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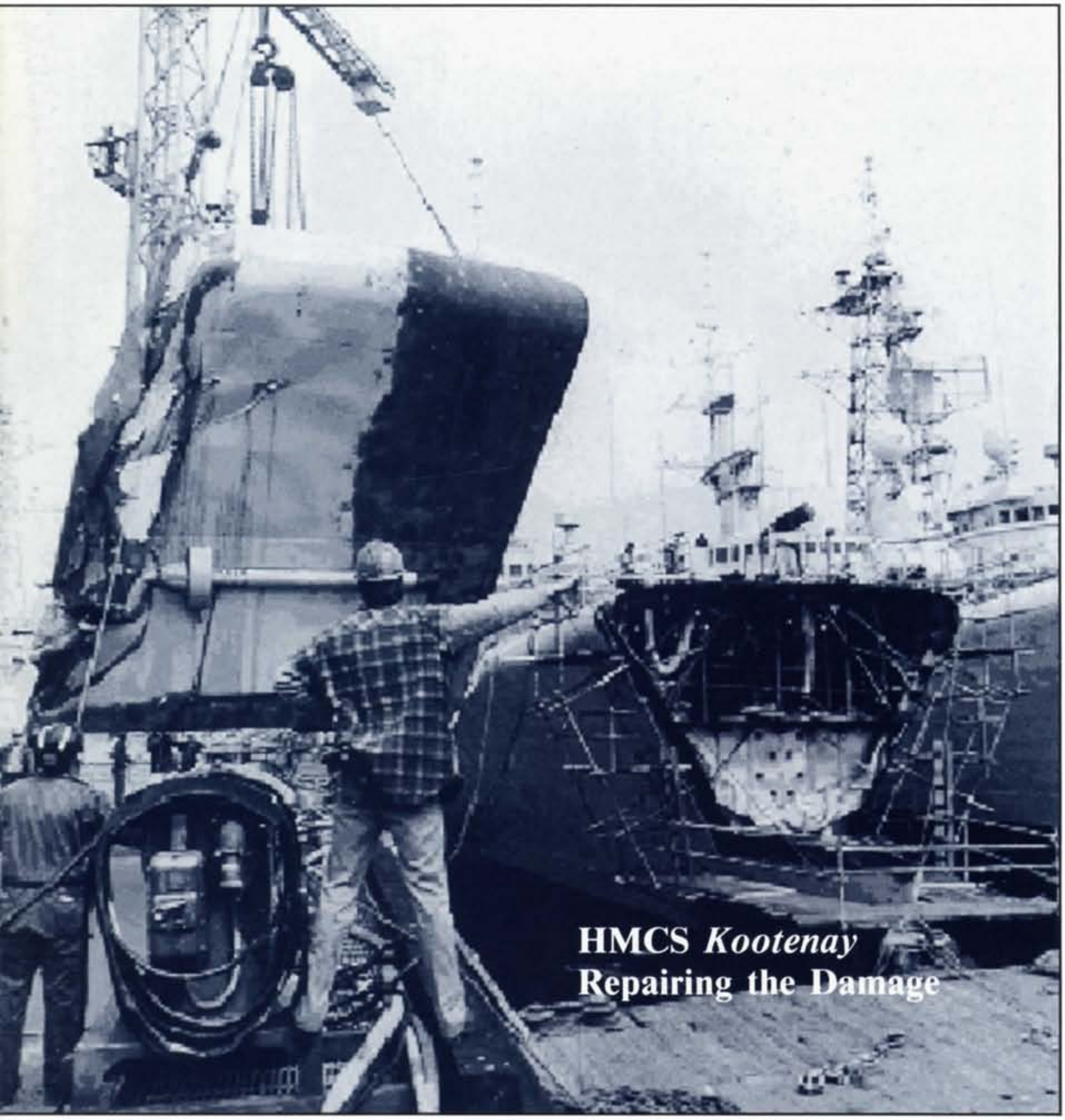
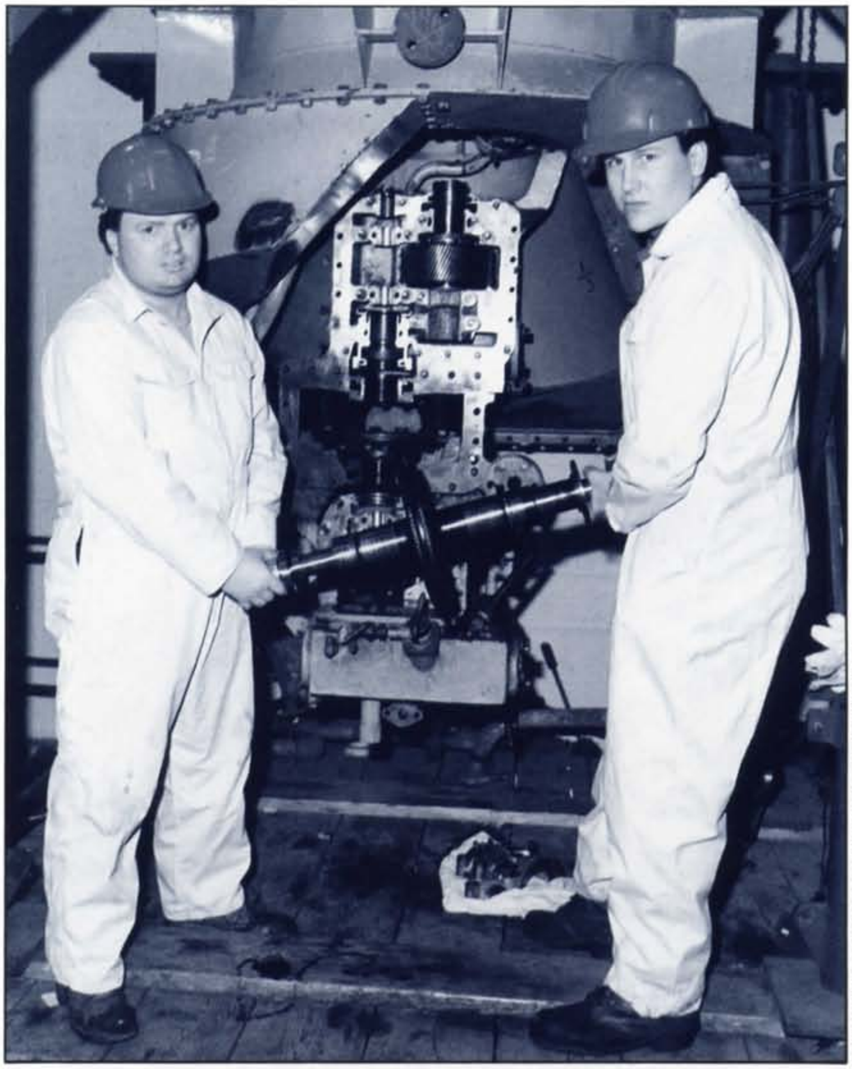


HMCS *Kootenay*
Repairing the Damage

Canada



CFB HALIFAX PHOTO by Cpl Steve McNeil

Turboblowers
What went wrong?

...page 10

Maritime Engineering Journal

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OUR COVER

HMCS *Kootenay's* crushed bow unit is landed for replacement two weeks after the destroyer collided with a 60,000-ton freighter off Cape Flattery last June. *(Canadian Forces photo)*

JANUARY / APRIL 1990

DEPARTMENTS

FEATURES

The Maritime Engineering Journal (ISSN 0713-0058) is an authorized, unofficial publication of the maritime engineers of the Canadian Forces, 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, MGen George R. Pearkes Building, Ottawa, Ontario, Canada K1A 0K2. The editor reserves the right to reject or edit any editorial material, and while every effort is made to return artwork and photos in good condition the Journal can assume no responsibility for this. Unless otherwise stated, Journal articles may be reprinted with proper credit.

Editor's Notes

Putting "Humpty" Together Again

East coast and west, our dockyards get the job done

When HMCS *Kootenay* collided with the bulk carrier *Nordpol* off Cape Flattery last June, some quick decisions had to be made regarding the repair of the destroyer's crushed bow. Although limited to forward of the collision bulkhead, the damage was extensive and would require that the bow unit be replaced or reconstructed.

Once the on-site inspections were made the repair options were fairly clear. The Ship Repair Unit (Pacific) could be requested to construct a new bow — an expensive, time-consuming proposition — or replace the damaged unit with an existing one. As chance would have it a sister ship, the decommissioned *Chaudiere,* was being stripped for disposal at the time of *Kootenay's* mishap. After some careful measurements were taken, a decision was made to undertake a bow-replacement job in the dockyard.

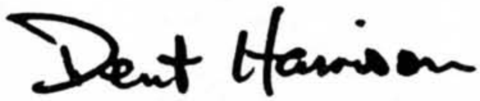
In our lead article, naval architects LCdr Vern Archibald and Lt(N) Doug O'Reilly take us on an interesting, well-illustrated technical walk-through of the *Kootenay* collision repair. One thing that struck them was the excellence of the work done by the dockyard in Esquimalt. And that's the other side of the story, how the various dockyard agencies worked together to put "Humpty" together again.

Many people are unaware of the amount of dedication and cooperation that went into making the *Kootenay* repair a resounding success story. But it's a fact that many of the dockyard refit crew from HMCS *Terra Nova* were called in to put *Kootenay* to rights as quickly as possible. And that kind of thing takes some doing.

The same element of people power came out in the "*Huron* Underwater Propeller Change" article we ran last September. The Fleet Diving Unit, assisted by the dockyard, tried something new, gave it their best effort and in the end had something positive to show for their efforts. And in the second article of this month's issue, we go to Dockyard Halifax for the remarkable story of how a group of equally determined people sorted out the fleet's long-standing turboblower troubles.

In each of these articles we get a glimpse of the importance of the human factor in keeping our fleet operational, something that is too often overlooked and underrated. So here's a tip of the hard-hat to all the men and women of the dockyard units, laboratories and shops for their part in getting the job done well.

Bravo Zulu!



Letters to the Editor

Dear Sir,

I feel I must rebuke some of the statements in Cdr Cyr's *"Proposed Naval Combat Trades' Structure for the 1990s"* (MEJ: September, 1989, page 27).

When MORPS was implemented in 1985 for NE Techs it was to serve the fleet of the future, not the present alone.

The variety and complexity of specific discipline equipment requires more than a technician with a "Tech Course." It requires in-depth theory and an understanding of total systems.

Because Fleet School Halifax has yet to develop the QL6B steady state "Systems Technician Course," I find it hard to understand why Cdr Cyr has so harshly criticized this product by saying it is unsuited for the future fleet. We have yet to see it.

He is quite correct in alluding to the fact we are running out of our most highly qualified maintainers, however it is not because their professional qualifications are going unrecognized. If one were to tour the prime and subcontractors for the patrol frigate, the missing professionals would be found in large numbers wearing civilian suits in lieu of salt and pepper. The fact that private industry recognizes our in-house expertise and the navy does not may indicate an attitude problem, not a training problem.

Cdr Cyr tries to draw a parallel between his Combat Systems Engineering Technologist (CSET) and the METTP training program. The METTP produces a quality product but it does not solve the problem for which it was started, namely to produce engine-room tickets more quickly. The program has produced MARE officer candidates and UTPM candidates, but not too many Cert 3As.

At this present time training of Naval Electronic Technicians is being closely scrutinized by MARCOM and NDHQ OPIs in the hope of streamlining, not eradicating or altering to a great extent, the training. Community college training is one of the options but this is dangerous ground. If the member is trained to the technologist level he becomes an excellent candidate for commissioning as a CSEO and is lost by the technical MOC for which he was trained. If he is undertrained he is of no use. Before we lose sight of why community college training was even considered, let me say it is because we have an urgent requirement to produce QL6A technicians, not necessarily a more highly trained technician.

When Paramax was designing the training package for CPF technicians, the terms of reference were the MOC trade specifications and training qualifications the NE Techs presently have. Technical training has commenced with the graduates being able to perform maintenance duties on the next generation of HMC ships.

Cdr Cyr would like his technologist graduates awarded the rank of master seaman upon entry. Rank is not awarded, it is earned. If his reasoning for doing this is pay, then he should have addressed that problem separately. Leadership is as much a part of being a naval technician at the system level as is training, a fact the navy may be slowly losing sight of. If leadership is foregone at the entry and journeyman level, do not be surprised if it is still lacking at the chief and petty officer ranks.

I do not think Cdr Cyr has reached a reasonable conclusion or researched his material in enough depth. There are a myriad of problems in the NE Tech community at this time, but jumping to conclusions, assuming results and judging an unforeseen product are not solutions. They merely create more problems.

G.W. Ferrall
CPO1
NET(S) 286

Commodore's Corner

By Commodore E.R. Murray

When last I wrote in this journal I was headed for the Royal Military College and yet another non-engineering position. Despite my assumptions, I realized soon after my arrival that I knew very little about RMC. As time progressed I found that most officers in the Canadian Armed Forces, even those who have attended RMC, are unaware of the breadth and depth of activity here and its relation to naval engineering. I will therefore give you a naval engineer's perspective of Canada's premier military college.

RMC has always been a naval place. Two hundred years ago the naval dockyard for the Great Lakes was established on Point Frederick. This was an important centre of naval activity, particularly during the war of 1812 when warships as large as any in the world were built on the slips at Point Frederick. A commodore's pennant flew over Point Frederick from 1789 until 1846.

I live in the oldest building on the Point, the original naval hospital built in 1813. Buildings from this early period can still be seen on the point, the most prominent being the Stone Frigate. Originally constructed as a storehouse in 1825, it became the first barracks for RMC and is still used as such. For a short period it was commissioned HMCS *Stone Frigate* while it housed the Royal Canadian Naval College, and is still known as "The Stone Boat."

The naval presence on Point Frederick since the establishment of the Royal Military College in 1876 has been slight until recently. I am only the third naval officer to be Commandant — my predecessor left 17 years before my arrival. The small number of serving and retired naval officers on the staff include: the Principal, Capt(N) John Plant (a retired MARE); the Registrar (an ex-Pusser); two MAREs and a USN officer who are engineering lecturers, and about a dozen others. Only two MAREs are among the 23 military lecturers in the faculty of engineering. Nevertheless, there is definitely a naval quality to the College now. In fact, RMC is regularly referred to by the cadets as the Royal *Maritime* College.

RMC has a long connection with the engineering profession, having always been primarily a school of engineering. Seventy-five percent of today's students study engineering, and the College graduates three percent of all the engineers each year in Canada. Although the naval presence at RMC is relatively small, the College is critically important to the naval engineering profession. It is the main source of our undergraduate educated officers, an important source of our postgraduate degrees, and its research program contributes to the naval program. RMC's importance as a source of naval engineers can be seen in the current composition of the MARE Branch: 50 percent of the commanders, 13 of 17 captains and three of five commodores are ex-cadets. In recent years more than 50 percent of all new MAREs have come from RMC.

RMC is an important source of postgraduate education, both in studies leading to a Master's degree and in short courses for professional upgrading. Last year, for example, the College conducted two nuclear "acquaint" courses for some 70 naval officers and DND civilians, and by May 1990 ten MARE officers will have completed their Master's degrees in nuclear engineering.

Of the short courses available, Electro-Optics, Computer-Aided Design, Reliability and Maintainability, Engineering Maintenance Management, Computer Systems and Corrosion Control are of direct interest to MARE officers. RMC's supporting laboratory facilities are some of the best in Canada such as the eight in the Electrical Engineering Department: communications, microprocessors, microwave and radar, control systems, robotics, power, electronics, and software engineering and graphics. Computer support for engineering research consists of a mainframe, microprocessors and 38 Apollo workstations. Graduate courses of particular interest to MAREs include: Advanced Radar Systems; Digital Communications; Systems, Networks and Computation; Optimization in Control; Advanced Topics in Power; and Software Engineering and Management.

The graduate studies program at RMC is complemented by a strong research program, fully 90 percent of which is in support of DND. A significant portion of the program is in direct or indirect support of the navy, nuclear research being the best known in recent years (RMC is one of only six Canadian universities with a nuclear reactor). However, there is important activity in a variety of subjects of interest to the navy such as ship's structures, sonar signal processing, ICE combustion, electro-optics, robotics, artificial intelligence, active and passive gun recoil systems, batteries, fuel cells and radiation-based NDT. RMC is the only university still active in gas turbine research, with current interest being focused on turbomachinery aerodynamics.

Thus far I have outlined how RMC contributes to the navy and naval engineering in particular. But RMC's principal role is to produce leaders, education being but one component of leadership development. My background as a MARE has been excellent preparation for commanding this combined university and officer training establishment. (The Royal Navy must have come to the same conclusion as the new commanding officer of RNC Dartmouth is also an engineer.)

I have now been Commandant of RMC for almost two and a half years, and it has been a marvellous experience. It has certainly produced a whole new basket of challenges, but as I said in the September 1987 issue of the *Journal*, naval engineers are well prepared to deal with the new and unexpected. I traded dockyard mateys for professors, but the fundamentals of dealing with people are still the same. Dealing with cadets, however, makes running a refit seem easy! I never imagined what being surrogate father to 700 other people's children would be like, and I certainly haven't found it boring!

Returning to RMC as Commandant has been something of a voyage of discovery for me, the most important revelation being that the College is a great institution which plays a key role in support of the navy. I have visited officer training establishments in the USA, Britain, Australia, New Zealand and Turkey, and can assure you that we Canadians do the job very well indeed. Academically RMC is the best engineering college in the country, producing a Rhodes scholar on average every two and half years from a graduating class of less than 200! The engineering education here aims at breadth, so that our graduates are well prepared for more than just the technical side of life. Consequently, RMC's engineers spend one third of their time on arts subjects and graduate less than one year short of a Bachelor of Arts degree.

It is important in my view that we MAREs take a keen interest in ensuring that RMC maintains its high standards and continued support of the navy. One of the most effective ways of achieving this is to maintain and, if possible, increase the presence of MARE officers on the staff and in the graduate studies program, as well as by taking advantage of the research capabilities and short courses. We are currently under-represented relative to the other engineering classifications, and when I leave we will be left with only the Principal and two MARE officers on the academic staff to represent naval engineering interests. In the words of a senior politician, "Use it or lose it!"

I therefore encourage those of you who are junior officers to seriously consider RMC as a possible posting either as a military Wing officer or an academic lecturer. To the more senior MAREs, I encourage you to take advantage of RMC as a source of support for novel programs and education. We are not as involved in this great institution as we should be.

Commodore Murray is Commandant of the Royal Military College at Kingston.

MARITIME ENGINEERING JOURNAL OBJECTIVES

- To promote professionalism among maritime engineers and technicians.
- To provide an open forum where topics of interest to the maritime engineering community can be presented and discussed even if they may be controversial.
- To present practical maritime engineering articles.
- To present historical perspectives on current programs, situations and events.
- To provide announcements of programs concerning maritime engineering personnel.
- To provide personnel news not covered by official publications.

WRITER'S GUIDE

We are interested in receiving unclassified submissions, in English or French, on subjects that meet any of the stated objectives. Final selection of articles for publication is made by the Journal's editorial committee.

Article submissions must be typed, double spaced, on 8 1/2 × 11" paper and should as a rule not exceed 4,000 words (about 17 pages). The first page must include the author's name, address and telephone number. Photographs or illustrations accompanying the manuscript must have complete captions. We prefer to run author photographs alongside articles, but this is not a must. In any event, a short biographical note on the author should be included with the manuscript.

Letters of any length are always welcome, but only signed correspondence will be considered for publication.

HMCS *Kootenay* Collision Repair

By LCdr H.V. Archibald and Lt(N) J.D. O'Reilly

CF photos by MCpl Denis Lepage, except where noted.

In the foggy early morning hours of the 1st of June 1989, KMCS *Kootenay* and the 60,000-ton bulk carrier MV *Nordpol* collided off Cape Flattery at the western entrance to the Juan de Fuca Strait. *Nordpol* sustained minor penetration of the side-shell on her starboard bow (*Fig. 1*) and *Kootenay* had her bow crushed back approximately 16 feet. Only minor personnel injuries occurred and both vessels were able to return to port unassisted.

Upon arrival at Esquimalt, *Kootenay* was immediately surveyed by a team of inspectors from the Naval Engineering Unit Pacific (NEUP). It was determined that the damage was limited to the structure forward of the ship's collision bulkhead (Frame No. 2). The bow had been crushed back (*Fig. 2*) starting from the upper starboard corner of the bulkhead, across the upper deck at approximately 30° and down at a 65° angle to a point on the stem 12 in. above No. 3 deck. The clear geometry of the damage was due to the angle and flare of *Nordpol's* bow and the relative positions of the vessels at the point of impact (*Fig. 3*).

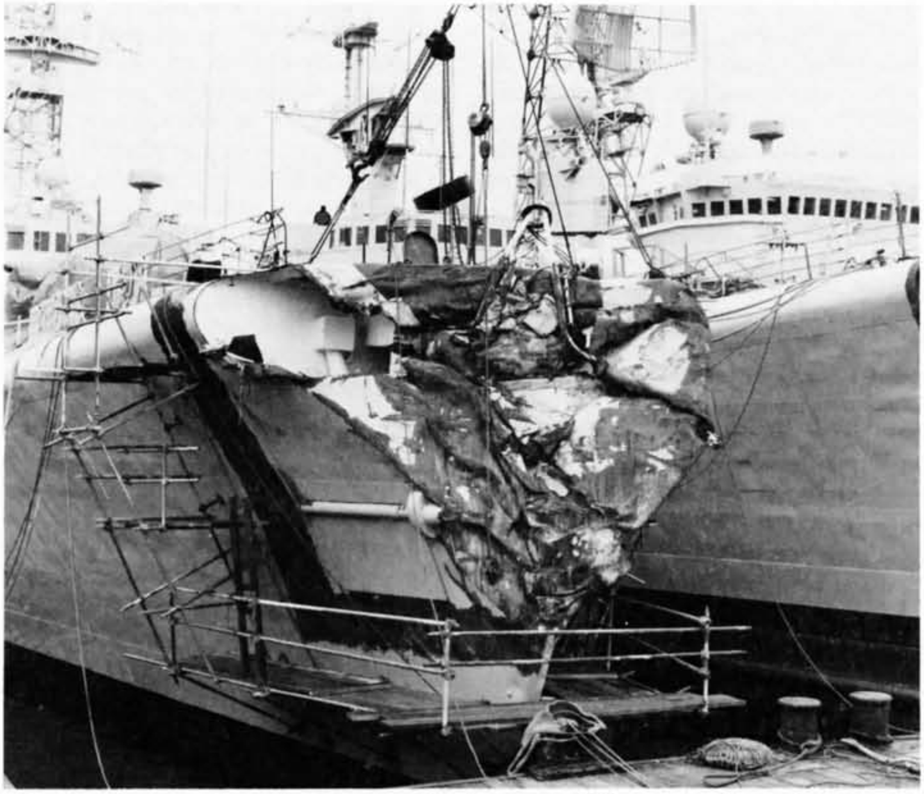


Fig. 2. *Kootenay*'s crushed bow section is prepared for removal. No damage was sustained abaft the collision bulkhead.

Repair Solution

Dockyard was presented with a rare opportunity to perform repairs of a magnitude which could be expected in wartime. One repair option was to construct a new bow. Dockyard had some experience in bow construction with *Terra Nova* and *Chaudiere,* but not to the extent of repair required in *Kootenay*. Such a task would be expensive and time consuming, and would necessitate furnacing (heating) the steel plating for the round-down (which was not within the capability of the Ship Repair Unit — SRUP).

Chance provided a second option. A sister ship, *Chaudiere*, was being stripped in Esquimalt prior to disposal. As *Kootenay*'s damage (*Fig. 4*) was limited to one of the ship's original prefabricated units (No. 31), it was considered feasible to exchange bows. The process would be similar to the original construction method and was the preferred option if alignment of the unit proved possible.

Chaudiere and *Kootenay* were built from the same construction drawings. However, as *Chaudiere* was built in Vancouver and *Kootenay* in Halifax, it was necessary to verify that the dimensions of the two prefabbed units were within tolerable limits. Datums were set

Fig. 1. Bow section of the MV *Nordpol* following the collision. A crumpled piece of *Kootenay*'s steel plating protrudes from the gash.

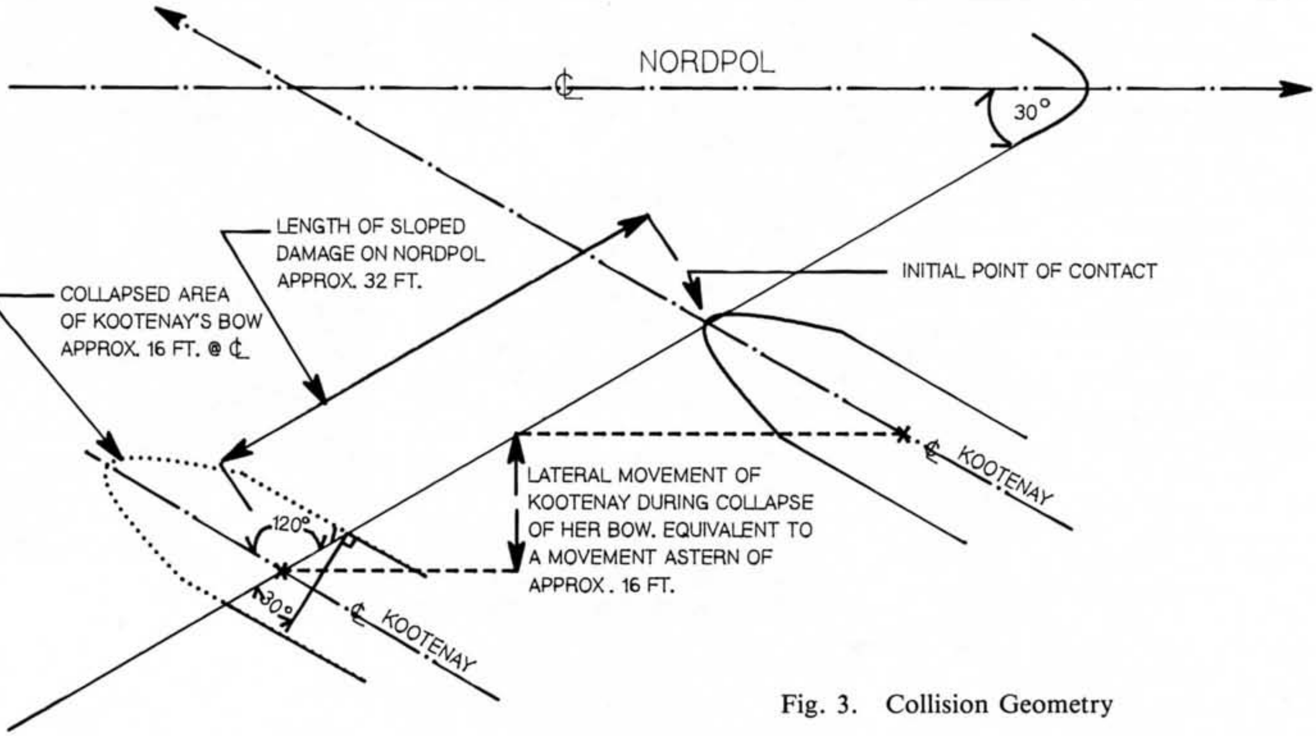


Fig. 3. Collision Geometry

up on both ships just abaft the collision bulkhead, using Frame No. 3 as a longitudinal reference and the upper deck as a vertical reference. FR 3 was chosen to ensure the reference point was well removed from the damage and any possible misalignment. The upper deck was used since alignment of the round-downs was considered critical. NEUP draughtsmen, using batons, took measurements from the datums to all the longitudinals and frames. Measurements were also taken between frames and longitudinals. Templates were then made of the port and starboard round-downs, and of the stem just above 3 deck.

All measurements and templates indicated a surprisingly close fit. The only areas significantly out of agreement were:

a. Starboard round-down was out approximately 3/4 in. in places;

b. No. 2 deck was approximately 1-1/2 in. higher on *Kootenay* than on *Chaudiere;* and

c. No. 2 WTB was approximately 1-1/4 in. further aft on *Kootenay* than on *Chaudiere*.

As internal alignment was not considered critical, neither of the misaligned areas (b. and c.) presented a major problem in repair. The round-down (a.) was a more serious concern, but the feeling was that the bow sections could still be faired to an acceptable fit.

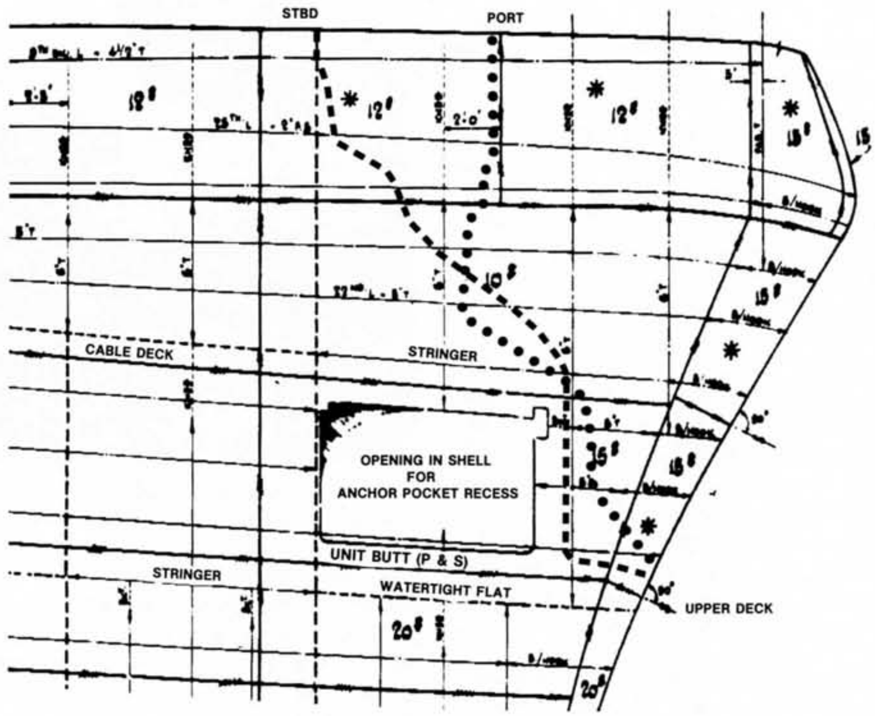


Fig. 4. Structural Damage Profile

Exchange of the Bows

The ships were placed side by side and the bow sections prepared for removal. *Chaudiere*'s bow section was cut 3 in. proud of the unit butt to allow a margin for trim during alignment. Following removal of the bow unit on the 9th of June, the longitudinals were cropped back to 4 in. and 7 in. forward of the butt on the deck and side-shell respectively. The frames were cut 3 in. proud of the seam. *Kootenay*'s bow was cut along the butt joint of pre-fab unit 31. The longitudinals were cropped back 12 in. and 20 in. from the cut along the deckhead and side-shell respectively. The frames were cropped back to 3 deck. The damaged bow was removed (*Fig. 5*) on the 13th of June.

Cropping back the longitudinals in both the ship and new bow unit was a departure from original construction methods. To properly integrate the structure, longitudinals and frames should have been left proud of the main hull. However, this was not done for three reasons. First, considerable fairing was anticipated due to the minor misalignments indicated by the initial measurements. Removal of the longitudinals on both sides of the unit butt reduced the hull stiffness, easing the process of shifting and aligning shell plating. Second, as the method proposed for aligning and trimming required the bow unit to be brought in close the main hull, proud longitudinals would have been of considerable hindrance. Finally, new stiffeners could be fitted with a gradual transition between units to take up any misalignment in the longitudinals or frames.

In preparation for initial trimming of the bow unit, brackets were welded along the lower seam on *Kootenay*. Eight lugs were welded to the bow unit, four on the upper deck and two on each side. On the 22nd of June the 13-ton unit was lowered between the brackets and butted up close against *Kootenay*'s main hull (*Fig. 6*). Using batons, the distance between FR 3 on *Kootenay* and WTB 2 on the bow unit was checked. The unit was shifted using chain blocks until the distance was the same all around FR 3, and the centre of the unit was in line amidships. A 3-in. block was run along the edge of the *Kootenay* butt to mark the excess material to be removed from the bow unit.

Following the removal of the excess material the bow unit was again brought in tight against the main hull. The fit was checked and small amounts of final trimming were required to bring the total length of the butt together. Prior to removing *Kootenay*'s bow, sighting points had been set up on Frames 2, 4 and 7. Similar sights were subsequently placed on *Chaudiere* at FR 2 and the forward perpendicular, enabling the rise of the new bow unit to be verified as acceptable. Finally, the alignment was checked visually to ensure all was aesthetically correct.

Fairing and Welding

Fairing the shell plating was achieved by welding an L-shaped bracket to whichever was the lower of the two plates on either *Kootenay* or the bow unit (*Fig. 7*). A wedge was then driven under the open end to force the proud surface into line. Once in line, the plates were tacked together. The process was started on the upper deck amidships and proceeded outwards. This drove any "wrinkles" out to the sides and down to the bottom of the unit where they would be trimmed off. The deck, round-down sides and lower seam of the unit were all eventually faired to the main hull. The only minor problem area was at the stem where the bottom of the new bow section was slightly proud. A cruciform was therefore cut at the stem. Excess material was removed from the legs and the stem welded together.

Fig. 7. Fairing the hull using L-brackets.

Fig. 5. As the bow section is landed on B Jetty, the 65° line of damage is clearly visible. (*Photo by R.L. Hopkins, QHM Esquimalt.*)

Once the bow unit was faired, the final welding to the main hull commenced. A welding sequence was devised by dividing the butt into nine sections and having three welders work simultaneously. To prevent distortion and maintain alignment during the welding process, strongbacks were positioned across the weld-line at short intervals (*Fig. 8*). On one side of the weld-line the strongbacks were temporarily welded in place, and on the other side were wedged hard against the deck. This arrangement allowed for longitudinal expansion during welding, but did not allow distortion.

The misaligned No. 2 WTB was corrected by cutting out the lower 3 ft. - 4 in. section of the bulkhead on the new bow unit. A new section was inserted to provide structural continuity between

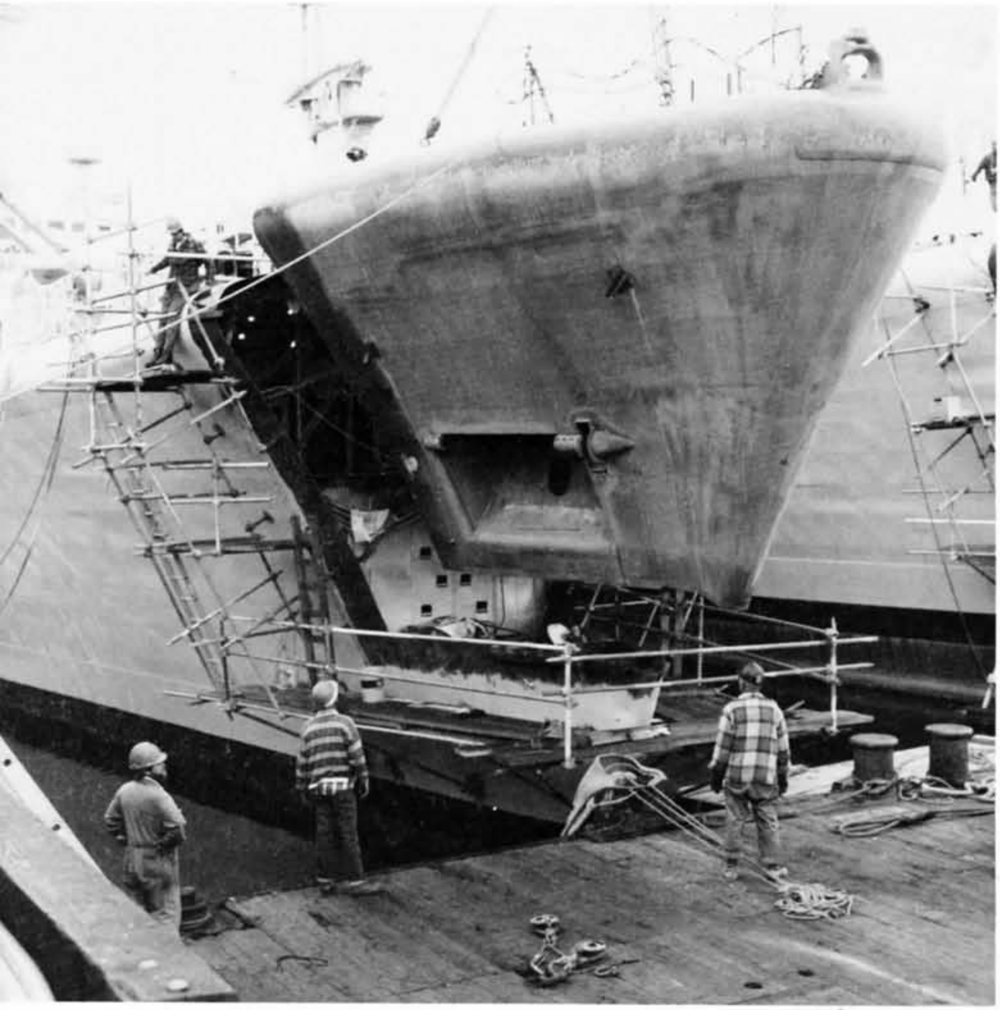


Fig. 6. The "new" bow unit from *Chaudiere* is lowered onto *Kootenay*.

Fig. 8. Preparing for final welding, strongbacks are welded and wedged into slotted brackets on either side of the weld-line to prevent distortion.

the top and bottom and welded into place. The misaligned No. 2 deck from abaft the collision bulkhead to the main hull butt was removed and a new section fabricated. All welding was completed by the 6th of July.

The finishing touches were applied by the 25th of July and the job was completed as originally scheduled. The work performed by NEUP and SRUP was excellent. The ability of our dockyards to undertake abnormal and technically difficult tasks quickly and efficiently was once again clearly shown. The incident also further demonstrated the excellence of the original bow design. *Kootenay*'s bow absorbed tremendous energy, yet collapsed only as far back as the collision bulkhead, which remained intact and preserved the watertight integrity of the ship.

LCdr Archibald, formerly head of NEUP's Naval Architecture Division, is the Project Naval Architect in PMO CASAP in Ottawa.

Lt(N) O'Reilly is Ship Architect for the Naval Architecture Division at NEUP.

The Trouble with Turboblowers

By LCdr Kevin Woodhouse

It all began innocently enough in April 1987 with a telephone call from a colleague in Esquimalt. Were we in Halifax having any problems with Y-100 turboblowers? Apparently, the West Coast fleet had experienced four failures in as many months.

A search of NEUA files produced nothing — even calling upon the unit's "corporate" memory drew a complete blank. In 10 years or more there was not a single report of any failure. The West Coast problem seemed like a string of coincidences, which sometimes occurs. Becalmed in complacency the "problem" slipped to the back of the mind, leaving us quite unprepared for what was about to happen. Over the next year and a half 26 turboblowers would fail, throwing the logistics world into overload as the navy worked non-stop at juggling spares, ships and manpower to meet its commitments.

The failures were irritatingly unaccountable, occurring as they did at random under a wide variety of conditions, with little regard for occasion. Turboblowers failed while in the steady state at sea; during ship manoeuvring at low, intermediate and high speeds; entering and leaving harbour; and once during a full-power trial. One even failed in the early stages of a basin trial. The only thing that connected the failures was, in each case, a bent turbine rotor.

The severity of the rotor bends and the speed at which the failures commenced determined the extent of physical damage sustained by the rest of the machine. Some rotors had bent in one direction only. Others, in a most bizarre fashion, had bent in two diametrically opposite directions, as if they had been fixed at either end and flexed from side to side at the centre. Even stranger, some rotors had bent, damaged the stator, and gone straight again.

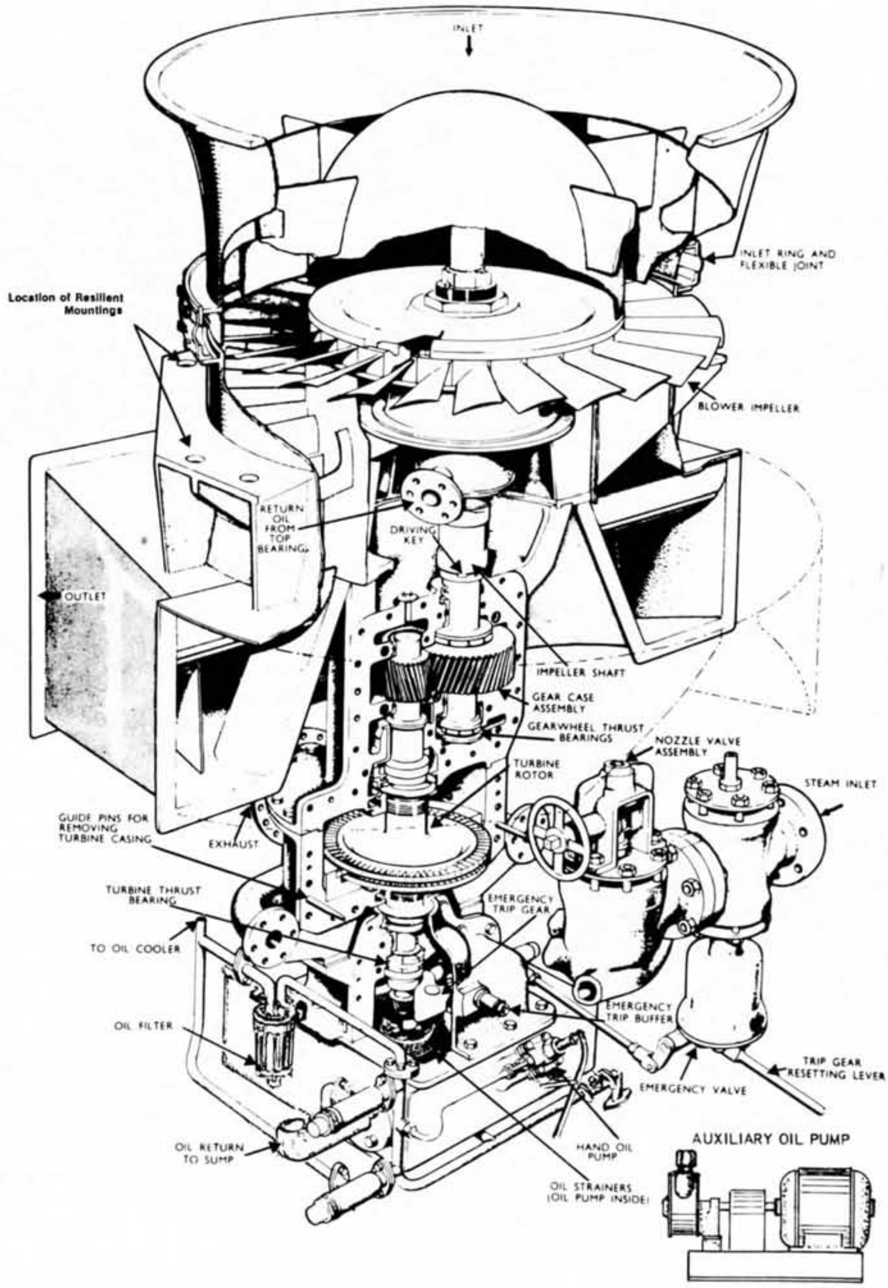


Fig. 1 Y-100 Turboblower General Arrangement

To get to the bottom of this conundrum we eventually had to go back 20 years or more in Y-100 turboblower history, and simultaneously engage ourselves in state-of-the-art x-ray diffraction technology. The painstaking search for clues would be done under the sustained pressure of having to provide fully operational units from ever-dwindling resources.

Design of the Turboblowers

The Y-100 turboblowers (*Fig. 1*) were originally designed and manufactured by WH Allen of Bedford, England. They first entered service in the mid-1950s in the Canadian *St. Laurent*-class destroyers and the *Whitby*- and *Rothesay*-class frigates of the Royal Navy. Later they were installed in the RN *Leander*-class frigates and all Canadian Y-100 steam destroyers. There are presently 17 Canadian Y-100 warships, each with two turboblowers installed.

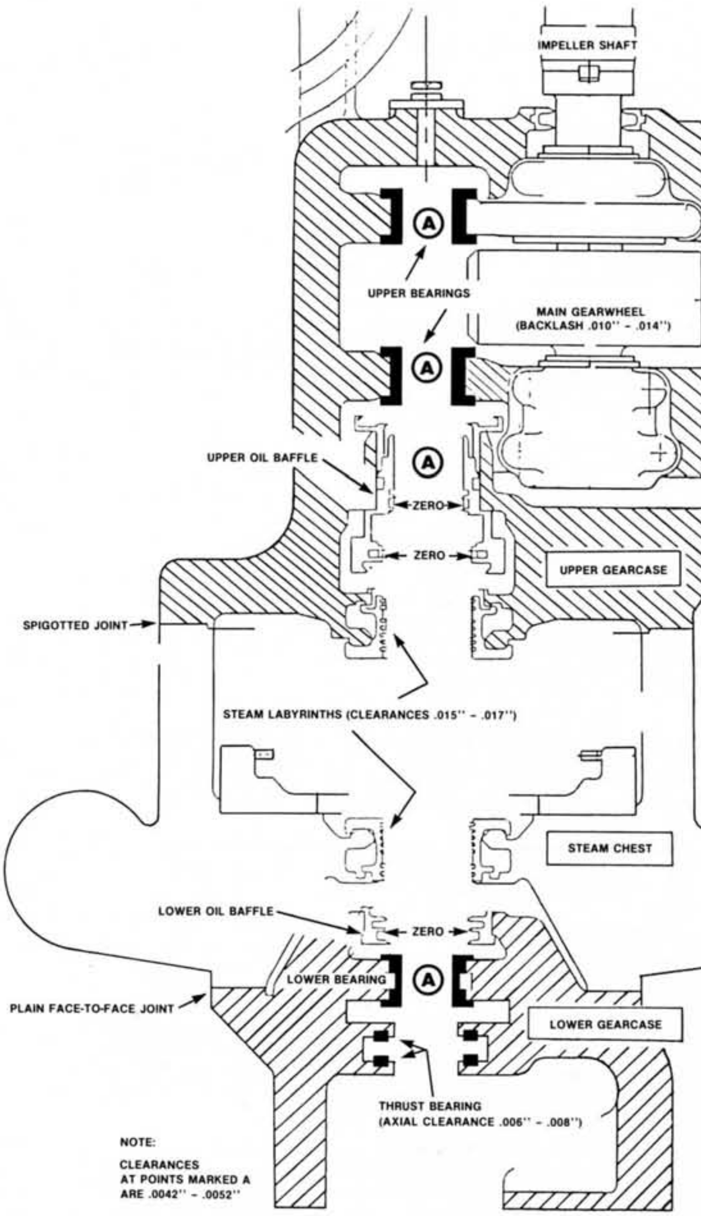


Fig. 2 Y-100 Turboblower Casings with Rotor Removed — 3 Casings and 2 Joints

The turboblowers provide combustion air for the two Y-100 boilers in each ship, drawing air through ducts in the superstructure and passing it through trunkings to the boiler casings. The blower fan (impeller) is a single-stage, axial-flow type driven by a two-row curtis wheel steam turbine through single-reduction helical gearing. Using 550 p.s.i. superheated steam (825°F) at a rate of 8,000 lbs/hr, it can produce a maximum of 65,000 cubic feet of air per minute at 4,750 impeller r.p.m. and 13,614 r.p.m. at the turbine. Each Y-100 turboblower measures eight feet high, six feet across and weighs in at about 1-1/2 tons.

The turbine rotor is manufactured from forged carbon steel. There are three journals, one on either side of a single-helical pinion at the top, and a third at the lower end of the rotor. To prevent steam from leaking into the machinery space, labyrinth glands are machined on either side of the turbine disc, and moisture-excluding oil thrower rings sit outside the labyrinths. There is also an upper oil baffle and lower oil seal. A thrust collar is fitted at the lower end to ensure axial location and this is adjacent to a double-ring overspeed trip mechanism. An auxiliary drive shaft, driven by a single-helical pinion is fitted at the bottom of the unit.

Rotor Casings

A more detailed examination of the turbine casing exposes a complex assemblage (*see Fig. 2*). The stator casing is comprised of three separate sections bolted together at two horizontal flanges. The upper section houses the gearing, the lower section the auxiliary drives and overspeed mechanism. The central section comprises a steam chest, housing the turbine stator nozzles and lower steam labyrinth.

It is important to take note of the two joints which connect the three casings. The upper joint is spigotted, the lower joint is not and only has two securing bolts to maintain positive location in the horizontal plane. The significance of the triple bearing arrangement is of leading importance too. The upper bearings on either side of the pinion are in the upper gearcase, but the lower bearing, fitted at the other end, is in the lower gearcase. Oil baffles, seals and labyrinths are also fitted into the casings.

All the damage observed in each failure was confined to the turbine rotor and those stator elements with which it had come into contact. The impeller fan, main gearwheel and impeller shaft have been unaffected by any of the failures, except the most severe, where slight damage was done to the main gearwheel by some broken pinion teeth.

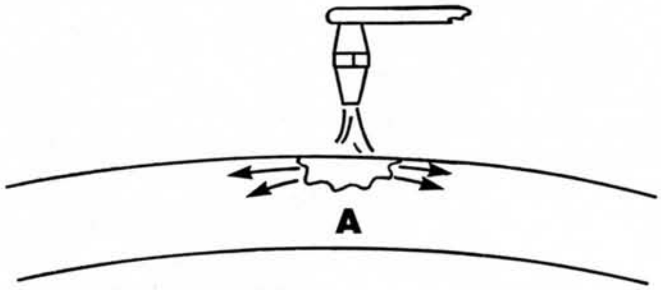
Overhaul and Repair

The Stator Casings

The bulk of the failures during 1987 and 1988 took place on the East Coast (Halifax-based) ships. Only five failures were recorded on the West Coast (Esquimalt-based) ships. One significant difference was that the naval dockyard at Esquimalt held a spare turboblower stator casing, complete with spare turbine rotor, fully shop-overhauled and available to R&R in a refitting West Coast ship. The East Coast ships, often being refitted in the province of Quebec — 800 km from the Halifax dockyard — would receive in-situ turboblower reconditioning to replace bearings, labyrinths, oil seals and turbine rotor, all matched and aligned to the main gearwheel without removal of the casings.

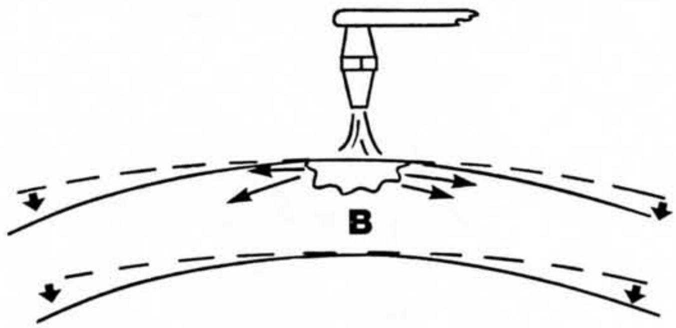
The blower installation in the Canadian Y-100 configurations is quite different to that of the British counterpart. The Canadian blower casing is underslung from the boiler-room deckhead. The upper section of the trunking passes through the deckhead, thereby making the upper impeller bearing housing a virtual part of the ship's superstructure. Sited above the blower intake trunking is a helicopter hangar. From the lower end the unit is not easily accessed, by virtue of its height above the reserve feed-tanks sited immediately below. To gain reasonable access to the upper part of the turbine it is necessary to build staging in the boiler-room.

As such, it is impossible to remove the complete unit from the ship without major surgery. Consequently the practice developed during ship refits of conducting in-situ overhauls of the unit. It is important to remember that the triple bearing configuration comprises three thick-walled whitemetal plain bearings. These are hand-scraped and hand-fitted to an alignment mandrel which, itself, must match another mandrel set in the fan impeller bearings. Once this has been achieved, grinding

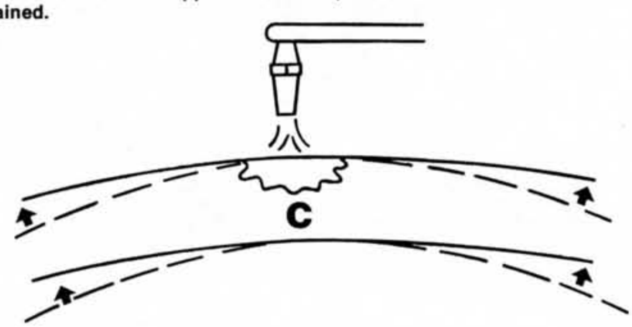


Consider the bent rotor shaft (A):

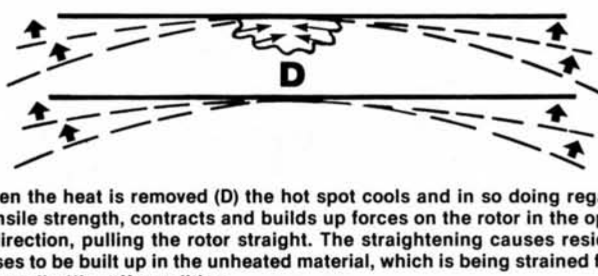
A small area on the convex side of the bend is heated by a torch. The area under the torch warms and expands elastically. (In other words, if the heat were taken away at this stage the heated area would return to its original size.)



As it expands (B) it exerts forces against the untreated mass and causes the rotor to bend even further. This causes stresses to be set up in the unheated material in the opposite direction; i.e. the unheated material is being strained.



As heat continues to be applied (C) the hot spot area begins to approach plastic flow and in doing so loses its tensile strength. The forces created by the hot spot disappear. The residual stresses in the rotor's unheated material force the shaft into its original bent condition.



When the heat is removed (D) the hot spot cools and in so doing regains its tensile strength, contracts and builds up forces on the rotor in the opposite direction, pulling the rotor straight. The straightening causes residual stresses to be built up in the unheated material, which is being strained from its naturally "bent" condition.

The rotor now contains residual stresses acting in opposition, and it is the very high levels of tensile stress in the hot spot which keep the rotor straight. Sometimes several hot spots are used to achieve straightening on the same rotor. When this is the case, the spots have to be located in different places.

Fig. 3. Hot Spot Thermal Straightening Technique

mandrels are used to align the steam labyrinth fins and oil seal baffles — all done above the boiler-room reserve feed tanks. This on-site repair technique is a most difficult undertaking, in view of the very fine tolerances which have to be achieved.

The Turbine Rotors

An examination of the manufacturer's turbine rotor overhaul records opened up a whole new can of worms. In the five years prior to 1987 some 52 rotors had been returned to Allen's in Bedford, England for refurbishing, 38 of them needing straightening. Going back to 1971 a total of 156 rotors had required overhaul and in one five-year period alone, from 1959 to 1964, there were 106 rotor refurbishments. All told there have been literally *hundreds* of failures in the more than 30 years the Y-100 turboblower has been in service. Yet, in all that time, *not a single Unsatisfactory Condition Report was raised!*

The damaged rotors were machined back to parent metal in the areas subjected to circumferential grooving or scoring and replated by a nickel electroplating technique. This reclamation method is straightforward and acceptable. Remachining follows, bringing the rotor back to original design; the areas affected by damage usually being around the steam labyrinths, oil baffles and bearings. Occasionally a pinion would have to be replaced. (These are a shrink fit on the turbine rotor.) Very rarely would repairs to blading take place. If a rotor had bent out of tolerance (as a majority of them had done), they were straightened by a "hot-spot" thermal straightening technique (*Fig. 3*).

Digging for Clues

Between January and November 1987 there were 14 Y-100 turboblower failures in the Canadian fleet, four of them occurring in HMCS *Assiniboine* in only a matter of weeks. Of these, three had been in rapid succession during set-to-work immediately following in-situ repair. Eventually, operational considerations were pushed aside and the opportunity was given at long last to completely investigate the turboblower installation.

The manufacturer's representative arrived from England to join the search, however none of his questions were new. According to WH Allen all the work we had been doing up until now appeared satisfactory. The early search for clues was fruitless. Nonplussed, the WH Allen rep returned to Bedfordshire.

We returned to the problem and decided that the investigation would be two-pronged — the engineers would tackle the stator installation while metallurgists at the DREA Dockyard Lab would examine the microstructure of the rotor, an outside possibility at this stage. (When you don't know which way to turn, you tend to look in all directions!)

The Stator Evidence

As the stator investigation progressed, a number of conditions emerged that, we thought, might explain the turboblower failures.

It appeared that the loading and rigidity imposed on the stator casings acted in some way in the dynamic condition to create uneven stresses about the stator casings, pulling the upper and lower sections into relative misalignment. The steam line support arrangements differed significantly even between ships of the same design, and when we disconnected the supply and exhaust lines from the steam chest the pipes sprung away as soon as the flanges were broken. It was quite obvious that, over the years, supports and hangers had been moved and removed, apparently with reckless abandon.

We noticed too in the older ships that the two steel lube oil pipes formed a rigid connection between the upper part of the blower and the underslung sump. (In later ships these lines were fitted with flexible elements at the midpoint.) We also observed hardened, ineffective resilient mountings which in some cases probably had not been replaced in two decades or more. However, none of this could explain the significant number of failures in the steady state.

We tried another tack:

The Canadian Y-100 turboblower is notorious for its oil leaks at the seals. The installation was modified in 1964 to incorporate a motor-driven auxiliary lube oil pump for use during start-up, shut-down, and in the event the impeller fan should begin to windmill when shut down. It is the *use* of this pump that has been the cause of the oil leaks.

Continuous use of the motor-driven pump while the turboblower is running overpressurizes the system and overloads the seals. This sends oil oozing outward towards the steam labyrinth glands where, in contact with the hotter part of the rotor and steam chest, it saturates the lagging and carbonizes on the rotor shaft. Hosing cold water onto a steam chest and rotor running at about 750°F, in order to extinguish fires, had obviously in some instances created a thermal shock sufficient to cause serious damage. But again, this only explained one or two of the turboblower failures.

There had also been suggestions that rotor distortion had been created by maloperation of the gland steam evacuation system — by back-flooding and quenching the rotor at the glands — but more than one catastrophic failure was observed with the system working entirely satisfactorily.

Unsuccessful with the in-situ investigation, we removed *Assiniboine*'s turbine casings to the workshop for closer scrutiny. And it was there that the first important item of evidence pointing to the cause of the blower failures was discovered — almost by accident.

It happened when an attempt was made to manually lift the assembly from the bottom end. The very slightest of movement was observed between the lower gearcase and the turbine steam chest. As the lifting pressure pushed the lower casing flange faces together, a minuscule amount of residual cleaning fluid was squeezed out. It was barely perceptible, but sufficient for the eagle eye of our machinery inspector.

In retrospect, it is most probable the investigation into the stator casings would have gone no further had this not been noticed. Once the two casing joints were broken it became obvious that the upper spigotted joint had been held rigidly in alignment. But the bottom plain flange, located by only two fitted bolts, showed quite clear signs of fretting. Indeed there had been movement between the casings and, ipso facto, misalignment between the upper (two) and lower (single) turbine bearings.

The Metallurgical Evidence

Remarkably, about the same time as the stator casing discovery was made, scientists at the DREA Dockyard Laboratory produced a most impressive report on metallurgical studies done on a damaged rotor. They had begun by trying to find a means of determining strain levels in the rotor and by subsequent calculation the stress levels, necessarily at first by non-destructive means. Initially they had to find the positions of the hot spots. This was done by a simple acid etching technique which renders them quite visible to the naked eye (*Fig. 4*). To determine the stress levels three methods were considered:

a. Stress measurement, using strain gauges and the blind-hole drilling method;

b. Measurement of neutron diffraction (through Atomic Energy of Canada, Ltd.); and

c. Stress measurement by means of x-ray diffraction.

The first method would be satisfactory only in measuring the average of the surface stress gradient across a hot spot. The neutron diffraction process would be accurate at measuring stresses deep in the hot spot, but would be less accurate at measuring surface stresses. Moreover, this method would be most expensive and time-consuming and could never be used in the field. It was the x-ray diffraction technique that produced the goods, however, for we were looking for precise measurements of the surface stress profile across the hot spot. The test equipment was reasonably portable and Proto Manufacturing of Ontario was able to transport it to the DREA laboratories in Halifax where they eventually conducted the work.

X-ray diffraction enables the precise measurement of material crystal lattice spacings. Lattice structure and the proximate stratification of crystallographic planes determine residual stress levels. The closer the crystallographic planes are together, the higher the residual tensile stress. By bombarding a material with x-rays, and measuring the extent to which the x-ray becomes diffracted on the other side, it is possible to measure the distances between the crystallographic planes, and subsequently the residual strain from which the residual stresses can be calculated.

Figure 5 shows both the expected stress profile of a hot spot and profiles of two actual hot spots on the same rotor. The very high levels of compressive stresses at the centre of the hot spots indicated the rotor had been overheated, and the critical phase transformation temperature exceeded.

Fig. 4. An acid etching process was used to reveal this hot spot.

As the centre of an overheated spot cools, martensite is formed. The periphery of the hot spot is relatively cold and the lattices are fixed, whereas the martensite phenomenally undergoes a specific volume *increase* during its cooling process. The centre of the hot spot is trying to expand, but is constrained by its periphery. As a result, massive compressive stresses build up. Note in *Fig. 5* the radical changes from tensile to compressive stress.

The presence of martensite could only be confirmed by microscopy. A section was cut through a hot spot (for by this time a damaged rotor was available for destructive analysis), and was polished and etched. Once under the microscope quite vivid inconsistencies were observed in the microstructure (*Fig. 6*). The areas at the centre of the hot spot were identified as martensite. As well as containing high levels of residual stress,

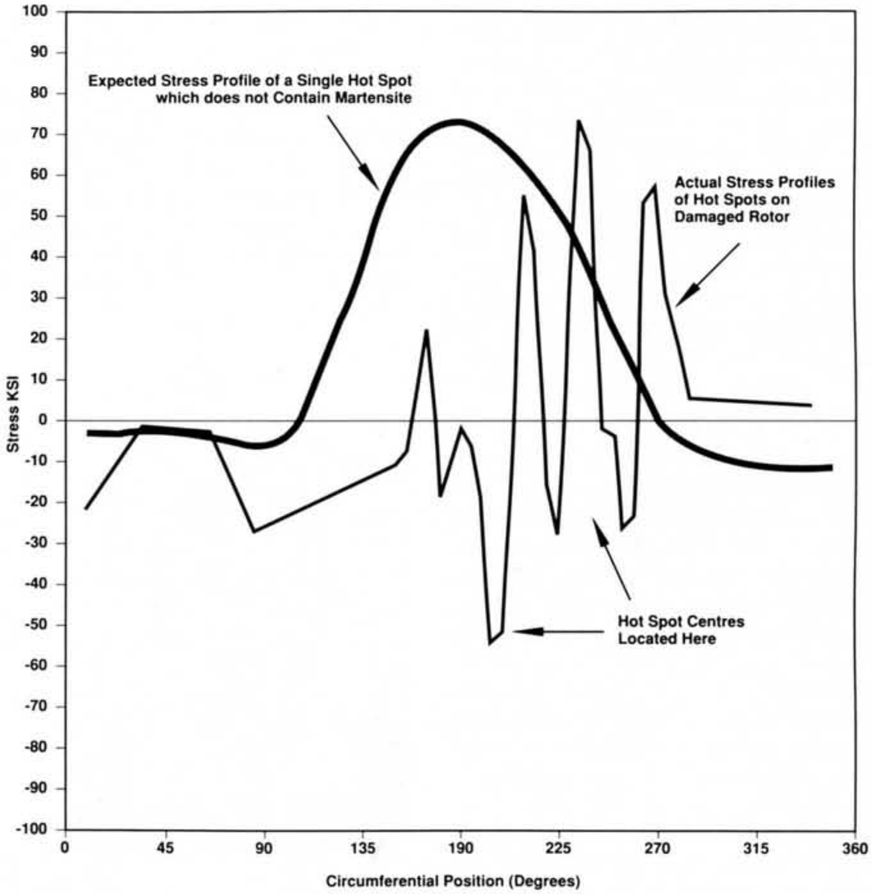


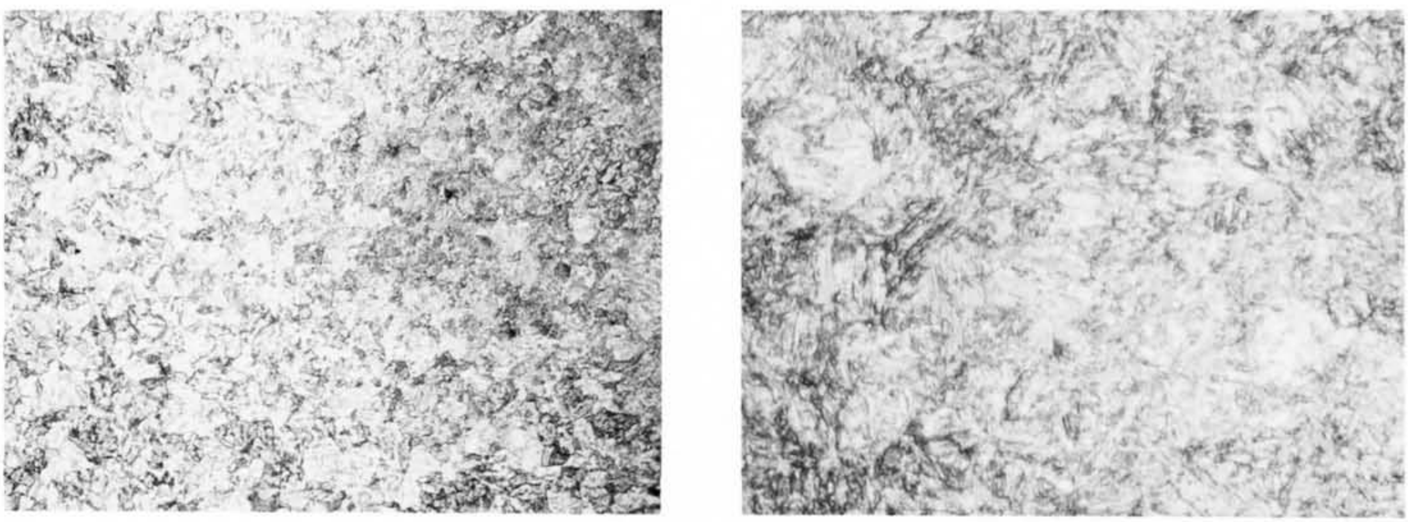
Fig. 5. Residual stress measurements, showing hot spots on repaired rotor No. 2.

martensite is also a very hard material. A hardness test gave final confirmation that the material was indeed martensite. So here was the major clue behind the rotor failures, because it is an accepted phenomenon that *the high residual stresses in martensite will relax over time*.

The Trouble with Turboblowers

The two major causes had been identified. Either independently, or in combination, they produced the 26 or so random failures of 1987 and 1988.

Residual stresses in rotors which contained martensite would progressively relax in service, allowing the rotors to return to their "original" bent condition. Depending on the turbine speed at which this occurred, a rotor would damage not only the stator, but would cause local overheating in itself along one side. This would increase the degree of rotor distortion, cause the rotor to wipe out the fin packing and gland labyrinths, create wide clearances, cease to rub, then cool, and in some cases, bend in the opposite direction — just like a hot spot process — and rub with the opposite side. Sometimes, once cooled, the rotor would be straightened by this process.



UNAFFECTED MICROSTRUCTURE OF CARBON STEEL (X 500)

MICROSTRUCTURE CHANGES BEGINNING

MARTENSITE (X 1000)

Fig. 6. Hot Spot Microstructure

In some installations the rotor and stator damage would be minimal. The rotor would run with a minor bend, having created its own clearances within the stator, and would continue to give satisfactory service for years, only to be discovered when opened during the ship's refit. It also explained the random nature of failure. The number of hot spots varied between rotors, as did the residual stress levels induced during overhaul.

There is no doubt the looseness of the bottom casing joint — not evident in every case observed — allowed a misalignment condition and gave a rotor opportunity to make hard contact with the stator labyrinths. Once contact was made, again depending on the metallurgical stability of the rotor, damage was either catastrophic or merely the source of vibration at higher speeds.

Conclusion

Much has evolved as a result of investigating the failures:

a. The hot-spot rotor straightening method has been replaced by a mechanical straightening technique, followed by thermal normalization. Mechanically straightened rotors are now operating satisfactorily in service, and some rotors which would have had to be scrapped because the hot-spot process had been exhausted have been salvaged for reuse.

b. In-situ repairs no longer take place and spare overhauled casing assemblies are held for R X R in the East Coast ships.

c. Resilient mountings are progressively being renewed throughout the fleet.

d. Certain modifications are being processed:
   (1) A pressure switch in the motor-driven lube oil pump circuitry, to allow the pump to remain shut down and cut-in only should the lube oil pressure fail; and
   (2) Flexible elements for the two steel lube oil pipes which connect the top and bottom casings.

The problems encountered in Y-100 turboblowers over a period of a quarter of a century were deep-rooted indeed. They were occasioned by a number of almost independent factors, which when brought together precipitated the high failure rates experienced in more recent years. Hundreds of rotor failures had inexcusably gone unchallenged over decades. The rotor repair line, far on the other side of the Atlantic, functioned in ignorance of the environment in which the machine operated. The rotors were not identifiable by serial number — They are now! — meaning suspicions could not be automatically aroused.

The rotor hot spot or "flame" straightening technique had a fair history of success in larger turbines over a number of years. But without records, no one could possibly have suspected the long-term damage being done to the spindly, high-speed rotor of the Y-100 turboblower. Had the turbine rotors been overhauled in a Canadian naval dockyard, and there exist the skills and means to do this, knowledge of what had been going on over time would have prevented the crisis of 1987 and 1988. It is some credit, though, that the Y-100 turboblower problems were resolved entirely by Canadian expertise, dogged though it had to be in the face of disbelief and foregoing the more tranquil waters of conventional wisdom.

Acknowledgments

Again it has been great fun playing Dr. Watson to Doug Nickerson, the Command Machinery Inspector at NEUA. Thanks to John Porter and Danny Moorehouse of the DREA Dockyard Laboratory for the pains they took to explain the metallurgical and residual stress work, and lastly to Susan MacDonald for patiently suffering many revisions to the typescript.

LCdr Woodhouse is Marine Equipment Condition Assessment Officer at NEUA

Gas Turbine Transient Performance Health Monitoring

By LCdr N. Leak

The need for gas turbine health monitoring and diagnostic systems has been evident for as long as gas turbines have been in service. This is especially true in the case of the marine gas turbine, of which a high degree of availability is demanded with limited access to maintenance and repair resources. For naval applications this implies that the early prediction of failure through the identification of engine faults and performance degradations is vital in maintaining optimum plant availability while minimizing through-life costs.

Engine health monitoring (EHM) has been identified as being instrumental in the maintenance of high availability and general equipment readiness. Unfortunately, to achieve this and given that no single EHM technique can monitor all aspects of engine performance and achieve the objectives of life expectancy, maximum availability and minimum through-life cost, a comprehensive EHM system is required. Such a system must not only be capable of continuously monitoring all aspects of engine mechanical condition, but also the steady state and transient behaviour.

Implementation of such a comprehensive system has, in the past and particularly with respect to performance monitoring, been restricted by the limitations of instrumentation systems. Advances in sensing and data manipulation systems, coupled with improvements in computer reliability and processing power should prove to be the key to overcoming these limitations. The introduction of the integrated machinery control system is a major step in the application of these advances.

Performance Analysis

The identification of faults by examining the steady state behaviour of the gas turbine has also proven difficult due in part to the self-regulating nature of the engine. It is suggested that during an engine transient, where self-regulation will be less precise, the engine responses would be a better indicator of engine health. Intuitively this is logical, in that the first indications of deteriorated engine health will be evident as a degradation in engine response. The monitoring of engine start-up and rundown cycles already provides an indication of ignition and fuel system health, and information regarding interspool bearing condition.

Investigations into the transient performance of the F-404 engine fitted in the CF-18 has indicated that there is a definite change in transient performance, as measured by engine thrust during take-off, due to the existence of a fault condition; for example, HP compressor damage. This provides a basis for the concept of Transient Performance Analysis and the problem then becomes one of quantifying and relating these degradations to engine health.

Engine manufacturers normally provide performance specifications for a nominal engine in the form of power and fuel consumption variations with ambient conditions, along with suitable suggestions for limiting values to ensure safe operation or long life. This data is essential to ensure that the engine is capable of meeting the specified requirements.

In the event of engine deterioration, nominal engine data is of minimal use in assisting with fault diagnosis which could range from atmospheric fouling of the compressor, corrected by compressor cleaning, to severe mechanical damage requiring overhaul of a component module or the complete unit. Before informed decisions can be made, it is necessary to establish a knowledge base for any state of engine health.

Performance Simulation

In the past, attempts have been made to implant mechanically damaged components into gas turbines to determine the effect of the resulting deterioration on performance, all without notable success. This clearly is an extremely expensive method and it is not possible to implant severely damaged components because of the likelihood of causing further damage. The only safe method of systematically investigating engine deterioration is by the use of well-validated mathematical models based on established thermodynamic techniques. Since detailed computer models of gas turbine engines have demonstrated a record of success in predicting engine behaviour, they are considered appropriate for the purposes of modelling engine fault conditions.

To enable investigation into the concept of transient performance with respect to marine gas turbines, it is necessary to develop a modelling program that simulates engine performance with and without fault conditions. This program must be designed to model both the transient and steady state performance of a typical simple cycle, twin-spool marine gas turbine engine installation. Simulation can be achieved by considering the engine as a set of components and applying the appropriate thermodynamic relationships to each of these components. Gas path performance parameters can then be computed at the inlet and outlet of each component to provide a complete knowledge of conditions throughout the engine. Control of the model can be maintained by means of a fuel control algorithm which determines the fuel input necessary for the simulation to remain within the bounds of the engine operating envelope. Schematics of engine and model are shown in *Figures 1* and *2,* respectively.

With any computer model there is a temptation to analyze every possible performance parameter; however, this is extremely time consuming and has, in the past, proven to be impractical. Conversely, the analysis of too few parameters results in a low level of confidence in the simulation output and is equally as impractical. To ensure that the necessary parameters are selected for analysis, selection can be based initially on the criterion that parameters be normally monitored inputs to an integrated machinery control system.

A further consideration when applying the selection criteria is that if parameter signal quality meets the specifications of a digital machinery control system, then it should be acceptable for input into a performance monitoring system. This, in turn, results in a health monitoring system in the form of a relatively inexpensive add-on package versus a more costly stand-alone EHM system.

Fault Simulation

Ideally, the faults that should be considered for simulation are those which are known to exhibit the highest probability of occurrence. Another factor to be considered is the extent and precision to which faults are modelled. Given that there is limited, in-service detailed gas turbine transient performance data available, the practical answer is to carry out a number of simulations to establish a transient performance data base which can be verified with in-service data. An added complication is that no simple formulae exist for assigning relative ratios of mass flow and efficiency changes to simulate specific fault conditions.

The simulation of fault conditions is achieved through the use of scaling

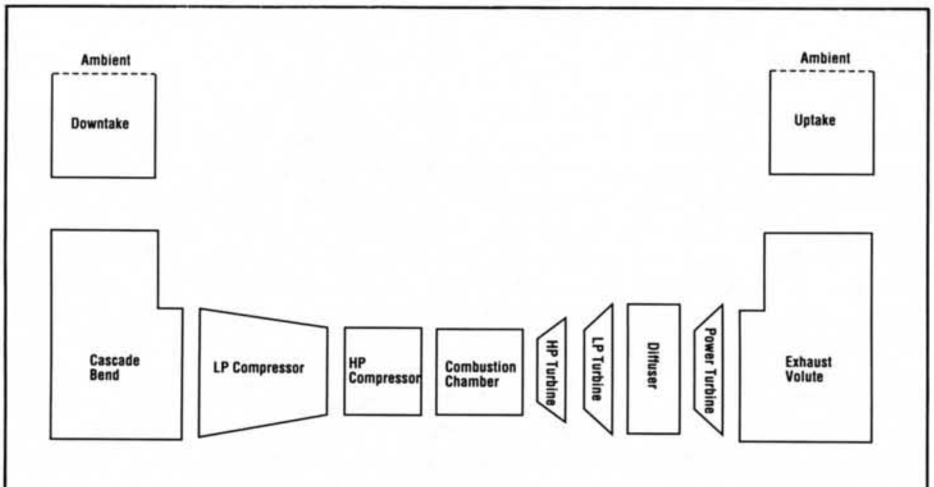


Fig. 1 Engine Schematic

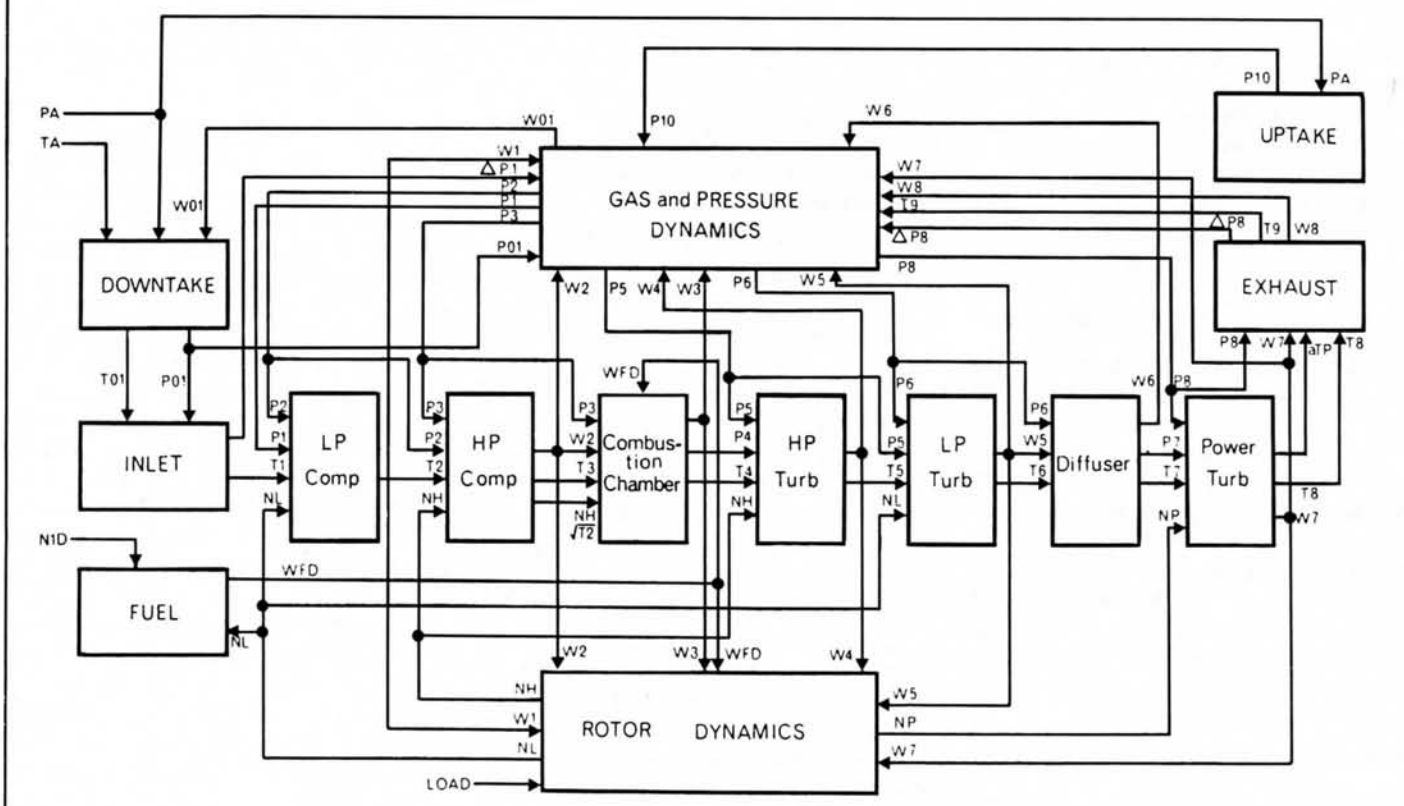


Fig. 2. Model Schematic

coefficients introduced in the appropriate component thermodynamic relationships. These coefficients are assigned values to represent percent changes in component efficiency, corrected mass flow and mechanical efficiency, as required.

Fault Selection

The probability of only one fault condition occurring during the life of an engine is extremely low. Assuming that it would be unlikely for an actual fault to be represented solely by change in a single performance variable, then to be effective the EHM system must be capable of identifying multiple fault conditions; i.e. faults in more than one component, or a number of faults in a component.

Previous studies have observed that the effects of multiple faults can be predicted by superimposing the effects of the appropriate single-fault conditions. This observation was the result of analysis of faults which were characterized by small changes in component characteristics. Therefore, the initial selection of fault conditions to be simulated should concentrate on introducing a smaller range of fault conditions, but to a greater number of engine components. In cases where a knowledge base does not exist, this is the preferred approach as it provides a better indication of where transient performance analysis is most effective, establishes the transient performance data base and provides direction for further simulation.

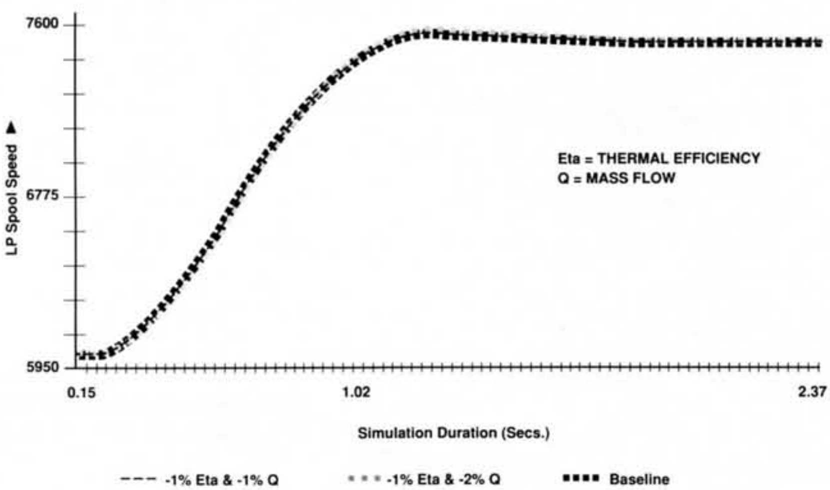


Fig. 3. Overlay of LP spool speed responses for LP compressor degradations

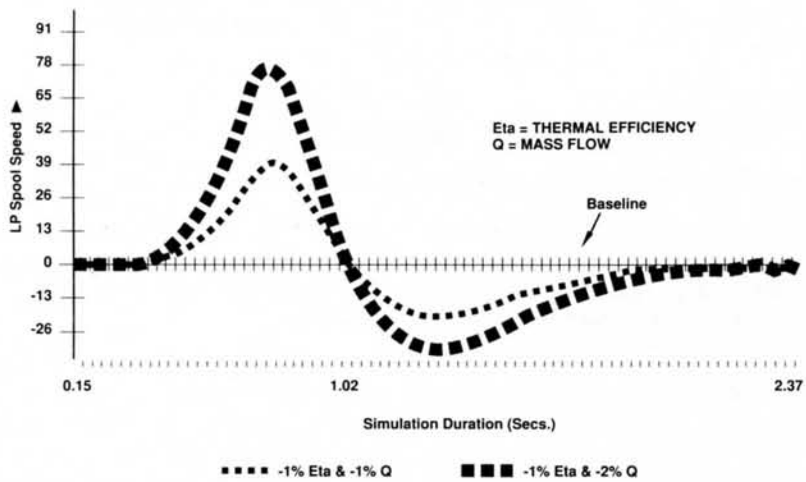


Fig. 4 Direct comparison, with baseline, of LP spool speed responses due to LP compressor degradations

Transient Performance Analysis

Having established the analytical approach, determination of the analytic process is required. Analysis would normally be based on an existing method; however, as there appears to be no method which is ideally suited to transient analysis this is not feasible. Since it is not practical to develop a dedicated method, the analysis must adapt an existing steady state method.

An analytical approach based on the steady state performance fault matrix method, relying on unique fault signatures to identify fault type and location, can be applied. A fault signature is defined by a parameter's response to a fault condition. Unique fault signatures occur when this response is uniquely identifiable with a particular fault condition. This consists of describing each parameter response qualitatively to enable the identification of fault conditions which display similar, but unique parameter transient responses. Once the data base is sufficiently established, a quantitative approach can be applied.

Parameter responses are initially analyzed by overlaying the plots of each simulation output on the appropriate clean-engine (baseline) response. An example of this is illustrated in *Figure 3,* in which spool speed responses for two combinations of LP compressor efficiency and mass flow degradation are overlaid on a baseline response. However, in this particular case, such an approach is impractical due mainly to the relatively small differences between simulation outputs as a result of scaling. This raises the problem of how to present the transient response simulation data in such a way that it can be readily analyzed.

To address this situation, a model-generated direct comparison approach is adopted (*Figure 4*). The same responses previously shown are now directly compared within the modelling program before being plotted. Transforming the baseline response onto the horizontal time axis results in output response plots being representations of parameter responses as functions of time with respect to this selected baseline. The axes now represent a difference in LP spool speed against time. If two identical baseline conditions are compared, there should be a zero difference plot. This approach produces an output which is better suited to analysis.

The Analytical Approach

Initial inspection of the simulation comparison plots reveals that virtually every fault condition produces noticeable differences in the transient behaviour of the monitored parameters.

The first phase in developing the analysis consists of examining the effects of introducing a degraded fuel to an engine. Simulations of substandard fuel quality are conducted by mathematically reducing the fuel calorific value. This results in marked changes in the transient responses of all parameters, as shown in *Figure 5*. The significant point here is that variances in the transient responses are preceded and followed by a return to baseline steady state values for all parameters, with the exception of throttle angle (fuel flow). On these results the first fault signature is identified. A marked change in the transient response of all monitored parameters, preceded and followed by a return to their steady state baseline values (with the exception of throttle angle) is a probable indication of degraded fuel quality.

The development of a health monitoring system with on-line capability for identifying degraded fuel quality can be a valuable asset for the gas turbine operator. Hot section problems have a major influence on gas turbine life expectancy and are known to be influenced by the burning of contaminated fuel.

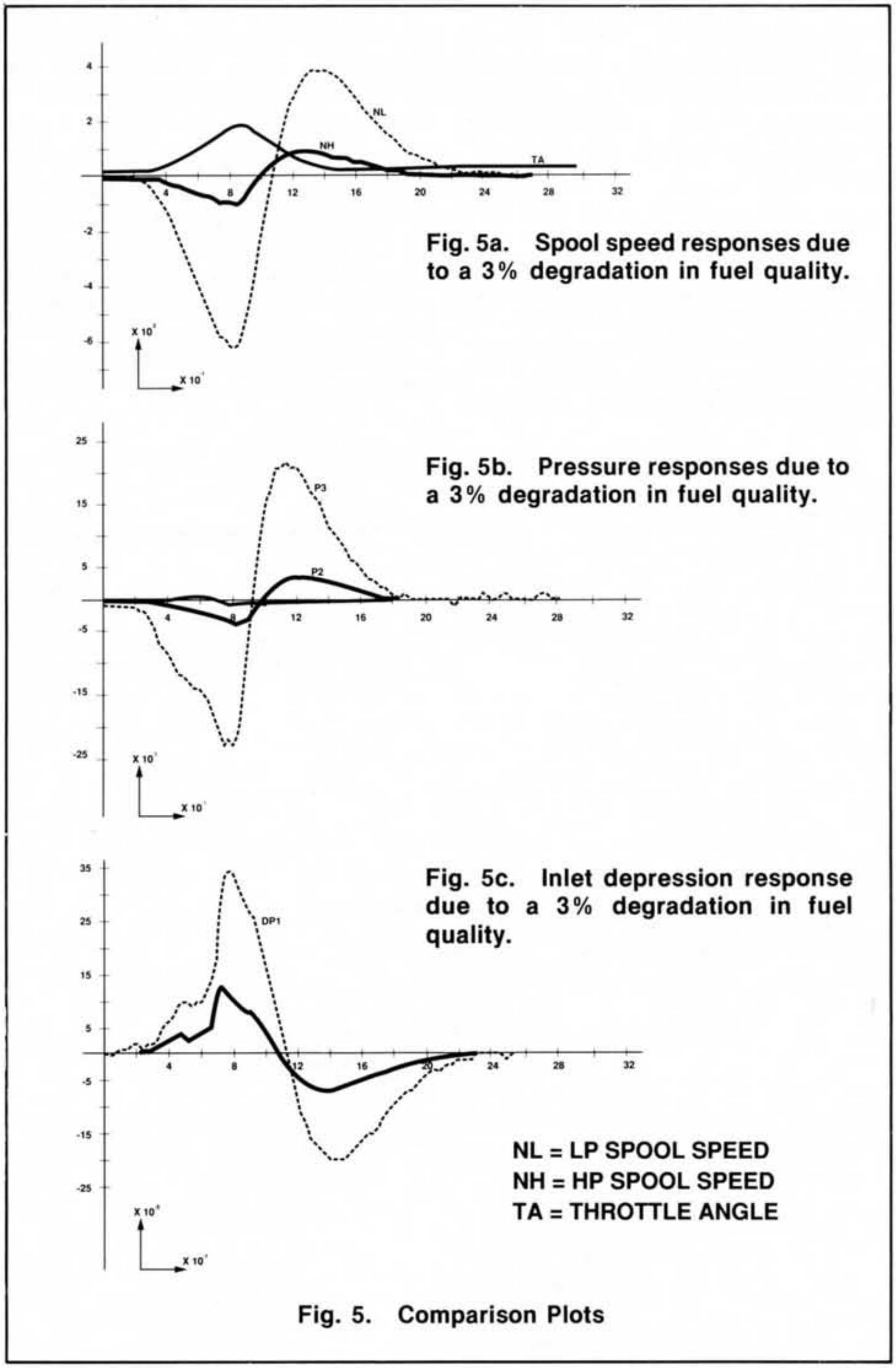


Fig. 5a. Spool speed responses due to a 3% degradation in fuel quality.

Fig. 5b. Pressure responses due to a 3% degradation in fuel quality.

Fig. 5c. Inlet depression response due to a 3% degradation in fuel quality.

Fig. 5. Comparison Plots

The next analysis phase involves the identification of component transient fault signatures through the application of qualitative database-type rules. This results in the identification of unique fault signatures for the LP compressor, LP turbine and HP spool. Samples of these fault condition responses are shown in *Figure 6*. The significant points to note are the different shapes of the LP spool speed response plots for the four compressor and turbine components which appear to assume three distinct wave-forms. Of the fault simulations conducted, those which represented LP compressor or LP turbine faults demonstrated transient responses simular to those on the left-hand side of *Figure 6*.

Qualitatively, the LP compressor response at the top left-hand corner of *Figure 6* is described as having a form resembling a positive sine wave, while the LP turbine response resembles a two-cycle negative sine wave, but with a pronounced negative peak. The identification of these different responses indicates that these components exhibit unique fault signatures and that transient analysis is capable of identifying faults located in the LP compressor and LP turbine.

Considering the responses due to HP compressor and HP turbine fault conditions, shown at the upper and lower right-hand side of *Figure 6* respectively, it can be seen that the LP spool speed responses display very similar forms. These responses represent the third of the observed wave-forms, which for the purposes of the analysis is considered to resemble a negative sine wave.

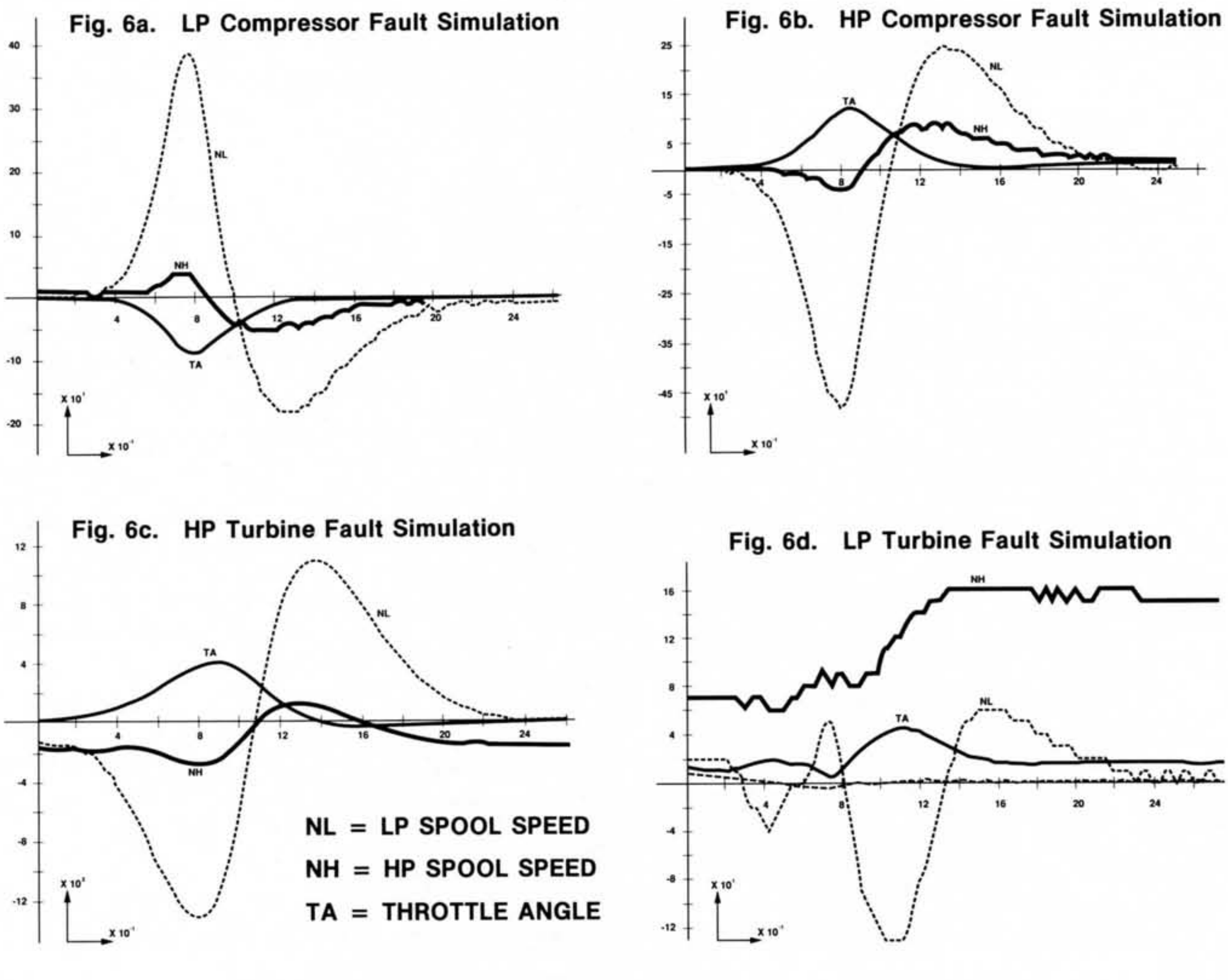


Fig. 6. Comparison Plots

Further examination can then concentrate on other monitored parameter transient responses. However, if unique fault signatures for the HP spool components cannot be identified, then there may exist a possibility that transient analysis is not able to differentiate between HP compressor and HP turbine faults. This observation is considered premature and based on incomplete data as the investigation into the transient performance of the GE F-404 engine revealed that an HP compressor fault was detected by analyzing engine thrust transients. In the case of a marine gas turbine, this type of response would be reflected in the transient performance of the power turbine. Therefore, the analysis of power turbine performance parameters is necessary to identify unique fault signatures for the HP spool components.

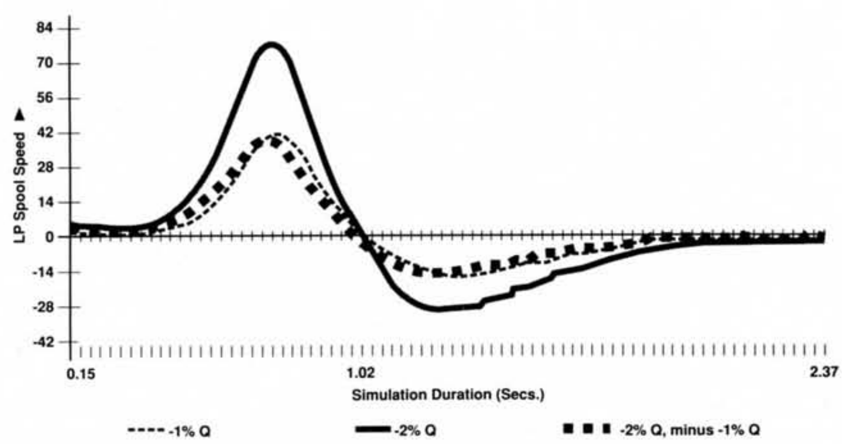


Fig. 7 Comparison of LP spool speeds due to degradations in LP compressor mass flow

Illustrations of a Conceptual EHM System

This conceptual system is intended for integration with a simulation module in a proposed advanced condition monitoring system. The system design depicted in *Fig. A* illustrates the wide applicability of expert systems to assist different functions of the integrated system.

The specifications of the fault diagnostic expert system include:

a. Early recognition of specific engine component or sensor faults.

b. Recognition of multiple fault conditions.

c. Identification of probable faults with reduced number of sensors.

d. Provision for reporting unrecognized changes in engine operating parameters.

e. Advice to operator requesting additional information in the case of unrecognized conditions.

f. Interface with other modules for the evaluation of future effects from the identified faults.

g. Communication with the user, allowing the user to make a diagnosis, and providing the user with a critique.

Development of the system (as shown in the flow chart, *Fig. B*) is based on the establishment of an experimental results data base, containing associations between symptoms and engine faults from extensive modelling and test-bed data. This data base is then augmented with specialized knowledge to form a general information data base. Experimental files reflect the effect of the selected matrix of fault conditions on sensor systems. In the first prototype rule-based system, production (IF/THEN) rules were generated for each fault within the engine subsystem.

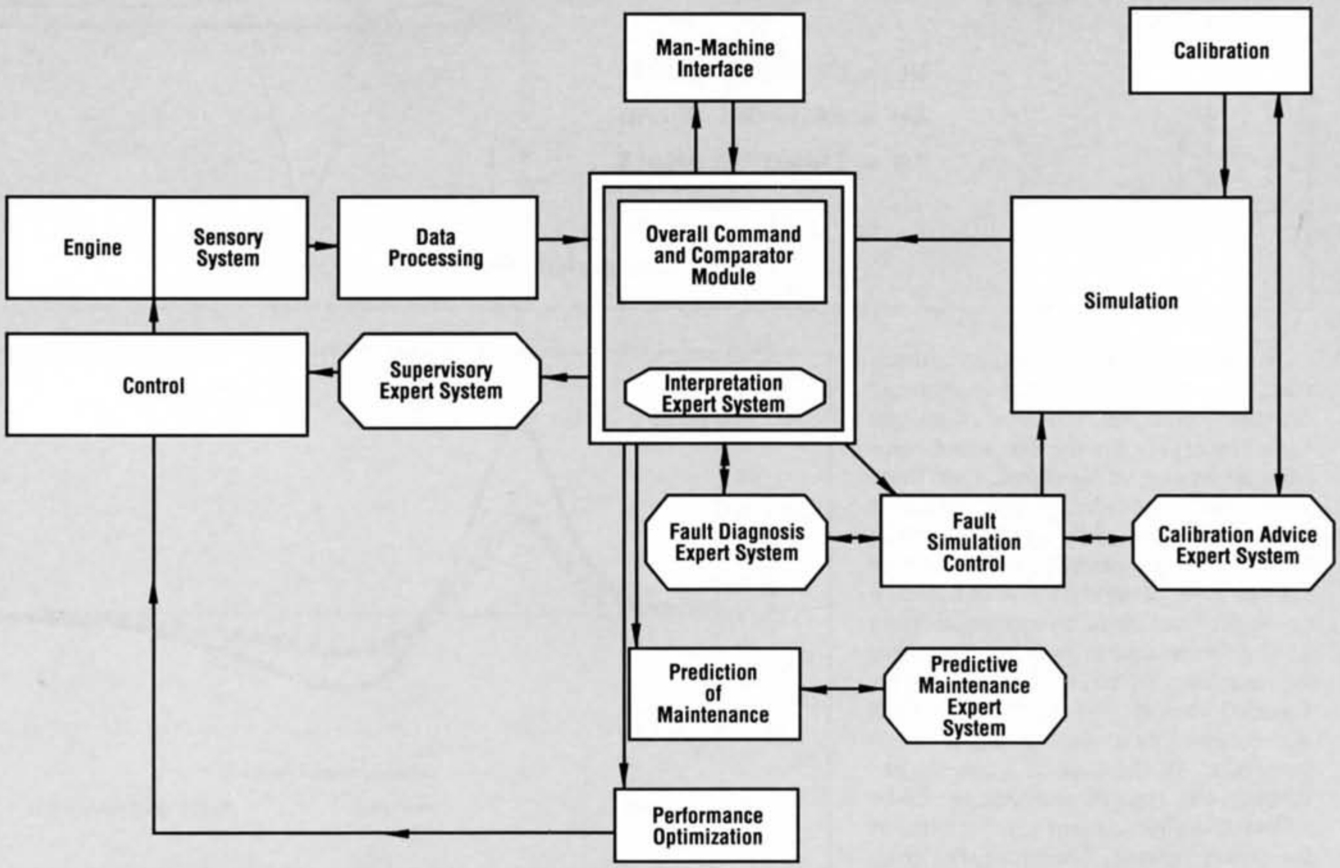


Fig. A Conceptual design of an advanced Condition/Performance monitoring system.

The information data base is also employed to assist in developing an engine causal model by the use of an artificial intelligence development environment. Pattern recognition techniques are used to assess sensor redundancies and multiple faults.

In the eventual application situation, the fault diagnosis expert system is complemented with an engine simulation model, also incorporated into the system. This model needs to be able to respond to changes in engine parameters, fuel quality and ambient conditions. Deviation files are generated when sensor data differ from the simulation reference values. Fault hypotheses are generated by a number of alternative techniques (rules or pattern matching). Confirmation of a fault is accomplished if sufficient supporting evidence of the initial hypothesis is found. Supporting evidence is sought from a number of sources, with the simulation model providing the final confirmation for any fault identified by the expert system.

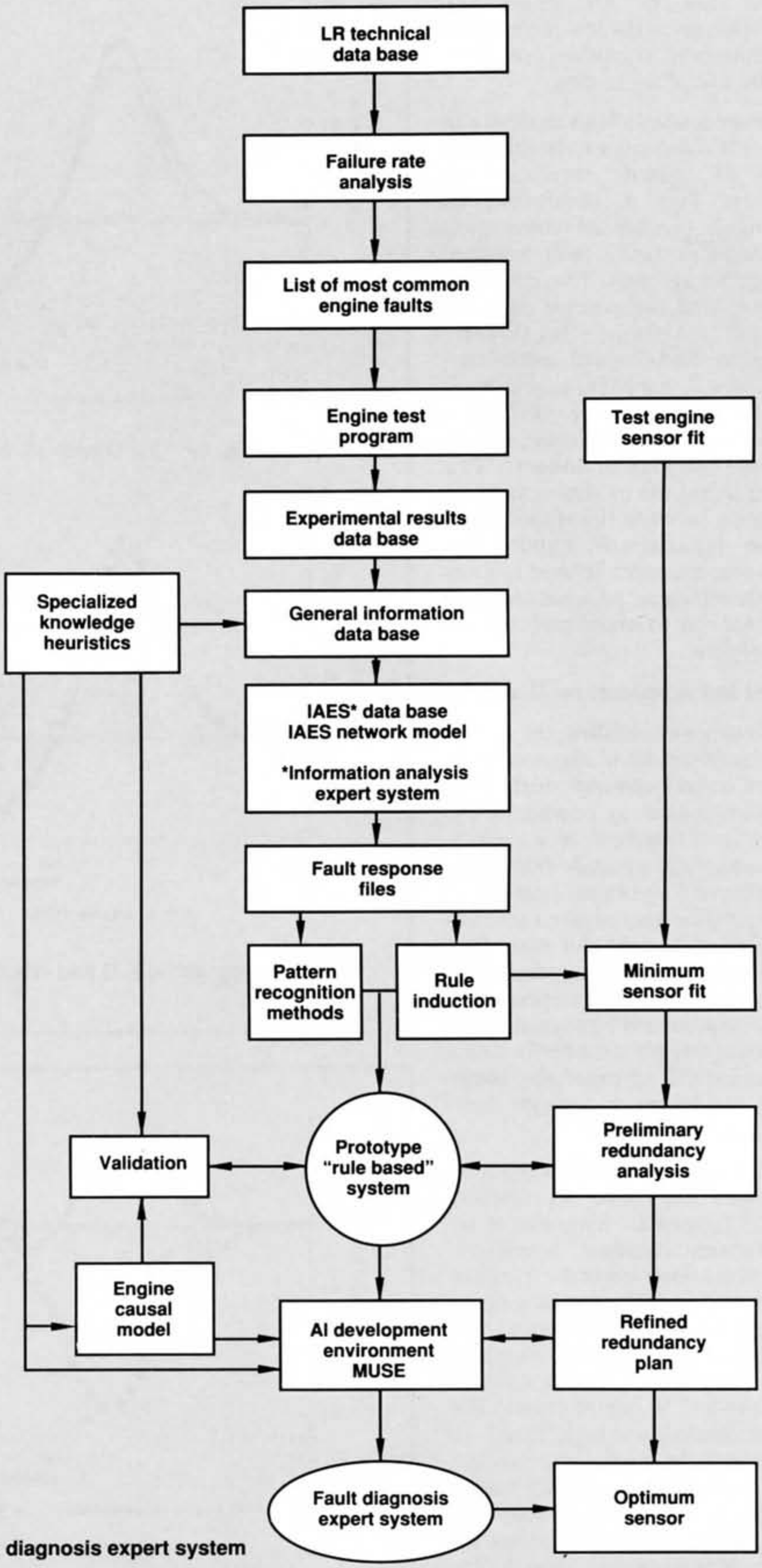


Fig. B Development of a fault diagnosis expert system

The final phase of the analysis examines responses to multiple fault conditions. This is an important consideration given the low probability of only one fault condition occurring during the life of an engine.

Before the multiple fault analysis can commence it is necessary to establish the existence of linearity between fault conditions. This is conducted by comparing a number of simulations representing a worsening fault condition in a single component. The responses due to one- and two-percent degradations in LP compressor mass flow are compared to the LP spool speed baseline in *Figure 7.* An additional curve is shown to represent the difference between these two responses, which suggests the existence of linearity. This result, regarding the existence of linear relationships between the responses of successive degradations, implies that transient responses can be used to identify trends in engine performance and hence, contribute to engine performance trend analysis.

Combined and Superimposed Responses

With linearity established, the prediction of multiple fault signatures by means of superimposing single-fault effects is conducted by comparing the combined fault responses to a summation of the appropriate single-fault simulations. *Figure 8* shows an example of the superposition analysis for two combinations of efficiency and mass flow degradations. The close agreement between the combined fault response and the response predicted by superposition demonstrates that transient performance analysis is capable of predicting multiple fault conditions in a single component.

An off-design simulation is required to determine the effect of climatic changes in outside air temperature on engine transient response. Significant differences are observed in the transient responses of all parameters as a result of varying the inlet air temperature, confirming that engine transient behaviour is sensitive to both changes in ambient temperature and to engine faults. The off-design analysis method, based on the superposition approach, predicts off-design responses to a fault condition. Superimposing a comparison of standard and off-design simulations, for a given baseline condition, onto the appropriate standard condition fault simulation results in the predicted response

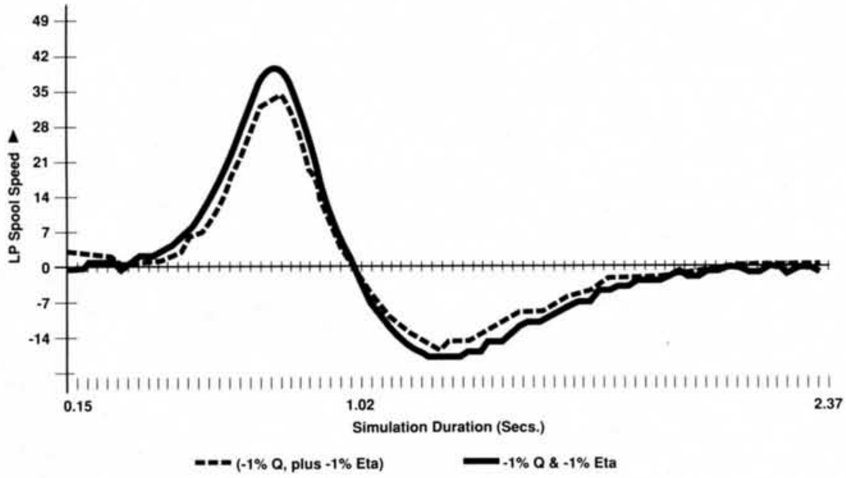


Fig. 8a -1% Q and -1% Eta LPC fault comparisons

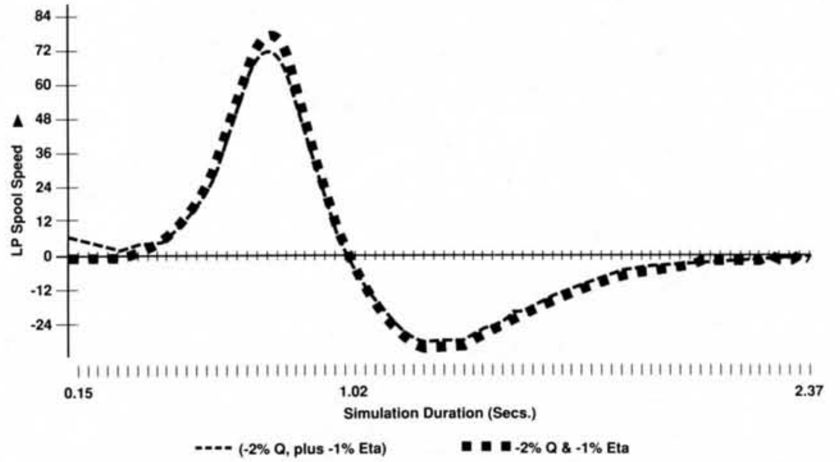


Fig. 8b -2% Q and -1% Eta LPC fault comparisons

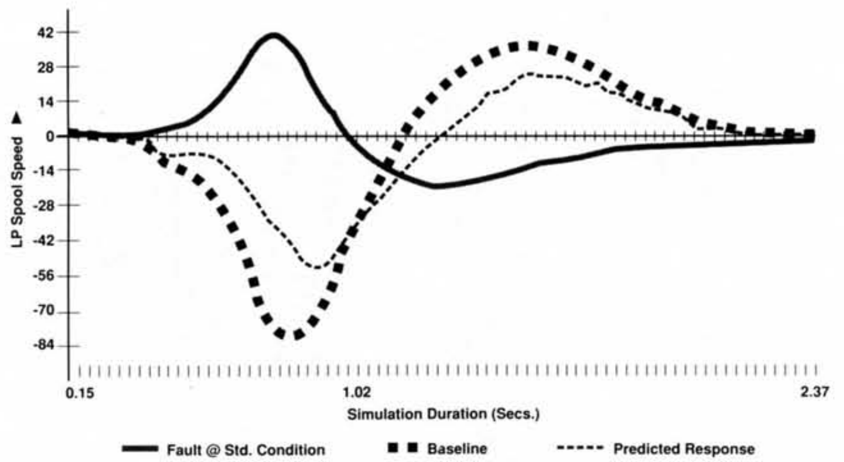


Fig. 9 Prediction of LP spool speed response to an off-design fault condition

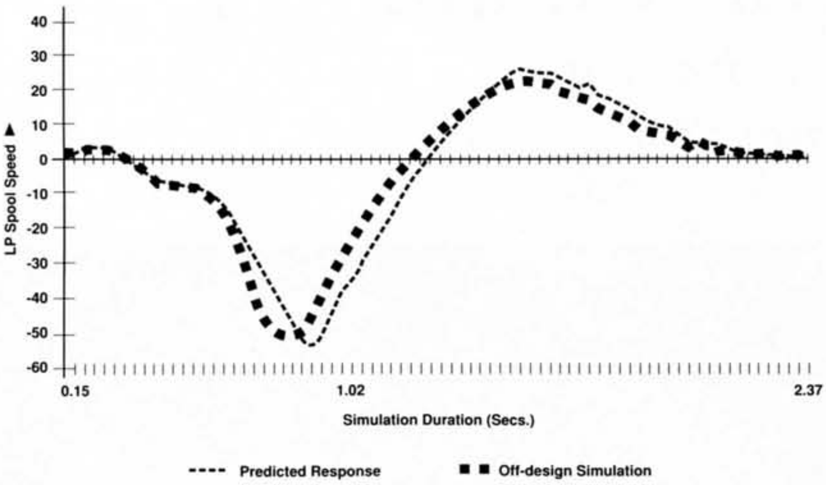


Fig. 10 Simulated and predicted LP spool speed responses to an off-design fault condition

shown in *Figure 9*. This predicted response is then compared to the off-design fault condition simulation shown in *Figure 10*. The close agreement between the predicted and simulated responses shows that transient analysis can be applied over varying operating ranges with the superposition approach. This result eliminates the requirement for extensive parameter correction algorithms within an on-line health monitoring system. The computation power required for performance calculations is then reduced, which in turn would be reflected in a simpler and less costly health monitoring system.

Future Development

From the development of this analysis process, sufficient evidence exists to demonstrate the feasibility of transient performance analysis as an engine health monitoring technique for simple cycle, twin-spool marine gas turbine engines.

As the concept of gas turbine transient performance health monitoring is still in its relative infancy, it is recognized that further research and development is necessary. A number of areas can be identified as being prime for further development; these include:

Model Validation. Precise engine modelling is not as critical at the initial stages of the analysis as is the requirement for believable results, providing these results are ultimately validated. Validation accompanied by the necessary model refinements will be required as part of any future efforts.

Expansion of Analytical Approach. Given that the response comparisons resemble periodic wave-forms, investigations into a frequency domain analysis should be considered.

Machinery Control System Health Monitoring. Fault simulation studies, and their subsequent validation, may form the basis of a process capable of identifying machinery control system problems which affect the engine's transient performance, but are undetectable in the steady state.

Complementary Performance Analysis. It may not be practical to consider steady state and transient performance analysis independently, due mainly to the difficulties associated in defining delineations between transient and steady state conditions. As this process can also provide information regarding responses in the steady state, then a much-improved, performance-based engine health monitoring system could be provided on the basis of complementary transient and steady state analysis.

Integrated Engine Health Monitoring. A logical extension to the complementary performance analysis concept is to consider integrating all available health monitoring techniques. Along these lines, investigations are being conducted into the feasibility of integrating performance analysis health monitoring techniques with a machinery control system, for a test engine based on microcomputers with expert system software. This system could also provide the option of accepting inputs from other health monitoring techniques, thereby taking a major step forward with respect to the development of a totally integrated health monitoring system.

There currently exists a progressive environment in the field of marine and industrial engine health monitoring which offers encouragement and definite direction for future research and development.

Acknowledgment

The author wishes to acknowledge the contributions of Lt. Cdr J. Davis, RN in making this article possible.

Reference

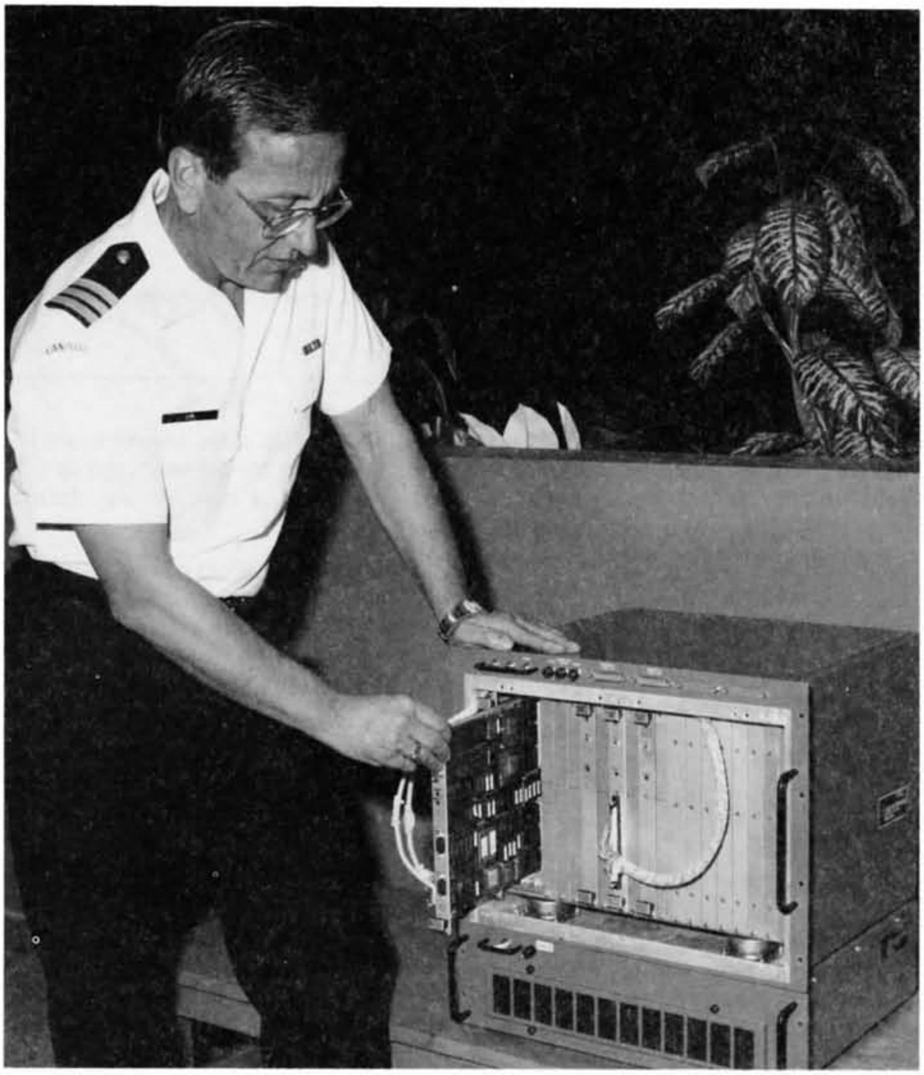
N. Leak, *Gas Turbine Transient Performance Health Monitoring*, M.Sc. Thesis, Royal Naval Engineering College, Manadon, June 1988.

LCdr Leak is the DMEE 5 subsection head for diving support, environmental protection and auxiliary systems research and development.

Standard Naval Computers

Is naval computer technology catching up to the past?

By Cdr Roger Cyr



Material Management Instruction 1405, which was promulgated in December 1981, directs that the AN/UYK-502 and AN/UYK-505 standard naval computers be used for all shipboard systems requiring a processor. This policy of enforced computer standardization was primarily established to avoid the chaos and expense of maintaining a proliferation of different shipboard computers. It also served to identify computers that could be programmed in the navy's own software programming language — CMS-2.

Back then, with so many different, enormously expensive and often unreliably complex computers on the market, the policy more or less accomplished what it set out to do. It effectively put the reins on what could have been a costly, uncontrolled venture into shipboard computer acquisition and kept our ships (at least from a computer standpoint) from becoming the fleet of Babel. But that was eight years ago. Things have changed.

In view of the high cost of the AN/UYK standard computers and the superiority and relatively low cost of today's digital processors, the continued use of standard, stand-alone computers for all shipboard tactical data processing must now be questioned.

The Standard Computers

The AN/UYK-505 computer is a Canadian variant of the U.S. Navy's AN/UYK-20 standard computer. The AN/UYK-502 is a slower and cheaper version of the 505. These computers are closed architecture, 16-bit processors with a very small memory of 512 kilobytes partitioned into page sets. This type of architecture briefly surfaced in the marketplace some 20 years ago, but was quickly discarded by most computer manufacturers because of its limitations in memory management. Now the architecture is unique to the Canadian navy's UYK-502 and 505 and to the U.S. Navy's UYK-20 and UYK-44 computers. These computers are programmed using the CMS-2 language, which is itself unique to military applications.

Why not standard computers?

Even though it is a matter of policy that the standard stand-alone computers be used for all applications, there is an increasing requirement for systems to use non-standard machines. In the Integrated Machinery Control System, for example, commercial microprocessors had to be used because the standard computers could not meet the processing, memory and input/output requirements.

From a logistic point of view, the requirement for standard computers for all applications is no longer considered valid. The increase in reliability that has come about with each new generation of computer technology has resulted in computers today being cheaper and more reliable than most other shipboard electronic components. More importantly, they are readily available in the marketplace.

Comparison of Processing Costs

COMPUTER	MEMORY (KBytes)	SPEED (MIPS)	COST ($K)	COST per MIPS
L304	160	0.14	500	3,704,000
AN/UYK-502	512	0.22	175	795,000
AN/UYK-505	512	0.45	275	611,000
M68030 SINGLE BOARD COMPUTER	4,000	6.00	155	26,000

NOTES:
1. The L304 is the command and control computer which was fitted in the DDH-280 class prior to the TRUMP refit.
2. "MIPS" is millions of instructions per second.
3. The Militarized Reconfigurable Multiprocessor, currently being developed as the next-generation naval standard computer could contain up to ten M68030 Single Board Computers. The Advanced Development Model of the MRM contains two Single Board Computers and has the equivalent processing power of 16 AN/UYK-505 computers.

It should also be remembered that computers are useful to a system only when they are programmed and that the major cost of a computer-based sensor or weapon system today is in its software. Given the high cost of producing this software, commercial off-the-shelf software should be used whenever possible — something the present generation of standard computers will not allow because they are restricted to CMS-2 software.

The U.S. Navy recognizes that its current series of AN/UYK computers does not meet the processing requirements of today's sophisticated combat systems. For example, in the AEGIS ships, all new operational requirements are being programmed in embedded commercial microprocessors instead of the six AN/UYK-43 standard computers originally fitted. The standard computers now account for less than 50 percent of the total processing power in these ships. For its next-generation submarine combat system, the AN/BSY-2, the U.S.N. has completely ignored the standard, stand-alone computers in favour of Motorola's 68030 embedded 32-bit microprocessor.

One striking example of problems associated with standard computers is in the B-2 Stealth bomber, widely considered the most advanced aircraft in existence. For all that, its computers depend on obsolete 16-bit processors, when modern 32-bit processors could have been obtained for just a few dollars at any downtown computer store. This situation occurred because the developers of the B-2 were directed to use standard military computers for all applications in the aircraft. Now they and the air force must live with the limitations imposed by dated processors.

Should there be standards?

The basic problem with the present standard computers is that they are unique to the military and use a unique software language. The objective should be not to eliminate standard stand-alone computers completely, but to restrict their use to applications which cannot employ commercial embedded processors. Hence, all applications should *first* consider making use of commercial embedded microprocessors, but if a stand-alone computer must be used, then the standard computer of choice should reflect widely accepted commercial standards, interfaces, protocols and software language.

It should be noted that this objective is being achieved in the development of the navy's next-generation standard computer — the Militarized Reconfigurable Multiprocessor (MRM). The MRM is based on a VME-bus, open system architecture which is recognized worldwide as the defacto industry standard. It uses Motorola 68030 microprocessors in parallel processing and reflects state-of-the-art commercial technology. The Advanced Development Model (ADM) of the MRM was delivered to DMCS 8 in August 1989.

The ADM consists of two Single Board Computers mounted on two circuit cards, each card having a Motorola 68030 microprocessor and four megabytes of memory. The two circuit cards have a combined processor instruction rate of approximately 12 MIPS and processing power equivalent to 16 AN/UYK-505 computers. And yet, these two cards weigh only 2 lbs (compared to the 16 505s which would have a total weight of about 4,000 lbs).

Embedded processors should reflect what is readily available commercially. In other words, the embedded processor for a subsystem should be seen as any other component of that subsystem, be it an amplifier, an oscillator, a driver, etc. There is no doubt that standard, stand-alone computers are required for some specific shipboard applications, but in most cases the required processing power can be embedded in a particular combat subsystem. The subsystem itself would, in many cases, be built around a VME-bus in a militarized chassis.

Nowadays it is entirely possible to have a subsystem with a built-in computer, or a computer with a few extra circuit cards for the subsystem functions. For example, each of the CPF's 13 UYK-502 command and control display drivers could today be easily replaced by an embedded microprocessor circuit card.

Conclusion

Computers have become an essential element of all naval systems and are now widely used both as embedded processors and as stand-alone machines. The navy's reliance on standard computers for all shipboard tactical data processing has shown not to be cost-effective because of the standards' lack of commercial compatibility, their poor performance and their short effective life. Moreover, since standard naval computers cannot use off-the-shelf software as do the commercial micros, potentially major life-cycle savings are not being realized.

Standard, stand-alone computers may be needed for specific applications, but greater use must now be made of embedded commercial microprocessors as the primary source of processing power in shipboard systems. Otherwise, the continued introduction of standard computers that feature architectures and languages unique to the navy will only serve to have naval computer technology catch up to the past.

Cdr Cyr is the DMCS 8 section head for naval computer technology at NDHQ.

ACM SIGAda Conference
1989 Ottawa Meeting

By R.C. Johnston

I had the good fortune, recently, to attend the first SIGAda[1] conference to be held in Canada. During the week 8 - 12 August, 1989 more than 350 people from Ottawa and across North America attended a variety of intensive sessions on: Software Engineering and Ada; The Ada 9X Project; Economical, Social and Legal Issues of Software Reuse; Computer Aided Software Engineering; Ada Development Methods; the Canadian Space Program; Ada and Government; and Software Engineering Education. The theme for the conference was "Ada: A Driving Factor for Software Quality and Productivity Improvement." Here are a few of the highlights:

Ada 9X refers to the revision of the Ada programming language, ANSI/MIL-STD-1815A, for the 1990s to reflect current essential requirements. The language was standardized in 1983 and its revision is viewed as a natural part of the language maturation process. An international team of Ada experts is currently collecting and reviewing Ada language revision requests. Of note in this project is that the project office's aim is to revise and reaffirm Ada as the DoD, American National Standards Institute (ANSI), International Standards Organization (ISO) and National Institute for Standards and Technology (NIST) standard for the 1990s. Adoption of the revised Ada standard is planned for the fall of 1992.

Software Reuse is one of the cornerstones upon which the use of Ada is based. Intellectual property laws, such as copyright, patent and trade secrets, will often render unlawful the reuse of a software product or some component of a product without first obtaining the permission of the owner of the intellectual property rights. Managing projects which expect to show cost benefits through the reuse of software must therefore take into account licensing and the possibility of copyright infringement (intentional or otherwise). Some tools to facilitate reuse are emerging, mostly integrated with design tools, but much work is still required before a (set of) tool(s) is available which is capable of determining a best-fit of the characteristics of a requirement or design with a component from the reusable software library.

Computer Aided Software Engineering (CASE) and *Ada Development Methods* are merging technologies whereby many of the software engineering methodologies, primarily related to software design, have been given computer assistance. These methodologies use graphical notations to represent the design of a system. A typical CASE tool is [2]*Adagen*™ by Mark V Systems Limited, a windows-based, graphical software design tool for the design and maintenance phases of Ada-based software development projects. It features: high-level design and requirements analysis using object interaction diagrams as proposed by Ed Colbert; Ada detailed design, using object-oriented software development diagrams as proposed by Booch and Buhr; automatic generation of compilable Ada code and specifications from detailed design diagrams; and DoD-STD-2167A graphics and text capture and export.

Another CASE tool demonstrated during the conference was [3]*CASEworks/RT*™ by Multiprocessor Toolsmiths Inc. of Nepean, Ontario. Running in any of MS-DOS, Unix or VAX/VMS host systems, CASEworks/RT provides complete graphical editing, checking, code generation and display, simulation and system generation capabilities, source and system level debugging support for simulations and real-time applications, and a real-time multiprocessor operating system.

A discussion arose out of these presentations on the effect of software development tools on the DoD-STD-2167A software development life-cycle model. The standard requires that detailed design, software test descriptions and interface design documents be delivered for critical design review prior to coding and testing computer software units. But when is source code *not* source code, but detailed design? The problem arises from the nature of Ada in that it is usable as a design language; i.e. the detailed design is done using an Ada program design language, it is compilable, and it will be incorporated into the source code.

A related issue arising from this discussion is in the partitioning of the development between designers (engineers/CSEs) and coders (technicians/NCMs). It is no longer practical to separate software design from coding. Similarly, in the in-service phase of software, saying that it is analogous to hardware doesn't acknowledge that rigorously designed software is more complex than hardware, and that changes may be required in the design of the software (which requires many of the tools that were used in its development). You can't take a piece of software out of the spares box and replace it like a circuit card or a resistor. Repairing software requires much broader skills than a coder can provide.

DoD-STD-2167A and its "waterfall" life-cycle model was a topic which arose several times in discussions. The observation was made that the model and the phasing of documentation reviews and delivery is not consistent with efficient system design practices. The preferred software life-cycle model for system development is a spiral[4] (*Fig. 1*) which uses prototypes: to determine objectives, alternatives and constraints; evaluate alternatives, identify and resolve risks;

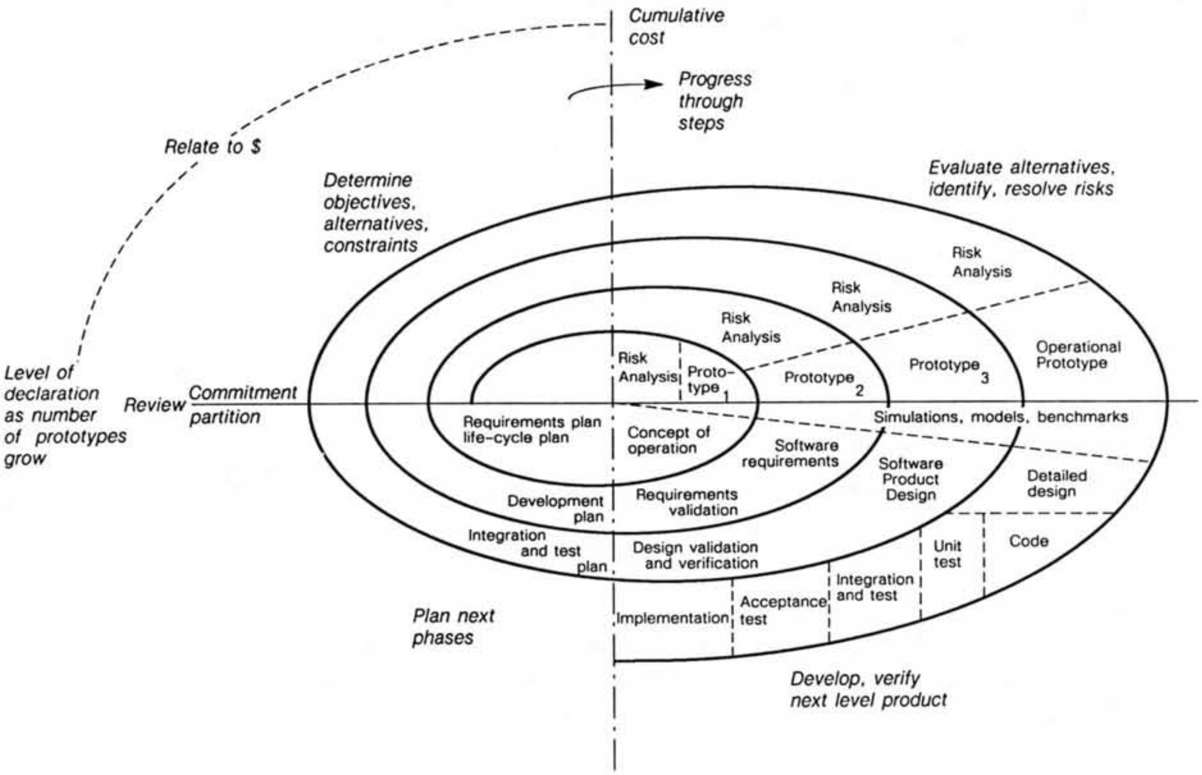


Fig. 1. Spiral Model (Boehm, 1986)

develop and verify the next-level product/prototype; and plan for the follow-on phases. Prototyping provides some assurance that a usable product will be delivered within the budget constraints of the project.

Canadian Space Applications, focusing specifically on the *Mobile Servicing System* (MSS), dealt with Canada's $700M contribution to the NASA space station "*Freedom*." The MSS consists of an "attachment fixture" (for attachment, power and data) at each end of a segmented, 16-metre-long manipulation arm, a movable base for the arm, a two-armed auxiliary robot, the software to control all of these, as well as ground-based support software for operation and maintenance. The purpose of the MSS is to assist astronauts to assemble and maintain the space station, and to handle and service satellites and on-station payloads. An estimated 350,000 lines of critical Ada code will be needed for both the orbiting and ground-based systems. Project risk is reduced and quality software is developed by the use of software prototyping and on-the-job training in methodology, tools and Ada.

Ada and Government covered a variety of presentations and discussions on: the Ada policy and implementation plan of the Department of National Defence; the NATO Ada Programming Support Environment; the New Shipborne Aircraft project; and the use of Ada for the Canadian Automated Air Traffic System. In all cases, significant benefits have arisen from the application of Ada and software engineering where, in the words of Dr. Charles McKay:

"*Software Engineering* is the establishment and application of sound engineering *concepts, principles, models, methods, tools and environments,* combined with appropriate *standards, procedures, guidelines and practices,* to support computing which is *correct, modifiable, reliable and safe, efficient and understandable* throughout the life cycle of the applications."[5]

Dr. McKay, of the Software Engineering Research Center at the University of Houston, gave the keynote address on *Software Engineering Education.* The attendees who chose to stay for this, the last session of the last day, listened with spellbound attention as he unravelled the complex domain of software engineering. His address ranged from the problems that led to the creation of software engineering, through the myriad advances in theory and technology, to the growing complexity and size of applications, concepts, principles and models, and the major activities in the life cycle of software/hardware systems. In all, it was a witty and informative dissertation which emphasized the need for perseverance in developing the theoretical foundations of software engineering.

References

1. **Special Interest Group in Ada, part of the Association of Computing Machinery (ACM)**
2. **Adagen is a registered trademark of Mark V Systems Inc.**
3. **CASEworks/RT is a registered trademark of Multiprocessor Toolsmiths Inc.**
4. **Proposed by B. Boehm in 1986**
5. **Dr. Charles McKay, 1985**

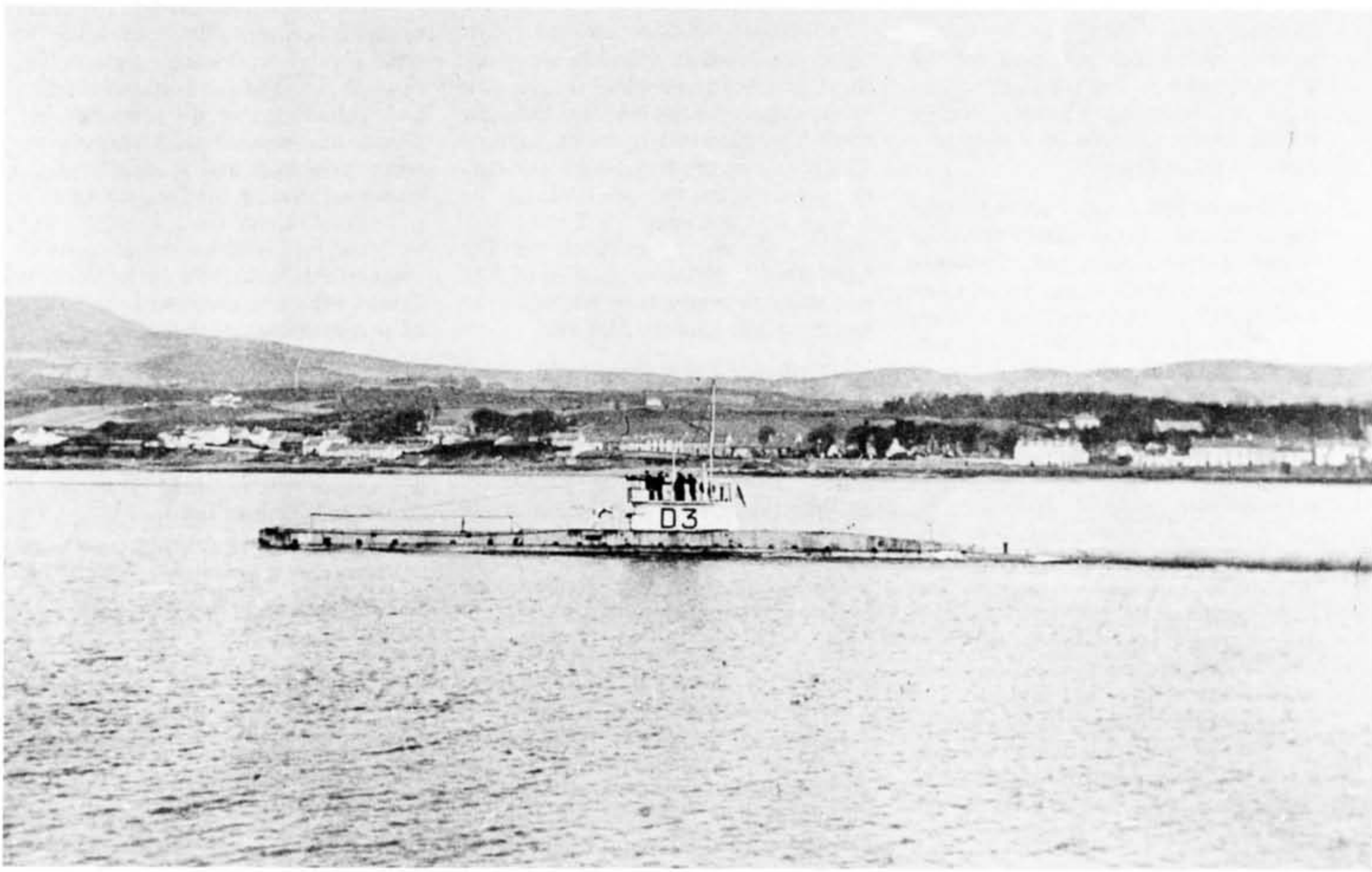
Robert Johnston is on the staff of DMCS 8, where he is responsible for software technology development and application.

Looking Back: 1917
*A Rough Patrol**

By J. David Perkins, CD

***Excerpted from CANADA'S SUBMARINERS, 1914 - 1923, *By Dave Perkins (Boston Mills Press, 1989)*. This article was prepared for publication in the *Maritime Engineering Journal* by the author and is reprinted with permission.**

From April 19, 1916, until she was sunk in the English Channel on March 12, 1918, HM Submarine *D3* was commanded by Canadians. At first by Lieutenant Commander Barney Johnson, RNR, of Vancouver and later by Lieutenant William McKinstry Maitland-Dougall, RCN, of Duncan, B.C. Both officers had started their submarine careers aboard the CC-boats in Esquimalt when the war began. When the RN built and commissioned submarines at Montreal, they went overseas in the new boats — Barney in command of *H8,* Maitland-Dougall as third hand in *H10.* After many adventures they took over *D3* as captain and first lieutenant and were eventually assigned to the depot ship HMS *Vulcan* based at Immingham on the Humber River for employment on East Coast patrols. This is an account of *D3*'s second wintertime patrol on Dogger Bank.

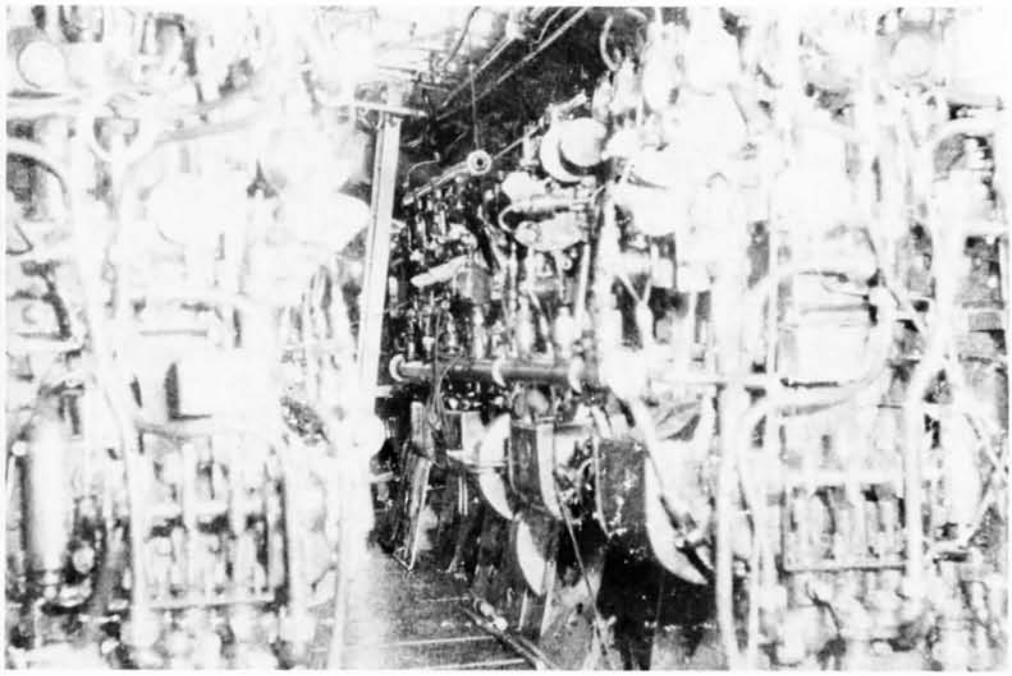


D3 at Rathmullen, summer 1917. *(RN Submarine Museum photo)*

The Patrol

By the end of January 1917 Cap' Johnson's boat was ready for another trip to the Dogger Bank, which is no place to be in the middle of winter with the weather bad so much of the time. When *D3* arrived on station around sunrise on February 2 it was already blowing hard. She dived for the day, surfaced after sunset to charge the battery then went to the bottom in 20 fathoms for a quiet night's rest.

At 0500 hrs the next morning they surfaced into a moderate southwesterly gale accompanied by heavy snow squalls and carried out the mandatory wireless listening watch. Johnson dived an hour later for the usual periscope and hydrophone daylight routine of ten minutes at periscope depth keeping a visual lookout, and 20 minutes between 30 and 60 feet keeping a listening watch on the hydrophones. There wasn't much chance of seeing anything, and even less of hearing anything, under the circumstances.



D-class engine-room, looking aft. *(Author's collection)*

Once safely under, the coxswain issued "war comforts" to the messes to augment the pusser rations. On this occasion he gave out 8 tins of bully beef, 6 tins of sausages, 4 tins of bacon and 4 bottles of fruit preserves. Up Spirits would be held after surfacing, while waiting for the evening meal to be cooked. Cooking while dived was wasteful of precious amps and only added to an already heavily polluted atmosphere.

By late afternoon the seas were running at between twelve and fourteen feet, while the wind had freshened bringing intermittent snow squalls. At 1730 hrs Barney surfaced the boat and ordered a battery charge using both engines. Despite the best efforts of the Chief ERA and his men, both diesels were completely flooded-out through the exhaust system during efforts to get them started. This was an engineering disaster of the worst kind. Both engines would have to be purged of salt water, examined for damage, repaired and reassembled before they could attempt to start them again. The Chief ERA and his crew had their work cut out for them.

Relentlessly, the steep, white-crested, seas smashed onto the 600-ton submarine, so much so that without the need to supply air to the engines the tower was shut down to keep the seas from flooding into the boat. No one knew how long it would take to make repairs; connecting rods could be bent and cylinder liners split, while just getting the engines cleared of salt water would take long enough. The battery, already low after the day-long dive, had to be made to last as long as possible, which meant slow revolutions, no cooking, minimum lighting and no electric heaters.

The interior of the submarine was soon a scene of utter misery; a heaving, cold, foul-smelling, sodden length of pipe packed with twenty-odd half-frozen, hungry, frustrated humans. Those who manned the bridge with only a canvas dodger to keep out the elements, and muffled to the ears in "lammies" (duffle coats and felt trousers) and oilskins, were quite content to be clear of the chaos that reigned inside their submarine.

Ordinarily the diesels occupied a good quarter of the vessel, but when stripped down, large, greasy parts of the engines littered the single interior compartment from bow to stern. The stink of diesel oil permeated everything as the decks were soon covered in a thick, slippery, sludge of sea water, oil, grease and carbon. At least the engines hadn't had a chance to heat up. It was bad enough having to work on them in a gale when

HMS/M *D3* at Harwich, June 1916. The officer on the casing is believed to be Wm. Maitland-Dougall, First Lieutenant in *D3* at the time. *(RN Submarine Museum photo)*

D3

D3 had a dived displacement of 620 tons, was 162 feet long, 20.5 feet on the beam. Internally the submarine was open throughout, there being no full bulkheads. She had two screws and was powered by a direct driving, 600 h.p., six-cylinder Vickers diesel and a 275 h.p. electric motor on each shaft. Speed on the diesels was 16 knots, on the motors a maximum of 9 knots. The D-class boats were armed with three 18-inch torpedo tubes, two forward one above the other, one aft. One reload for each tube was carried. *D3* also carried a high-angle 6-pdr gun. They were fitted with two periscopes, wireless (radio) sending and receiving sets and hydrophones. There was one head — aft, in the engine-room — which emptied into a trim tank. Maximum diving depth was about 150 feet.

The complement was three officers and 23 men. The three ERAs stood a watch apiece, while the remainder of the ship's company was in two watches. There were two bunks only, one for the CO, the other being shared by the first lieutenant and navigator. Senior hands slung hammocks, the rest dossed down wherever they could.

they were cool. Hot engines would have meant much slower progress and certain burns. Despite the desperate working conditions the ERAs and stokers struggled manfully to get their engines going again.

By midnight the port engine was running again, "bumping amps into the box" as hard as it could be made to go. The hands eagerly anticipated that moment when the battery would be "up" and they could dive out of the weather.

By 0200 hrs Barney had had enough and took the boat down to the bottom for what was left of the night. This respite from the effects of the weather gave the engine-room staff considerably better working conditions, but there would be no sleep for any of them until both engines were restored to full working order. All through the remainder of that night and into the next morning tools clanked and clattered in tune with the ERAs' and stokers' cursing as the recalcitrant engines were repaired.

By 1000 hrs *D3* was back on the job at periscope depth keeping her watch. The seas were falling, visibility had improved considerably and, with two good engines, the patrol was continued until they finally surfaced 48 hours later and set course for Flamborough Head.

Some patrols were definitely better than others and that had been a bad one. It is interesting to note that despite their nearness to home port and the state of the weather there was never any thought of breaking off the patrol and heading for base. That was not Cap' Johnson's way of doing things.

Upon arrival only a "make and mend" was granted to the crew and the customary three days' patrol leave was withheld from the watch whose turn it was to take it. Exciting things were happening all around the depot and the boats had been ordered to hold themselves in readiness to go to sea at short notice. The most significant event, and that which heralded everything else that was about to happen to *Vulcan* and her charges, was the arrival of Captain M.E. Nasmith, V.C., one of Britain's foremost submariners. He had relieved Commander White in command of the 3rd Flotilla during *D3*'s absence, and the rumour soon reached the messdecks — the flotilla was headed overseas.

David Perkins served 25 years in the Canadian navy, mostly in the submarine service. Following his retirement as a C2WU (torpedoman) in 1979, he began a study of Canada's involvement in submarines. This research led to the writing and publication last September of Canada's Submariners, 1914-1923. *A sequel covering the period of World War Two and afterward is planned. Mr. Perkins is shown holding the bell of the Vickers Montreal-built submarine* H6 *(May 1915).*

News Briefs

TRUMP progress slow, but steady

At present, both HMCS *Algonquin* and HMCS *Iroquois* are in the Davie yard at Lauzon, Quebec. *Algonquin* is afloat and is now beginning to appear in her post-modernization form. The VLS has been installed, as have the forward gunhouse structure, the funnel and auxiliary uptakes. The only major components now missing are the two masts. Major systems such as the auxiliary seawater circ system are still being installed, while much effort is being devoted to the main machinery raft and the alignment of the shaftlines.

Iroquois is still in drydock and is likely to remain there for a second winter. The long and arduous task of stripping out old equipment and structure is almost complete, and some work has begun on installing the new systems. Structural work is well underway in the forward half of the ship and the VLS should be installed in the near future.

Training of *Algonquin* and *Iroquois* ship's crews is progressing with personnel attending a variety of system courses. Training continues in Holland at the Hengelo Land Based Test Facility on the new search and fire-control radars, while on the marine engineering side, courses have been run on the new 1000-kW DG set and the Fire Detection and Suppression System.

Finally, the Vertical Launch System Test Facility at Osborne Head is proceeding well and has been successful in addressing possible interface problems between the ship and VLS, and providing assessments of necessary corrections.

ADM (Mat) retires

Mr. Eldon J. Healey, Assistant Deputy Minister (Materiel) at National Defence Headquarters, will retire from the Department of National Defence and from the Public Service at the end of February 1990. His retirement caps a 4 1/2-year career with the Public Service and a military career of over 32 years.

Mr. Healey was appointed Assistant Deputy Minister (Materiel) for the Department of National Defence in September 1985. In this capacity he has also served both as Canada's National Armaments Director in NATO and as a member of the Board of Directors for Defence Construction Canada (1951) Ltd.

Mr. Healey enrolled in the Royal Canadian Navy in 1953 and underwent engineering studies at Royal Roads Military College in Victoria and the Royal Navy Engineering College in England. He served in a number of ships and held staff positions at various headquarters during his military career.

Mr. Healey is a graduate of the National Defence College in Kingston, Ont. In 1979 he was appointed Director, Maritime Engineering and Maintenance at National Defence Headquarters. He then became the project manager for the Canadian Patrol Frigate project. In 1984 he was appointed Chief, Engineering and Maintenance and promoted to the rank of rear-admiral. He retired from the Canadian Forces in August 1985.

New ADM (Mat) appointed

The Deputy Minister of National Defence, Robert R. Fowler, has announced the appointment of Robert D. Gillespie, 39, of Guelph, Ont., as Assistant Deputy Minister (Materiel) for the Department.

Mr. Gillespie's appointment is effective February 21, following the retirement of Mr. Eldon J. Healey who currently holds the position. Mr. Gillespie is currently the Chief of Supply for the Department of National Defence, a position he has held since 1985.

Certificate of Merit!
Mr. Healey with Cdr Sylvester. *(Canadian Forces photo)*

The *"Midas Touch"*

Congratulations go out to Cdr Jim Sylvester, former DMES 6 section head for maritime maintenance management in DGMEM.

In February Cdr Sylvester was awarded the ADM(Mat) Certificate of Merit. Mr. Eldon J. Healey, Assistant Deputy Minister for Materiel, presented the certificate in recognition of Cdr Sylvester's achievements with the NETE upgrade project, configuration management and the naval maintenance policy.

Former DMES Harvey Neilsen was also on hand to attest to Cdr Sylvester's achievements. "Everything he touched turned to gold," he said.

Cdr Sylvester is currently on French-language training in Ottawa.

MRM ADM accepted

A major milestone occurred in August with the development of the next-generation computer for the navy. The Advanced Development Model of the Militarized Reconfigurable Multiprocessor was accepted by DMCS. The MRM ADM chassis (which has space for 20 circuit cards) contains:

- two single-board computer cards. Each card has a Motorola 68030 processor and 4 MBytes of memory
- two NATO 4153 serial interface cards
- one NATO 4146 parallel interface card

The two single-board computer cards have a combined processor instruction rate of approximately 10 million instructions per second (MIPS), and with the 8 MBytes of memory are equivalent in processing power to 16 AN/UYK-505 computers. This new generation of naval computer provides extensive expansion and growth capabilities by simply adding more processor or memory cards to the chassis. Growth and expansion capability for some designs could be over 1,000 percent. Because the MRM is based on commercially compatible systems, the costs for development and training will be significantly reduced.

The MRM ADM may be seen in DMCS 8.

New Shipborne Aircraft -- project update

In June, 1986 the government provided the direction and funding necessary to see the NSA project through the project definition phase. On August 3, 1987 European Helicopter Industries was identified as the prime contractor to supply between 28 and 51 "Canadianized" EH-101s to DND. The intention is to deploy these helicopters in the fleet in the same numbers as Sea Kings are deployed today.

The NSA's primary missions are anti-submarine warfare, anti-ship surveillance and targeting, while secondary missions are search and rescue, medical evacuation, and vertical replenishment. To carry out these missions the NSA features long range and endurance, a large payload capability, sophisticated avionics and acoustic processing equipment, and will be able to operate in all weather conditions and conduct ship operations in up to sea state 5.

At a current maximum all-up weight of 31,500 lbs, the NSA is both heavier and larger than the Sea King. With the CPF being originally designed for a future NSA of 30,000 lbs, however, some integration problems at the ship/helo interface are expected. The two AORs and DDH-280s were not designed for such helicopters, and so will require a greater effort at the ship/helo interface.

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Naval Reserve NCM Engineers
Coming up in our July issue