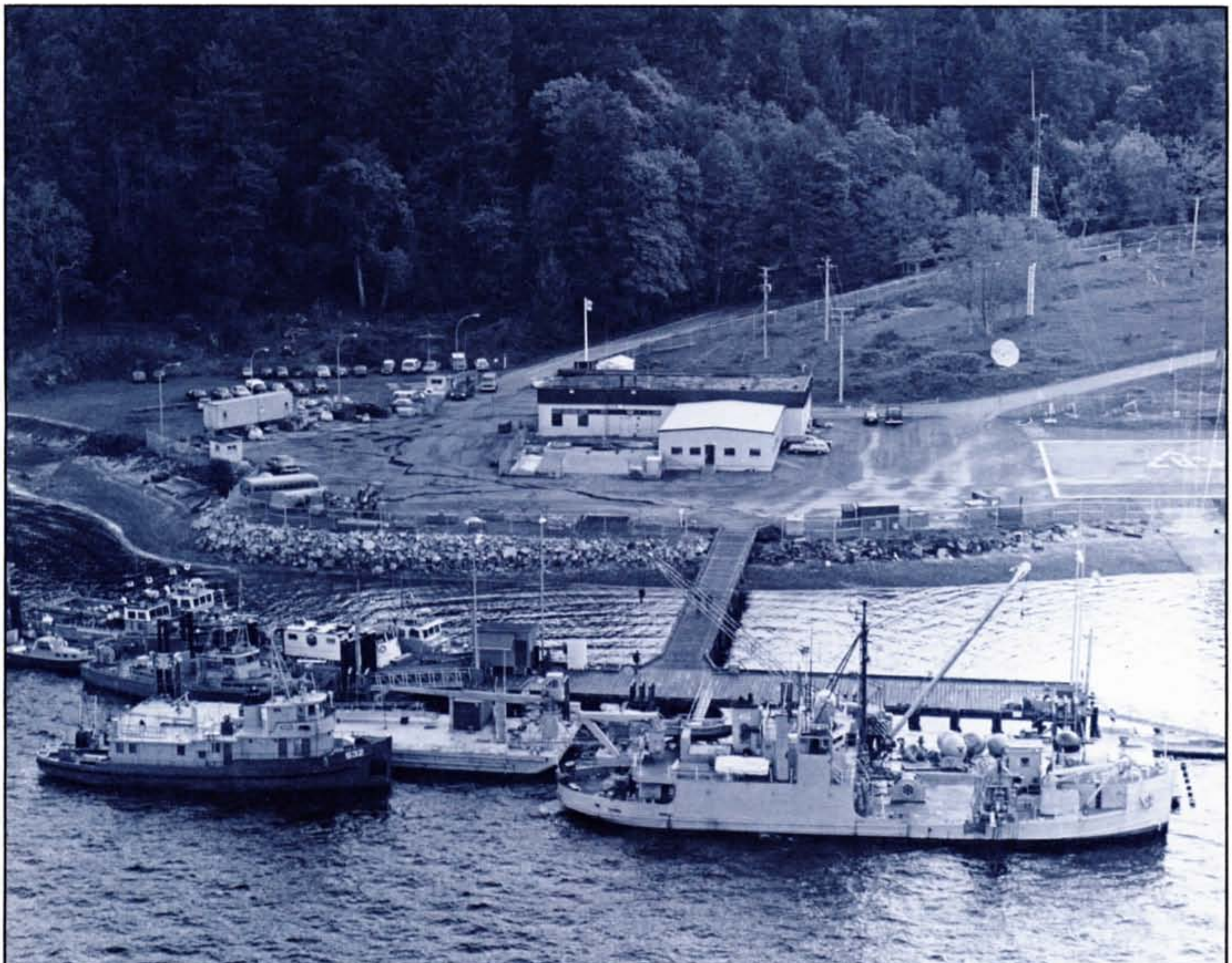
National Defence / Défense nationale

MARITIME ENGINEERING Journal du GÉNIE MARITIME



Canada

September 1986 Septembre

LCdr David Nairn poses for photos with Lt.-Gov. Lincoln Alexander after being awarded the Ontario Medal For Good Citizenship.
Profile begins on page 16

MARITIME ENGINEERING

Journal

du GÉNIE MARITIME

OUR COVER

Canadian and American range vessels alongside CFMETR's Ranch Point facility at Nanoose.

SEPTEMBER 1986

DEPARTMENTS

FEATURES

MARITIME ENGINEERING JOURNAL
ISSN 0713 - 0058

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

JOURNAL DU GÉNIE MARITIME
ISSN 0713 - 0058

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

Editor's Notes

It is a pleasure, this issue, to welcome the newly appointed Director-General of Maritime Engineering and Maintenance — Commodore D.R. Boyle. By way of introduction, we offer this biographical sketch of our new MARE Branch Adviser.

Cmdre Boyle was born 10 April, 1935 in London, Ontario where he completed his high school education and subsequently enrolled in the Royal Canadian Navy in 1953. He graduated from Royal Roads Military College in 1955. During his career, he also attended the Royal Naval Engineering College at Plymouth, England where he qualified in 1960 as a Marine Systems Engineer; the Canadian Forces Command and Staff College (1968-69); and the National Defence College (1978-79). In 1971 he obtained a BA in Economics at York University, and in 1983 completed the Continuous French Course at BFC St-Jean.

During the early part of his career he served on some dozen different warships, including the aircraft carrier HMS *Bulwark*. He has been Marine Systems Engineer Officer of HMCS *Beacon Hill* (1960-62) and HMCS *St Laurent* (1965-66). Subsequently, at NDHQ, he served as Senior Staff Officer, Naval Maintenance Management Systems, and as Director of Marine and Electrical Engineering where he participated in the formulation of the technical requirements for the CPF. From 1979 to 1982 he was Chief of Staff, Personnel and Training at Maritime Command Headquarters in Halifax.

Cmdre Boyle was promoted to his current rank on 9 May, 1983, and in August assumed the position of Director-General Recruiting, Education and Training at NDHQ. He was appointed to his current position as DGMEM on August 25th of this year.

Cmdre Boyle is a member of the Association of Professional Engineers of Ontario and the Canadian Institute of Marine Engineers.

He is married to the former Joanna E. Sweet of Plymouth, England. They have two sons who are engineering graduates of the University of Waterloo.

* * * * * *

Our lead article in this issue takes a look at DGMEM's west-coast field unit, the Canadian Forces Maritime Experimental and Test Ranges on Vancouver Island. Established in the 1960s as a sonobuoy and torpedo testing facility, CFMETR incorporates a number of test ranges, including the fully instrumented, joint CF/USN 3-D range at Nanoose. On this the 20th anniversary of CFMETR's operational beginnings, Commanding Officer LCdr Mike Dunn gives us an insight to the history, functions and controversy associated with this important facility.

And from the Naval Engineering Test Establishment (DGMEM's field unit in LaSalle, Quebec), Special Projects Engineer Bill Glew describes the installation of the Solar Saturn engine at NETE. Also in this issue, LCdr Bill Hilts and Lt(N) Dave Marecek collaborate on a discussion of life-cycle RAM and a proposal for a maritime RAM analysis programme, and the *Journal's* own production editor profiles the longest-serving MARE in the navy today — LCdr David Nairn.

And finally, with our next issue we will be conducting a readership survey to find our what you do and don't like about the *Maritime Engineering Journal*. Your comments and suggestions are always welcome, but please take the time to complete and return the questionnaire that will appear in our January issue. We need to know how we can make the *Journal* better for you.

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

Dear Editor,

I always look forward to receiving the current edition of the Maritime Engineering Journal and was pleased to receive my Jan 86 issue. What struck me immediately was the "crispness" of this issue. The format was good and the way the articles were laid out was pleasing to the eye. I thought the photographs and illustrations stood out particularly well.

The content of this issue has provided interesting reading. The articles on NETE, on passive protection and on desalination remind all of us about some fundamentals of our business. The article on RCM is most timely in light of the evolution to this philosophy of maintenance from the old planned maintenance way of doing things.

I thought that Capt(N) Reilley's retrospective "On Being a Base Commander" was most thoughtful and, indeed, even inspirational. It should be required reading for all MAREs aspiring to the job of Base Commander and should encourage MAREs to strive for this type of employment.

Please pass my compliments to your editorial staff for a job well done and ask them to keep up the good work.

Yours aye,

Commodore E. Lawder
Chief of Staff Materiel
Maritime Command Headquarters

Monsieur,

Je me suis récemment enrolé dans les Forces canadiennes et j'étudie présentement à l'Université Laval en génie mécanique au sein du programme ROTP. Je suis classifié MARE 44U.

J'aimerais que vous me fassiez parvenir les copies de tous les articles qui ont été publiés dans le Journal du Génie maritime. Toute cette documentation me serait utile comme information sur ma future carrière. Depuis mon enrolement, j'ai reçu 2 journaux et j'aimerais m'assurer d'avoir les futurs journaux qui vont paraître.

Je trouve ce journal très intéressant au point de vue technique. Félicitations pour une bonne publication.

Bien à vous,

Yves Perron, ELOF

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 $8\frac{1}{2} \times 11$ 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

The Canadian Patrol Frigate Project

An Exercise in Positivism

by Commodore J.E. Green, Project Manager

Unlike other previous naval ship projects in Canada over the last three decades, the Canadian Patrol Frigate (CPF) Project is neither being managed nor designed by National Defence personnel. A major objective of the ship-replacement programme is the transfer of these two capabilities to Canadian industry, with government personnel primarily using their expertise in a monitoring role — ensuring that both the contractor and the Government meet their respective contractual obligations.

This new role, especially for DND personnel, has imposed a philosophical shift in thinking and in attitudes. It requires us to concentrate on obtaining a positive visibility into the project while concurrently establishing and maintaining high-level interpersonal relationships with industry. The CPF Project is not just building ships, it also involves a significant support and logistical build-up with industrial participation and benefits across Canada. In this respect the CPF Project differs significantly from many other major defence procurements where off-the-shelf equipment is often acquired from foreign sources.

In selecting Saint John Shipbuilding Limited as the prime contractor, the Government has also vested in this company specifically, and in the entire Canadian shipbuilding industry indirectly, the total responsibility not only for providing six ships, but also for establishing a long-term capability to develop, manage and deliver naval ships and complex weapon systems to a potential world market. Therefore, we are in the delicate position of being unable to interfere with the process for fear of assuming the risk which accompanies the contractor's responsibility, while at the same time ensuring that the Government gets "the most bang for its bucks".

How has the Government organized itself to ensure good public relations with the prime contractor while simultaneously making it happen in the role of customer? A Project Management Office (PMO CPF) was established in National Defence Headquarters, Ottawa at the onset of the naval modernization programme. It is a tri-departmental office comprising the departments of Supply and Services (DSS), Regional Industrial Expansion (DRIE), and National Defence (DND). DSS is responsible for contract enforcement; DRIE for the achievement and distribution of industrial benefits; while we in DND are responsible for technical contract compliance, monitoring cost, schedule and risk and then finally accepting the products of the procurement.

Playing a significant role in the technological transfer to industry, and the group most heavily affected by implementation and introduction of the CPF and its related systems, is the maritime engineering (MARE) community. Traditionally, when the navy required new ships, the MARE community had the responsibility for the design of the ship, integration of its systems, technical documentation and the responsibility of overseeing ship construction. Government policy — to develop within Canadian industry the expertise to design, manage and construct sophisticated warships — has led to the navy passing on these traditional roles to industry. This does not mean to suggest that we no longer have the need to remain current in these disciplines. On the contrary, even more so, we must remain in the forefront of state-of-the-art development for all engineering disciplines associated with warship design and construction. The design and construction of a warship is, in itself, an exceedingly complex undertaking. However, the scope of the project encompasses far more than ship design and construction. It includes full logistic support, the construction of new support facilities ashore, the development of combat systems software and the provision of the requisite training and technical documentation needed to operate and maintain these ships in the years ahead.

The MARE community is directly involved, not only in monitoring the technical performance of the prime and subcontractors, but in many instances in providing advice in the fields of design, weapons and marine systems, as well as in activities related to human engineering. The MARE group has to ensure that equipment purchases are compatible and that system integration is feasible. It is still incumbent upon the entire team to deliver to Maritime Command the most operationally effective ship that can be produced. This is of paramount importance since Canadian industry has not been involved in warship construction for some years and has lost much of the expertise required, particularly so with the ever-increasing technological advances made over the last twenty years in the methods of ship design and ship construction.

The responsibility to ensure that the navy receives a ship that meets its needs does not rest solely in PMO CPF. On the contrary, the entire MARE community whether in PMO, in NDHQ or, for that matter, in Maritime Command must be involved. It is crucial that the CPF Project delivers the type of ship that will meet the operational requirements of the navy; therefore, user input is vital throughout the total process and especially during the Project Implementation Phase.

The MARE officer must be cognizant of, and sensitive to, the need to keep a positive approach and to maintain a professional type of relationship with his industrial counterparts. With industry having total system responsibility for all aspects of the CPF Project, we now become the engineering managers, the evaluators, the reviewers and the overseers to ensure that the final product meets the navy's requirements. Only with this maritime engineering involvement will the rationalizations reached, and the decisions rendered, ensure that Maritime Command gets the ship it needs. As professionals our task is clear.

Commodore Green specialized in Maritime Engineering training at the Royal Navy Engineering College in Plymouth, England. Prior to his appointment as CPF Project Manager in July 1984, he commanded Ship Repair Unit (Atlantic) in Halifax. Commodore Green attended National Defence College in August 1980.

Canadian Forces Maritime Experimental and Test Ranges

by LCdr M. Dunn, Commanding Officer

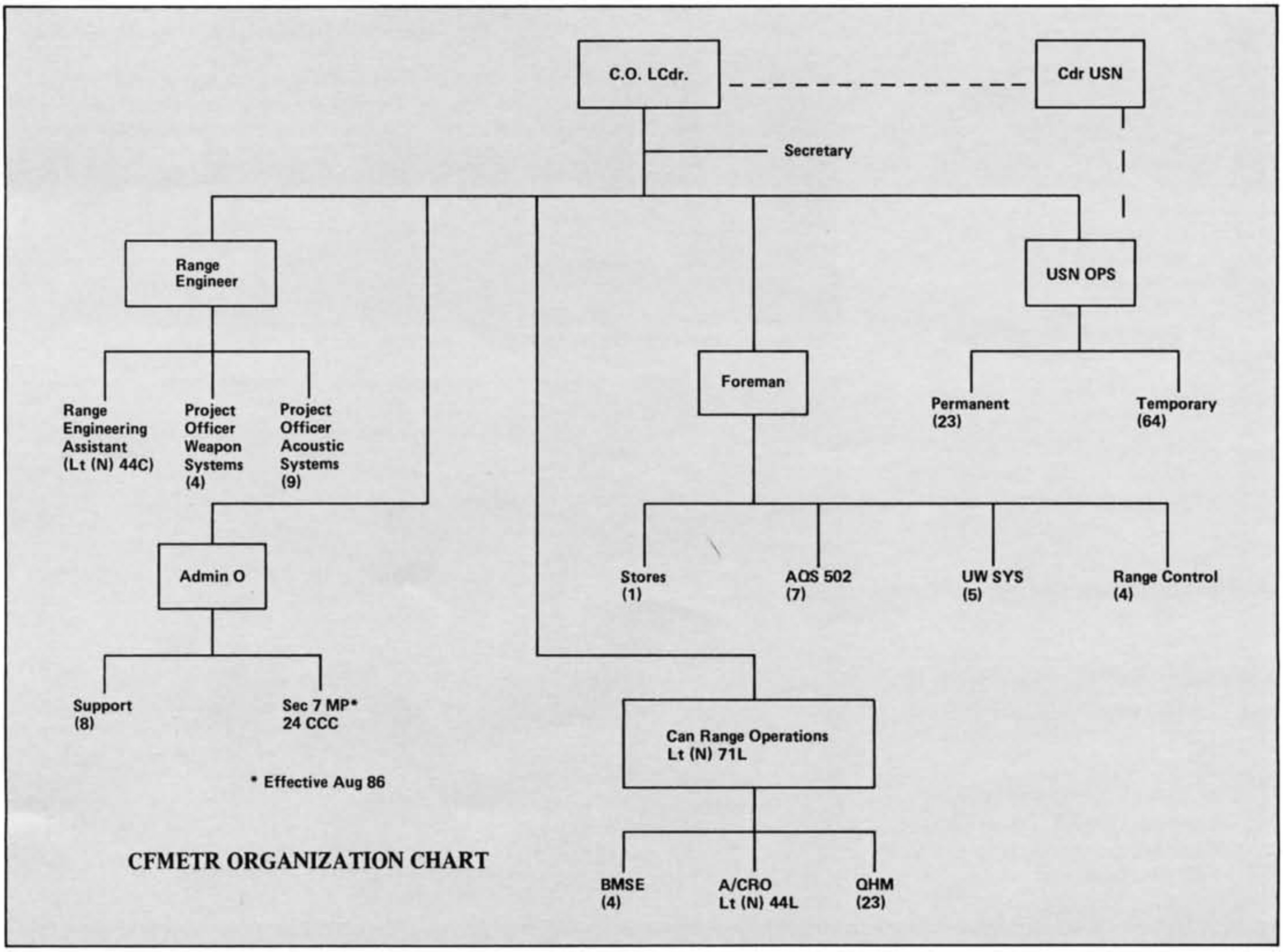
Introduction

The Canadian Forces have operated a torpedo test range continuously since 1953 when the first range was established in Patricia Bay, just north of Victoria, B.C. The Pat Bay range afforded a sheltered but confined operation area, and as torpedoes became more sophisticated Canada was faced with the problem of finding suitable waters in which these torpedos could be run and tested to their design limits.

The United States Navy found itself in a similar predicament. Their own ranges at Dabob Bay and Hood Canal in Washington State were too confined to handle the greater operating depths, running times and acquisition ranges of the newer torpedoes.

An area in the Strait of Georgia adjacent to Nanoose Harbour seemed ideally suited for such activities, and was of special interest to the USN as it met most of their additional requirements for the operation of a fully instrumented 3-D tracking range. In 1962 a temporary installation was established on Ballenas Island. The initial survey and evaluation of the range verified the usefulness of the Nanoose Range.

The use of this area by both the Canadian Forces and the USN became the subject of diplomatic discussions which culminated with the signing of an international agreement. The agreement, signed on May 12, 1965, established the Nanoose 3-Dimensional Range which became operational early in 1966. The agreement entered into force for a ten-year period, with continuation in force thereafter until terminated by mutual consent. It was revised and signed for a second ten-year period in 1976, and was renewed again in June of this year for a third ten-year period.



CFMETR ORGANIZATION CHART

Canadian Forces Maritime Experimental and Test Ranges is a field unit of NDHQ's Material Group, and its OPI is the Resources Management section of DGMEM (DGMEM/RM). As a field unit of NDHQ, CFMETR is not self-accounting, and therefore all support services are provided by the Commander of Maritime Forces Pacific, and CFB Esquimalt.

The functions of CFMETR are:

a. operation and maintenance of the Nanoose 3-Dimensional Range;
b. Conducting and analyzing Canadian ship-system trials on the range;
c. Conducting Canadian torpedo trials on the range, and analyzing all Canadian exercise torpedo firings;
d. Canadian sonobuoy proofing and testing; and
e. AN/AQS-502 airborne sonar repair and overhaul.

The Nanoose 3-D Range

The Nanoose 3-D Range is located in the Strait of Georgia, immediately adjacent to the Winchelsea and Ballenas Islands near Nanoose Harbour. Its position 80 miles north of Esquimalt and 130 miles northwest of Keyport, Washington gives it the advantage of being in reasonable proximity to Canadian and American operational and support facilities. These facilities include, for Canada: CFB Esquimalt, HMC Dockyard, CFAD Rocky Point, and CFB Comox; and, for the United States: Naval Undersea Warfare Engineering Station (NUWES) Keyport, Bremerton Shipyard, and Naval Air Station Whidbey Island.

By the terms of the joint agreement, Canada is responsible for the:

a. construction and maintenance of all fixed facilities (including buildings, roads, jetties, power, water, etc.);
b. provision of technicians and personnel to operate the facilities;
c. provision of range vessels and crews; and
d. administration, security, and operational control of the Nanoose 3-D Range.

The United States is responsible for the:

a. supply, installation, and maintenance of all technical equipment for operating the 3-D range;
b. provision of technical personnel;
c. provision of all technical training for range personnel, both Canadian and American; and
d. provision of range vessels and crews.

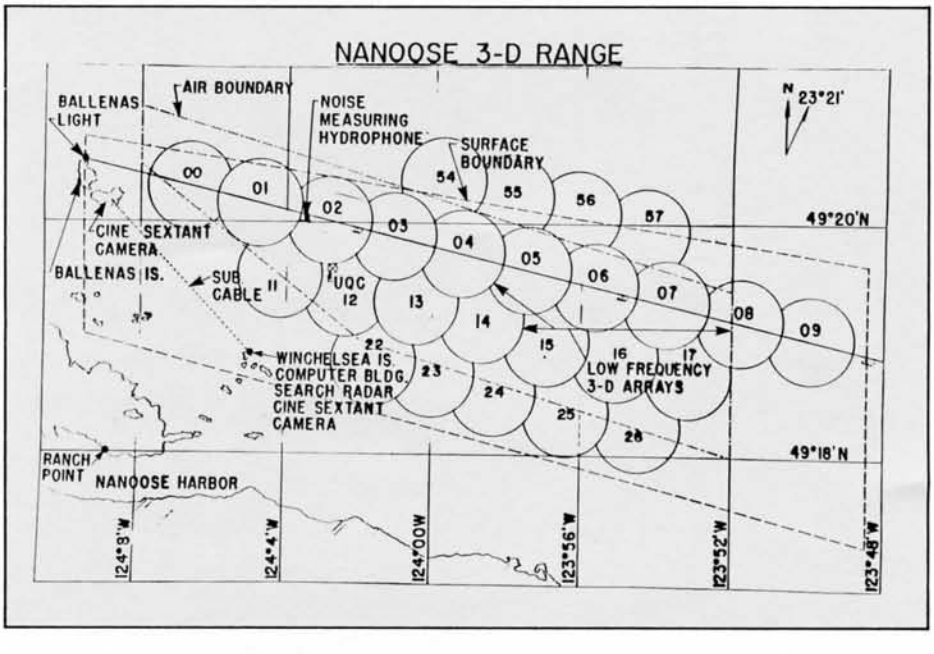
The available operating time on the 3-D range is allotted equally between Canada and the United States. Canada, historically, has not used all of its allotted share of range time. The USN may utilize available range time in excess of its share in return for financial recompense.

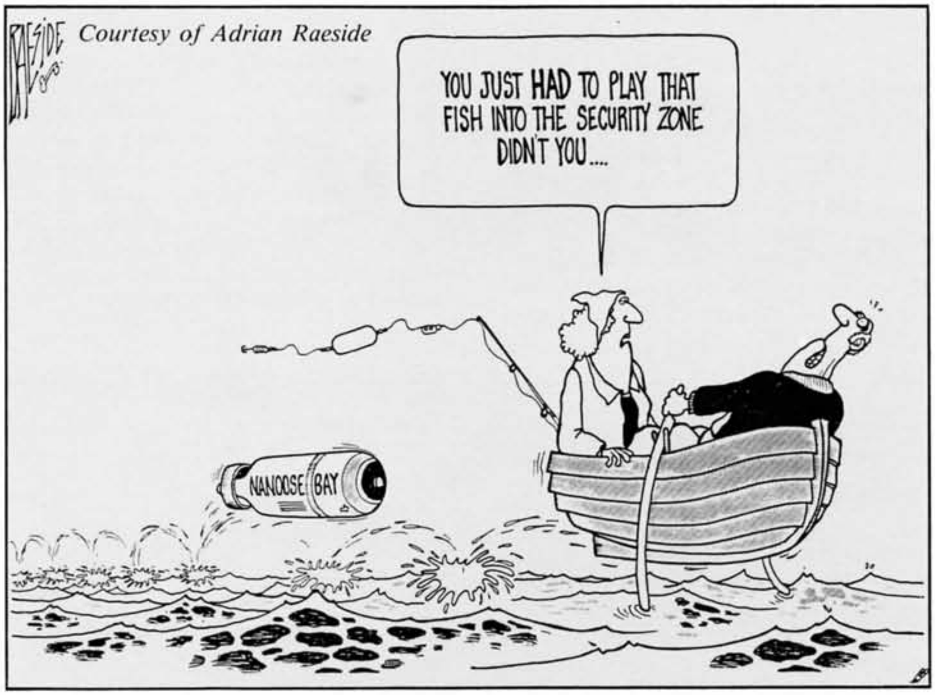
The range covers an effective area 15 miles long and varies in width from two to five miles, giving a total instrumented area in excess of 50 square miles. This instrumented area is contained in a large, mud-bottom trough extending south-east from the Ballenas Islands towards the Fraser River Delta, providing water depths of 1,000 to 1,480 feet.

Specially-instrumented objects may be tracked in three dimensions throughout the instrumented portion of the range. Tracking is implemented through the use of a complex system of transducers, receivers and computers. Evenly spaced about the seabed under the range are 24 arrays, each holding four hydrophones. Acoustic pulses from the object being tracked are received by this bottom-mounted array, amplified, multiplexed, and relayed to the computer site. The computer analyzes this information and displays the tracks of torpedoes, submarines, surface ships, aircraft and mobile targets for test control, and stores the data for post-run detailed analysis.

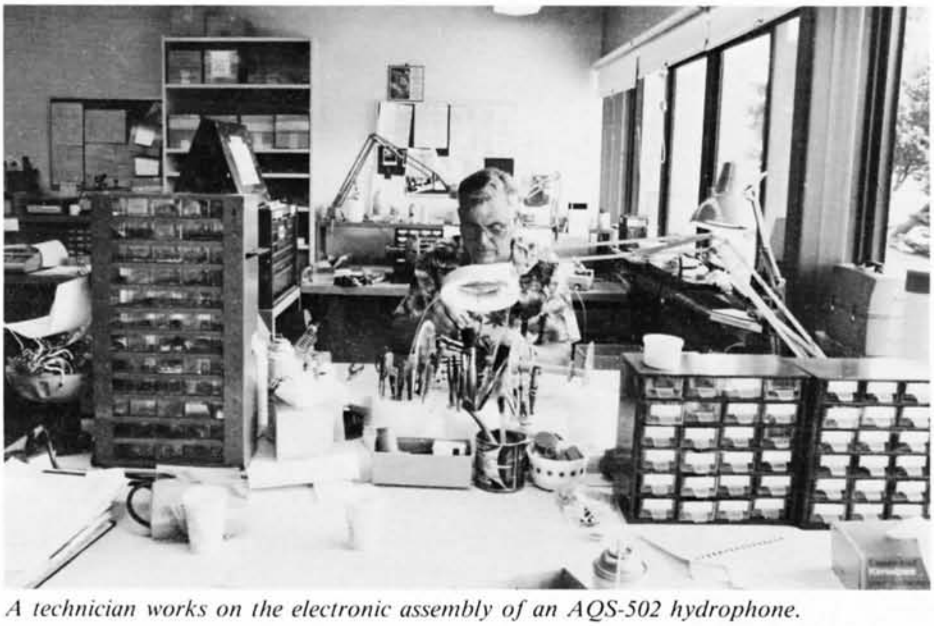
Interruptions from commercial and pleasure boaters straying onto the range have been somewhat of a problem, but fortunately the frequency of these intrusions is declining due to a greater aware-

The cine-sextant optical tracking system on Winchelsea Island.






The sonobuoy test-control room.


A technician works on the electronic assembly of an AQS-502 hydrophone.

ness on the part of all concerned. In this regard, a briefing presented by Lt(N) Ray Smith to the various power squadrons and yacht clubs throughout the Pacific Northwest has been invaluable.

Sonobuoy Testing

CFMETR is tasked by DGMEM/RM (for DMAEM) to conduct all sample proofing, testing and evaluation of sonobuoys procured for the Canadian Forces and (occasionally) foreign governments. Testing can be conducted in any one of four areas: Nanoose Bay, the Nanoose 3-D Range, Jervis Inlet, or Hotham Sound. The last two areas are approximately 45 miles north of CFMETR, and although they are not instrumented they are well sheltered and provide for quiet, deep-water testing (the average depth of water being some 2,400 feet).

Operations in the isolated areas are increasing in frequency and, in 1986, are expected to last from 10 to 12 weeks. The headquarters for these tests (run for the Naval Avionics Center of Indianapolis) are located in a converted barge that is towed from Vancouver and moored for the duration of the testing. Control of the operation is vested in a Canadian Range Officer, usually a sub-lieutenant, who reports to CFMETR each morning.

The proofing and testing of sonobuoys in Nanoose Bay and on the 3-D Range are concerned with the units manufactured by Sparton of London, Ont. and Hermes of Dartmouth, N.S. In a typical test a sample of 34 sonobuoys is selected from each 1,000 production lot by a DND representative and shipped to CFMETR. From this sample, 32 are air-launched from a civilian-operated, locally contracted Beaver aircraft, and the remaining two are kept as spares. Performance is monitored by the shore-based facility and the laboratory vessel *Nimpkish*, and all drops are video-taped for trajectory and drop analysis.

Thanks to the extensive work done on the range, Canada has become a world leader in sonobuoy testing.

AN/AQS-502 Repair and Overhaul

CFMETR is also the repair and overhaul facility for the hydrophones and projectors of the AN/AQS-502 helicopter-borne sonar used by the CF Sea King squadrons. This involvement dates back to 1972 with the first in-house overhaul of the AQS-13, the predecessor to the AQS-502. The development and evaluation of modifications to this equipment also take place here.

Today's R & O facility consists of an acoustic test barge and a large work-shop area where a charge-hand and six workers perform all electronic and mechanical repairs. This facility has been instrumental in the development and evaluation of modifications that have enhanced the operation of the AQS-502. The operation is geared to support an annual workload of 60 hydrophones and 20 projectors.

CFMETR's broad experience in the specialized field of underwater acoustics, and its year-round, protected-ocean test facility make it ideally suited for this type of work.

Summation

This short article was written in order to familiarize readers with the functinos of CFMETR. It is hoped that the intent has been satisfied.

LCdr Dunn joined the RCN in 1956 as a stoker, but transferred soon afterwards to the Electrical Branch. Prior to receiving his commission in 1974 he served in HMC Ships Sussexvale, Athabaskan, Fraser, St Laurent *and* St Croix, *and in the submarines* Grilse *and* Rainbow. *Since 1974 he has served as the Combat Systems Engineer in* Gatineau, *as the CS Repair Officer at FMG(P) and the Sonar and Underwater Weapons Officer at NEUP. He also served three years as the Combat Systems Training Officer at the Naval Officer Training Centre before assuming command of CFMETR in 1985.*

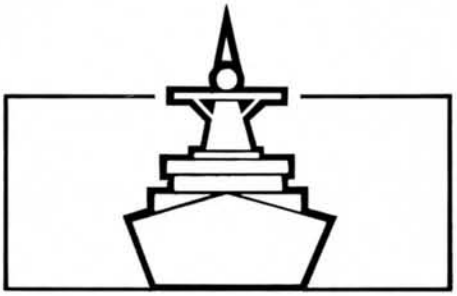
Other Activities

Since April 1985 there has been a continuous campaign to close the test-range facility and convert it to "peaceful purposes". The campaign, which at times has spread country-wide, is organized by a protest group calling itself the Nanoose Conversion Campaign.

The stated aims of the Campaign are to halt USN usage of the range and terminate the international agreement. As well, the Campaign is calling for a public inquiry into the range and for government funding to establish alternate usage for it.

The Campaign has established what is locally referred to as a "teepee town" on the shoreline across the bay from CFMETR. Repesentatives from all 28 protest groups on Vancouver Island, and from groups in Vancouver, Manitoba and California now occupy the three Indian-style teepees on a permanent basis.

The local population is generally sympathetic to the Campaign and will participate in the demonstrations. The sympathy, it is felt, is due in most part to an ignorance of the issues involved. To rectify this situation, CFMETR's commanding officer and administration officer attended the Deterrence, Arms Control and Disarmament seminar given by DG Info. Since then they have been meeting with local community groups in order to brief them on the facts of the current world situation. The response by groups such as the various Chambers of Commerce has been gratifying.



Reliability, Availability and Maintainability: *RAM for the Canadian Navy*

by LCdr William Hilts and Lt(N) Dave Marecek

Introduction

The new naval maintenance policy that was promulgated by the Director-General of Maritime Engineering and Maintenance (DGMEM) on 26 July, 1984 stated that the requirements for preventive maintenance would be determined by using the techniques and procedures of reliability centred maintenance. The following elements of reliability centred maintenance were identified in the policy statement and are included in the naval maintenance policy implementation plan:

a. RCM training for life-cycle material managers and fleet-support units;

b. briefings to explain RCM to fleet maintenance personnel;

c. *Reliability, Availability, Maintainability (RAM) analysis of equipment and systems in support of LCMM RCM decisions;*

d. Equipment Health Monitoring (EHM) programmes to support RCM;

e. Maintenance Management Information System (MMIS) enhancement to provide feedback to LCMMs; and

f. The application of condition-based maintenance as a guide to the maintainer to indicate when to perform preventive maintenance.

The following quote from the policy statement summarizes the requirement for RAM analysis:

"The rapidly rising maintenance costs of Naval Weapon Systems (which comprise ships and integral systems) in recent years has emphasized the requirement to ensure optimum benefit is realized from the total maintenance effort being applied. Equally important, is the requirement to ensure availability goals set by the operational commanders for these systems are attained. Naval Maintenance Policy is therefore predicated on the achievement of a balance between the resources available (personnel, material and financial) and the degree of operational availability required."

Reliability, Availability, and Maintainability (RAM) analysis uses maintenance and operational data to identify:

a. the maintenance resources expended to meet the operational requirements;

b. whether the operational requirements were in fact met, and

c. if the system is meeting its RAM design criteria.

Aim

It is the purpose of this paper to introduce reliability, availability and maintainability throughout the four phases of a system's life cycle, and to propose the requirements for a maritime RAM analysis programme in support of life-cycle material managers and the naval maintenance policy. In addition, by identifying the various components and methodologies of RAM analysis, the linkages between reliability centred maintenance and a maintenance-management information system will be identified.

Background

In July 1960 the United States Navy developed its first set of reliability requirements for shipboard electronic equipment, and in 1961 established procedures for the prediction and reporting of the reliability of naval weapon systems. The ARINC Research Corporation also started developing, refining, and implementing approaches to analyzing USN maintenance data to identify improvements in ship reliability and maintainability. At the same time, the American airlines were working on reliability centred maintenance RAM analysis and condition-based maintenance. The United States Navy adopted RCM and RAM for its aircraft fleet in the early 1970s, and in 1978 applied RCM/RAM to a surface ship.

In the late 1970s the Canadian navy started following the USN RCM and RAM developments, and in 1980 DGMEM (through the Director of Maritime Engineering Support) established the Shipboard Machinery Performance Test (SHMaPTs) programme to study the effectiveness of condition-based maintenance on four equipment items of the ISL-class destroyers. The SHMaPTs programme identified 80% of the unsatisfactory conditions with an 88% confidence using equipment health monitoring techniques, thus establishing that condition-based maintenance could be an effective maintenance concept for the navy.

Part I: RAM and System Life-Cycle Management

All systems pass through four major phases from the time of their creation to the time of their disposal. RAM analysis is a tool that is used throughout the life-cycle phases:

a. to ensure systems meet the operational specifications in the design phase;

b. to ensure they meet the RAM design criteria in the acquisition phase;

c. to ensure they meet the operational requirements in the in-service phase; and

d. to identify the life-cycle RAM data in the disposal phase.

RAM in the Design Phase

Reliability and maintainability are design parameters and, thus, during the design phase, RAM analysis is used to: minimize the incidence of failure, simplify maintenance, and meet operational requirements with a reduced dollar investment to support the system during the in-service phase.

Reliability and maintainability data are input to logistic support analysis in the design phase. LSA is a process by which the logistics support necessary for a new system is identified. It includes the determination and establishment of logistic support design constraints (including RAM criteria), consideration of those constraints in the design, and analysis of the design to validate the logistic feasibility of the design and identify the logistic resources required to support the system.

The major LSA activities consist of:

- Functional Failure Analysis (FFA)
- Failure Modes, Effects and Criticality Analysis (FMECA)
- Reliability Centred Maintenance Analysis (RCMA)
- Maintenance Task Analysis (MTA)
- Level of Repair Analysis (LORA)
- Sparing Analysis
- Life-Cycle Costing (LCC)
- Value Engineering

The LSA activities are linked together (see *Fig. 1*) with the RAM data being a starting point. At each step of the process essential data is withdrawn and consolidated into a Logistic Support Analysis Record (LSAR) that describes the system and its support, including the maintenance for the life cycle. Of note in the LSAR is the original RAM design criteria, including the system inherent availability to which acquisition and in-service RAM data can be compared.

The requirement for reliability and maintainability in this phase flows chiefly from the intended conditions of use for a system, and from user expectations of availability in the presence of their intended conditions. The mission profile, environmental profile, and availability targets will define the R&M requirements. While inherent reliability is a function of design, the achieved reliability is dependent upon system usage. Maintainability is therefore reliant upon human engineering consideration during design, and upon available logistics resources during the in-service stage.

The reliability specifications are the first step. They must contain the quantitative goal of the system under stated conditions and the method of determining if the RAM goals have been met. Operational requirements are then stated at the system level, and R&M parameters are allocated to the individual components in a top-down breakdown structure. At this point the RAM design curves are established from the individual component reliabilities. The design is sufficiently fluid that the reliability of the system can be increased by identifying components with low MTBFs and replacing them with more reliable components. Also, the design can be simplified, thus decreasing the MTTR, resulting in a higher availability that meets the operational specifications. Next, R&M prediction, using a bottom-up structure where each component has an individual R&M specification, is used to define a system R&M specification. At this point, the RAM specifications are inserted into the LSA process described previously. The system is broken down into units by functional failures, and then a Failure Modes and Effects Criticality Analysis is completed on each unit, identifying the units with low reliabilities.

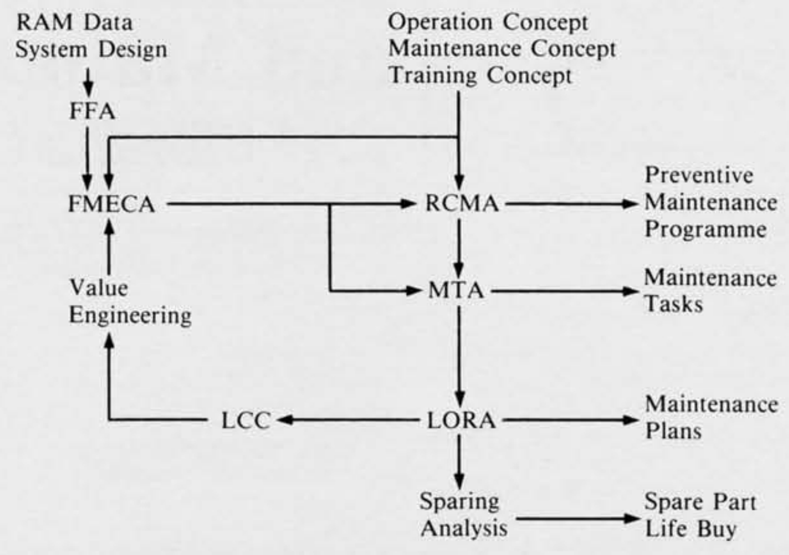


Figure 1. The Logistic Support Analysis Process

These concepts form the R&M programme for systems during the development and acquisition phases.

RAM in the Acquisition Phase

Once the inherent availability of a system has been established in the design phase, the emphasis of RAM during the acquisition phase can be placed on testing the system for conformity to the original statement of requirements.

The acquisition phase revolves around translating the elements of integrated logistics support into actual support requirements. ILS ensures that a system can be supported effectively and economically so as to conform to specified operational performance requirements within the resources of available personnel, logistic support and maintenance throughout the life cycle. It is composed of the LSA elements, configuration management, publications management and performance monitoring. The acceptance testing and RAM analysis of this phase are part of the performance monitoring.

Five qualification tests may be conducted during this phase which will lead to the acceptance or non-acceptance of a system:

a. *Environmental Stress Screening* identifies early failures due to weak parts, workmanship defects, and other nonconforming anomalies to allow their removal from a system;

b. *Reliability Development/Growth Testing* uses pre-qualification testing to identify reliability problems, allowing corrective action to be taken prior to the start of production;

c. *Reliability Qualification Testing* determines if the specified reliability requirements have been met;

d. *Production Reliability Acceptance Testing* assures that the reliability of the hardware has not been degraded as a result of changes in the production line; and

e. *Maintainability Testing* provides verification, demonstration, and evaluation of qualitative and quantitative maintainability requirements. It also provides for qualitative assessment of various ILS factors relating to maintainability parameters and item down-time.

The reliability and maintainability testing occurs at three distinct levels — part, equipment and system. When specifying tests, the prediction techniques, type of test, field environment and type of failure must be defined so that the results of the RAM analysis will not be open to question. Once a system has been accepted in this phase the system reliability and maintainability are fixed, and the system will enter the in-service phase.

RAM in the In-Service Phase

The inherent availability is now fixed as the R&M characteristics have been designed into the system and proven in the acquisition phase. The major RAM

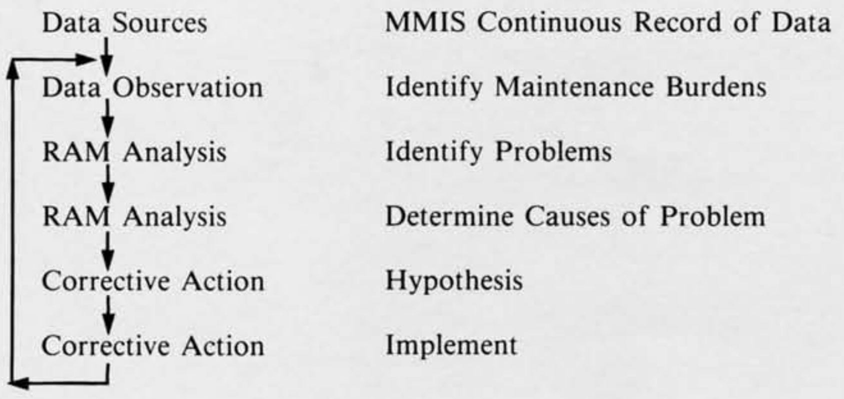


Figure 2. The RAM Analysis Programme

task during the in-service phase, then, becomes one of failure monitoring.

RAM data is collected during the in-service phase primarily for the following reasons:

a. to identify variations from the predicted RAM criteria of the Logistic Support Analysis Record and to alter the logistics support accordingly;
b. to carry out trend analysis and to determine the cause of any failure;
c. to initiate corrective action through new procedures, modifications, or redesign of the system;
d. to establish data banks on in-service systems which can be used to assist in the design and decision-making process for future systems using RAM data; and
e. to provide RAM data to support component life and rationalization procedures.

(The data collection and RAM data banks, RAM analysis, and RAM corrective action procedures will be discussed in detail later as the basis for a proposed maritime RAM analysis programme.)

Throughout this phase the failure rates are plotted on the life-cycle curve, and if they start to increase, then the remaining usable life of the system may be in question.

RAM in the Disposal Phase

Disposal may result when a system becomes unsupportable due to increasing failure rates or rising support costs, or when it becomes obsolete or unable to meet its operational role. RAM analysis is completed during this phase to establish the final RAM values attained over the system life cycle. This information becomes useful during the design and acquisition of future systems with the same operational function, thus bringing the RAM process through a full circle to the design of a new system.

Part II: A Proposed Maritime RAM Analysis Programme

The naval maintenance policy RAM requirements are centred around the design and in-service phases of naval systems. But since the design phase of new systems, specifically the logistics support analysis, is being produced by industry, the remainder of this paper will be devoted to a proposed maritime RAM analysis programme in support of life-cycle material managers for the in-service phase of systems.

The effects of current ship-maintenance practices are manifested in the conditions of equipment, the frequency and severity of failures, the availability of equipment and the corrective maintenance burden. These effects can be examined, and in some cases measured, through the analysis of recorded data — analysis which can lead to the solution of problems. The process is demonstrated in *Fig. 2*, where all available data sources are used to identify the maintenance resources being used, as well as the maintenance problems and their possible causes. Hypotheses can then be formulated so that solutions to the problems can be developed. The same data sources can be reviewed after the solutions have been implemented so that the effectiveness of the solutions can be evaluated.

The proposed maritime RAM programme is divided into three separate sections: the *RAM data base, RAM analysis*, and *RAM corrective action*. It should be noted that all of these processes are management tools that have been developed and implemented for LCMMs. The RAM evaluation of a system assists the LCMM in the maintenance management of the system by identifying whether or not it is meeting its operational requirements and original design criteria, and the amount of maintenance resources being expended to support it.

The following sections will be presented in the above order, as it is the logical process of RAM analysis. Additionally, the resources required to establish a comprehensive maritime RAM capability will be discussed.

The RAM Data Base

The purpose of a maintenance-management information system (MMIS) is to collect data which provide ongoing system information that is used to analyze, evaluate and assess:

a. the performance and effectiveness of the system;
b. the maintenance and logistic support of the system;
c. the reliability and maintainability of the system;
d. the system's manpower requirements; and
e. the life-cycle cost of the system.

This in turn requires that an information system be capable of providing specific data at any time to the individual, thus supporting the requirements for an automated system. Since the status of a system is always changing throughout its life, an information system must continuously reflect the changes and grow with the system.

To have an effective RAM programme, certain first-line data from the ships must be recorded and updated continuously. The majority of the data is currently recorded on the CF1304 Maintenance Action Form, but the specific data required from the fleet for RAM analysis is as follows:

Type of unit
Serial Number
Part Number
Modification Number
Type of Installation
How Failure was Found
Description of Failure
Failure Effect on Mission
Time of Failure
Operating Hours
Standby Hours
Preventive Maintenance Time
Corrective Repair Time
Parts Replaced

Additional data that is required for RAM analysis must be collected from second- and third-line units. The data to be collected can be grouped by the organization that must supply the data as shown in *Figure 3*.

Once all of the data has been submitted, an automated information system must be available to accept, process, and transmit the data to the user. Currently the Shipboard Maintenance Management Information System (SMMIS) controls the data flow. However, with the increase in data input, data input locations, processing, and output locations required for RAM analysis, a comprehensive maintenance-management information system must be developed.

The data flow diagram *(Fig. 4)* is a summary of the data requirements listed in the previous paragraph, and could be used as a starting point for the development of an automated RAM maintenance-management information system for the navy.

With a data system established, the data sources must be analyzed as to their structure. The RAM analyst must understand the reporting policies and actual practices, how the data is processed by the ADP system, and how the data is maintained. Any anomalies within the data base would render a RAM analysis useless.

Thus, a RAM maintenance-management information system is the first step in establishing a maritime RAM analysis capability that would support LCMMs with useful management data on their systems, and assist them in identifying systems that do not meet the operational requirements or original design specifications. The RAM MMIS data base would require a minimum of three years of data input before there would be an adequate sample such that inferences drawn from the RAM analysis could be considered valid.

FMG	Standard CF1304 data (as listed for the first line)	**NETE**	Performance test results
NEU	Trials data and performance test results Unsatisfactory Condition Reports Class equipment health monitoring trends	**MARCOM**	Operational data reports CASREPS Ship-mission profiles Operational availability requirements Technical readiness inspections
SRU	Standard CF1304 data (as listed above) Refit data Performance test data Strip-down reports	**LCMMs**	System RAM design criteria (LSAR) System engineering criteria
Contractor	(Refits and Third-Line R&O) Refit failure data Parts usage Strip-down reports Performance tests	**CFSS**	Immediate Operational Requests Pre-Installation Failure Reports Part usage
CFTSD	Kalamazoo data Trial results Performance test results	**GIDEP**	(Government Industrial Data Exchange Program) RAM data and failures

Figure 3. RAM Data Supplied by the Organization

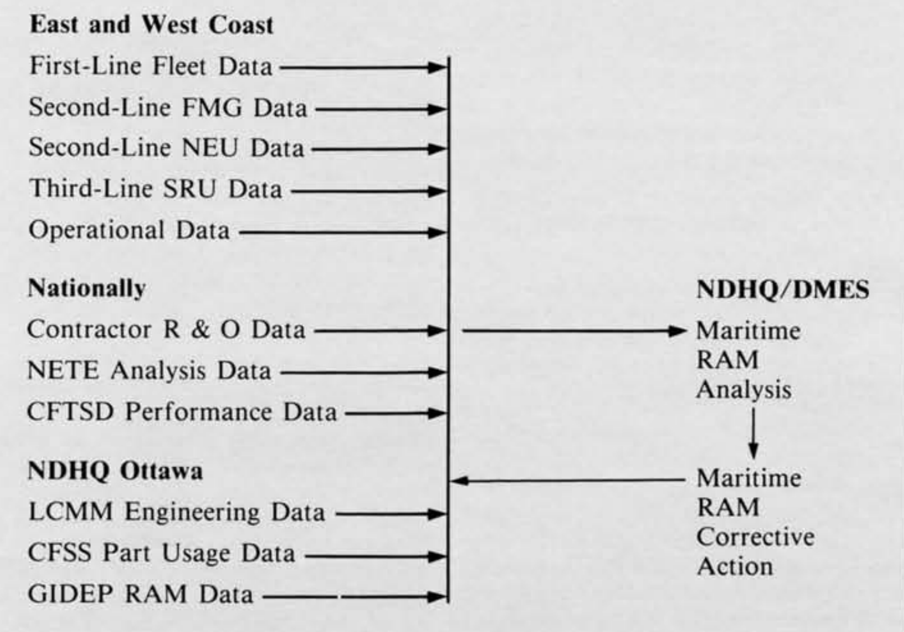


Figure 4. RAM Data-Flow Diagram

RAM Analysis

The purpose of RAM analysis is to review the fleet maintenance and operational data, and to identify equipment or systems that:

a. are not performing satisfactorily for the duration of their mission;

b. are not performing their missions when called upon to do so; and

c. are not meeting the design performance criteria.

The above criteria can also be referred to as performance measures of mission reliability, operational availability and design capability respectively. These performance measures form the triad that defines system effectiveness, the measure of how well a system performs in its intended function in its intended operating environment. The concepts and internal workings of system effectiveness are very intricate and will not be discussed, however, the analytical process of evaluating the data will be described.

The in-depth analysis begins with the compilation of all data and information relevant to the maintenance history and operation of the system being analyzed. If a ship is under analysis, the equipment or systems that are critical to the mission must be identified. Then, all of the data is analyzed to establish which systems, equipment or parts are the major contributors to the overall corrective maintenance burden as defined by corrective maintenance man-hours, overhaul frequency, parts usage frequency and CASREP experience. These items are then subjected to further in-depth analysis.

Equipment problems are identified by using the various data sources to cal-

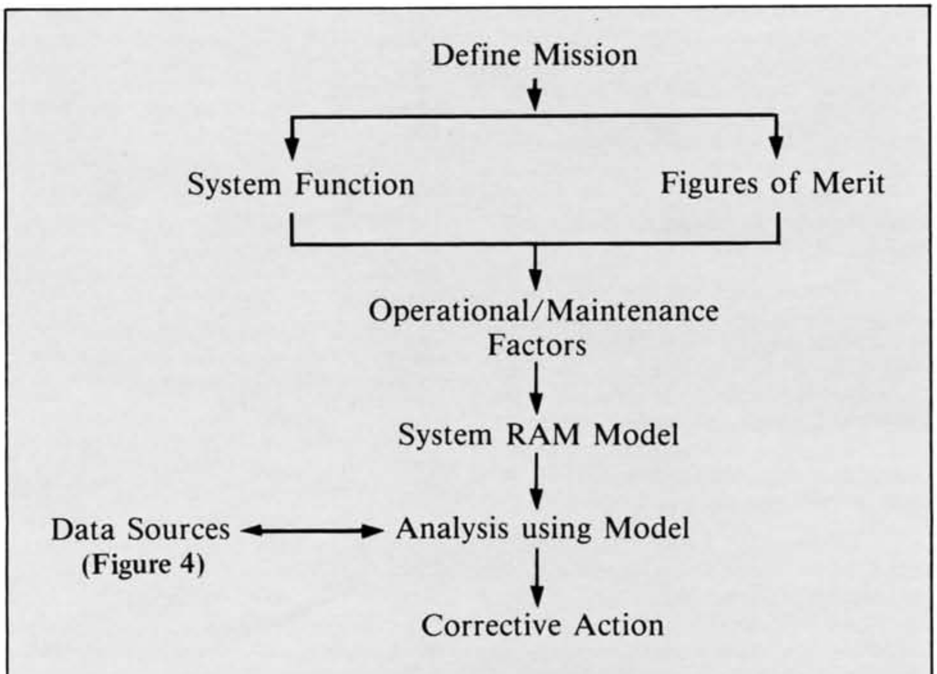


Figure 5. RAM Analysis Model

culate figures of merit that indicate the relative magnitude of the maintenance for the equipment, and to evaluate maintenance trends. Typical figures of merit for the fleet/ships/systems/equipment items are as follows:

Maintenance man-hours per operating period
Maintenance actions per operating period
Mean Time Between Failures (MTBF)
Mean Time To Repair (MTTR)
CASREP frequency
Overhaul frequency
Inherent availability
Parts replaced ratio to total parts
Parts cost per maintenance action
Maintenance frequency

It must be noted that the figures of merit are treated only as indicators in the analysis process, as to do otherwise would assume completeness and total accuracy of the maintenance data sources.

To identify maintenance problems, trends must be developed for such typical maintenance-data elements as:

Maintenance man-hours
Maintenance actions
Deferred maintenance actions
Condition-based maintenance actions
Parts cost

Analysis of these trends identifies problems associated with operation, maintenance periods, planned maintenance, and design faults. This analysis is intended primarily for the LCMMs of the equipment.

To identify if the operational requirements are being met, the trends can be analyzed to give mean values of the various figures of merit from which the analysis of operational availability can begin. A model must be developed to describe how the system is connected to the operational mission of the platform. This again involves system effectiveness, as the model takes into account the various system effectiveness, as the model takes into account the various mission objectives, profiles, and environments. There are no models developed for the Canadian navy, but the general model shown in Figure 5 is applicable.

A large proportion of RAM analysis involves mathematical manipulations and, thus, the analyst must have a firm understanding of statistical concepts. It is for this reason that RAM analysis must be completed by a cell of personnel who are trained in statistical concepts. The maintenance managers should understand the concepts behind the analysis, but would not be involved in the mathematical calculations.

Once a problem has been identified, a study of the system is initiated between the RAM analyst and the LCMM. Specifically, the Functional Failure Analysis and the Failure Modes, Effects and Criticality Analysis are reviewed to identify which components of the system are causing the problem. Additionally, all documents related to the equipment must be reviewed, and fleet personnel must be interviewed to determine operating practices and environmental considerations. This in turn will lead to reasonable conclusions regarding the causes of identified problems, and when the entire process is completed solutions must be developed.

RAM Corrective Action

The purpose of RAM corrective action is for the LCMM and RAM analyst to hypothesize and implement solutions to the problems identified in the RAM analysis. Moreover, at this point, senior management can identify the priority of the problem and develop a long-term solution.

Hypothesized solutions are developed by examining answers to the following questions:

a. Is the problem known to the naval community, and has a solution already been proposed?
b. Will a design change reduce or eliminate the problem?
c. Is the problem related to the preventive-maintenance plan?
d. Can the problem be reduced or eliminated by Integrated Logistics Support (ILS) improvements?
e. Can the problem be eliminated by increasing personnel resources?
f. Can the problem be reduced or eliminated by periodic restorative maintenance?
g. Is a run-to-failure concept viable?

An affirmative answer to any question leads to an analysis of the effects of implementing the solution by using reliability centred maintenance techniques, specifically, RCM analysis, Maintenance Task Analysis, Level of Repair Analysis and Sparing Analysis.

The final step is to implement the corrective action that was shown to be most appropriate through the analysis of RCM techniques. Typical corrective actions are:

Redesign the equipment to be more reliable
Replace equipment with more reliable equipment
Change the preventive-maintenance plan (time- or condition-based)
Change the corrective-maintenance plan (repair by exchange, fix on failure, restorative)
Change operating practices
Improve training
Increase personnel resources
Increase spare parts

Once a solution to the problem has been implemented by the LCMM, the system will be monitored over a period to ensure that the change did in fact solve the problem. This brings the RAM process through a full circle to the beginning of the process, collecting data.

Proposed RAM Programme Resources

If a comprehensive maritime RAM programme is to be established, resources to establish a complete MMIS data base and to undertake the RAM analysis and corrective action processes will be required.

Three options are available for acquiring personnel resources needed for a RAM analysis programme: establish maritime reliability engineers within the navy, create a centre of expertise at NETE, or contract the work to industry. However, all three options would require the navy to have engineers who are fluent in RAM analysis who can work with LCMMs. RAM analysis in the navy requires that an analyst be totally familiar with the ships' equipment and operating environments, as the evaluation of failure data would be misleading without a maritime background.

If a maritime RAM programme is established it must be run as a continuous programme whose primary function is to monitor fleet systems. The organization would ideally consist of two maritime engineers, from both the combat and mechanical disciplines, with masters degrees in reliability engineering. Personnel with mathematical backgrounds in statistics and RAM analysis and who are familiar with the systems they are monitoring would work with these engineers. The entire organization would be supported by an automated MMI system.

At this point the resources have only been roughly outlined. The bulk of the analysis (the monitoring of the fleet) has not yet been undertaken on a large scale, and the actual amount of work has not been accurately defined. However, some resources will be required if any progress at all is to be made in maritime RAM analysis.

Summary

Reliability, availability and maintainability parameters are the cornerstones of every system throughout the life-cycle. RAM creates continuity across the four phases of a system's life cycle and closes the data loop by ensuring that operational specifications are met in the design phase, RAM design criteria are met in the acquisition phase, operational requirements are met in the in-service phase, and that RAM criteria for the new equipment can be developed on a sound basis.

The new ships and systems designed by industry are brimming with RAM criteria in the form of logistic support analysis records. The carry on from the LSAR RAM design criteria is a maritime RAM programme to monitor systems throughout their in-service lives to ensure they meet their operational requirements and design criteria.

The maritime RAM programme requires an automated RAM maintenance-management information system to collect and distribute system data, a RAM analysis cell to monitor fleet systems, identify those that consume an excessive proportion of the maintenance resources and identify the problem areas, and a RAM corrective-action process to assist the LCMMs in implementing corrective action.

Thus, RAM analysis monitors an LCMM's systems to identify equipment that is not meeting the operational goals, equipment that is consuming excessive maintenance resources, and systems that are not meeting the design criteria. Additionally, RAM analysis provides the LCMM a resource and a process for correcting problems that are identified with his systems. For senior management, RAM analysis identifies problem systems and gives management a chance to plan corrective action.

Finally, in order to support the operational commanders and meet their requirements, RAM becomes the maintenance manager's tool to judge the performance of his systems throughout their life cycle.

Bibliography

1. Dhillon, B. and H. Reiche. *Reliability and Maintainability Management*, Van Nostrand Reinhold Co.: New York, 1985.

2. Hough, LCol B. and Maj. R. Morton. *Concept for an ILS Management System for Improved Weapon System Management*, Directorate General Aerospace Engineering and Maintenance, DAS Eng Report, November 1985.

3. *Integrated Logistics Support for the Department of National Defence*, Amtek Management Inc., 1985.

4. *Maintainability Engineering Theory and Practise*, AMCP 706-133, U.S. Army Material Command, 1976.

5. Pilnick, S. *Phased Mission Reliability Analysis for a Hypothetical Naval Weapon System*, Naval Postgraduate School, Monterey, NPS55-77-28, June 1977.

6. *Reliability and Maintainability Guidelines*, MMI 1487, Canadian Forces Material Management Instruction, CEM/DEMPS, 1982.

7. Rienes, J. and J. McCormick. *Maintenance Data to Improve Fleet Maintenance Practises*, presented at COMNAVSURFLANT/ANSE conference, Fall 1978.

8. *Test and Evaluation of System Reliability, Availability and Maintainability*, DOD 3235, Department of Defense, Director Test and Evaluation, 1982.

LCdr Hilts joined the RCN in 1958 and trained as an Armourer's Mate. In 1960 he undertook naval technical apprentice training and, in 1963, went to sea as a P2ER. He has served in HMC Ships Ottawa, New Glasgow *and* Mackenzie, *and was commissioned as a MARE in 1969. LCdr Hilts has been the RAM/RCM sub-section head in DMES 6 since 1984, and is currently involved with the fleet implementation of the new naval maintenance policy.*

Lt(N) Marecek graduated from the University of Calgary in 1982 with a degree in electrical engineering, majoring in computerized control systems. He completed his A/CSE phase in HMCS Gatineau *in 1984 and went on to become the technical officer for CFS Aldergrove and, later, the EHM project officer in DMES. Dave Marecek left the navy this past July to take up a civilian position with SED Systems of Saskatoon.*

RAM Terminology

Reliability (R(t)) — the probability that a unit will perform its intended function for a specified interval under stated conditions. Reliability is a function of the failure rate, time, and type of failure.

Mean Time Between Failures (MTBF) — a basic measure of reliability where the total number of life units (during which all parts of the item perform within their specified limits) is divided by the number of failures for that unit during a specified time interval. MTBF can be interpreted as the expected length of time a system will be operational between failures.

$$\text{MTBF} = \frac{\text{Total Number of Units Operating in Time } t}{\text{Total Number of Failures in Time } t}$$

Maintainability (M(t)) — the probability that when a maintenance action is initiated under stated conditions a failed system will be restored to an operable condition, within a specified down-time, when prescribed procedures and resources are used.

Mean Time To Repair (MTTR) — a basic measure of maintainability where the sum of corrective maintenance times (at any specific level of repair) is divided by the total number of failures within an item repaired at that level during a specified time interval.

$$MTTR = \frac{\text{Total Corrective Maintenance Time in Time t}}{\text{Total Number of Failures in Time t}}$$

Availability (A) — a measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at a random point in time. Availability is the parameter that translates system reliability and maintainability characteristics into an index of effectiveness. The basic mathematical definition of availability is:

$$A = \frac{\text{Up Time}}{\text{Up Time} + \text{Down Time}}$$

Inherent Availability (Ai) — system availability with respect to operating time and corrective maintenance time. Inherent availability is the best availability the system can achieve, as delay times (such as logistic delay) are ignored. Inherent availability can be written mathematically as:

$$Ai = \frac{MTBF}{MTBF + MTTR}$$

Operational Availability (Ao) — all segments of time that an equipment is intended to be operational are included in the up-down time relationship. Up-time is divided into operating time (OT) and standby time (ST), and down-time is divided into total preventive maintenance (TPM), total corrective maintenance (TCM), and administrative logistics delay time (ALDT). Operational availability can be written mathematically as:

$$Ao = \frac{OT + ST}{OT + ST + TPM + TCM + ALDT}$$

Reliability Centred Maintenance (RCM) — an analytical process that is used to determine what, if any, preventive maintenance is to be applied to a specific system. The analysis is applied at the system level and is designed to identify appropriate maintenance tasks based on the operational significance, the safety implications of failure, and the cost-effectiveness of carrying out selected maintenance tasks. Where preventive maintenance is deemed necessary, the tasks will fall into one of two categories: condition-based maintenance or time-based maintenance.

Condition-Based Maintenance (CBM) — preventive maintenance performed when warranted by the condition of the system. The prime means of determining the condition of the system will be Equipment Health Monitoring techniques which are applicable to that system and for which sufficient historical information is available to permit the equipment's health to be assessed with an acceptable degree of confidence.

Time-Based Maintenance (TBM) — preventive maintenance tasks that are performed at a set interval, usually calendar time or running hours, regardless of the condition of the equipment.

Equipment Health Monitoring (EHM) — processes that: use and collect system performance data; analyze the collected data by use of various techniques and instrumentation; and result in a condition-based maintenance decision for the system.

Maintenance Management Information System (MMIS) — an automated or manual system that provides information in areas of operations, maintenance, personnel and logistics support to assist in monitoring and measuring maintenance functions within the life cycles of equipment or systems.

Life Characteristic Curve — the life-cycle failure rate of a system can be described by the bath-tub curve or parts of the curve depending upon the type of equipment being discussed. The curve of *Fig. A* has three distinct regions known as **"burn-in"**, where the failure rate decreases, **"useful life"**, where there is a constant failure rate and **"wear out"**, where the failure rate is increasing. The increasing failure rate indicates that the useful life period of the system is in question.

RAM Design Curves — *Fig. B* demonstrates that for an improved inherent availability (i.e. moving from A1 to A2) a larger MTBF and a smaller MTTR are required. Both will increase costs in the acquisition phase, but will result in lower life-cycle costs and a greater likelihood of meeting the operational requirements.

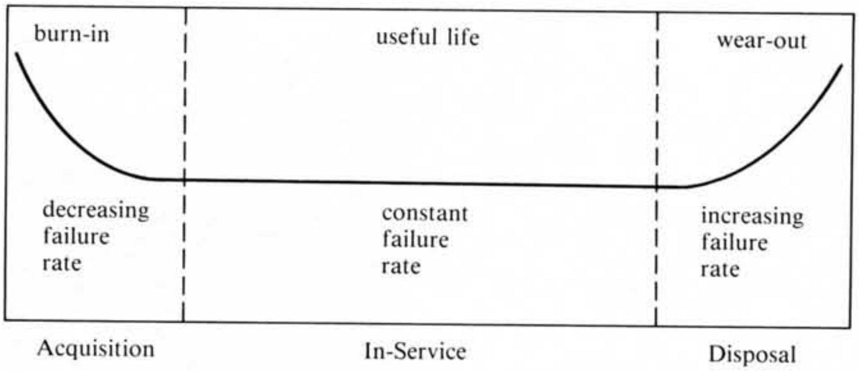


Figure A — The Life-Cycle Curve

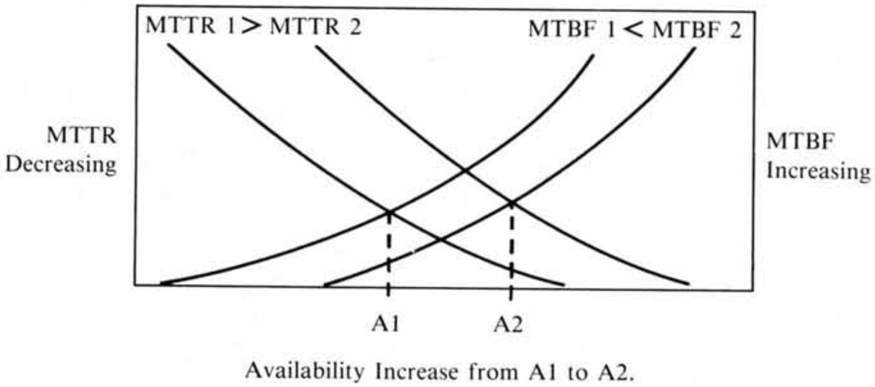


Figure B — RAM Design Curves

Profile: ***David Alexander Nairn***

Canada's Longest-Serving MARE

by LCdr(R) Brian McCullough

Lieutenant Commander David Nairn is anything but superstitious. When he was 17 he stepped aboard Winnipeg's HMCS *Chippawa* to be sworn in as an ordinary seaman in the Royal Canadian Navy. The date — *Friday the 13th* of August, 1948.

"I always tried to figure out whether it was unlucky for the navy or for me," says the 55-year-old Nairn with mock seriousness, "and I'm beginning to have my doubts, now, that I came out the winner."

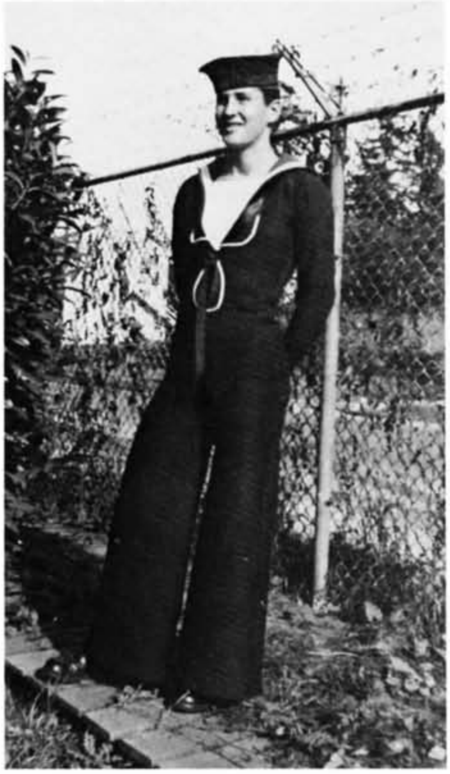
Winner or not, this soft-spoken native of Birtle, Manitoba is quick to extol the virtues of his chosen profession. "I would recommend the military for anybody," he said in a recent interview. "The military can offer something no other experience can offer."

And when it comes to experience, Dave Nairn knows what he is talking about. Not only is he the longest-serving maritime engineer in the navy today, but (as of July) is also the longest currently serving member of the Canadian Forces. When he retires this December he will be closing the books on a career that has lasted more than 38 years, spanning the tenures of eight prime ministers and 16 defence ministers.

In some ways Nairn has become a politician himself. Since the stabbing death of his youngest daughter in 1983, he has been an unrelenting and eloquent champion for victims' rights in Canada. This "simple sailor" (as he sometimes describes himself) now has the ear of police chiefs, Crown attorneys, judges and members of parliament. He has been interviewed on radio and national television, and has even appeared before two House of Commons Legislative Committees reviewing bills to amend the Parole and Penitentiary acts and the Access to Information Act.

* * * * * *

Within two years of his joining the navy, Nairn was an AB electrician's mate in HMCS *Sioux* on his way to Korea. "It was an adventure," he said, recalling the excitement of the Inchon landings and the later Chinnampo operations. During the entire period that *Sioux* was on sta-



tion in Korea, Nairn was "on the air" with a nightly (operations permitting) entertainment broadcast for the ship's company. He recalled one memorable broadcast when one of the crew received word from home that his wife had just had a baby. In honour of the occasion Nairn dedicated a song to him — *"Whose Baby Are You?"*

After Korea Nairn went on to trades training where he qualified as an air electrician with the fledging Royal Canadian Naval Air Arm. But with the navy having only one aircraft carrier *(Magnificent)* he became disenchanted by the lack of opportunity for sea duty, and in 1953 remustered as a P2 sonar technician.

Around this time he was selected as an Upper Yardsman candidate for university degree-level training. He never did complete the prerequisites, though, and said that in retrospect he considers this to be the greatest missed opportunity of his career. He returned to sea for a 14-month posting in *Lauzon*, and afterwards undertook advanced trades training at Electrical School, graduating second in his class.

From there he embarked on a 42-month tour of duty in *Nootka*, during which he received a suggestion award for developing a means of taking raw data from the search sonar, converting it, and feeding it into the attack computer as a back-up for the primary sonar systems. And although he didn't get a second award, he also developed a method for alongside replacement of the depth-predicting sonar transducer in cases where the integrity of the sluice valve could not be maintained, thereby obviating costly dockings.

Nairn left *Nootka* in 1959 to become an instructor at the Electrical School in *Stadacona*. He was there when the navy first trialled the user-maintainer concept, and according to him there were problems.

"When they came out and decreed that everyone would be a Rembrandt, although 50% of them were barn painters, we knew that the user-maintainer thing would not work. Maintenance is about 80% instinct," he said. "If (you) don't have that instinct you can't do it. When you've got card replacement and automatic test equipment, then you can use user-maintenance."

He was an instructor for only one year, but said that he considers this to have been his greatest contribution to the navy. "You could feel you were accomplishing something there," he said.

In 1960 he was selected for commissioning and was posted to *Naden* for the eight-month Branch Officer's Qualifying Course. Nairn smiled as he recalled one of the more humorous aspects of his new status. As a lower decker "you ran on wits," he said. "You walked around with about five stories in your head for describing your activities or whereabouts. And depending on how The Question was asked, that's what story you would give. When I was commissioned it was a great thing for me. Nobody wanted any of these stories."

But he remembered, too, how the sudden change from NCO (he was a C2 at the time) to commissioned officer in May 1961 left him perplexed. "One day I was *Chief* Nairn, and listened to in terms of matters technical. . . .My opinion would be sought out. Then, next day, I'm *Commissioned Officer* Nairn and nobody wants to talk to me — I'm instant stupid. And that confused me; that was a hard thing to come to grips with. That I am now a makey-learnie again, and I had been well respected as a petty officer and a chief — that was hard to accept."

An even more bitter pill was the later realization that he was virtually being sidelined from the mainstream of naval technological training. After four years with DGFE (fighting equipment), during which he was heavily involved with complex technical programmes, Nairn expected to be sent on course for technical update training. Instead, he went directly to a three-year posting in the DEVIL integrated-logistics programme, and then on to three years of staff work in the Directorate of Military Occupational Structures.

"A group of us got caught up in the shift in technology," he explained, "and we were put aside so that the younger people could be trained in the new technology. We ended up holding the fort while other people were off doing their training. I thought the system would take care of me."

In 1974 Nairn was promoted lieutenant commander and posted to SSO Combat Systems. While in MARCOM he made a significant contribution to the investigation into the variable-depth-sonar towed-body losses. Where the official reports focused only on the engineering defects, Nairn investigated the personnel aspects. His findings proved valid and new training standards for handling the VDS were subsequently written.

In 1976 he was seconded to the Director of Operations at COJO headquarters in Montreal, and in the same year received his second posting to DMOS in Ottawa. Nairn served there until 1982 when he took up his current posting in the administration and training section of DGMEM. He couldn't possibly have known it at the time, but within a year his world would be turned upside-down.

When his 17-year-old daughter Roxanne was stabbed to death in March 1983, Nairn was unprepared for the nightmare of judicial double-dealing that was to follow. It was a process that catered to the offender at the expense of the victim, he said, and the biggest shock was to see the courts in action. On the day he went to the courthouse to watch the jury selection for the upcoming trial, he was subpoenaed — as a witness for the defence of his daughter's killer. It

was a defence-counsel ruse that would effectively exclude him from the trial proceedings, and he never was called to take the stand.

"I went into that courtroom a God-fearing, authority-fearing individual," he said. "And when I saw what went on . . . I lost all respect for the Canadian criminal justice system. It's just that — *criminal*. The victims are the forgotten part of the equation."

Roxanne's killer was sentenced to three years in prison, but in fact served only 2 years and 6 days because of the government's mandatory supervision programme. "They've removed the punishment from sentencing," Nairn said angrily.

His indignation spurred him to action. He went on to form a local self-help group for other crime victims, and at the same time launched campaigns to abolish mandatory supervision for violent offenders and to have victims included in the judicial process. He said that the confidence he got from his military training helped him through the difficult times. "If you have confidence," he said, "you can go anywhere."

Despite his personal tragedy, Nairn said he still believes that just as there is some bad in all of us there is some good. If he had a hero, he said, "he'd be the type of person that had compassion and understanding for people." He paused for a moment, and then added, "That's the type of person that I admire."

Perhaps unwittingly, he has named that particular quality that others see in him. Just this summer David Nairn was awarded the Ontario Medal For Good Citizenship for his selfless dedication to the cause of victims' rights. Of the 171 recipients in the award's 13-year history, Nairn is only the second member of the Forces ever to be so honoured.

As his 38-year service with the navy draws to a close, Nairn says that he is looking forward to his retirement. He said that he would like to spend some time at his cottage and maybe do a little deer hunting. But one thing is certain, he said. He intends to continue his work for victims.

Perhaps something he said about the way things should be done in the navy could be said about his plan for the future. "You've got to have time to sit down and reflect on what you've been doing and decide whether or not you're going the way you want to go."

For David Nairn that means taking things one step at a time. It's the way he likes it.

LCdr McCullough is the Production Editor of the Maritime Engineering Journal.

Installation of the Solar Saturn in the NETE Internal Combustion Engine Test Facility

by C.A.W. Glew

Introduction

Installing an engine in a test cell is not the stuff of exciting composition. However, if we discuss the problems and our solutions to them during the installation of the Solar Saturn for the prototype TRUMP System tests, the difference between the ideal and the actual world will, we trust, be of interest to engineers.

The possibility of testing the TRUMP System before its installation in the ships was raised at a meeting in May 1984 between personnel from DMEE 2, NETE and the engineering consultants who were developing the TRUMP generator system. The package consisted of:

a. a modified engine base with a new engine-mounting system;

b. a new acoustic enclosure, designed to be easily removed and replaced to facilitate engine maintenance;

c. a new external lubricating oil system package, readily accessible for maintenance;

d. an air-eductor in the exhaust system to draw the cooling air through the engine enclosure;

e. a microprocessor-based engine-control system; and

f. internal oil system modifications which were to be incorporated by the engine manufacturer.

The design of the new engine-mounting system was complete, so in June 84 we made a cost estimate for manufacturing the prototype, but substituting 316 stainless steel and Atlas Alloy SPS for esoteric-sounding aircraft engine steels with specifications like ASA 4130 and 3140. Manufacture of a set of mounts with the substitute materials was approved by NDHQ in September 84, but delays in delivery of specialized bushings from the U.S. held up completion of this work until February 85.

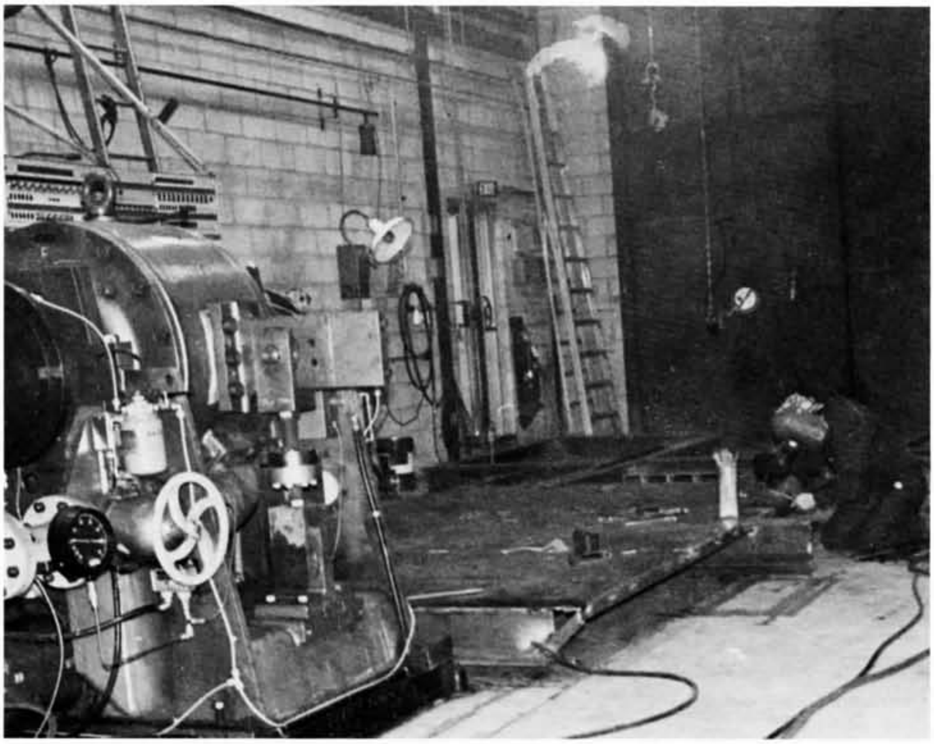
Preliminary drawings of the shipboard TRUMP installation were forwarded to NETE in July 84, so we made a preliminary project plan with an estimate of 20 weeks from commencement of work to the first runs of the Solar Saturn with the TRUMP system. This project plan was approved in October 84. The TRUMP system layouts were prepared, and as soon as the Bombardier diesel test programme on future naval fuels was completed in December 1984 construction of the simulated section of the DDH-280 mezzanine deck was begun.

Layout of the Installation

Initially it was intended to mount the engine to the dynamometer in the test cell, and the first layouts reflected this. The only awkward part of the design was the requirement to install a waste-heat boiler test section, together with the 33-inch-diameter shipboard piping system into which the eductor for the engine-enclosure cooling air was to fit.

The NETE test cell was not big enough to accommodate the standard shipboard generator system, so we had to juggle the package around a little. The preliminary layout consisted of a port engine and intake system coupled to a starboard exhaust diffuser and simulated waste-heat boiler via a simulated section of the shipboard ducting and bends, incorporating the eductor. This system discharged into the existing NETE acoustically lined exhaust duct and silencer system.

The eductor was a most unusual design and would probably have never worked, but fortunately other constraints appeared and this design feature was soon abandoned. Drawings to simulate the end face of the generator could not be supplied, and with the known requirement to overhaul the NETE dynamometer after the diesel generator tests, plus the desirability of verifying the engine alignment procedure with the TRUMP package, a decision was made to pull a spare ship's generator from stores and build a complete generator set for the TRUMP tests.



Construction of the simulated DDH-280 mezzanine deck for the Solar Saturn gas-turbine installation.

The NETE design effort concentrated on the following areas:

a. a section of the ship's mezzanine deck, incorporating modifications for the new acoustic enclosure;

b. the engine base, with modifications to suit the enclosure;

c. the exhaust system, with simulated waste-heat boiler section;

d. the intake system;

e. the load banks and water cooling system;

f. the enclosure air cooling system; and

g. the instrumentation and engine-control system.

The final layout for the installation is depicted in *Figure 1*.

Building the Mezzanine Deck

A deck structure was built on the NETE seismic block, incorporating the modifications to accommodate the TRUMP intake and acoustic enclosure. The ships' drawings were dimensioned in inches, but the TRUMP modifications were in metric units. We corrected any errors that we found in the preliminary drawings (which defined the modifications), but one that we missed resulted in the gap between the generator and the acoustic enclosure being 2'' instead of ¾''. On our system we fitted a sheet of Urethane foam as a temporary acoustic barrier.

One interesting anomaly had us puzzled for awhile. Our drawings of the ship's deck showed five equispaced mounts for the engine base, but the drawing of the generator system showed four closely spaced mounts under the generator and one set at the front end of the base. We eventually realized that HMCS *Iroquois* and *Huron* had the first arrangement, and that *Athabaskan* and *Algonquin* had the second. We built to the *Iroquois* standard.

Building the Engine Base

Initially NETE built a half engine-base to the consultant's plans for the installation of the Solar Saturn engine alone. We were surprised to find that when it was supported on three corners, the fourth dropped 0.125''. This raised doubts as to whether the complete base presently used on the ships is sufficiently rigid. According to MIL-E-17431 (ships) ''The base must be sufficiently rigid to prevent misalignment of the attached units when it is supported on three of the four corners''. Therefore, when the generator set base was built, a test was carried out to determine if any distortion of the base could occur under heavy roll conditions at sea. The base was shock-mounted to the mezzanine deck, and the generator bolted into position. When a weight was placed on one side of the generator to simulate the uneven weight distribution of the generator on the base during a 30° roll, it was found that the front end of the base twisted 3 minutes relative to the generator end. Calculations showed this would induce misalignment between the three main-engine bearings of the order of 0.005'' (0.010 TIR). This is thought at NETE to be one of the causes of wear on the end faces of the main roller bearings which have been seen so often on stripped Solar Saturns. It should be noted that the shock mounts on *Athabaskan* and *Algonquin* give better support under the generator and, thus, greatly reduce engine misalignment due to the ship rolling. This may account for the fact that up to the end of 1984 there had been 54 Solar Saturn failures in *Iroquois* and *Huron*, but only 36 in *Athabaskan* and *Algonquin*.

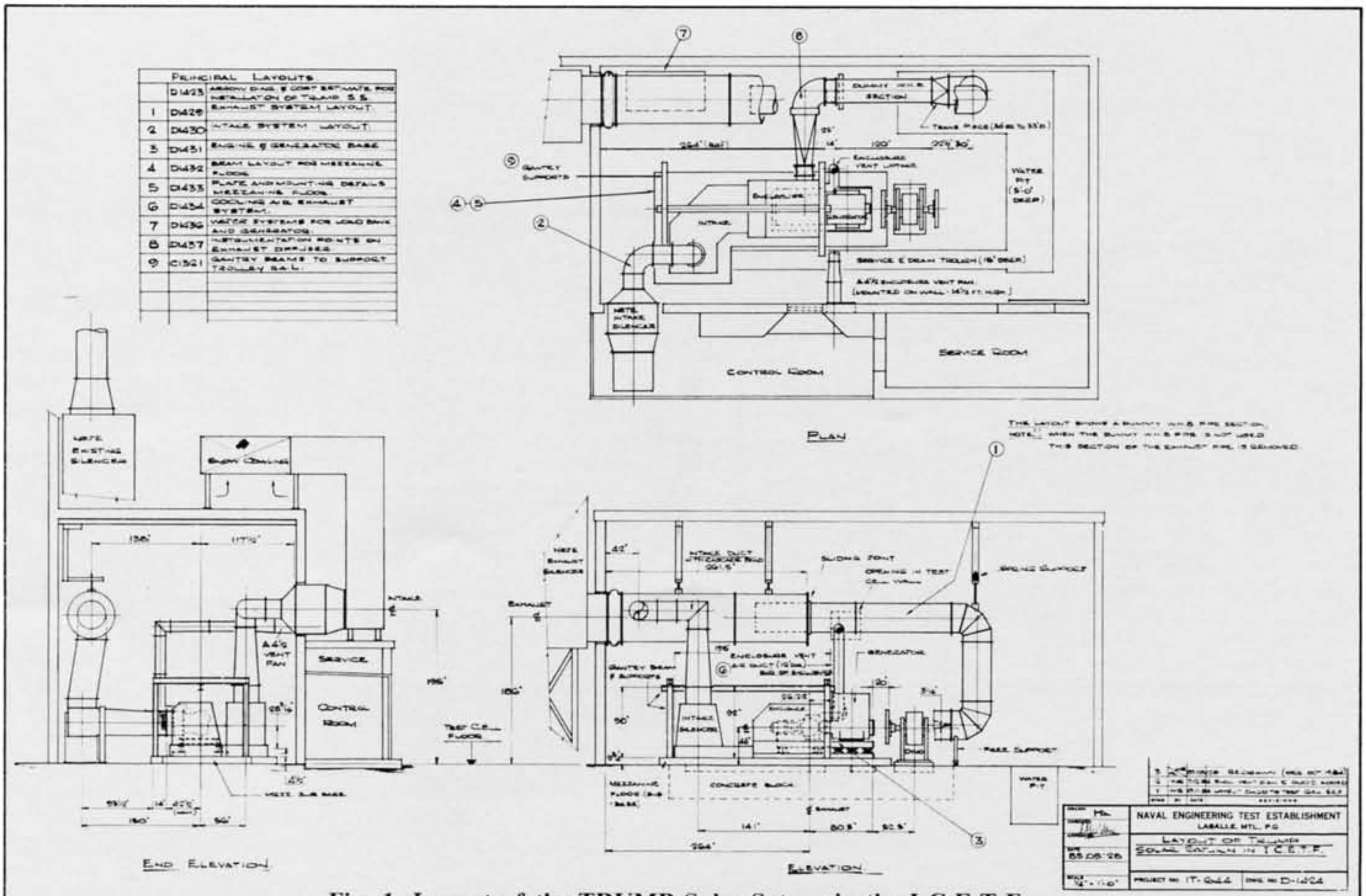


Fig. 1. Layout of the TRUMP Solar Saturn in the I.C.E.T.F.

The new mounting system compensates for thermal growth and any transient misalignment provided it is properly installed and lubricated. We carefully checked and corrected errors in the contractor's preliminary drawings of the engine base, and sent our inspector to the jobbing shop which machined the base. Errors of between ⅛ and ⅜ inches were discovered in the location of the generator mounting bolts and were corrected prior to acceptance of the unit.

The Alignment Procedure

It is preferred to align the engine mounts to the generator centre line using a dummy RGB (reduction gearbox) as an alignment jig, but the drawings for this item had not been produced when the engine was installed. One was later manufactured, but in the meanwhile the system was aligned as follows:

a. The generator was aligned centrally with scribed marks on the engine base and bolted down.

b. With the generator rotor centralized in the casing, the height to the base of the mounting feet was measured, and shims of 0.241'' and 0.248'' were fitted under the mounts to bring the centre line of the mounts up to the centre line of the generator. The mounts were positioned to scribed lines which had been previously marked on the engine base, and were tightened in place. To avoid having to make oversized dowels on a shipboard installation, neither the generator nor the mounts were dowelled at NETE.

c. The engine, with RGB fitted, was lifted with a modified gas-generator hoist designed at NETE (see *Fig. 2*) and lowered into place. The front mounts were then adjusted to the right height.

d. To eliminate parallelity errors in the engine location, it was necessary to insert an additional 0.010'' shim under each engine-mount foot and move the mounts slightly horizontally. A 4mm washer was placed on the inside of each trunnion bearing to accommodate an 8mm discrepancy between the actual RGB width (500mm) and that quoted on the preliminary layout (508mm).

e. During the above adjustments, angularity errors between the engine and generator axes were minimized by adjusting the front-end mounts as required to ensure that the front face of the RGB was square to the generator axis.

Problems During Engine Installation

Two problems with the mounting system surfaced during the engine installation, and it was also found that a problem existed with the present shipboard alignment check on the RGB face.

a. **The engine front-mount bracket**

(1) The mounting lugs on the compressor case have a width tolerance of 0.020''.

(2) The distance between the centre of the holes for the mounts on the compressor case can vary by 0.028''.

(3) There was interference between the overhung section of the front-mount bracket and the lugs on the compressor case.

(4) There was not sufficient clearance between the air intake case and the mounting lugs on the compressor to fit the specified securing bolts.

These problems were circumvented at NETE by the design changes shown in *Figure 3*. In general terms, to eliminate problems (1) and (2) above, the

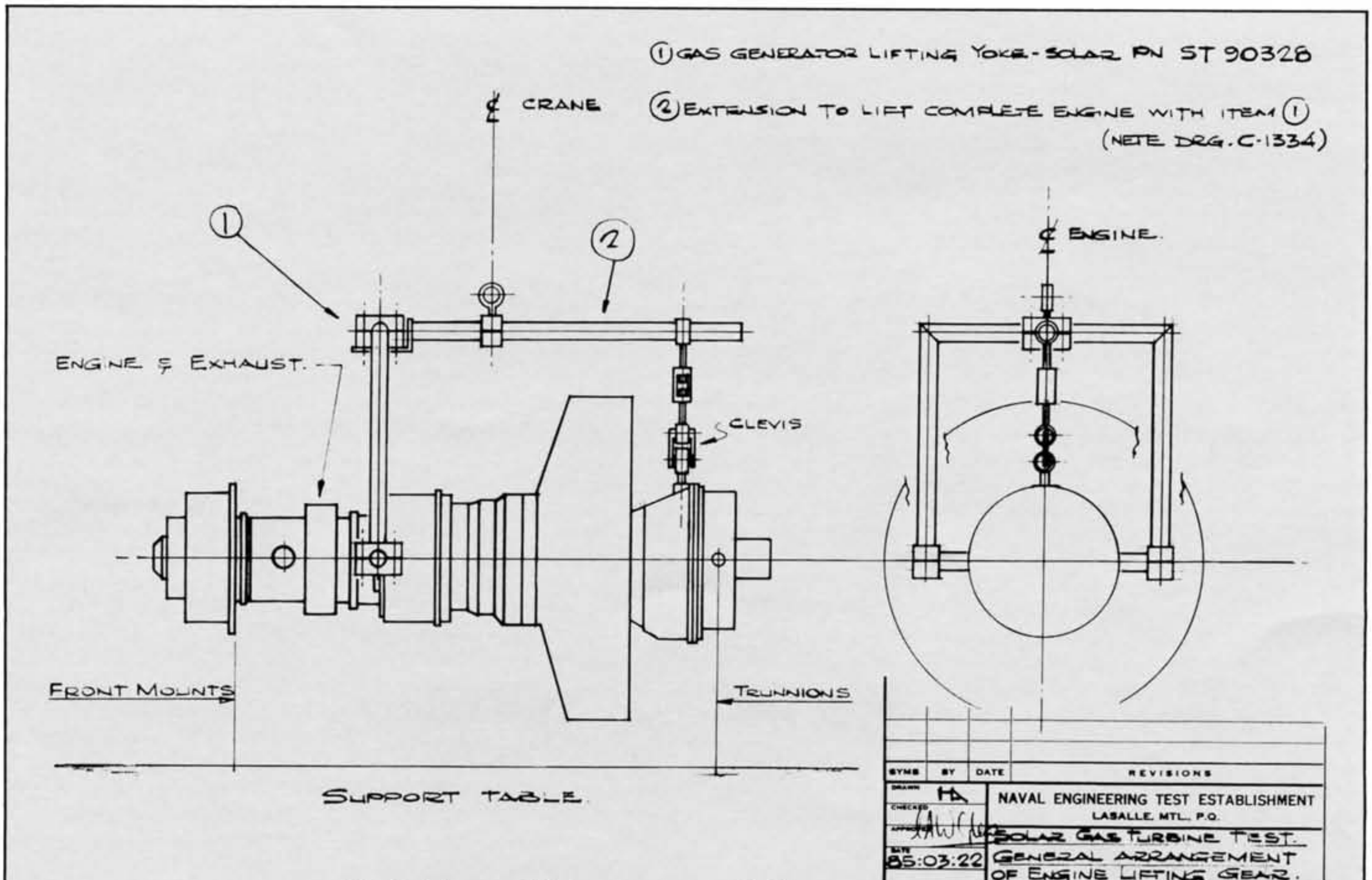


Fig. 2. The modified gas-generator hoist.

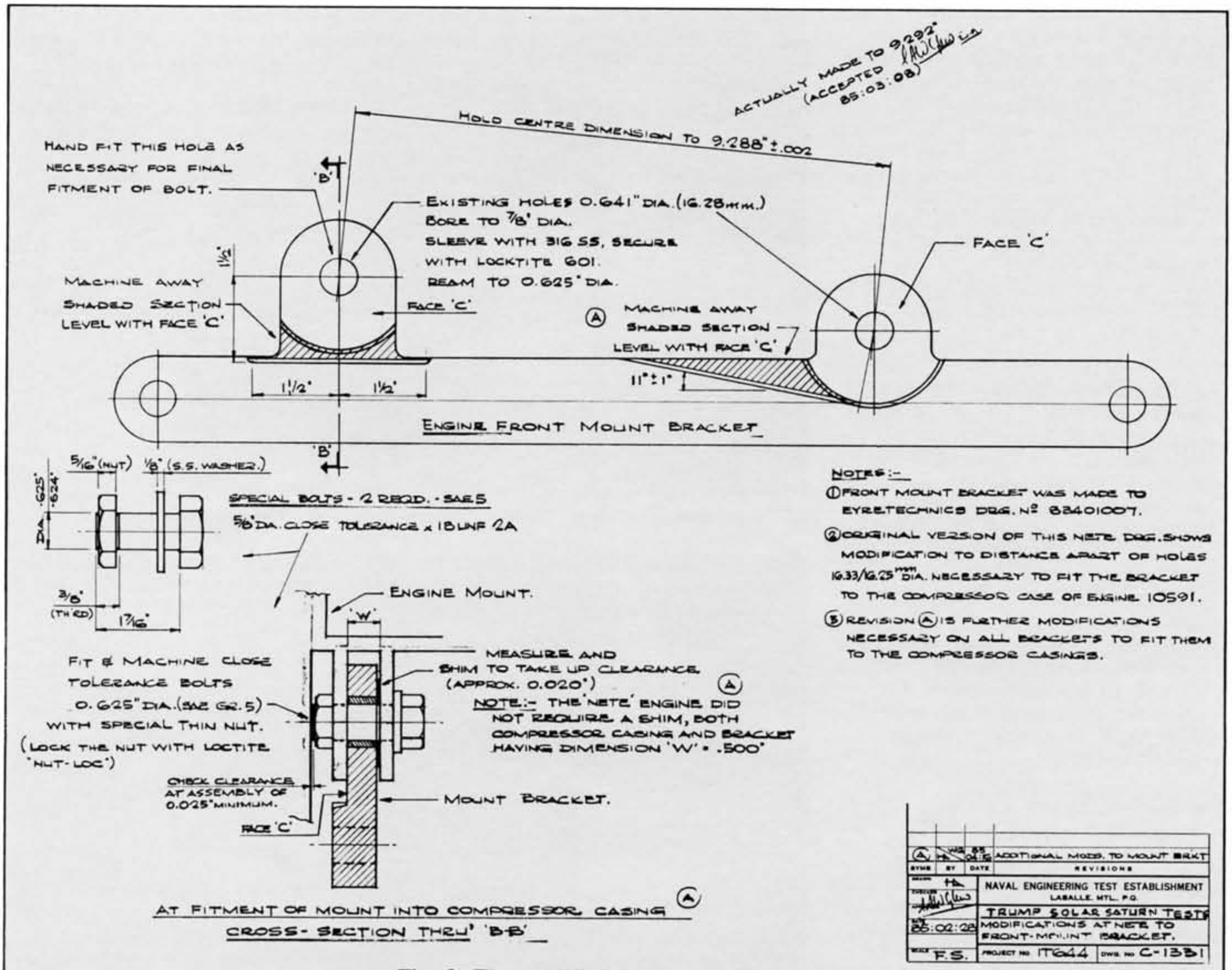
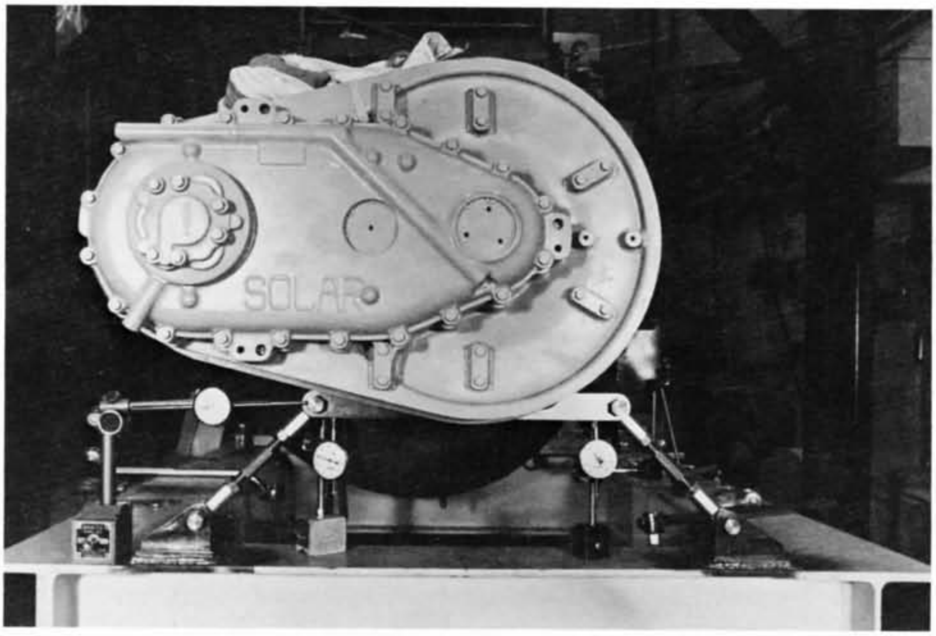


Fig. 3. The modified front-mount bracket.

front-mount brackets should be fitted individually to the compressor cases at the engine overhaul shop, and design changes should be incorporated to the manufacturing drawings to accommodate problems (3) and (4).

b. **The sliding bearing on the port rear trunnion**

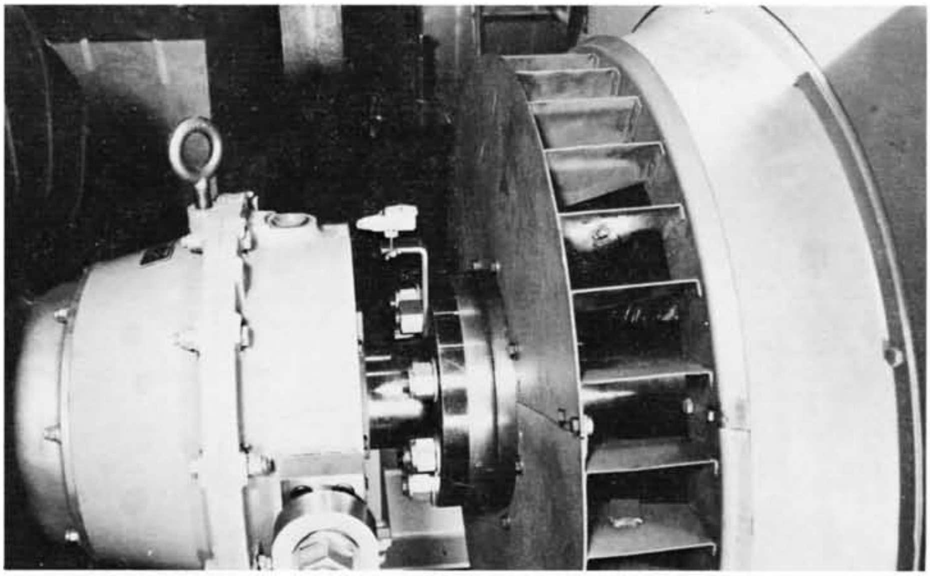
When the engine was first installed we fitted three dial indicators onto the front-mount bracket (see photo) so that we could see if the engine frame twisted as the turnbuckles were adjusted. On the first adjustment of the left-hand-side turnbuckle the frame twisted easily, with the left-hand side dropping 0.050" for ¾ of a turn on the turnbuckle. This was a graphic illustration of how easily misalignment can be built into the present engines at shipboard assembly, for if the front-mount lugs on the engine base are incorrectly positioned the frame can easily twist during installation without the operator's knowledge.



Dial indicators mounted to measure movement of the engine-front during alignment checks.

We supported the engine, removed the starboard rear-mount sliding bearing and lubricated it with molycote grease. The alignment system worked perfectly after this. The sliding rear-mount bearing ensured that when (for example) the starboard turnbuckle was shortened one turn, the engine, rotating about the port trunnion spherical bearing, moved 0.039" to the starboard side at the front end and dropped the same amount without twisting at the front end. NETE has recommended to DMEE 2 that a grease nipple be fitted to lubricate the starboard rear-mount sliding bearing.

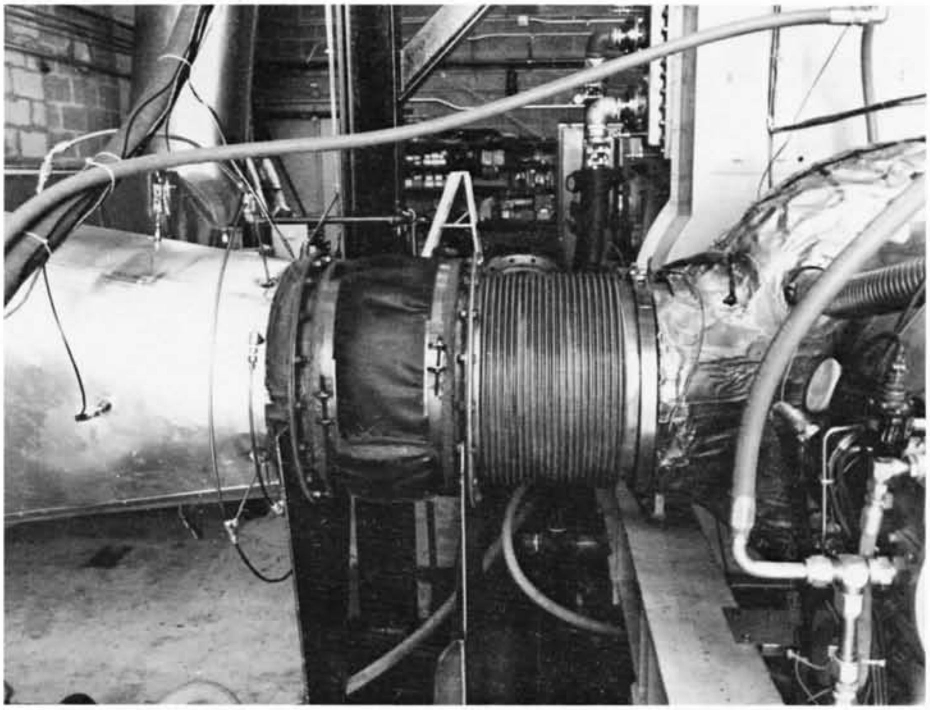
c. **Mounting the indicator for the RGB squareness check**
When a standard indicator was mounted from a magnetic block and used for the RGB squareness check (i.e. engine axis alignment with the generator shaft axis) we found that the weight of the indicator caused a variable error of up to 0.014" TIR in the squareness reading. A miniature TESA dial indicator was then fitted onto a short stiff bracket (see photo), giving satisfactory results. This also showed that the CFTO limit of 0.003" TIR could not be achieved in this case because the RGB datum face was 0.005" out of flat.



The miniature TESA dial indicator mounted for the RGB squareness check.

The Exhaust System

We designed the exhaust system ducting to give back-pressure conditions similar to those existing on the ships. The outline of the exhaust system is shown in *Figure 1*. The trunking was manufactured locally and was thermally insulated to reduce heat loss and, hence, uneven air temperatures in the test cell. The exhaust diffuser was manufactured to the original Garrett Manufacturing Company drawing, except that it was made of mild steel. It cost $4500, and incorporated the original diffuser turning vanes (which had been removed from the ships' systems ten years ago) to enable measurements of the aerodynamics of the Garrett system to be included in the test programme. Multiple static pressure, total pressure and temperature monitoring points were also incorporated in the unit so that the performance of the TRUMP package exhaust diffuser manufactured by Bristol Aerospace of Winnipeg could be compared with the present and the original units.



The flexible exhaust joints on either side of the simulated enclosure wall. Some of the monitoring points can be seen on the exhaust diffuser at the left of the photo.

We made the exhaust system flexible joints, using a method developed in 1974 when the test cell was built, but there were problems with the flexible Solar engine bellows. The Marman flange face of the first unit we received was ⅜" out of flat (see photo), and both it and the replacement unit had small indentations due to improper packaging. We knew from past experience that these indentations would generate fatigue cracks which would result in failure of the units while in service. We have recommended that the cardboard boxes in which the units are transported be enclosed in wooden crates.

We found that the Marman V rings on the flexible exhaust bellows and the engine joint were of different sections, and consequently the Marman clamp did not adequately close the joint ring (see *Figure 4*). We also realized that the Solar bellows had very little torsional flexibility, and that on the TRUMP installation under pitching conditions the engine would have a small but definite angular movement relative to the enclosure about the athwartships axis of the ship. This would create severe torsional (shear) stress in the bellows which could lead to rapid fracture. These problems are currently being investigated as part of the TRUMP exhaust system update package.

The Intake System

The intake system layout for the baseline test is shown in *Figure 5*. When this arrangement was originally used on tests in 1977 we were concerned that the sudden enlargement of the air-flow section at the front of the intake plenum

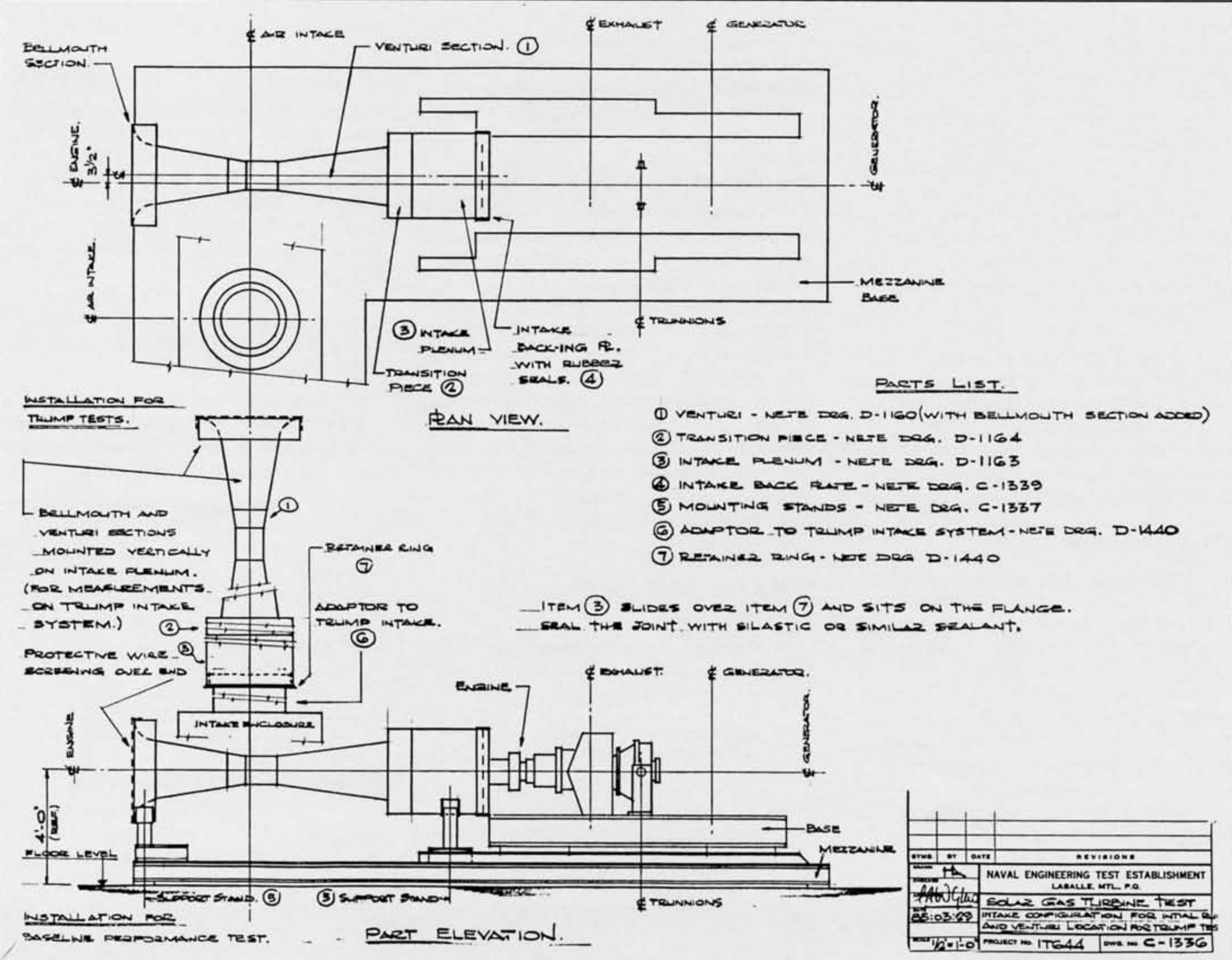


Fig. 5. The intake system layout.

chamber would affect the air-flow measurements. We sought the advice of specialists from the National Research Council, and they assured us that the effect on the venturi calibration would be negligible.

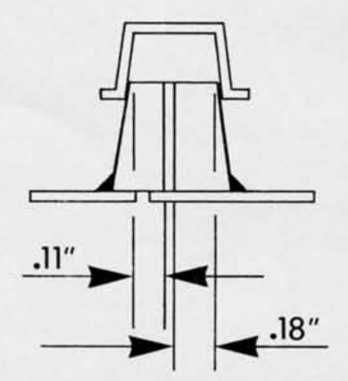


Figure 4.

A damaged Marman flange.

The purpose of the baseline tests with the venturi was to calibrate the pressure drop across the engine air-intake as an air-flow measuring device. After defining the calibration curve we used it as a control, and interestingly enough we found that when the man-catcher screen was fitted to the front of the venturi (see photo), the air-mass flow through the venturi was reduced by ½% for a given pressure drop between the test-cell air pressure and the venturi throat pressure. (We ignored this small change in the venturi calibration.)

Several changes were made to the TRUMP intake system design along the way, like changing the ducting from round to square and changing the location of the cooling air inlet to the acoustic enclosure, but it was always a simple matter to adapt and fit to suit.

The Fuel System

The NETE test-cell fuel system is similar to the ships' fuel systems. We experienced no problems because we did not have saltwater contamination to contend with, and our coalescer is easily serviced and works well. However, the fuel control unit on the TRUMP package is mounted vertically, and it was necessary to turn the governor 90° to operate it. This caused interference with the accessory gearbox vent so a special banjo fitting was designed and installed as shown in *Figure 6*.

Air-Start System

The only problem we came across here was that the Marotta valve which we drew from stores was set to 300 p.s.i. It was adjusted to 500 p.s.i. before attempting engine starts.

The Engine Oil-and-Vent System

It had been originally intended to fit a proprietary external lube oil package as part of the TRUMP modification kit, but this did not materialize. Instead, the oil tank built at NETE in 1975 for the first series of gas-turbine tests was set up with an array of pipes to simulate the TRUMP modification (see photo). The pump on top of the oil tank was used for system flushing and initial oil-priming. However, the pump was inadequate in the former capacity as it did not adequately clean the debris left in the oil tank from the gas-turbine tests of five years earlier.

The Load Bank and Generator Controls

The load-bank controller came with the load banks from stores, but with the generator it was necessary to:

a. determine details, make up drawings, manufacture and assemble a DC field exciter; and

b. determine the wiring and components required to provide a manual generator control and monitoring system, then to purchase the components and build the system.

Engine Controls and Instrumentation

A microprocessor-based starting sequencer and engine-control package was scheduled to arrive in June 85, and so DMEE 2 authorized NETE to make a temporary control box for the preliminary runs. An attempt was made to keep this controller simple, with manual safety shut-downs, but in the end a sophisticated controller was built, incorporating most of the regular engine-safety devices. It was just as well because it was still in use in October 85.

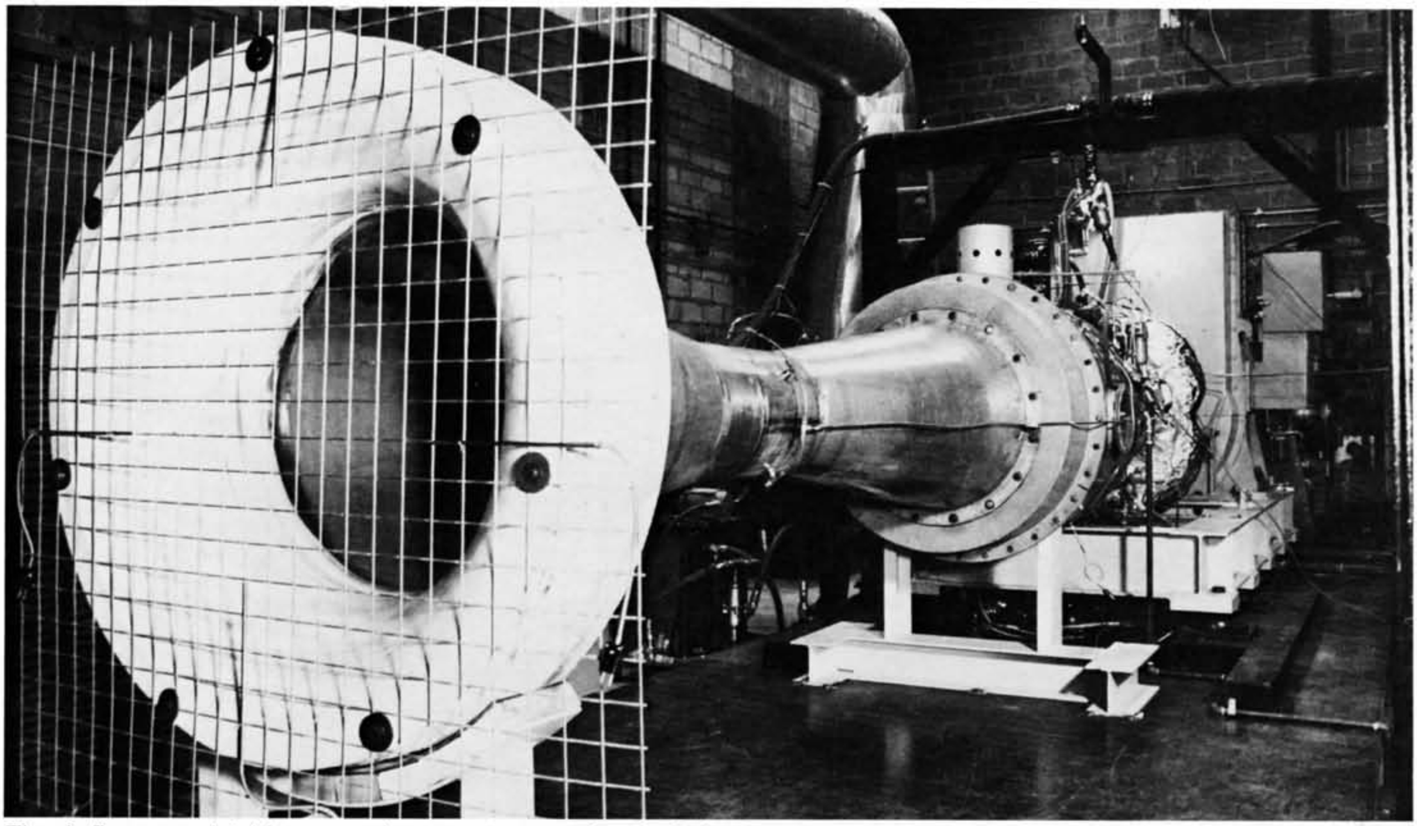
The engine was instrumented quite comprehensively for the baseline performance test, with monitoring points established for the following:

a. **Engine-running instrumentation.**
- oil- and fuel-system temperatures and pressures,
- vent-system pressures for the TRUMP package,
- vibration measurement

b. **Engine-performance instrumentation.**
- gas-path analysis
- exhaust-gas analysis
- generator-power measurement

Shakedown and Baseline Tests

Mr. Dave Connolly, the Solar representative from Halifax, piloted us through the flash-up, and thanks to his



The air-flow venturi (with man-catcher screen) mounted to the Solar Saturn.

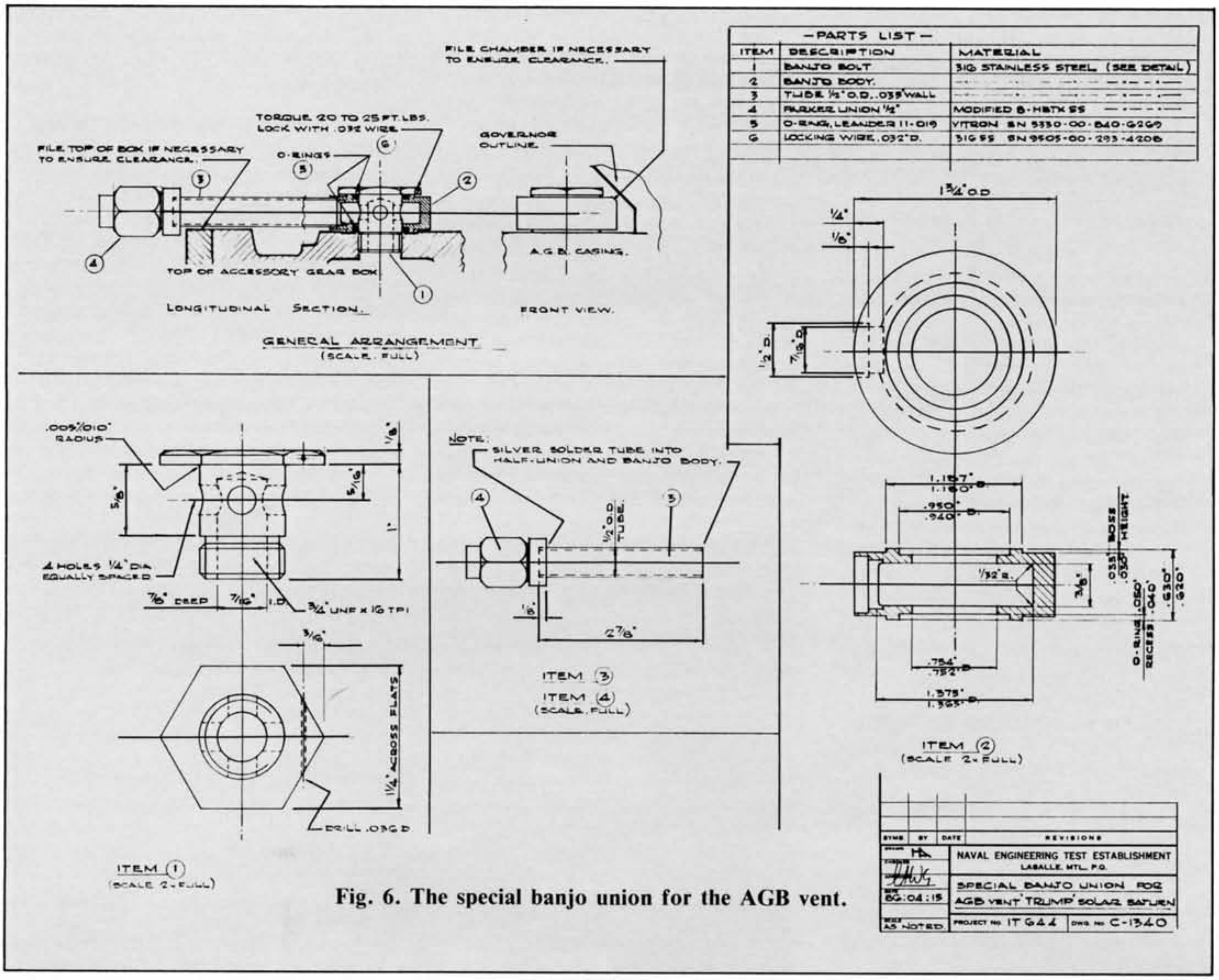


Fig. 6. The special banjo union for the AGB vent.

tender-loving care Murphy's Law was rendered ineffectual.

The following is taken from his report on the shakedown tests which were conducted over three days in May 1985:

Inspected the Navy 750 kW package. The package is similar to shipboard installations, less the enclosures.

With the package ready for first rotation on the starter, the unit was rotated to approximately 10% speed. There were no unusual noises or vibrations on the rundown.

The unit was again rotated on the starter, this time to 40% speed. Again no unusual noises on the rundown. Lube-oil pressure was established during cranking.

The unit was started but light-off did not occur before the 15-second time-delay relay timed out. The time delay was jumpered and another start was made. No light-off again.

The governor was checked for proper operation. It would stroke to minimum fuel position during rotation, but it appeared not to be set up to stroke to maximum fuel position without an electrical signal to the governor actuator coil. The governor was replaced by an overhauled unit which went to maximum position during engine rotation, indicating a good governor.

The unit was started and accelerated to 90% speed where it shut down on a low-lube-oil-pressure malfunction. The engine lube-pressure did not make 20 PSIG before reading 90% speed. The governor speed setting was lowered and the unit was started again. This time it settled at some point below 90% speed and continued to run. The package was checked for leaks, unusual noises, etc.

The engine lube-oil pressure was much lower than normal. It appeared that the oil line from the lube-oil filter to the distribution cross was undersize. Also, the pressure-relief valve was not installed in the best location. The oil supply line was increased in I.D. to one inch, and the pressure-relief valve was relocated to control the lube pressure at the distribution cross. This corrected the low-oil-pressure problem, but now the lube filter differential was very high.

The duplex lube filter was changed over to a clean element but the unit shut down on low oil-pressure. The clean filter probably had too much air inside and required a purge period during the changeover. The other filter had high differential pressure and quickly climbed even higher. The unit was shut down at this point and the lube filters were inspected.

One element of the AAE filter system had collapsed. The other element was okay, but very dirty. The dirty element was cleaned as well as possible and reinstalled. The crud which came from the filter bowl did not look like it came from the engine, and must *have come from the old oil lines or the sump. When the sump was drained and opened for inspection it was found that the sump contained the same crud found in the lube filters. The sump was cleaned and refilled with new oil. The unit was run up but the lube-oil-filter differential pressure was still high. The differential pressure was monitored closely during the day's run.*

The engine/reduction-drive vent manifold, mounted above the engine, was indicating in excess of 20 inches water pressure. This excessive back-pressure was causing heavy oil losses through the top of the governor and the reduction-drive output seal. It appeared that the vent manifold was filling with oil, but this was to be expected because of the venting arrangement of the RGB. It was known that there would be excessive oil discharge from the RGB vent line. A combination of too much oil to the RGB and excess sealing air supply contributed to this condition.

The RGB lube-oil supply was reduced by lowering the pressure to 30 PSIG, and an orifice of 0.062 inches was placed in the supply line to the RGB forward seal. This action helped some, reducing the vent back-pressure to 6 inches of water. Traps in the excessively long RGB drain lines were the cause for most of the vent back-pressure still present.

The unit was run up to check the generator and load systems. The generator was flashed and the AC voltage adjusted to 450 VAC. The electric governor system was energized, but it did not function.

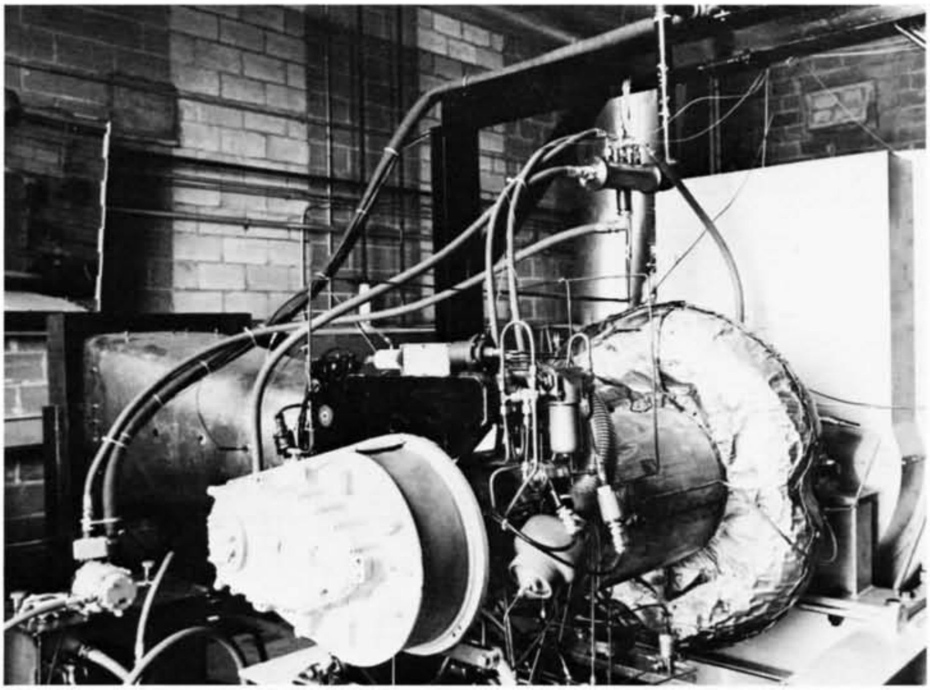
The output from the governor was checked at terminals 17 and 18, and the DC voltage was found to be over 8 VDC. The electric governor adjust switch was operated in the lowering direction, but the behaviour of the electric governor suggested that the actuator coil circuit was wired in reverse. It was eventually discovered that the mechanical/electrical toggle switch had been labelled backwards, and when the wires on terminals 17 and 18 were interchanged the governor operated correctly.

The unit was loaded in steps to full 750 kW, and it performed very well. NETE staff gathered data at various load levels, however the run was limited to approximately one hour when the lube-filter differential pressure rose to 40 PSIG. The lube-filter element was cleaned and reinstalled.

The unit was again operated at various loads to observe the vibration levels. The lube-filter differential pressure remained at approximately 15 PSIG, and it appeared that the lube system had flushed itself of the contaminants. The unit was now operating satisfactorily for NETE to carry out their testing.

After Mr. Connolly left, we corrected instrumentation snags and ran off the baseline engine-performance and vibration characteristics tests. The normalized engine performance parameters are shown in *Figure 7*. We ran off discrete frequency and octave-band vibration spectra. The comparison of the octave-band levels with the shipboard norms is given in *Figure 8*.

One particularly interesting outcome of these tests was a comparison between the combustion efficiency of this engine, with its regular high-pressure spray nozzles, and that of an engine having atomized air combusters which



The Solar Saturn dressed for shakedown tests, including oil-vent header with drain back to the oil tank (bottom left of photo).

SOLAR SATURN 10591 BASELINE TEST
AT NETE WITH ELECTRICAL LOAD 400 KW. (6 JUNE, 1985)

						E26190						
POINT	0.A	8HZ	16HZ	31HZ	63HZ	125HZ	250HZ	500HZ	1KHZ	2KHZ	4KHZ	8KHZ
01V	0	0	107	96	104	102	104	103	106	96	97	99
02V	0	0	108	96	107	100	109	114	101	96	99	106
03V	0	0	100	88	100	97	100	94	95	104	113	106
04V	0	0	100	85	103	104	85	83	84	81	84	87
05V	0	0	105	102	111	103	101	105	97	97	107	103

			E26190						-E26190AV				
POINT	0.A	8	16	31	63	125	250	500	1K	2K	4K	8K
01V	0	0	10	0	2	-2	-5	-6	-1	-6	-7	0
02V	0	0	8	-2	2	-4	-6	-3	-4	-5	-5	8
03V	0	0	3	-5	2	-2	0	-8	-7	-8	-3	-1
04V	0	0	1	-7	11	9	-3	-2	1	3	7	13
05V	0	0	6	1	1	-3	-6	-4	-4	-9	-1	6
NO OF EXCURSIONS ZERO:	0	0	5	1	5	1	0	0	1	1	1	3
NO OF EXCURSIONS 6VDB:	0	0	2	0	1	1	0	0	0	0	1	2
NO OF EXCURSIONS 12VDB:	0	0	0	0	0	0	0	0	0	0	0	1

Fig. 8. Comparison of vibration levels with shipboard norms.

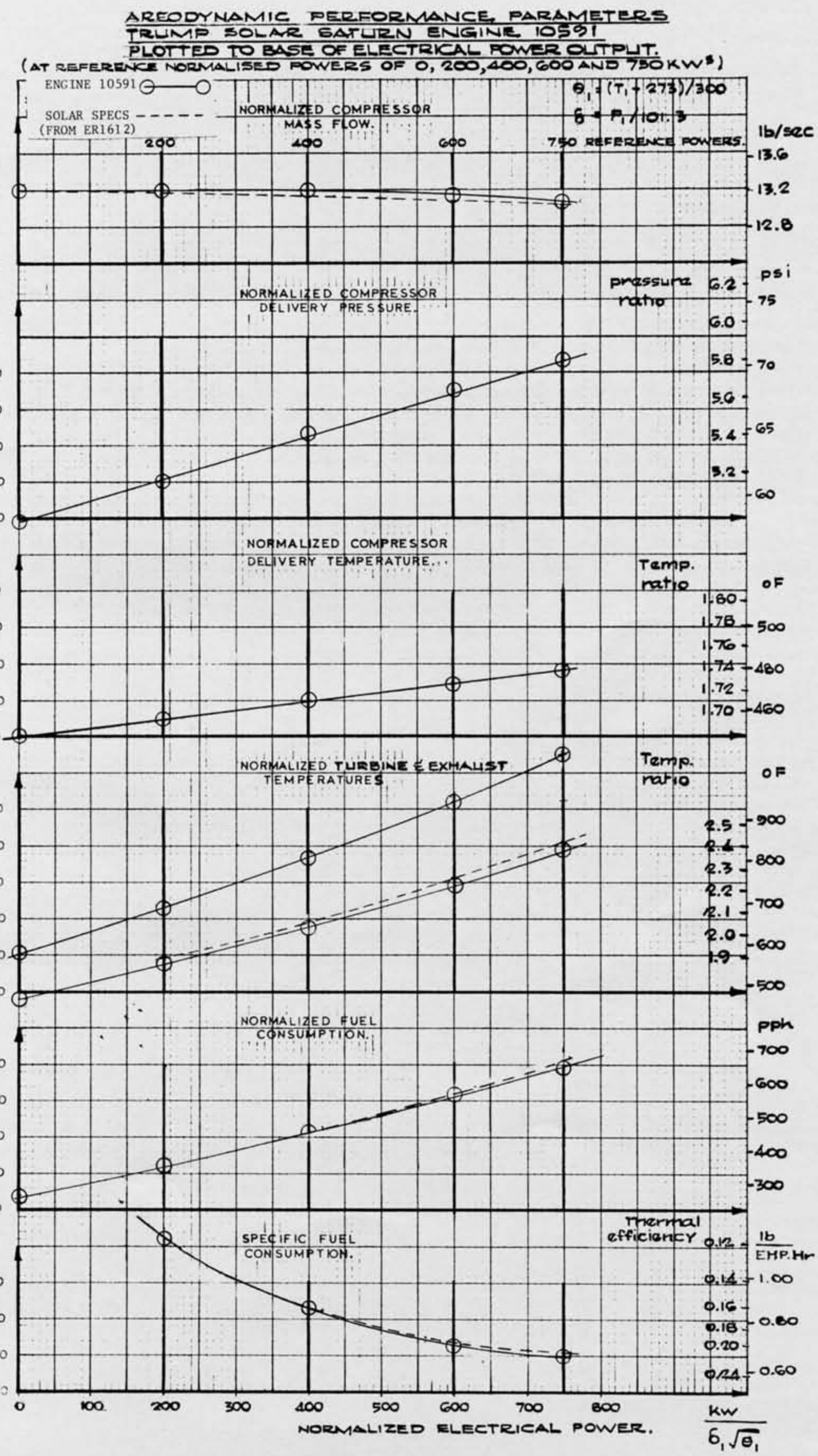


Fig. 7. Normalized engine-performance parameters plotted to base of electrical power output.

was tested in 1980. The engine with the high-pressure nozzles clearly outperformed the other:

Combustion Efficiency %					
Load kW (Electrical)	0	200	400	600	750
1980 Test (Atomized Air Nozzles)	98.33	99.19	99.43	99.53	99.62
1985 Test (HP Fuel-Pressure Nozzles)	99.56	99.66	99.54	99.73	99.82

This brings us to the end of the Solar engine installation project. The baseline runs were completed at the beginning of June 1985, almost on schedule, 23 working weeks after the Bombardier diesel was removed from the test cell. The TRUMP package tests had already commenced on 13 May 85, but that's another story.

(Ed's Note: An evaluation of the Solar TRUMP modifications will appear in an upcoming issue.)

Author's Acknowledgement

Thanks are due to *LCdr Lavallée*, Commanding Officer NETE; *Mr. Costis*, Manager NETE; *Mr. Speirs*, Technical Services and *Mr. Abdelrazik* for constructive critiques of the drafts of this article. *Mr. Banford, Mrs. Henderson* and *Mrs. Valardo* of NETE Office Services achieved the impossible — they made the manuscript readable.

C.A.W. Glew served with the Royal Air Force as an engine fitter and flight engineer for 12 years after completing an aircraft engineering apprenticeship in 1943. He subsequently obtained a B Sc in Mechanical Engineering at London, England in 1957 and a Master of Engineering degree at McGill in 1964. In between university spells he worked on free-piston engine development, and tested Pt 6 gas-turbine engines for Pratt and Whitney of Canada Inc. In 1964 he joined the Naval Engineering Test Establishment as a project engineer specializing in heat transfer, and later worked in the areas of machinery vibration monitoring and gas-turbine engine health monitoring. He is currently the Special Projects Engineer at the Establishment. Mr. Glew co-authored "The Development of Vibration and Rundown-Time Norms as a Quality Control Tool for Overhauled Electric Motors" *that appeared in our January 1985 issue.*

Editor's Note: The installation of the Solar Saturn at NETE was originally done in support of development work for a stand-alone SHIPALT which is now planned to coincide with the TRUMP refits.

Correction

In our April 86 issue we erred in the transcription of two equations contained in LCdr Lenk's article on "The Fast Fourier Transform". The equations, on p. 29, should have read:

a. For a sequence x(n), the DFT X(k) is defined as:

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

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

b. The IDFT is defined by:

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

Also, the submarine sketch on pp. 10-11 of Dave Perkins' article should have been labelled as CC2.

Combat Systems News Briefs

Embedded Systems Processor

Computing Devices Company of Ottawa is developing a replacement for the AN/UYK-502 processor used by the SHINPADS standard display. The new processor will be based on the Motorola 68020 microprocessor and will be embedded in the display driver assembly. Software development will be done in Ada. The first phase of the work is expected to be completed by mid-1987.

Acoustic Range Prediction System (ARPS)

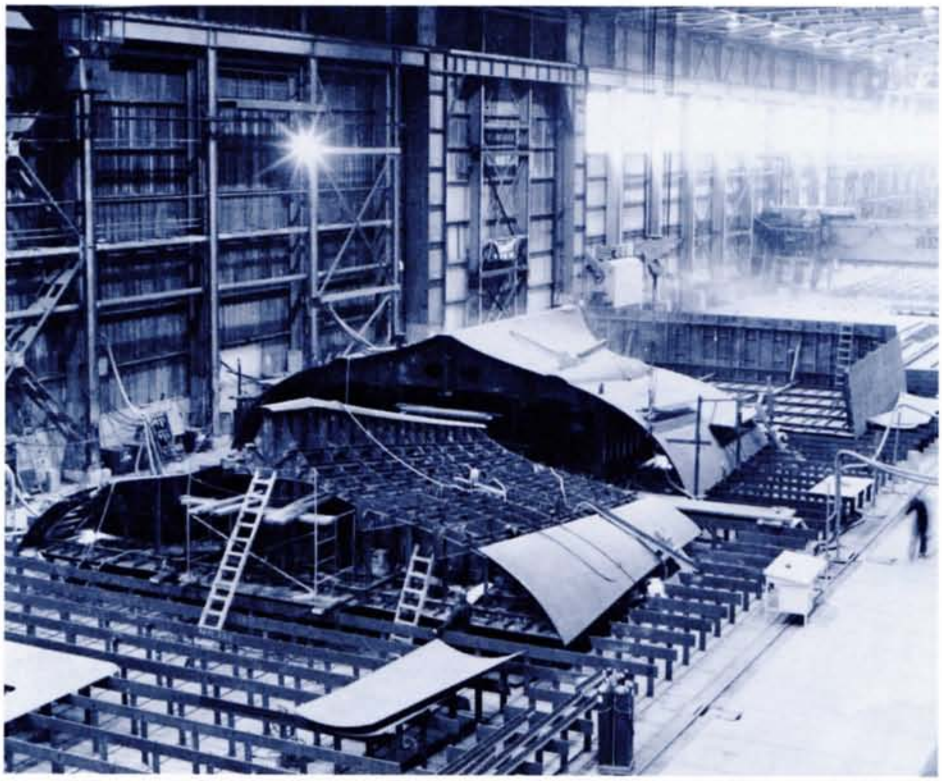
In order to proceed with CRAD development funding for a Canadian ARPS, a contract was let to Oceanroutes Ltd. of Bedford, N.S. in April 86.

Two Hewlitt Packard high-performance, full 32-bit computers (HP9050) are being procured. Oceanroutes has completed the conversion of an improved ICAPS software program to run on an HP desktop computer. This ICAPS variant uses FACT 9D as the basic propagation-loss model.

ARPS(I) will provide the capability to calculate, in real time, low-frequency propagation-loss curves from local bathy measurements, and to update predicted range in response to any change of environment. This autonomous capability will ensure optimum deployment of sonar sensors and assess the effects which own ship or target manoeuvres may have on submarine contact holding ability. Initial trials are scheduled for HMCS *Fraser* this fall.

Future enhancements will include other active/passive propagation-loss models and associated data bases.

CPF Construction



Coming up in our January issue!

MARE

RELIABILITY AND ACCURACY

Maritime Experimental and Test Ranges