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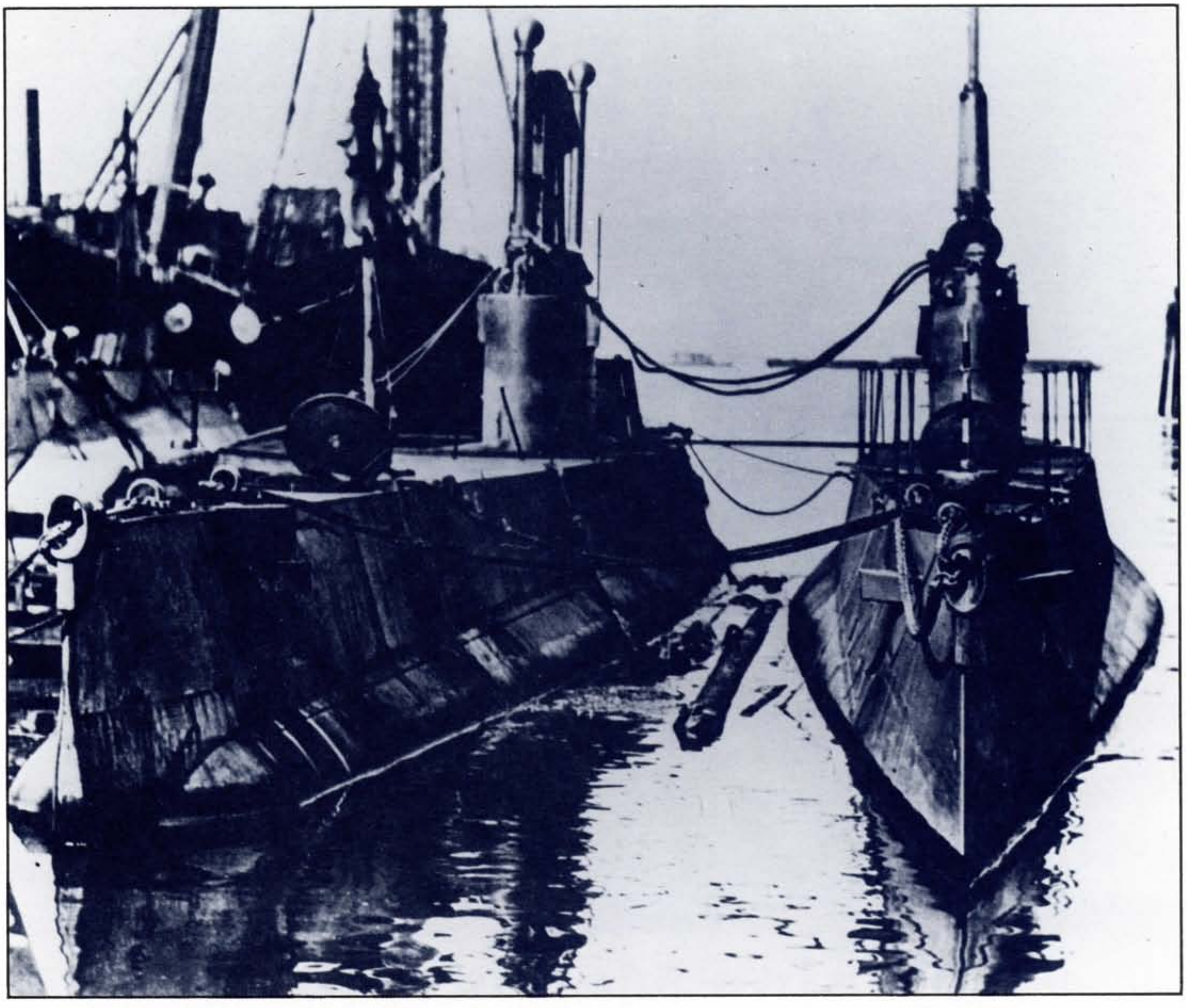
MARITIME ENGINEERING Journal du GÉNIE MARITIME



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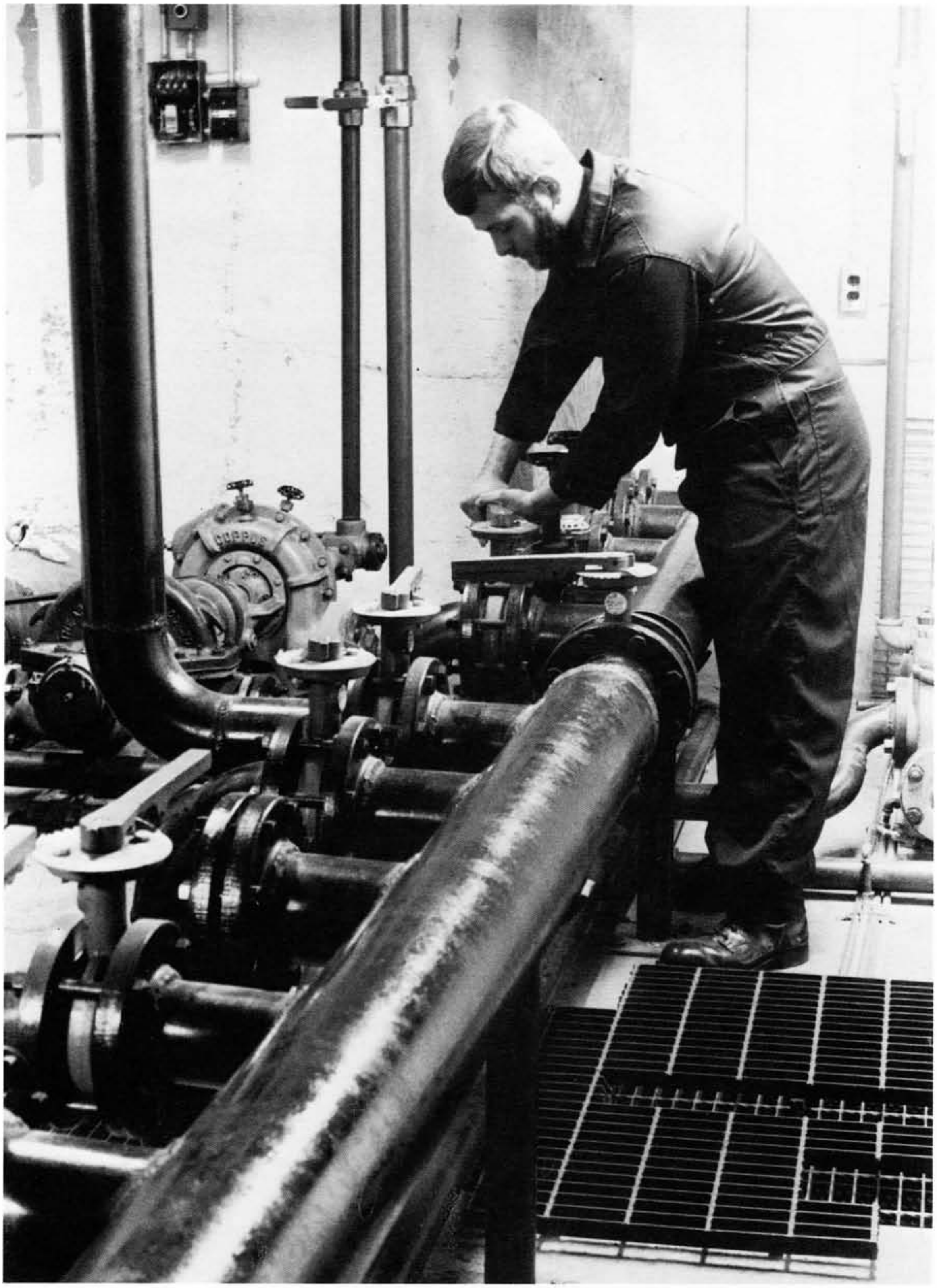
PFTM Rimouski –



turning Mechs into Techs...

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MARITIME ENGINEERING

Journal

du GÉNIE MARITIME

DIRECTOR-GENERAL
MARITIME ENGINEERING and
MAINTENANCE
Commodore J.A. Gruber

OUR COVER

CC1 and *CC2* at Seattle, Washington in August 1914. The submarine in the background (left) is probably the USS *Walrus* (K8).

APRIL 1986

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MARITIME ENGINEERING JOURNAL
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JOURNAL DU GÉNIE MARITIME
ISSN 0713 - 0058

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

Editor's Notes

Digital signal processing has been recognized as the way ahead for sonar for some time, but it is only recently that developments in semiconductor technology have made it both technically and financially feasible. A number of capable signal processors are currently available, but it is Motorola Information Systems' Teamed-Architecture Signal Processor (T-ASP) that has been selected for development into the militarized AN/UYS-501 for active- and passive-sonar applications. T-ASP's high performance rating and low cost make it the most cost-effective signal processor on the market today. In our first major combat systems article since the January 1985 edition of the *Journal*, authors Tony Yuan and LCdr Roger Miskowicz describe the functional characteristics and merits of T-ASP, and compare this signal processor with its closest competitors. The design philosophy of T-ASP is based on the assumption that the "Fast Fourier Transform" is the single-most important algorithm in digital signal processing, and in a companion piece to the article LCdr Peter J. Lenk describes this mathematical technique for translating a signal into its component parts.

L.T. Taylor is no stranger to the *Journal*. His article on *An In-Line Speed-Change Gear Unit* appeared in our July 83 issue. In his current article, *The Operational Range Factor,* Mr. Taylor describes a method for numerically comparing competing warship machinery options. The "factor" is a single range representative of operating a ship and machinery for an operational profile on a full load of fuel. Since it can be computed for any combination of machinery arrangement and ship-employment profile, the operational range factor becomes useful as a single point of comparison during the machinery selection process of warship design.

Also in this issue, Petty Officer F.B. Kirke proposes a revised training profile for marine engineering training in spectrometric oil analysis, and Lt(N) Serge Lamirande introduces us to the francophone version of the Marine Engineering Technician Training Plan — the *PFTM* at Rimouski. Of special interest, here, is that later this year students of the 1983 inaugural class will complete the three-year training programme to become PFTM's first graduating class.

In our lead article, Dave Perkins gives us an exclusive, in-depth technical description of Canada's first submarines — the "CC" boats. Purchased in 1914 for the Naval Service of Canada, the two submarines were used for short-range coastal patrols during the First World War and were paid off in December 1918. Very little has been previously published about the technical aspects of the "CC" boats, but through extensive research on the subject Mr. Perkins has been able to piece together enough details to present this first-of-its-kind technical description. Working from his home in Dartmouth, Nova Scotia, Dave Perkins is currently researching and writing a book he plans to call *Canadians in Submarines, Submarines in Canada, 1914-1946*. The article in this issue is based on his research for that larger work.

And finally, it has been brought to my attention that FORCES SOUS-MARINES has prepared a two issue "Special Canada" edition for their International Journal of Naval Warfare, Space and Submarine Technology. One-year subscriptions (6 issues) are available at a cost of $30 U.S. for surface-mail ($38 U.S. air-mail) delivery to Canada. Requests should be addressed to: FORCES SOUS-MARINES, the International Journal of Naval Warfare, Box 38 — Succ. Outremont, P.Q. H2V 4M6.

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 programmes, situations and events.
- To provide announcements of programmes concerning maritime engineering personnel.
- To provide personnel news not covered by official publications.

LES OBJECTIFS DU JOURNAL DU GÉNIE MARITIME

- promouvoir le professionnalisme chez les ingénieurs et les techniciens du génie maritime.
- offrir une tribune libre où l'on peut traiter de questions d'intérêt pour la collectivité du génie maritime, même si elles sont controversées.
- présenter des articles d'ordre pratique sur des questions de génie maritime.
- présenter des articles retraçant l'historique des programmes actuels et des situations et événements d'actualité.
- annoncer les programmes touchant le personnel du génie maritime.
- publier des nouvelles sur le personnel qui n'ont pas paru dans les publications officielles.

Letters to the Editor

Editor:

Please accept sincere best wishes for continued success in your well written and thoroughly enjoyable professional journal. The articles reflect much credit on the authors, your staff and on the engineering community in general.

As a ship's Captain I find the *Journal* keeps me abreast of some of the current interests and concerns of our engineers. Additionally, its scope and content serve as a training aid by providing an excellent perspective for all junior officers under training.

Cdr K.A. Nason
Commanding Officer
HMCS *Mackenzie*

Dear Editor,

Thank you for sending me a copy of the latest (January 1986) edition of the Maritime Engineering Journal. The recent graphic and layout changes make for a vast improvement on readability and professional appearance.

However, I would like to make an observation. It is not uncommon for the Naval Reserve to be overlooked. In this case I refer to the very small but highly motivated Naval Reserve Maritime Engineering community. We are just 8 active and serving officers in the MARE 44 MOC. This number has been on the decline for several years — just two years ago we numbered twenty on strength. I would surmise that this indicates a degree of disenchantment with the role and employment of NR MAREs. It would appear to be time for an NR MARE Get-Well Program.

We have our own problems, mostly from being outside the regular force MARE community and information main stream. Some of your readers will know already that few of us spend any time on steamers or 280s. Instead we tend to be involved in running the Reserve Engineering trades training in-unit and with looking after unit tenders.

I would like to see an article or two on small vessels, such as minesweepers, coastal patrol and inland (riverine) vessels. The rumoured minor war vessel acquisition program might make for interesting reading.

Please accept my thanks for the latest copy and my appreciation for an excellent, informative engineering magazine.

Yours truly,

Lt(NR) P.A. Warner

WRITER'S GUIDE

We are interested in receiving *unclassified* submissions on subjects that meet any of the stated objectives. Manuscripts and letters may be submitted in French or English, and those selected by the Editorial Committee for publication will be run without translation in the language which they were submitted.

Article submissions must be typed, double-spaced, on 8½ × 11 white bond paper and should as a rule not exceed 6,000 words (about 25 pages double-spaced). Photographs or illustrations accompanying the manuscript must have complete captions, and a short biographical note on the author should be included in the manuscript.

Letters of any length are welcome, but only signed correspondence will be considered for publication. The first page of all submissions must include the author's name, address and telephone number.

At the moment we are only able to run a limited number of black and white photographs in each issue, so photo quality is important. Diagrams, sketches and line drawings reproduce extremely well and should be submitted whenever possible. Every effort will be made to return photos and artwork in good condition, but the **Journal** can assume no responsibility for this. Authors are advised to keep a copy of their manuscripts.

GUIDE DE RÉDACTION

Nous désirons recevoir des textes non classifiés qui répondent à l'un ou l'autre des objectifs mentionnés précédemment. Les manuscrits et les lettres peuvent être présentés en anglais ou en français, et les textes choisis seront publiés dans la langue d'origine, sans traduction.

Les articles doivent être dactylographiés à double interligne sur feuilles de papier à lettre de 8-1/2 sur 11 et, en règle générale, ils ne doivent pas dépasser 6,000 mots (environ 25 pages à double interligne). Les illustrations et les photographies doivent être accompagnées d'une légende complète, et le manuscrit doit comprendre une brève note biographique sur l'auteur.

Les lettres de toutes longueurs sont les bienvenues. Cependant, seules les lettres signées pourront être publiées. La première page de tout texte doit indiquer le nom, l'adresse et le numéro de téléphone de l'auteur.

À l'heure actuelle, nous ne pouvons publier qu'un nombre limité de photographies en noir et blanc dans chaque numéro. C'est pourquoi la qualité des photos est très importante. La reproduction des diagrammes, des croquis et des dessins est d'excellente qualité et nous vous encourageons à nous en faire parveir lorsque c'est possible. Nous ferons tout en notre possible pour vous retourner les photos et les présentations graphiques en bon état. Cependant, le Journal ne peut assumer aucune responsabilité à cet égard. Les auteurs sont priés de conserver une copie de leurs manuscrits.

Commodore's Corner

by Commodore J.A. Gruber, OMM, CD, DGMEM

In this my last contribution to the MARE Journal, I thought it appropriate that I examine some of the major influences that have affected our craft and out of that suggest how we are coping and then provide a future perspective.

Certainly, our emergence after the Second World War was centred around high-pressure steam systems for propulsion and electrical/mechanical drive systems as a fundamental way of controlling our sensor and weapon systems. We developed a complete professional and cultural structure to suit. In developing the successors to these warships, the influence of the cancelled G.P. Frigate, while somewhat lost in history, should not be underestimated. While it was a program disappointment it did shape, not without criticism and pain, the DDH-280 with its total gas-turbined propulsion and fully integrated command, control and weapon systems. Another influence was, of course, the decision to marry the ASW helicopter to the destroyer as an integral part of the weapon system.

In more recent times the development of digital distributed architecture (the SHIN family) has heralded a new order. However, in a program sense the most significant influence has been the CPF and its emphasis on developing an industrial warship design management and construction base. Clearly this latter change, as well, has not been without pain and a degree of professional trauma. The fact that there have been significant problems surely must have been expected and only the most naive among those who directed the concept could expect a pain-free or perfect transition.

The coincident shortages of personnel and resources have forced us into a mode where we are unable to do everything we would like. Those whose only professional challenge is to say that "I can touch what I have built" should not feel any less satisfied given that "our" footprint is all over this ship as I am convinced it will be in the other upcoming programs. Of particular significance are the unique Canadian developments which were produced through the initiative of those in the Naval design system.

We have modernized our trade and classification structure and withstood the ravages of high attrition and earlier stagnation in our vessel replacement programs. We have attacked the MARE production problem and can see the point in the future when our numbers may meet our needs. The quality has never been in question.

We have maintained our existing Fleet with fewer resources yet to as high or higher standards than in the past. Where else will you see 27-year-old destroyers with platform and weapon systems unreduced from the day they were first trialled.

Having reached this point, where do we go? The technology and our ability to adapt to it is the key. A recent article states that rather than be frightened of computers, those who are not adept at them, may have an advantage as the intelligent computer starts to emerge. That may be glib but the message to use rather than resist technological progress seems clear. What we must do is continue the major Maritime Research and Development in a structured and disciplined way. What we also must do is continue to hone and retain our total warship design capability. Out of these activities we will retain the base on which to demonstrate our ability to operate and maintain the Fleet and new systems as they are introduced to demonstrate why we can be entrusted with the Fleet's technical preparedness.

I am convinced we must encourage those among us with the ideas and concepts which will influence future systems and above all, we will have to show new and improved ability to lead, manage and be accountable. In this regard we must continue to expand our ability to undertake Sea General Naval and Any positions as well as MARE. As I watch the emergence of our LCDR, CDR, CAPTAIN(N) inventory I can see a strong blend. The young have never been better.

The era of the new programs such as CPF, SRP II, TRUMP, CASAP is another of those significant times in our history. In the past it hasn't been easy, nor will it be in the future but there is a future with real challenge and promise. It has been my privilege to have served as a MARE in our Navy.

Editor's Note: Commodore Gruber will be retiring later this summer and so this will be his last issue of the Journal *as DGMEM. On behalf of the* Journal *staff and all MAREs I would like to thank Commodore Gruber for his unswerving support for this magazine, and wish him all the very best in his future endeavours.*

CC1 and *CC2*: The First Canadian Submarines

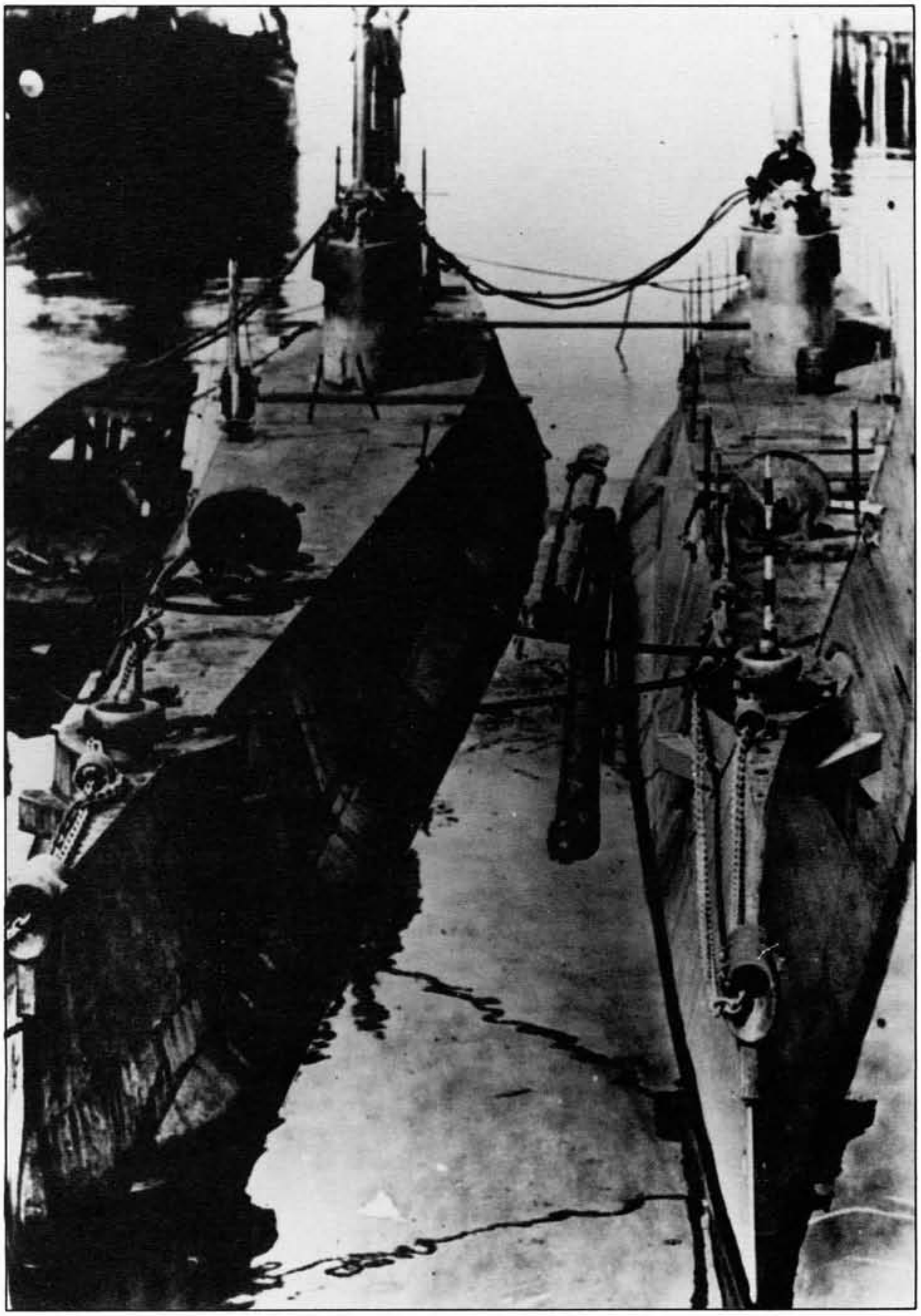
by Dave Perkins Copyright 1986

Background

Canada's first submarines were purchased in a private deal negotiated by the Premier of British Columbia on behalf of the Naval Service of Canada. These vessels had been assembled at the Seattle Shipbuilding and Drydock Company for the Chilean navy. Built to Electric Boat Company designs, all material, engines and equipment were supplied by Electric Boat from their plant in Groton, Connecticut. Ordered in 1911, laid down the following year, launched in June and December, 1913, the two boats were christened *Iquique* and *Antofagasta*. During trials the Chilean authorities rejected both submarines as being unstable when dived, for exceeding the designed tonnage and for failing to meet the endurance specifications. As a result the Chilean government suspended payments on the boats.

By that time war between the Central Powers and Britain and France was imminent. Sensing an opportunity, the builders offered the boats to Sir Richard McBride, the Premier of B.C., who was seeking modern warships to support the old cruiser *Rainbow*, the RCN's only effective warship on the west coast. With powerful German cruisers loose in the Pacific, and being the only Commonwealth target on the Pacific North American coast, B.C. felt vulnerable. As time was running out and there were no other warships available, it was decided to go ahead and buy the boats using provincial funds while waiting for Ottawa to make up its mind.

Arrangements for the purchase and transfer of the submarines were completed on the day that Great Britain declared war against the Central Powers on behalf of herself and the Empire. The boats arrived at Esquimalt the following morning. On the 7th of August, 1914, the federal government ratified the deal and commissioned the boats into the RCN as HMCS/M *C1* (*Iquique*) and *C2* (*Antofagasta*). It soon became common to refer to them as Canadian *C1* and *C2*, or more simply *CC1* and *CC2*. This form of identification was officially adopted in October, 1914.



CC1 *and* CC2 *at Seattle, August, 1914.*

The Submarines

Hull

The "CC" boats were of single-hull design and all tanks were internal to the pressure hull. Each displaced 313 tons surfaced and 421 tons dived. They were almost identical, the major difference being that *CC1* had four 18-inch bow tubes and was 144 feet in length while *CC2* had only two tubes forward and was 152 feet long. Externally *CC1* had a bluff bow shape while *CC2* was given a much finer run forward which accounted for the extra length.

The basic shape of the hull was that of a cigar with a fairly consistent taper throughout, and was circular in section except at the stern. The stern portion was in the shape of a horizontally flattened ellipse with the propeller shafts exiting from the two corners.

The outer shell, or pressure hull, was formed of mild-steel plate and "L" section ribs. The plates varied in thickness between 7/6" and 5/16", the ribs were 3" on the flat and 5" deep and were spaced at 18" centres. The hull was designed for a diving depth of 200 feet. The submarines were of rivetted construction throughout, all joints and rivet holes being sealed with "red-lead" during assembly. The box-shaped keel was built up of 1/2" steel as it was anticipated the boats would encounter the bottom fairly frequently.

CC1 on the cradle at Yarrows, Esquimalt, July, 1916. The ship alongside the jetty is the cruiser HMS Newcastle.

Casing

The top of the hull was covered by a light steel casing running from the stem-post to a point 20 feet from the stern. Amidships was a small fin-like structure that protected the conning tower, periscope sheers and battery ventilation exhaust ventilators, and which provided a bridge platform for surface navigation. Here the casing was 6 feet wide and it tapered to a point at both ends. From where the deck ended aft, the structure was continued in an inverted "V" shape that sloped down under the waterline to terminate at the stern-cap housing. The entire casing was free-flooding and self-bailing with vent holes around the upper perimeter and drain slots at the bottom of the sides.

Inside the casing were located the forward hydroplane tilting and housing gearing, a sloping bed for the deck anchor, the anchor windlass and the stowage for a small utility crane fitted with a winch used for handling the anchor, torpedoes and other heavy gear. Berthing lines and wires, fenders and the gangplank were also stowed inside the casing.

Ground Tackle

In addition to the deck anchor the boats were provided with a one-ton mushroom anchor that was housed in the keel near the bows. A hawse-pipe led to a roller in line with the windlass under the forecasing. This anchor could be worked from inside the boat and was used to moor the submarine while dived. The anchor windlass held 50 fathoms of steel-wire rope which could be rigged for either anchor.

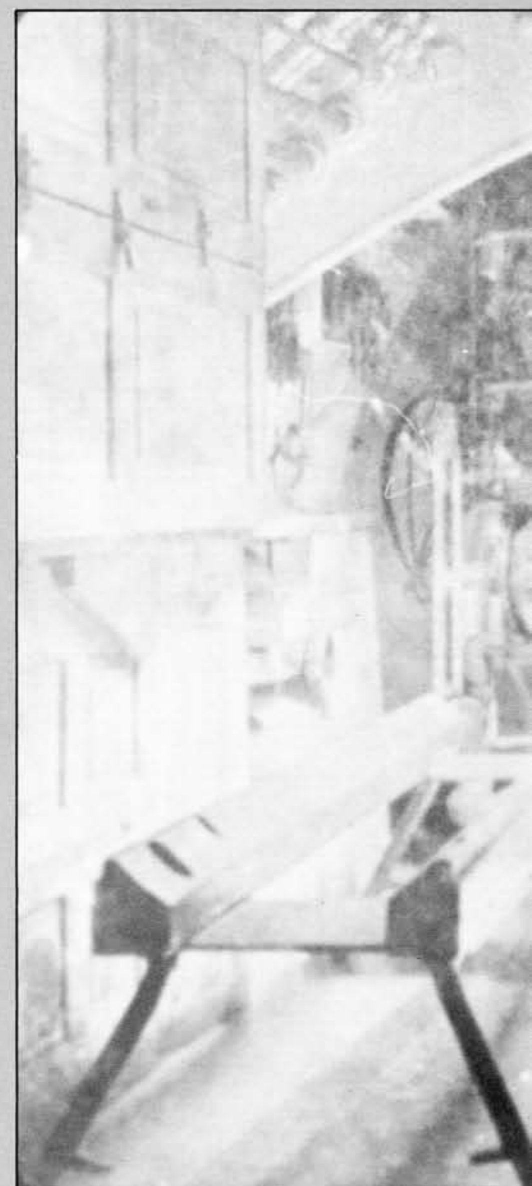
Bridge

The bridge platform on top of the fin had small extensions at each side to provide additional deck space. Ventilation exhausts for the forward and after batteries protruded from the deck at the front and rear. The periscope sheers rose 6 feet from the centre of the fin and were plated over with sheet brass to form a streamlined fairwater. Brass was used so as to reduce the magnetic field near the compass. The magnetic compass (these boats were never fitted with a gyro compass) was housed inside a cast bronze steering stand mounted on the deck immediately forward of the tower. The stand also contained electric steering controls and engine telegraphs, and was sealed with a pressure-tight lid when preparing to dive. The top of the conning tower protruded high enough between the stand and the sheers to allow the viewing ports fitted around its perimeter to clear the deck. The upper conning tower hatch was located in the front of the top of the tower and was hinged on its after edge. A chest-high canvas screen could be rigged on light stanchions around the front of the bridge to provide the watchkeepers with some protection from the weather.

Compartmentation

Forward Compartment

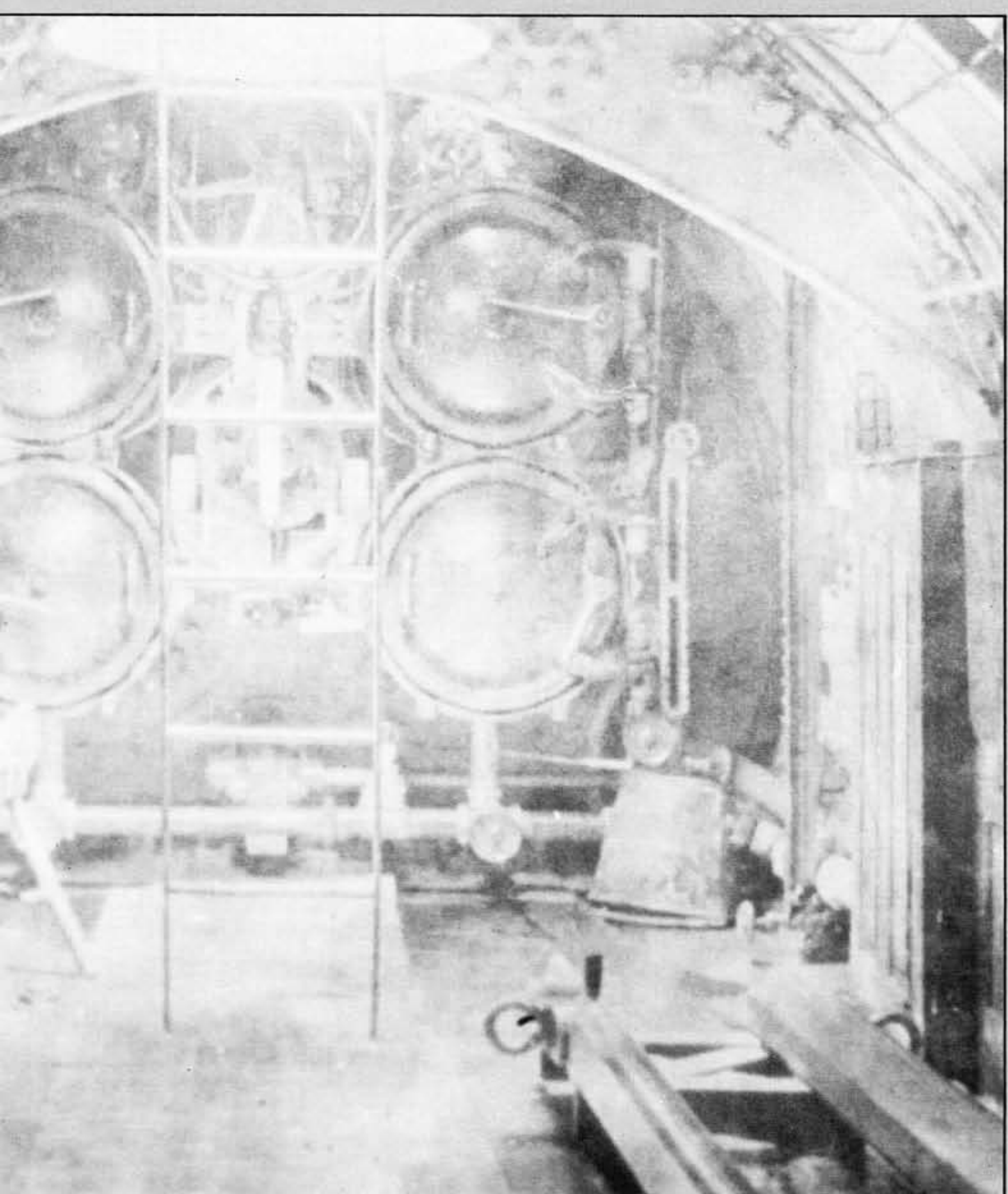
The "CC" boats were divided by watertight bulkheads into four major compartments. The foremost of these, the torpedo tube and stowage compartment, measured 23 feet in length and contained the breech ends of the bronze 18-inch-bore torpedo tubes, the reload torpedoes (all stowed on the deck) and the officers' accommodation which included built-in bunks and panelled wooden closets. One of the port-side cabinets contained the wireless set. On either side, mounted facing out-



Forward torpedo compartment of CC1. (Maritim board just abaft the tubes, were the transducers for the "Fessenden" underwater signalling gear for boat-to-boat Morse communication. Below deck were the three forward fuel tanks and the 32 bottles holding 142.7 cubic feet of air at 2,500 p.s.i. that made up the five high-pressure (HP) air groups.

The space between the torpedo tubes was occupied by the bowcap operating gear and the valves for working the tubes. In *CC2* there were simple handwheels for opening and closing the individual door-type bowcaps, while *CC1* had a single dome-shaped bowcap that covered all four muzzles. The gearing rotated a spindle that extended from the fore-ends through the bulkhead, the forward tanks and the centre of the bowcap, and ended in a bearing in the cast steel stem-post. The bowcap was fixed onto the spindle. There were two openings in this bowcap, 180° apart. To fire, the dome was rotated 45° left or right to bring the openings in line with diagonally opposite top and bottom tubes. Once these had been fired it was a simple matter to rotate the cap 90° to line up the other two tubes. When in the shut position the openings were hidden inside the casing and keel. The entire bowcap was drawn in against the hull so that the plate spanning the open face of the dome was hauled hard up against rubber gaskets on the tube muzzles to make them watertight. There was no interlocking between rear doors and bowcaps in either boat.

Firing air was supplied from two, large air-impulse tanks sited behind the side-panelling, and was admitted to the torpedo tubes by means of solenoid operated firing valves actuated from the control room. The tubes were fitted with air-operated side-stops for holding the torpedoes in place prior to firing.



Museum of British Columbia photo).

The forward torpedo compartment was provided with two hatches — an escape hatch and a "loading scuttle". The escape hatch was situated forward, just abaft the torpedo tubes, and opened onto the upper deck. The "loading scuttle" was an angled hatch at the after end of the compartment used for embarking and disembarking torpedoes. In common with most other hatches in the boat, these were secured by strongbacks, "J" bolts and wing-nuts.

Forward Battery

The next compartment aft was known as the "forward battery" and was 17' 6" long. Below the wood-planked deck was a tank containing one half of the main battery. The space above was devoted to crew accommodation and featured two fully enclosed heads, one forward on the starboard side for the officers, and one aft to port for the crew. There were no sinks or other personal washing facilities. The boat's sides were lined with stowage lockers for personal kit, and suspended from the deckhead were nine, pipe-framed, canvas-bottomed bunks, sufficient for half of the crew.

Control Room

Amidships were the control room and, abaft this, the "after battery". Together these formed one large compartment with a combined length of 24 feet, with the control room proper taking up only 7 feet. In these boats the control-room area was variously described as the "central operating space", the "central command post" or the more familiar "control room". It contained the diving controls, helm, trim pump and valves, Kingston flood-valve levers, 100 p.s.i. low-pressure (LP) air vent-and-blow manifold, electric torpedo tube order panel, the main periscope and the lower conning tower hatch. Below the steel deck was a small compartment in which were mounted the cylindrical "buoyancy tank" (350 gals.*), freshwater tanks (250 gals.) and the operating mechanism for the Kingston valves. The LP air reservoir that supplied the panel in the compartment above was also located in this space.

*In all cases, references to gallons in this article are U.S. gallons.

Conning Tower

Above the control room was the conning tower. This was oval in shape, measured 3'6" fore and aft by 2'6" athwartships, and had a clear 6 feet above the circular deck. The lower hatch-coaming projected 18" below the deck into the control room so that the hatch swung clear under the deck when opened. The conning tower was fully equipped for navigation with a compass reflector, electric steering controls, engine telegraphs and repeat gongs, clinometer, vent-and-blow-panel pressure gauge and a periscope. Six glass ports around the top of the tower provided an all-around view.

The tower was fitted out as an escape chamber, being provided with a flood-valve, vent, drain, and a means whereby the upper lid could be opened and shut from the control room.

At the top of the back of the tower was a flap-valve which shut off the ventilator pipe that ran between the periscopes and extended to the top of the fairwater, 6 1/2 feet above the bridge deck. This "ventilator", or induction pipe, was provided to supply air to the engines when running on the surface with the upper-tower hatch shut, as was often necessary in rough weather. The deck of the bridge was only nine feet above the surface and sea water easily found its way down the tower into the boat where it posed a serious problem. To keep the pipe dry when submerged there was a hinged flap at the top that was opened and shut by means of a long rod, pivoted from the underside of the flap, that hung down inside the pipe. It was operated by reaching through the opened bottom flap-valve, grasping a "T" handle on the end of the rod, and pushing it open or pulling it shut as appropriate.

Periscopes

The "CC" boats carried two periscopes. The after (main) periscope had a bronze tube 4" in diameter which extended into the control room. Fully raised it reached five feet above the top of the fairwater and was provided with power hoisting gear. This periscope was monocular and was provided with a natural-distance as well as a high-power eyepiece that gave a magnification of about two diameters. There was a rubber eye-guard, a selection of filters and the lens had horizontal and vertical scales for 25 and 1000 yards respectively.

The forward scope was located inside the conning tower, extended four and a half feet upwards, and had a three-inch diameter bronze tube. This periscope was used mostly for navigation and keeping a lookout, and had only a natural-distance eyepiece. It was raised by brute force although a tackle could be rigged to assist if needed. Both scopes only lowered to the deck.

An air-drying apparatus (dessicator) was provided for ridding the lenses and prisms of moisture. The compressor for this equipment was mounted on the tank-top beneath the handwheel for the after hydroplanes.

One serious drawback of these periscopes was that they did not have a sky-search capability. Both were replaced with more up-to-date models about mid-way through the life of the boats.

After Battery

The space abaft the control room, the "after battery", contained the second half of the main battery in a below-deck tank identical to that forward. Electrical panels for controlling the main motors, regulating battery charging and for auxiliary power distribution were ranged along both sides above the deck.

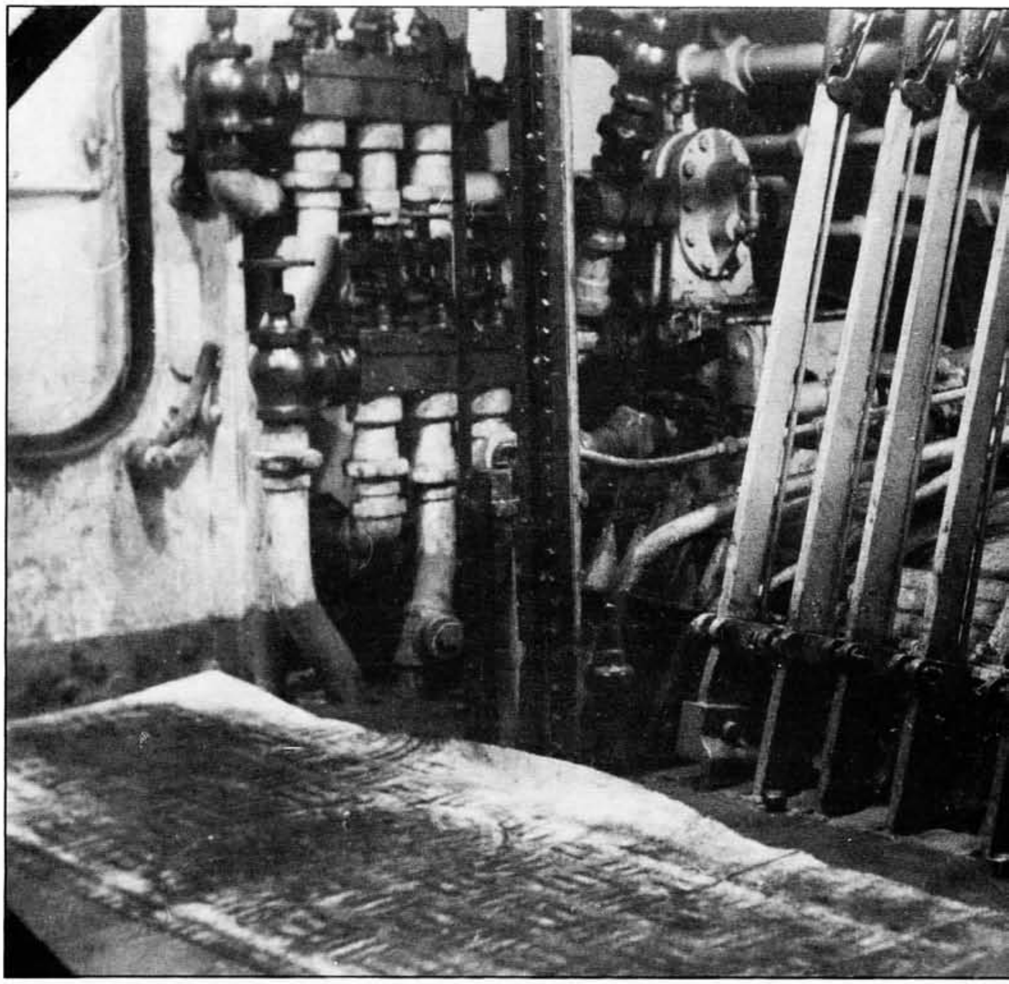
This compartment doubled as a cafeteria for the ship's company. Forward of the electrical panels on the port side was a small galley complete with electric range, oven, water boiler and sink. Overhead was an escape hatch leading to the back of the bridge deck. In the opposite corner were cupboards for mess traps and stores. Down the centre of the wood-planked deck was a long mess table (with folding edges) which was mounted on a box-shaped base in which additional victualling stores were kept.

Battery Tanks

The two battery tanks were virtually identical. They measured 17 feet long by 4'3" deep and 8'3" across. The walls and floors of the tanks were lined with lead, and the hardwood battens used to secure the cells in place were impregnated with wax to prevent damage by spilled acid. Each tank was provided with a sump connected to the main line.

The cells, arranged fore and aft in six rows of ten, were secured such that any single one could be removed without disturbing the others. All wiring and the bus bars were led aft to the control panels in the after battery compartment. The cells were completely sealed, being provided with a removable hand hole in the top cover to permit topping up. To remove gases produced in the cells each cover was connected by a tube to one of two exhaust-pipes running the length of the tank. These ventilators originated near the top of the compartment above and were led down the sides into the tanks. At the other end, where they exited the tanks, they were fitted with electric exhaust-fans. From there the

Close-up view of (left to right) trimming manifold, trim pump, ballast-tank Kingston valve levers, steering-gear drive motor and battery ventilation intake pipe. Note the top of the auxiliary ballast tank behind the levers and the primitive combined vent-and-blow tankside at the back. (Maritime Museum of B.C.)

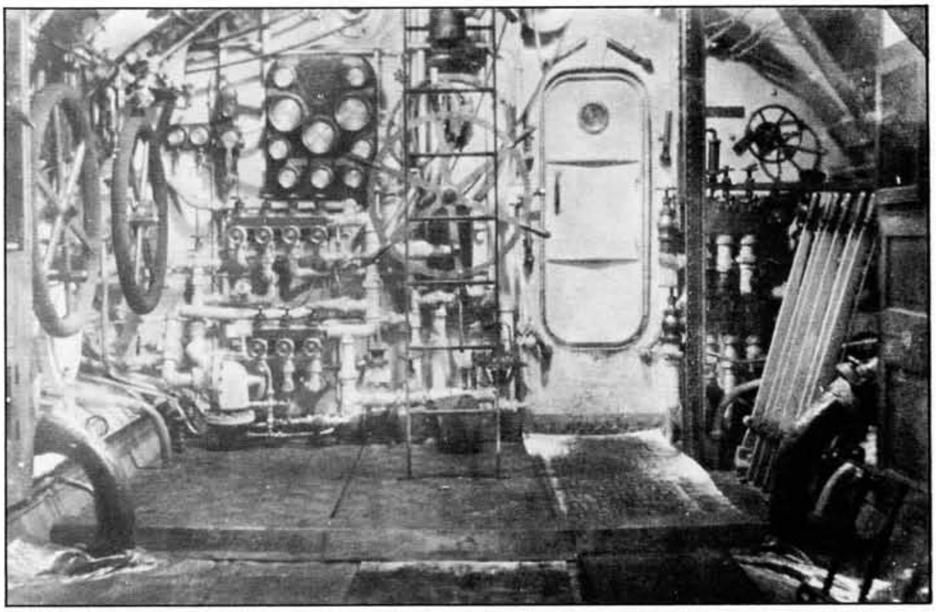


trunks were joined and led upward through a hull-valve to the top of the bridge fin where they were provided with a hinged flap-valve. When ventilating, this valve would be opened and the trunks could be extended well above the reach of the sea by means of cowled extensions.

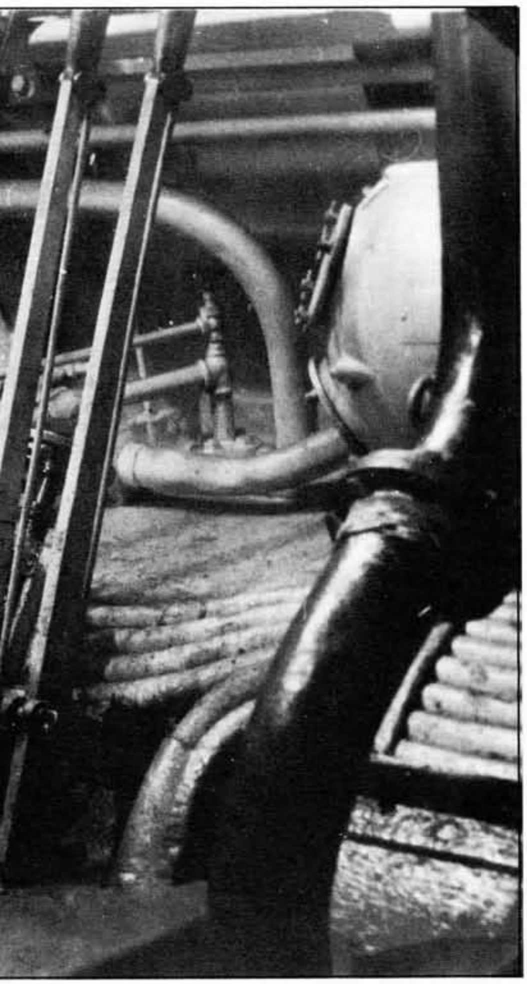
The cells themselves were covered by wooden panels over which was laid a single piece of special, thick acid-resistant cloth. Deck boards were wedged tightly into place on top of this to keep out dirt and sea water.

Engine-Room

The aftermost compartment consisted of the combined engine and machinery spaces. It was 36'6'' long and, from about mid-point, tapered sharply towards the stern. Directly above the engine-operating platform at the forward end of the compartment was an escape-hatch leading to the upper deck abaft the fin. Taking up much of the space to port and starboard were the main engines. The main motors were sited directly abaft each engine with a manually operated clutch between them. Abaft these was the machinery space. Here were located the two ballast pumps and a pair of compressors. These were disposed singly on either side and took their drive from the main shafts through gears and friction clutches. The two ballast pumps were situated directly abaft the motors and were mounted outboard of the shafts. The two compressors were further aft, almost straddling each shaft. Abaft these were the tail clutches, thrust blocks and the after, internal watertight bulkhead.



Control room looking forward. From left, the hydroplane handwheels, LP vent-and-blow manifold, LP gauge panel, helm, conning tower ladder and bottom of main periscope, door to the fwd. battery compartment, periscope chain-hoist, trim manifold and Kingston flood-valve levers. (Maritime Museum of B.C. Photo).



Machinery

Main Engines

The main engines consisted of two direct-drive, reversible, six-cylinder, two-cycle diesels. The cylinders were 9 7/16" in diameter, and the stroke was 10 1/4". Each engine developed 300 b.h.p. at 500 r.p.m. The engines operated under blast injection with a two-stage air compressor driven directly from the main crankshaft at the forward end of the engines. Blast air, supplied at 1,000 p.s.i. was restricted to 900 p.s.i. at fuel nozzles. Circulating water, lubricating oil, and primary fuel pumps were connected to a single cross-head driven by a small auxiliary crankshaft also geared to the main crankshaft at the forward end. A single camshaft, driven by a gear train from the main shaft at the after end of the engine, operated the fuel injection valves, scavenger valves and air-start valves and was mounted along the tops of the cylinders. It was fitted with a reversing clutch. Lubrication was by the closed pressure system, and the oil, after passing the main bearings and top-ends of the connecting rods, passed into the piston-heads in order to cool them before returning to the crankcase.

The engines were normally started by turning them over using the main motors. Air-start was fitted, but it was neither liked nor trusted and was seldom, if ever, used.

Fuel and Lubricating Oil

Fuel for the engines was taken from No. 5 fuel tank located in the boat's bottom under the engine frames. Tanks No. 1, 2 and 3 in the fore ends, No. 4 under the engine operating platform, and No. 6 in the stern abaft the trim tank all fed into No. 5.

A 1,047-gallon reserve of lubricating oil was carried in a tank inset in the fuel-oil tank under the operating platform from where it was pumped by hand. There was a similar tank for the storage of drain oil.

Main Motors

These were Electro Dynamic, single-armature motors of the multipolar, interpole, reversible, direct-current type. The armature circuit was for 220 volts, 480 amps, while the field was excited from a separate 110-volt supply to provide a field voltage of about 80 volts. These motors had an output of 160 h.p. at 370 revolutions.

The motors were mounted on the main shafts immediately abaft each engine, with the engine clutch between. The main motors were capable of being used as propelling motors, whereby they took power from the main battery and rotated the shafts and propellers with the engines unclutched. As generators, they supplied current to the battery while being turned by the engines with the tail-shafts disconnected.

An auxiliary use of the main motors was for running the ballast pumps and compressors. Under normal circumstances, when propelling at sea, these machines would simply be clutched-in and take their power from the already spinning shaft. In harbour, or when that particular shaft was stopped, it was possible to disconnect the main engine and tail-shaft by means of the clutches, clutch-in the appropriate machine, and use the main motor to turn the shaft for the exclusive use of that pump or compressor.

Stern Bulkhead Arrangement

The stern torpedo-tube rear door pierced the after bulkhead centrally near the top. The stern-cap operating gear was mounted in a separate hood projecting above the pressure hull, while the impulse air tank was located in the free-flood space inside the casing above. The two main shafts exited the compartment through *lignum-vitae*-lined stern glands at the sides of the bulkhead. The control rods for the after planes and steering left the hull through glands on either side of the bottom of the bulkhead.

Systems

Ballast Tanks

These boats had three main ballast tanks (MBTs). One was in the bows in the hull space ahead of the forward inboard bulkhead, with the other two extending under and flanking the battery tanks. These MBTs extended in a continuous "U" shape from the foremost forward battery bulkhead, through and under the control room to the after bulkhead of the after battery. The tops of these tanks protruded about 18" above deck level on both sides and curved outwards to meet the hull. That forward of the control room was known as the "midship tank", that aft as the "after tank". The space between these was partitioned off near each end of the control room to form the "auxiliary ballast" tank.

The MBTs were all provided with large-diameter, outward opening Kingston flood-valves. The valve for the forward tank was located between the tubes while the remainder were clustered under the control room. Except for the auxiliary ballast tank they were also provided with outboard vents operated by handwheels in the deckhead, and blows operated from the LP manifold in the control room. The three MBTs were completely flooded to provide negative buoyancy in order to submerge, and were blown empty with LP air from the panel in the control room to bring the boat to the surface. The auxiliary ballast was used primarily as a midships compensating tank and was fitted with a small-bore inboard vent only. However, as it could be blown quickly, it provided a means of gaining extra buoyancy in an emergency.

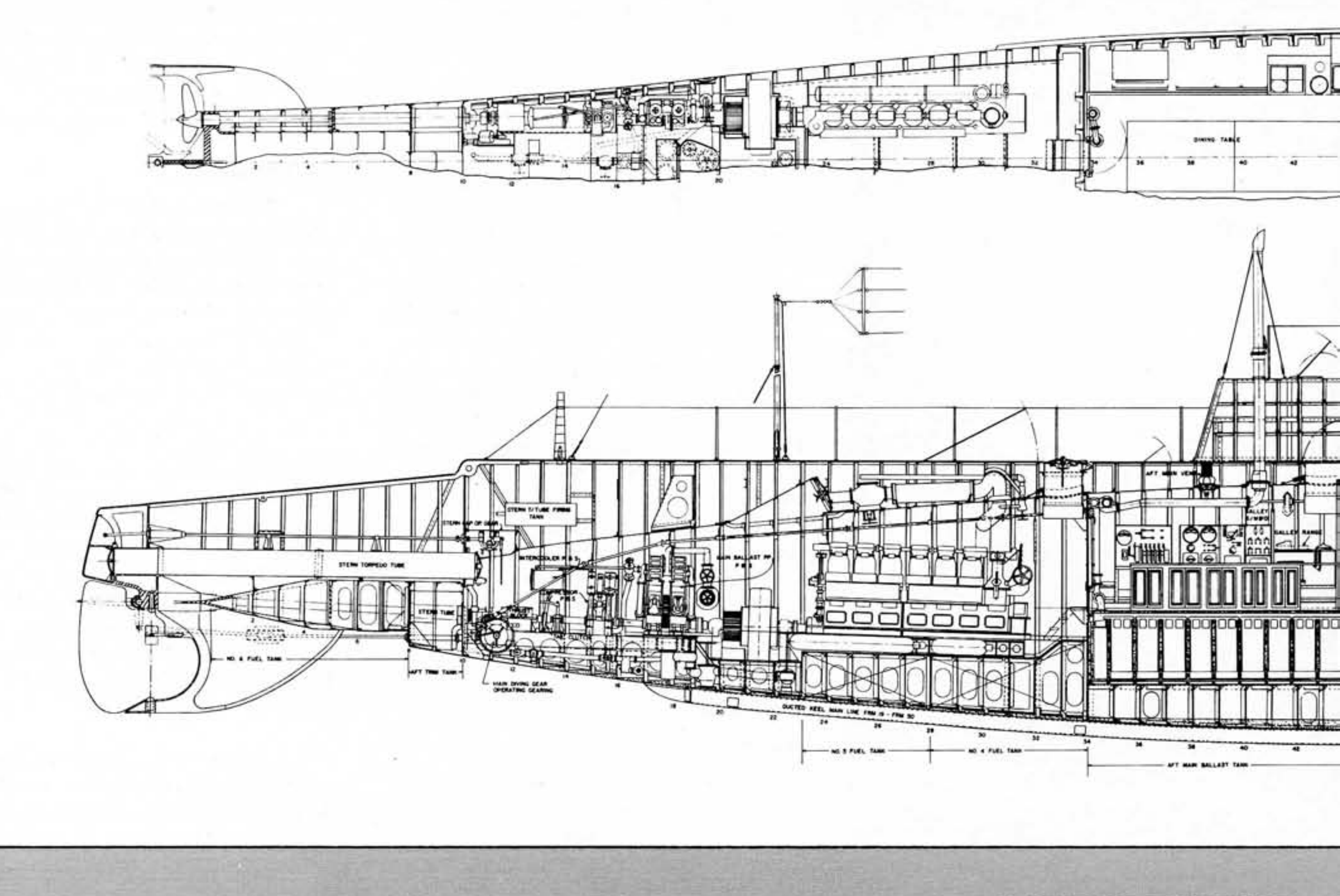
Trimming System

There were three main trimming tanks: one forward in the hull-space ahead of the forward ballast tank; one under the control room, known as the "adjusting" or "buoyancy" tank; and another aft in the hull-space under the torpedo tube abaft the after internal bulkhead. The trim pump, or adjusting pump as it was then called, was located in the starboard forward corner of the control room. It was powered by a reversible 5 h.p. motor and rated at 60 g.p.m. at a 30-foot head. Against the bulkhead near the pump was the trimming manifold for controlling the distribution of water from tank to tank or from the tanks to the sea. The trimming system could be cross-connected with the main pumping and flooding line.

Ballast Pumps and Main Line

The two ballast pumps in the machinery space were connected to a common drain line running from the after trim tank to that in the bows. From a point under the pumps to the forward end of the control room the hollow keel was utilized as a drain line, while forward of and abaft the ducted keel the line was formed of ordinary pipe. All tanks and bilges were led into this line by way of branch pipes and screw-down stop-valves. Each pump was provided with its own sea inlet controlled by hull and intermediate valves. This system permitted pumping out all tanks and bilges in the boat and controlled flooding into the tanks. The pumps were each rated at 2,500 g.p.m. at a 20-foot head and could be used singly or together, although one was normally sufficient.

CC1



In *CC2* there were two identical, two-stage rotary piston-pumps, while *CC1* had a 5 h.p. electric-motor-driven centrifugal pump in lieu of the starboard piston-pump.

Compressors and Air Services

The HP air compressors in these submarines were the two-stage type. These were rated at 10 cubic feet per hour at 2,500 p.s.i. Each was provided with a water-cooled air cooler (intercooler) and a separator. Both compressors had a common connection to the HP air main that ran the length of the boat. All of the HP air groups were connected to this line and it also supplied all services requiring HP air including the LP reducer station. An HP air-burst in this system was a serious matter as there was only the one line.

Control Equipment

The "CC" boats were controlled by conventional forward and after hydroplanes and a rudder. The forward planes were known as the "bow diving gear" or "bow rudders", and the after planes were known as the "main diving gear". This nomenclature was universal at the time, being common in both USN and RN submarines.

All three sets of control surfaces (i.e. the rudder, fore planes and after planes) were controlled by handwheels in the control room. The rotation of these handwheels was transmitted by means of gearing and chain drives to rodding that carried the movement from the control room forward and aft. Both the steering and after planes' rodding were provided with electric-motor-driven turning gear, the operation of which was controlled by the handwheel drive chains.

In the stern the rudder and after planes' rodding terminated in worm gears. These in turn drove gear wheels with pinion gears in their centres that operated on toothed racks at the inboard ends of layshafts. These horizontal shafts passed through glands in the after bulkhead, transmitting fore-and-aft motion to a quadrant arm connected to either the rudder or the planes to create left and right rudder or up and down hydroplane movements.

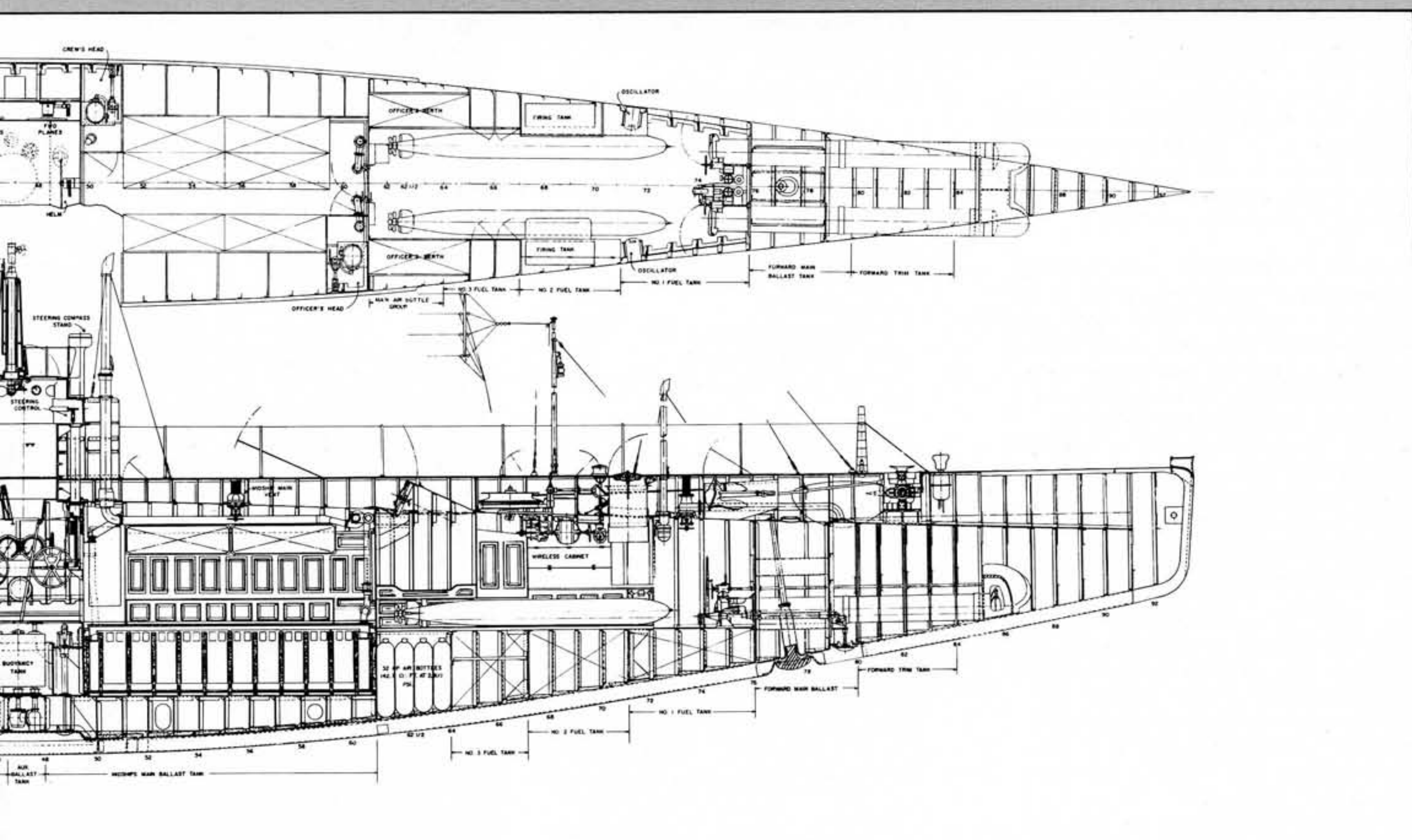
The fore planes' rodding was led into the fore-ends where it passed through a hull gland and terminated in the gearbox that was part of the planes' housing. This gearing transformed the rotational motion of the shafting into tilting motion of the planes. This was probably accomplished with a worm and gear drive. The fore planes had no power assistance.

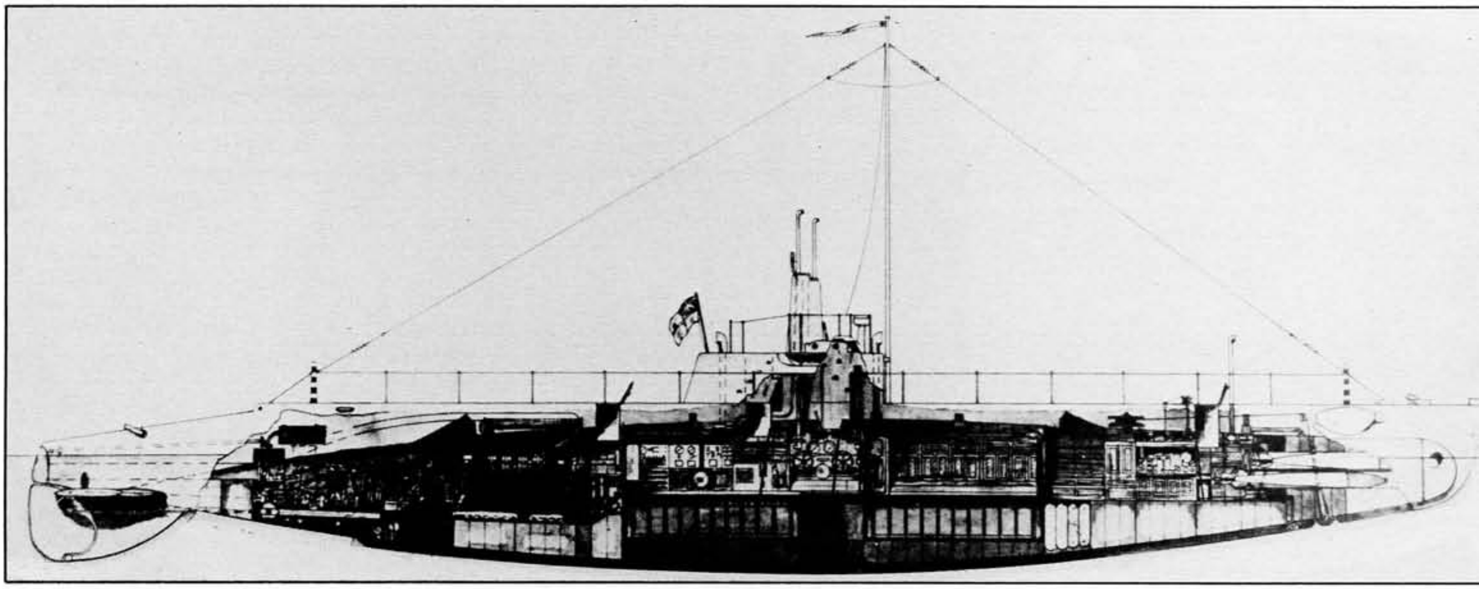
Commentary

By the time the "CC" boats were launched many of their design features were already obsolete, most seriously the engines. In 1914 this phenomenom had much the same impact as it does today. Many other features had been superseded during the prolonged construction period and the boats were becoming redundant even as they were launched. *CC1* and *CC2* were unique, however, in that they were the only American-built Holland boats to feature a stern torpedo tube. It is significant to note that units of two more modern classes of American submarines, the "H" and the "K" classes, had been built and launched at the same shipyard during the construction of the Chilean boats.

The reasons for the differences in bow armament are now obscure. It is of interest to note, however, that *CC2*, with her much finer forward lines, was the more economical of the two in fuel consumption when cruising on main engines (2.94 g.p.m. compared with 3.32 g.p.m. for *CC1*).

Both hulls suffered from severe corrosion problems in the region of the waterline. Originally this was thought to have been caused by electrolytic action between the pressure hulls and the copper cladding on *Shearwater's* timber-sheathed steel hull. (*Shearwater*, a former British sloop, was being used as a submarine depot ship.) The copper was stripped off early in 1915 but the problem persisted. Corrosion was only held in check by regular six-monthly dockings and by constant attention to the cleaning and painting of the affected areas. Ulti-





CC1.

mately it was proven that the steel used in the hulls had been improperly pickled during manufacture.

Engine problems were chronic. This was due as much to the limitations of the early design and the state of metallurgy at the time of manufacture as to the inexperience of the operators. Similar problems were encountered in all contemporary USN boats and the Americans re-engined many of their earlier classes during 1915-16.

Quality control was seriously neglected during construction and many faulty valves found their way into the boats. Seats were scored, spindles bent, bonnets warped and solid debris was found throughout the piping and trapped in the valves. During the first dockings such things as rags, a length of plank and a pair of overalls were found in the tanks.

Zincs fitted in the internal tanks had been installed on top of the paintwork rendering them totally ineffective. After a year in operation wholesale replacement of hull rivets had to be undertaken because of the corrosion problems. This would become a continuous process right up to the last docking. Most, if not all, of these problems could be corrected or anticipated, and as long as the boats were operated with due regard to their design limitations they could be considered a success as short-range coastal-defence submarines.

The "CC" boats remained on the west coast station for three years. In June 1917 they sailed for the east coast (becoming the first "white-ensign" warships to transit the Panama Canal), and arrived in Halifax in October after a four-month passage. By the war's end, though, their days were numbered. *CC1* and *CC2* were paid off in December 1918 and sold for scrap in 1920.

Dave Perkins joined the RCN in 1954 as an ordinary seaman (TAS). In addition to his service in HM Submarines Solent, Scythian and Alliance, *he served one year in HMCS* Haida, *five years in* Victoriaville, *eight years in* Ojibwa, *and four years ashore with the submarine squadron before retiring in 1979 as a CPO2 underwater weapons technician. Mr. Perkins is currently writing a 1914-1946 history of Canadians in submarines and submarine activities in Canadian waters. Publication is planned to coincide with the 75th anniversary of the submarine service in 1989.*

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   - b. Vol. 4018 File 1062-1-2 Correspondence relating to Submarines.
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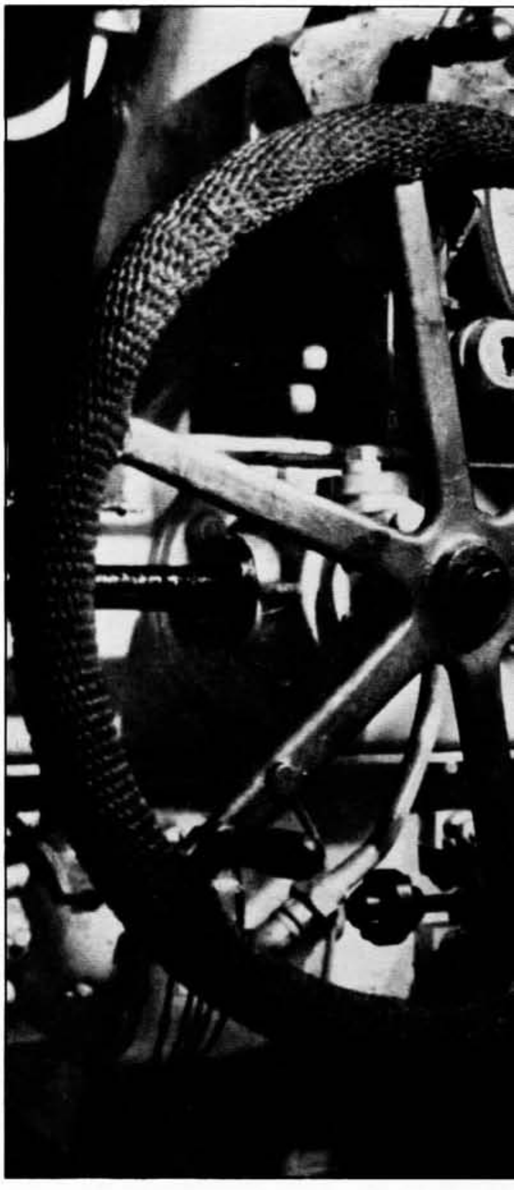
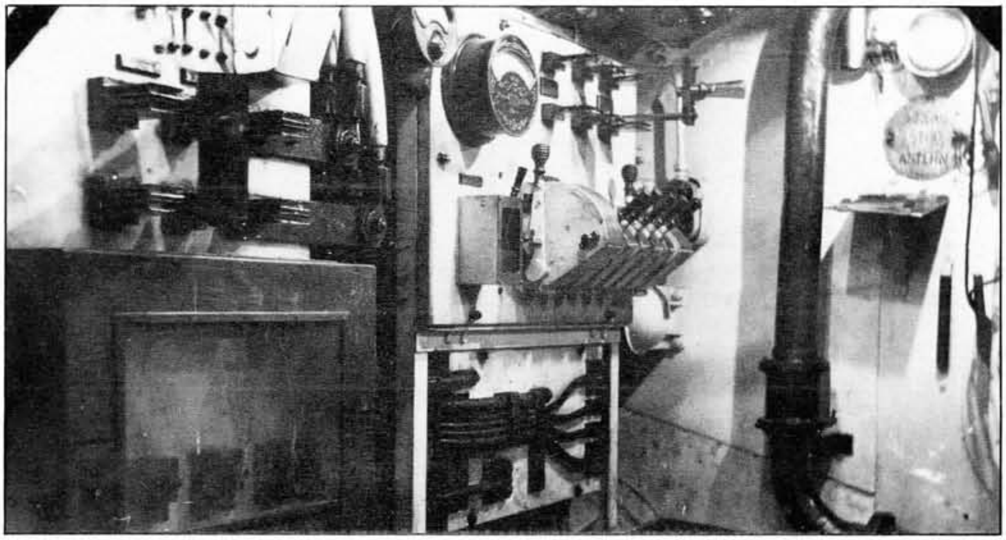
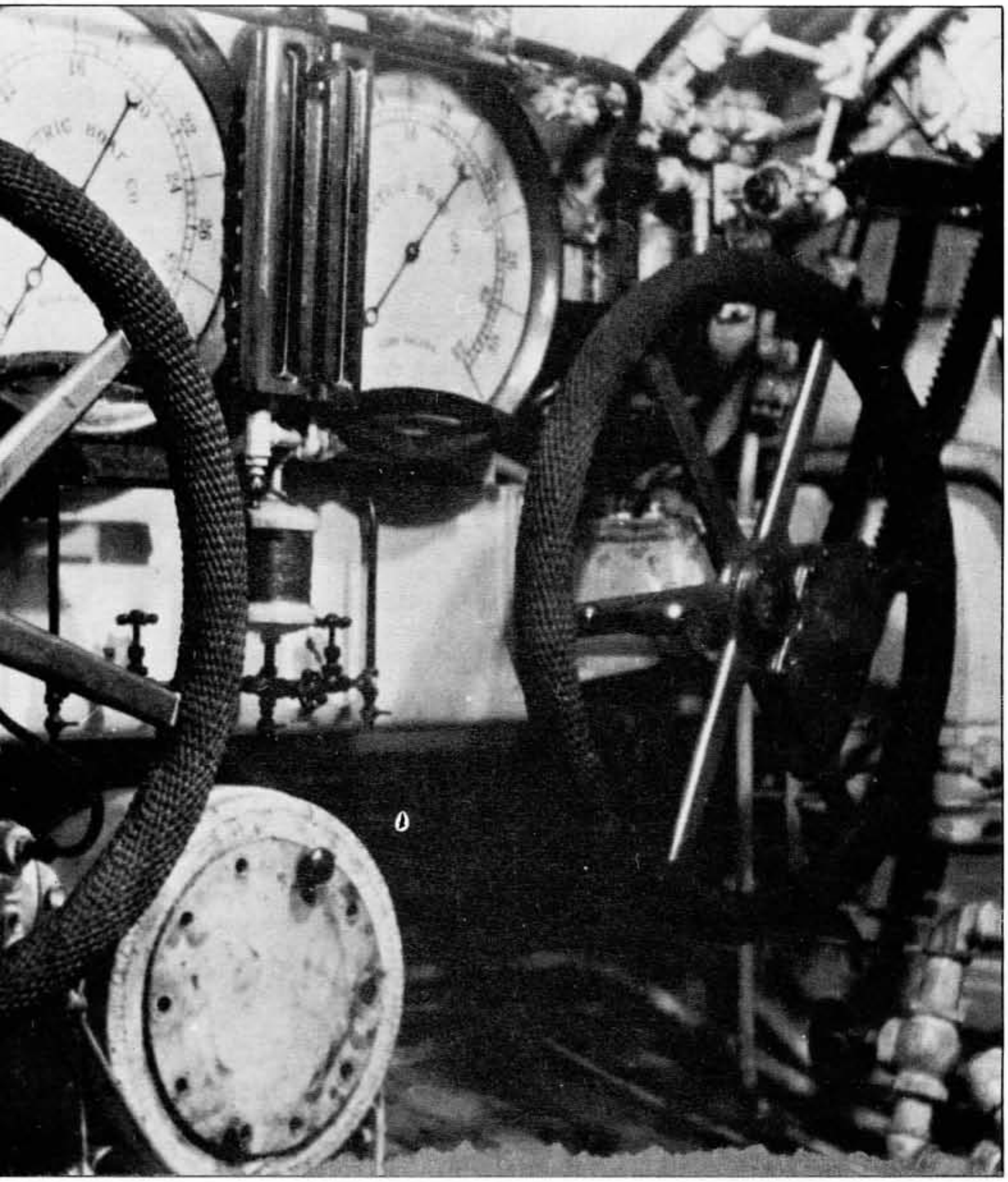
Hydroplane handwheels and depth gauges. (Maritime Museum of British Columbia photo).



Starboard main switchboard showing (L. to R.) battery grouper switch and main fuse panel, ahead/astern switch, main-motor starter switches and, overhead, the field current regulator. Note the telegraph instrument on the after bulkhead beside the door leading to the engine-room. The large pipe is one of two battery ventilation exhausts. (Maritime Museum of B.C.).





***CC1* (ex-*Iquique*)/**
***CC2* (ex-*Antofagasta*)**

Class: Electric Boat Co. Holland Patent

Design: 19-E (*CC1*); 19-B(*CC2*)

Cost: $575,000

Launched: 3 June, 1913 (*CC1*); 31 December, 1913 (*CC2*)

Hull: Single hull

Displacement (tons): 313 surfaced; 421 dived

Length (overall): 144.5 feet (*CC1*); 151.5 ft. (*CC2*)

Beam: 15 feet

Draught: 11 feet

Diving Depth: 200 feet

18" Torpedo Tubes: 4 bow and 1 stern (*CC1*); 2 bow and 1 stern (*CC2*)

Reloads Carried: 4 fwd and 1 aft (*CC1*); 2 fwd and 1 aft (*CC2*)

Periscopes: 2 — main scope in control room, secondary in conning tower.

Main Machinery: — 2 direct-drive, reversible, two-cycle six-cylinder diesel engines (300 b.h.p. at 500 r.p.m.)
— 2 Electro Dynamic Co. Type 19C electric motors (220V, 130 h.p. each at 370 r.p.m.)
— main battery of 120 cells in two 60-cell tanks (capacity — 3,800 amp. hrs.)

Propellers: 2 three-bladed, 4½ ft. diam., 40" pitch.

Speed: 13 knots surfaced (on main engines); 10 knots dived (on main motors).

Fuel Carried: 5,356 U.S. gals. (normal); 8,448 U.S. gals. (maximum).

Complement in 1918: 24 (3 officers, 21 ratings) — captain, first lieutenant, navigating officer, CPO Cox'n, PO LTO, 3 leading seamen, 4 able seamen, 1 W/T operator, CERA, 2 ERAs, 1 stoker PO, 2 leading stokers, 3-4 stokers. An additional AB was usually carried as cook.

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The Operational Range Factor

by L.T. Taylor

The Operational Range Factor described in this paper is proposed as a method of numerically comparing the capabilities of competing warship designs. The factor is a single range which takes into account a ship's machinery arrangement, operational employment and amount of fuel carried. It is calculated by dividing the time-weighted average fuel consumption into the fuel load to determine steaming hours, which when multiplied by the time-weighted average speed gives a range representative of operating the ship and machinery for an operational profile on a full load of fuel.

The Need

The selection of a propulsion machinery package for a ship is a complex process. Factors to be considered include: capital cost, size, weight, fuel, simplicity, reliability, maintainability, life-cycle cost, manning requirements and training. For merchant ships, there are some well established criteria which enable optimum service speed to be worked out. This coupled with an installed power to match the service speed eases comparison between competing options of diesel or steam (or maybe gas turbine). For a warship, consideration also has to be given to operating over a wide speed-range with much of the time spent at part power rather than at optimum service speed. The endurance curves in Figure 1 provide a method of comparing straightforward diesel or steam options.

Comparing the diesel and steam curves in Figure 1, the cross-over point is the specified design point of 4,500 nmi range at 15 knots. Below this speed the diesel has the range advantage, but above 15 knots the steam plant has a greater range on the fuel carried. Taking this a step further, if a ship spends more time operating below 15 knots than above, the diesel engine will be more capable in terms of endurance. Conversely, if it spends more time operating above 15 knots, the steam plant will be more capable.

The introduction of the CODOG and COGOG machinery arrangements have made such direct comparison of endurance curves much more difficult, if not impossible. Figure 2 illustrates this problem. The discontinuity in the curves at different points for different combinations of engines cloud the comparisons which could previously have been made.

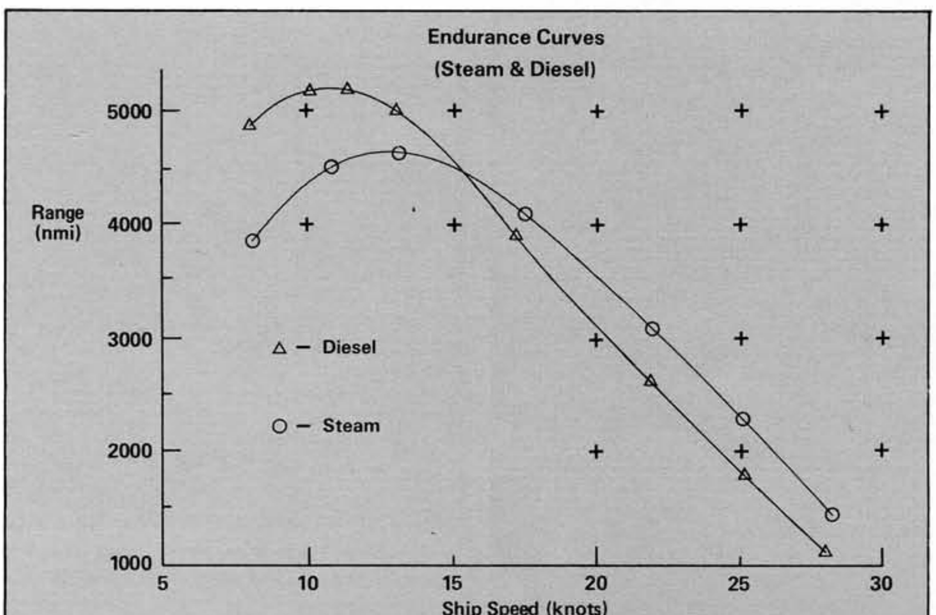


Figure 1.

Inputs

One of the elements which the Operational Range Factor takes into account is the amount of fuel carried. This is based on a specified range at a given speed, which is one of the standard requirements included in the statement of requirements given to a warship designer. Fuel carried varies with the machinery options and will only affect the Operational Range Factor by its interaction with the arrangement and employment of the machinery. Other factors in the machinery selection process will directly compare fuels.

The other element taken into account is the intended employment profile. The warship designer may be given this in several ways but the most useful form is the time-versus-speed curve. The employment pattern of a ship changes with different situations, and to account for this three profiles are used throughout this paper:

a. a peacetime profile;
b. a wartime profile; and
c. a sprint & drift profile.

Figure 3 gives these three profiles in the form of cumulative time underway at or below a given speed. A steep slope is indicative of high usage; a flat slope, low usage. The peacetime profile reflects the concern for economy in a climate of high fuel-costs where speed is kept down to reduce fuel consumption and operating costs. The wartime profile is biased to increased use of high speed. The sprint & drift profile is an altered operating profile where low speeds (drift mode) dictated by sensor limitations are followed by high-speed dashes (sprint mode) when the ship is rejoining the force.

Method

A simple computer program in BASIC language was developed to calculate the Operational Range Factor. The program calculates the time-weighted average endurance. This approach was taken as it had endurance as an intermediate step, facilitating the preparation of endurance

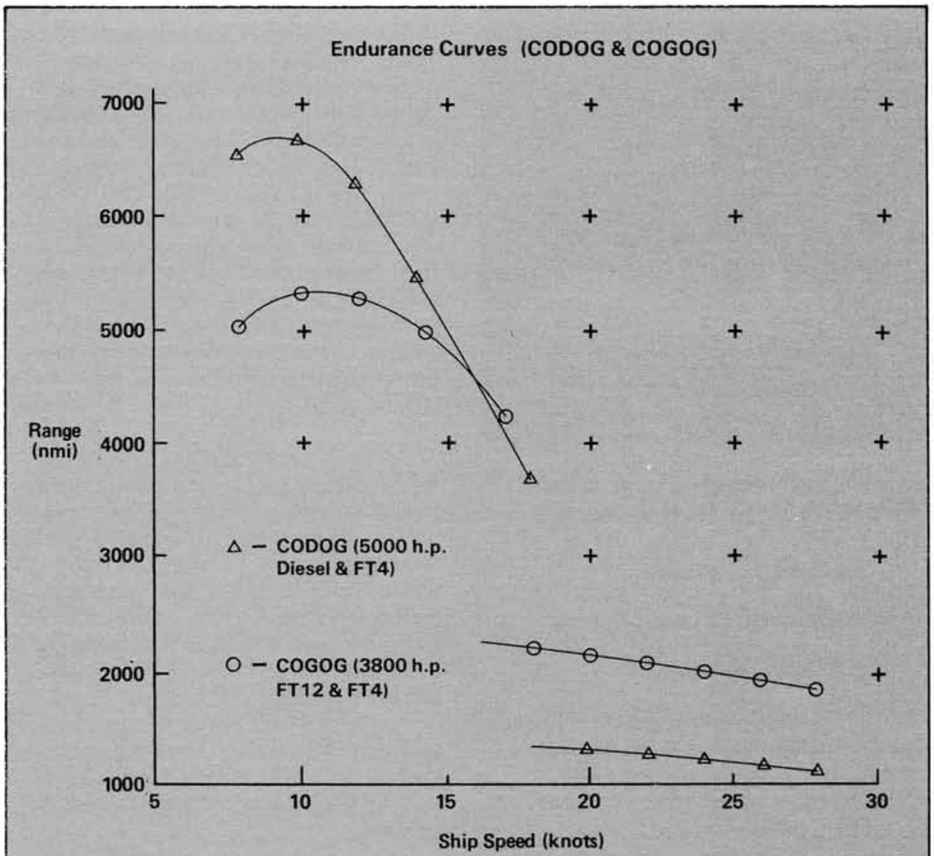


Figure 2.

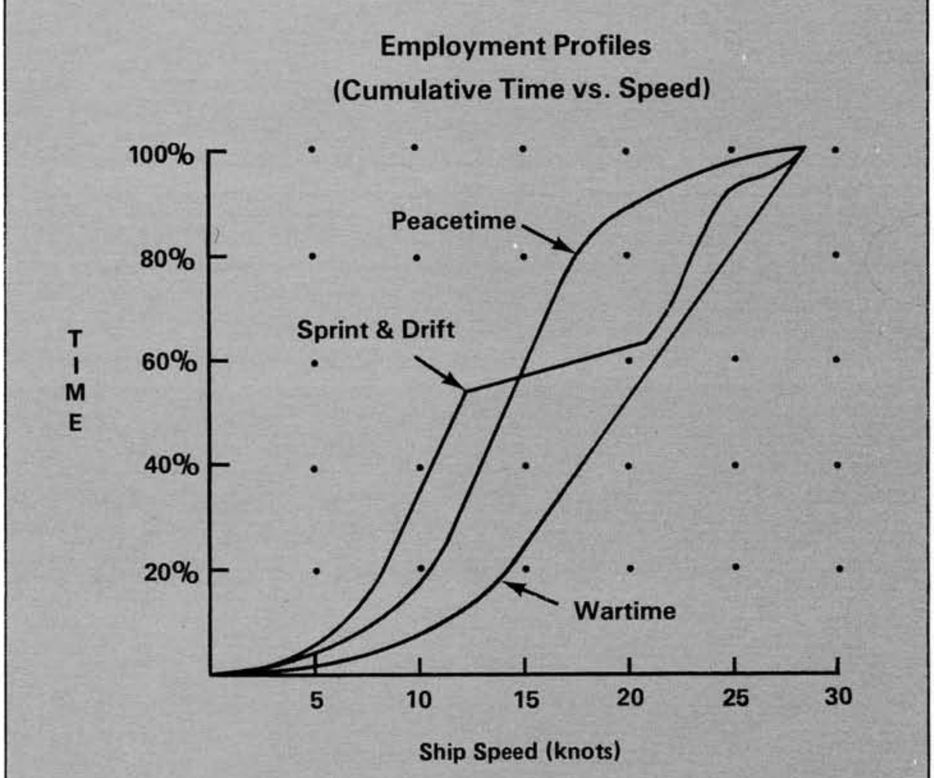


Figure 3.

curves as well as producing the Operational Range Factors for each operational profile. Various features of the program are a result of the computer used, a Commodore Super Pet. Some program development was done on a Texas Instruments TI99/4a. The program included the specific fuel consumption calculations for a range of candidate engines as subroutines.

The program starts by reading the speed-versus-time data from within the program into subscripted variables with speed as the subscript. The program is interactive and uses the screen to prompt the operator who inputs the following at the keyboard:

a. Specified range and speed;
b. Machinery arrangement and engines (narrative);
c. Auxiliary fuel consumption;
d. Power-speed curve constant and index;
e. Cruise-engine power and choice of cruise engine;
f. Main-engine power and choice of main engine; and
g. Arrangement used (either multiple equal mains, or any of CODOG, COGOG, CODAG or COGAG).

The fuel load is calculated to meet the specified range and speed. Then, using this fuel load, the program goes through a loop of speed from 8 to 28 knots to produce a table of speed, endurance, peacetime time-based incremental endurance, wartime time-based incremental endurance, and sprint & drift time-based incremental endurance while keeping running totals of these to print out totals at the end. (See "Sample Output".)

Sample Results

Table 1 summarizes the results of a series of program runs for a 28-knot frigate of between 3,500 and 4,000 tons with the following machinery arrangement:

a. CODOG with two 500 h.p. cruise diesels and two first-generation boost gas turbines (nominally FT4s);
b. COGOG with first-generation gas turbines for both cruise and boost (nominally FT12s and FT4s);
c. COGOG with second-generation gas turbines for both cruise and boost (nominally DDA570 and LM2500); and
d. COGAG with three, mid-size second-generation gas turbines (nominally SPEYs).

No account is taken of the difference in size and displacement the ship might have to be to accommodate the different arrangements with fuel. Table 1 represents a first iteration design. The method will work on subsequent iterations but the additional ship-particular information required would unnecessarily complicate this paper.

TABLE 1: Operational Range Factors for various arrangements and various operating profiles	CODOG Diesel FT4	COGOG FT12 FT4	COGOG DDA570 LM2500	COGOG three SPEY
Peacetime	5040	4480	4510	4330
Wartime	2890	3030	3300	3330
Sprint & Drift	4380	3920	3910	3630
(Fuel Load)	(399)	(656)	(495)	(480)

Reviewing the results in Table 1, the economy of the cruise diesel shows well in the peacetime role with the maximum range (and the minimum fuel). Similarly, the economy of the cruise diesel gives the maximum range in the sprint & drift mode. Here the relatively high powers of the sprint mode mean the gas turbine is used at a power level where its specific fuel consumption is reasonable. Not surprisingly, the COGOG with first-generation gas turbines requires the most fuel; however, having the fuel gives it the advantage of greater range than the CODOG in the wartime profile.

The two all-second-generation gas turbine arrangements, COGOG and COGAG, make for an interesting comparison. The COGAG has a very minor edge in wartime operational capability (and a minor edge in fuel load). It loses out to the COGOG in peacetime and sprint & drift modes because of its poor endurance at very low speed. Figure 5 shows the endurance curves for these two options. (Figure 4 shows the specific fuel consumption curves for the three engines.) A review of these curves with the results in Table 1 serves to illustrate the problem in comparing competing arrangements.

Another comparison of interest is the 2 LM2500 COGAG (such as the USN FFG-7 class) and the diesel LM2500 CODOG (such as the Italian LUPO class). Table 2 gives the Operational Range Factors for these two options and Figure 6 illustrates their endurance curves. Again the diesel shows its tremendous economy in the peacetime and sprint & drift modes with low, time-based average speeds. The COGAG arrangement, with its greater fuel load needed to meet the specified range, has the advantage on the wartime operating profile where use of the diesels in the CODOG is restricted by the higher proportion of higher speeds.

Effect of Inputs

Table 3 shows how the results obtained in Table 1 change as the specified range and speed are changed. Table 1 was based on 4,500 nmi at 16 knots as the design point. Table 3 uses three design points:

a. 4,000 nmi at 18 knots;

b. 4,500 nmi at 16 knots; and

c. 5,000 nmi at 13 knots.

The available power of the FT12 has been artificially increased for this table so that the first-generation gas turbine COGOG can achieve the 18-knot speed on its cruise engine.

The most dramatic changes occur in the CODOG and COGAG arrangements. The CODOG arrangement loses out when its economical speed is approached as the design point and Operational Range Factor in all operating profiles falls behind all the others. This change stems from the reduction in the required fuel load which reflects the reduction in power to produce the speeds for the diesel with its flat specific fuel consumption. The COGAG arrangement increases in fuel load opposite to the others because the rate of increase in specific fuel consumption of the engine is greater than the corresponding reduction in power.

Table 4 compares the Operational Range Factors for the four arrangements used previously, but now with two operating profiles each with a time-based average speed of 15.5 knots. One profile is the sprint & drift mode with low-speed and high-speed peaks and a gap in the middle. The other profile reverses this, being high in the middle with little at the high-speed and low-speed ends. The change in the Operational Range Factor for the 15.5 knot average profiles ranges from negligible for the first-generation COGOG and slight for the CODOG to a 15% change for the COGAG.

TABLE 2: Operational Range Factors (2 LM2500 COGAG/Diesel LM2500 CODOG)

	Peacetime	Wartime	Sprint & Drift
COGAG	4240	3430	3510
CODOG	5000	3080	4590

TABLE 3: Change of Operational Range Factor using different design points

	Range Speed	Fuel Load	Peace Time	War Time	Sprint Drift
CODOG	4000/18	437	5530	3160	4810
Diesel	4500/16	399	5040	2890	4380
FT4	5000/13	339	4280	2450	3720
COGOG	4000/18	661	4520	3050	3960
FT12	4500/16	656	4480	3030	3920
FT4	5000/13	634	4330	2930	3790
COGOG	4000/18	514	4680	3430	4060
DDA570	4500/16	495	4510	3300	3910
LM2500	5000/13	492	4480	3280	3890
COGAG	4000/18	475	4270	3290	3590
three	4500/16	480	4330	3330	3630
SPEY	5000/13	494	4450	3420	3740

TABLE 4: Operational Range Factor for two different operating profiles with the same average speed

	CODOG DIESEL FT4	COGOG FT12 FT4	COGOG DDA570 LM2500	COGAG THREE SPEY
Sprint & Drift	4380	3920	3910	3630
Other 15.5 Avg	4300	3940	4200	4140

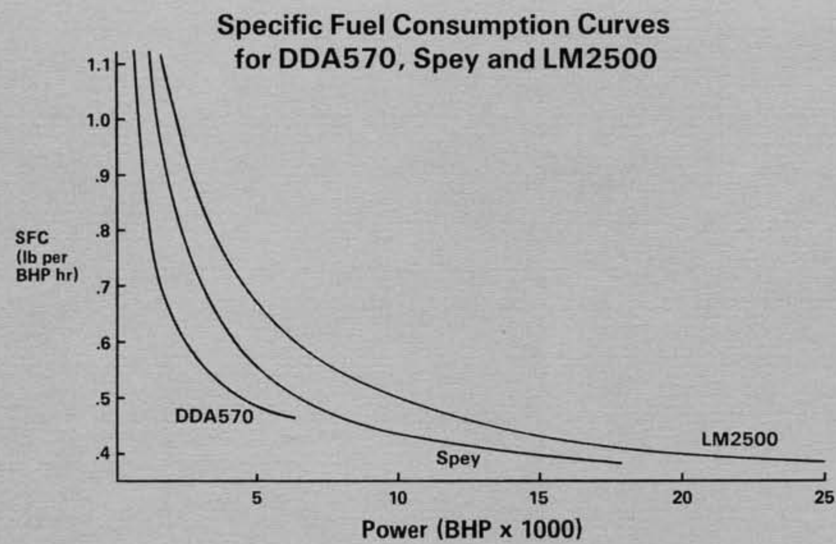


Figure 4.

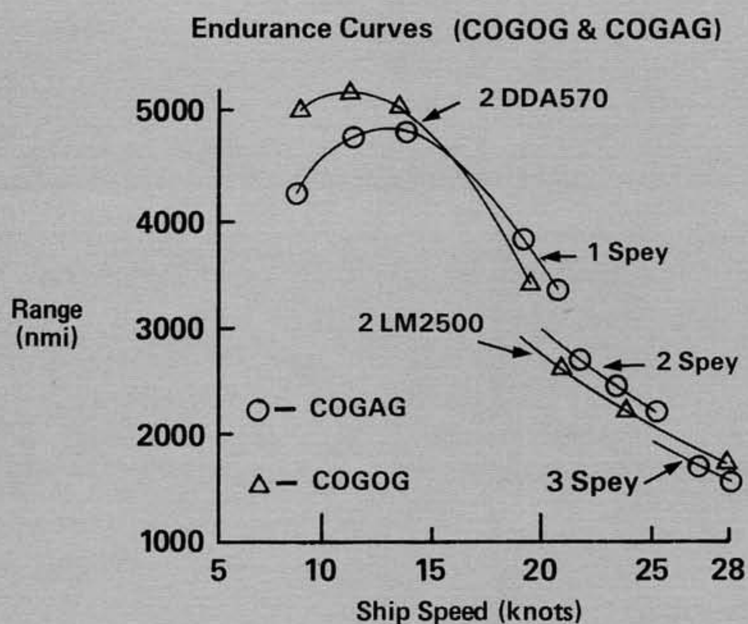


Figure 5.

The big differences here are in the second-generation gas turbine arrangements. With the second profile, they are not required to operate very much in the region of high, specific fuel consumption at very low power. Their ranges go up accordingly. The COGAG arrangement shows up even better because for a large part of the time on the second profile it is using only one engine at fairly high power and thus achieves good specific fuel consumption.

Summary

By combining intended employment profile with machinery arrangement and thus fuel carried, the Operational Range Factor can provide a single-value numerical range for each employment profile. Competing machinery options can be compared using it. Although it was developed at the start of the paper as a means of determining the operational implications of the steps in a combined machinery arrangement's endurance curve, it can equally provide a numerical comparison to quantify the visual comparison discussed at the opening of the paper for steam or diesel machinery.

The Operational Range Factor is not meant to be a stand-alone item for machinery selection. It is just one of many factors which are considered in the machinery selection process for warship design. It will have to be weighted in a decision matrix along with all of the other factors. The factors calculated by the method described in this paper are only as good as the validity of the employment profiles and the design point of range and speed input.

L.T. Taylor served almost 22 years in the Canadian navy before retiring in 1983. He is a former engineering officer of HMC Ships Iroquois, Annapolis, Fraser *and (notably)*Bras d'Or. *Since his retirement, Mr. Taylor has been on the MSEO staff at NEU(A).*

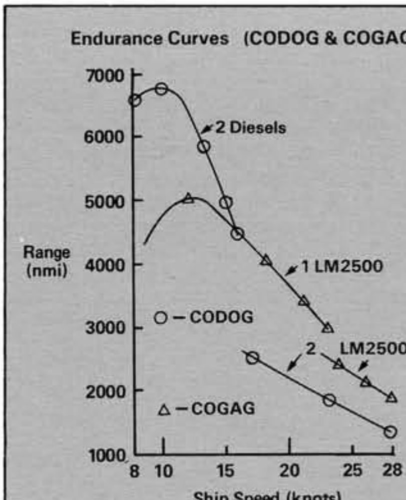
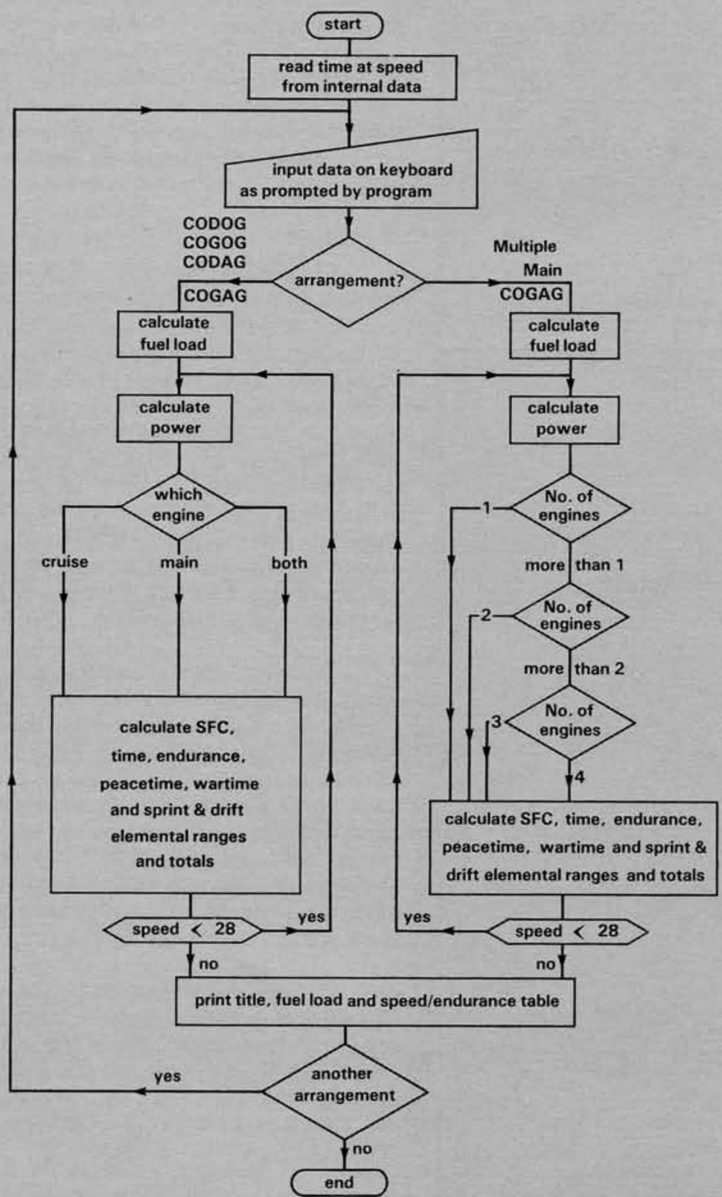


Figure 6.

Program Flowchart



SAMPLE OUTPUT

COGAG 2 DDA570 AND 2 SPEY   POWER – .225 × SPEED ^ 3.65

AUX FUEL CONSUMPTION 750 LB/HR

FUEL LOAD FOR 4500 NMI AT 16 KNOTS IS 495 TONS

SPEED	ENDURANCE	PEACETIME	WARTIME	SPRINTDRIFT
8	4780	311	191	717
9	5010	200	75	501
10	5130	333	102	513
11	5170	517	129	517
12	5130	513	153	513
13	5030	503	176	50
14	4880	488	170	48
15	4700	517	235	47
16	4500	427	247	45
17	4220	232	253	42
18	3850	134	211	38
19	3530	88	211	35
20	3060	61	168	30
21	2900	43	174	29
22	2730	27	164	218
23	2560	25	141	282
24	2400	24	144	192
25	2250	22	135	67
26	2100	21	115	21
27	1760	17	97	35
28	1650	24	99	49
TOTALS		4530	3390	3990

READY.

```
100  REM ENDURANCE AND OPERATIONAL RANGE FOR FRIGATE
110  DIM PTPC(29), WTPC(29),DTPC(29)
120  DATA 6.5,4,15,4,1.5,10,6.5,2,10,10,2.5,10,10,3,10,10,3.5,1
125  DATA 10,3.5,1,11,5,1,9.5,5.5,1,5.5,6,1,3.5,5.5,1
130  DATA 2.5,6,1,2,5.5,1,1.5,6,1,1,6,8,1,5.5,11
135  DATA 1,6,8,1,6,3,1.5.5,1,1.5.5,2,1.5,6,3
140  FORS = 8 TO 28
150  READ PTPC(S)
160  READ WTPC(S)
165  READ DTPC(S)
170  NEXTS
180  INPUT ''SPECIFIED ENDURANCE RANGE AND
     SPEED:RG,SPD'';RG,SPD
190  INPUT ''POWER SPEED CURVE CONSTANTS (P = K*S ^ C) : K = ,
     C = '';K,C
200  INPUT ''AUXILIARY FUEL CONSUMPTION (LB/HR) IS'';AUXF
210  INPUT ''MACHINERY ARRANGEMENT AND ENGINE USED'';CO$
220  INPUT ''CRUISE ENGINE MAXIMUM POWER IS'';CRPWR
230  INPUT ''CRUISE ENGINE: DIESEL = 1, FT12 = 2, DDA570 = 3, SPEY
     = 4'',CE
240  INPUT ''MAIN ENGINE MAXIMUM POWER IS'';MNPWR
250  INPUT ''MAIN ENGINE: FT4 = 1, LM2500 = 2, SPEY = 3'';ME
260  INPUT ''ARRANGEMENT MAIN/CRUISE OR OR AND (1) OR
     MULTIPLE EQUAL MAIN(2)''; ARR
270  OPEN1,4:CMD1
280  PRINTCO$;PRINT:TPEACE = 0:TWAR = 0
282  PRINT ''POWER -'';K;'' X SPEED ^ '';C:PRINT
284  PRINT ''AUX FUEL CONSUMPTION'';AUXF;'' LB/HR'':PRINT
285  T = 0
290  ONARRGOTO300,600,260
295  REM CALCULATIONS FOR CODAG, CODOG, COGAG OR COGOG
     ARRANGEMENTS
300  SHP = K*SPD ^ C
305  CP = (SHP + 400)*1.015/2
310  ON CE GOSUB 2305,2125,2005,2250
320  FLD = (RG/SPD) * (2*CP*CSFC + AUXF)
330  PRINT''FUEL LOAD FOR'';RG;''NMI AT'';SPD;''KNOTS
     IS'';INT(FLD/2240);''TONS''
340  PRINT
350  PRINT''SPEED'',''ENDURANCE'',''PEACE-
     TIME'',''WARTIME'','SPRINTDRIFT''
360  FORS = 8TO28
370  :SHP = K*S ^ C
375  :P = (SHP + 400)*1.015/2
380  :IFP > CRPWRTHEN430
385  :CP = P
390  :ON CE GOSUB 2305,2125,2005,2250
400  :HRS = FLD/(2*P*CSFC + AUXF)
420  :GOTO510
430  :IFP > MNPWRTHEN480
435  :MP = P
440  :ON ME GOSUB 2405,2505,2205
450  :HRS = FLD/(2*P*MSFC + AUXF)
470  :GOTO510
480  :CP = P*CRPWR/(CRPWR + MNPWR)
482  :ON CE GOSUB 2305,2125,2005,2250
484  :MP = P-CP
488  :ON ME GOSUB 2405,2505,2205
490  :CFC = CP*CSFC + MP*MSFC
500  :HRS = FLD/(2*CFC + AUXF)
510  :NDUR = 10*INT(HRS*S/10)
520  :PEACE = PTPC(S)*HRS*S/100
530  :TPEACE = PEACE + TPEACE
540  :WAR = WTPC(S)*HRS*S/100
545  :D = DTPC(S)*HRS*S/100
550  :TWAR = WAR + TWAR
```


```
555  :T=D+T
560  :PRINT'' '';S.;'' '';NDUR,;'' '';INT(PEACE),;'' ''INT(WAR),;'' ''INT(D)
570  NEXTS
590  GOT0910
595  REM CALCULATION FOR MULTIPLE EQUAL MAIN ENGINES
600  SHP=K*SPD ^ C
605  MP=(SHP+400)*1.015
610  ON ME GOSUB 2405,2505,2205
620  FLD=(RG/SPD)*(MP*MSFC+AUXF):PEACE=0:TWAR=0:T=0
630  PRINT''FUEL LOAD FOR'';RG;''NMI AT'';SPD;''KNOTS
     IS'';INT(FLD/2240);''TONS''
640  PRINT:PRINT''SPEED'',''ENDURANCE'',''PEACE-
     TIME'',''WARTIME''. ''SPRINTDRIFT''
650  FORS=8T028
660  :SHP=K*S ^ C
665  :P=(SHP+400)*1.015
670  :IFP > MNPWRTHEN720
675  :MP=P
680  :ON ME GOSUB 2405,2505,2205
710  :GOT0830
720  :IFP > 2*MNPWRTHEN770
725  :MP=P/2
730  :ON ME GOSUB 2405,2505,2205
760  :GOT0830
770  :IFP > 3*MNPWRTHEN820
775  :MP=P/3
780  :ON ME GOSUB 2405,2505,2205
810  :GOT0830
820  :MP=P/4
825  :ON ME GOSUB 2405,2505,2205
830  :HRS=FLD/(P*MSFC+AUXF)
840  :NDUR=10*INT(HRS*S/10)
850  :PEACE=PTPC(S)*HRS*S/100
860  :TPEACE=PEACE+TPEACE
870  :WAR=WTPC(S)*HRS*S/100
875  :D=DTPC(S)*HRS*S/100
880  :TWAR=WAR+TWAR
885  :T=D+T
890  :PRINT'' '';S.;'' '';NDUR,;'' '';INT(PEACE),;'' ''INT(WAR),;'' ''INT(D)
900  NEXTS
905  PRINT:PRINT
910  PRINT''TOTALS'' ,,,10*INT(TPEACE/10),10*INT(TWAR/10),''
     ''10*INT (T/10)
912  PRINT#1:CLOSE1
915  REM QUERRY TO GO AROUND LOOP OR QUIT
920  INPUT ''IS THERE ANOTHER ARRANGEMENT? YES=1 OR
     NO=2'';AGN
930  ONAGN GOT0940,960,920
940  INPUT ''WHOLE NEW SHIP (1) OR JUST ARRANGEMENT (2)'';SHIP
950  ONSHIP GOT0180,210,940
960  END
2000 REM DDA 570 SFC CALCS
2005 IF CP < 3500 THEN 2030
2010 CSFC=0.5-0.04*(CP-3500)/3000
2020 GOTO 2040
2030 CSFC=0.5*(1+0.526*((3500/CP) ^ .66-1))
2040 RETURN
2120 REM FT12 SFC CALCS
2125 CSFC=0.685*(1+0.413*((3800/CP) ^ 0.75-1))
2130 RETURN
2200 REM SPEY SFC CALCS AS MAIN OR CRUISE
2205 IF MP < 1207 THEN 2230
2210 MSFC=0.38*(1+0.17*(18000/MP-1))
2220 GOTO 2240
2230 MSFC=-0.0012035*MP+2.7314
2240 RETURN
2250 IF CP < 1207 THEN 2280
2260 CSFC=0.38*(1+0.17*(18000/CP-1))
2270 GOTO 2290
2280 CSFC=-0.0012035*CP+2.7314
2290 RETURN
2300 REM DIESEL SFC CALCS
2305 IF CP < 0.1*CRPWR THEN 2370
2320 IF CP > 0.9*CRPWR THEN 2340
2330 CSFC=0.4
2335 GOTO 2390
2340 X=10*(CP-0.9*CRPWR)/CRPWR
2350 CSFC=0.4+(0.1*X ^ 2)
2360 GOTO 2390
2370 X=10*(0.1*CRPWR-CP)/CRPWR
2380 GOTO 2350
2390 RETURN
2400 REM FT4 SFC CALCS
2405 MSFC=0.48*(1+0.27*((25000/MP) ^ 1.25-1))
2410 RETURN
2500 REM LM2500 SFC CALCS
2505 IF MP < 2000 THEN 2530
2510 MSFC=0.38*(1+0.279*((25000/MP) ^ 0.75-1))
2520 GOTO 2540
2530 MSFC=-0.001237*MP+3.495
2540 RETURN
```

PFTM (METTP) Rimouski

by Lt(N) Serge Lamirande

Introduction

PFTM Rimouski is the francophone version of the Marine Engineering Technician Training Plan (METTP). Like its counterpart, PFTM is an accelerated programme designed to prepare Mar Eng Mechs for Cert II qualification as Mar Eng Techs. Initiated in May 1983 with the establishment of a Maritime Command detachment in Rimouski, Quebec, PFTM is run in collaboration with the *Institut de Marine du Cegep de Rimouski* (IMCR), the only francophone institution in Canada offering courses in marine engineering. The programme consists of a three-year, combined academic and naval training syllabus and culminates in a *Diplôme d'Études Collégiales* in marine engineering. Later this year the students of the 1983 inaugural class will become PFTM's first graduating class.

IMCR

Founded in Rimouski in 1944, IMCR oriented its efforts towards producing marine navigation and engineering officers, thus making it the first and only school of its kind in Canada. Although its beginnings were quite modest, the quality of its graduates quickly gained it the high regard of the maritime industry and IMCR has kept that precious esteem to this day. Many of IMCR's graduates hold important positions in today's national and international maritime industry.

Today, IMCR's aim is to provide the civilian maritime industry with graduates who have acquired the best specialized training in Canada. IMCR orients its courses towards ship administration and operation, covering such areas as communications and maritime electronics. Students taking courses at IMCR can look forward to having their courses accredited by Transport Canada, and need only complete the necessary sea time to become eligible to write the Transport Canada certification exams.

IMCR's Teaching Staff

The IMCR marine engineering teaching staff is composed mainly of bilingual, professional merchant marine engineers who possess either 1st- or 2nd-class tickets in combined steam and diesel. Their experience varies from Great Lakes shipping to deep-sea companies around the world. Most of them go back to sea during the summer months to keep in touch with the technological progress of the marine industry. Thus keenly aware of the industry's needs, the teaching staff is able to constantly reevaluate the IMCR programmes and model them accordingly.

The PFTM Programme

Since the 1983/84 academic year about 20 fleet and direct-entry candidates have been recruited annually for the PFTM programme. Fleet candidates are required to follow a pre-academic instruction package at the Fleet School Engineering Division during April and May, but then join the direct-entries in June to commence Phase I of the programme proper.

The PFTM programme is accomplished within ten training phases:

Phase I (June to August): New-entry training covers a fifty-day period and offers the student a combined basic recruit and sea/surface environmental course: six weeks at CFRS St-Jean, as well as three weeks' Fleet School including one week of NBCD School.

Phases II and III (September to April): First and second CEGEP semesters at IMCR.

Phase IV (May to August): Mar Eng Cert I training in the fleet. Promotion to Able Seaman upon successful completion.

Phases V and VI (September to April): Third and fourth CEGEP semesters. Promotion to Leading Seaman on successful completion.

Phase VII (May to August): Junior Leadership course, and a special TQC course which includes fitting, diesel and gas-turbine courses.

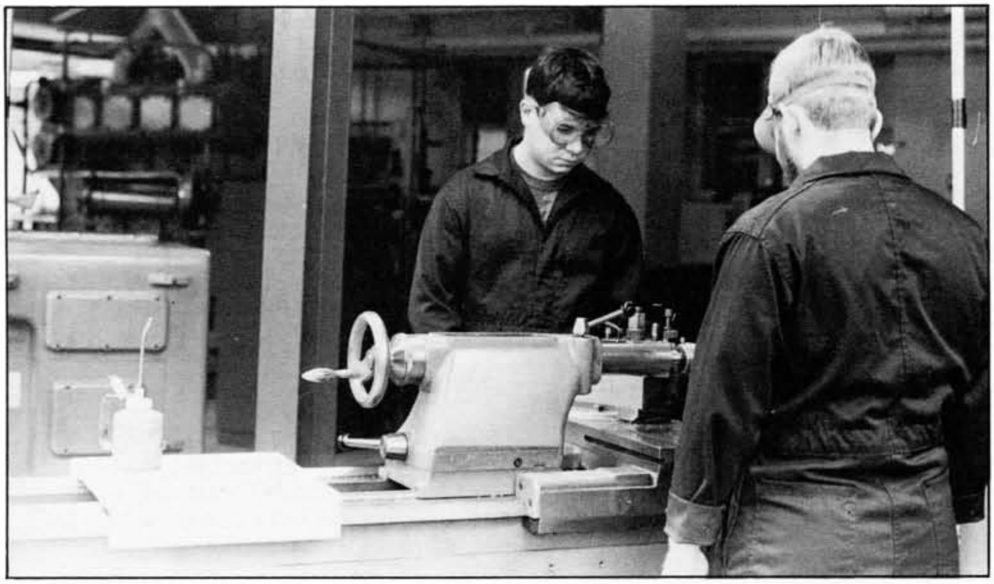
Phases VIII and IX (September to April): Fifth and sixth CEGEP semesters.

Phase X: Completion of the TQC course (machine-skills phase) during the months of June and July. Promotion to Acting (lacking qualification) Master Seaman on successful completion.

PFTM students receive considerable hands-on training during their three-year programme. Here, 1st-year students undergo basic handskills training in the IMCR workshops.

The PFTM students can look forward to being taught about equipment that is of particular interest to them. The IMCR instructors, with their wealth of marine engineering experience, are eager to teach students about current military machinery. The 3rd-year diesel course to be offered next year, for example, will include instruction on the injector and fuel-pump system of the DDA Type 71 engine presently in use in some of our warships.

Although the PFTM students are integrated into the civilian student classes at IMCR, there are major differences between the two groups. The civilian students follow a four-year programme (compared with three years for PFTM), spending anywhere from 12 to 16 months aboard ship completing their course requirements. By the end of their second academic year they are eligible to write the Transport Canada certification exam for a 4th-class engineering ticket (see box), and upon completion of the third academic year and nine months' sea time as 4th-class engineer may write the 3rd-class ticket. Although the PFTM student possesses the necessary academic background,



he does not have the minimum sea time required for these tickets. The PFTM graduate must still complete six months' sea time to be eligible to write even a 4th-class ticket.

PFTM students also differ from their civilian counterparts simply because of their military status. Even though they are functioning in a civilian environment, they remain servicemen subject to the Code of Service Discipline. The limited number of senior staff at the Rimouski detachment (one MARE MS lieutenant and a Mar Eng Art petty officer) means that the students must be relied upon to look out for one another. In this respect, Detachment Standing Orders firmly establish the requirement for discipline amongst the student body, and support it with a clearly defined student seniority structure in which 3rd-year leading seamen play an important role in maintaining control and discipline.

As military candidates, the PFTM students are under considerable pressure to achieve academic success while they are at Rimouski. In addition to the time they spend in regular classes, they are expected to devote many of their evening and weekend hours to study. Their performance is closely monitored, and students are counselled whenever their academic success is deemed to be in jeopardy.

Importantly, PFTM orients a large portion of its course content towards hands-on training at sea and in the IMCR workshops — experience that is indispensable in the making of marine engineering technicians. All told the programme provides a solid educational base from which graduates have the potential to progress to the P2 level and Cert III qualification in much less time than if they had followed the normal trades training route. The actual progress of PFTM's first graduates will be watched closely as they join the fleet as Mar Eng Techs later this year.

Lt(N) Lamirande received his engineering degree from the Royal Military College of Canada in 1980. He has served as Assistant E.O. in HMCS HURON, *and as the DDH-280 Class Officer at NEU(A). He is currently the MARCOM HQ METTP Detachment Commander in Rimouski, Quebec.*

The Marine Engineering Ticket System in the Merchant Navy

There are four levels of tickets for marine engineers in the Canadian merchant marine. The tickets are granted by the Transport Canada Maritime Safety Section to candidates who have the required sea time and who have passed the certification exams. The ticket levels are as follows:

1st-Class Officer: Senior engineer on board, responsible for the overall safe and efficient operation of the ship's machinery, and for the administration of the Engineering Department. A 1st-Class Officer may be tasked to such shore duties as:

— Maritime expert for Transport Canada;
— Maritime expert for insurance companies;
— Personnel manager for shipping companies; and
— Sea Trial Officer for shipyard companies.

(The 1st-Class Officer's duties are equivalent to those of a ship's E.O. in the Canadian navy.)

2nd-Class Officer: Responsible for the maintenance management of the ship's machinery and the regulation of the engineering personnel (his duties are equivalent to those of a CERA/Regulating Chief in the Canadian navy).

3rd- and 4th-Class Officer: Engineering Officer of the Watch, responsible for the supervision of the engine-room during his watch in addition to other specific duties (equivalent to Cert II and Cert I).

AN/UYS-501: A High-Speed Signal Processor

by T. Yuan and LCdr R. Miskowicz

Foreword

This article describes the functional characteristics and the technologies behind the AN/UYS-501 Advanced Development Model (ADM) Teamed-Architecture Signal Processor (T-ASP*) designed and built by Motorola Information Systems of Brampton, Ontario. The AN/UYS-501 ADM is described and evaluated through comparison with two close competitors. Special attention is given to the ST-100 Array Processor, recently developed by STAR TECHNOLOGIES Inc., because of its impressive performance and competitive price. The ASP (Advanced Signal Processor) of IBM is also mentioned. Supercomputers such as the Cray-1 and the CYBER 205 are briefly discussed to put the AN/UYS-501 in perspective with today's "state-of-the-art" supercomputers. A second-generation processor, the T-ASP 2000, is being marketed internationally by Motorola Information Systems.

Readers of this article are assumed to have at least some knowledge of computer systems. However, technical details will be described in plain English to accommodate a wide range of readers.

Introduction

Recent developments in semiconductor technologies have vastly reduced the size and the cost of digital computing devices. For this reason, digital signal processing in sonar applications has become technically and financially feasible. Digital signal processing has distinct advantages over analogue methods in terms of its guaranteed accuracy and, more importantly, its versatility in performing various tasks programmed by the user.

In 1975, the Defence Research Establishment Atlantic (DREA) recognized that digital signal processing was the way ahead for sonar. The basic concept of the machine was developed by Mr. R.C. Trider of DREA in cooperation with Motorola Information Systems (then ESE Limited). Motorola was further contracted to design and produce the AN/UYS-501 ADM.

**T-ASP is a registered trademark of Motorola Information Systems Ltd.*

The first and principal sections of this article provide a background knowledge of the design and performance of the AN/UYS-501 ADM, with overviews of Star Technologies' ST-100 and IBM's Advanced Signal Processor. The article continues with a discussion of the merits of the AN/UYS-501 ADM, vis à vis the ST-100 and ASP, and concludes with a report on the status of the AN/UYS-501 ADM.

The Teamed Architecture Approach

The design philosophy of the AN/UYS-501 is based on the assumption that fast Fourier transform (FFT) is the single-most important algorithm in digital signal processing (see box).

Parallel, Pipeline.
The AN/UYS-501 is an extremely fast signal processor capable of performing 320 megaflops (i.e. 320 million floating-point operations per second). This high-speed capability is not attained through the use of exotic devices (e.g. very large-scale integration devices) but through a highly parallel structural design which allows many operations to be performed simultaneously. Furthermore, its performance is enhanced by its pipelined architecture, which executes arithmetic operations and routes data movements concurrently.

An eight-arithmetic-unit (AU) AN/UYS-501 ADM is contained in two, 19" EIA standard rack-mounted cabinets which are bolted together with their centre side-panels removed *(Fig. 1)*. Smaller, less powerful, versions with 2 or 4 AUs are contained in single cabinets. The major components of the AN/UYS-501 ADM are:

a. Communications Controller (Control Processor)
b. Arithmetic and Transfer Controllers
c. Arithmetic Units — 2, 4 or 8
d. Working Memory — 2, 4 or 8 segments
e. Cache Memory — 2 sections, 2, 4 or 8 segments
f. Input/Output Interface
g. Host Computer Interface

Communications Controller.
The communications controller is the central executive processor of the AN/UYS-501 *(Fig. 2)*. It is a DEC PDP-11/23 mini-computer that governs the activities of the arithmetic and transfer controllers. This microprogrammable mini-computer is connected to the host computer through a host interface and its program is initiated and terminated by the application program executing in the host computer. The communications controller has direct access to the working memory through an I/O channel.

The responsibilities of the communications controller include loading of the arithmetic and transfer controller program memories, starting and aborting these programs, passing and reading parameters to and from the arithmetic and transfer controllers, and assisting in system diagnostics. Control instructions and data are passed to the arithmetic and the transfer controllers through a first-in-first-out (FIFO) memory buffer.

Arithmetic and Transfer Controllers.
Arithmetic and transfer controllers are independent, programmable processors that are under the control of the communications controller. The arithmetic controller's role is to control the operations taking place between the arithmetic units and the cache memory. The transfer controller controls the data flow between the working memory and the cache memory.

Conceptually, each controller may be divided into two halves *(Fig. 3)*: the left-hand side (LHS) and the right-hand side (RHS). The LHS's of the two controllers are identical; they communicate with the communications controller and set up address and mode registers for their RHS's. The RHS's act as slaves to their corresponding LHS's. In the arithmetic controller, the RHS has the actual control over the arithmetic operations that are taking place in the arithmetic units. The RHS's of the transfer controllers do the actual governing of data movement between the working memory and the cache memory. This LHS/RHS split allows the next transfer or arithmetic operation instructions to be set up in the

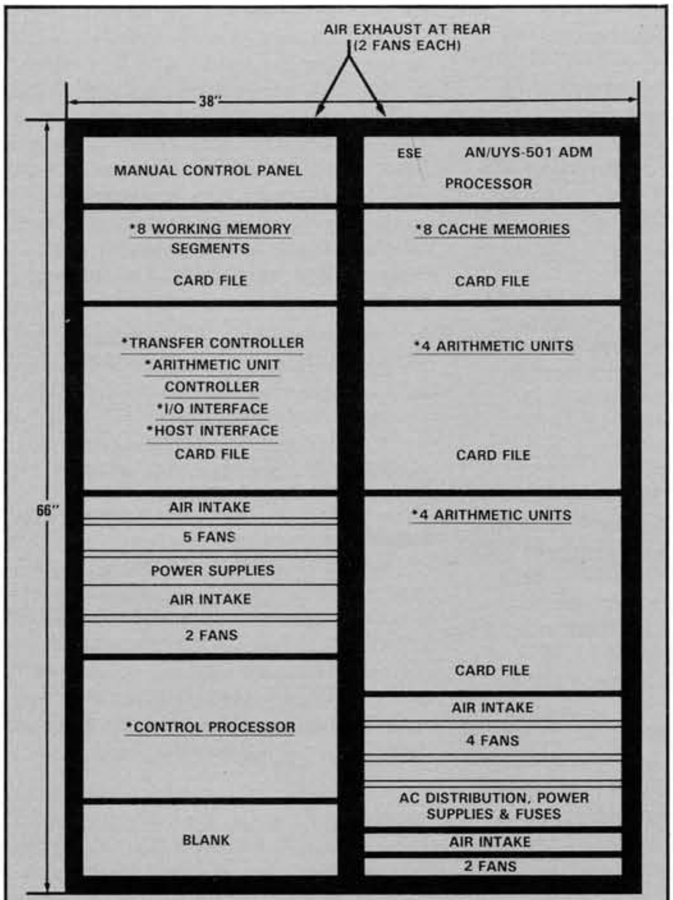


Figure 1. AN/UYS-501 ADM Cabinet Layout (8-Au Configuration)

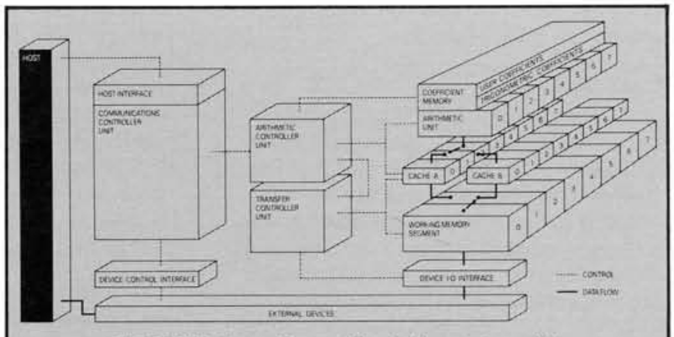


Fig.2a. T-ASP Architecture (*Courtesy of Motorola Information Systems Ltd*).

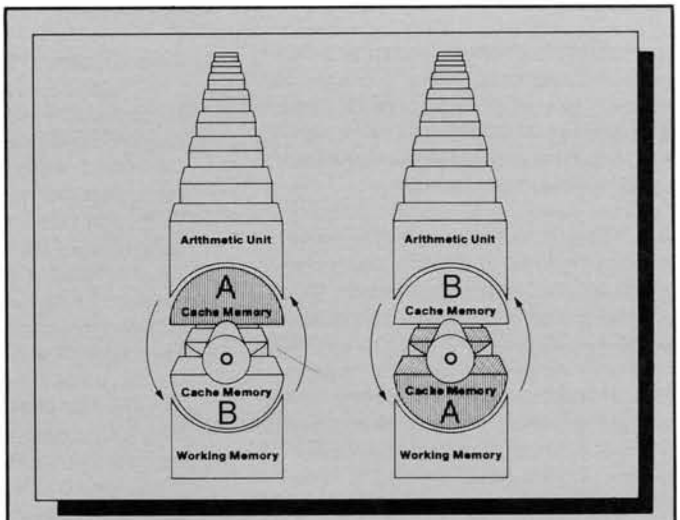


Fig.2b. Cache Memory Swap (Courtesy of MIS Ltd).

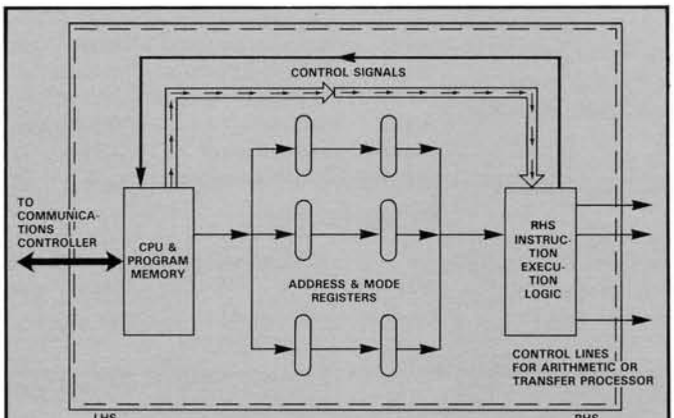


Figure 3a. LHS and RHS of the Controllers

TRANSFER CONTROLLER		ARITHMETIC CONTROLLER	
Left-hand side	Right-hand side	Left-hand side	Right-hand side
General Housekeeping	Vector Transfer		Operations on Cache
– register operations – looping control – subroutine calls – logical – communications – TCU/ACU synchronization	– WM to Cache – Cache to WM – zeros to Cache	(same as TCU)	– Summation – vector product – dot product – FFT

Figure 3b. Transfer and Arithmetic Controller Functions

LHS while the RHS executes current functions. This reduces housekeeping and overhead and allows more efficient computing. The AN/UYS-501 ADM controllers thus perform like a well-balanced team, each specializing in a controlling function, acting concurrently and yet in concert. This additional LHS/RHS controller parallelism achieves far greater efficiency and speed than is possible within a single controller.

Working Memory.

The working memory is a dynamic MOS RAM (random access memory) with a read-write cycle of 375 nanoseconds (ns = 10^{-9} second). The 24-bit addressing of the memory provides up to 16 million 40-bit words of data storage capability. The working memory is divided into multiple segments and the segments are interleaved to increase data transfer rate. The number of segments (there can be either 2, 4 or 8) depends on the number of arithmetic units in the system. Addressees separated by 2^N (where N = 0, 1, 2, 3......15) locations are stored in different segments to allow access to multiple words simultaneously.

Regular memory refreshing is required for a dynamic MOS memory which can only retain information for several milliseconds. Two types of memory refresh are performed on the working memory: a high-priority refresh is scheduled to occur every 96 memory cycles, and a low-priority refresh occurs whenever the working memory is not used by any device or controller. If the low-priority refresh completes its refresh successfully, the high-priority refresh will skip its scheduled refresh cycle until the next cycle. When the high-priority refresh occurs, the system is interrupted.

There are two I/O ports attached to the working memory to accommodate up to 32 external ports. One port (lowest in priority) is dedicated to the communications controller, while the other 31 ports interface to external devices.

Cache Memory.

The cache memory is a fast bipolar RAM with a read- write cycle of 125 ns. It has 32K 40-bit words of data storage. The cache memory has two sections, and each section is further divided into either 2, 4 or 8 segments corresponding to the number of arithmetic units. At any one time, one section is connected to the working memory while the other is associated with the arithmetic units. Sections are swapped when jointly requested by the arithmetic and transfer controllers.

Each segment is divided into two parts: left and right. Hence, each section has a maximum of 16 parts of 1K memory. This arrangement allows simultaneous access to 16 words in the cache memory by the eight arithmetic units.

Data transfer between the cache memory and the working memory is in 40-bit words. During the transfer, data addresses may be re-mapped through an address mapping PROM (programmable read-only memory) which allows up to 512 different mapping variations. This address mapping facility enables FFT bit-reversal operations and matrix manipulations to be done "on the fly" (no processing time required).

Arithmetic Units.

The AN/UYS-501 ADM can incorporate a maximum of eight arithmetic units (AUs) in a parallel configuration. Each AU performs operations in the form of A + BC and A-BC, where A, B and C can be complex or real. Data is processed in 40 bits through an arithmetic pipeline (*Fig. 4*) consisting of 6 steps:

1. Extended heterodyne facilities (not shown);
2. Access Coefficient Memory (if necessary);
3. Multiply;
4. Add;
5. Normalize;
6. Function Module

Each step in the pipeline is separated by a register so that data may be saved and passed to the next step synchronously. Each step processes data from the previous step. The whole pipeline requires 8½ machine cycles to complete. Under a maximum efficiency condition, where all steps are utilized, the AN/UYS-501 ADM can perform complex A + BC and A-BC FFT butterfly operations in 250ns. These involve 10 real operations per butterfly (or 320 megaflops for an 8-AU machine).

Input/Output Interface and Device Interface.

The I/O interface allows up to 15 external devices and the communications controller to access the working memory. Only one device may access the working memory at a time. Access to the working memory is granted on a priority basis; device #15 would have the highest priority, device #14 the next highest, and so on. The communications controller has the lowest priority. Data is written and read in 16-bit or 40-bit words which can be in either fixed or floating-point format.

The device interface provides communication links between the communications controller and the external devices. The information passed between them is 13-bit control words which can be initiated at either end.

Host Computer Interface.

The host computer (see box) acts to initiate and terminate the communications controller software. The host computer interface is a synchronous serial interface providing communications between the host computer and the communications controller of the AN/UYS-501 ADM. The user terminal of the host computer can be used as the console of the AN/UYS-501 ADM. Files on the host computer can be loaded into the communications controller on-line using the on-line down-load facility (XLD). The programs executing in the AN/UYS-501 processors are developed and tested on the host computer system and then down-loaded into the appropriate program memories of the processors in the AN/UYS-501 ADM.

Control and Data Flow.

External devices inform the communications controller of the AN/UYS-501 that data is ready for transmission. Access to the AN/UYS-501 working memory is granted on a priority basis. Data enters through the I/O interface and is stored in the working memory.

Executing its own instruction set as initiated by the communications controller, the transfer controller transfers data from the working memory to the cache memory. The transfer controller then sends a request for the cache memory swap. The swap is not done, though, until the arithmetic controller completes its functions and sends a request for a swap. After the swap is completed, the arithmetic units process the data while the transfer controller routes the results calculated from the previous set of data back to the working memory and loads in a new set of data for subsequent operations.

The communications controller at this point informs external devices through the device interface that results are ready for output. Data exits the AN/UYS-501 via the I/O interface. *Figure 2* illustrates the general control and data flow of the AN/UYS-501 ADM system.

Software.

The AN/UYS-501 ADM is supported by an extensive network of software packages for programming convenience. These software packages include on-line and off-line diagnostics, and debugging and editing facilities. They not only help the development of programs but also detect and locate error sources in the system.

The programs in the communications controller of the AN/UYS-501 are written in the Macro-11 Assembly Language (see box). The program language for the arithmetic and transfer controllers is the XAS Assembly Language. These programs are compiled in the host computer and down-loaded to the appropriate controller program memories by the host computer *(Fig. 5)*. These programs are executed under TOS (T-ASP Operating System), a real-time multi-tasking executive which is initiated and terminated by the application programs in the host computer.

ST-100 Overview

The ST-100 Array Processor, considered to be the AN/UYS-501 ADM's closest rival, has impressive performance and a

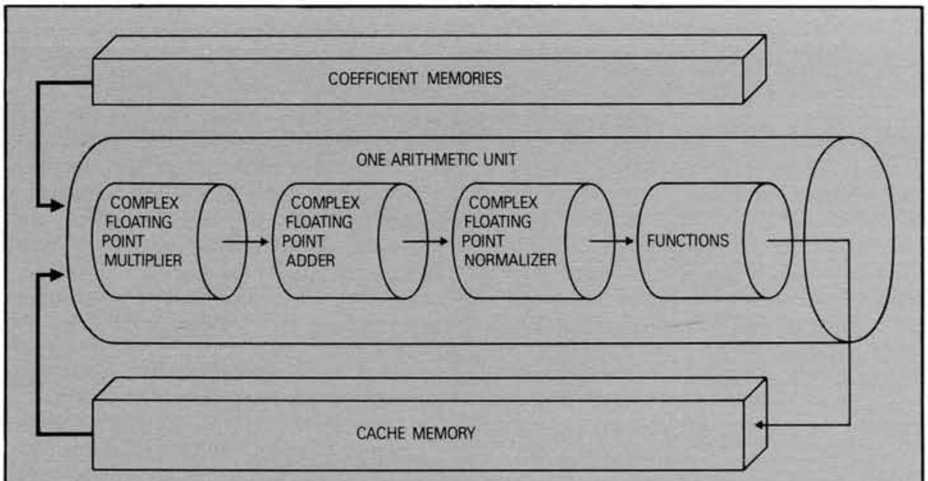


Fig.4 The Arithmetic Pipeline (Courtesy MIS Ltd).

competitive price. It employs multiple processors and segmented memories to allow parallel control and data flow *(Fig. 6)*. Also, like the AN/UYS-501, the ST-100 processes arithmetic operations in a pipeline to attain a higher processing speed. ST-100 consists of the following components:

a. Input/Output Subsystem
b. Control Processor
c. Main Memory
d. Data Cache
e. Storage Move Processor
f. Arithmetic Section
g. Maintenance Terminal

ST-100 has four independently programmable processors. Their functions include the control over external data flows, resource synchronization and management, internal data flows, and arithmetic processing. These processors are the I/O processor in the I/O subsystem, the control processor, the storage move processor, and the arithmetic processor in the arithmetic section respectively. Each processor has its own registers and control program memory.

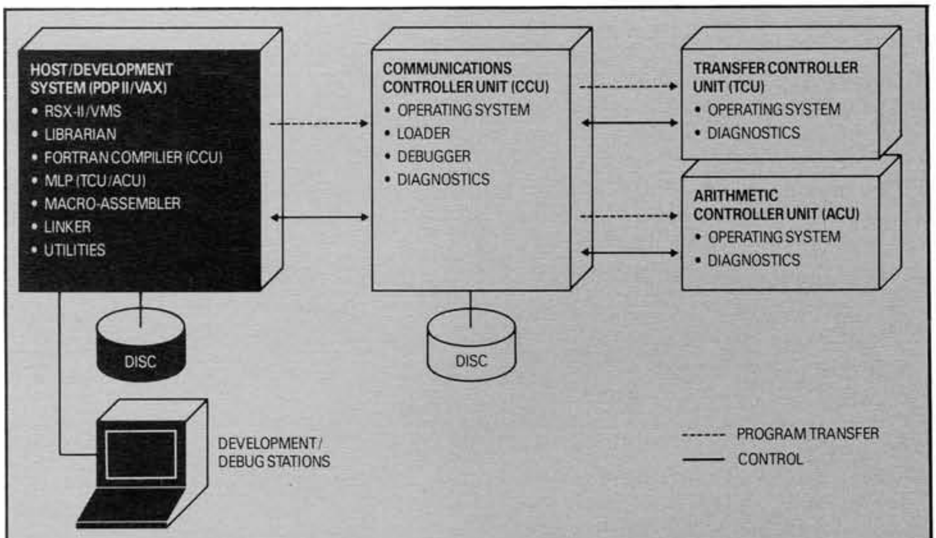


Fig.5 T-ASP Software Development (Courtesy MIS Ltd).

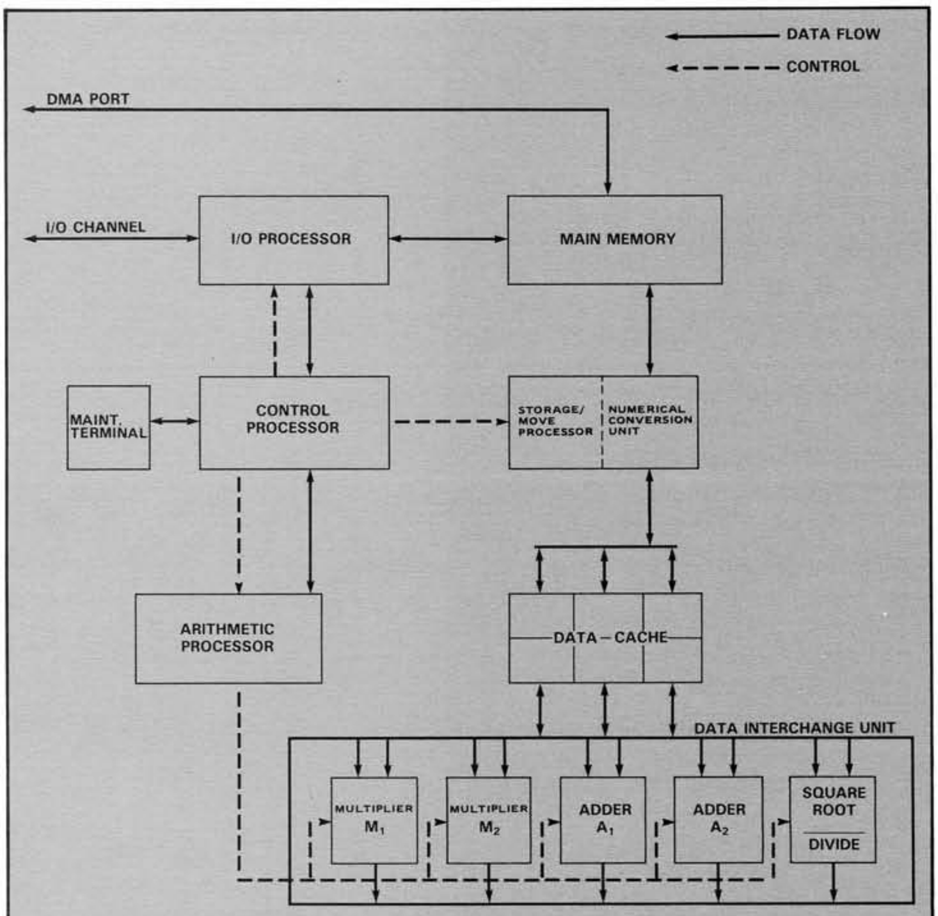


Figure 6. Components, Control and Data Flow of the ST-100 Array Processor

The control processor consists of two Motorola 68000 microprocessors, each capable of operating independently to provide a parallel control over the other processors in ST-100. The storage move processor contains an NCU (numerical conversion unit) that converts any input data into the format required by the arithmetic elements of the ST-100. This NCU permits different host computer systems to be attached to the ST-100. The main memory is segmented and interleaved to provide a higher data-transfer rate. The arithmetic section consists of an arithmetic processor and arithmetic elements which include two multipliers, two adders, and a divide/square root section. The multipliers and adders form a 3-step arithmetic pipeline which requires three 40ns machine cycles to finish. The maintenance terminal is responsible for loading and initiating the ST-100 processes, diagnostic program loading and executing, and error logging. This terminal is directly connected to the control processor of ST-100.

ASP Overview

The Advanced Signal Processor is a microprogram-controlled digital signal processor produced by IBM. It consists of six functional components:control processor, I/O channel, arithmetic processor, bulk store, storage controller, and the option of either an input signal conditioner or a high-speed port. The ASP also has its own operator control panels, and interfaces for remote control panels are provided.

The control processor is the central executive of the ASP system as it controls all other functional components. Input data enters the bulk store either through the I/O channels, the input signal conditioner or the high-speed port. The storage controller pages data from the bulk store to the working store in the arithmetic processor for signal processing. Final results are transferred to the bulk store and output through the I/O channels.

Performance

Specifications.

The performance data and specifications of the AN/UYS-501 ADM, the ST-100, the IBM ASP and the T-ASP 2000 are summarized in *Table 1*.

"Is The AN/UYS-501 ADM Superior?"

In comparing the AN/UYS-501 ADM with the ST-100 (or any other machine for that matter) the factors that must be considered include hardware design, performance, and cost.

Differences.

There are fundamental differences between these signal processors. The arithmetic pipeline set-up of the AN/UYS-501 ADM is such that maximum efficiency is attained while performing complex FFT calculations. In 250ns, AN/UYS-501 executes a complete FFT butterfly loop (A + BC and A-BC). The disadvantage of this pipeline set-up occurs when a simple operation like X + Y is calculated. In this case, the AN/UYS-501 must still go through the same pipeline to compute this simple operation consuming the same amount of time as a complex FFT butterfly loop. The arithmetic pipeline of the AN/UYS-501 consists of five steps, requiring 8½ 250ns cycles to finish. Therefore, the start-up time for the AN/UYS-501 requires 2.125 microseconds. ST-100 has a more general approach to its arithmetic pipeline design. The pipeline consists of two multipliers and two adders. It is a three-step pipeline which requires three machine cycles to finish, resulting in a 120ns start-up time. With the shorter start-up time the ST-100 is more suitable for short-vector computations, while the AN/UYS-501 ADM is more efficient in long-vector computations.

The design of the AN/UYS-501 ADM is targeted towards maximum efficiency in FFT calculations. An additional feature which increases the efficiency of the AN/UYS-501 ADM is that the bit-reversals of FFT are done "on the fly" (during data transfer), requiring no processing time.

The cache memory of the AN/UYS-501 ADM is also a unique feature. This memory is divided into two sections, allowing one section of data to be processed by the arithmetic units while the other section engages in data transfers with the working memory. These sections can be swapped upon the completion of data processing and data transfers. This feature, achieved through a complex network of de-multiplexers, reduces the overhead of time-consuming data transfer.

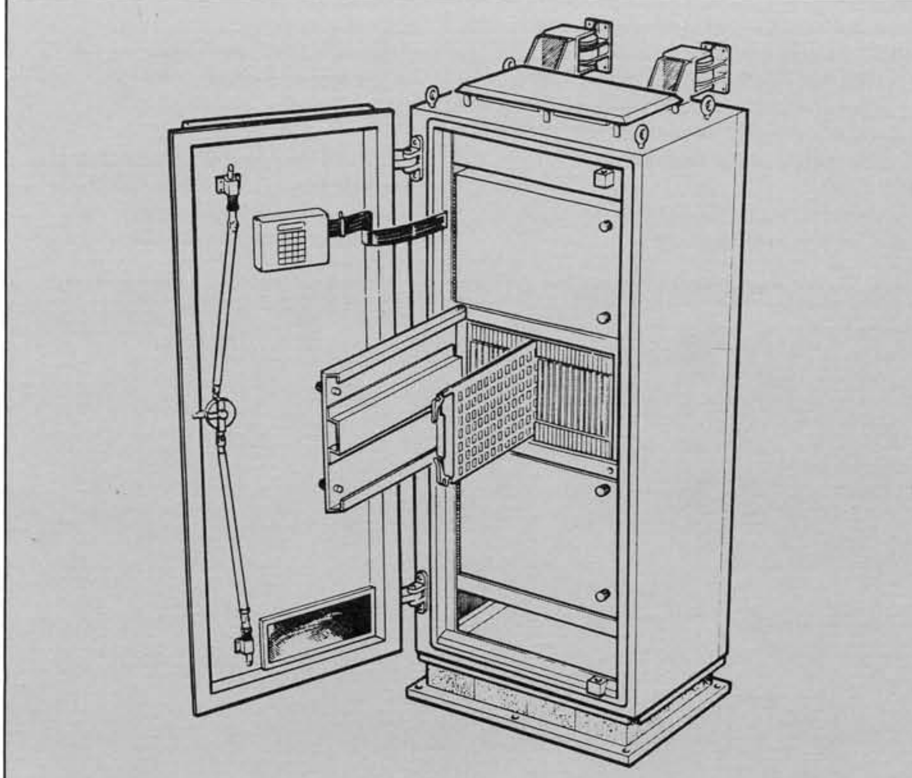


Figure 7. Militarized AN/UYS - 501 Array Processor

TABLE 2. COST VS PERFORMANCE

SINGLE PROCESSOR	PEAK MEGAFLOPS	WORD SIZE	APPROX. COST	APPROX. COST PER MEGAFLOP
CYBER 205	800	32-BITS	$ 12M	$ 15K
CYBER 205	400	64-BITS	$ 12M	$ 30K
AN/UYS-501 ADM (8 AU)	320	40-BITS	$ 0.6M	$1.88K
CRAY — 1	140	64-BITS	$ 8M	$ 57K
ASP (4 AU)	120	32-BITS	$ 4M	$ 33K
ST-100	100	32-BITS	$0.25M	$ 2.5K
ASP (1 AU)	30	32-BITS	$ 1M	$ 33K

TABLE 1. PERFORMANCE

Item	Description	IBM ASP	Star ST-100	AN/UYS-501 ADM	TASP-2000
1	Manufacturer	IBM	Star Technologies	Motorola Information Systems	Motorola Information Systems
2	Architecture	parallel	pipeline/parallel	pipeline/parallel	pipeline/parallel
3	Machine Cycle	300 nsec	40 nsec	250 nsec	250 nsec
4	Arithmetic Units	4	1	2, 4 or 8	2, 4 or 8
5	Word Size	32 bits	32 bits	40 bits (64 bits militarized)	40 bits
6	Cache Memory	2K per AU	40K	2 banks of 2K per AU	2 banks of 4K per AU
7	Bulk Memory	256K expandable to 1024K	up to 8M	up to 2M (64M militarized)	up to 64M
8	Memory Transfer Rate	20 Mwords/sec	25 Mwords/sec	16 Mwords/sec (8 AU)	16 Mwords/sec (8 AU)
9	Butterfly Cycle	390 nsec	160 nsec	250 nsec	250 nsec
10	Floating Point Ops/sec	120 Mflops	100 Mflops	320 Mflops	320 Mflops
11	I/O Transfer Rate	2.5 Mbytes/sec	12.5 Mbytes/sec	7 Mbytes/sec	17.5 Mbytes/sec
12	1K FFT Computation	2000 microsecs	862 microsecs	160 microsecs (8 AU)	160 microsecs (8 AU)
13	8K FFT Computation	unknown	8850 microsecs	1664 microsecs (8 AU)	1664 microsecs (8 AU)

Flexibility.

Both the AN/UYS-501 ADM and ST-100 are capable of memory expansion. The AN/UYS-501 offers a unique flexibility to suit the computing power required by the purchaser of the machine. It can be fitted with either 2, 4 or 8 arithmetic units for different computing power, and allows one host computer and up to 31 external devices to be connected to the system. ST-100 can support up to 7 host computers and peripheral devices. The multiple host computers can be of any type since the storage move processor of ST-100 is capable of converting different data formats into its system format. In addition, ST-100 offers a special DMA (direct memory access) channel to the main memory to allow fast access of data at full memory bandwidth (100 Mbytes/sec).

Cost vs. Performance.

Performance is perhaps the most publicized aspect of these machines. Cost, however, becomes an inseparable factor in considering such a machine. *Table 2* summarizes the performance, precision, and cost of the machines discussed earlier and shows their costs per megaflop.

The performance rating of the AN/UYS-501 ADM is among the highest and yet its cost is among the lowest, thus making it the most cost- effective signal processor on the market today.

Status

Two AN/UYS-501 ADM units have been produced for DMCS. One is being used in an active-sonar development project and is currently on board HMCS *Nipigon* in the AN/SQS-510 Advanced Development Model. The second unit is being used in a passive-sonar project and is currently at the Computing Devices Company plant in Ottawa for integration into CANTASS, the Canadian Towed Array Sonar System. DMCS 3 is presently in the process of developing the militarized version of the AN/UYS-501 ADM *(see Fig. 7)*. Future prospects for the AN/UYS-501 and T-ASP 2000 include a synthetic aperture radar project and a satellite imaging project.

LCdr Roger Miskowicz is the DMCS 3 project manager for the AN/SQS-510 active sonar and the militarization of the AN/UYS-501. Tony Yuan wrote the first draft of this article while he was a University of Waterloo student on a cooperative engineering work assignment in DMCS 3.

The AN/UYS-501 ADM MACRO Assembler

An assembler is available which offers frequently required functions as MACROs. Some of these MACROs are:

SYMBOL	FUNCTION MACRO
SGN	**COMPLEX SIGNUM:** Replace the contents of the real (Re) and imaginary (Im) parts with 1 if the current value is positive and −1 if negative. Note the Re and Im parts are handled separately.
ABS	**ABSOLUTE VALUE:** Replace and Re and Im part with their absolute values.
ANTLOG	**ANTILOGARITHM:** Replace the real part with its inverse logarithm.
ARCSIN	**ARCSINE:** Replace the real part with its trigonometric arcsine.
RCP	**RECIPROCAL:** Replace the real part with its reciprocal value.
SQRT	**SQUARE ROOT:** Perform the square root on the real part.
SIN	**SINE:** Perform the trigonometric sine of the real part.
COS	**COSINE:** Perform the trigonometric cosine on the real part.
SQ	**SQUARE:** Square the real part.
LOG	**LOGARITHM:** Replace the real part with its logarithm.
ARCCOS	**ARCCOSINE:** Perform the trigonometric arccosine on the real part.

SYMBOL	MODE MACRO
DPM	**DOUBLE PRECISION MULTIPLY:** The real and imaginary parts are interpreted as a double precision value.
DPR	**DOUBLE PRECISION REAL:** Return only real part of result in double precision.
RLM	**RETAIN LOCKED MULTIPLIER:** Lock cache multiplier address. (Permits the use of constant multipliers in vector operations.)
ICA	**COEFFICIENT INDIRECT ON ADDRESS:** Select the coefficient from the address contained in register RO.
DIV 2	**DIVIDE BY 2:** Divide results by 2 before storing.
QCIP	**QUADRANT CONTROL BY IMAGINARY PART:** Allow the sign of the imaginary part to select the quadrant in ARCSIN and ARCCOS operations.
ZIP	**ZERO IMAGINARY PART:** Set imaginary part of result to zero.
FIX	**FIX:** Convert the result to fixed point by shifting mantissa right until exponent zero.
FIXS	**FIX AND PRESERVE SIGN:** Same as FIX but retains the sign.
ADDI	**ADD ONE:** Execute all A + BC operations as 1 + BC. (If Accumulate Mode is set this bit is ignored.)
FCA	**TAKE AND FIX COEFFICIENT ADDRESS** for FFT instruction.
PLD	**PIPELINE DRAIN:** Force left-hand side to wait until right-hand side instruction completed.

SYMBOL	FFT MACRO
FFT	Performs a Forward Fast Fourier Transform on normally ordered input vectors producing bit-reversed output vectors.
FFTR	Performs a Forward Fast Fourier Transform on bit-reversed input vectors to produce output vectors in normal order.
IFFT	Performs an Inverse Fast Fourier Transform on normally ordered input vectors and produces bit-reversed output vectors.
IFFTR	Performs an Inverse Fast Fourier Transform on bit-reversed vectors to produce normally ordered output vectors.

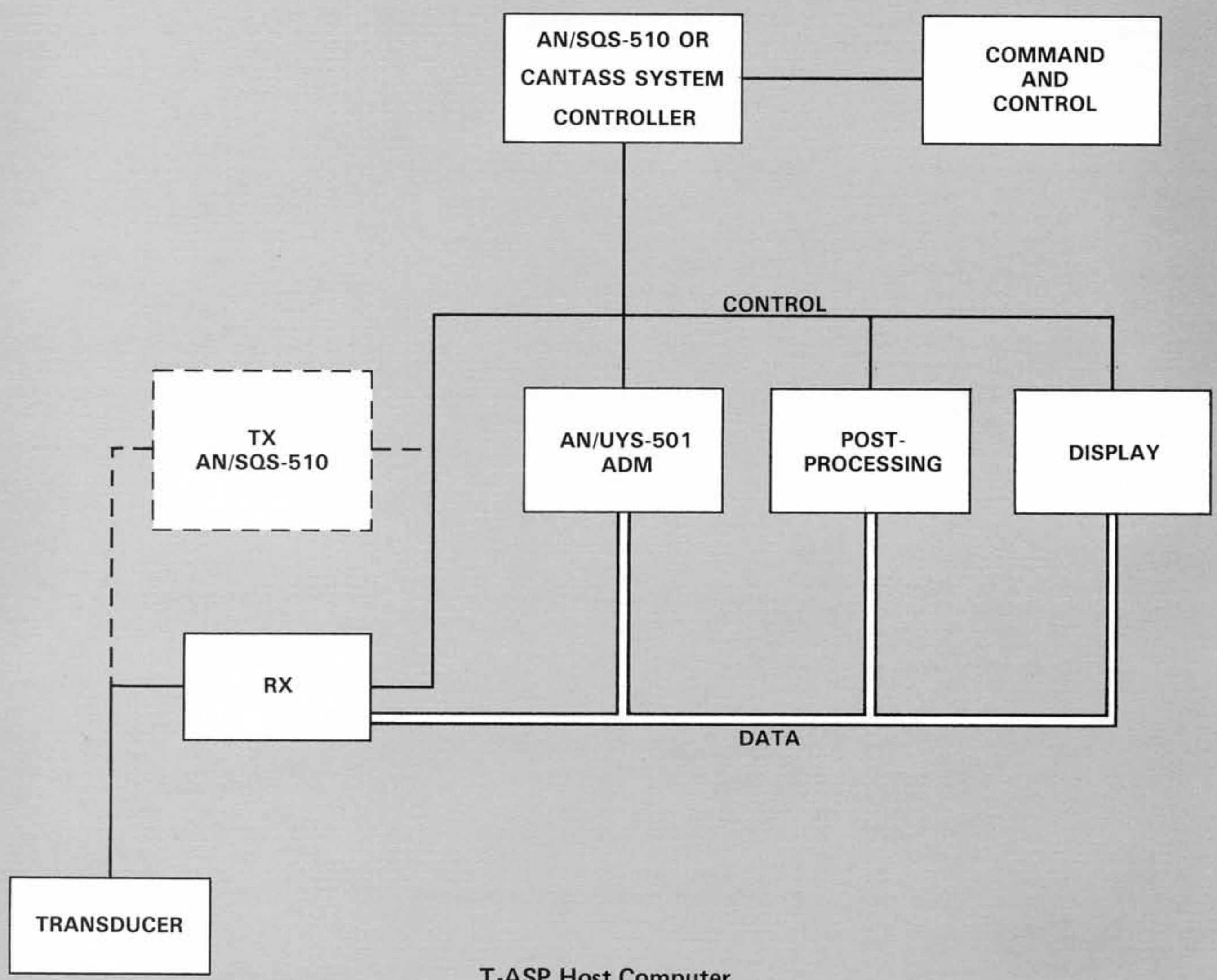
Supercomputers

Large-scale computers of today such as the Cray-1 and the CYBER 205 are estimated to perform about 140 megaflops and 400 megaflops respectively. These "super computers" offer many excellent features such as their wide (64-bit) word size, large memories, high data-transfer rates (80 million words/sec for Cray-1 and 800 million words/sec for CYBER 205), and the ability to double their processing speeds with half precision. However, these machines cost from 8 to 12 million dollars. The AN/UYS-501 ADM's performance is rated at 320 megaflops which is second only to the CYBER 205 and surpasses even the Cray-1. The cost of an 8-AU AN/UYS-501 ADM is below $500K, making it much more cost-efficient than the "supercomputers". Contained as even this engineering development model is, in two 19" racks, it is also certainly much smaller.

Most modern computing devices, including the Cray-1 and the CYBER 205, use similar techniques such as parallel processing and pipeline structuring to improve processing speed. All the signal processors discussed in this article implemented the basic concepts of these techniques in their designs.

Host Computer

The AN/UYS-501 ADM is a very specialized, high-speed "number cruncher" which requires a general-purpose computer to act as its host. In both of the latest active- and passive-sonar developments in Canada (AN/SQS-510 and CANTASS) the duties of host will be performed by the respective system controllers. A simplified block diagram displaying how the AN/UYS-501 ADM is used in these systems is shown below:



T-ASP Host Computer

The Fast Fourier Transform

by LCdr Peter J. Lenk

The Fourier transform is a mathematical technique for the translation of a signal into its component parts. Frequency or spectral information from a target provides a valuable additional tool in distinguishing the presence of, or identifying, a target. In the radar domain, the comparatively large doppler shift associated with an incoming threat sets it dramatically apart from the otherwise overwhelming effects of sea state and weather. In the sonar domain the ability to discriminate velocity is perhaps surpassed in importance by the ability to recognize and classify a threat by its acoustic spectrum or noise signature.

The continuous Fourier transform of a time-varying signal into its frequency spectrum is an essential feature in the design of analogue systems for the analysis of continuous signals. The Discrete Fourier Transform (or DFT) forms the basis of most digital signal processing algorithms. Efficient computation of the DFT has revolutionized many of the methods of engineering and science. Tasks can now be performed by computer, in real time, where formerly the only possible choice was to use analogue devices and accept their inherent limitations and complexities. The DFT has found use in such applications as filtering (removing unwanted signal components), spectral estimation (estimating the frequency content of a signal), and modulation, to name but a few.

The DFT is analogous to the continuous Fourier transform for the special case of a discrete and periodic[1] signal. By a discrete signal we understand that it only occurs at discrete moments in time (or space), and not continuously. For such a sequence x(n), the DFT X(K) is defined as:

$$X(K) = \sum_{n=0}^{N-1} x(n)W_{n}^{nk}$$

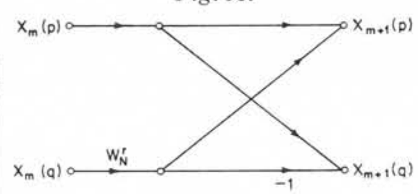
where $W_N = e^{-j\frac{2}{N}}$

We can regenerate the original sequence, x(n), from the X(K) through the inverse relationship, called the Inverse Discrete Fourier Transform (or IDFT) defined by:

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(K)W_N^{-kn}$$

The Fast Fourier Transform (or FFT) is a family of computationally efficient algorithms used for evaluating the Discrete Fourier Transform. The first such algorithm (and still the most commonly used) was described by J.W. Cooley and J.W. Tukey (Ref. 1) in 1965. This algorithm has come to be known as the Cooley-Tukey algorithm. It is based on a "divide and conquer" strategy. The DFT of an N-point sequence can be accomplished by appropriately combining the results of the DFT of two N/2-point sequences[2]. This decomposition can be continued until all sequences are of length 2. It turns out that all the two-point DFTs and the combining operations can be described by the structure shown in *Figure A*. This basic operation has sometimes been referred to as a "butterfly" because of the obvious resemblance of the structure to the winged insect. For the case of the two-point

Fig. A.



Flowgraph of simplified butterfly computation requiring only one complex multiplication.

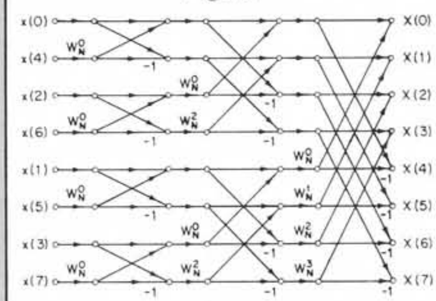
DFT, the multiplier involved in the butterfly operation, W^k_N, is simply equal to 1 so that the multiplication becomes trivial. Direct implementation of the DFT would require N^2 complex operations[3] (multiplications or additions) (Ref.2:p. 367). By applying the Cooley-Tukey algorithm this requirement can be reduced to N $\log_{2N}$ complex operations (Ref.2: p. 367). In order to appreciate the significance of the savings offered by this algorithm, refer to the following table:

N	N^2	$N\log_2 N$
2	4	2
4	16	8
8	64	24
16	256	64
32	1024	160
64	4096	384
128	16384	896
256	65536	1024
512	262144	4608
1024	1048576	10240
2048	4194304	22528

Figure B depicts the computational structure required to perform an 8-point FFT. Note that the data must initially be reordered. The required order can be obtained by taking the binary representation for the sequence number,n, and reversing the bits. For this reason this order has come to be known as "bit-reversed".

This short introduction is only meant to provide an overview of the how's and why's of the FFT. For further details the interested reader is directed to References 2 and 3.

Fig. B.



Flowgraph of eight-point DFT using the butterfly computation of Fig A.

LCdr Peter Lenk is the DMCS 3 project engineer for the AN/SQS-510 active sonar and the militarization of the AN/UYS-501.

Notes

1. The requirement for periodicity is not a problem since we can always consider the signal of interest to be a single period of a periodic signal. It is this periodic nature of the signal that makes its transform (DFT) discrete.
2. The algorithm described here is known as a radix-2 algorithm in that it decomposes the N-point DFT into N/2 2-point DFTs. For this to work properly N must be chosen to be an exact power of 2 (i.e. $N = 2^M$ where M is a positive integer).
3. A complex multiplication involves four real multiplications and two real additions. A complex addition equates to two real additions.

References

(1) J.W. Cooley and J.W. Tukey, "An Algorithm for the Machine Calculation of Complex Fourier Series," *Math. Comp.*, 19, pp. 297-301, Apr. 1965.

(2) L.R. Rabiner and B. Gold, *Theory and Application of Digital Signal Processing*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1975.

(3) A.V. Oppenheim and R.W. Schafer, *Digital Signal Processing*, Prentice-Hall, Englewood Cliffs, NJ, 1975.

Marine Engineering Training in Spectrometric Oil Analysis (SOAP)

by Petty Officer 1st Class F.B. Kirke

Editor's Note: This article was first written as a technical service paper while the author was a student on the Marine Engineering Artificer TQ7 course.

Aim

Spectrometric oil analysis has been an important part of the navy's preventive-maintenance programme since 1966, yet its recognized potential has still not been realized. There is now evidence that some 50% of the oil samples being taken in the fleet are unwittingly being invalidated during the all-important collection and documentation stages. The main reason for this, according to the shore-based MARCOM and MARPAC SOAP monitors, is the apparent lack of understanding of SOAP concepts by ships' technicians because of inadequate training.

Investigation into the present situation regarding SOAP training for the marine engineering trades does indeed appear to substantiate a requirement for more extensive training at most levels. The aim of this paper is to address the shortcomings of the current training profile, and to propose a revised profile that could lead to a more effective spectrometic oil-analysis programme for the fleet.

Introduction

Between 1958 and 1963 the navy conducted a trial marine spectrometric oil-analysis programme (SOAP) with the diesel engines of the minesweeper HMCS *James Bay* and the submarine HMCS *Grilse*. The eventual failure of two defective connecting-rod bearings in the starboard main engine of *James Bay*, and a ring failure in *Grilse's* number four main engine, were discovered as a result of SOAP. The success of this trial resulted in oil-sampling being added to the navy's preventive-maintenance programme in 1966.

In 1968 a TECHRON AA100 spectrometer was installed in HMCS *Yukon* for a five-week trial and evaluation by the Defence Research Establishment Pacific (DREP). The subsequent relocation of the instrument to HMCS *Provider* in 1970 provided the navy with its first mobile SOAP laboratory which, incidentally, was operated under the charge of a P1 marine engineering technician. The mobile laboratory proved successful, and during *Provider's* 1982 refit a Perkin Elmer model 370 spectrometer which had been trialled at DREP for one year was fitted. A Perkin Elmer model 2380 was installed at DREP to replace the unit sent to *Provider* as the model 370, which was also fitted in the two east-coast AORs and DDH-280s, was no longer being produced.

Today, the mobile labs in the AORs and DDH-280s provide the fleet with spectrometric oil-analysis services for marine and aircraft systems during extended deployments. The labs compare their onboard analyses of ships' oil samples with historical data supplied by the dockyard SOAP analysts, then report the results to the ships. At present the lab on the west-coast AOR is operated mainly by marine engineering technicians. On the east coast, however, there is a deficit of qualified marine engineering personnel trained in the operation of the equipment, and responsibility for operating the labs has been delegated mostly to aero-engine technicians.

The MARCOM/MARPAC monitors employed by NEU(A) and NEU(P) are the

resident dockyard SOAP analysts. Working out of laboratories at DREA and DREP, they are responsible for:

a. monitoring the receipt of oil samples from the fleet;

b. the prompt testing of all samples;

c. assisting with and reviewing wear-metal guidelines;

d. maintaining SOAP records on each item of equipment;

e. assessing oil-analysis results; and

f. preparing reports and advising monitors and ships of test results that may indicate changes in equipment serviceability.

The responsibility for supplying the mobile and dockyard labs with valid oil samples for testing and analysis rests with the ships. All ships are directed to participate in SOAP and are responsible for:

a. taking samples at specified intervals (following methods and data recording procedures defined in MARCORDS);

b. identifying and packaging samples for delivery; and

c. dispatching oil samples to the appropriate dockyard or mobile laboratory.

Ships also bear responsibility for maintaining accurate machinery records and for taking appropriate action with suspect equipment.

Since the inception of SOAP in 1966, however, there have been numerous problems in obtaining valid oil samples and recorded information from the ships. There have been many attempts to solve these problems, but in most cases any action has met with little success.

Marine SOAP Problem Areas

From 1966 to 1980 information regarding the SOAP programme was generally disseminated by "word of mouth", and most personnel were only aware that it was something that had been tested and that there were few written details. The original MARCORD was open to interpretation, and usually only the Engineering Officer and CERA on any ship had any experience or training. This expertise remained at the senior level and was seldom passed on to the junior tradesmen who were being tasked with taking the samples and maintaining the records.

Some training has taken place since 1980, but current conservative estimates place invalid samples in excess of 50%. Approximately 15% of these were invalidated because they were taken improperly:

a. on shut-down of machinery;

b. after machinery had been shut down in excess of requirements;

c. with definite emulsion problems; or

d. with samples containing fuel dilutions.

A further 35% lacked the proper documentation to carry out an analysis and evaluation of the sample, which prevented the analysis facility from providing adequate test results to the unit that sent the sample.

It must be stressed that SOAP is a scientific evaluation based on empirical data; therefore, if the raw data is incomplete or incorrect, an invalid assessment could possibly be derived. (The data base prior to 1980 was considered so poor that a computerized SOAP management system would not be valid because of limited or non-existent records and poor samples.)

Discussions with SOAP monitors from both coasts have indicated that the programme is not operating the way it was designed mainly because of a lack of understanding of concepts due to a lack of training of personnel. It has also been determined that adequate training is being carried out far too late in an individual's career to convince him of the value of SOAP. An attitude now exists that SOAP is one of those "must do" tasks, and the importance of the function is considered cursory.

SOAP Requirements for a Good Non-Destructive Test

As in any non-destructive testing there are requirements that must be addressed to provide a good test. These requirements also exist for SOAP and are indicated as follows:

a. integrity of purpose —

(1) reason for test being performed;
(2) attitude of those doing the testing; and
(3) results of the testing;

b. provision of trained personnel — time and training must be made available to those who will be tasked to test and provide analysis of samples. This training must include equipment used, methods, test specifications and reports required, and must provide trainees with an understanding and belief in the methods. Senior personnel must possess an in-depth knowledge of the programme and methods (provided by advanced training) in order to evaluate test results, reports and acceptability of methods in order to maintain quality control;

c. provision of quality testing devices — if SOAP deals in areas of analysis that provide critical assessments which affect the operation of ships in Maritime Command, then provision of high-quality test equipment and adequate test facilities are essential. Technical expertise is mandatory in planning the purchase of new equipment; that is, those who use the equipment must know which devices best meet the requirements, bearing in mind cost versus performance.

d. provision of clearly written test specifications—the test specifications should be well written (understandable), and should provide specific requirements of methods to be used. These specifications should be designed to be followed to the letter, and should not deal with the intent, in order to provide meaningful test results; and

e. provision of complete test reports — the test reports should provide results of tests that were conducted to specifications and, therefore, should not be written as simple statements but rather as cumulative reports of findings. These reports must be specific, not general, and must readily identify equipment problems in understandable terms.

SOAP Training — Current Status

The levels of training in SOAP procedures at present for marine engineering tradesmen are as follows:

a. 312 TQ3 — no training provided;

b. 312 TQ4 — four periods health monitoring (SOAP/VA);

c. 312 TQ5 — three and one half periods (PO 426), possible tour of dockyard laboratory;

d. 313 TQ6 — three and one half periods assigned from NDT performance objective to SOAP health monitoring, possible laboratory tour;

e. 314 TQ7 — included in NDT/corrosion phase if time available, dockyard tour of forty-five minutes; and

f. SOAP Analysis — (any rank) one week training at AMDU Trenton, four weeks' training in a SOAP laboratory and one week in ship's laboratory.

Proposed Training Profile

A revised training profile, which would provide more extensive SOAP training at all trade levels, is proposed as follows:

a. 312 TQ3 — one to two periods as an introduction to SOAP, including an explanation of the programme, the importance of record keeping and the methods of taking samples;

b. 312 TQ4 — five periods, to provide initial refresher of TQ3 material, instruction in completion of the CF 730 (Used-Oil Analysis Report), and mandatory tour of a dockyard or mobile laboratory;

c. 312 TQ5 — sixteen periods, to provide instruction in SOAP sampling, laboratory results and meanings, wear-metal historical data and their assessment;

d. 313 TQ6 — twenty-four periods, to provide complete review of all SOAP standards and wear-metal guidelines, instruction in the interpretation of SOAP data, reports, specifications and methods. Instruction to provide the necessary supervisory skills required at an advanced level;

e. 314 TQ7 — eight periods, as a review of previously instructed SOAP techniques, a tour of SOAP facilities; and

f. SOAP Analysis — six weeks (as in f. above).

In restructuring the training profile it is realized that a short-term solution to training deficiencies is not possible. In the long term, however, the importance of a creditable SOAP training programme, inserted as part of trades training at all levels, will ensure a marked improvement in the reliability of test results.

Conclusion

The spectrometric oil-analysis programme, as developed over the years, was written with good intent but has not achieved the results expected. The programme was based on the theory that it would provide a reduction in requirements for inspection maintenance while also providing an indication of machinery faults as they developed. Such notification of faults would aid in detailing corrective maintenance requirements prior to a major breakdown occurring. The end result would be a savings in money, manpower and equipment down-time, and would increase the operational availability of ships of Maritime Command.

As a single method of non-destructive testing SOAP is not a cure-all, but when it is used in conjunction with normal maintenance and other health-monitoring techniques (such as vibration analysis) it does play a large role in helping to identify degraded equipment. The major area of concern in making SOAP work, though, is the level of training of personnel who are required to take samples and provide subsequent testing and test results to the fleet.

SOAP is a discipline of naval condition-based maintenance, and must be recognized as such. And as COS MAT has so aptly stated already, if condition-based maintenance is to be implemented, then the price of training must be paid.

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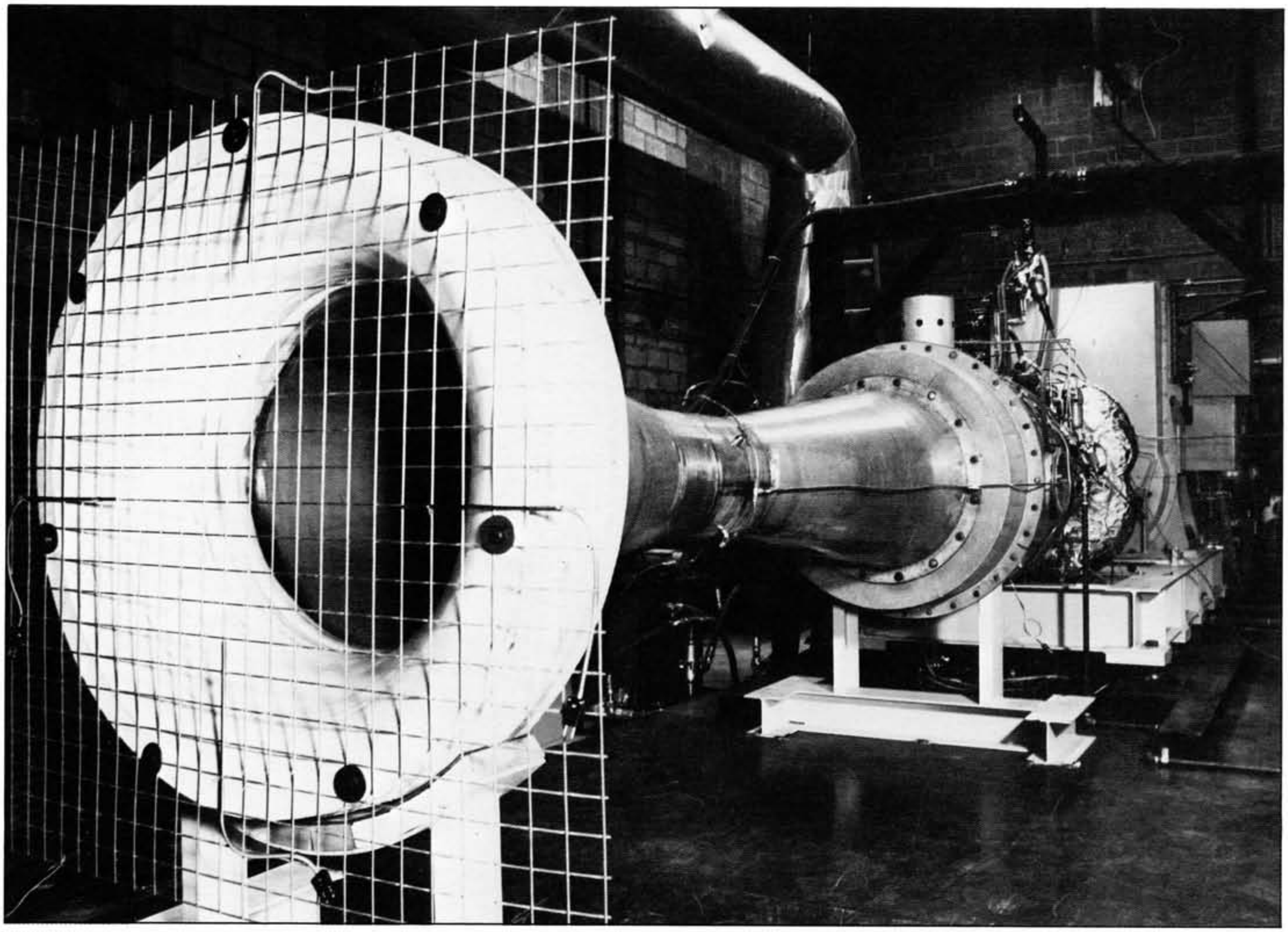

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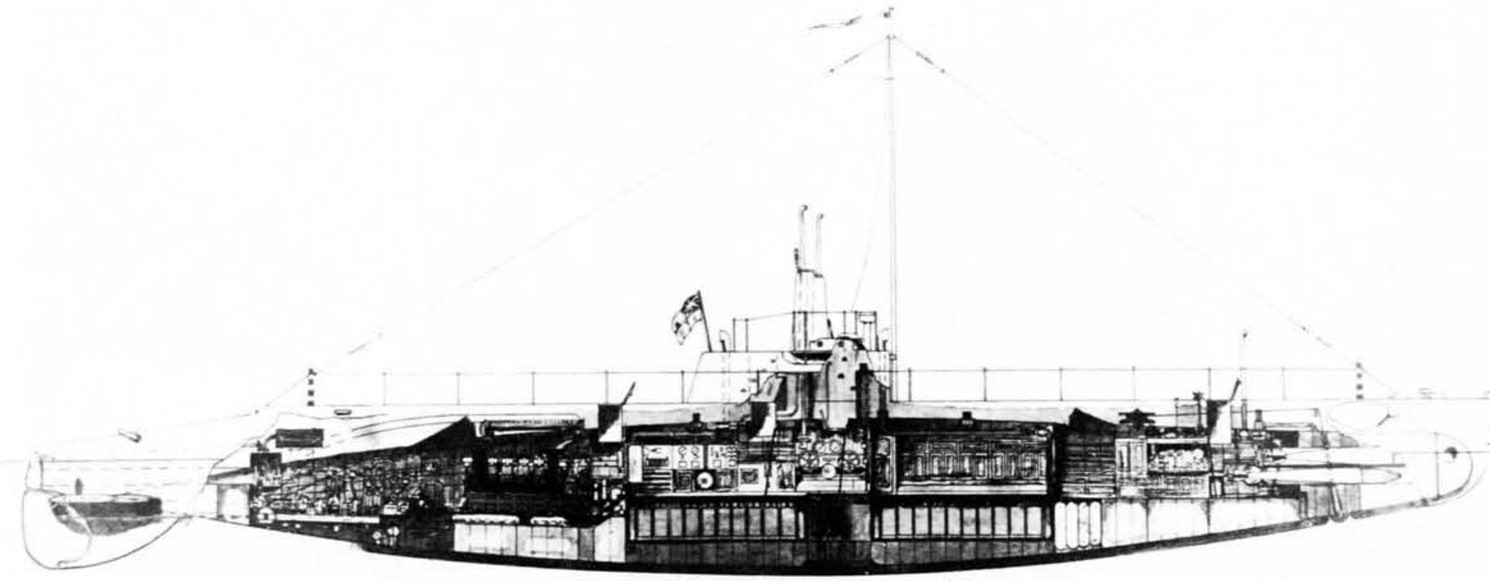

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