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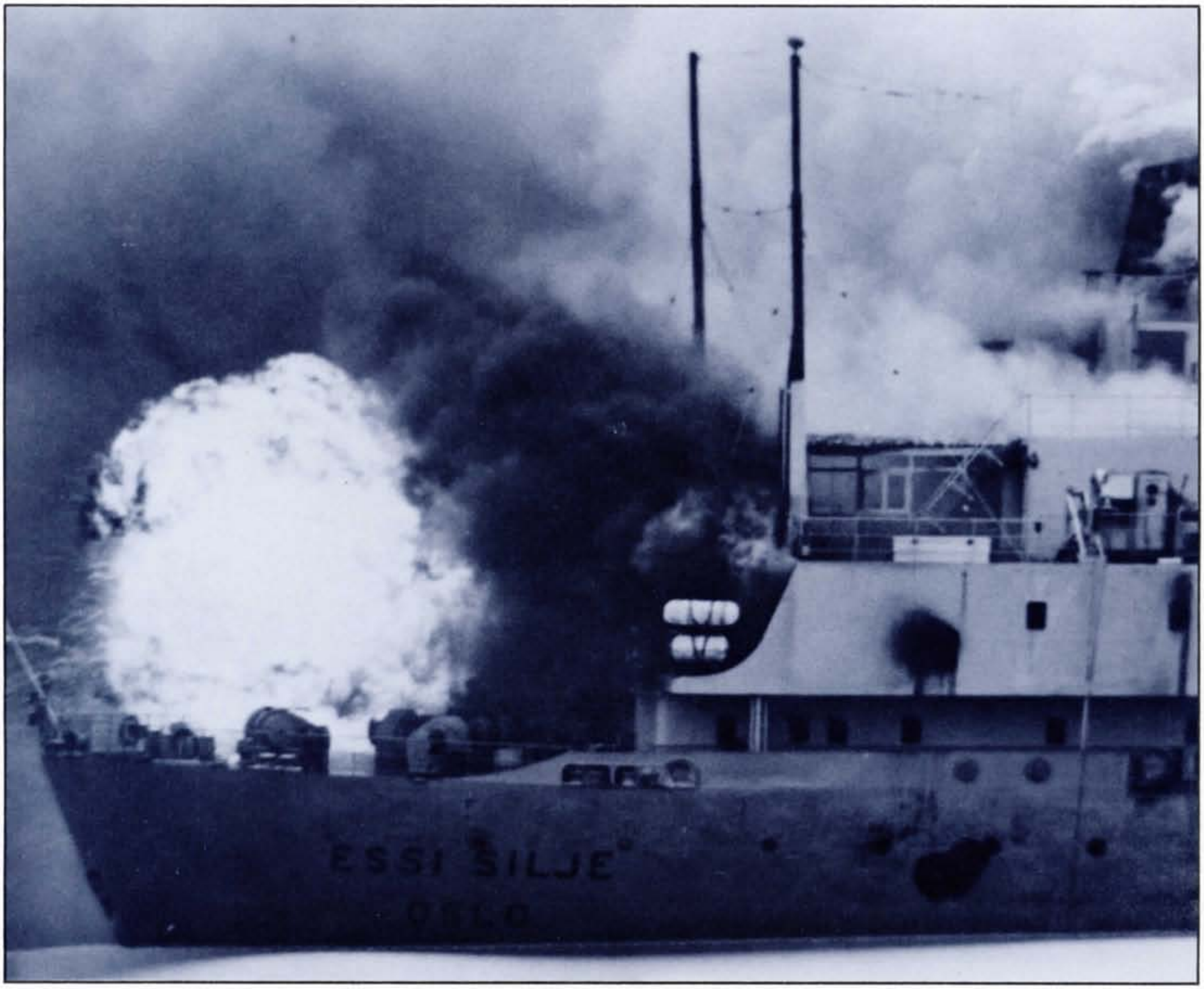
MARITIME ENGINEERING Journal du GÉNIE MARITIME



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Goodbye Mister Transmission

Au revoir monsieur transmission

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MARITIME ENGINEERING

Journal

du GÉNIE MARITIME

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OUR COVER
The MV *Essi Silje* ablaze in the North Atlantic.

PHOTO COUVERTURE
Le MV *Essi Silje* en flammes dans l'Atlantique.

JANUARY 1988 JANVIER

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FEATURES/ARTICLES

MARITIME ENGINEERING JOURNAL
ISSN 0713-0058

The Maritime Engineering Journal (ISSN 0713-0058) is an authorized unofficial periodical of the maritime engineers of the Canadian Forces, and is published three times a year by the Director-General Maritime Engineering and Maintenance. Views expressed are those of the writers and do not necessarily reflect official opinion or policy. Correspondence can be addressed to **the Editor, Maritime Engineering Journal, DMEE, National Defence Headquarters, Ottawa, Ont., K1A 0K2.** The Editor reserves the right to reject or edit any editorial material. Journal articles may be reprinted with proper credit.

JOURNAL DU GÉNIE MARITIME
ISSN 0713-0058

Le Journal du Génie maritime (ISSN 0713-0058) est une publication autorisée et non-officielle des ingénieurs maritimes des Forces canadiennes. Elle est publiée trois fois l'an par le Directeur général du Génie maritime et de la maintenance. Les opinions exprimées sont celles des auteurs et ne reflètent pas nécessairement les politiques officielles. Le courrier doit être adressé au **Rédacteur en chef du Journal du Génie maritime, DMGE, Quartier général de la Défense nationale, Ottawa, Ont., K1A 0K2.** Le Rédacteur en chef se réserve le droit de rejeter ou d'éditer tout matériel soumis. Les articles de ce journal peuvent être reproduits tout en tenant compte des mérites de l'auteur.

Editor's Note

There is little question that going to the assistance of a burning vessel on the high seas represents an extremely hazardous undertaking, but for just about as long as man has been going to sea in ships it has been the code of the mariner to go unquestionably to the aid of others whose vessels are in distress. Understandably, the main concerns centre on rescuing the crew, salvaging the ship and her cargo, and doing everything possible to minimize pollution of the environment. But is this enough?

In our lead article, a special reprint feature, Edwin Chan documents a 1982 rescue-salvage incident, involving the naval supply ship HMCS *Protecteur* and a Norwegian chemical tanker which caught fire and was abandoned in the North Atlantic. Responding to the distress call, *Protecteur* rescued the tanker's crew from lifeboats and undertook a salvage operation before the arrival of the salvage tugs. The vessel was eventually salvaged, but a dispute arose over the amount to be awarded to the salvors by the insurers. In his article, Mr. Chan describes the technical basis for the dispute and the results of the technical investigation for the Lloyd's arbitration hearing of the case. Since, as he says, the dispute was "the direct result of the lack of information on the actual condition of the vessel", he makes a number of recommendations for "what more" a salvor should do.

Also in this issue, we take a look at a new fluid-analysis program developed by NETE for Equipment Health Monitoring of shipboard machinery. As Michael Davies writes, the new Oil and Coolant Condition Analysis Program (OCCAP) has been successfully evaluated as a pilot program on a limited number of diesel equipment types and is now being developed for other equipment types. Designed to maximize ship-system reliability in accordance with the navy's RCM policy, OCCAP will soon be standardized across the Canadian fleet.

Finally, in response to popular demand, we are introducing a nostalgia section to the *Journal*. "Looking Back" will be a regular feature of the magazine where we focus briefly on interesting aspects of naval history. We invite your submissions for this section.

Note de la rédaction

Il y a peu de doute que l'on s'expose à des risques lorsqu'on entreprend de sauver un navire qui a pris feu en haute mer, mais pratiquement depuis les temps les plus reculés, le marin a pour principe indiscutable de porter secours aux navigateurs en détresse. Ce qui compte, naturellement, c'est de secourir l'équipage, de sauver le navire et sa cargaison et de réduire au strict minimum la pollution de l'environnement. Mais est-ce suffisant?

Dans l'article de tête que nous publions en réimpression, Edwin Chan relate un incident de sauvetage survenu en 1982, mettant en cause le ravitailleur NCSM *Protecteur* et un transporteur de produits chimiques qu'on abandonna, en proie aux flammes, dans l'Atlantique Nord. En réponse à l'appel de détresse, le *Protecteur* est allée au secours des membres de l'équipage du transporteur, qui avaient emprunté les chaloupes de sauvetage, et a entrepris de sauver le navire avant l'arrivée des remorqueurs. On a fini par sauver le bâtiment, mais le montant à verser aux sauveteurs par les assureurs a fait l'objet d'un litige. Dans son article, M. Chan fait état des fondements techniques du litige et des résultats de l'enquête technique réalisée en prévision de l'arbitrage du différend par la Lloyd's. Le litige étant, à son avis, directement attribuable au manque de renseignements sur l'état réel du navire, il recommande aux sauveteurs de prendre d'autres mesures.

Nous examinons également dans le présent numéro un nouveau programme d'analyse des fluides élaboré par le CETM pour la surveillance de l'état de l'équipement à bord des navires. Comme l'écrit Michael Davies, le nouveau programme d'analyse de l'état des pétroles et fluides de refroidissement a été jugé un succès comme programme pilote sur un nombre restreint de pièces d'équipement diesel et est en voie d'être appliqué à d'autres types d'équipement. Conçu pour maximiser la fiabilité des systèmes de navire en conformité avec la politique de maintenance de la marine axée sur la fiabilité, le programme d'analyse de l'état des pétroles et fluides de refroidissement sera bientôt normalisé à l'échelle de la flotte canadienne.

Enfin, pour répondre à la demande de plusieurs, nous lançons une chronique intitulée « Rétrospective », qui nous permettra de jeter un coup d'oeil sur des éléments intéressants de l'histoire de la marine. Vos contributions à cette chronique sont les bienvenues.

B.H. Baxter

Commodore's Corner

Chronique du Commodore

by Commodore D.R. Boyle, DGMEM

One year ago in this column I gave you an overview, as I saw it, of where we were and where we were going as a Branch. I can now be a little more specific by discussing one recent MARE Get Well activity — the MARE Establishment Review.

No doubt many of you were aware that an establishment review was being conducted, but probably few MAREs know either why it was conducted or what its outcome was. There were a number of reasons why an establishment review was needed, and my purpose is to highlight the major aims and findings of the review. First, though, a bit of background might be helpful.

Although the MARE occupation did not carry out a formal classification review, as did our MARS brethren, we did go through a similar process during the early eighties. The process culminated in the 1983 MARE Study, which in turn led to the creation of much-needed new personnel specifications for four sub-occupations and revised training programs to meet these specifications. The normal final step in completing a classification review, a review of the qualifications identified for each establishment position, was never completed in detail for a number of reasons.

The primary purpose of the establishment review was to go over the establishment position qualifications, which were still based on the pre-1983 specifications, and update them as necessary to make them conform to the new specifications. Almost as a by-product, it was intended that the review also provide us the opportunity to gather data from which we could address some of the other personnel problems facing us.

At the moment we have a very large "bubble" of MS officers completing sub-occupation training and will soon be faced with a similar situation for CS officers. The problem lies in an insufficient number of billets to allow us to send all of these officers to sea for their first employment as AMSEOs and ACSEOs. We had to find out, therefore, what alternate positions existed ashore in which some of the newly qualified officers could be usefully and productively employed. In addition, we had to assess the overall requirement for sea experience for MS and CS officers.

It had also been suggested that we might break up the rather lengthy MARE training schedule by inserting a period of "junior engineer" employment part way through the program. So this too had to be investigated. And finally, because of the growing requirement for MAREs to meet our capital project needs, we had to verify that each designated MARE position on the establishment truly needed to be a "MARE" position.

Texte commodore D.R. Boyle, DGGMM

Il y a un an, je vous ai donné un aperçu de l'état de notre situation et de notre avenir en tant que groupe. Je suis maintenant en mesure d'apporter des précisions sur une activité récente, soit l'examen des effectifs du G Mar.

Je suis persuadé que bon nombre d'entre vous êtes au courant de la tenue de l'examen des effectifs du G Mar, mais il est probable que très peu de spécialistes du G Mar savent pourquoi l'examen a eu lieu et quels en furent les résultats. L'examen des effectifs se fonde sur plusieurs motifs, et j'entends en faire ressortir les grands buts et les principales conclusions. Je commencerai par vous situer en contexte.

Même si la spécialité du G Mar n'a pas été l'objet d'un examen officiel de classification, comme ce fut le cas de nos collègues du groupe Mar SS, nous avons été soumis à révision semblable au début des années 80. Le point culminant a été l'étude du G Mar de 1983, qui a mené à la création de spécifications nouvelles dont on avait grand besoin sur quatre sous-groupes professionnels et à la révision des programmes de formation en fonction de ces spécifications. L'étape finale habituelle d'un examen de la classification, soit l'examen des qualités requises pour chacun des postes inscrits à l'effectif, n'a jamais été achevée pour diverses raisons.

L'examen des effectifs avait pour but premier de passer en revue les qualités requises associées aux postes inscrits à l'effectif, encore fondées sur des spécifications datant d'avant 1983, et de les mettre à jour au besoin pour qu'elles soient conformes aux nouvelles spécifications. En conséquence, on s'attendait que l'examen nous donne l'occasion de réunir des données qui nous aideraient à résoudre certaines des autres difficultés que nous affrontions en matière de personnel.

Nous comptons en ce moment un très grand bassin d'officiers spécialistes des systèmes marins qui terminent leur formation dans un sous-groupe professionnel, et la situation sera bientôt à peu près la même pour ce qui est des officiers spécialistes des systèmes de combat. Le problème qui se pose est le nombre insuffisant de postes nous permettant d'offrir à chacun de ces officiers une première affectation en mer à titre d'officier adjoint des systèmes de marine ou de combat. Il nous fallait donc trouver des postes à terre qui pouvaient rentablement être comblés par ces officiers nouvellement qualifiés. Il nous fallait en outre évaluer la nécessité de l'expérience du service en mer pour les officiers spécialistes des systèmes de marine ou de combat.

On avait proposé par ailleurs d'entrecouper le long programme de formation du G Mar par un stage d'emploi à titre de technicien subalterne. Il faillait donc se pencher sur cette question également. Enfin, vu que le besoin de spécialistes du G Mar augmente pour mener à bien nos projets d'immobilisations, nous avons dû vérifier que chacun des postes du G Mar à l'effectif devait réellement être un poste du G Mar.

With these aims in mind, a team of officers sponsored by the Naval Personnel Planning Project set about conducting extensive interviews on both coasts and in Ottawa, comparing job requirements with the MARE specifications. The review team submitted its report last June. In it they made a number of recommendations regarding minor changes to position qualifications to define more accurately the sub-occupations needed for each position. At the time of writing, we have started the staffing process to implement these changes.

Overall, the MARE establishment was found to be quite lean, and the requirements for MARE officers have not been overstated. A small number of positions were determined to be more appropriate for other MOCs, such as MARS or TDEV, and some were broadened to SEAGEN (i.e. MARS/MARE) or ANY, but the review confirmed that the MARE 44B, C, D or E qualification is essential for almost all MARE positions, and particularly so for those at sea or in shore units having large civilian contingents. In short, we are not overtraining MAREs for their first jobs. This does not imply for one minute, however, that some improvement or fine tuning of training is not possible. In fact it is recognized that some such adjustment to MS and CS sub-occupation training is necessary. My staff are actively working with MARCOM training staff to achieve this.

The need for a basic level of software engineering training for MARE officers (quite apart from that needed by officers who will be working in that field as their specialty) was examined during the review. Software is increasingly becoming an integral component of all naval systems, and as system engineers, an understanding of software engineering will have to become part of every MARE's tool kit. Again, we have started to define the required training and determine the best means of implementing it.

In closing, the MARE Get Well Project is working. We can see the results. The MARE target strength can be expected to grow even more over the next few years as we proceed with the re-equipping of the navy, but we are also producing a very large number of junior officers. Although the match will by no means be perfect, we should be able to meet the overall manning requirement with fully trained officers in another two to three years. To this end, the establishment review has answered many questions and has provided a fair data base from which we can better define and resolve some other current and projected MARE manning difficulties.

Compte tenu de ces objectifs, une équipe d'officiers parrainée par le projet de planification du personnel de la Marine a entamé une série d'entrevues dans les régions de la côte est et de la côte ouest ainsi qu'à Ottawa, afin d'établir une comparaison entre les exigences des postes et les spécifications du G Mar. L'équipe a présenté son rapport en juin dernier. On y trouve un certain nombre de recommandations sur des changements d'ordre secondaire à apporter aux qualités requises des titulaires des postes pour que les sous-groupes nécessaires à chacun des postes soient mieux définis. Aux dernières nouvelles, les mécanismes de dotation en personnel qui permettront d'appliquer ces changements ont été établis.

Dans l'ensemble, on a trouvé l'effectif du G Mar relativement peu nombreux, et les besoins en fait d'officiers du G Mar n'ont pas été exagérés. On a jugé qu'un nombre restreint de postes conviendraient mieux à d'autres groupes professionnels militaires, tel le Mar SS ou le DEVI, et certains ont été élargis à Mar SS/G Mar ou à "TOUT CODE", mais l'examen a permis de confirmer que le niveau de qualification 44 B, C, D ou E du G Mar est essentiel à pratiquement tous les postes du G Mar, en particulier à ceux des unités en mer ou à terre dont l'effectif civil est important. Bref, nous n'offrons pas aux spécialistes du G Mar une formation excessive en prévision de leur première affectation. Il ne faut toutefois pas sous-entendre par là que la formation ne peut nullement être améliorée. De fait, on reconnaît qu'il y a lieu d'apporter quelques modifications au programme d'instruction des sous-groupes des systèmes de marine et de combat. Les membres de mon personnel ont entamé à cet effet une étroite collaboration avec le personnel instructeur du COMAR.

On a étudié dans le cadre de l'examen la nécessité d'instaurer un niveau élémentaire de formation en génie logiciel à l'intention des officiers du G Mar (qui se distingue de la formation dont ont besoin les officiers qui serviront dans ce domaine en tant que spécialité). De plus en plus, le logiciel fait partie intégrante des systèmes navals, et à titre de spécialiste des systèmes, tous les membres du G Mar devront avoir une connaissance du génie logiciel. Là encore, nous avons entamé la définition des cours nécessaires et une analyse des meilleurs moyens de mettre en oeuvre le projet.

Pour conclure, le projet "Get Well" du G Mar s'avère une réussite. Les résultats sont tangibles. On peut s'attendre que l'effectif visé du G Mar augmente encore à mesure que nous rééquiperont la Marine au cours des années à venir, cependant nous formons un très grand nombre d'officiers subalternes. Même si l'équilibre ne sera pas atteint à la perfection, nous pouvons compter que des officiers dûment formés se joindront à l'effectif d'ici à trois ans tout au plus. Dans cette perspective, l'examen des effectifs a permis de répondre à de nombreuses questions et de constituer une basse de données à partir de laquelle nous pourrons mieux cerner et résoudre d'autres difficultés posées par la dotation en personnel du G Mar.

The Salvage of MV *Essi Silje* and Lloyd's Arbitration Hearing[1]

by Edwin S. Chan

In 1982 the chemical tanker MV Essi Silje *caught fire and was abandoned in the North Atlantic. The Canadian naval supply ship, HMCS* Protecteur, *undertook the salvage operation before the arrival of the salvage tugs. The vessel was eventually salvaged. For the subsequent Lloyd's Arbitration Hearing in London, the author was tasked by the Department of Justice of Canada to provide evidence for presentation at the hearing. This paper presents a brief account of the incident, the technical investigation, the technical disputes, and provides recommendations for future salvage operations.*

The incident

On 8 June 1982 the chemical tanker MV *Essi Silje* (registered in Norway) sailed from Ellesmere Port, U.K., for Curacao with a load of 9234 tonnes(t) [9088.2 long tons (LT)] of tetraethyl lead antiknock compounds, 2175.6t (2141.2 long tons) of caustic soda, and 354.96t (349.4 long tons) of potash. At about 2055 hours, on 11 June, at an approximate position 44°40'N and 20°40'W in the North Atlantic, fire erupted in way of the port main engine. The fire spread quickly into the accommodation space and, within half an hour, the crew lowered the lifeboats and abandoned the vessel after the "Mayday" call was sent out.

The Canadian naval supply ship HMCS *Protecteur*, carrying two Sea King type helicopters, on passage from Plymouth, U.K. to Halifax, Canada, upon receiving the distress signal, directed the helicopters to the scene to provide assistance. At the same time *Protecteur* was approaching the burning vessel at high speed, from a distance of 41.7km (25 miles). *Protecteur* arrived alongside the lifeboats at about 0030 on the 12th and the crew of the vessel was picked up, including the master of the *Essi Silje*, after a brief visit to the burning vessel.

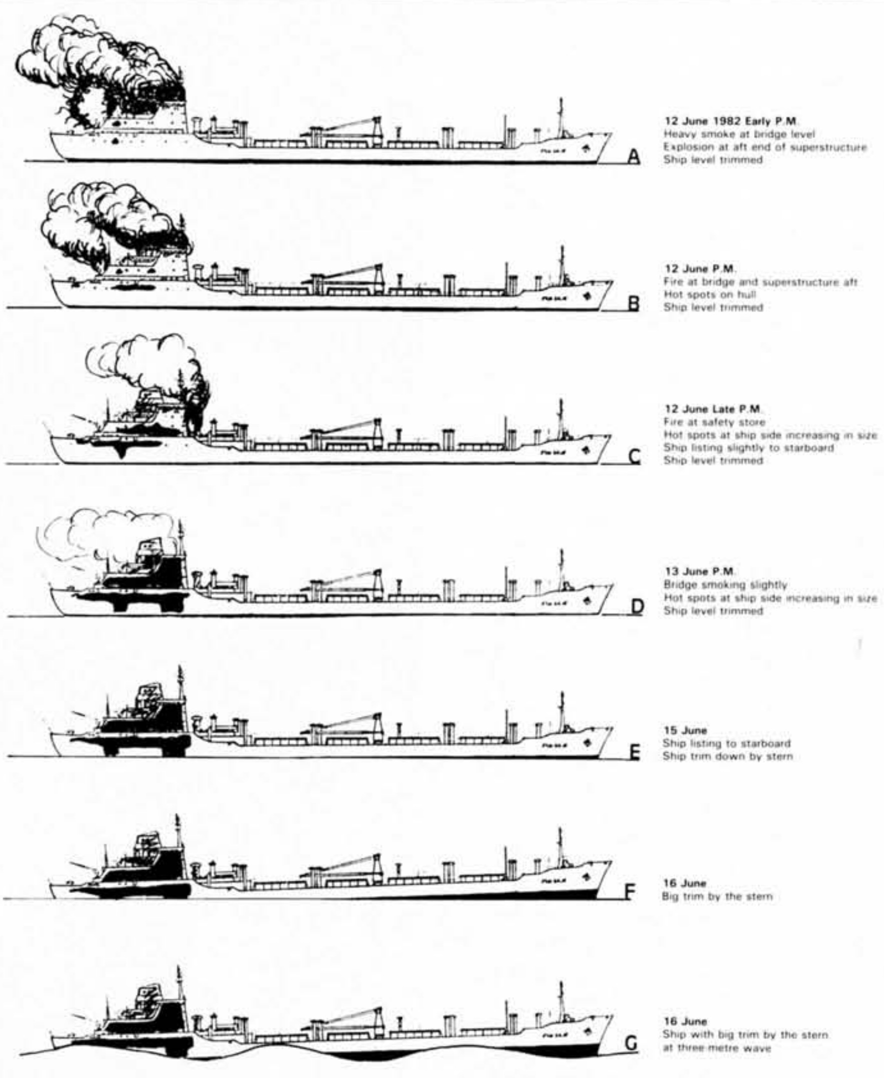

Figure 1. Observations based on photographs taken by crew of HMCS *Protecteur*.

At early dawn of the 12th, the fire in the engine room appeared to be out but the fire in the superstructure appeared to intensify, with flames on various parts of the bridge and funnel area. Periodic explosions were observed. In the afternoon the paint on the ship sides peeled off and burned. By evening the fire appeared to have peaked — after the fire

[1]*Presented at the April 10, 1986 meeting of the Eastern Canadian Section of the Society of Naval Architects and Marine Engineers, and published in the January 1987 issue of Marine Technology.*

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on the bridge was out. Figure 1 shows the condition of the vessel at different time periods, based on the photographic record of the crew of *Protecteur*. Figure 2 shows actual photographs of the burning superstructure.

Throughout the 13th, the vessel continued to burn, especially around the fuel tanks in the engine room. *Protecteur* patrolled around the burning vessel at a radius of one nautical mile. By midday on the 14th the fire seemed to have burned itself out, but the vessel was observed to start trimming down by the stern (Fig. 3). After 1300, the boarding party discovered that the engine room was flooding rapidly. Coventry Climax portable fire pumps were transferred from *Protecteur* and were set up in the engine room above the main diesel engine by the crew of *Protecteur*, who worked under great difficulties and hazards due to flooding water and heavy smoke. The pumps could not operate effectively because of the lack of oxygen in the space. With the rising of floodwater in the engine room, the master considered it unsafe for anyone to remain on board. Therefore the vessel was abandoned once again.

With the rescue tugs chartered by the owner of the vessel still a long distance away, and in consideration of the ecological damage to the sea had the vessel sunk, the commanding officer of *Protecteur* undertook the salvage responsibility after signing of a Lloyd's Open Form during the morning of the 15th. *Protecteur*'s crew undertook measures to stop the flooding of the vessel and to dewater the flooded compartments. Navy divers were sent to plug up sea inlets at the bottom of the vessel. Due to the rolling of the vessel the underwater work was extremely dangerous, but three leaking inlets were plugged with plastic cloths, canvas and wooden damage-control plugs. At the same time, personnel, pumps and other necessary equipment were transferred by helicopter from *Protecteur* to the vessel. Pumps were set up to pump water from the space forward of the engine room, which was now starting to flood. The portlights at the starboard poop close to the trim waterline were plugged to prevent water from entering.

During the evening, it was decided that the vessel should be towed toward the rescue tugs, which were still a long distance away. A helicopter was used to transfer wire pendant and shackle. With some difficulties, the towline was finally connected at about 2155, and towing by *Protecteur* commenced. All together, the vessel was towed by *Protecteur* a distance of 297km (178 miles) during a period of 43 hr.

Figure 2. Bridge area of MV *Essi Silje* on fire. Note hot spots (dark patches) appearing on hull.

Figure 3. MV *Essi Silje* down by the stern.

On the 16th, due to the ineffectiveness of the Coventry Climax pumps, the helicopters were sent to locate the approaching rescue tugs and bring back pumps. In the afternoon the approaching tugs *Seefalke* and *Sypestyns* were located and pumps with operators were airlifted to the vessel. When the new pumps were set up, the flooding seemed to be checked. However, the new pumps turned out to be unreliable and continued to break down. The diesel unit from *Sypestyns* was the only one that provided continuous pumping service. With the few pumps running intermittently, they were unable to dewater the spaces.

On the 17th, the rescue tugs arrived, and *Protecteur* continued to provide support by sending the helicopters to airlift equipment, and by repairing the broken-down pumps. The towline was slipped at about 1614, and the tug *Seefalke* had the vessel in tow by 1910. The *Protecteur* stood by overnight and departed for Halifax at about 0828 on the 18th.

It was a long tow for the salvage tugs to their destination in England. The problems with the pumps continued. On 22 June, the tug *Sypestyns* was tied up to the stern of the vessel and four electric pumps were set up to clear the water from all flooded spaces. Leaks through the condenser and evaporator oil cooler were discovered and repaired. On the 24th, the tow was transferred to the tug *Baltic*, which towed the vessel to Barry, arriving 1 July.

The hearing

An arbitration hearing took place in London, England on 14 March 1984. An arbitrator was appointed by the Committee of Lloyd's. There were three parties involved: the Government of Canada, including the commanding officer and crew of HMCS *Protecteur*, Messrs. Bureau Wijsmuller, the salvage tug company, and the Respondent Ship and Cargo Interests, the owner of the ship and cargo.

The normal practice in a Lloyd's Form Hearing is that the parties first open their cases with short summaries of the points at issue and then the arbitrator is invited to read the bundles of evidence in private. Once the arbitrator indicates that he has completed his reading, the parties return and make their final submissions. This procedure is time efficient and usually is applied to cases where the parties generally agree to the circumstances of the service and the value of the vessel and cargo.

When there may be disputes in both the circumstances of the service and the value of the vessel, each counsel presents his case by reading the entire evidence bundles in front of the arbitrator. Before the final evidence bundles are agreed upon by all parties, questions are asked, rebutting arguments are presented and new evidence can be substituted. During the hearing it is not unusual for expert witness to present oral evidence and to be cross-examined.

It was perceived that the amount awarded to the salvors was based on the degree of risk of the vessel and her cargo becoming a total loss, the danger of the operation, and the merit and contribution of the salvors to the recovery of the vessel. Because of that, the main dispute of this case was centered around the issue of whether the vessel was in any danger of becoming a total loss, especially without the salvage operations undertaken by the crew of *Protecteur*. The author was tasked by the Department of Justice firstly to provide a technical opinion of the situation in the form of an expert's report to be presented as evidence. He was also present at the hearing to provide technical advice to the Government's legal counsel and to prepare rebutting arguments.

In order to provide a clear picture of the arrangement of the vessel, especially the key locations of the doors and hatches, a rough model of the stern of the vessel was also constructed of transparencies made from the general arrangement drawings and structural plans. This model became an important piece of evidence.

Ship characteristics

The *Essi Silje* was a chemical tanker with engine room located aft. The hull was a typical bulk carrier hull with a bulbous bow. Her principal dimensions were as follows:

Length (OA)	154.500m	(506.9 ft)
Length (BP)	142.240m	(466.7 ft)
Breadth (mld)	20.600m	(67.6 ft)
Depth	12.700m	(41.7 ft)
Design draft	9.785m	(32.1 ft)
Displacement at design draft	23,231 t	(22,864.2 LT)

At full displacement, the vessel was capable of carrying from 8961 to 9894 t (8819.5 to 9737.8 LT) of antiknock compound and at the same time 6233 to 7166t (6134.6 to 7052.8 LT) of caustic soda, depending on the loading situation.

A general arrangement of the vessel is shown in Figure 4. Longitudinally the vessel was divided into ten watertight compartments by nine watertight bulkheads. All watertight bulkheads except the one at frame 37 were tight all the way to the main deck. There were two doors on bulkhead frame 37 at the level between the main deck and the second deck. It is unknown whether the doors were watertight.

In the aft end of the ship abaft frame 37, with the exception of minor tanks in the double bottom and the fuel oil tanks in the engine room, there were very few compartments that would cause asymmetric flooding. The pump and gas space was located between frames 37 and 47; this space was divided into three transverse compartments by two longitudinal bulkheads. The space at the starboard wing was larger than that at the port wing, and the flooding of one or both wing spaces would cause asymmetric flooding, or listing of the vessel.

In the cargo tank area, frames 47 to 177, there were two longitudinal bulkheads running the whole length on each side of the centerline. The tetraethyllead cargo tanks were located in between the two longitudinal bulkheads. Those tanks were separated from the ship's structure by spaces known as cofferdams. Outboard of the longitudinal bulkheads were wing tanks including the caustic soda tanks.

The crew accommodation was all located aft and in the superstructure above the engine space from the main deck up. The navigation bridge was located at the top of the superstructure.

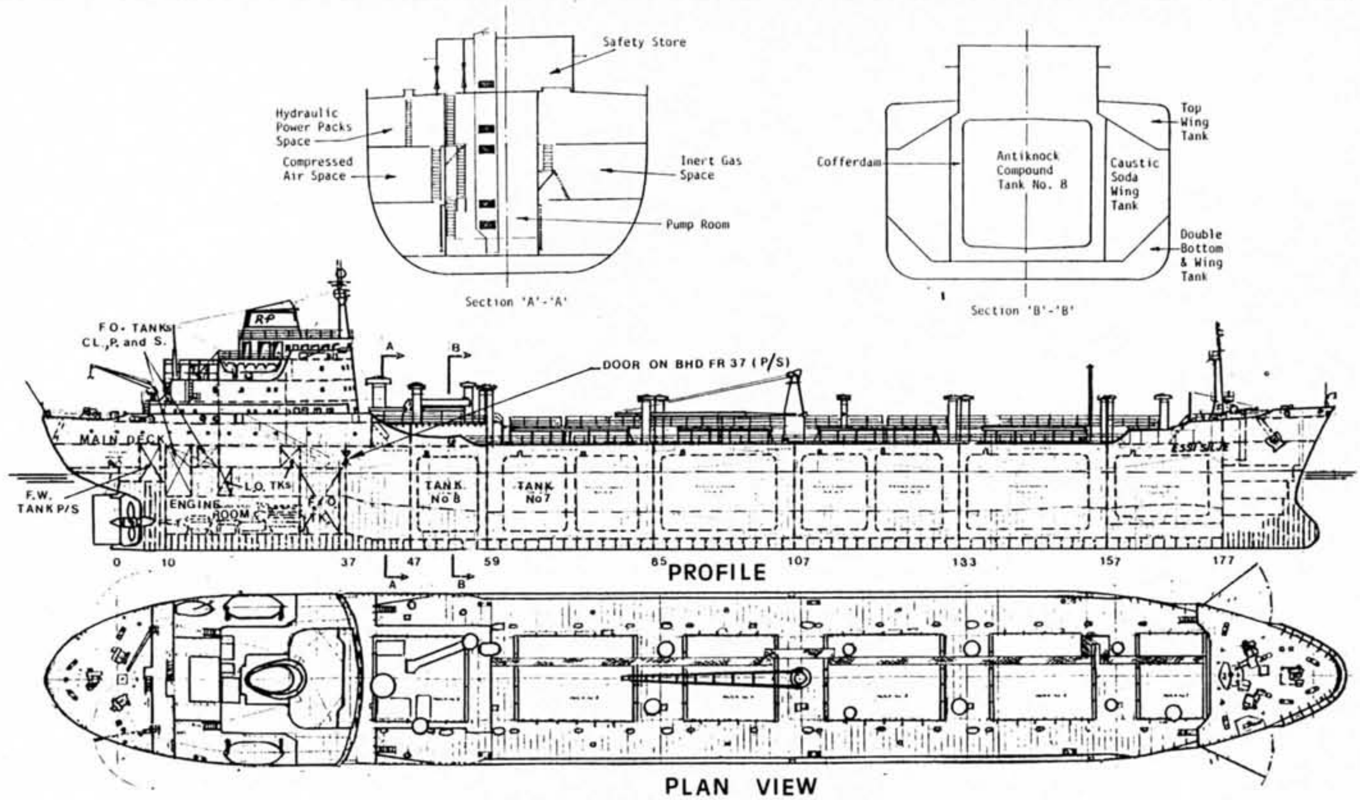


Figure 4. General arrangement

The engine room was located below the accommodation between frames 10 and 37. Fuel tanks were located in the engine room.

Technical investigation

As a result of the fire and the subsequent flooding of the vessel, there are three possible ways that the vessel might have become a total loss:

a. Vessel could have broken in two due to structural failure as a result of the intense heat and stress built up by the excessive weight at the stern due to the flooding of the spaces.
b. Vessel could have been destroyed by explosions as a result of chemical cargo reaction to the fire and sea water.
c. Vessel could have been sunk by stern due to excessive trim by stern as a result of progressive flooding.

As it was necessary to show that the vessel was in danger of one or more of the above possibilities, solid evidence in the form of expert testimonies or reports, photographs, test results or calculations was required. Throughout the hearing, there had been marked reluctance of the ship and cargo interests to supply technical data regarding the design and construction of the vessel, especially in areas surrounding the cargo storage space. Data related to the transportation and safety of the antiknock compound were not released unless absolutely deemed necessary to their benefit, and usually at the last possible moment.

The vessel was originally built as a bulk cargo carrier, the MV *Sabinia,* but was later converted into a special carrier to transport antiknock compounds. The pump room space was added or converted at a much later date. As a result, there were few drawings available, except for an outdated general arrangement plan, some machinery arrangement drawings, piping line diagrams and the pump room arrangement. There was a copy of the stability booklet for typical loading conditions, but no hydrostatics or lines plan was available.

At Barry, U.K., the damaged vessel was inspected by surveyors who were mainly interested in the cause of the fire and the cost to repair the vessel. Their reports did not clearly address which compartments were flooded, level reached by the floodwater, condition of the piping and glands, and the integrity of the steel watertight bulkheads.

Soon after, the vessel was taken to a shipyard and the damaged stern, considered to be a total loss, was cut off and replaced by the stern from another retired bulk carrier. The damaged stern was scrapped before the author had the opportunity to make arrangements for inspection. In order to proceed with the technical investigation, the major source of data therefore came from the few drawings mentioned above, the reports and photographs from the crew of *Protecteur*, the surveyors, the salvors and the crew of the casualty.

Hull structural failure

Due to the intense heat of the fire at the stern, it was perceived that the hull structure was weakened, and with the increase of bending stress as a result of flooding, the stern of the vessel might have been broken off somewhere behind frame 37. The bulkhead at frame 37 would then be subjected to wave action. If this bulkhead failed, the bulkhead at frame 47 would be the last line of defence before the cargo tanks were subjected to damage resulting in the spilling of the toxic chemical.

It was not possible to either prove or disprove this hypothesis because of the lack of information regarding the actual loading of the cargo tanks, the weight distribution, the midship section or structural details, and the longitudinal strength data of the vessel.

Two officers on board *Protecteur* thought that they had spotted cracks on both sides of the shell along the welds in way of the forward end of the engine room. This may have indicated a weakening of the ship's hull structure, but this was not confirmed by the surveyors' inspection at Barry. Without any photographs to back up the officers' observations, their observations were not considered accurate, and the evidence of structural failure could not be pursued. The conclusion at the hearing was that structural failure was unlikely to occur.

The chemical cargo

The chemistry experts in the Department of National Defence were tasked to investigate the hazards of the chemical cargoes. Their report indicated that the caustic soda was unlikely to have any reaction that would threaten the ship when mixed with sea water. A caustic soda solution is not flammable and also will not deteriorate under elevated temperatures. In high concentration caustic soda is toxic and extremely caustic and causes irritation and damage to tissue contacted. It is toxic to human and aquatic life, and therefore the chemical was a threat to the salvors if spilled.

The tetraethyllead, the antiknock compound, is highly toxic both in liquid and vapor form. It is fatal to human and marine life if ingested, inhaled or physically contacted. It is not soluble in water, and since its density is higher than water, it will sink and break up into globules under turbulent conditions and eventually affect a large area.

Tetraethyllead is combustible with a flashpoint of approximately 85°C (185°F). The vapor will ignite once this temperature has been reached. Bulk tetraethyllead cannot burn without sufficient oxygen, and therefore it probably would not burn unless spilled out of tanks. On burning, toxic fumes of lead oxides will be produced, and can decompose and eventually explode at temperatures above 110°C (230°F). It is possible that a fire involving the chemical could cause the destruction of the vessel. The main fire burned itself out in the engine space and the aft superstructure. Therefore, except for the close call of the burning of the kerosene tanks in the safety store abaft the cargo tank cofferdam (see Fig. 1.c), the fire never penetrated the forward compartment bulkhead and the chemical cargo was at no time in the way of the spreading fire.

The conclusion is that the vessel would not have been destroyed by the cargo she was carrying, but the spilling of either one or both of the chemical cargoes would have constituted an ecological disaster.

Damaged stability investigation

The next issue to be considered was whether the vessel would sink as the result of progressive flooding. Due to the small amount of technical data available, as indicated before, the vessel's lines were constructed based on the outlines shown in the general arrangement, the deck structural plan, and the machinery and piping diagrams. Some guesswork was required for the forward end of the vessel to match the hydrostatic properties indicated by the stability booklet. Offsets were lifted from the body plan, which was produced from the lines. The offsets were used to prepare the hydrostatic properties and compartment description with the aid of the CASDOP computer program of the Department of National Defence of Canada. Later the same program was used to perform damaged stability calculations.

More than 30 cases of flooding were investigated and the key conditions are summarized in Figure 5. Case B of Figure 5 demonstrates that once the engine room is completely flooded, the water level will be above the doors at bulkhead frame 37. If the doors are non-tight, the water will flood into the forward spaces. Case G demonstrates that if all the spaces abaft frame 47 and together with the cofferdam around the cargo tank No. 8 are flooded, the vessel would sink by the stern. The investigations also showed that the vessel had maintained enough margin of stability under all stern flooding conditions that there would be no danger of capsizing.

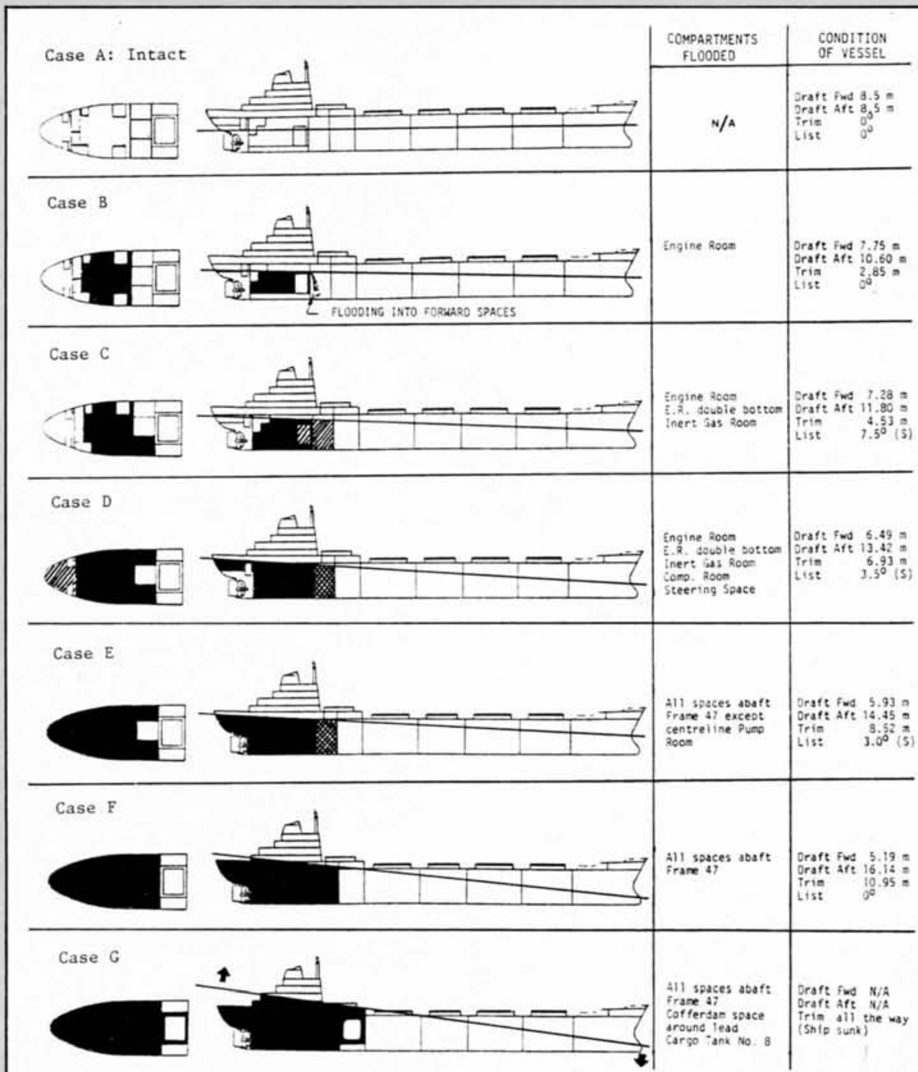


Figure 5. Summary of technical investigation

The worst trimming condition of the vessel observed by the crew of *Protecteur* was somewhat similar to Cases D and E of Figure 5. The actual trim of the vessel was unknown because no freeboard or draft readings were taken during the salvage. Also, the time when the photographs showing the various trimming situations were taken was not recorded. The result was that it was not possible to deduce the rate of flooding and sinking of the vessel.

With the knowledge of the mechanism required to sink the vessel, it had to be convincingly demonstrated to the arbitrator how the flooding from Case B to Case G was possible.

Progressive flooding abaft frame 47

The flooding of the vessel was the direct result of the fire. The fire was concentrated in the after section of the vessel, abaft frame 47. Figure 2 shows hot spots at the side of the ship in way of the main deck. The peeling off of the paint indicated that a hot fire was burning inside the hull, most likely in way of the diesel fuel oil and lube oil tanks in the engine room. Because of the intense heat it is highly possible that most of the fuel tanks with their fuel lines, vents and sounding pipes were damaged and no longer watertight. Similar damage could be expected in way of the glands and stuffing boxes for the pipes or cables penetrating the watertight bulkheads, decks and side shell. In fact the flooding of the vessel was due mainly to the failure of the seawater inlet to the evaporator and the condenser, where the non-metallic parts were destroyed by the fire.

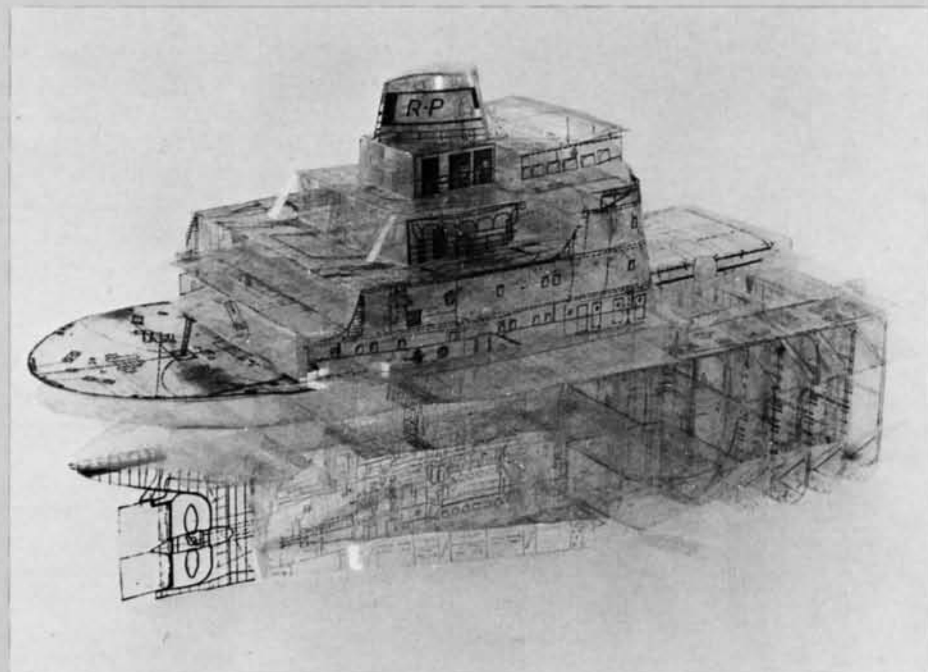
There were conflicting reports regarding the conditions of the tanks in and around the engine room. The contents and sounding of those tanks were not systematically checked and recorded after the fire. When the vessel was safely in port a mixture of oil and water was found in the double bottom tanks, and the sight windows of their sounding pipes in the engine room were discovered to be melted. There was no concrete proof that the tanks were damaged, but there was evidence that water could enter and fill these tanks when the engine room was flooded.

Once the engine room was completely flooded, as indicated in Case B of Figure 5, the water could flood into the forward spaces through the two doors on bulkhead frame 47 on the main deck. It is unknown whether they were watertight doors, but the photographs show that both the doors and their frames were greatly distorted by the fire. It was suspected that the wing spaces forward of frame 47 were flooded before the doors were under water, possibly as a result of leaking pipe glands on the watertight bulkhead damaged by the fire. It might also be possible that the watertight integrity of the bulkhead was destroyed. There was no report on the condition of the bulkhead or its penetrations, and no photograph of the area was taken. Therefore, the method by which the wing spaces such as the hydraulic power pack room, the compressed air space and the inert gas space were flooded could not be determined, and the floodwater was assumed to have passed through the doors. It is possible that the starboard wing space was flooded first, because the observed eight-to-ten-degree list to starboard at one time may be similar to Case C of Figure 5.

Water was observed in the steering space. With the large trim of the vessel by the stern, under wave action, water came in through the damaged portlights. It was also reported that water came up through an air pipe, location unknown, from the engine room. It is believed that with the vents and sounding pipes damaged, the floodwater at the steering flat would eventually fill up the tanks below. Therefore it is highly possible that, without assistance, all spaces abaft frame 47 other than the centerline pump room would have been flooded.

The pump room

The next stage was to consider the flooding of the pump room. It was recognized that there were three possible



This rough, three-dimensional model of the after section of Essi Silje *became an important piece of evidence during the 1984 arbitration hearing. Constructed by the author from transparencies of the ship's general arrangement drawings and structural plans, the model clearly showed key locations and arrangements on the vessel. (DND Photo by Cpl Paul Howe)*

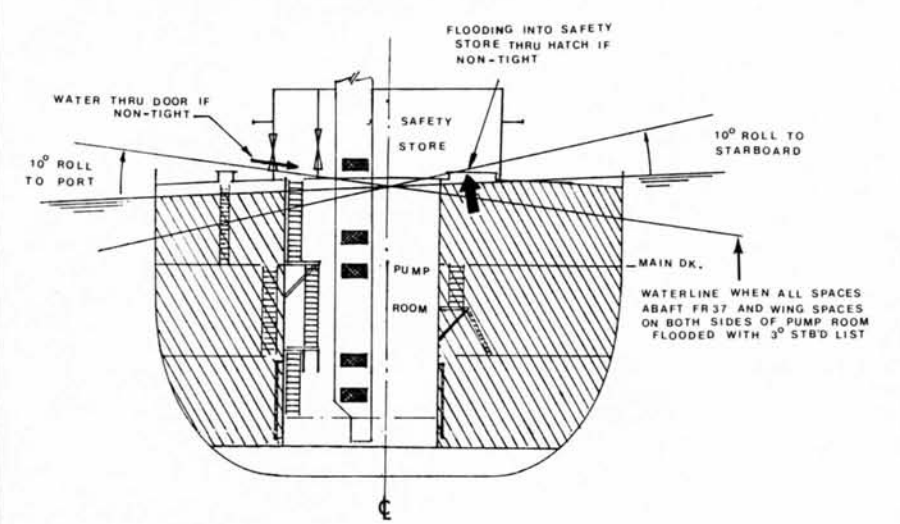


Figure 6. Flooding of pump room

routes through which the water might enter the space:

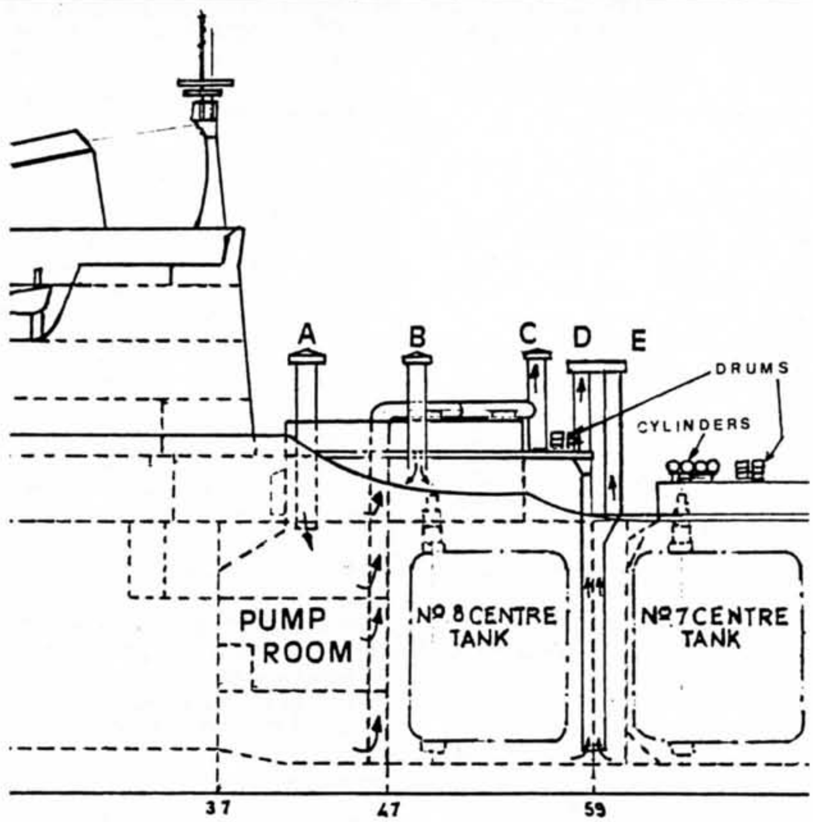
a. via the port-side door of the safety store and the hatch on the port side of the pump room,
b. via the hatch from the inert gas space on the starboard side of the safety store and across to an opening in the pump room ventilation trunk in the safety store, and
c. via the ventilators if they were damaged.

In the reports of witnesses, on many occasions the pump room was mixed up with the compressed air space, the inert gas space or the hydraulic power pack room, and the actual condition of the space was unknown. Photographs of the space showing pieces of ash on top of all horizontal surfaces indicated that the space must have been on fire at one time. It might be due to the extreme high temperature on bulkhead frame 47, with a fire burning on the other side in the engine room, that the paint was ignited. With no report of the space having been flooded, the space was considered by the arbitrator to be intact.

The main entrance to the pump room was through a door on the port side of the safety store, and then down a hatch along the port side of the pump room. This door was left open when the crew abandoned the vessel. It had been observed that during the worst trimming condition, the waves were breaking at the front face of the poop. When all space abaft frame 47 had been flooded (Case E, Fig. 5), in high sea states water would get into the pump room through the door. The master of the vessel closed the door upon his first return to the vessel and the danger of downflooding through the door was minimized. There were doubts whether he would have been able to return to close the door if he had been picked up by another passing cargo vessel which, with a tight schedule to meet, would not have stayed around for a long period of time like *Protecteur*.

Later on there was a raging fire in the safety store due to the burning of the kerosene tank. Photographs showing the door and its frame all charred indicated that the gasket and sealing might have been destroyed, and water would once again be able to pass through the closed door. However, with the vessel listing to starboard, the rate of water getting into the space would be much slower compared with the case of the door wide open.

The next alternate route for the water to enter the space was to go through the hatch on top of the inert gas space. The closing appliance of the hatch was unknown. Again, with a raging fire on both sides of the hatch, the watertightness of the cover, if any, would have been destroyed. A vent trunk joining one of the ventilators passed through the safety store to the pump room below with a vent opening a few inches above the deck of the safety store. The water coming into the space through the hatch would rush to the port side when the vessel rolled to port, and drained into the pump room below. Figure 6 demonstrates such a possibility for a three-degree listing to starboard and under a ten-degree roll. On the other hand, there was a chance that the hatch might still be watertight. Without taking the rolling of the vessel into consideration even if water was able to enter the space through the hatch, the amount might have been small, and with



Profile View

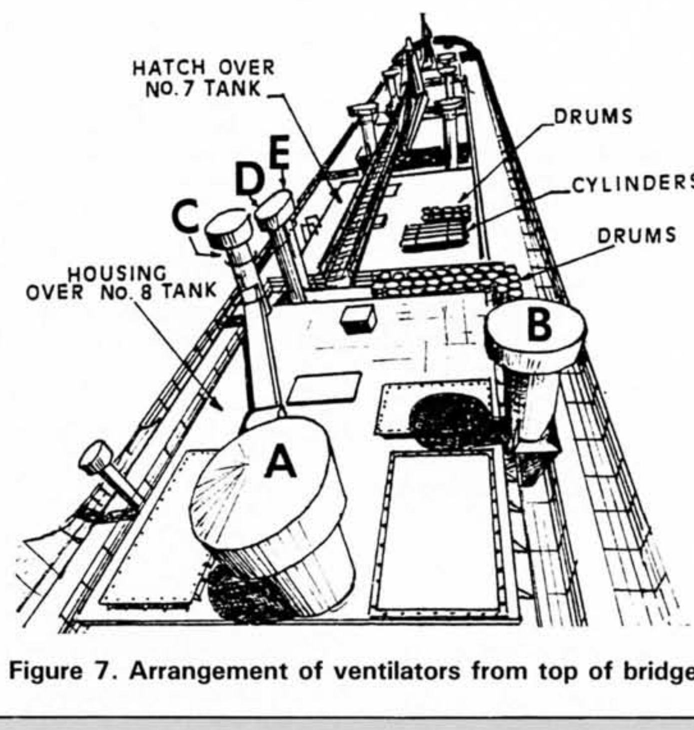


Figure 7. Arrangement of ventilators from top of bridge

the vessel listing to the starboard it would be an uphill run for the water to reach the vent opening. Under such circumstances the flooding scenario of the pump room might be remote.

The ventilators

The third possible route for the water to get into the pump room was through the ventilators. There were five ventilators around the No. 8 cargo tank (Fig. 7). Ventilators A and C were connected to the pump room, B and D were connected to the cofferdam around No. 8 cargo tank, and E ran into the cofferdam around No. 7 and No. 6 cargo tanks. Therefore, the risk of the vessel becoming a total loss depends on whether any of those five ventilators might be damaged and allow the ingress of sea water.

The existence of drawings showing the arrangements and detail construction of the ventilators was not disclosed by the cargo and shipowners until well into the hearing, and it was too late to perform any analysis on the magnitude of impact wave force that those ventilators could withstand. The experts on behalf of the cargo owner cited examples that ventilators on similar chemical tankers in laden condition received no damage when the decks were partially submerged in heavy seas.

The ventilators were constructed from 10-mm-thick (3/8 in.) steel plates. Because ventilators A and C were situated on top of the hatch housing, and their bases were above the reach of 12-ft (3.5m) waves (the worst sea state during the salvage), even with the trimming and listing of the vessel taken into consideration, the chance of flooding into the pump room through the ventilators was insignificant. The base of ventilator B was located on the starboard side of the hatch coaming, but its base structure was heavily constructed and well supported by brackets, and was considered to be strong enough to withstand wave impacts.

Ventilators D and E were tied together at the fore end of the hatch housing. At the trimming condition, the main deck area at the base of ventilator E would be awash under a 12-ft (3.5m) wave, and the wave most likely would break at the front of the hatch housing. Directly on the starboard side of the base of ventilator D were drums of unknown material and, on top of the hatch above cargo tanks 6 and 7 were long torpedo-shaped steel cylinders (Fig. 7). If some of these drums and cylinders had been torn loose under constant wave impact, the ventilators, especially E, not only might have been subjected to wave impacts but also there could have been damaging collisions of the drums and cylinders. If sea water had been allowed to flood into the large cofferdam around cargo tanks 6 and 7 through ventilator E, the vessel would have sunk.

The assessment

In summary, the vessel was not considered to be in danger of sinking due to structural failure, loss of stability or chemical reaction of the cargo with fire and water. There was a possibility that in time, with changing weather and sea states, progressive flooding would lead to the loss of the vessel and its cargo.

Considering the toxic nature of her cargo, if the vessel had sunk, it would have been a major environmental disaster. The prompt response and service rendered by the crew of *Protecteur* was highly meritorious. The risk taken by the crew of *Protecteur* during the salvage operation, especially those involved in the dangerous diving mission, those working on board the burning vessel amidst the smoke and fumes, and those involved in the helicopter operations carried out over long distance in unfavorable weather should be specially recognized.

Recommendations

From the earlier discussions it can be seen that many of the disputes were the direct result of the lack of information on the actual condition of the vessel. If the evidence is indisputable, and all parties can come to a consensus of opinion much sooner, the time required for the hearing can be shortened considerably. Good information must come from the observations of the salvors, the inspectors and the surveyors. From the salvors' reports and the experience of the author during the technical investigation and the hearing, the following is a list of recommendations for future salvors, surveyors and inspectors who are involved in salvage operations:

For the salvors:

1. Check the draft or freeboard of the vessel at regular intervals.
2. Check the listing and trimming of the vessel at regular intervals.
3. Record the compartments that have been burned or flooded.
4. Note and record the conditions of the watertight doors and hatches.
5. If possible, sound all tanks and determine the contents.
6. Take ample photographs and record the time.
7. Gasoline fire pumps or other pumps whose operation requires a large amount of oxygen should not be used for dewatering. Carry the appropriate equipment.
8. A helicopter is highly valuable in salvage operations.
9. A diving team definitely has its place in salvage operations.
10. Determine the cargo carried, the quantity and location of stowage.

For the inspectors and surveyors:

1. Note the drafts of vessel at time of inspection.
2. Check and record the amount of cargo left on board the vessel, with its location.
3. Sound all tanks and determine their contents.
4. Note which bulkheads have been subjected to intense heat, and degree of damage.
5. Note which compartments have been flooded, and measure the highest point reached by the floodwater at each of the bulkheads.
6. Check and record the condition of the pipes, pipe glands, stuffing boxes and bulkhead penetrations.
7. Take ample photographs of bulkheads, decks, doors and hatches which have been damaged by fire or flooding.
8. Appropriate sketches and part prints of general arrangement drawings should be included in the report, showing the area under consideration.

Edwin Chan is a graduate of the University of Michigan (M.S.E. Naval Architecture, 1970). His considerable experience in commercial ship design and DND ship-system engineering led to his being selected to conduct the technical investigation of the Essi Silje *incident on behalf of the Government of Canada. His thorough investigation and expert testimony at the Lloyd's Arbitration Hearing were largely responsible for the captain and crew of HMCS* Protecteur *being awarded compensation for their salvage efforts. In recognition of his contribution, Mr. Chan was awarded the ADM(Mat) Certificate of Merit in October 1986. Edwin Chan is currently the DMEM 2 project manager of the Naval Reserve Modernization Project.*

The Oil and Coolant Condition Analysis Program (OCCAP) as an Equipment Health Monitoring Technique

by Michael Davies

Cet article décrit le programme d'analyse d'huiles et d'agents de refroidissement. Ce programme consiste en une technique de contrôle de l'état de l'équipement qui fut établie par le Naval Engineering Test Establishment pour usage dans l'entretien de la machinerie à bord des navires.

Introduction

The concept of using fluid analysis as an equipment health monitoring (EHM) technique was introduced to the Canadian navy in the late 1960s when the Defence Research Establishment Pacific initiated the Spectrometric Oil Analysis Program (SOAP)[1,2]. The rationale used to support the SOAP concept for the naval environment is that if abnormal mechanical or corrosive wear is detected in the early stages, then the affected unit can be repaired during a short work period such that the costs and detrimental effects on naval operations are minimized.

The advent of the reliability centred maintenance (RCM) policy prompted DMES 6 to undertake a critical review of the effectiveness of SOAP as an EHM program. RCM is an analytical process which is to be used by the system life-cycle materiel managers (LCMMs) in determining what, if any, preventive maintenance is to be carried out on a particular system[3]. The objective of RCM is to develop a more effective maintenance program that ensures maximum safety and reliability at the lowest cost[4]. The preventive maintenance tasks identified under RCM are categorized as either *condition-based* or *time-based* maintenance procedures. In the CBM category, preventive maintenance is performed only when warranted by the condition of the system. The prime means of determining equipment condition are the EHM techniques applicable to the system which have been demonstrated to be reliable.

DMES 6 has subsequently identified the following characteristics of the existing SOAP which do not meet the objectives of RCM[5]:

a. SOAP detects wear, but does nothing to prevent its onset;
b. SOAP does not provide quality assurance of lubricant type and condition;
c. the importance of maintaining good coolant quality has been neglected;
d. SOAP has not been standardized across the fleet;
e. current SOAP documentation has not been widely available;
f. feedback from the ships is often vague or non-existent;
g. poor sampling techniques decrease the effectiveness of SOAP; and
h. SOAP, isolated from other EHM techniques, is an ineffective program.

As part of the review process, the Naval Engineering Test Establishment was tasked to develop and evaluate an Oil and Coolant Condition Analysis Program (OCCAP) as an EHM technique for use in CBM of shipboard machinery. OCCAP was to include SOA and any other analytical technique deemed necessary to:

a. ensure the use of correct lubricants and coolants;
b. maintain high fluid quality while in service; and
c. detect and identify mechanical and corrosive wear at an early stage.

The overall objective of the program was to maximize ships' system reliability according to the RCM policy.

Regardless of the methods employed, NETE was requested to establish a program which would be standardized across the Canadian fleet. The protocol for sampling, fluid analysis, data interpretation and reporting of results was to be the same at each coast. This was seen as an essential requirement to allow for the interchange of ships and their related data bases from one coast to another.

At the present time, OCCAP has been successfully evaluated as a pilot program on a limited number of equipment types. These include three-, six-, eight-, 12- and 16-cylinder diesels, LP air, HP air and JOY air compressors, and 75-ton refrigeration equipment. This paper will summarize OCCAP as it pertains to diesel engines because the diesel portion of the program is well established and is ready for implementation at the Coast level.

Program Structure

The first step in the development of OCCAP was to define the following list of requirements which apply to any fluid analysis program, regardless of the type of equipment being monitored or the nature of the laboratory tests:

a. representative samples at regular intervals;
b. valid and meaningful laboratory tests;
c. quick reporting of fluid condition to equipment maintainers;
d. quick maintenance action when required; and
e. feedback from equipment maintainers to project engineer and laboratory to assure continuous program evaluation and development.

The pilot program was then structured in consideration of the objectives, requirements and naval protocol at each Coast (Figure 1). The OCCAP operations are summarized as follows:

Sampling

The success of any oil-analysis program hinges on obtaining timely and representative samples from the units of interest. In order to eliminate as many sources of error as possible during the development stages, NETE personnel themselves collected samples at source using a uniform and optimum sampling procedure for all units.

As it is intended that ships' staffs eventually assume responsibility for sampling, a CANAVMOD is being considered by NDHQ for the installation of a quick-sampling valve on all diesels covered by OCCAP[6]. (Until now, the samples had been extracted using a hand-operated vacuum pump.) The valve operates on the same principle as a Shrader air valve and is to be installed on the pressure side of the fluid pump. This will ensure that units are operating at the time of sampling, and will eliminate most of the

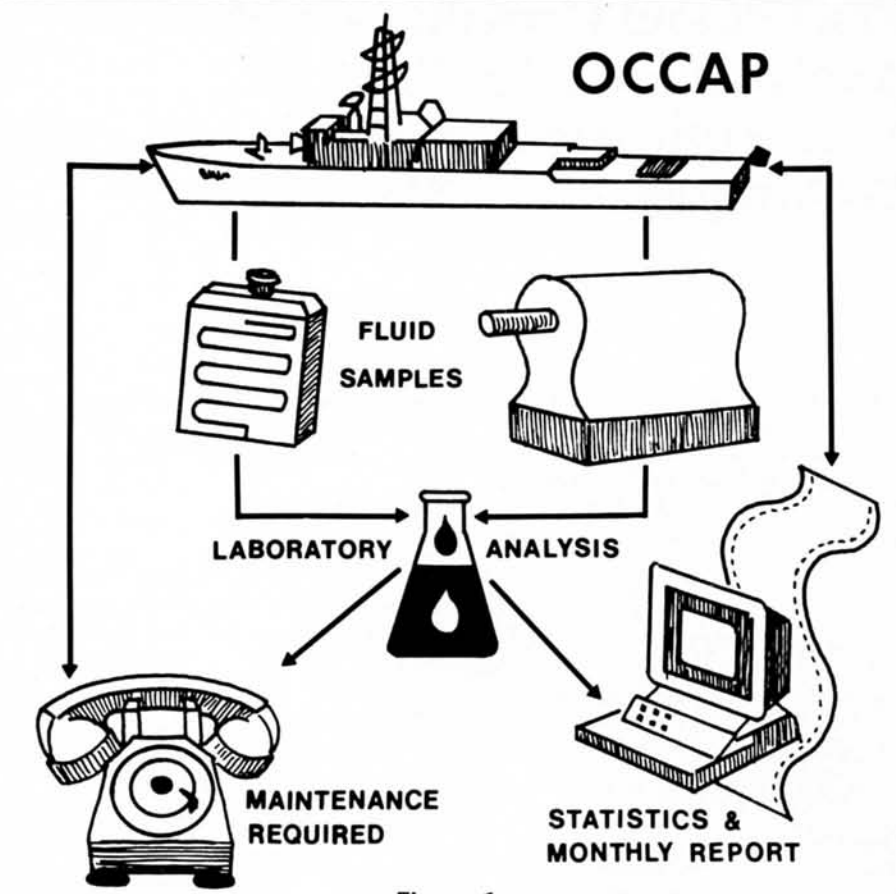


Figure 1.

inconvenience associated with current SOAP sampling.

Laboratory Tests

Potential test methods for determining oil and coolant quality were selected after searching the relevant literature and after discussions with other laboratories actively involved in oil analysis. All of the suggested tests[7] were conducted on numerous samples during the first six months of the program. The results were then reviewed to determine which of the test methods provided information which was useful according to the program guidelines. Based on that review and on additional work completed since then, the program has been reduced to provide only that information which is of immediate use to the equipment maintainers[8].

The tests performed at present are:

a. Diesel Oil Tests
   - Kinematic Viscosity, ASTM D445
   - Percent Fuel Dilution, ASTM D3524
   - Flame Atomic Absorption Determination of Wear Metals (SOA)
   - Percent Water, ASTM D1796 (when appropriate)

b. Coolant Tests
   - Percent Glycol-Based Antifreeze
   - pH when commercial antifreeze not used as the inhibitor package
   - Hardness

These tests are outlined as follows:

Kinematic Viscosity

Viscosity is the most important physical property affecting the ability of a lubricant to prevent excessive wear. A lubricant of the proper viscosity will form a film of sufficient thickness to minimize wear between moving parts, without unnecessary heat or waste of energy. The lower viscosity limit for each oil type has been set to coincide approximately with the reduction in viscosity associated with 3.0 percent fuel dilution. The upper viscosity limit allows for the accumulation of some combustion products in the oil, as is the norm for diesel operation; however, the viscosity is not to exceed a value equal to 1.2 times the new oil viscosity.

Percent Fuel Dilution

The presence of fuel diluent in lubricating oil acts to decrease its viscosity,

NAVAL ENGINEERING TEST ESTABLISHMENT
PROJECT IT-684
OIL and COOLANT CONDITION ANALYSIS PROGRAM (OCCAP)
LABORATORY DATA FOR SAMPLES TAKEN 6 MAY 1987 TO 25 JUNE 1987

LAB#	UNIT DESCRIPTION	SAMPLE DATE MM/DD/YY	HOURS SINCE OVER-HAUL	HOURS SINCE OIL CHANGE	PPM CU	PPM FE	PPM PB	PPM CR	PPM NA	PPM AG	PPM AL	VISC-OSITY (cSt)	WATER (%)	FUEL DILU-TION (%)	%ANTI-FREEZE IN COOLANT	COOLANT PH	COOLANT HARDNESS (ppm)	COMMENTS AND/OR WARNINGS
** SHIP PENNANT NO.: 264																		
* NEI CODE: E262010000000000																		
509	NO 3 D/G	12/12/86	2909	565	29	7	6	4	26	0.5	6	11.5		2.1	1.8	9.7	34	LOW VISCOSITY
670	NO 3 D/G	03/04/87	2988	63	2	8	3	7	16	0.4	2	13.3		0.3	3.5	9.5	38	
992	NO 3 D/G	06/22/87	3108	172	5	14	0	1	18	0	0	13.5		0	0	9.5	23	
* NEI CODE: E262170000000001																		
508	NO 1 D/G	12/12/86	171	75	30	8	6	9	30	0.7	6	12.1		1.2	0	9.4	41	
669	NO 1 D/G	03/04/87	175	80	32	9	8	14	31	0.4	3	12.1		0.9	9.5	9.6	26	
990	NO 1 D/G	06/22/87	182	87	33	10	0	8	33	0	6	12.3		1.2	0	9.4	15	
* NEI CODE: E262170000000003																		
510	NO 2 D/G	12/12/86	163	65	4	15	2	1	16	0.2	6	13.7		0.4	0	9.5	43	
991	NO 2 D/G	06/22/87	174	82	33	9	0	3	29	0	8	11.7		1.8	0	9.6	25	AL,LOW VISCOSITY

Figure 2.

thus reducing the effectiveness of lubrication. The fuel also causes a reduction in the flashpoint of the lubricant, creating a definite explosion hazard. The maximum acceptance limit for percent fuel dilution was set at 3.0 percent in consideration of these safety and mechanical factors.

Wear-Metal Analysis

The concentrations of wear metals in the lubricant are being determined by Flame Atomic Absorption Spectrometry (FAAS) using a computerized, fully automated instrument. The wear-metal limits (alarm levels) for OCCAP are set according to the following:

a. All data from identical units (make and model) are averaged as a common data set.
b. The alarm level for each element (metal) is set as the average concentration plus twice the standard deviation for that element.

The number of elements being reported is gradually being reduced and will be different, depending on the materials of construction, for each specific equipment type. Although the wear-metal concentrations are being reported, NETE does not currently make predictions based on wear metal as to the nature of a suspected fault. The naval engineering units are responsible for interpreting the wear-metal data based on their experience and advising the ships accordingly. The data base is presently under review and any correlation between specific metals and recurring faults will be reported in an OCCAP laboratory manual to be published at a later date.

Percent Water

The presence of water in the lubricating oil indicates: the breakdown of a mechanical seal between the coolant and lubrication systems, contamination of the new oil stock, or contamination from the environment. For diesels, the maximum allowable water contamination has been set at 0.2 percent (by volume). This limit has proven to be easily adhered to and it provides good protection from corrosion which could be a particular problem for units which operate only occasionally and/or intermittently.

Coolant Tests

A combination of hardness, pH, and percent antifreeze measurements are being used to assess the quality of the coolant samples. The hardness, as determined by the FAAS measurement of Fe, Ca and Mg, is an indication of the quality of the water used to prepare the coolant mixture (Ca and Mg) and it gives a quantitative value based on ppm Fe for the level of ferrous corrosion products.

When a nitrite-based coolant inhibitor is used, such as Dearborn 527 or Alchem

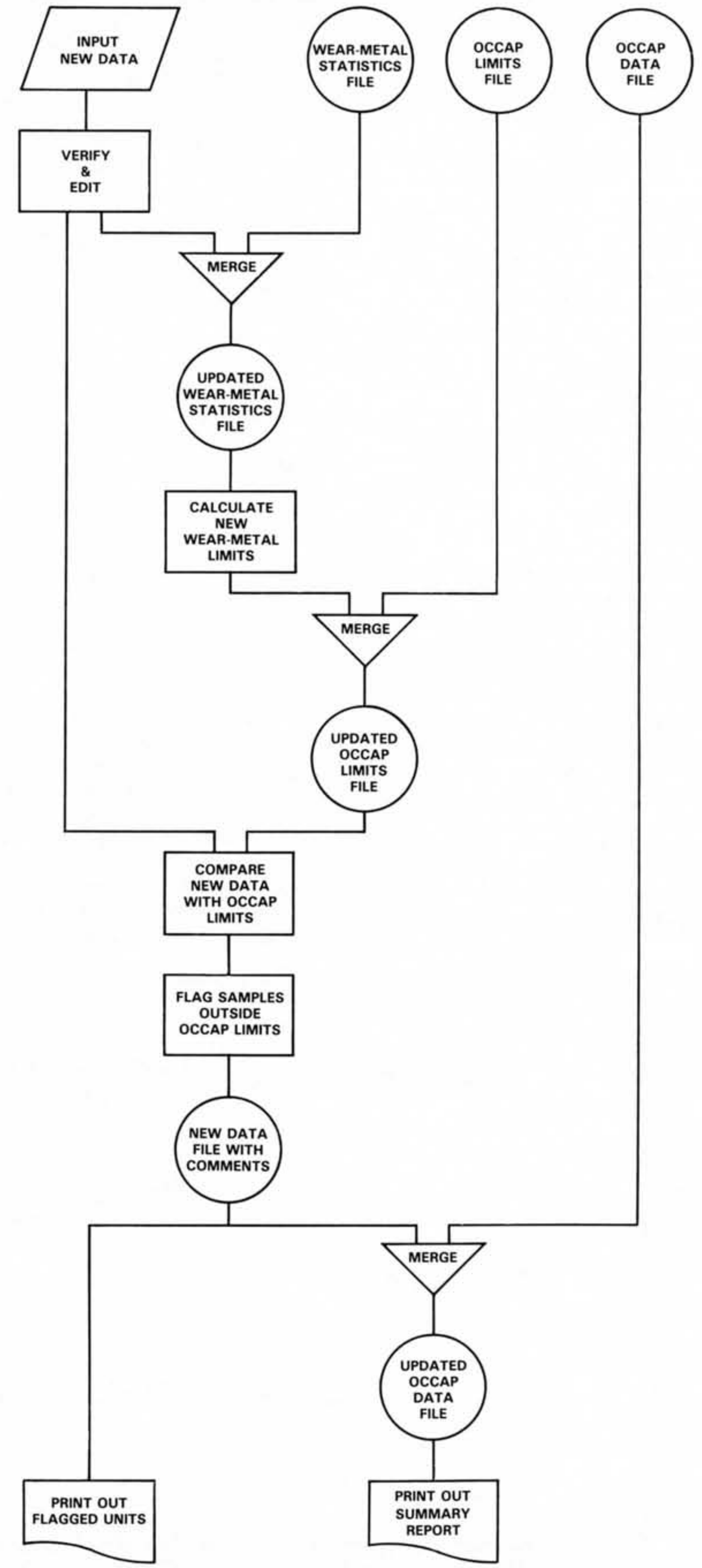


Figure 3. Structure of OCCAP Data Management Software

39C, the pH is important for proper action of the corrosion inhibitor. Since the coolant mixtures are alkaline, measurement of the pH indicates to the lab if inhibitor has been added. pH does not quantify the ppm inhibitor remaining in the coolant.

Units which require freeze protection typically use a commercial antifreeze which includes an inhibitor package (in accordance with C-24-001-002/TB-002). The percent antifreeze is measured by specific gravity, the acceptable range being between 30.0 and 70.0 percent.

The protocol for coolant analysis will be revised in the near future so that the ppm inhibitor will be reported in place of pH. This will make OCCAP data more compatible with the shipboard coolant test kits and will provide information which is more meaningful to the equipment maintainers.

Program Reports

The OCCAP data is managed using a dBASE III software package. The software and OCCAP were developed in parallel at NETE, and so the data structures and program functions have been tailored specifically to naval requirements.

Immediately after the analysis of any sample is complete, the sample information and laboratory results are entered into an IBM PC/AT. The new data is merged with the historical OCCAP records and the wear-metal limits are mathematically calculated and stored in a "Limits" file. The new data is then checked against the limits for wear metals and oil and coolant quality. Any deviations are automatically flagged with standard comments and a hard-copy report is printed (Figure 2). If any of the laboratory test results indicate a need for corrective maintenance, a routine message is sent from NETE to the applicable NEU with an information copy to the ship and all relevant NDHQ departments. An updated hard-copy report is issued every two months to the local (dockyard) and NDHQ departments responsible for the sampled equipment. All of the data-processing functions (Figure 3) are carried out sequentially by the software by entering a single command after the new data is input.

The status of OCCAP is summarized in a project report which is issued approximately every six months.

Program Results

Through OCCAP, the first-line maintainers responsible for the sampled equipment have been made aware of the importance of fluid quality to machine reliability and performance. This has prompted a higher level of maintenance and has resulted in a continual improvement in the overall quality of the in-service fluids. Figure 4 shows the trend in oil quality over the 600 samples up to 22 June 1987. The increase in the number of unacceptable units for the last 100 samples is not indicative of fleetwide deterioration. It is attributed to only a few vessels which were sampled at the same time and which regularly do not meet the OCCAP lubricant quality standards. Figure 4 also illustrates the improvement in coolant quality which has been gradual and does not have the fluctuations as seen for oil quality. This is because when a cooling system has been replenished with acceptable coolant the quality does not generally deteriorate with normal operation over the short term. It is expected that the number of unacceptable coolant samples will decrease even further as the ships flush their cooling systems in order to replenish with Alchem 39C.

Future Plans

Under a separate tasking, NETE Project No. IT-770, it has been recommended that the shore-based Flame Atomic Absorption Spectrometers currently being used to analyze for wear metals as part of the SOAP at each coast be replaced with ROTRODE Atomic Emission Spectrometers. This change will make the Canadian naval program more compatible with the Air program (AOAP) and the American Joint Oil Analysis Program (JOAP). The new instrumentation will be accompanied by personal computers and software which will interface the OCCAP data management system with the instruments' analytical output. When the installation is completed, the routine management of the diesel portion of OCCAP will be transferred to the local NEUs to replace the diesel SOAP. NETE will continue to develop the program for other equipment types and will assist the NEUs as requested. Once firmly established and documented, the OCCAP protocol for each equipment type will be incorporated into the relevant planned maintenance schedules.

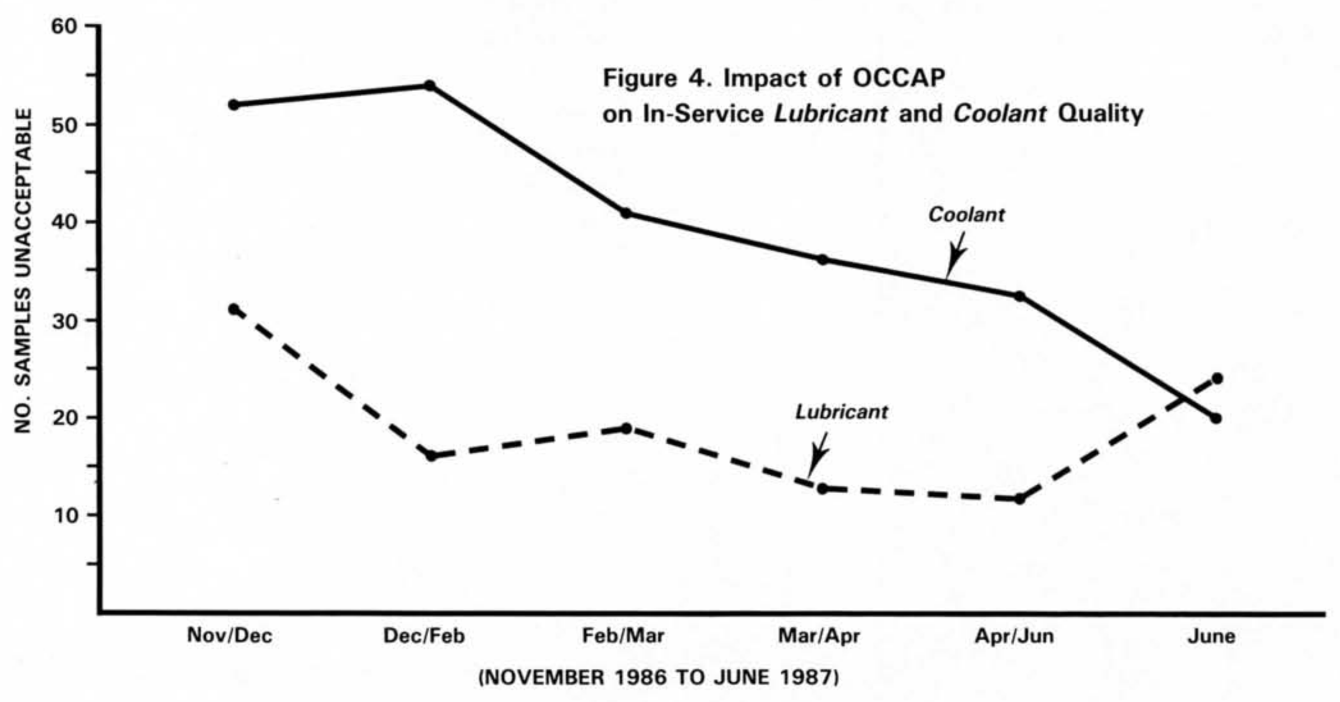


Figure 4. Impact of OCCAP on In-Service *Lubricant* and *Coolant* Quality

It is anticipated that the use of shipboard SOA equipment will be phased out and that OCCAP will be managed from one shore-based laboratory on each coast. By centralizing OCCAP resources it will be easier and less costly to manage the program and maintain the labs with up-to-date instrumentation.

There will no longer be a requirement for ship (AOR) personnel to conduct wear-metal analyses, however it is imperative that the equipment maintainers understand OCCAP if its full benefit is to be realized. As a first step in providing the necessary training NETE will include an introduction to OCCAP in a series of EHM courses currently being developed for fleet school. NDHQ, dockyard and shipboard personnel are also encouraged to contact NETE with any suggestions, comments or queries pertaining to OCCAP.

Conclusion

Using oil and coolant quality as a guide, OCCAP has improved the level of maintenance of shipboard diesel equipment. This improvement has the potential of increasing the service life and reliability of the sampled equipment.

Acknowledgement

The success of OCCAP is not attributable to any one organization but is due to a combined effort by the ships, NEUs and NDHQ. The author wishes to thank all those involved, in particular DMES 6 and DMEE 2, for their input and support.

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Michael Davies joined NETE in 1979 as a lab technician after three years with General Foods Research. He is currently supervisor of laboratory services and is responsible for the development and implementation of OCCAP.

Fabrication of Submarine Valves in Canada

by Z. Joseph Podrebarac, P. Eng.

Ce rapport discute de récent travaux accomplis au Canada sur le développement de technologie dans le domaine de la fabrication de soupapes pour les sous-marins Canadien de classe Oberon.

Abstract

This report discusses the work conducted in Canada from January 1986 to June 1987 on the development of technological expertise in the fabrication of submarine valves in Canada. The technology development included upgrade of the existing valve design as well as improving hardware documentation and traceability.

Introduction

The "O" Class submarines used by the Canadian navy were brought into service in the mid-1960s and at that time the method of valve support was established via procurement request from the Royal Naval Spare Parts Distribution Centre at Eaglescliffe — a method which was satisfactory until recently. At the end of the last decade Canada initiated a valve quality control system because of problems that resulted from improper welding of nickel-aluminum-bronze valves. The inspection for improper welding also identified numerous other deficiencies in general valve construction.

Castings were found to have wall-thickness problems, mostly due to casting core shift, that resulted in gross dimensional discrepancies (see Figure 1). The problem was not confined to nickel-aluminum-bronze valves, but was also found on gunmetal valves. In addition, there were many subsurface casting defects evident.

Discussions with other navies in late 1985 indicated that the problem being experienced by Canada was not unique, nor did a resolution appear to be forthcoming for a number of years. Items received from the U.K. were of questionable quality since there was no QC applied at source and the quality of valves on supply shelves in Canada was unknown.

In late 1985 an investigation was conducted by CDLS/Staff Officer Technical Services and DMEE 5 to identify the reasons behind long procurement times, receipt of valves differing from those fitted and generally poor quality. It was also discovered that new U.K.-sourced valves typically required rework by MOD(N) yards prior to fitment and that this was causing problems as privatization proceeded since private yards would charge for rework of government-issued components. The report identified that the drawings and patterns in use in the U.K. were of various modification revision level and not kept in current state of repair. The unfortunate reality was that the "O" Class submarines took second priority to the nuclear submarines due to manpower limitations. The result was that Canada undertook to define the revision level that would be used for Canadian boats and develop a data package that would define the valves required, and initiate procurement. Industries from the U.K. and Canada were invited to bid on the manufacture of submarine valves in the summer of 1986.

Specification Development

Valves purchased from the U.K. had previously been identified by a British stock number without relation to the revision level. The revision level would not only identify the valve configuration, but also the material, and the inspection requirement. Many of the problems experienced were found to be related to the change-over of material by the MOD(N) from gunmetal to nickel-aluminum-bronze (NAB) for hull valves. The update of drawings to show the material change was not issued to Canada in a systematic way, resulting in various revision levels.

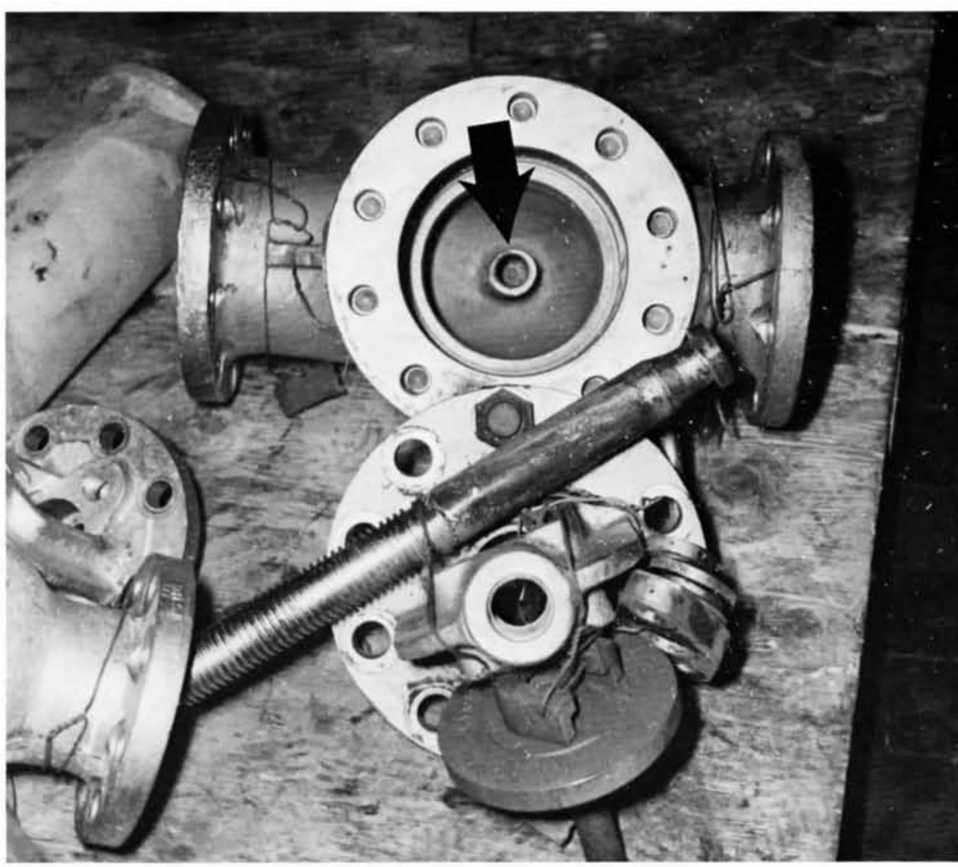


Figure 1. Example of Core Shift

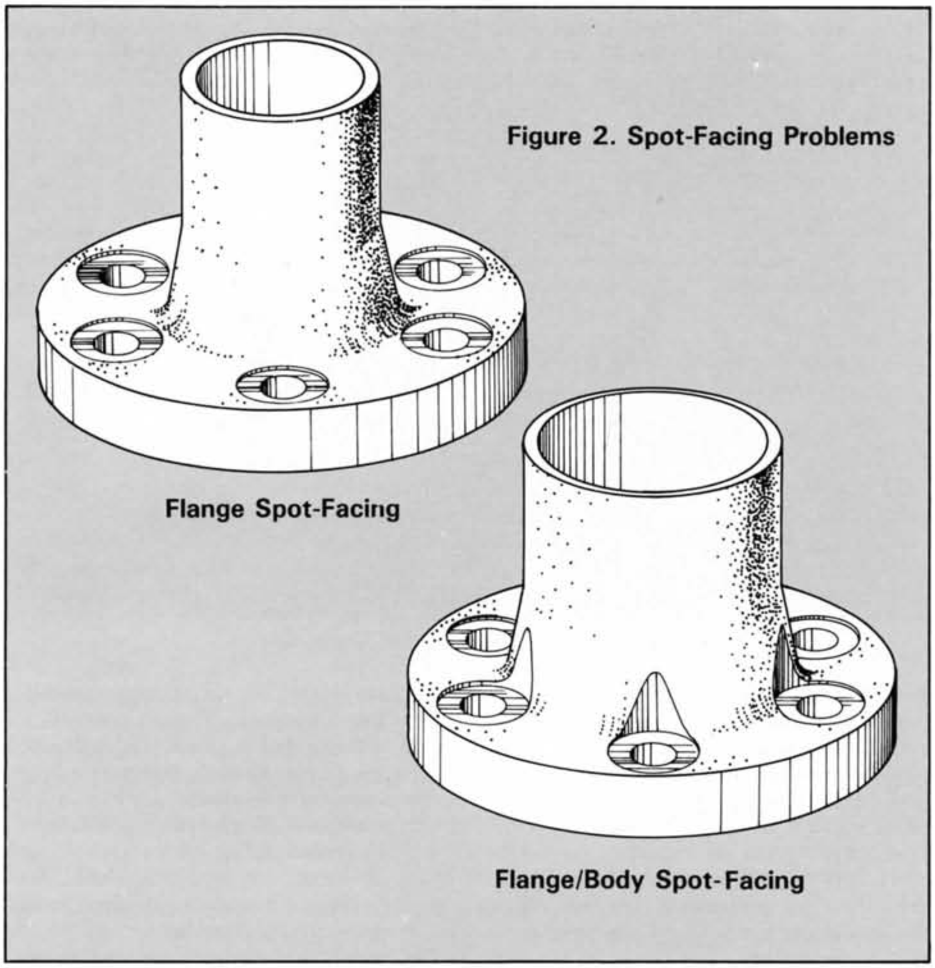


Figure 2. Spot-Facing Problems

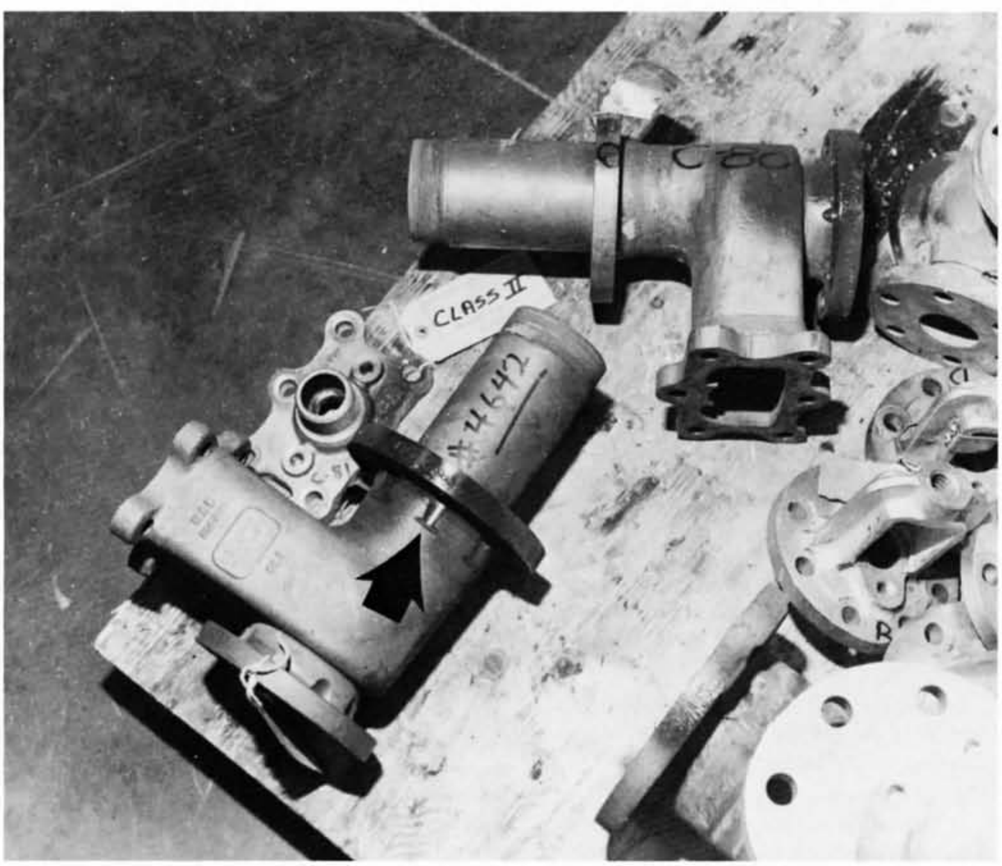


Figure 3. Example of Valve Body Damage

The valves were originally fabricated to meet a U.K. casting standard (DGS 9010), but not to a valve specification. The interpretation of the DGS 9010 was found to be difficult and likely to lead to many problems in determining acceptability (namely, the interpretation of subsurface defects using radiography). A Canadian version of the specification, D-27-002-001/SG-001, was written to simplify the interpretation of DGS 9010 and to include material composition traceability and documentation control during manufacture.

Data Package

The definition of valve configuration previously required numerous drawings for the complete detail of each valve. For construction purposes this was probably satisfactory, but it was found that there were many conflicts in the information available (i.e. between "cock" sheets, casting drawings and detail drawings).

The solution to the problem of hidden dimensional conflicts required the review of each drawing that was called up as a detail or reference and rationalizing the information. The review of this information was performed over an eight-month period by DMEE 5. For manufacturing purposes the data package is cumbersome to handle and in future will be replaced with a new package showing all details in an orderly fashion.

Valve Design Improvements

The process of assembling the information necessary to produce submarine valves brought to light many materials and configurations that were causing problems. The change to NAB and the subsequent increase in wall thickness (without changing the bolt-hole circle dimension) produced an interference of the fastener and the valve body. The natural solution was to spot-face the nut-seat area to allow the fitting of the fastener. However, the spot-facing usually impinged on the valve wall thickness, reducing this dimension by as much as 40 to 60 percent and creating stress concentrations in the local area (Figures 2 and 3). To prevent this, the fastener dimension was taken into account and the flange back-face was machined to incorporate a one-quarter-inch radius to allow for clearance, thereby eliminating the need for spot-facing.

Valve bodies were reviewed in an effort to eliminate asymmetry and rapid changes in sections. This review was conducted for all valve bodies; cast components as well non-functional webs were removed. It was also noted that there was interchangeability possible between hull-valve components and in-line components, as well between 400-p.s.i. and

150-p.s.i. valve components, and steps were taken to identify the differences.

As a result, all valve casting drawings were redrawn and dimensions were rationalized. NAB was incorporated for all castings, resulting in an increased cost of seven percent for those castings previously made from gunmetal, but the inherent gunmetal problems of porosity and inclusions were eliminated. Care was taken not to place Class I requirements on those components that were previously made from gunmetal.

Various component changes were made, such as substituting packing material and O-ring materials with modern, readily available material. Fasteners are now being made of monel to increase service life. Figure 4 illustrates steel fastener corrosion.

Foundry Process

New casting patterns were constructed using the drawings produced, incorporating the design changes noted previously. Initial pourings experienced problems with shrinkage in the seat area and oxide formation on the casting surface.

The procedures and raw materials used at the foundry were examined. The sand was found to have the proper moisture content, and the alloy used was being poured at the proper temperature. A few improvements were made, in that a zircon sand core was incorporated and ceramic filters were used. In addition, webs were removed to alleviate hot spots. All of these modifications assisted in improving the success rate of the foundry.

Machining

The machining of castings and barstock is assisted by special jigs, fixtures and tooling to ensure the design dimensions are met consistently. Down stream, this tooling will be used for repair and overhaul of the valves at the ship repair unit in Halifax.

Original drawings contained errors such as incorrect gland-packing configuration which would result in the gland O-ring residing outside the cover bore. In order to correct such deviations, the machine dimensions were carefully scrutinized and calculations were performed to determine the correct thread engagement, number of packing rings and machining tolerances. Valves manufactured to date have demonstrated the ability to maintain test pressure using either O-rings or packing.

Documentation Control

Each valve produced in Canada will have casting markings identifying the valve pattern number, the operating pressure, material and classification, and in addition will have raised pads for process marking. The process marking will identify by serial number the radiography records, dye penetrant records, dimensional inspection records and any deviation report number. In this way, by referring to a traveller document, it is possible to obtain the complete valve history. This record will be extended during the repair and overhaul process to control the machining activity and any testing that is conducted.

Figure 4. Steel Fastener Corrosion

Each component of a valve assembly is identified by a number which will allow it to be traced back to the original raw material "heat" number. Any loss of parts or exchange with another valve's components will be readily identified. This is not to say that the valves are custom assemblies; rather, the identification of all valves and components will reduce the chance of operational failure.

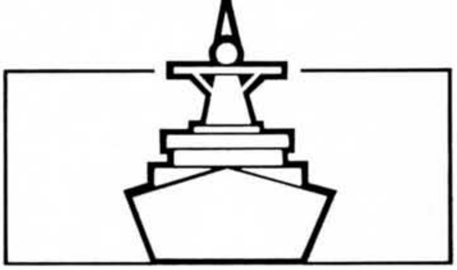
Summary

The work conducted in Canada over the eighteen-month period was originally intended to provide a Canadian source of supply that met "O" Class design standards. The result has been the bridging of the gap between post-second-war and modern submarine material handling. Though the "O" Class submarines are a twenty year (plus) design, equipment and system improvements and continued operation require that their valves be regarded as critically as those of the most modern submarines.

In conclusion, the valves produced in Canada at the present time include the following upgrades:

a. all castings are made from NAB DGS 348;
b. radiography is more stringent for hull valves than line valves and is performed on all castings to establish a baseline;
c. dimensional inspection is performed on all components and held within required tolerances;
d. fasteners are made of monel (for increased service life);
e. all items such as packing and O-rings are made of modern, readily available materials;
f. all valve component assemblies are rationalized to ensure they will withstand the rigours of operation;
g. traceability is provided for the duration of each component life; and
h. valves are produced to high standards at a competitive price.

Joseph Podrebarac is a mechanical engineering graduate of McMaster University in Hamilton. Since joining DGMEM in 1982, he has worked in the gas-turbine and diesel sections of DMEE 2, and with fire-suppression systems in DMEE 5. He is currently responsible for seawater systems in the Auxiliary Systems section of DMEE.



SWATH Ships — A New Term in the Equation[1]

by Cdr John N. Edkins

Cet article discute du vaisseau à bicoque à petite surface de flottaison (SWATH) comme une alternative au vaisseau monocoque pour certaines applications maritimes.

[1]Presented at the May 1987 Engineering Institute of Canada Centennial Convention in Montreal.

Introduction

Why SWATH? Single-hulled vessels (monohulls) have served us well since their first appearance about 6000 years ago. Isn't this proof of their versatility and reason enough to dismiss unconventional hull-forms like SWATH (Small Waterplane Area, Twin Hull) ships? Yes . . . and no. Yes, monohulls are enormously versatile; they are built to carry passengers in luxury, to move millions of barrels of oil around the world, to push and pull river barges and to project military power overseas. The monohull's longevity is an evolutionary success story. On the other hand, SWATHs are now being designed and constructed in increasing numbers; they are no longer a mere novelty. The reason for their recent emergence can be explained by the tandem forces that create change in this and other industries; "technology-push" and "requirements-pull".

Although the SWATH concept is quite old, it has become a viable alternative to monohulls only recently. Two things happened to cause this. A full-scale prototype, *Kaimalino*, was built which impressively demonstrated that superior sea-keeping could be achieved in small-displacement vessels. The second stimulus was a heightened awareness of seakeeping as an important measure of performance, a change which has led to increasingly demanding seakeeping requirements. The combined technology-push and requirements-pull has produced enough impetus to give SWATH a proper launching.

This paper will focus on the emergence of SWATH ships as an alternative to monohulls for a number of special maritime applications. SWATHs will be described, their historical development outlined and the basic design and performance principles discussed. A critical appraisal of SWATH pros and cons will indicate why, in the complex and expensive arena of ship design, construction and operations, SWATH ships can now be seen as an attractive option to monohulls in a number of applications.

A SWATH Primer

SWATHs are ships with two identical, widely-spaced hulls connected to a box-like cross-structure by narrow surface-piercing struts (Figure 1). The hulls are torpedo-shaped and provide 70-80 percent of the buoyancy. They are submerged far enough below the water surface to escape the worst effects of wave motions. The slender struts are designed to have as small a waterplane as possible within the constraints of other design considerations. It is this characteristic, the small waterplane area, which distinguishes SWATHs from other displacement ships and provides them with markedly reduced motions in waves. This same principle is used by floating, offshore drilling platforms; the slender legs relatively unresponsive to passing waves, the buoyancy provided by large, well-submerged pontoons. Figure 2 illustrates a typical SWATH shape as compared with monohulls, catamarans and other unconventional ships.

The struts support a large cross-structure, or "box", far enough above the water surface that waves contact the underside of the box infrequently and without excessive force. The wide spacing of the struts drives the box width, resulting in wide, rectangular decks enclosing a large internal volume.

A History of SWATH Development

The first recognizable SWATH concept has been attributed to a Canadian, Frederick G. Creed. Born in Nova Scotia in 1871, Creed conceived what he called the *Seadrome* (Figure 3), a SWATH aircraft carrier about 1100 feet in length which bears a remarkable resemblance to modern SWATH forms. His idea suffered the fate of so many radical ideas, however, and was not taken seriously. When the *Seadrome* was offered to the British Admiralty in 1939, Creed was told that the idea was impractical. Similar approaches to American and Canadian navies and to private industry yielded

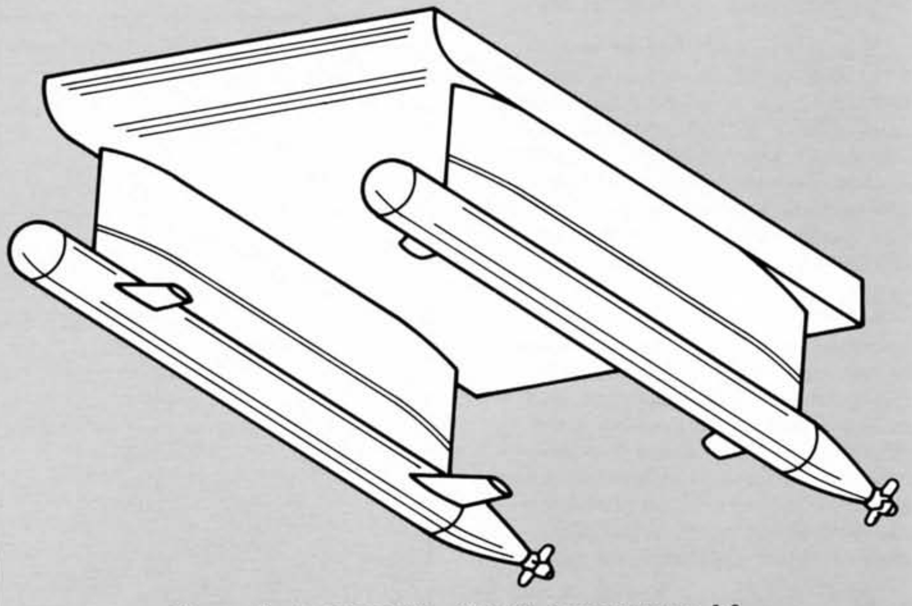


Figure 1. ILLUSTRATIVE SWATH CONFIGURATION [1]

more cold shoulders and a few gems of excuses, including one advising that it would be of little use meeting with Canadian navy ministers as they would follow England in any new developments[2].

It was long after Creed's death in 1957 before the U.S. Navy commissioned the building of *Kaimalino*, launched in 1971. Meaning "calm seas" in Hawaiian and displacing 220 tonnes, *Kaimalino* generated much interest and sparked a steady, if slow, program of SWATH construction in the United States and Japan, where these ships are called SSCs (Semi-Submerged Catamarans).

Two Japanese SWATHs in particular, the 350-tonne ferry *Seagull* and 3400-tonne oceanographic survey ship *Kaiyo*, contributed to SWATH popularization because the selected missions capitalized on SWATH's unique advantages. Figure 4 illustrates these two ships and Figure 5 plots the development of existing SWATHs. A recent U.S. Navy decision to build a class of 3500-tonne *T-AGOS 19* ocean surveillance SWATH ships is the latest indication that Frederick Creed's concept has finally caught on.

An interesting footnote is that a 1160-tonne Dutch SWATH named *Duplus* actually predated *Kaimalino* in 1969. Its offshore support mission included a heavy lift requirement, however, and as this was an inappropriate mission for a SWATH, a major 1971 refit added wing tanks (sponsons) to the struts, increasing the displacement to 1400 tonnes. The waterplane area consequently grew by 50 percent; the world's first SWATH had become an MWATH (medium waterplane area, twin-hull)! This ship is now named *Twin Drill*.

Basic Principles of SWATH Ships

This section describes the basic features that set this type of ship apart from conventional monohulls. While the hullform is an area of obvious difference, this feature also impacts on the engineering considerations addressed in structural and machinery design as well as the general arrangement of the payload and compartments.

Hull-Form

SWATHs may be characterized as having four distinct parts: lower hulls, struts, box and deckhouse. The lower hulls and struts are central to hydrodynamic performance and thus must be carefully designed in order to achieve a balance between the oft-conflicting requirements of speed, seakeeping, manoeuvrability, stability and buoyancy.

SWATH hull-forms are readily described mathematically and may be solved explicitly, permitting the rapid generation

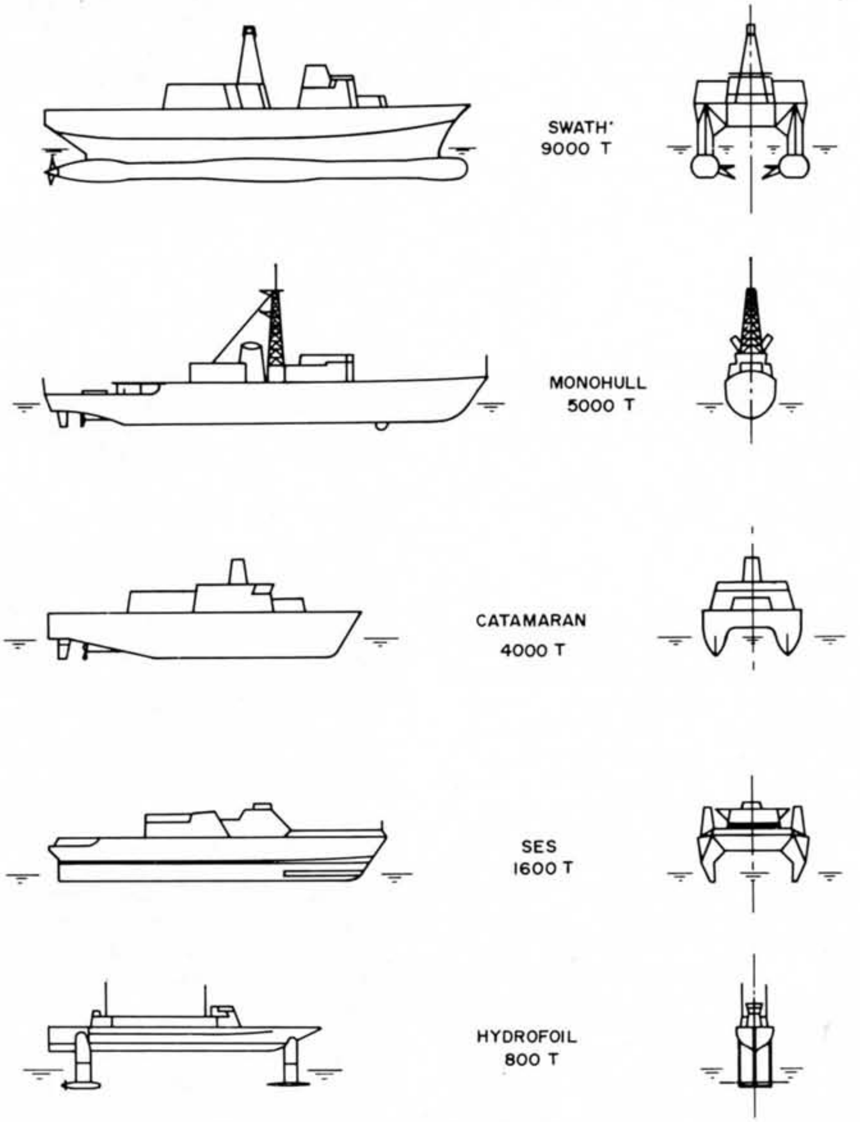


Figure 2. Comparative hull forms

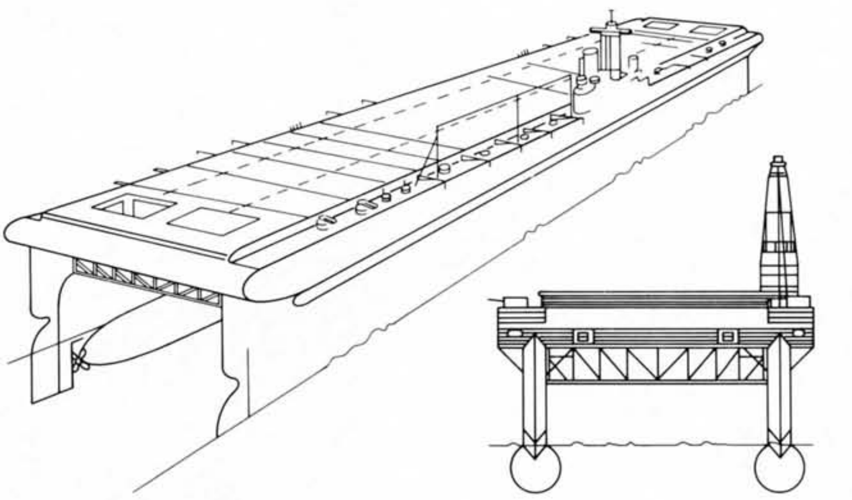


Figure 3. An artist's impression of Frederick Creed's Seadrome

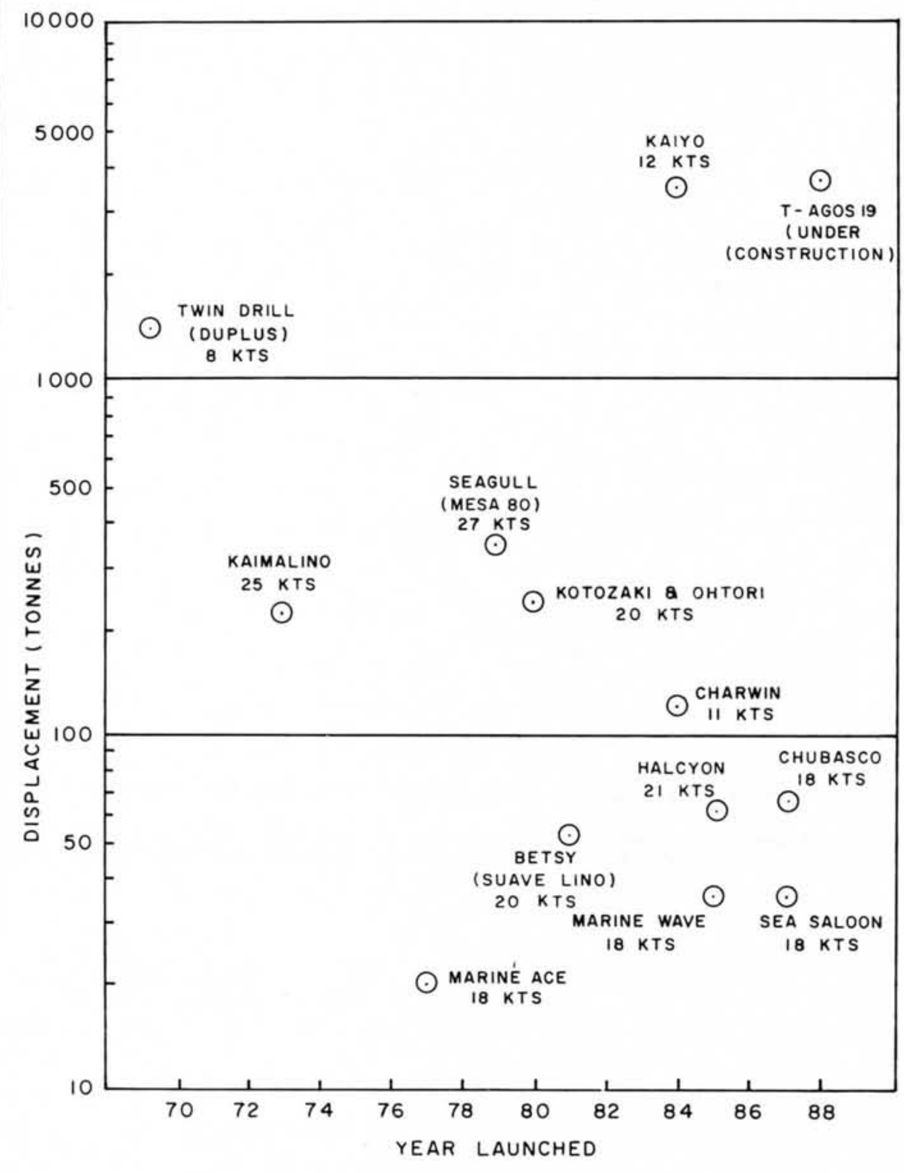


Figure 5. Existing SWATH ships

of hulls for analysis. While SWATH's geometric flexibility theoretically affords limitless hull-form variations, experience has generated a number of rules of thumb to guide designers. For instance, lower hulls of elliptical cross-section are preferred to those of circular cross-section for two reasons: (a) reduced draft for equal buoyancy, and (b) increased damping against heave, pitch and roll motions.

Another rule of thumb is that long, slender (defined by length-to-diameter ratio, L/D) lower hulls having a large prismatic coefficient (Cp) are best for performance at top speeds. The trade-off is reduced efficiency at medium (cruise) speeds and difficulty in maintaining a constant speed in the "hollows" of the speed-power curve. Conversely, careful design of the lower hulls can achieve cruise speed efficiency and a smooth curve, but at the expense of top speed. A comparison of the two SWATH curves in Figure 6 illustrates the impact which may be achieved by varying the prismatic coefficient.

A fundamental difference between SWATHs and monohulls is the wetted-surface area. Monohulls have a more compact shape than SWATHs and thus a smaller wetted-surface area for equal displacement. Therefore, SWATHs *generally* have greater resistance (drag) than equal-displacement monohulls and require more power to attain the same speeds. Figure 7 compares the speed-power curves for representative 7000-tonne ships (two SWATHs and three monohulls). Notice the wide speed-range for equal power, a strong function of hull-form for both monohulls and SWATHs. Figure 6 illustrates that, in certain circumstances (i.e. low length-to-beam ratio, L/B), monohulls may have greater drag than SWATHs.

Perhaps most critical to the success of any SWATH design is the simultaneous

Figure 4. Japanese SWATHs

achievement of good seakeeping and adequate intact stability. The size, shape and spacing of the struts are the important variables in this case. Reduced motions depend on the struts' waterplane area (horizontal cross-section at the waterline) being small, but stability is a strong function of the product of waterplane area and beam. Therefore, to achieve satisfactory transverse stability, a small waterplane area must be accompanied by a wide beam. Above displacements of approximately 10,000 tonnes, optimum seakeeping will be sacrificed in order to constrain the ship's beam to the maximum dimensions of the Panama Canal and drydocks.

The small waterplane area is responsible for another, very important, SWATH characteristic; extreme sensitivity to weight change. Figure 8 illustrates, for representative SWATHs and monohulls, draft change as a function of weight change. The slope of the curves is TPI (tonnes per metre immersion). Significant draft increases (greater than ten percent of design draft) have an adverse effect on SWATH performance, particularly in the areas of resistance and seakeeping (box slamming). Primary structural stresses also increase as a function of increased draft. The consequences of this weight sensitivity are very important. Missions requiring a ship to handle large, variable payloads cannot be considered and SWATHs must be designed to carry variable ballast to compensate for normal weight fluctuations, including future growth. Also, extra diligence and/or higher weight margins are required during design and construction to ensure that the design draft is achieved.

Thus far we have discussed only the submerged portion of the ship geometry. Suspended well above the waterline and enclosing the bulk of the ship's payload and arrangeable volume are the box and superstructure. In smaller SWATHs the box is nothing more than a grillage, plated top (main deck) and bottom (wet deck). Above 1000 tonnes, the box may become deep enough to enclose compartments, and very large SWATHs displacing in excess of 7000 tonnes may use two internal deck levels. Shallow innerbottoms are sometimes used for added strength and to locate piping, ducting and auxiliary machinery.

While monohull weatherdecks are characteristically slender (length-to-beam ratios of between five and ten), SWATH aspect ratios hover around three. In warships, where the separation of antennas is an important consideration, a compressed SWATH superstructure may be a disadvantage. On the other hand, the large rectangular deck areas may be used to advantage in arranging the maze of

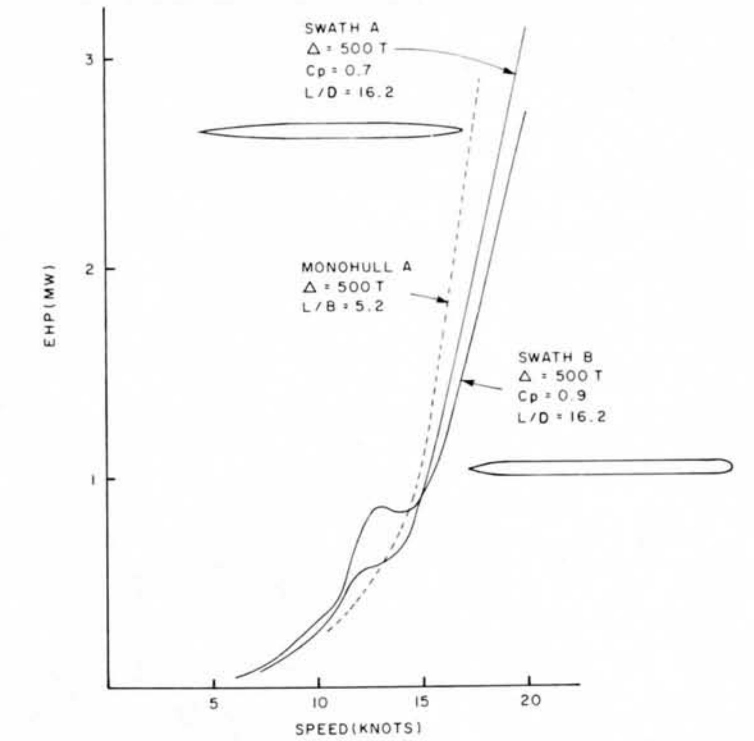


Figure 6. Speed - Power comparisons for 500-tonne ships

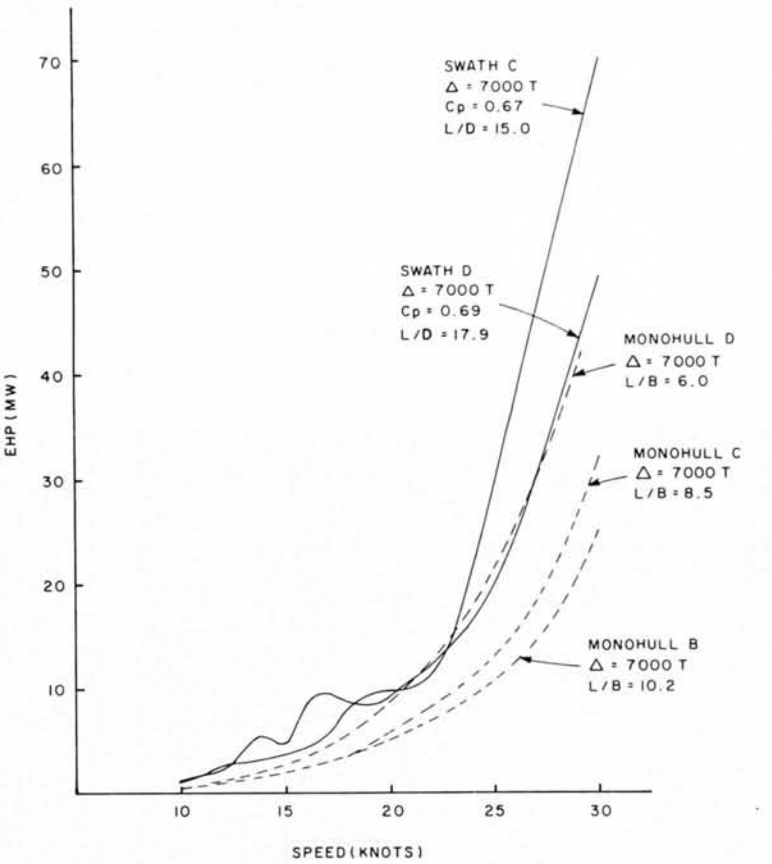


Figure 7. Speed - Power comparisons for 7000-tonne ships

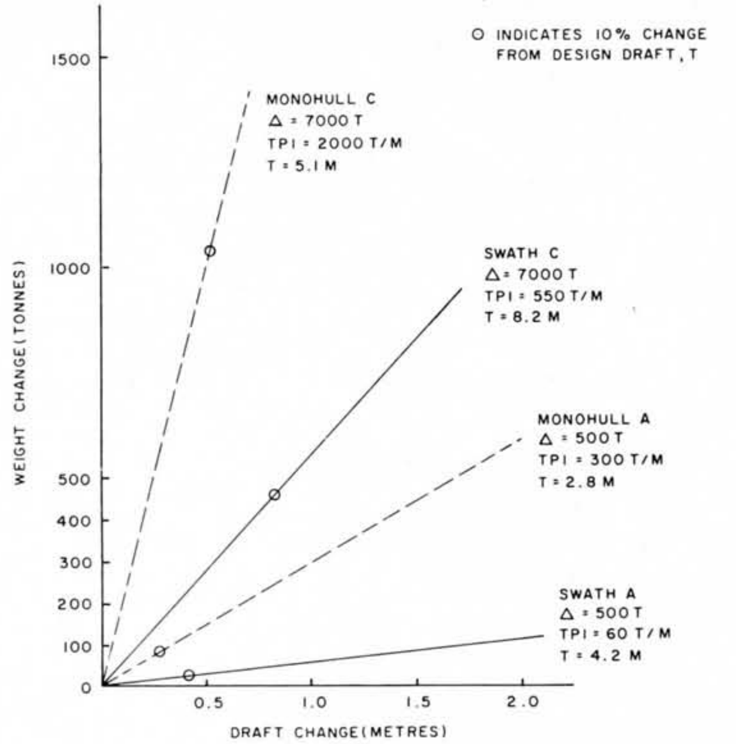


Figure 8. Comparative draft sensitivity - to - weight - change for SWATHS and Monohulls

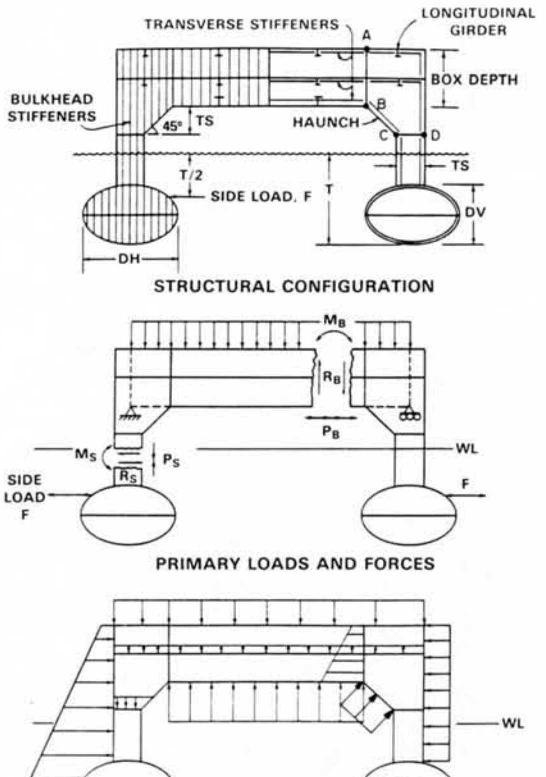


Figure 9. Representative structural configuration and loading conditions (3)

A-frames and other deck-equipment needed in oceanographic ships.

A further advantage of SWATH's wide beam lies in its improved ability to survive the attack of a sea-skimming missile. While monohull frigates and destroyers do not incorporate longitudinal subdivision, SWATHs employ a number of longitudinal bulkheads. The extra layers of structural steel provide additional protection to vital spaces from the blast and fragmentation effects of warheads.

Structures

Structurally, SWATHs are a problem. This is again a result of the non-compact, inverted U-shape. Figure 9 illustrates a typical structural configuration and characteristic primary and secondary loads. SWATHs experience both longitudinal and transverse bending as well as torsion. The dominant primary stresses, however, result from transverse bending which is caused by a wave-induced side-load, considered to act perpendicular to the centreline at mid-draft. Its direction alternates, producing both hogging and sagging moments. The side-load is also responsible for in-plane axial box stresses and strut shear stresses[3].

As a non-compact shape, SWATHs are structurally inefficient. To make matters worse, they experience large stress concentrations in the vicinity of the haunches (points A-D; Fig 9) which may be reduced by using doubler plates and radiused corners. While large SWATHs must be designed to meet these primary stresses, small SWATHs are governed by local (secondary) loads.

Designed conservatively, steel SWATHs have structural weight fractions equal to approximately 42 percent of full load-weight, compared to 35 percent for monohull combatants. The result of higher structural weight fractions is a reduced capacity to carry useful loads. This problem is even more pronounced in small SWATHs which must revert to the use of aluminum in order to carry a useful load. Structural weight reduction by the use of alternative materials and clever structural design is a goal which will benefit from further research and development.

Machinery

SWATH machinery plants differ from monohull installations in a number of ways, but primarily in the choice of machinery location and transmission types. The slender struts required for small SWATHs preclude locating maintenance-intensive machinery in the lower hulls. Thus, main machinery sited in or on the box transmits its power to the propellers via belt, Z-drive or electric transmissions. While greater access to the lower hulls is available in large SWATHs, locating prime movers in the box is preferred in most applications. Generally speaking, prime movers in the lower hulls have difficult removal routes, long uptakes/downtakes, long drive shafts and are inflexible in the distribution of power to the shafts. The preferred arrangement places prime movers in the box, supplying power to an electric transmission. Aside from rectifying the above-mentioned mechanical transmission drawbacks, the prime-mover-generated electrical power may also be tapped to supply hotel (ship services) electrical loads. Tables 1 and 2 present the trade-offs related to transmission selection and prime-mover location.

The design of auxiliary machinery for SWATHs is not significantly different from that of monohulls, but one area for special consideration is the requirement for controlling variable ballast; a necessity for weight-sensitive SWATHs.

Performance

The raison d'être for SWATH ships is seakeeping, so it is not surprising that they demonstrate lower motions than monohulls. Impressive side-by-side trials between the 220-tonne SWATH *Kaimalino* and two monohulls, the 3100-tonne U.S. Coast Guard cutter *Mellon* and 110-tonne USCG patrol boat *Cape Corwin* were conducted in 1978 by the U.S. Navy and the U.S. Coast Guard[4]. Figure 10 illustrates that the SWATH experienced less pitch, roll and heave motions than both monohulls. This is particularly instructive in the case of *Mellon* which is 14 times *Kaimalino*'s displacement.

The most obvious manifestation of SWATH's inherently good seakeeping is the increased operability in high seas. For example, the operability of a warship engaged in anti-submarine warfare (ASW) depends on the ship's ability to maintain station, replenish at sea, search, detect and track submarines, launch and recover helicopters and detect and defend against surface and air threats. To varying degrees, the success of each of these mission areas depends on the steadiness of the platform.

Another area critical to the successful operation of an ASW ship is its ability to detect other ships and submarines acoustically while itself avoiding detection. SWATHs propelled by prime movers located in the box and slow-turning propellers driven by electric motors in the lower hulls offer the promise of improved acoustic silencing. Deeply submerged sonars and low relative motions further improve performance by virtually eliminating sonar quenching and emergence.

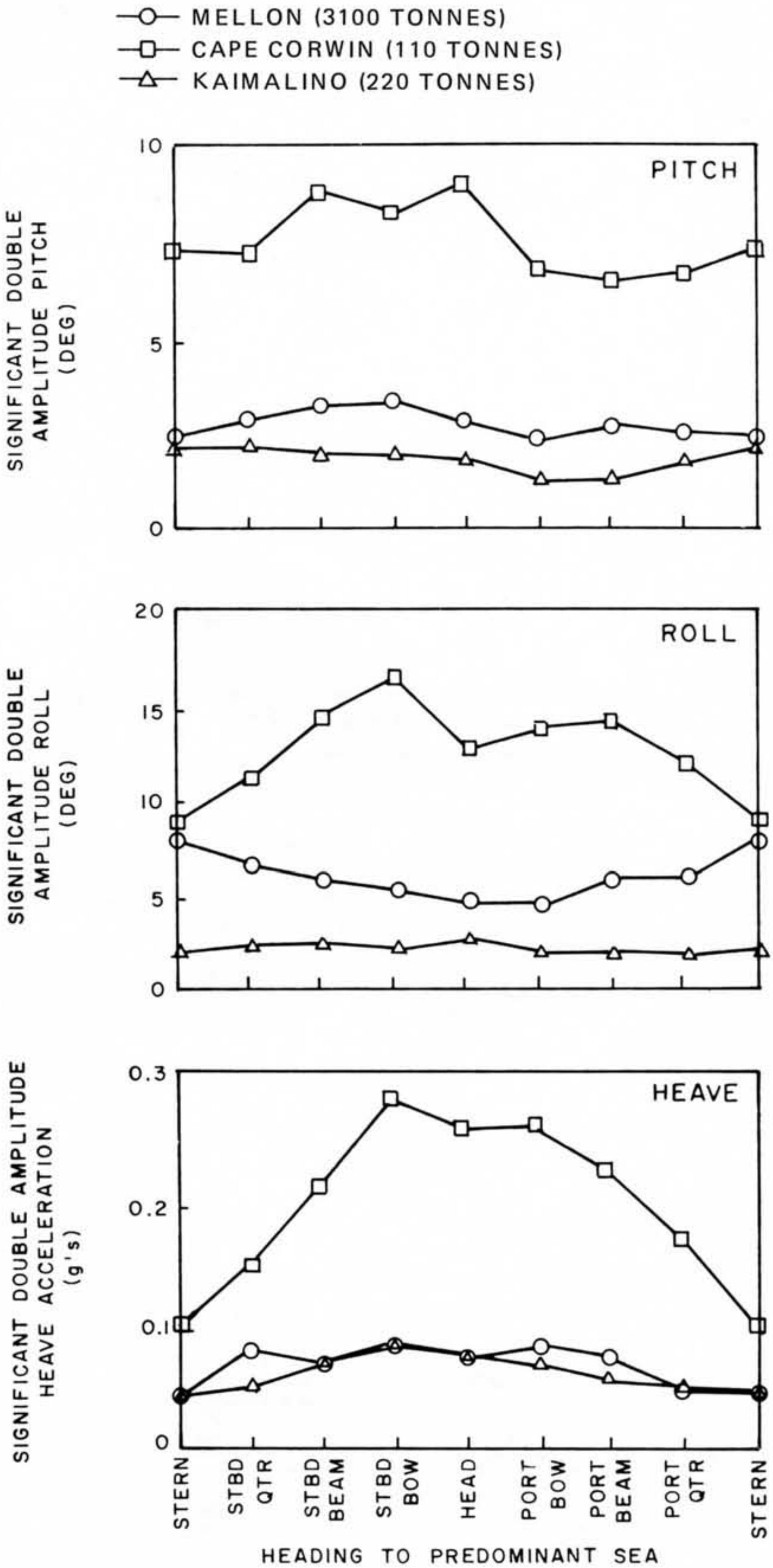


Figure 10. Motion comparison (vertical plane) between SSP Kaimalino and USCG Monohulls (4)

A popular misconception is that SWATHs are high-speed ships. SWATHs are capable of "high" speed, but only with liberal application of installed power and particular attention to hull-form. In general, SWATHs are slower than "comparable-payload" monohulls for the same power and in calm water. On the other hand, it may be argued that ships seldom operate in calm seas and therefore such a comparison is meaningless. Figure 11 (Ref 4) demonstrates the order of speed degradation due to waves which may be experienced by typical 3000-tonne SWATHs and monohulls. The monohull first reduces speed in an effort to maintain ride quality. Increasing wave-height further necessitates speed reduction in order to limit deck wetness and slamming. SWATH speed degradation is more gradual, however, and is governed by the frequency and magnitude of wet-deck slamming.

Using differential thrust from widely spaced propellers, SWATHs display excellent manoeuvrability at low speeds and can easily turn in place. At higher speeds, SWATH turning-circles will be approximately the same as for monohulls.

Payload

The capacity of any ship to carry a payload is measured in weight, volume and deck space. The nature of SWATH's sensitivity to weight makes the carrying of high-density and highly variable payloads impractical and uneconomical. Low-density payloads, on the other hand, are well suited to SWATHs as adequate deck space and internal volume are the driving factors. In this respect SWATHs hold an advantage over monohulls which tend to be volume-critical.

The percentage of arrangeable volume (useable volume/total internal volume) varies depending on the type of payload and the size of the SWATH. Generally, the box is easily arrangeable (being an efficient rectangular shape) while the struts are of limited use due to the difficulty of access. The lower hulls are best used to hold machinery and liquids.

There is no significant difference in the deck areas of monohulls and SWATHs of comparable displacement. Slender monohulls typically distribute their useable deck-area over the length of the ship while SWATHs offer one or two large rectangular locations well suited for the placement of bulky deck-gear, helicopters or containers.

A Critical Look at SWATH

Table 3 presents the advantages and disadvantages of SWATHs in relation to monohulls. Consistent with this paper's thesis that SWATHs are specialty ships, note that many of the advantageous characteristics are offset by equally impressive

	Advantages	Disadvantages
Electric Transmission	1. Arrangement flexibility 2. Potential for quietness 3. Power use flexibility	1. Heavy
Geared Drive	1. Efficient 2. Lightweight	1. Prime movers must be located in lower hulls 2. Long shaft lines 3. Noisy 4. Long uptakes/downtakes
Right-Angled Geared Drive or Belt Drive	1. Convenient for small SWATHS	1. Upper limit on power Transmitted

Table 1 Transmission Selection

	Advantages	Disadvantages
In Cross-Structure (Box)	1. Remote from water (quietness) 2. Short uptakes/downtakes 3. Easy access for removal 4. Arrangement flexibility	1. High vertical centre of gravity
In Lower Hulls	1. Low vertical centre of gravity	1. Long uptakes, downtakes 2. Difficult access for removal 3. Noise transmission to water 4. Arrangements difficult

Table 2 Location of Prime Movers

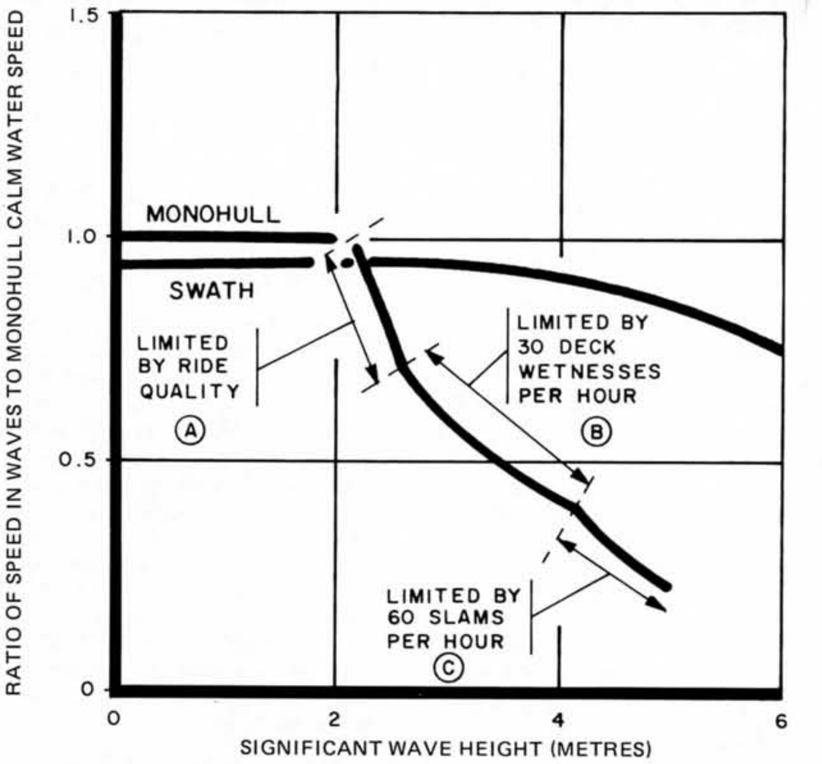


Figure 11. SWATH and Monohull speeds in rough seas (4)

drawbacks. For example, the single characteristic which makes SWATH an excellent seakeeping ship (its small waterplane area) also guarantees that this ship-type can never be as versatile as a monohull.

Risk Areas

SWATHs built to date have been essentially medium-tech and low-risk. The missions have been carefully selected to favour SWATH's attributes and avoid the drawbacks. In addition, appropriately conservative design approaches have been followed, consistent with the lack of a validated design data base.

The following factors will have the greatest influence on the *performance risk* of new SWATH designs:

a. matching SWATH with the appropriate mission;
b. achieving a balanced design, one which does not overemphasize one attribute at the expense of others; and
c. ensuring that the design draft can be achieved and maintained throughout the life of the vessel.

In addition to the above, the design of "high-performance" SWATH combatants (i.e. frigates and destroyers) introduces other, mission-related performance risks associated with achieving required levels of acoustic, infra-red and radar signatures, survivability against subsurface and air weapons and adequate damaged stability.

There are few areas of *technical risk* unique to SWATH ships. Structurally, transverse bending stresses are very high and require special treatment. In addition, designers must consider fatigue as a likely failure mechanism. Propulsion systems vary markedly depending on the size of the ship, with the use of belt or Z-drives in smaller SWATHs and electrical propulsion in larger ones. The only risk here is that associated with the selection of an inappropriate propulsion system.

That SWATHs are often classified as "advanced naval vehicles" (ANVs) is misleading in that it suggests a high-risk vessel. Unlike hydrofoils and air-cushion vehicles (including surface-effect ships) which rely on dynamic lift mechanisms for their success, SWATHs employ conventional surface-ship technology. The difference is that SWATHs are packaged in an unconventional hull-form. These ships are merely a variation (albeit a significant one) on catamarans and it may be more appropriate to refer to them as "*alternative* naval vehicles".

Characteristic	Advantage	Disadvantage
1. Cost	– most cost-effective, rough-water ship	– more expensive per tonne of payload carried
2. Displacement	– smaller than monohull for motion-critical missions	– larger if mission is payload-driven
3. Beam	– wide beam provides rectangular deck area for payload flexibility	– wide beam produces navigation, building, docking restrictions in larger SWATHs
4. Draft	– sonar, propellers deeply submerged	– navigation restrictions
5. Large wetted surface area		– higher drag than "equivalent" monohull
6. Small water-plane area	– significantly reduced vertical plane motions – can maintain speed in high sea states	– sensitive to weight change – future growth margin must be carried from commissioning – underwater damage causes large heel and trim
7. High freeboard	– dry decks in heavy seas	– complicated off-board evolutions – large sail area – increased radar cross-section
8. Large structural weight fraction		– reduced payload capacity (weight)
9. Large internal volume	– arrangements flexibility – reduced vulnerability – increased payload capacity (volume)	– long ducting, piping runs – wasted volume
10. Widely-spaced propellers	– increased survivability – good low-speed manoeuvring	– single-propeller SWATH impractical
11. Stabilizer fins	– improved seakeeping in following seas	– increased drag, weight – acoustic noise source
12. Slender struts, hulls	– good directional stability	– difficult access to lower hull spaces
13. Box clearance	– large separation of box from water surface reduces wave impacts	– strong influence on VCG

TABLE 3
Advantages and Disadvantages of SWATH Ships Relative to Monohulls

Relative Costs

It is well understood that cost is the bottom line. Unfortunately, two factors conspire against a definitive statement relating SWATH and monohull costs. Most important is the futility of trying to define an "equivalent" monohull for a given SWATH, and vice versa. When compared to a baseline SWATH, a motions-equivalent monohull will be a vastly different ship than a payload-equivalent monohull[5]. The essence of unconventional ships like SWATH is that there is *no* equivalent monohull; (if there were, then SWATHs would not be necessary). Secondly, monohull cost-estimates are generated from a large data base while SWATH cost-estimating is immature.

Shipyard surveys conducted among American and British firms have indicated that, tonne for tonne, SWATHs should cost no more to build than monohulls. Where SWATHs become expensive is when the size is driven by a demanding payload. In short, payload-critical SWATHs will be bigger and more expensive than monohulls, and motions-critical SWATHs carrying an undemanding payload may very well be less expensive than the mission-equivalent monohull.

Appropriate Applications

In general, owners and operators will want to build SWATHs for missions which will benefit from superior seakeeping, but which do not specify dense or variable payloads. Secondary benefits such as arrangeable deck area, speed maintenance in a sea state, low-speed manoeuvrability and acoustic benefits may contribute to the decision, but in the end seakeeping should be the deciding factor.

Possible naval applications include frigates and destroyers (particularly ASW mission), offshore patrol, coastal surveillance, scientific research, mine countermeasures and diving-support vessels. Other government applications would include search-and-rescue and oceanographic/hydrographic research. Commercially, SWATHs appear to be appropriate candidates as cruise ships, passenger ferries, sport- fishing vessels and pleasure craft. Other applications are limited only by imagination tempered by common sense. Figure 12 illustrates two of the above applications, a 175-tonne ferry[6] and a 9500-tonne ASW combatant.

Conclusion

SWATH ships are a new breed. They have matured from novelty prototype to proven hull-form in the short span of twenty years.

SWATHs provide superior seakeeping performance for a wide range of ship sizes and are probably the most cost-effective, rough-water ships available today. They have many advantages with respect to monohulls, but these are balanced by a long list of drawbacks which limit this concept's appropriate missions; SWATHs are essentially specialty ships.

SWATHs should not be seen as a panacea or as a replacement for monohulls, but as an option to be considered for specific missions which require their unique attributes.

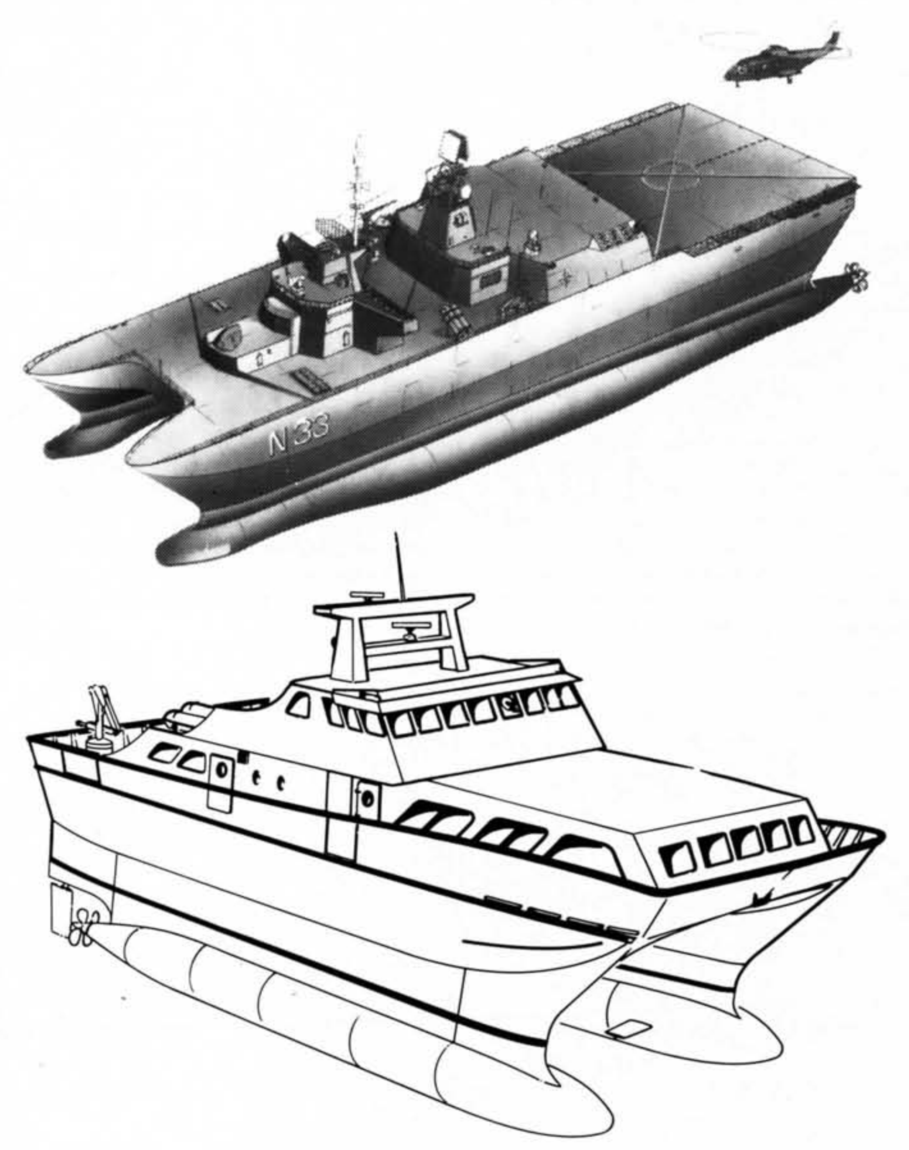


Figure 12. SWATH Ferry and ASW Combatant

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Cdr John Edkins was the DMEM section head for concept formulation before taking up his position last August as the Naval Architect Officer in NEU(A). Cdr Edkins co-authored the article "DISC — Integrated Software for Ship Design and Analysis" which appeared in our April 87 issue.

The Replacement Cruise Engine for the DDH-280 Tribal Class Destroyer[1]

by Cdr D.J. Hurl

Cet article décrit la décision de remplacer la machine de croisière actuelle des DDH-280 par la turbine à gaz Allison 570-K. L'article décrit aussi les considérations techniques qui sont associées avec cette installation.

[1]Presented at the ASME Gas Turbine Conference and Exhibition, Anaheim, California, May 31-June 4, 1987.

Abstract

A description of the existing propulsion plant in the DDH-280 Class destroyer and problems with the existing cruise engine fit are outlined. The trade-off analysis and option study which led to the decision to replace the existing cruise engine with a replacement gas turbine is examined and the criteria which were used in the selection of the Allison 570-K are then briefly addressed. Finally, the intended technical fit and design considerations associated with the installation into the vessel are described.

The opinions expressed herein are those of the author and not necessarily of the Department of National Defence, Canada.

Introduction

In the early 1980s the Canadian navy embarked upon a program to replace the cruise gas turbine engines in the four DDH-280 Tribal Class destroyers. In previous times, the spending of valuable mid-life conversion funds to change platform prime movers instead of modernizing weapons would have been seen as ill-advised. The purpose of this paper is to describe the process by which our navy embarked on such a program. The unique performance requirements identified and the resultant engineering solutions involved in the fit of the replacement gas turbine will also be examined.

Existing Propulsion System

The main propulsion machinery system in the DDH-280s consists of a two-shaft arrangement of geared gas turbines (COGOG). Each shaft set comprises a main turbine (P&W FT4A-2 rated at 18,650 kW Power shaft(Ps)) and a cruise engine turbine (P&W FT12A-3 rated at 2536 kW Ps) arranged side by side, driving into a common gearbox through SSS clutches. The main and cruise engines, enclosures, gearboxes and ancillary equipment are mounted on a rigid raft which is mounted to the ship's structure via resilient mounts (Figure 1). All propulsion gas generators rotate in the same direction, but the free turbines drive in opposite directions (left- and right-handed) to suit the inboard rotation of the propeller shafts. [The existing DDH-280 propulsion system was the subject of a previous ASME paper presented in 1969 (1).]

The operational requirement when the original cruise engines were selected dictated a maximum vessel cruising speed of 20 knots. This speed reflected the fact that a Canadian destroyer spends approximately 85 to 90 percent of its time operating below this speed during peacetime operations. For the DDH-280, as commissioned, this speed required approximately 3730 kW Ps per shaft. As there were no marinized engines in this power range available when the 280 propulsion machinery design decisions were made in 1965, the FT-12s (rated at 2536 kW Ps) were fitted, producing a 17-knot cruising speed. The FT-12 was out of production when installed and the requirement for a half-life changeout was acknowledged at that time, providing the engines were not uprated to 3730 kW Ps in the interim.

Problems with the FT-12 Fit

The FT-12 engines provided good service during the 1970s. In the 1981 time frame, problems became increasingly common. These problems were twofold:

a. the engine was inefficient by current standards and resulted in high operating costs which were continuing to escalate; and
b. difficulties associated with availability and a diminishing industrial support base.

The FT-12s, being first-generation gas turbines, compared poorly with second-generation engines such as the GE LM-500 and Allison 570-K with respect to specific fuel consumption (see Fig 2). In addition, the fact that the boost engines had to be used between the 17-knot maximum speed available on the FT-12s and the 20 knots which would be made available with a 3730 kW Ps engine caused an extra expenditure on fuel. In 1972 it was estimated that the fuel saving which would accrue from fitting a 3730 kW Ps engine in the four ships of class would be $2 to 3 million (Canadian) annually. To this estimate was added the incremental repair and overhaul costs assessed against the FT-4 engines for operation in the 17- to 20-knot band. This cost was estimated at approximately $1 million per year.

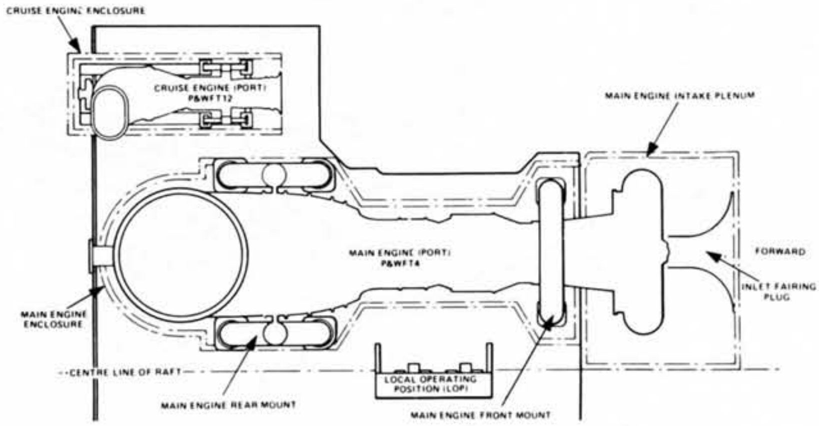

Figure 1. Existing DDH-280 Arrangement (Port)

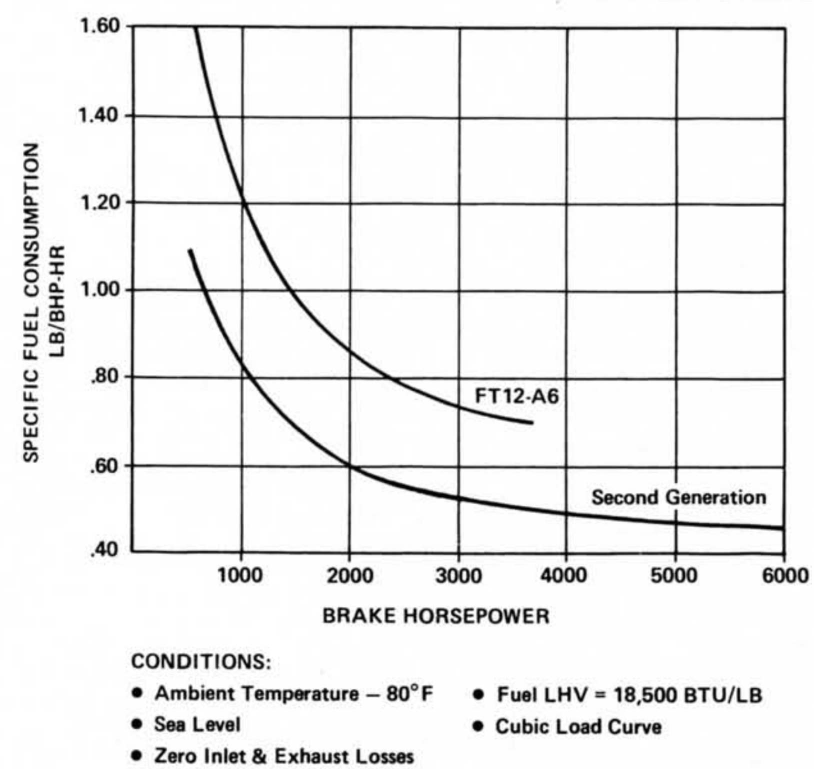

Figure 2. Gas Turbine Average Performance

MATRIX OF RANKING
(BEST OPTION RATED AS 1)
(WORST OPTION RATED AS 5)

	FT-4 FT-12	FT-4 ONLY	NEW GAS TURBINE	NEW DIESEL	ELECTRICAL CROSS CON
CRUISE RANGE	4	5	2	1	5
NOISE	1	1	1	5	1
FIRST COST	1	1	3	5	3
ANNUAL MAINT	4	4	1	2	1
ANNUAL FUEL	3	5	2	1	4
OTHER SUPPORT	2	1	4	5	3
UNWEIGHTED TOTAL	15	17	13	19	17

Figure 3

The other major problem identified with respect to continued operation of the FT-12 was the diminishing industrial support base. The engine had never achieved wide commercial acceptance and had become a relative orphan operated by the Canadian navy. In 1982 a special buy of critical spare parts sufficient for two to three years was initiated and it was determined that a further purchase of spares (in excess of $35 million Canadian) would be required by 1985 if the engines were to be retained for the lifetime of the vessels.

Option Study

An option study was conducted to determine the optimum solution to resolving the cruise engine problems for the remaining life of the vessels, estimated at 20 years. Options which were examined were:

a. continue to support the FT-12s;
b. operate the FT-12s as long as they could be economically supported, and then operate on boost engines alone;
c. remove the FT-12s and fit gas turbine cruise engines;
d. remove the FT-12s and fit diesel cruise engines; and
e. remove the FT-12s and fit synchronous generators in their place so that one FT-4 could drive two shafts in the cruise condition.

Factors which were considered during this option study included:

a. the original operational requirement for a specified range at 20 knots on cruise engines;
b. generated underwater noise in view of the vessels' anti-submarine mission;
c. acquisition and installation cost;
d. annual maintenance costs;
e. annual fuel cost; and
f. cost of other support such as spares, training, manuals and field-service support.

The results of this study are shown in very generalized, unweighted matrix form at Figure 3. Space and weight considerations were dealt with under the acquisition and installation cost factor. The list of options reduced quickly to either retaining the FT-12s, accompanied by a lifetime buy of engine and installation support spares, or replacing the engines with a modern, efficient gas turbine capable of meeting mission requirements.

Ultimately, the decision was taken to replace the FT-12s in anticipation of the following benefits:

a. improved reliability;
b. improved availability and supportability;
c. reduced operating hours on the FT-4 boost engines, with resultant cost savings;
d. fuel savings which would result in a payback period of 10 to 11 years; and
e. most significant of all, meeting the original operational requirement of 20 knots on cruise engines.

Even though it had been recognized by some, when these ships were built, that there may be a need to change out the FT-12s, it was only after reviewing these options that it became very clear that the navy was facing a major engineering design requirement at mid-life, when many more constraints exist than at initial construction. It is unlikely that the extent of these considerations was fully appreciated when the early decision was taken to fit FT-12s in lieu of more traditional cruise power options such as diesel.

Engine Selection Criteria

It is beyond the scope of this paper to examine in detail the rationale and trade-off process which led, in 1982, to the selection of the Allison 570-K as the replacement cruise engine. In brief, the selection criteria were as follows:

Tribal Class Update Program

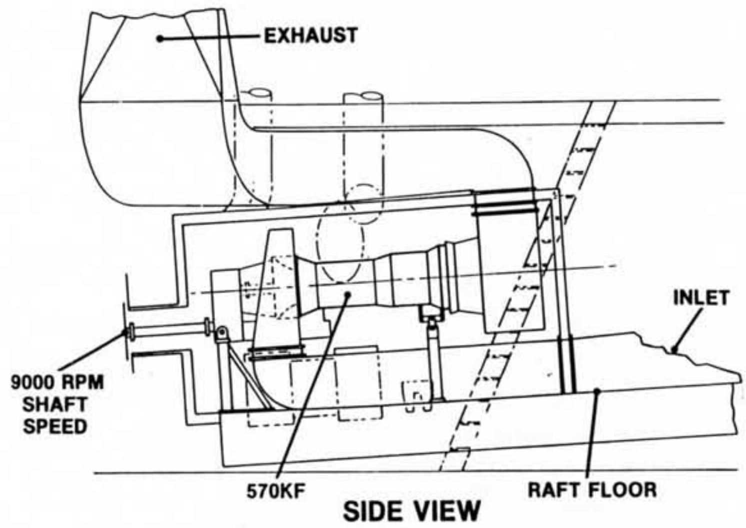

Figure 4

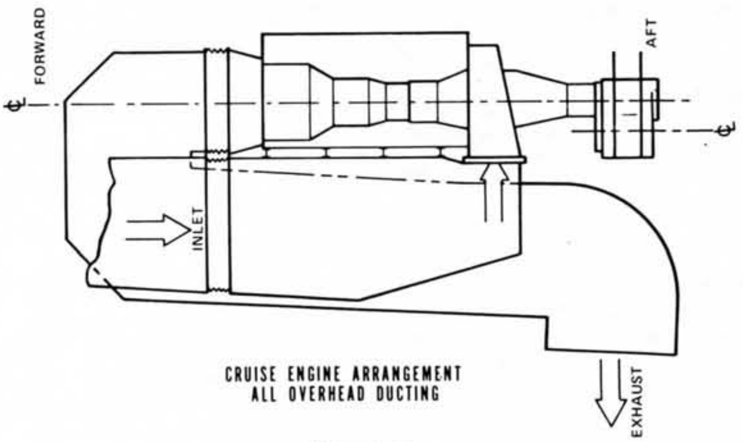

Figure 5

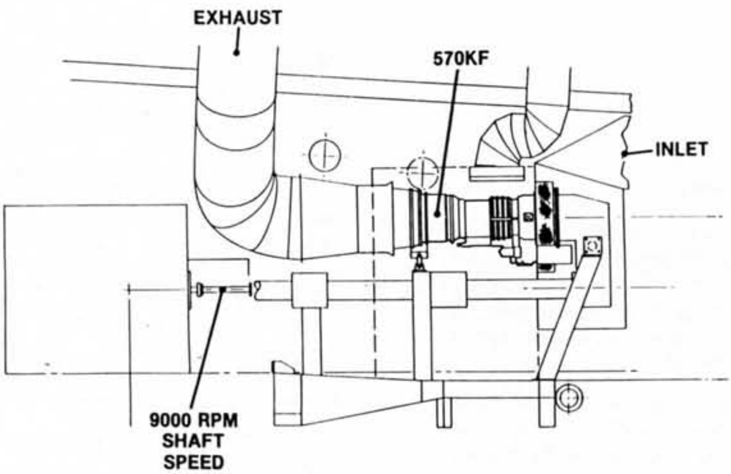

Figure 6

a. a proven marine engine;
b. cost (capital and life cycle);
c. sufficient power to meet the 20-knot cruise speed;
d. ability to provide compressor bleed air for underwater air emission;
e. weight/size;
f. overhaul capability within Canada; and
g. industrial offsets.

The Allison 570-K underwent a U.S. military test designed to evaluate turbine engines for marine service. The test included 1105 hours of operation with salt ingestion, at power levels up to 110 percent, and involved 2400 starts. Although the engine required some internal parts' replacement during the test, it successfully met the stringent salt ingestion requirement. In the 1982 time frame, best information indicated that the Allison 570-K had been selected by the Swedish navy and was being considered by the American, British, French and Israeli navies for retrofit and new-ship propulsion. [Other potential applications for the Allison 570-K are discussed in a previous ASME paper (2).] The other major factor was that the engine had sufficient power to meet the 20-knot cruise speed requirement, well within the maximum continuous rating. With respect to the other criteria the Allison 570-K was considered comparable or better on a case by case basis.

Installation in the DDH-280

The installation of the Allison 570-K gas turbine in the DDH-280s is being carried out as an integral part of the Tribal Class Update and Modernization Project (TRUMP) for which Litton Systems Canada Limited (LSL) has been selected as the prime contractor. LSL has subcontracted the design of the propulsion system elements of TRUMP to Pratt & Whitney Canada.

The TRUMP performance requirements call for increased fuel effectiveness and range of the ship for all speeds up to 20 knots, using the government-supplied cruise engines delivering 3850 kW at the power turbine outlet coupling. The noise attenuating capability of the existing machinery/raft mounting system is not to be compromised. An infra-red suppression system for the exhaust plume is required, as is the future capability to supply underwater air emission using bleed air. The engines are to be controlled by a new integrated machinery control system which will be fitted concurrently.

The integration of the Allison 570-K into an existing propulsion plant has posed some very interesting problems which have called for unique solutions.

Engine Orientation

The most obvious problem was the integration of a faster speed (11,500 rpm maximum speed) unidirectional, cold-end drive engine into a plant which currently comprises hot-end drive and handed turbines turning at 9000 rpm at full power. Two possible options which provided no disruption above the engine-room deckhead were at first considered. These were:

a. a reversed ducting arrangement — the engine drive was to be directed aft, short-coupled through a speed reducing gearbox, with ducting routed as necessary to match existing penetrations at the engine-room deckhead. Two subsets of this proposal were studied:
   (1) the first involved the intake ducting passing underneath the enclosure and the exhaust passing over the enclosure (Figure 4), and
   (2) the second was an over/beside arrangement in which the inlet and exhaust ducting were suspended from the engine-room deckhead (Figure 5); and

b. reverse shafting arrangement — the engine drive-shaft was to be directed forward so that ducting could be routed directly to the existing penetrations at the engine-room deckhead, while the shafting was to be rerouted as necessary to match the existing input flange on the main gearing (Figure 6).

Both options had acknowledged drawbacks. The over/under ducting proposals required significant volume in an already crowded engine-room. The reverse shafting proposal increased underwater noise due to additional gears and introduced complex balancing and alignment requirements. Fortunately, the orientation problem was significantly eased by a TRUMP design change to fit a single integrated auxiliary/main funnel in lieu of the existing dual bifurcated design (Figure 7). (Weapons suite considerations were the driving factors which led to this design change.) The new funnel fit eliminated the requirement for reversal of the intake and exhaust ducting in either the engine-room or the funnel itself. The selected arrangement is shown at Figure 8.

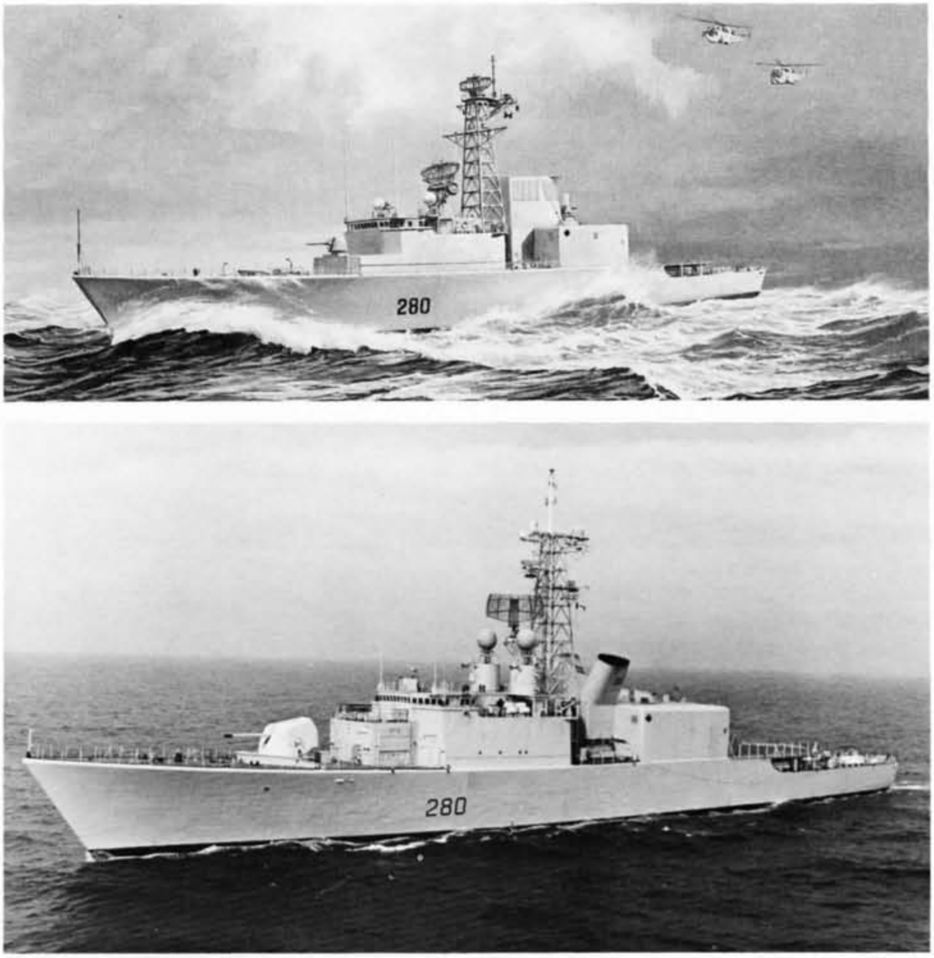

Figure 7

Auxiliary and Main Gearing

The need to match a high-speed, unidirectional turbine output to the existing power train will be dealt with by introducing two auxiliary gearboxes designed and manufactured by the Maag Gearwheel Company Limited of Zurich. The port gearbox will comprise a single helical arrangement, with thrust absorption provided by thrust bearings. The starboard unit will be of similar design but will incorporate an idler gear to achieve the necessary reversal in rotation.

Modification of the cruising train of the main gearing will also be necessary to allow transmission of the higher power and torque provided by the new cruise engine. Within the constraints of the existing gearcase these modifications consist of replacing the primary reduction pinion, wheel and thrust bearing with a single helical gear pair incorporating thrust cones, and increasing the size of the secondary reduction pinion journal bearings. As a result, the cruise drivetrain will be able to transmit the maximum continuous power available from the engines at standard day conditions. The cruise train will be power limited by the engine at temperatures slightly above 15 degrees centigrade, and torque limited by the main gearing below this temperature. Maximum delivered power to the propeller will be 4233 kW Ps on a standard day. The increase of 500 kW per shaftline, over the original 3730 kW, has become necessary as the displacement of the vessel has increased steadily since commissioning and will have grown in total by an estimated 18 percent on completion of the TRUMP modernization. The maximum cruise speed approaching 20 knots in sea state two, six months out of dock, should still be attainable.

Exhaust Considerations

The introduction of an infra-red suppression system will impose a total back-pressure loss of an estimated 5.72 kPa on the engine. This back-pressure results from a high-velocity eductor in the uptakes which draws cooling air into the exhaust stream with resultant dilution and cooling. A 112 kW loss in available power is anticipated. The 570-K has been modified to provide smokeless operation at all powers by making changes to the original combustor design. The modifications included adding a swirler to the combustor dome concentric with each fuel nozzle and making the fuel-air mixture of the primary combustion zone more lean. The engine successfully passed an exhaust smoke emission test (to U.S. military specifications) in December 1985 under normal back-pressure conditions, but concern existed that the unusually high back-pressure in TRUMP might affect exhaust smoke performance. Further tests were conducted in May 1986 with back-pressures up to 7.5 kPa with no problem identified.

Fuel

For reasons of ship stability a water-compensated fuel system (WCFS) is being introduced during TRUMP. This will be the Canadian navy's first experience with water compensation in conjunction with gas turbines. A retrofit design of a WCFS has proved difficult, with respect to minimizing the fuel/water interface, due to existing tank layout and internal tank structure. Studies by the TRUMP contractors indicate that the stringent fuel quality requirements of the Allison engine can be met by the addition of pre-filters (three microns absolute) and an extensive stripping system to the existing fuel treatment equipment. The existing equipment presently comprises two Alpha Laval centrifugal purifiers and two sets of filter coalescer units. With these changes the fuel/water interface is not predicted to introduce significant problems.

Control

Concurrent with the fit of the Allison engine, an integrated machinery control system capable of automatic remote bridge, machinery control room and local operation will be fitted. This system is the fully distributed digital system developed and manufactured by Canadian Aviation Electronics Ltd under the trade name SHINMACS (Ships Integrated Machinery Control System). The Allison engine interface with this control system will be at the 570-K electronic control unit (ECU). The primary governing of the engine's fuel control will be carried out at the ECU with the SHINMACS providing executive orders such as start/stop, "assume power" and set power.

Bleed Air

To provide bleed air to meet the future underwater noise control/reduction requirement, the Allison engine was modified by incorporating bleed ports at the tenth-stage compressor. These bleed ports will extract up to five percent of the total engine airflow from idle to full power.

Maintenance

Previous Canadian operating experience with in-service gas turbines has clearly demonstrated that inadequate maintenance access and poorly designed enclosures have caused errors during maintenance procedures resulting in reduced reliability and availability. For this reason particular attention has been devoted to both the engine mounting arrangement and enclosure design. Engine replacement will be via a removable hatch in the engine room deckhead and then out of the ship through existing passageways. Cruise engine changeout will require less than 48 hours.

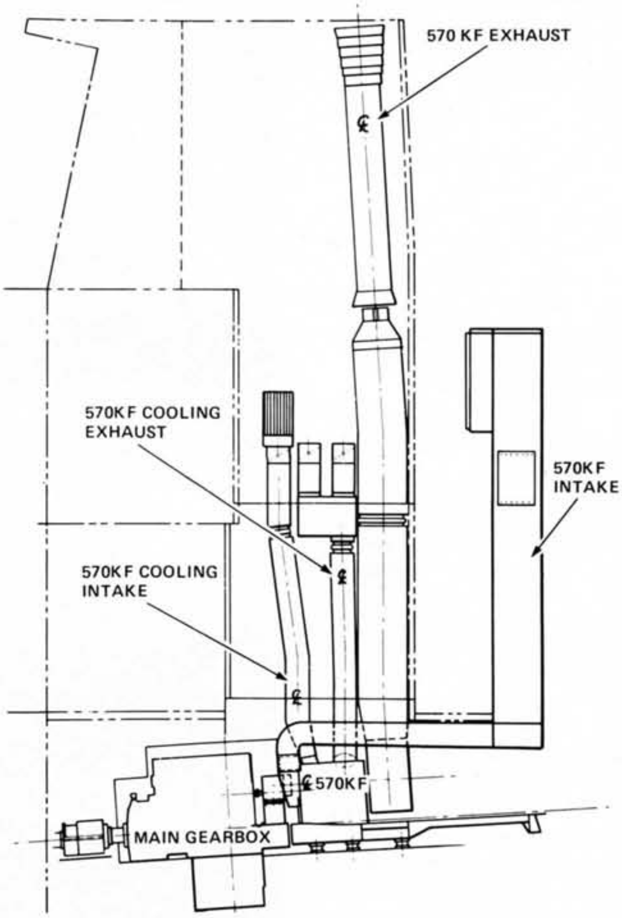

Figure 8. TRUMP Cruise Engine Installation

Conclusion

The replacement of the cruise turbines concurrent with a major modernization program for which a contractor has full responsibility has posed many challenging engineering problems and called for unique solutions. The arrival of the first converted DDH-280 complete with a successful cruise engine fit is eagerly anticipated for mid-1989.

Nothwithstanding, we have now come to fully appreciate the implications of choosing gas turbines for propulsion in naval warships. As a smaller navy, our fleet of engines will never justify, by themselves, support from industry for the 30-year life of the ship. The risk of losing support and mandating changeout, as with the FT-12s, has and will likely continue to be an important factor in future decisions on warship propulsion and electrical generator prime mover selection in the Canadian navy.

Acknowledgements

The author gratefully acknowledges the assistance of Cdr. S. Lowrie and Messrs. G. Amundrud and L.T. Taylor, as well as Mr. P. Malone and Mr. J. Murray of Allison Gas Turbines, Indianapolis, Indiana.

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Cdr Hurl has considerable experience relating to DDH-280s, having served aboard HMCS Huron *as deputy engineering officer,* Athabaskan *as the engineering officer and in the Naval Engineering Unit (Atlantic) as the DDH-280 Class Officer. His NDHQ experience includes DMEE TRUMP Coordinator, gas turbine subsection head (DMEE 2) and, currently, section head Auxiliary Systems (DMEE 5).*

Looking Back

Canada's First Naval Board

Rétrospective

Le Premier Conseil Naval du Canada

The first Naval Board for the RCN was established by order-in-council on January 22, 1942 to supersede the Naval Council in the newly reorganized Naval Service Headquarters. As an advisory body without authority, the Board convened to discuss matters of naval policy and procedure affecting more than one branch of the service.

In the photograph above, the Hon. Angus L. Macdonald (Minister of National Defence for Naval Services) is shown presiding over a meeting of the first Naval Board. Although he was not a member under the terms of the order-in-council, he often took the chair at meetings. The Minister is flanked on his right by VAdm Percy Nelles (Chief of Naval Staff), Cmdre Howard Reid and Captain H. Grant; and on his left by Deputy Minister Gordon Mills, Engineer Captain George L. Stephens (Chief of Naval Engineering and Construction) and Captain Godfrey Hibbard. Facing the Minister is Paymaster Com. Robert Pennington, R.C.N.V.R. (Secretary to the Board).

One of the interesting aspects of the Naval Board was that it counted the Chief of Naval Engineering and Construction among its members. According to The Naval Service of Canada, "the appointment of an officer of the engineering Branch as a member of the board was a departure from the policy and tradition of the Admiralty; but it found a precedent in the Australian naval organization, and seemed to accord with the ever-increasing importance of the technical aspects of Canadian naval activity".

Le premier Conseil naval (Naval Board) fut établi par Décret en conseil le 22 janvier 1942, comme successeur au Conseil naval (Naval Council) du nouvellement réorganisé Quartier-général de la Marine. Étant un groupe consultatif, le conseil se reunissait pour discuter de conduite et procédures navales affectant plus d'une branche du service.

Dans la photo ci-dessus, l'honorable Angus L. MacDonald (Ministre de la Défense nationale pour le Service naval) préside une réunion du premier Conseil naval. Quoique n'étant pas membre comme tel d'après les termes du Décret en conseil, il présidait souvent à ces réunions. A la droite du Ministre on retrouve le Vice-amiral Percy Nelles (Chef de l'État-major de la Marine), le Commodore Howard Reid, et le Capitaine H. Grant; à sa gauche se trouve le Sous-ministre Gordon Mills, le Capitaine ingénieur George L. Stephens (Chef naval de l'ingénierie et la construction) et le Capitaine Godfrey Hibbard. Faisant face au ministre se trouve le Maître de la solde Commandant Robert Pennington RCNVR (Secrétaire du conseil).

Un des aspects intéressant du Conseil naval fut qu'il comptait parmi ses membres le Chef naval de l'ingénierie et la construction. D'après le Service naval du Canada, "la nomination d'un officier de la branche génie comme membre du Conseil était à contre-temps de la politique et des traditions de l'Amirauté. Mais ceci avait auparavant été fait au Service naval Australien, et était apparamment en consonance avec l'importance toujours croissante des aspects techniques des activités navales Canadiennes.

DND Photo by WO Vic Johnson

Flame holds different meaning for two MARE torch runners

by LCdr Brian McCullough

When it comes to athletics, John Gruber and Fred Jardine are as different as night and day. Yet when the Olympic torch relay swung through Eastern Ontario in mid-December, each of these men — a retired MARE commodore and a serving combat systems engineer — donned official jogging suits and carried the Olympic flame one kilometre closer to Calgary for the opening of the winter games on February 13.

But the event which involved these two and more than 6,000 others in the pursuit of a common goal, also gave them the chance to achieve personal goals that were as different as the runners themselves.

When 55-year-old retired Commodore John Gruber carried the Olympic torch down from Parliament Hill on December 16, Day 30 of the flame's cross-Canada journey, he was testing himself.

Up until four years ago, the extent of his involvement with physical fitness was limited to the periodic fitness tests that were mandatory in the Forces. "My contribution," said Gruber, who retired as DGMEM in 1986 ". . . was to quit smoking at midnight to run (the fitness test) at eight o'clock in the morning."

Heart bypass surgery following a heart attack in early 1984 changed all that, and for him the Olympic torch run became something of a test of his recovery. "I had been doing exercise every day as a result of post-surgery, and it just seemed a good way of testing that whole process," he said. As he told The Kanata Standard last November, "It's a unique opportunity to participate in an event that only athletes would be thought of as doing."

Speaking from his Ottawa office, where he is general manager of the Canadian NATO Frigate Group Inc., Commodore Gruber said that "you will never see an opportunity like this again in a lifetime."

LCdr Jardine with his mother, Mary, and his sister Erin, 11.

For 30-year-old LCdr Fred Jardine, carrying the Olympic torch on Day 32 of the tour near Gananoque, Ontario meant taking a short time out from his Masters studies in electrical engineering at RMC. But for this self-professed enthusiast of amateur sports, it also meant seeing one of his wishes fulfilled.

"I've always been emotionally involved with things of this nature," said Jardine, a 1987 recipient of the CF Award of Aerobic Excellence. "I love athletics."

This isn't the first time Jardine's penchant for amateur sports has brought him into the limelight. At the Canada Games last year in Sydney, NS he refereed amateur freestyle wrestling, a sport for which he is a nationally rated official. And in the fall of 1986 he was one of 26 CF men and women who accompanied Rick Hansen on the Man in Motion tour through Nova Scotia. Jardine described that experience as "one of the premiere emotional highs" of his life. "I found that a very emotional trip," he said. "It was an exciting feeling."

Jardine said that some day he would like to referee at the Olympics, but admitted the possibility of that is pretty remote. He added that he has a more realistic, short-term goal of refereeing freestyle wrestling at the 1994 Commonwealth Games in Victoria.

For the moment, though, it's the Olympic torch run that has captured his enthusiasm, an enthusiasm shared by his wife. "I think it's a really good idea," Sarah Jardine said from their home in Kingston. "It's a good way of getting the country involved."

And as for Fred: "I was very very happy to be selected," he said, ". . . proud to be a part of the Olympic event. It was something I was keen to do."

DND Photo by Brad Lowe

News Briefs

Appointment of Chief, Submarine Acquisition

Rear Admiral John R. Anderson, C.D., formerly the Chief of Maritime Doctrine and Operations at NDHQ, has been appointed as Chief, Submarine Acquisition.

Appointed last September, Rear Admiral Anderson will personally direct the team of naval experts whose task it is to recommend to Ministers the design for Canada's future fleet of 10-12 nuclear-propelled submarines announced in the White Paper. Canada is currently considering two designs, the Rubis/Amethyste class from France and the Trafalgar class from the United Kingdom.

"Rear Admiral Anderson is appointed the Chief of a project which will have an immense impact on the future of our naval forces and indeed on the NATO alliance as a whole," said Defence Minister Perrin Beatty. "He will be required to consult extensively with his counterparts in other countries to gain the necessary information required to select the best submarine for Canada's maritime needs."

Bulletin d'information

Nomination du Chef du projet, d'acquisition de sous-marins

Contre-amiral John R. Anderson, anciennement le Chef, Doctrine et opérations maritimes, a été nommé au poste de Chef, du projet d'acquisition de sous-marins.

Nommé en septembre dernier, le contre-amiral Anderson sera à la tête de l'équipe d'experts de la Marine qui ont pour tâche de choisir le modèle des 10 ou 12 sous-marins à propulsion nucléaire dont le Canada fera l'acquisition, comme il a été annoncé dans le Livre blanc. Le Canada examine présentement deux modèles, soit un de la classe Rubis-Amethyste (France) et un de la classe Trafalgar (Royaume-Uni).

"Le contre-amiral Anderson sera le chef d'un projet qui aura de grandes répercussions tant pour l'avenir de nos forces maritimes que pour l'Organisation du Traité de l'Atlantique Nord dans son ensemble," a déclaré Perrin Beatty, ministre de la Défense nationale. "Il devra avoir des consultations suivies avec ses homologues d'autres pays afin de receuillir les informations qui permettront au Canada de choisir le sous-marin qui répondra le mieux à ses besoins maritimes."

New Shipborne Aircraft Project

Canada has moved an important step closer to replacing the navy's aging Sea King helicopter.

Following a comprehensive and detailed evaluation of submissions from European Helicopter Industries (Canada) Inc. and Canadair/Aérospatiale, the government decided last August to enter into negotiations with EHI (Canada) Inc. for the definition phase of the New Shipborne Aircraft Project (NSA).

The new aircraft, known as the EH101, will provide the third arm of the triad of the surface navy's ASW system which includes the Canadian Patrol Frigate and its primary sensing device, the Canadian Tactical Towed Array Sonar System. A wide range of sophisticated, computerized detection and information processing systems will enable the aircraft to detect hostile submarines, surface ships, aircraft and their weapons while operating with Canadian and NATO warships.

The British Royal Navy has already ordered 50 EH101s for their similar maritime role and Italy is expected to place an order for 36 EH101s. Canadian industry is already participating in the EH101 program by providing approximately $44-million worth of helicopter avionics and specialized castings for the European manufacturers of the helicopter.

EHI is expected to complete the definition phase by the end of 1989. At that time, the Government will make a decision whether or not to proceed with a production contract for up to 51 helicopters and associated support systems to meet the Canadian navy's maritime roles.

Projet du Nouvel aéronef embarqué

Le Canada a franchi une étape importante en vue du remplacement des vieux hélicoptères Sea King qu'utilise actuellement la Marine canadienne.

Après avoir fait une comparaison complète et détaillée entre les soumissions de l'European Helicopter Industries (Canada) Inc. et de la Canadair/Aérospatiale, le gouvernement a pris la décision en Août dernier, d'entamer les pourparlers avec HEI (Canada) Inc. pour l'étape de définition du projet du Nouvel aéronef embarqué (NAE).

Le nouvel aéronef, appelé EH101, constituera le troisième volet du système de défense ASM de la Marine, lequal comprend la Frégate canadienne de patrouille et son principal dispositif de détection, le sonar tracté canadien. Grâce à une gamme étendue de systèmes perfectionnés et informatisés de détection et de traitement de l'information, le nouvel aéronef sera en mesure de détecter les sous-marins, les navires de surface et les aéronefs ennemis ainsi que leurs armes, tout en manoeuvrant avec d'autres navires des Forces canadiennes et de l'OTAN.

La Marine royale britannique a déjà commandé 50 appareils, et l'on s'attend à ce que l'Italie passe une commande de 36 appareils. Le Canada participe déjà au programme du EH101 en fournissant pour environ 44 millions de dollars d'avionique d'hélicoptère et de pièces coulées aux constructeurs européens de l'hélicoptère.

EHI devrait avoir terminé la définition du projet à la fin de 1989. ce moment-là; le gouvernement décidera s'il doit conclure un contrat en vue de la production de 51 hélicoptères et de leurs systèmes de soutien, afin de répondre aux besoins de la Marine canadienne.

Phase One MOU Agreement

A memorandum of understanding was signed 19 October by the United States, Great Britain, Canada, Federal Republic of Germany, Spain and the Netherlands for the concept exploration phase of a NATO Anti-air Warfare (AAW) System Program. The purpose of this program is to improve the short-range AAW capability of NATO surface ships to be effective against the airborne threat, including anti-ship missiles in the late 1990's and 21st century.

The cooperative development will benefit from the pooling of technology of all participating nations. It will provide a fully integrated AAW system and have direct application to the NATO frigate replacement, other national new ship construction programs and backfitting into existing ship classes.

The NATO AAW program will be managed by an international program office comprising personnel from all participating nations and will be based in Washington, D.C.

Protocole d'entente — Phase 1

Un protocole d'entente a été signé 19 octobre par les États-Unis, la Grande-Bretagne, le Canada, la République fédérale d'allemagne, l'Espagne et les Pays-Bas en vue d'amorcer la phase d'exploration des concepts portant sur le programme du système de défense antiaérienne de l'Otan. Cette initiative vise à améliorer la capacité de défense antiaérienne des navires de surface de l'OTAN face à la menace aéroportée, y compris les missiles anti-navires qui seront mis au point à la fin des années 90 et au 21e siècle.

La mise en commun des technologies des pays participants sera très avantageuse pour la réalisation de ce programme. Ceci permettra d'élaborer un système de défense antiaérienne entièrement intégré et aura des répercussions sur le remplacement des frégates de l'OTAN, sur d'autres programmes nationaux de construction de navires et sur la remise à neuf de navires aujourd'hui en service.

Le programme du système de défense antiaérienne de l'OTAN sera géré par un bureau international situé à Washington (D.C.) et dont le personnel proviendra de tous les pays participants.

Mechanical Test Facility opens at SRUA

A new $2-million Mechanical Test Facility for testing naval pumps and compressors opened its doors at the Ship Repair Unit (Atlantic) in December. Designed by Black and McDonald Ltd. of Halifax, the fully computerized and automated facility comprises three separate cells for testing repaired units before they are re-installed on board ship. Until now repaired items have had to be put back into the ships and tested in situ, an expensive process should the testing indicate further repairs are necessary at the SRU. According to DGMEM Project Manager Mike Edwards, the MTF will give the SRU a much-needed vibration analysis capability, and will speed up repair turnaround times.

Une installation pour les essais mécaniques au SRUA

Une nouvelle installation de $2 millions pour les essais mécaniques sur les pompes et les compresseurs a ouvert ses portes au Ship Repair Unit (Atlantic) en décembre. Une conception de la maison Black and McDonald Ltd d'Halifax, l'installation est entièrement automatisée et comprend trois différentes sections pour entreprendre les essais sur les composants avant qu'ils soient montés à bord des navires. Auparavant les composants réparés devaient être montés à bord des navires pour y entreprendre les essais requis, une proposition qui s'avérait coûteuse quand les essais indiquaient que des réparations additionnelles étaient nécessaires. D'après le directeur du projet Mike Edwards, cette installation va donné au SRU les moyens nécessaires pour entreprendre des analyses de vibration, et va aussi réduire le temps requis pour effectuer les réparations.

Don Nicholson Retires

The Department's own "Mister Transmission" retired last September after 34 years' service as a civilian engineer with the Canadian navy. Internationally respected for his technical expertise with ship propulsion, marine gearing and propeller design, Don Nicholson left his mark on virtually every Canadian naval vessel type introduced since the Second World War.

Shortly before coming to Canada in 1953 at the invitation of the RCN, Nicholson was involved with an Admiralty study which led to the development of the Y-100 steam propulsion plant used by Britain and Canada in their first major destroyer construction programs after the war. Once in this country, he established a propulsion design section to support the *St. Laurent* Class and follow-on shipbuilding programs, and was very much involved with the development of the facilities and techniques required to produce Y-100 type machinery in Canada, particularly with respect to hardened, ground propulsion gearing and noise-reduced propellers.

Nicholson, a 1944 engineering graduate of Woolwich Polytechnic in England and a former Royal Navy engineer officer, built a reputation as a strong advocate of hardened and ground gearing in warship propulsion systems, and over the years supported his arguments with a number of published technical papers.

Among his noteworthy achievements, Nicholson confounded the dire predictions of some shipbuilders by developing an installation

Don Nicholson à la retraite

Le Monsieur Transmission du ministère a pris sa retraite en septembre dernier après 34 ans de service comme ingénieur avec la Marine canadienne. Étant reconnu à travers le monde pour son expertise technique dans les domaines de la propulsion navale et le développement des engrenages et hélices, Don Nicholson a apposé sa signature sur presque tous les navires canadiens depuis la deuxième guerre mondiale.

Peu de temps avant de venir s'établir au Canada à l'invitation de la RCN, en 1953, M. Nicholson fut à l'origine d'une étude qui conduit au développement du système de propulsion Y-100 employé par la Grande Bretagne et le Canada dans la construction des premiers destroyers après la guerre. Une fois au Canada, il a créé une section responsable du développement des agents de propulsion pour soutenir les navires de classe St. Laurent et les programmes de construction navale qui suivirent. Il participa aussi au développement des resources requisent pour la production des machines du type Y-100 au Canada, et plus particulièrement en ce qui attrait aux engrenages trempés et aux hélices à bruit réduit.

M. Nicholson, un gradué en génie en 1944 du Woolwich Polytechnic, Angleterre, et un ancien officier ingénieur de la Royal Navy, a bâti une réputation de défenseur des engrenages trempés pour les systèmes de propulsion des bâtiments, élaborant sont point de vue en publiant plusieurs articles sur ce sujet.

and alignment procedure by which the DDH-280 raft-mounted propulsion system would satisfy vital, afloat alignment criteria. More recently, he was instrumental in the CPF being fitted with the largest known application of cross-connect gearing for the sake of fuel and engine economy. Nicholson, who conducted lengthy research into the cause of the 1969 *Kootenay* gearbox explosion, said he personally regards the results of that research as the most challenging accomplishment of his career.

It's not everyone who can smile while he's being given the "shaft", *but Don Nicholson (right) accepted it graciously from DMEE 3 engineer Steve Dauphinee.*

Don Nicholson souri alors qu'il reçoit un "shaft" de l'ingénieur Steve Dauphinee DMGE 3.

Parmi ses réalisations on remarque que M. Nicholson a développé une procédure de centrage des arbres qui sont montés sur un train de machines à bord des navires DDH-280 afin de satisfaire les besoins d'alignement en mer. Plus récemment grâce à ses efforts, les Frégates canadiennes de patrouille seront équipées de la plus imposante installation d'engrenages contre reliés afin de réaliser des économies de mazout. M. Nicholson, ayant conduit de vastes recherches sur la cause de l'explosion des engrenages à bord du Kootenay en 1969, affirme que les résultats de ces recherches furent la plus grande réalisation de sa carrière.

Captain Bruce Baxter (DMEE) with Don and Stella Nicholson.

Le Capitaine Bruce Baxter (DMGE) en compagnie de Don et Stella Nicholson.

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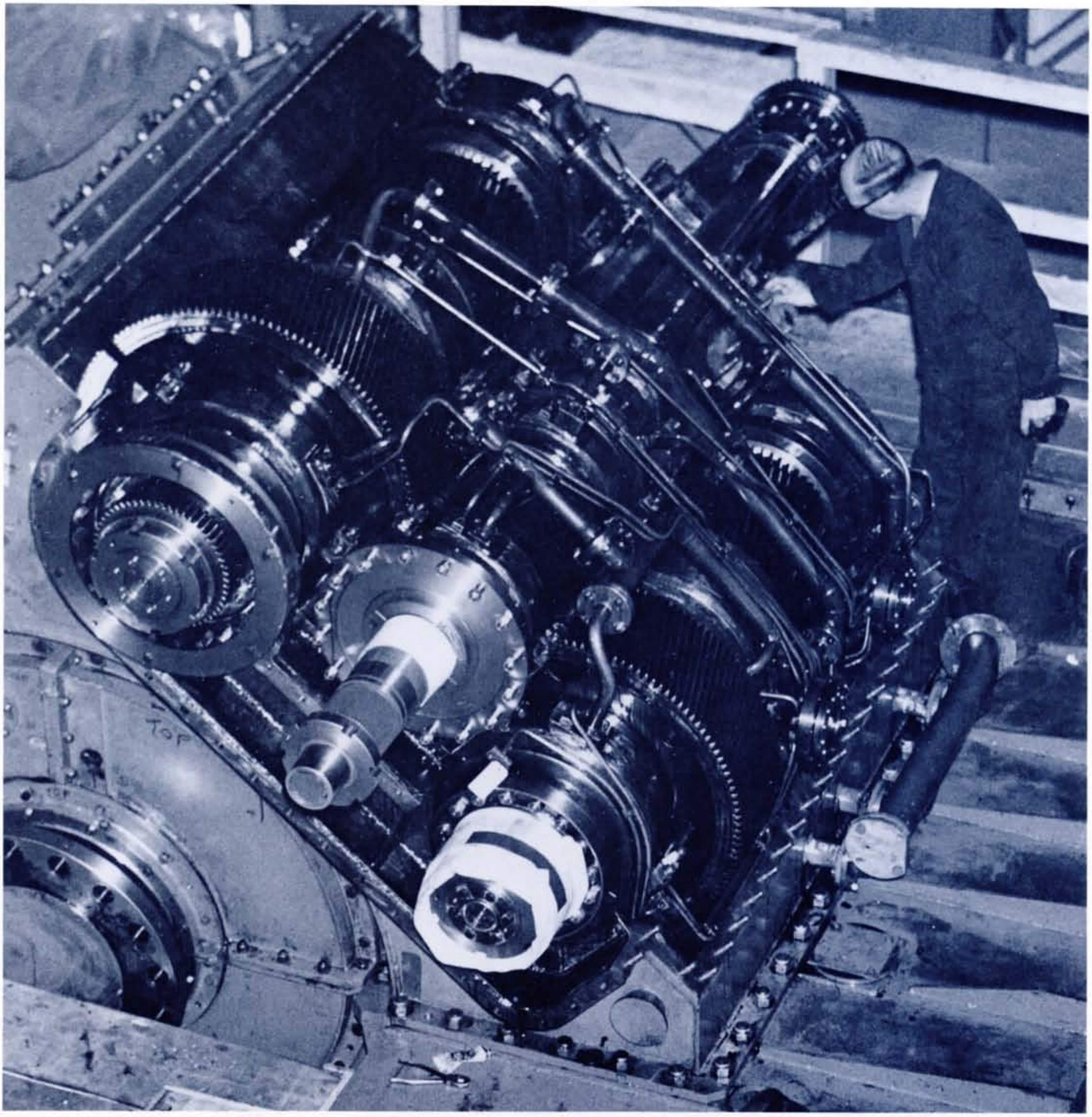
Naval Gearing...

Engrenages navals...



Coming up in our April issue

À venir en avril

MARE

DND Photo by Brad Lowe

MAREs carry the torch... page 36

Les G MAR portent la torche... page 36