a button. The tech performs the work and signs it off, instantly updating the central database. The tech can then use the same device to continue to upgrade technical skills and personal leadership development.

As we move forward it is likely that many of the products we eventually use will probably not be developed in-house by the CAF or RCN, but might very well require that they be adapted to our unique environment. Such solutions will require innovation – *new thinking* – to ensure the continual evolution and advancement of our operational effectiveness. This will call for innovators who understand their business and are ready for the challenge.

I am certain there are many other improvements to come and I look forward to seeing us advance together. From my perspective our newest sailors, those whom I have had the privilege to lead while at the school, have the ideas, drive and motivation to make a success of this sea change of opportunity and transformation that is being presented to them by the dedicated staff within the NPTG.

It is possible that some may consider these changes to be less significant than those of yesteryear, but they are just as tangible, real and important. What's more, they are built on the innovations that came before them and for that we are grateful to the naval technical innovators who led the way.

Renewal in any form presents an exciting opportunity and refreshes our own optimism. Innovation across the RCN will be required in order to achieve VAdm Norman's four command priorities of: ensuring excellence at sea; enabling the transition to the future fleet; evolving the business of our business; and energizing the institution. Innovators will be key to that success and are as present as ever. Within their own capabilities they are creating realities that did not previously exist.

# Letter to the Editor

## Dear Editor:

I just finished reading the latest issue of the *Maritime Engineering Journal* (no. 73 - Spring 2014). I can't overstate how delighted I was to come across the article, "Technical Evaluation of an Innovative Energy Efficient Waste Abatement System," by Cdr Jacques Olivier and Dr. Theodora Alexakis. Needless to say, I couldn't put the *Journal* down! Gripping stuff...well done to the authors. I am now suitably informed about the Micro Auto Gasification System, or MAGS. Who knew that hydrocarbons could be thermally broken down into solid carbon and synthesis gas, with the gas being used to fuel the process? Systems such as MAGS are increasingly seen as ideal for the remote Arctic communities in which we operate.

— **Capt(N) Derek Moss, Deputy Commander – Chief of Staff, Joint Task Force (North), Yellowknife, NT**

FEATURE ARTICLE

# In-theatre Repair of HMCS *Toronto*'s Port Gas Turbine Propulsion System

Article by Bob Steeb
Illustrations courtesy the author, FMF Cape Scott

The day shift crew poses with the new engine prior to craning it on board. It took the skills and effort of many people to put HMCS *Toronto* back on an operational footing as quickly as they did.

On October 3, 2013 while HMCS *Toronto* (FFH-333) was deployed on Op Artemis as part of Canada's contribution to maritime security and counter-terrorism operations in the Arabian Sea, the ship experienced a fire in the enclosure of her port main propulsion gas turbine. This article describes the failure and the subsequent repair accomplished while the ship remained in theatre, the magnitude and scope of which were unparalleled in recent memory.

## *Halifax*-class Main Propulsion

The *Halifax*-class propulsion plant is a CODOG (combined diesel or gas turbine) arrangement, consisting of two GE LM2500 gas turbines (GTs) and a Pielstick propulsion diesel engine (PDE). A cross-connect feature offers substantial redundancy by allowing any single engine to drive both propellers. Normally the plant is configured with the cross-connect engaged and, depending on the required speed of advance (SOA), will use one of the following drive-modes:

- PDE cross-connected – most economical but lowest SOA,
- one GT cross-connected – intermediate power levels capable of greater SOA than PDE, and
- two GTs cross-connected – highest power levels and SOA available with greatest redundancy.

## Fire and Damage Assessment

At approximately 06:45 a.m. on Oct. 3, *Toronto* was proceeding on the port gas turbine in the cross-connected drive mode and had just increased to near full power on that engine when the control system indicated a fire in the port engine enclosure. This was confirmed by the engineering watch personnel who took immediate action. As an engineering roundsman was investigating in the forward engine room, a loud explosion-like sound that was heard throughout the ship erupted inside the port enclosure and the port engine tripped. Subsequent action by the engineering watch and ship's company extinguished the fire with the fitted fire suppression system, and an investigative examination ensued.

At first the damage was believed to be localized to the port forward corner of the engine in the vicinity of the main fuel control and fuel pump (Figures 1 and 2). *Toronto's* marine systems engineering department informed the subject matter experts ashore and sought a way ahead on getting the required parts and troubleshooting to find and correct the source of fuel for the fire. As the LM2500 engines have an in-service support contract managed by the Directorate Naval Platform Systems 3 in NDHQ Ottawa, the General Electric (GE) East Coast senior field service representative (FSR), Del Rogers, was consulted along with Fleet Maintenance Facility Cape Scott (FMFCS) engineering in Halifax.

Ship's staff then did a number of troubleshooting checks to confirm that the engine core was not damaged and to investigate the source of the fuel. All checks done up to this point showed that the damage was external to the engine core and that repairs could be made by ship's staff on receipt of replacement parts that were being shipped into theatre. The source of the fuel for the fire was being particularly elusive in spite of numerous checks to find it.

Finally, a check was done to see if a gasket between the engine-mounted fuel pump and fuel control was damaged. Ship's staff found no damage to the gasket (Figure 3), but five of the six self-locking nuts that mount the fuel control to the pump were not torqued correctly. We now had a prime suspect but could not prove it as no fuel leak was seen through testing, and the engine could not yet be started.

Figure 1 – LM2500 gas turbine enclosure assembly.

Figure 2 – At first the fire damage appeared to be localized near the fuel pump and main fuel control toward the forward end of the engine enclosure.

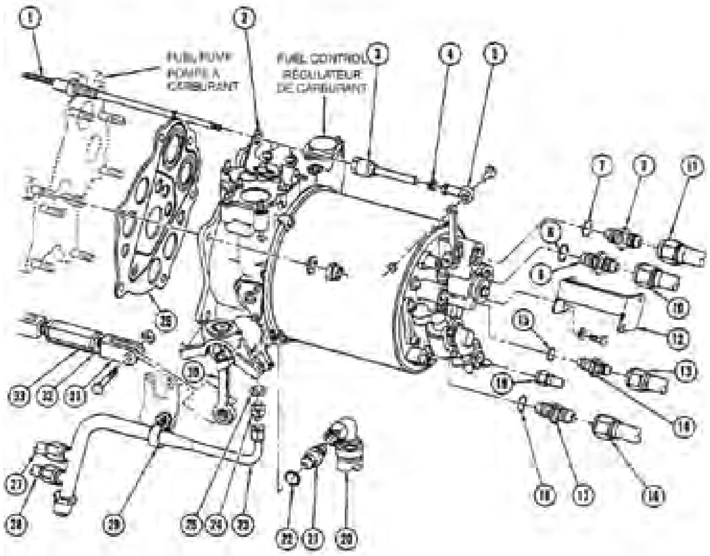


Figure 3 – Five of the self-locking nuts on the gasket (see no. 26) between the engine-mounted fuel pump and the fuel control were found to be torqued incorrectly.

While ship's staff was doing the troubleshooting, GE held an internal conference call to solicit advice and hear of any past experiences. From this came a suggestion to inspect the high-speed coupling shaft (HSCS) that connects the gas turbine package to the main propulsion-reduction gearing. Two other navies had found failed HSCSs when the fire was accompanied by high vibration and over-speed alarms. These alarms were present during *Toronto*'s event, but were believed to be false alarms caused by fire damage to instrumentation wiring inside the enclosure.

*Toronto*'s engineering department immediately opened the access panels (Figures 4 and 5) and reported back with the following game-changing news – "The HSCS is separated and destroyed!"

Figure 4 – Looking down into the engine exhaust duct of the enclosure, ship's staff get their first view of the damage to the HSCS.

## Decisions and Preparations

After discovering the extent of damage on Oct. 5, *Toronto* requested a technical assistance visit by Del Rogers (GE's FSR) and Bob Steeb, the FMFCS gearing and gas turbine inspector, to survey in detail the complete extent of the damage and help determine the repair options.

Del and Bob met the ship at the next port of call in Muscat, Oman, and on Oct. 14 a full survey was conducted with the help of ship's staff.

Basic major findings of the TAV:

- the gas turbine input shaft into the port reduction gearing was found with excessive run-outs indicating it was bent and required replacement,
- the LM2500 power turbine was damaged and needed to be replaced,
- the LM2500 gas generator would have to be replaced based on the hours remaining in its expected life and the fact that it experienced very high vibration levels when the original event took place,
- the exhaust duct needed to be replaced or possibly repaired *in situ*,
- the exhaust duct internal parts consisting of an inner deflector and diffuser required replacement, and
- two rear engine enclosure panels were damaged beyond repair.

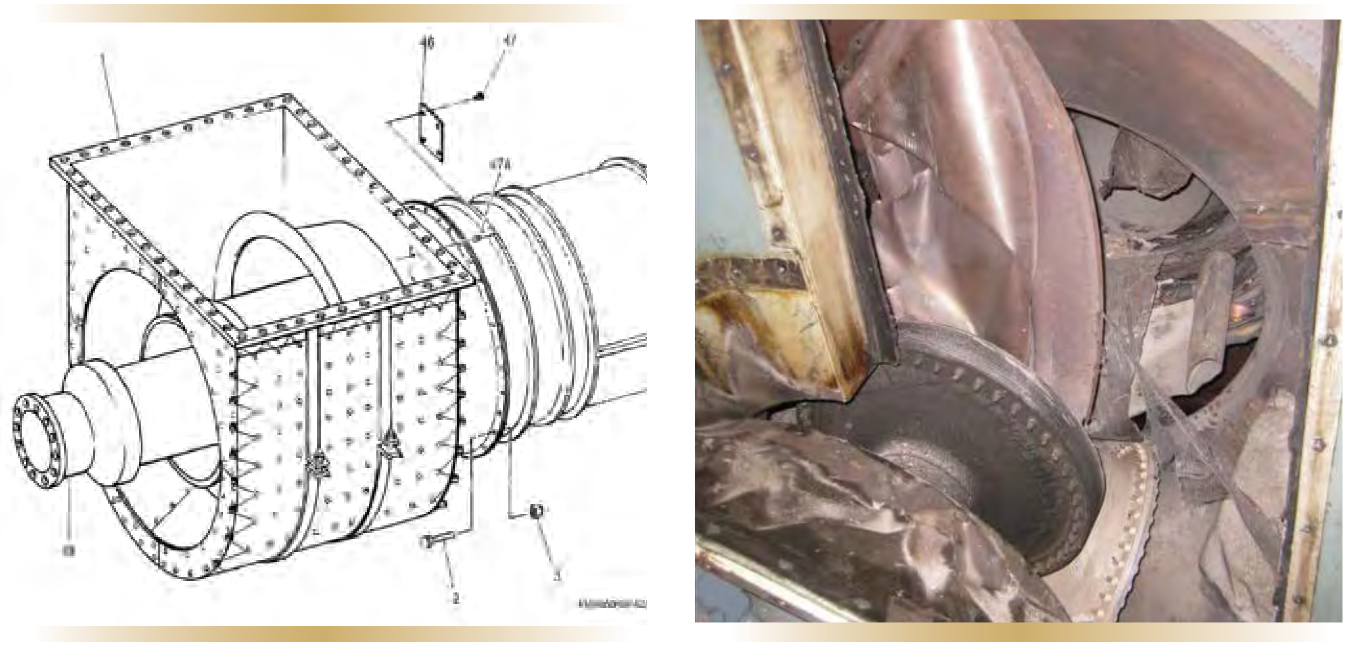


Figure 5 – What the exhaust duct (no. 1) and HSCS (no. 48) were supposed to look like – and what *Toronto*'s engineering staff found.

Since the exhaust duct was no longer serviceable it came down to two options: replace the complete assembly, or repair it *in situ* as had been done in the two incidents in other navies. The technical risk of an *in situ* repair was high. Specialized welding and post-welding procedures would be required, along with a very high degree of dimensional accuracy. Timelines were a major concern as well. The replacement option also had high risk associated with it because a removal route for the duct had not been designed into the *Halifax* class. Initial measurements indicated it could not be done while keeping the part in one piece.

FMF Cape Scott's naval architecture section worked on the weld procedure and qualification aspects, lifting appliances, and the possible removal route in partnership with GE. A beam and four lifting brackets for the exhaust duct were designed and manufactured by Cape Scott in record time. GE also created a 3D model of the LM2500 enclosure and exhaust duct to experiment with rotating and moving the duct through the enclosure to the air inlet trunk and determining if it was possible to remove it in one piece. The ship's exhaust trunk/uptake was not an option because it is too small.

At this time GE learned from one of its FSRs that a one-piece replacement had been successful in a *third* incident involving yet another navy 20 years earlier. After much deliberation involving all stakeholders, it was decided to pursue the replacement in a one-piece option. As a mitigation strategy, worst case scenarios were explored and preparations made to, if required, cut the old exhaust duct for removal and trim the new duct for installation on site.

Another problem was that DND did not hold a spare exhaust duct in its inventory. DNPS 3 and GE worked hard on a quick procurement, and a new collector was transported by truck from Massachusetts to Halifax just in time to be shipped overseas with the rest of the gear.

On Nov. 7, 2013 all the homework was done and a mobile repair party was approved to effect a complete repair of *Toronto's* port gas turbine and port reduction gearbox GT input shaft. A myriad of parts, equipment and tools was packed for transport by a Royal Canadian Air Force CC-177 heavy-lift aircraft. This consisted of three full 20-foot-long sea containers in addition to an LM2500 gas generator and power turbine, a new HSCS, a new exhaust duct, and a used reduction gearbox GT input shaft. (DND did not hold a spare input shaft, so one was transferred from HMCS *St. John's* which was in mid-life refit at the time.)

A multi-disciplinary team brought together two General Electric FSRs and a technician, along with an FMFCS crew of the gearing and gas turbine inspector that included four platers, two welders, six riggers, four gas turbine technicians, two mechanical fitters, one supervisor and one project leader. The team was divided into two 12-hour shifts to complete an estimated 22-day, round-the-clock project schedule (including a sea trial) during *Toronto*'s next rest and maintenance port of call in Dubai, United Arab Emirates.

Figure 6 – With the exhaust expansion joint moved forward, FMFCS rigger Spartius Toope (left) and plater Ryan Shaw have cleared the way for the exhaust duct to be rotated into position for removal.

Figure 7 – Up and out. The gas generator is hoisted up the air intake by shore crane.

## The Work

The team arrived on board on Nov. 18, five days ahead of the parts, so we began work on the disassembly. The enclosure exhaust expansion joint needed to be removed to allow enough overhead clearance for the exhaust duct to be rotated to the horizontal position. The only option was to slide the expansion joint forward over the enclosure (Figure 6); however, the exhaust nozzle/eductor, which is bolted to the duct, would prevent this because it extended too high and could not be lifted into the exhaust trunk/uptake due to insufficient room. To overcome this, the eductor was cut in half horizontally. The upper portion was temporarily tacked into the exhaust and the lower piece temporarily tacked into the expansion joint and then slid forward with it.

### Removing the GT Input Shaft from the Port Gearbox

The GT input shaft was removed from the port gearbox at the same time as the old gas generator and power turbine were being removed. The 3D model showed that an additional clearance of 23 cm was required abaft the GT enclosure to allow the exhaust duct to be rotated, and that removing the shaft would make this work. The following noteworthy defects were discovered during this removal:

- the labyrinth seal was found with heavy wear due to the bend in the input shaft,
- the locating taper pins for the labyrinth housing were found sheared, further indicating hard contact with the bent shaft, and
- the no.1 journal bearing was found with a hard rub on the forward end and a minor wipe in the lower half. The wipe was believed to be a pre-existing defect.

### Removing the Gas Generator and Power Turbine

The air intake removal route was prepped and a removal/installation rail system installed. The gas generator was removed (Figure 7), followed shortly thereafter by the power turbine.

### Removing the Exhaust Duct

The 1,500-kg exhaust duct was removed from its mounts and lifted as high as possible before being rotated 90 degrees to a horizontal position so that it could be pulled forward through the enclosure (Figures 8 and 9). The back wall of the enclosure also had to be removed for maximum clearance, in addition to removing the engine rail system from the enclosure and air intake.

Figure 8 – FMFCS rigger Steve Eddy guides the exhaust duct into a horizontal position.

Figure 9 – Clearances were as little as 3 mm as the exhaust duct was moved carefully through the enclosure for removal.

Figure 10 – The work went on 24/7. Here, shoreside, the night shift crew lowers a new diffuser into the new exhaust duct, then installs the unit into the engine enclosure.

A wood and metal plate cribbing was built by ship's staff along the sides of the enclosure base for the collector to slide on while being pulled forward. Once it was moved into the air intake plenum it was rotated 90 degrees back into an upright position and lifted by shore crane up through the air intake trunk to clear the ship. The clearances were extremely limited throughout the transit – as little as 3 mm at some locations.

After the enclosure was emptied, it was easy to see evidence of a fire – blistered and burnt paint and soot – at the aft end of the enclosure.

## Installing the New Exhaust Duct

Before the new duct could be rigged into the ship, a new inner deflector had to be rigged on board and pre-positioned in the exhaust uptake. Just before the new duct was ready to be rotated upright for its final position, the new inner deflector would be lowered into it. The new diffuser also had to be lowered and temporarily fastened into the new duct before rigging it on board (Figure 10).

With the new exhaust duct in position the enclosure rear wall was replaced, the expansion joint installed, and the eductor welded back into one piece. After this, the new GT input shaft was installed into the port gearbox with a new labyrinth seal and no.1 journal bearing (Figure 11).

The rail system then had to be reinstalled for installation of the new HSCS (Figure 12), power turbine and gas generator. Following the final hookups (Figure 13), alignment checks, closing up of the intake, and pre-start checks, the new engine had its first start on December 4, 2013. This was followed by a full basin trial on Dec. 5 and, days ahead of schedule, a sea trial on Dec. 6.

Figure 11 – Things begin to come together. With the new exhaust duct in position, the author (foreground) and FMFCS rigger Spartius Toope can install the replacement GT input shaft.

Figure 12 – FMFCS rigger Joshua Gordon, plater Ricardo Green and HMCS *Toronto*'s PO1 Steve Beaulieu install the new high-speed coupling shaft.

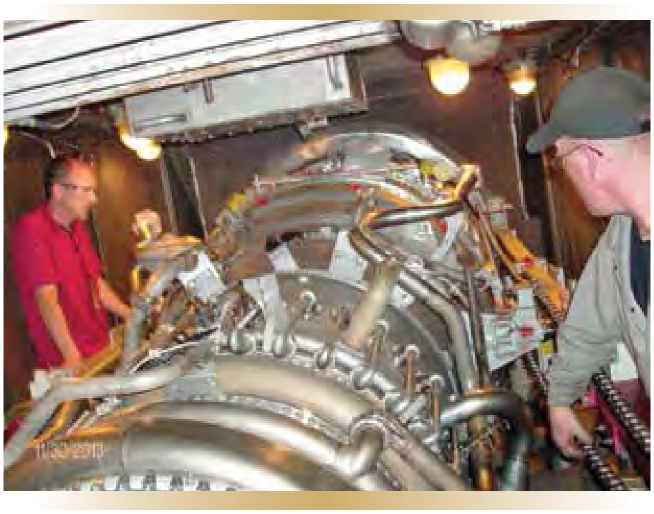


Figure 13 – GE field service rep Del Rogers (left) and FMFCS navy GT tech LS John Alford mate the gas generator to the power turbine. The ship went on to conduct sea trials days ahead of schedule.

## Aftermath

The failure of the high-speed coupling shaft in this and past events was theoretically caused by differential heat triggered by partial exposure to the direct flames of the enclosure fire. As fuel leaked from the engine into the forward end of the enclosure, some of the fuel accumulated in the extreme aft end of the enclosure due to the 3.7-degree downward rake of the enclosure and total propulsion system. There are drains at the aft end of the enclosure, but some accumulation of fuel is still possible. When the engine was run up to near full power, the high-speed coupling shaft was under maximum design torque conditions. The engine-produced heat increased significantly, igniting the accumulated fuel in the aft end of the enclosure and thereby putting a portion of the HSCS into direct contact with the flames. This caused a high differential temperature in the coupling shaft and initiated a material failure that resulted in the catastrophic damage that ensued.

A technical investigation was ordered by the MARLANT Assistant Chief of Staff for Naval Engineering and Maintenance to gather facts surrounding the specific incident and make recommendations to help prevent a reoccurrence. This investigation has been completed. DNPS 3 is also conducting an extensive engineering failure investigation through the Naval Engineering Test Establishment (NETE) with significant participation from Defence Research and Development Canada (DRDC) Atlantic – Dockyard Laboratory in consultation with GE. Additionally, a working group has been created that is co-chaired by DNPS 3 and General Electric Canada with participation from FMFCS, FMF Cape Breton, NETE, and DRDC.

## Conclusion

This short article does not do justice to the scope or complexities of the work carried out, especially away from home port. From the initial reporting of the failure, to the planning, organization and execution of the survey and repair – it was truly a testament to the high capabilities of the engineering and maintenance community as a whole. It was an honour to work alongside the skilled tradesman of FMF Cape Scott, the ship's company of HMCS *Toronto*, GE field service representatives, and the Directorate Naval Platform Systems 3 to see HMCS *Toronto* once again made fully mission-capable in her counter-terrorism and security tasks within the Arabian Sea region.

## Reference

GEK 50504: Illustrated Parts Breakdown GE LM2500 Marine Gas Turbine Systems.

*Bob Steeb is a former navy marine systems engineering officer (commissioned from the ranks) and is currently the Gearing and Gas Turbine Machinery Inspector at Fleet Maintenance Facility Cape Scott in Halifax, Nova Scotia.*

FEATURE ARTICLE

# Applications of Supercavitation to Hard Kill Torpedo Defence*

By Lt(N) Byron Ross, BEng

*[*Adapted from the author's 2012 master's thesis]*

Current torpedo defence for both surface and subsurface platforms is primarily constrained to soft-kill measures such as signature reduction, evasive manoeuvring and the employment of acoustic/magnetic decoys. As torpedoes have evolved, however, the effectiveness of these countermeasures has decayed to the point where they are of limited, if any, use. As early as 2006, former USN Chief of Operations(Surface) VAdm (Ret.) J. Metcalf characterized the severity of the threat by stating that the only effective defence against a modern wake-homing torpedo was to "position a frigate astern of every high value unit," a very expensive proposition.

Modern torpedoes are smart, fast, far-reaching and stealthy. The combination of high-resolution sensors and increased on-board intelligence has improved their ability to discriminate targets from decoys, and their great speed has compressed the time a vessel under attack has to react. Their ability to re-attack a target has increased the already significant push by naval powers to develop a true hard-kill defence against torpedoes.

Considering there exists a plethora of techniques and capabilities dedicated to countering *airborne* threats, it stands to reason there also exists the ability (if not already an in-service capability) to effectively counter these subsurface threats.

If a torpedo can't be seduced, distracted or out-run it has to be intercepted to incapacitate it, which means it must be detected and localized prior to the deployment of an interceptor. One aspect bearing consideration is the speed of the interceptor. The higher the speed of the interceptor, the less time required to travel out to a given range, thus serving to de-compress the reaction time line.

One possible hard-kill solution for increasing survivability might be the application of supercavitation (i.e. sustained full cavitation) – the creation of a gas bubble around an anti-torpedo munition to reduce its underwater drag when deployed against a hostile submerged target. By exploiting the phenomenon of cavitation and creating conditions suitable to maintaining it, a steady state can be achieved whereby the liquid flow detaches from the traversing body, separated by a layer of vapour, significantly reducing the total area subject to direct contact with the liquid-state fluid (Figure 1). Simply put, such a 'streamlined' defensive munition could then travel *up to three to ten times faster* to the target through its bubble of gas than when directly exposed to the much denser seawater.

The theory surrounding supercavitation is sound and well established, but its implementation is far more complicated (although, both the Russian and United States navies have developed supercavitating underwater vehicles).

## Forces at Work

In order to accelerate a body to a desired velocity, the thrust force must exceed the drag force. The greater the magnitude of the excess, the greater the magnitude of acceleration. To maintain a desired velocity the thrust force simply must equal the drag force. And just to complicate matters even further, the drag force experienced by a body moving through a fluid (be it gas or liquid) is proportional to the velocity at which it is moving *squared*.

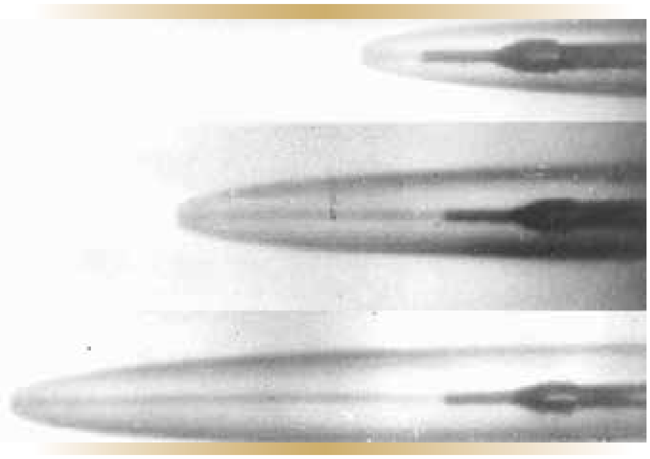


Figure 1 – 1. A submerged munition travelling inside a self-generated supercavity has up to a ten times speed advantage over a munition that is in direct contact with the sea. *(From Y.N. Savchenko 2001)*

The key difference encountered when attempting to increase the velocity of a body in water vice air is *density*, seawater being approximately 850 times more dense than air (at sea level). Though there are many means of reducing drag, supercavitation aims to reduce drag by reducing the local density of the fluid encompassing the body.

In the naval context we are familiar with cavitation as it relates to the increased noise created by rapidly accelerating the rotation speed of a propeller. This phenomenon occurs in liquids when the local pressure approaches the vapour pressure for the fluid, the pressure at which the fluid becomes a gas. The likelihood of cavitation occurring can be described by the *cavitation number*, which is proportional to the difference between the local pressure ($p_L$) and the vapour pressure ($p_V$), and inversely proportional to the inertial forces of the fluid. As the cavitation number approaches zero, cavitation is more likely to occur: $Ca = (p_L - p_V) / (1/2\ \rho V^2)$. When the cavitation begins to occur, numerous tiny vapour bubbles form, then quickly collapse under the pressure of the surrounding fluid, creating broadband noise in the process.

Stimulating cavitation requires establishing a sharp, adverse pressure gradient that causes the fluid pressure to drop significantly over a minimal duration. Counterintuitively, a non-streamlined geometry is desired to achieve this. As a fluid flow transitions from laminar (smooth) to turbulent (rough) the local pressure begins to drop. The greater the interruption in the flow, the greater the decrease in local pressure. Consider moving your hand through the water in a pool. If you lead with the edge of your hand there is minimal resistance. However, if you push your hand through the water *palm* first there is significantly more resistance, and if you do it fast enough you may see bubbles form. This is cavitation.

In the case of supercavitation, efforts are made to drive the cavitation number even closer to zero, mainly through decreasing the difference in pressure and velocity of the flow. Under these conditions the many small vapour bubbles that are created will join together to form larger cavities until they ultimately form a single supercavity. The size and geometry of the cavity are proportional to the size and geometry of the cavitator *and the velocity of the submerged body relative to the fluid*. (Think of moving your hand in the pool of water.) As velocity increases, so too does the drag force, meaning that a larger thrust force is required to maintain the velocity. Thus, a delicate balance needs to be achieved to ensure that any reductions in skin-friction drag are not lost to increases in form and pressure drag.

Ideally a supercavity would be sufficiently large to encompass most if not all of the submerged body, thereby reducing the magnitude of the skin friction drag force as the body moves through the water. While natural cavitation can generate a large cavity, it is possible to create an *artificial* supercavity by injecting a lower pressure gas vapour (Figure 2) or higher velocity fluid jet into the seawater medium immediately surrounding the submerged body. Several factors are involved in determining the size, shape, performance and stability of the artificial cavity, including, oddly enough, the effect of aerodynamic lift as the body moves at speed inside the vapour cavity.

## Application – Delivery and Control

Consideration must also be given to the range across which a supercavitating munition will be employed. The body must be accelerated to an optimal velocity such that the cavitation number drops low enough to not only initiate cavitation, but transition to supercavitation as well.

For short-range applications an impulsive delivery force such as that from a gun or mortar might suffice, while for longer-range applications a reaction force in the form of either a propeller/turbine or a rocket would be more suitable.The propeller/turbine option provides for greater endurance, but lower achievable velocity, and has to deal with a complex environment (potentially transitioning

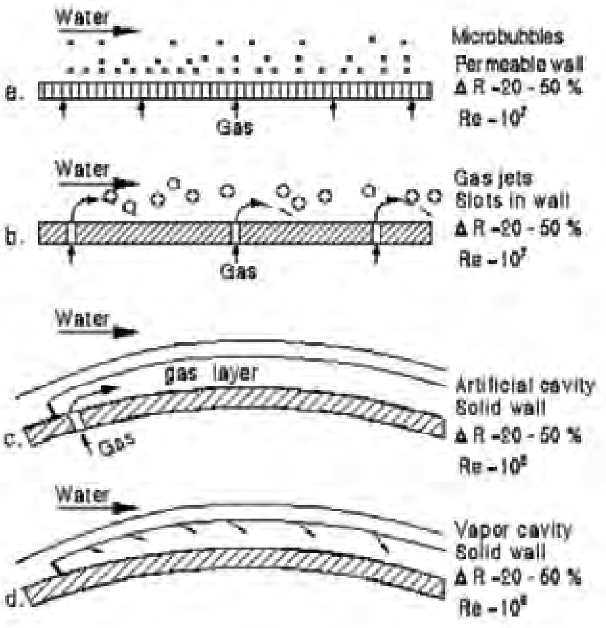


Figure 2 – Gas ejected through the skin of a submerged body artificially stimulates cavitation to the point of supercavitation, where most or all of the body becomes separated from the surrounding seawater medium by an envelope of gas. *(From Y.N. Savchenko 2001)*

Figure 3 – Controlling a supercavitating body is a complex dance between aerodynamics within the gas cavity and hydrodynamics in the sea surrounding the bubble. *(Source: http://cav.safl.umn.edu/gallery.htm)*

back and forth between liquid and gas as the cavity fluctuates). Some of this can be overcome by positioning, such as by having supercavitating screws mounted at the front of the submerged body, providing both the thrust force (in a tractor-pull fashion) as well as cavitation to form the supercavity. This particular arrangement comes at the expense of the highly desirable front end of the body, normally home to sensors, control surfaces and payload.

Rockets are much simpler to implement, and for the most part, operate independent of the surrounding environment. Solid-fuelled rockets provide a decent level of specific impulse and ease of storage and handling, at the expense of being difficult to adjust the thrust. Liquid-fuelled rockets provide the highest specific impulse and are capable of being throttled, but incur significant penalties in the realms of storage and handling.

From a guidance perspective, the best option may be to couple an autopilot with a gyroscope. Wire guidance would require a breach in the munition's surrounding gas cavity, thus exposing it to a significant shearing force, and an on-board target seeker would have to deal with the geometry of the body, the velocity of travel, and the two physical states of water present (gaseous and liquid).

Controlling the direction of travel of a body travelling through a gaseous cavity surrounded by liquid is no simple matter. Not only must the orientation of the body be altered to change the direction of travel, but the cavity itself must also be re-established in the new orientation to maintain a supercavitating state. Ideally the body should be shaped and controlled as an aerofoil within the cavity and as a hydrofoil beyond (Figure 3).

## Further Research

Within the field of fluid dynamics and supercavitation, further research could be conducted into the optimization of cavity formation and body geometry, stabilization of the body within the cavity, and deformation of the cavity in support of manoeuvres at supercavitating speeds. This could extend to the analysis of employing variable geometry cavitators and asymmetrical fluid gas/jet injection for the purposes of altering the cavity's size and geometry. Increasing the efficiency of establishing and subsequently maintaining the cavity would permit an increase in performance.

## Fully Referenced Thesis (available upon request)

*Applications of Supercavitation to Hard Kill Torpedo Defence*, Masters Thesis (July 2012), Lieutenant (Navy) Byron A. Ross, BEng (Mechanical), MSc Guided Weapon Systems, Cranfield University, U.K.; Advisors: Dr. D. Bray; Dr. A. Saddington.

*Lt(N) Byron Ross is the Combat Systems Engineering Officer in HMCS* Fredericton.

# Book Reviews

## RMS Empress of Ireland

*Pride of the Canadian Pacific's Atlantic Fleet*

Reviewed by Brian McCullough

***RMS Empress of Ireland***
Derek Grout © 2014
Dundurn (*www.dundurn.com*)
ISBN: 978-1-4597-2424-2 (pbk $35); 120 pages; illus.

It remains Canada's worst peacetime maritime disaster – 'Canada's *Titanic*,' some call it. Fourteen minutes after being struck a mortal blow by the Norwegian collier *Storstad* in the early hours of Friday, May 29, 1914 – two years after *Titanic* went to her own watery grave in the North Atlantic – the 26,000-ton Canadian Pacific Railway (CPR) passenger liner *Empress of Ireland* slipped beneath the surface of the dark, fog-bound waters of the St. Lawrence River near Rimouski, Quebec, taking 1,012 lives with her. There were 465 survivors.

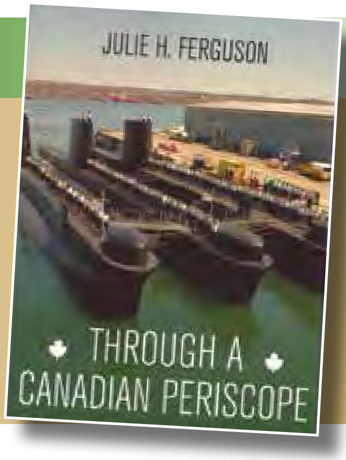
Pointe-Claire, QC maritime author Derek Grout wrote a detailed account of the disaster in his 2001 book, *RMS Empress of Ireland: The Story of an Edwardian Liner*. In this update prepared through Dundurn Press for the centennial of the tragedy, Grout uses excerpts from crew and passenger diaries, along with nearly 200 CPR promotional and other historical photos (half of them in colour), to present a more social perspective of the ship.

For a short while, at least, Grout lets us relive the glory days of a great ship through images of adult passengers playing cricket in the breezeways and children amusing themselves in an upper deck sandpit. A photograph of the ship's soccer team accompanies other crew sporting news in which we learn that the engineers beat the stewards at tug-of-war. (*Go engineers!*)

In the end, though, Grout draws us back as he must to the dark events and aftermath of the Black Friday that sent a great liner to the bottom of the St. Lawrence River. Canada Post and the Royal Canadian Mint have released some fine quality commemorative items on the tragedy, and an exhibition on the *Empress of Ireland* runs until April 6, 2015 at the Museum of History in Ottawa.

*During his service at sea, Brian McCullough sailed past the last known positions of both* Titanic *and* Empress of Ireland.

* * *



## Through a Canadian Periscope

*The Story of the Canadian Submarine Service*

Reviewed by Brian McCullough

***Through a Canadian Periscope***
Julie H. Ferguson © 2014
Dundurn (*www.dundurn.com*)
ISBN: 978-1-4597-1055-9 (pbk $26.99); 424 pages; illus.

The 2014 relaunch of Julie H. Ferguson's 1995 classic celebrates the story of the Canadian submarine service on the occasion of its proud centenary. Fully updated and with new and restored images, *Through a Canadian Periscope* offers a thoroughly researched account of our submarine service from its beginnings at the outset of the First World War to its activities today. The story is a compelling and fitting tribute to the stalwart professionalism both of the people who fought over the years to maintain a submarine service, and especially of those who "went down to the sea in boats" in service of Canada. *(Available through Dundurn in paperback, e-version and PDF.)*

* * *

## Book Reviews (continued)

# White Ensign Flying

Reviewed by Tom Douglas

**_White Ensign Flying_**
Roger Litwiller © 2014
Dundurn (*www.dundurn.com*)
ISBN: 978-1-4597-1039-9 (pbk $34); 1041-2 (epub $16.99)
192 pages; illustrated; appendices and author's notes

Readers who enjoyed *Warships of the Bay of Quinte,* Roger Litwiller's history of six Canadian warships of the 20th century (MEJ 71), will be equally enthralled by the sequel, *White Ensign Flying*.

Who better to write the detailed history of HMCS *Trentonian* than a naval historian who lives near Trenton, Ontario and has had an affiliation with the Royal Canadian Navy since joining sea cadets in his hometown of Kitchener, Ontario – followed by a stint as an officer in the Canadian Armed Forces Reserve and the Navy League of Canada?

It might be an overworked phrase, but 'labour of love' best describes the obvious effort Litwiller has put into this detailed history of HMCS *Trentonian*. Not only did he scour newspaper reports, journals, diaries and official documents in researching this gripping narrative, he also made contact with surviving crew members and relatives to add an enlightening layer of anecdotes to the mix.

Litwiller's skill as a story-teller makes the reader feel like a member of the *Trentonian* crew from the time of its launch at Kingston harbour on September 1, 1943 until its torpedoing by the German submarine, U-1004. The sinking, on February 22, 1945, gave the ship the dubious distinction of being the last corvette sunk by the enemy during the Second World War.

So thorough is Litwiller's research that he even records the thoughts of crew members awaiting rescue in the frigid waters of the English Channel – some of them hoping to see the U-boat destroyed by Allied warships in the area, others griping about the time spent in vain giving their ship a new coat of paint, still others breaking into song to keep their spirits up.

While 95 members of the crew were rescued, one officer and five ratings were killed in the attack. The survivors had to wait until December 1, 1945 for U-1004 to suffer the same fate as the *Trentonian,* although the crew had already been removed. The U-boat surrendered to the Allies in Bergen, Norway at the end of hostilities in Europe and was sunk by gunfire several months later as part of Operation Deadlight, the code name for the Royal Navy's scuttling of captured German submarines.

Litwiller ends his account of the life and death of *Trentonian* by quoting words of praise for the men who served about the ship as written in the *Trenton Courier Advocate* at the time: "All of Canada is proud of them, for they upheld the finest traditions of the Navy."

*Tom Douglas is the associate editor of the* Maritime Engineering Journal.

## Submissions to the *Journal*

**The *Journal* welcomes unclassified submissions in English or French. To avoid duplication of effort and ensure suitability of subject matter, contributors are asked to first contact the production editor. Contact information may be found on page 1. Letters are always welcome, but only signed correspondence will be considered for publication.**

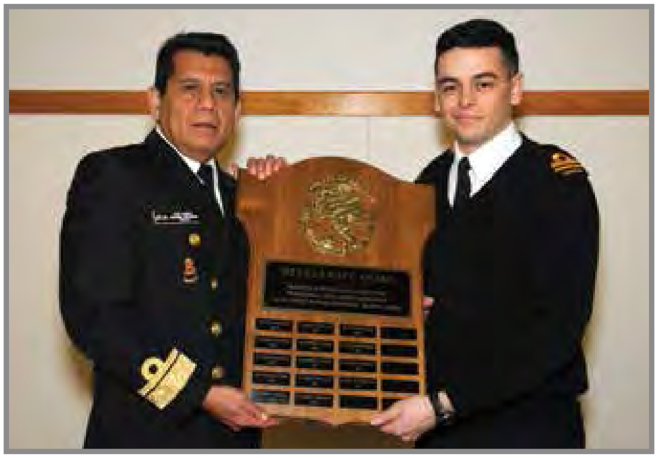
# 2013 NAVAL TECHNICAL OFFICER AWARDS

Halifax photographs by MCpl Leona Chaisson, Formation Imaging Services Halifax
Notes courtesy Lt(N) Christopher De Castro

## Naval Association of Canada (NAC) Award

**SLt John J. Lee**
Highest standing, professional achievement and officer-like qualities during Naval Engineering Indoctrination *(With Cmdre RCN (Ret.) Mike Cooper)*

## Mexican Navy Award



**SLt Riley Monsour**
Top student, Naval Combat Systems Engineering Applications Course *(With Mexican Naval Attaché RAdm José Manuel Guido Romero)*

## L-3 MAPPS – Saunders Memorial Award

**SLt Matthew Robbins**
Top student, Marine Systems Engineering Applications Course *(With HMCS Iroquois MSEO LCdr Frederic Bard, left)*

## MacDonald Dettwiler and Associates Award

**Lt(N) Philip Miners**
Top NTO candidate to achieve Head of Department qualification *(With Mark Higginson)*

# 2013 NAVAL TECHNICAL OFFICER AWARDS (continued)

## Weir Canada Award

**SLt Tommy Liu**
Top Marine Systems Engineering Phase VI candidate
*(With Serge Lamirande)*

## Lockheed Martin Canada Award

**Lt(N) Dusan Brestovansky**
Top Combat Systems Engineering Phase VI candidate
*(With Don McClure)*

## Royal Military College of Canada NTO Award

Photo by Mike Shewfelt

**NCdt Michael Baskin**
Top Naval Engineering Cadet
*(With Capt(N) Jim Carruthers, RCN (Ret.))*

# News Briefs

## Canadian War Museum acquires second of two Halifax Explosion medals

Ottawa's Canadian War Museum (CWM) has added to its collection the second of two Albert Medals for Saving Life at Sea awarded to Canadians for their attempt to rescue survivors of the Halifax Explosion of December 6, 1917. The explosion occurred after the French munitions carrier SS *Mont-Blanc* and the Norwegian vessel SS *Imo* collided in the Halifax Narrows.

In April of this year, the CWM obtained a medal awarded posthumously to Petty Officer Edmund Ernest Beard. Also turned over were PO Beard's three service medals, a memorial plaque given to the families of all servicemen/women who lost their lives in the First World War, and several documents and photographs.

The artifacts had originally been in the possession of PO Beard's older sister and designated next-of-kin Evelyn Dunn (now deceased). The acquisition was made possible in part by the National Collection Fund, which supports the purchase of nationally significant artifacts by the CWM and the Canadian Museum of History.

The other Canadian recipient of an Albert Medal linked to the explosion was Acting Boatswain Albert Charles Mattison. The CWM acquired his medal in 2011. The museum's collection also includes two of the four Albert Medals awarded to members of the Royal Navy for heroism on that day.

PO Beard was born in London, England on July 24, 1887. Immigration records show he arrived in Canada in 1911. Both he and Acting Boatswain Mattison were serving with the Royal Naval Canadian Volunteer Reserve at the time of the tragedy. They boarded the steam pinnace from HMCS *Niobe* and rushed to the aid of the *Mont-Blanc*, but as the would-be rescuers drew alongside the stricken ship the *Mont-Blanc* exploded, destroying the small boat and killing all on board. The bodies were never recovered.

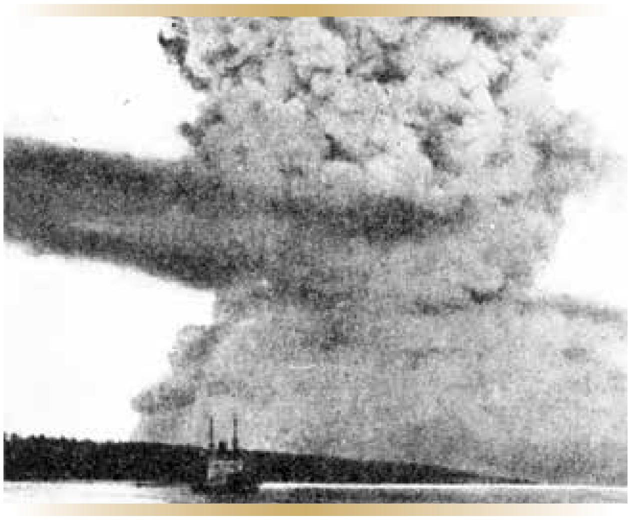
The Albert Medal for Saving Life at Sea was instituted in 1866 in memory of Queen Victoria's husband, Prince Albert, and discontinued in 1971. The 1917 blast in Halifax Harbour was the world's biggest man-made explosion prior to the dropping of the atomic bomb on Hiroshima, Japan on Aug. 6, 1945.

CWM 20130540-005 © Canadian War Museum

Stoker Petty Officer Edmund Ernest Beard

CWM20130162-001, Tilston Memorial Collection of Canadian Military Medals, © Canadian War Museum

Albert Medal for Saving Life at Sea awarded to Edmund Ernest Beard



The 1917 Halifax Explosion photographed from Bedford Basin, looking south toward the Narrows

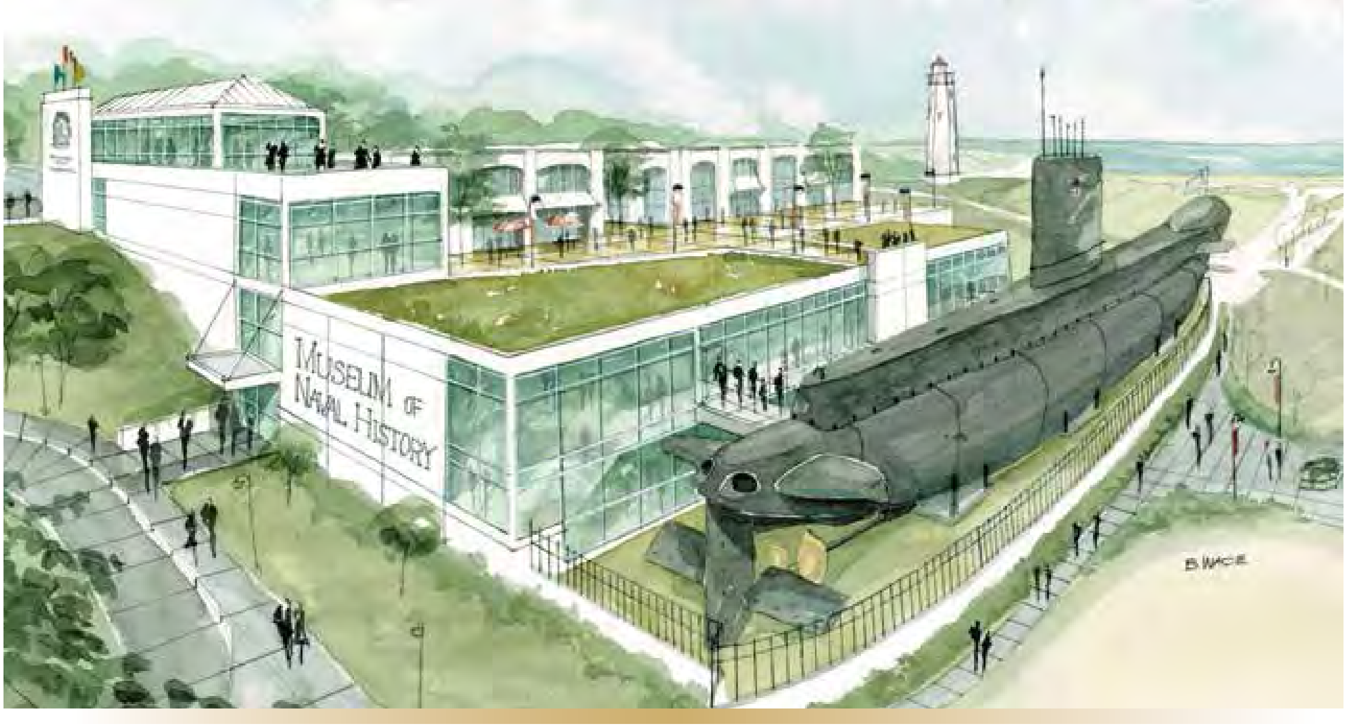
# *Ojibwa* at home in Port Burwell, Ontario

HMCS *Ojibwa* (S72), the first of Canada's *Oberon*-class submarines commissioned in the 1960s, has a new life teaching visitors from all over the world about the important role of the Royal Canadian Navy, particularly during the dark days of the Cold War.

*Ojibwa* served the navy from 1965 to 1998 and was saved from the wrecker's yard fate of her sister HMCS *Okanagan* (S74) by the Elgin Military Museum of St. Thomas, ON. The submarine now sits proudly restored and open for tours in Port Burwell on the north shore of Lake Erie. The site is open seven days a week until the end of September, and by appointment after that.

Fundraising is currently underway to build a new Museum of Naval History (pictured) that will be built beside *Ojibwa* to bring the story of the RCN to school groups, cadet corps and the general public. Anyone interested in supporting the project or helping the museum cover the more than $7-million cost of saving *Ojibwa* can reach the museum through *www.projectojibwa.ca*.

– **Melissa Raven, Director of Communications, Museum of Naval History, Port Burwell.**



Artist's concept rendering courtesy Museum of Naval History

# Memorial for RCN ships in Korea

The Honourable Rob Nicholson, Minister of National Defence, along with the Honourable Julian Fantino, Minister of Veterans Affairs and other dignitaries, participated in the unveiling of the Royal Canadian Navy Ships in Korea Memorial Monument in Spencer Smith Park, Burlington, Ontario on July 28.

This historic monument is dedicated to the eight Royal Canadian Navy destroyers that served in the Korean War from June 1950 until the armistice of July 1953, and patrolled thereafter until September 1955. It also honours the nine crew members who were either killed in action, lost at sea, or died in service, as their names are inscribed on the monument.

Photo by Tom Douglas

"We must always remain grateful to our veterans of the Korean War, which was one of Canada's most important military engagements. It is imperative that those who fought and gave their lives are not forgotten. I applaud the work done to create this monument, which will help preserve the legacy of our Veterans and a chapter in our nation's history." *– The Honourable Rob Nicholson, P.C., Q.C., M.P. for Niagara Falls and Minister of National Defence*

HMCS *Cayuga* was one of eight RCN destroyers that saw action in the Korean conflict.

The project to erect the Korea Memorial Monument was initiated by members of Korea Veterans Association Unit 26 in Hamilton and the HMCS *Haida* Association. Over the course of the five years the RCN deployed its entire available destroyer force of eight ships to the Korean theatre to perform escort duties, interdiction, fire support at points around the peninsula, and maintenance of sea control that enabled land forces to operate freely without concern of threats from the sea.

"This monument will be a lasting tribute to the sailors who served during this conflict and the ships they sailed on. It speaks to the proud history of the Royal Canadian Navy and its enduring contributions to international peace and security," said VAdm Mark Norman, Commander of the Royal Canadian Navy.

Photo by Tom Douglas

PRESERVING CANADA'S NAVAL TECHNICAL HERITAGE

CNTHA NEWS

Canadian Naval Technical History Association

# HMCS *Provider* Vibration Problem

By Cmdre W.J. Broughton, RCN (Ret.)

*CNTHA News* *Est. 1997*

**CNTHA Chairman**
Pat Barnhouse
**CNTHA Executive Director**
Tony Thatcher
**Directorate of History and Heritage Liaison**
Michael Whitby
**Maritime Engineering Journal Liaison**
Brian McCullough
**Newsletter Production Editing Services by**
Brightstar Communications
(Kanata, ON)
in association with
d2k Marketing Communications
(Gatineau, QC)

*CNTHA News* is the unofficial newsletter of the Canadian Naval Technical History Association. Please address all correspondence to the publisher, attention Michael Whitby, Chief of the Naval Team, Directorate of History and Heritage, NDHQ
101 Colonel By Dr
Ottawa, ON K1A 0K2
Tel. (613) 998-7045
Fax (613) 990-8579

**www.cntha.ca**

Soon after she commissioned in 1963, HMCS *Provider* suffered from severe hull vibrations when underway at high propulsion powers.

Alan Grundy, the civilian vibration engineer in NDHQ, made arrangements to conduct forced shaker trials in, I believe, Halifax. A mechanical shaker machine was mounted aft on the quarterdeck and some sort of deflection/velocity/acceleration instruments were installed in various locations over the length of the ship to determine the nature of the hull response. The results were compared with the vibrations at sea, and it was determined that the hull was being excited in its first horizontal mode. Additionally, the frequency matched the blade propeller frequency as the shaft revolutions approached full power.

The investigation then moved to an examination of the four-bladed propeller and the ship's wake into it. That's where I became involved. Model tests showed that the wake was very non-uniform and turbulent due to the underwater shape of the after part of the hull. Rather than narrowing gradually toward the stern to allow smooth water flow, the hull transitioned abruptly from a full profile to its final narrow profile in a very short distance. Clearly, as each blade rotated in its circular travel, there was a large variation in the produced thrust because of the great variation in the wake speed entering the propeller's path at the different positions of the blade's rotation. Each blade was seeing a change in wake from a positive to a negative speed of wake entry! As memory serves, the top shaft revolution was about 110 rpm. That would mean a pulsing action from the propeller at a frequency of about 440 cpm from the four blades. It turned out that the propeller pulse frequency was in exact tune with the frequency of the first horizontal mode of the ship's hull as determined by the shaker trial.

Grundy and I discussed possible remedies (not solutions) with senior engineering staff, with the obvious fix being to change the number of blades on the propeller to de-tune the synchronous effect with the hull. After some preliminary analysis I recommended a seven-bladed propeller. More blades, however, would mean a reduction in the propeller rpm and thus an increased torque on the shafting for the same power output. Our gearing and shafting expert, Don Nicholson, confirmed this would not be a problem. The LIPS propeller works in Drunen, Netherlands reviewed our work and agreed that the best remedy would be to increase the number of blades, but recommended a six-bladed propeller. This was subsequently ordered and installed. The fix was successful in eliminating the severe hull vibrations.

During our investigations I discovered that *Provider* was originally intended to have a nuclear propulsion plant. When that was dropped in favour of a steam plant, the hull was not broad enough to accept it. Apparently, instead of lengthening the hull to provide a fuller space aft, the length was kept unchanged and the existing full lines were extended farther aft, resulting in the final abrupt narrowing. As noted, it was this abrupt transition that was the source of the non-streamlined, turbulent wake. When the lines drawing was obtained it was observed that it had never been signed off. No one knew who had approved the change in *Provider's* after hull shape.