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Le Journal du Génie maritime est une publication autorisée des ingénieurs maritimes des Forces canadiennes, à caractère non officiel. Edité 2 fois par an par le Quartier général de la Défense nationale, il bénéficie d'une large diffusion dans les milieux du Génie maritime. Les opinions qui y sont exprimées n'engagent que la responsabilité de leurs auteurs et ne reflètent pas nécessairement le point de vue officiel. Le courrier doit être adressé au rédacteur du journal du Génie maritime, Directeur – Génie maritime et maintenance (DMGE 5), Quartier général de la Défense nationale, Ottawa (Ontario), K1A 0K2.

Couverture: Représente un projet non officiel d'écusson du G Mar, créé par le DGGMM. Les lecteurs sont vivement encouragés à exprimer leurs commentaires sur ce projet d'écusson, à suggérer toute amélioration ou nouvelle formule qui leur semblerait souhaitable. Il sera tenu compte de tous les avis et, pour finir, un écusson officiel sera retenu et soumis à approbation.

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Editor's Notes

MARITIME ENGINEERING JOURNAL
SUMMER EDITION, 1983

This is our third edition and we are now getting into the swing of regular productions. We think you will find this an interesting edition. The Commodore's Corner was written by Rear Admiral Hotsenpiller. He was a Commodore when we approached him to write for us but since then he has been promoted. We thought that you would still like to hear his perspective of the branch from where he sits. Commodore Ball has expressed his thoughts on OPDP in the NOTEBOOK of this edition. Our younger members will find it of interest. In March some of our fellow officers were involved in producing a MARE Classification Specification and Captain(N) Barrett has taken time to describe the process to us. While we are on personnel Captain(N) Baxter has written a paper describing the Marine Engineering Technologist Training Plan. Two technical papers have also been included, one on Health Monitoring and the description of An In-Line Speed Change Gear Unit. In addition, Commander Embree has submitted a submarine article he wrote during the 82/83 Staff College Course. As I said in the last edition, the Journal can only survive and thrive through the lively input of its readers so let's hear from you.

Letters to the Editor

THE MEAN LOOK

I imagine HMS GLASGOW, WW II vintage, would have warmed LCDR Wiseman's heart. As this 1946 photograph taken in Simonstown Dockyard shows, she managed to look fast and belligerent even in drydock with the anchor down!

Our MEAN LOOK, indeed our very manliness, was somewhat tempered when we emerged from that refit to become the first postwar flagship of the East Indies Station, painted in the peacetime colours of the station, white hull and superstructure, buff funnels and masts! The rather dainty curtains at the portholes, courtesy of the ladies of the Capetown Navy League, didn't help either!

Nevertheless, a ship to have pride in.

G. Blackwell
Director Maritime Engineering Support

THOUGHTS FROM THE VALLEY

I wish to comment on the second edition of the Journal and perhaps, also, bring you and others up-to-date on Cornwallis and recruit training.

I think you are well aware of my feelings about the necessity for a MARE Journal, particularly if we are to enhance our professional self-image. We older MAREs know and appreciate how professional we really are in relation to industry. The key is to demonstrate this to our young officers as they often cannot perceive what Marine Engineering is about beyond their early postings at sea. The MARE Journal is perhaps the best answer by far to tackle this problem. If properly done our cohesiveness as a professional body of Marine Officers will be enhanced. It is vital, therefore, that the MARE Journal continue. I am not privy to the response you are getting from the "field". Whether or not it is overwhelming, I consider it vital that you NDHQ folks continue to provide the necessary leadership in the form of articles, editorial work, and "Branch News". Keep up the good work.

The business of being a Base Commander is a natural for a MARE. Beyond the obvious requirement for leadership, a MARE can bring to the position an excellent understanding of: working with civil servants, BTSO activities, the realities of the Defence Services Programme, how to get support from NDHQ... etc. I find that my officers here at Cornwallis all tend to be specialized in what I consider to be very narrow pursuits. I am not talking about the doctors and lawyers, but rather about my support and, indeed, my "sharpenders". Put another way, MAREs in my opinion have a far more versatile upbringing than most. I am not suggesting we are "jacks of all trades and masters of none". Rather we are excellent at a far broader range of pursuits and this is a strength we should be proud of. I could dwell on this theme for pages. However, my main point is that MAREs should not shy away from Command postings as we are just as capable and often more so than those officers of other classifications.

Some words about new entry training. The standard of today's recruit is far superior to that which we normally picture. Gone is the day of the grade 8 drop-out. Rather, the recruits I have been exposed to on average have all graduated from high school. Many have advanced post secondary education. For example, one recruit I talked to recently had a BSc and one year towards a Master's degree. The excellence of today's recruits is reflected in Recruit School attrition figures which have plummetted from 19% to about 4%. In short, today's recruits are very capable and it is heartwarming to witness the desire to succeed displayed by them. As a MGen from the US Army Recruit School at Fort Dix, N.J. recently observed during a visit to Cornwallis: "US recruits under training display fear in their eyes, your display interest amd desire". Thus, make very certain that those of you who receive our Cornwallis graduates treat them with the dignity they deserve and not the old "cannon fodder" approach. Today's recruits are both tough and intellectually agile. If challenged they will "stick around for as long as Canada needs them". However, if taken for granted and not led, they will ultimately go elsewhere.

Keep up the good work with the Journal. I am looking forward to the next issue.

Captain (N) J.D.S. Reilley
Base Commander
Canadian Forces Base Cornwallis

Commodore's Corner

BY REAR ADMIRAL W.B. HOTSENPILLER, OMM, CD
CHIEF PERSONNEL SERVICES

Commodore Hotsenpiller was commissioned in June 1955 having attended, from 1952 until 1955 an Aeronautical Engineering course at what is now called Southern Alberta Institute of Technology in Calgary. After his first year of service on various squadrons at HMCS SHEARWATER and in the carrier HMCS MAGNIFICENT, he was appointed for further studies to the Royal Naval Engineering College Manadon. On graduation he was posted back to HMCS SHEARWATER for Air Engineering duties as the Squadron Air Engineering Officer on VT-40 and VU-32. In late 1959, Lieutenant Hotsenpiller joined HMCS BONAVENTURE to obtain a Marine Engineering qualification. His tour of duty in the carrier's engineering department ended in May 1961 with an appointment as Engineer Officer of HMCS JONQUIERE. In December of 1963 he was promoted to the rank of Lieutenant Commander and posted back for "Naval Air" employment at HMCS SHEARWATER, having obtained an "Upper Deck Watchkeeping Certificate" during previous sea deployments. In 1966 Lieutenant Commander Hotsenpiller was selected to attend Course #1, CF Staff College in Toronto, following which he was posted to NDHQ as the career manager for the MARE classification. He was promoted to Commander in 1969 and became the career management "section head", for majors and below, of all Engineering classifications. From 1970 to 1973, Commander Hotsenpiller was employed as Engineering Officer and finally as Planning Officer in HMC Dockyard, Esquimalt. He was promoted to the rank of Captain(N) in August 1973 and posted as the Director Personnel Careers (OR) – Operational/Technical in NDHQ where he served until the summer of 1976. Captain Hotsenpiller was then posted as the Commanding Officer, Ship Repair Unit (Atlantic), for two years. He was appointed an Officer of the Order of Military Merit on 11 December, 1976. He was promoted to the rank of Commodore in 1978 and took up duties as the Commanding Officer of CFB Borden until July 1980. He completed a 3 year review of personnel policies in June 1983 at which time he assumed his present duties and the rank of Rear Admiral.

I have been asked to prepare a short article on developments in the MARE branch from my perspective. In searching for a contemporary issue which would be consistent with the objectives of the Maritime Engineering Journal I was pleased to note Commodore Healey's article on the CPF program since this subject is uppermost in our minds at the moment. Obviously the MARE classification will be called upon to play a vital role in the major capital acquisition programmes of the late 1980s. It is equally clear that the future of the navy depends on the timely provision of adequate numbers of experienced and dedicated MARS and MARE officers if we are to meet the challenges which lie ahead. Nor can we neglect our men and the quantum leap in technological challenge which they face, thus it is gratifying to note that the efforts to introduce major changes implicit in the MORPS programme are beginning to bear fruit.

My subject therefore is people and in the interests of brevity I will confine my remarks to those initiatives which directly affect the MARE classification. Before venturing into the realm of future conditions it might be useful to dwell a pause and consider where we have come from. You will recall that the combat systems engineer emerged out of the ashes of the "General List Scheme" as a necessary evolution of the old Ordnance and Electrical branches. During the past two decades there have been numerous introspective examinations of the MARE classification and its professional capability. These ad hoc reviews resulted in a variety of improvements and we have watched our inventory of trained officers grow from 343 in 1973 to 450 early in 1983 (it is interesting to note that there are an additional 140 officers in various stages of academic and classification training).

Regrettably this steady growth in numbers has provided only a modest improvement in our ability to fill MARE positions, as the establishment requirement has increased at an even greater rate. Indeed, the current authorized manning level for trained MARE officers stands at 587, and we are currently unable to fill some 130-140 positions. The size of this deficiency primarily stems from the recent addition of 60 project management positions and unprecedented losses of trained officers in 1980 and 1981. Nor does this gap between requirement and MARE strength reflect major increases required to support a host of capital equipment acquisition programmes and the software development associated with these programmes. Since it takes from 4-8 years to produce suitable qualified engineers, our immediate reaction has been little more than a major redistribution exercise which will have undoubtedly affected many of you.

In addition to the foregoing numerical shortages we have recently discovered, thanks to Commodore Ball's "MARE Study", that the specifications which define our professional training and development were outdated. These training guidance documents concentrated primarily on the acquisition and employment of operator skills and contained only limited reference to the Life Cycle Management system upon which ship design, acquisition, and fleet support is based. The study raised other issues related to officer entry plans and the academic needs of the three sub-classifications which form the MARE classification.

It is worth noting that DGMEM and his advisory council have the professional development issue firmly in hand, due in no small measure to the fundamental analysis conducted under the auspices of the "MARE Study". Many of you are aware of the main features on this project and I will defer to Commodore Ball for an update in a future issue of the Journal.

Turning now to officer production matters you can be assured that the numerical health of the classification is receiving priority treatment within the ADM(Per) Group, assisted where necessary by MARCOM and DGMEM staffs. Short-term recovery is predicated on the need to take extraordinary measures to eliminate persistent backlog shortages and to ensure that we create sufficient steady state production capacity to match annual attrition. The time required to reach the approved manning levels will however be influenced by a variety of constraints, the most significant of which include:

a. the relative attractiveness of the MARE Classification to potential ROTP and DEO applicants;

b. the assimilation capacity at NOTC and in our training squadron;

c. the training effort and time required to achieve a sub-classification qualification, particularly where significant amounts of sea time are called up; and

d. the need to provide the young officers with satisfying employment as early as possible in their careers consistent with acquired levels of professional competence;

Our collective efforts to improve the MARE manning situation have received the personal support of the Maritime Commander and we are currently preparing action plans designed to produce about 50 more MAREs than we anticipate losing in each of the next three years. Assuming that we can achieve some immediate improvement in DEO recruiting and that we can attract the required numbers of CFR/UPTM officers we could reach target strengths prior to the introduction of the CPF into the fleet. The needed unity of purpose and determination within NDHQ and MARCOM staffs is obvious and I am confident that the MARE Classification will be "ready aye ready" to meet the exciting challenges which lie ahead. Indeed, I can't recall a time during the past 20 years when the needs of the navy have so completely overshadowed the parochial interests of individual components of the Naval family.

MARE Classification Specifications

AUTHOR CAPTAIN (N) N.A. BARRETT

Captain(N) Barrett is currently the Director of Military Occupational Structures (DMOS) in ADM(Per)/CPCSA/DGMU. He is a graduate of Acadia University, Nova Scotia Technical College, the 1958-59 Long Electrical Course at HMCS STADACONA, and the USN Post-graduate School in Monterey Ca, he has held a variety of posts including DMCS-6, Assistant Naval Attaché at CDLS(W) and CO NEU(P).

ABSTRACT

The purpose and meaning of the newly produced MARE Specification is situated within a perspective of the past. The processes by which the Specification is given effect are examined. It is concluded that with the MARE Study and Specification now nearly complete, the work of rebuilding the MARE community has just begun. Continuous active participation at all levels will be needed for some years. In this work MARCOM, DGMEM and ADM(Per) each play an important role.

INTRODUCTION

While most readers are generally aware of the principal findings of the extensive MARE Study conducted by DGMEM (Commodore E. Ball) over the past two years; and the fact that a MARE Specification Board was convened in March 1983, many are only vaguely aware of the processes by which the specification is put into effect and ultimately, the Career Manager has the right officer to post to the right job at the right time. For a number of reasons MAREs are somewhat suspicious of the CF Personnel System (the Green Machine Syndrome) mostly because they don't understand it nor do they perceive its relevance to their professional and naval lives. Yet, although often ethereal concepts are used, the Personnel System is a system. It is constantly at work changing lives in subtle ways and it constantly requires coherent inputs to remain stable.

The real purpose of this article is tutorial in nature, with the hope that it will have painted a broader picture within a conceptual framework.

Many MAREs perceive the Personnel System to be either somewhat irrelevant, or worse, a threat to their ability to exercise their profession as Naval Officers and Engineers. Some of this fear goes back to perceptions held at the time of Unification and some can be attributed simply to fear of the unknown. By shedding some light on the processes by which changes are instituted and controlled I hope to convince readers that the personnel part of the "Green Machine" is a system to be used, and not something to be feared.

SOME DEFINITIONS

Everyone in the Canadian Forces belongs to a Classification (Officers) or Trade (Other Ranks). At the moment there are 32 Classifications and 99 Trades in existence. This set of occupational groupings is called the Military Occupational Structure. Each member of the set is described by the Specification pertaining to that Classification or Trade. Each Specification enumerates the tasks, skills and knowledges expected to be inherent in all personnel in that Classification/Trade, at various stages of their careers. The Specifications define the parameters of the careers of every member of the CF. In effect, it is the "WHAT IS REQUIRED".

Given the Specification for a Trade/Classification, training is then designed to impart the necessary skills and knowledges to the members of each occupational group. The training is documented in course training standards, performance objectives and finally in the constituent parts, the lesson plans. These documents provide the "HOW IS THIS ACHIEVED" and should be prepared after the requirements are known, and not before, as is all too often the case.

PERCEPTIONS

Because all MAREs have spent so much time in classrooms there is a natural tendency to attempt to define solutions to perceived problems in terms of altered training requirements, rather than in terms of altered specification requirements. The original MARE specifications were drawn up in 1969 and after several revisions were approved in 1972. Since then, despite a number of significant changes in MARE training, the specification has not been changed. As a result, along the way we lost sight of what we were really trying to achieve. The recent MARE Specification Board went back to fundamentals, took a fresh fix on actual requirements and is now being staffed for approval. March 1983 will prove to be a significant new beginning.

The perception that the "Green Machine" is somehow menacing probably stems from the trauma surrounding Unification in the mid 60s. In a very short period of time the Navy's traditions were surplanted by a new order. On one hand the Navy recoiled to the sanctity of its wardrooms to try to preserve its ethos. On the other hand, NDHQ imposed very strict controls to ensure that the newly established order was not changed. As a result, a feeling grew up that the problems of the Navy could only be solved by the Navy, and only if NDHQ didn't know too much about it. Because of the strict injunctions against change within NDHQ, the mechanisms to allow and control change were allowed to atrophy. The net result was that the Navy tended to focus its attention on changed training as a means to meet new needs but tended to ignore other highly related aspects which were within the sphere of ADM(Per).

Thus the inherent training oriented focus of MAREs, coupled with the distrust of ADM(Per) engendered by attitudes formed in the mid 1960s, have in the past led the Navy to try to achieve better solutions by manipulation of only one of the variables available, the training scheme.

There are many other dependant variables in the equation and each has a significant effect on the total result. The Specification requirements ultimately have to be proven to be physically realizable in practice. The target strength for a Classification has to be drawn up to provide adequate career opportunities. The establishment has to be drawn up to meet operational needs but yet be realistic both in numbers and qualifications required. The training has to provide quality training but in a cost effective and timely manner. Entrance standards have to be set high enough to ensure that the training can be successfully imparted, but not so high that the numbers required can never be recruited given the climate of the day. To achieve a lasting stable classification all of these variables have to be considered simultaneously, and an iterative approach is usually required.

This iterative approach requires the full participation of three major agencies; the principal using Command (MARCOM), the Branch Advisor (CMDO and DGMEM) and ADM(Per). Whether or not this sharing of authority is necessary, is in itself a lively subject of debate. However, it is a fact, that has been for a number of years and will be a fact for the foreseeable future. It is clearly a case where it is better to use the system that exists than to attempt to solve problems by working the levers on only two sides of the triangle.

HOW THE SYSTEM WORKS

The process of changing the Military Occupational Structure (MOS) is complex and to date, not well defined. A new CFAO and amendments to A-PD-150/A-PD-123 (the Specifications) are being prepared in DMOS to provide some better visibility on what can be a lengthy, difficult process. However when one looks at all the functional steps in the process, a strong analogy can be drawn to the SHIPALT process.

As you will recall, a SHIPALT starts its life as a proposal and a certain amount of engineering is done to establish the theme design and likely costs. The proposal is then placed before the Naval Modification Review Board to seek approval to develop it in a full, engineered sense. When this work is completed approval of the Board is again sought to make plans for actual installation. This "Approval in Principle" allows further work to proceed culminating in "Approval to Implement", usually associated with a refit.

Figure 1 depicts the process used to modify the MOS in simplified diagrammatic terms. It has been portrayed in a form which closely parallels the SHIPALT process. The "MARE MODIFICATION REVIEW BOARD" in fact would be a "Steering Group" chaired by DGMU (BGen J.A. Williams) with the following as permanent members:

a. DGMEM (Branch Advisor);

b. DGPCO (Posting and Careers Officer);

c. DGRET (Recruiting Education and Training);

d. DGOM (Organization and Management); and

e. MARCOM COS P&T (Personnel and Training).

When a problem is detected in a Classification a proposal for change is initiated by the Sponsor. Any agency can be the Sponsor, (but usually it is either the Branch, the Command or an ADM(Per) staff). Branch and/or Occupation Analysis (OA) studies are then conducted to further define the problem(s) and the proposed solution. A Specification Board is then called by DMOS to enunciate the proposed solution in the form of revised draft Classification Specifications. The asterisk denotes the status as of 1 May '83 in respect to the MARE Classification.

The recent Specification Board chaired by Captain(N) J. Dean had a particularly challenging task. The old (1972) Specification was clearly overdue for change, the needs of Naval Architects and Constructors had to be addressed, ADP requirements considered, and all expressed within the bounds of personnel policies. The Board also was to write a version of the Specification for use should general mobilization ever be required. The membership of the board was carefully chosen to provide a balance of age, experience and expertise, and they set about their work with vigour, determination, professionalism and a great deal of lively discussion. DMOS sponsors a large number of Specification Boards each year and, without bias, Captain(N) Dean's Board was one of the best. The interests of the MARE community were exceedingly well served by:

a. Captain(N) J.G. Dean, Chairman;

b. Commander M.P. Wall NDHQ/DMEM 2;

SPEC BOARD CONVIENS 28 FEB 83

TOP:
CMDRE BRIEFS THE SPEC BOARD

BOTTOM:
DGMEM DIRECTORS, CAPT(N) DEAN, CAPT(N) GRUBER, AND CAPT(N) LAWDER ADD THEIR INPUT TO THE PROCESS

CAPTAIN (N) BARRETT BRIEFS THE BOARD.

THE BOARD HARD AT WORK

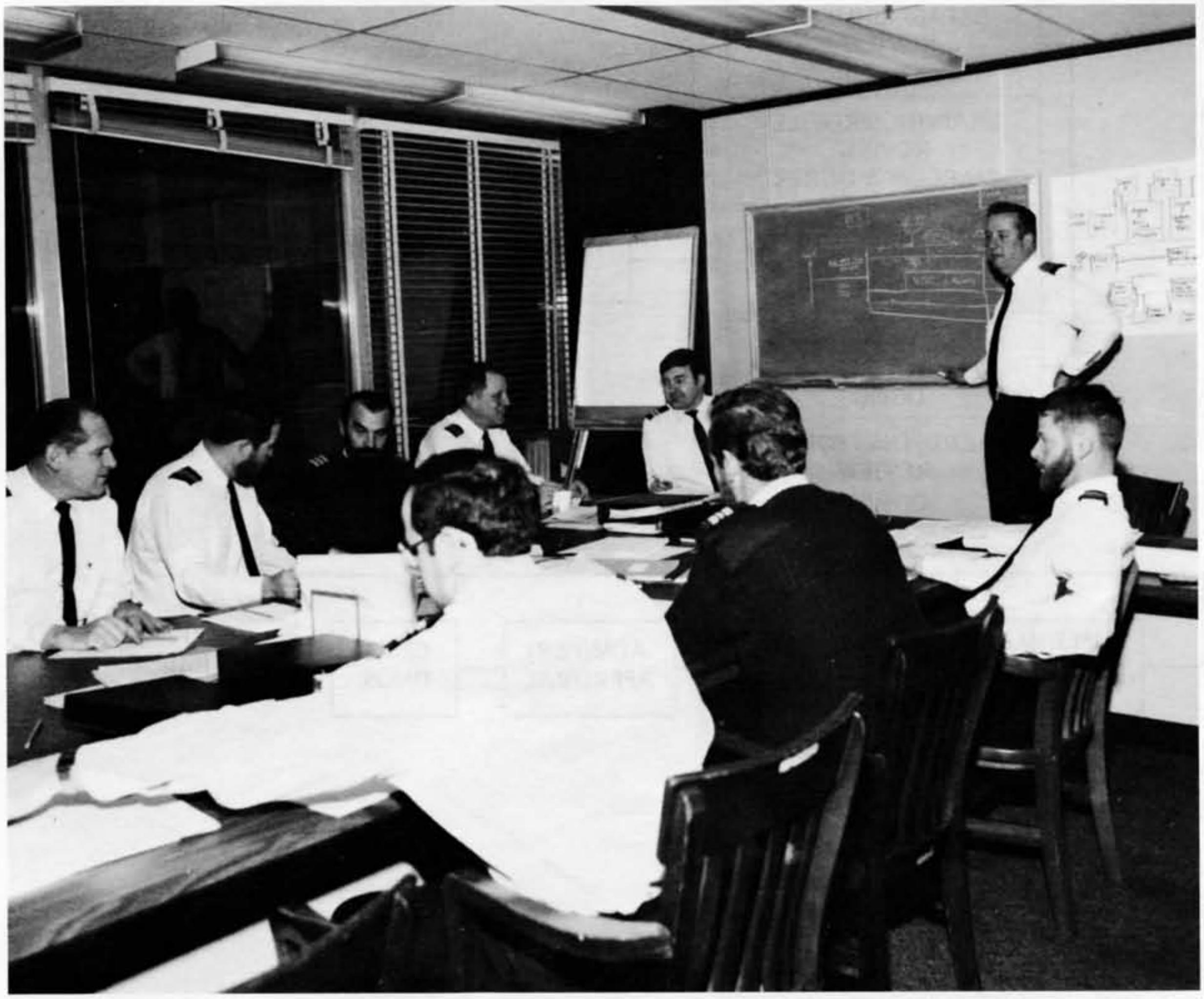
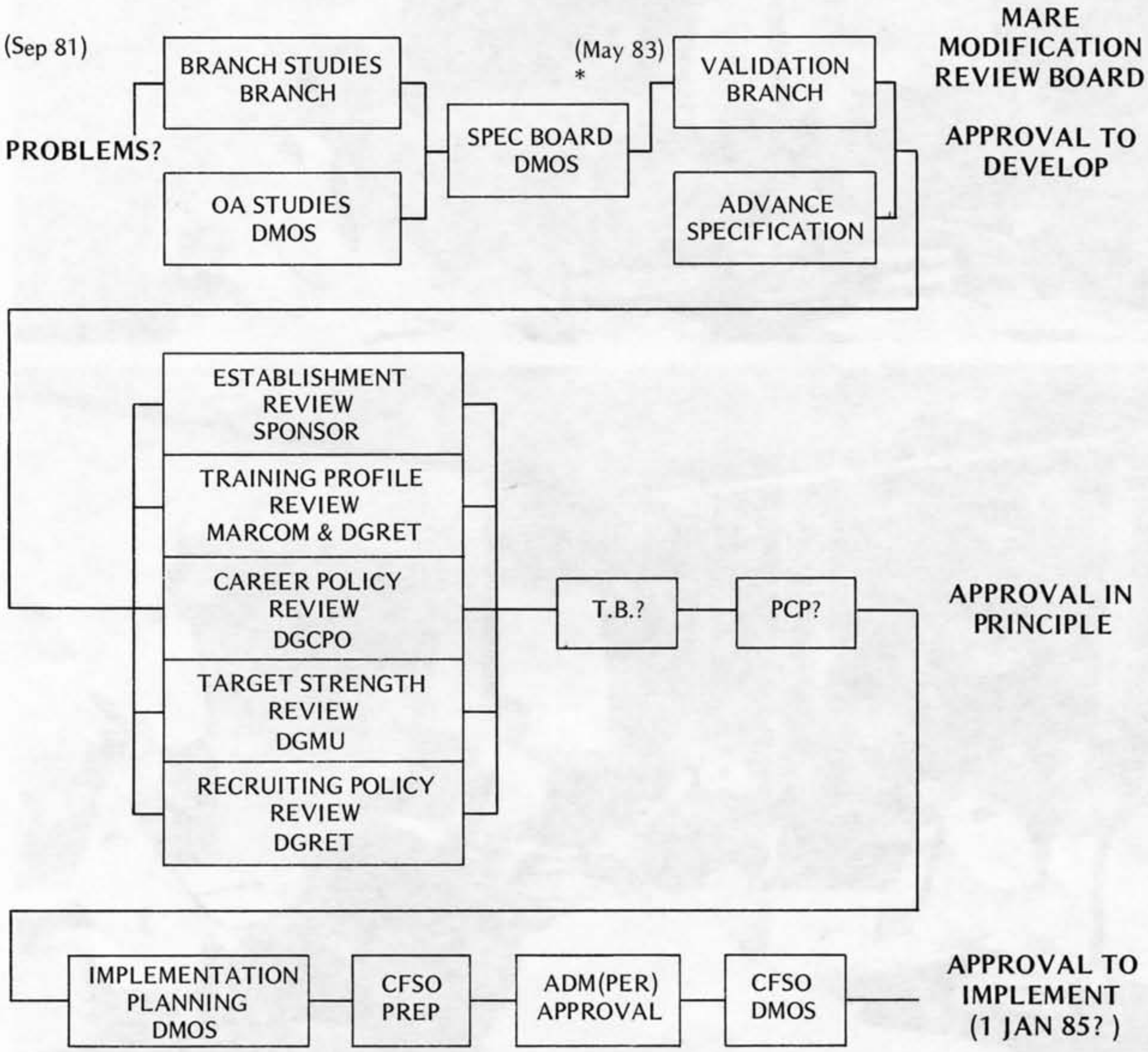


FIGURE 1

THE MARE ALTERATION PROCESS



c. Lieutenant Commander H.G. Lunn NDHQ/DMEM 3-3;

d. Commander N.J. Moir NEU(A);

e. Lieutenant Commander P.J. MacGillivray NDHQ/DMEE 7;

f. Lieutenant(N) V.A. Craig CFFS Halifax;

g. Commander A.G. Sinclair CFFS Halifax;

h. Lieutenant Commander P.A. Cadeau FMG Halifax;

j. Lieutenant(N) J.R. Fisher NDHQ/DMEE 7-2;

k. Lieutenant(N) W.L. Stanbrook NDHQ/DMCS 6-5; and

l. Captain S.W. Cote NDHQ/DMOS in support.

Upon ratification of their draft specification by the MARE Council, (hopefully in the near future), the MARE Steering Group would then be asked to give its approval to develop the design based upon the ratified draft MARE Specification.

At this point a series of parallel studies will have to be made. Given the ratified draft Specification the following questions have to be asked:

a. How many of each kind are needed in which jobs;

b. What would the training profile be and is it affordable;

c. Can we wait that long for the numbers we need;

d. What effect would implementation have on the careers of existing and future MARE officers in terms of promotion requirements and possibilities;

e. Including the effects of attrition, how many would have to be recruited and then trained to meet the need; and

f. How would we recruit that many of that quality.

As can be envisioned each of these studies depends on some aspect of other studies and any study has the potential to determine that it is impossible to achieve the aim given real life constraints. When this happens some of the starting assumptions (including the Specification) may have to be adjusted and the studies repeated. At some point the solution set converges (one hopes!) and the next set of questions is addressed.

In many cases the permission of the Treasury Board must be sought to change aspects of the MOS. In all cases where the solution is dependent upon the provision of either an increased Establishment or additional funds, a Program Change Proposal must receive the blessing of the Program Change Board. This is done in the same manner as a capital acquisition program except that the Preliminary Development Proposal step is bypassed. Once past this formidable hurdle the final proposal is ready to receive "Approval in Principle".

The Implementation Planning phase in itself can be complex because so many factors may have to be taken into account. As hypothetical examples, a change to Specificatons, requiring the Fleet School to build a new plant facility to enable the course to be given, can't be executed until the new facility is ready for use. The Personnel Management Information System's computer can't be told to implement new qualification codes until it has been programmed to accept these codes. The complex staffing of actions are coordinated by DMOS, but requires the full participation of both MARCOM and the Branch Advisor.

When all of this has been done, the CF Supplementary Order is prepared for ADM(Per) signature. When promulgated it becomes the executive order to put the changes into effect.

The whole process can take a number of years to complete, especially when the change is complex. While minor changes to Specification are routinely done by DMOS, the changes envisaged by the new Specification are major in nature and will require the full sequence to be followed. However, it is recognized that perhaps certain parts can be implemented immediately if it can be shown that the impacts are predictable and independent of other considerations. While there is no established "par time", a rough estimate of the time needed to complete necessary work is in the order of a further year and a half.

This may seem inordinately long and impatience may be displayed in some quarters. However, to give an example of what is involved in the consideration of just one of the requirements expressed in the Draft MARE Specification, the following may be instructive.

The Draft Specification requires that all CFR officers enter the Classification at the "Registered Technologist" level of competence. To establish whether this in fact is a practicable requirement requires answers to the following questions:

a. definition of "Registered Technologist";

b. definition of the difference between "Registered Technologist" and the certifiable levels reached by Tradesmen in both the present Terminal Trades and the new MORPS Trades;

c. quantification of costs of training needed to meet this standard in both financial and span time terms;

d. verification that the resources needed are available and the span times are acceptable;

e. verification that the numbers required by the Establishment and the OCDP career models can in fact be produced without causing an excessive drain on the Trades; and

f. determination of the disposition of current CFR officers who do not in fact hold "Registered Technologist" status.

Noting that it has taken over two years so far to arrive at the Draft Specification stage and perhaps another two to complete necessary actions, emphasizes the need for the MARE community to thoroughly examine requirements at least on a five year cycle rather than the current ten year cycle. The present status of the MARE Classification clearly demonstrates what can happen if it is assumed that stability can be retained for a decade by fine-tuning only the training part of the system.

CONCLUSION

It is encouraging to note that there is an increasing awareness in the MARE community of the need for continual professional introspection and that there is a growing understanding of the cooperative role played by ADM(Per) in this process. The staff of ADM(Per) is drawn from every military community and endeavours mightily to serve each to the very best of its collective ability. The communities that are the easiest to help are those who are the most informed and are able to interact well with those who stand ready to help.

Marine Engineering Technical Training Plan

AUTHOR CAPTAIN (N) B.H. BAXTER

Captain (N) Baxter joined the RCN in 1957 as a technical apprentice and graduated as a P2 ERA in 1961. Following service in HMCS Crescent Petty Officer Baxter was selected for the RCN Preparatory School as a College Training Plan student. This training included 4 years at the University of British Columbia and in 1968 S/LT Baxter graduated with a degree in Chemical engineering. From 1968 to 1971 he carried out both upper deck and engineering watchkeeping training in HMC Ships Saskatchewan, Chaudière and Gatineau. In 1972 LT Baxter was posted as the Engineer Officer of HMCS Terra Nova. After post-graduate training at Manadon LCDR Baxter assumed the position of Engineering Officer of HMCS Algonquin in 1975. Following Staff College in 1977 and promotion CDR Baxter was posted to NDHQ where he assumed Section Head duties in DMEE. During this period CDR Baxter completed his Destroyer Command Part 2 and was also awarded the Order of Military Merit (OMM). Commander Baxter is currently Section Head in charge of propulsion control and interior communications systems. Captain (N) Baxter was promoted to his present rank 18 July 1983 at which time he started French Language training.

ABSTRACT

This paper describes the development of the METTP programme and discusses those decisions which were fundamental to the overall METTP concept. The Canadian demographic scene is reviewed and the process leading to the pilot project is outlined. The selection of a METTP training facility is noted with a description of the programme implemented. The present status of the programme is reviewed.

INTRODUCTION

The Marine Engineering Technician Training Plan (METTP) is a pilot project whose aim is to assess the feasibility of a lateral entry recruiting and training concept in meeting Canadian Forces (CF) personnel requirements. The selection of the Marine Engineering trade to spearhead this initiative was based on several factors, including serious personnel attrition within this trade and a dramatic shift in marine systems technology which appeared to stretch the capability of existing marine engineering technicians beyond reasonable expectations. In addressing and resolving these marine engineering personnel problems, new concepts in recruiting and training were examined and METTP was developed to best meet these unique personnel requirements.

CANADIAN DEMOGRAPHIC PROJECTIONS

Demography is the study of statistics of births, deaths, educational trends, etc. as they apply to various population groupings. It is these demographic trends which strongly influence potential military recruiting markets. Failure to recognize these trends when addressing personnel requirements can result in a serious mismatch of personnel requirements and capabilities. In a rapidly changing technical environment this demographic realization is of paramount importance. Figure 1 illustrates the Canadian population trend in the 17 to 24 year old recruit market. The significant decrease in potential recruits (25% by 1990) is also adversely influenced by changing educational trends within the Canadian population. As shown in Figure 2 there is a marked increase in the number of Canadians who are electing to remain in school for post secondary education. The upper line of the graph represents this group. However, it is from the lower, less educated group that the CF traditionally recruits and with the exception of officer training programmes the vast majority of the Canadian population are not included in recruiting policies for highly skilled technicians and technologists. It is this untapped pool of Canadian expertise which is the cornerstone of the METTP concept.

The demographic projections clearly indicate that over the next 10 years military recruiters will be faced with an ever decreasing market of less capable recruits. These adverse conditions coincide with a era when advances in technology demand a more highly skilled military technician. It is clear that only by shifting recruiting plans to attract the more educated group of Canadians will the recruiters be able to meet their future personnel needs. Although these demographics represent the Canadian situation, similar trends are being observed in most other countries.

LATERAL ENTRY CONCEPT

To address the realities of the Canadian educational trends (Figure 2) there was a rapid increase in the number of community colleges throughout Canada. Many of these schools included study programmes which are compatible with existing CF trade requirements, including marine engineering. The schools not only contained modern instructional training aids but also included study programmes in the most advanced technologies. In particular, courses on micro-electronics, digital techniques, micro-processors, etc. are applicable to many of the high technology systems being considered by the Navy for all its existing and future (CPF) warships. As most of the community colleges were relatively new, their facilities and course curricula represented the latest state-of-the art development in both teaching techniques and technology.

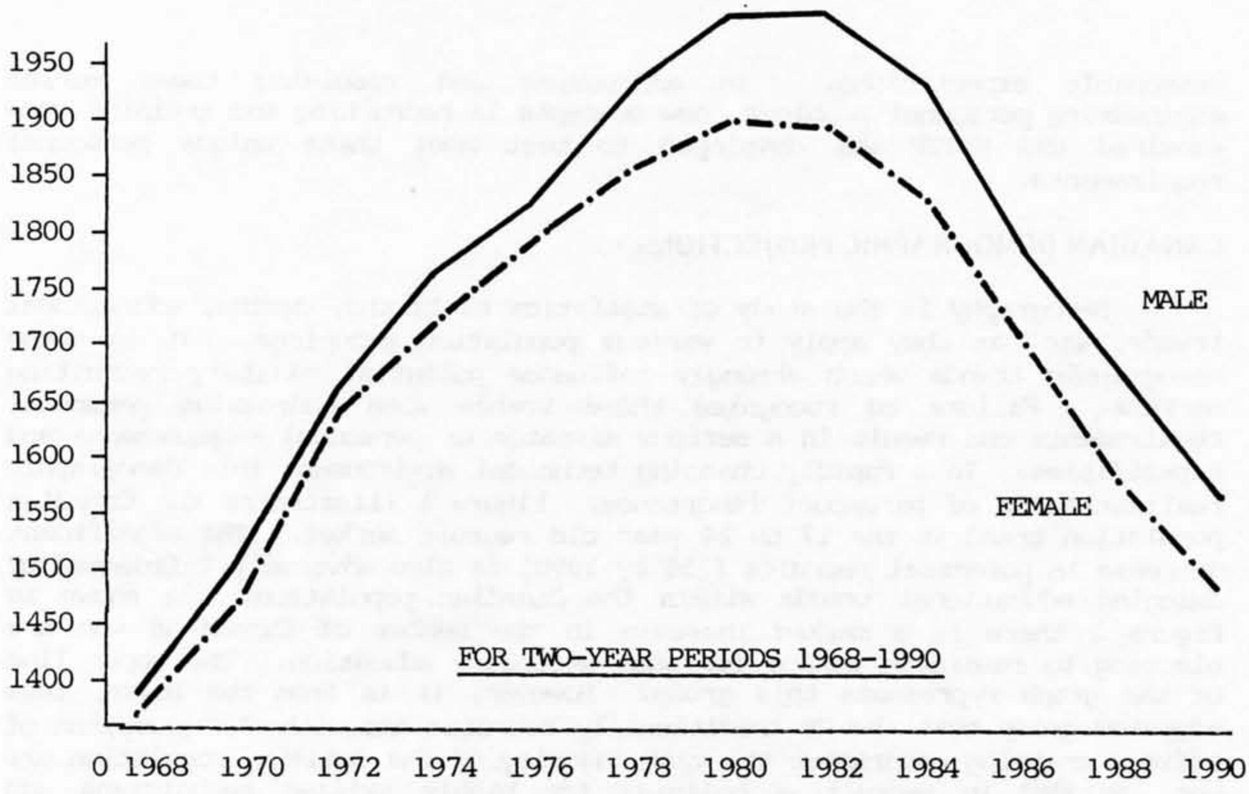


FIGURE 1. CANADIAN POPULATION TREND (17-24 YEARS OLD) IN THOUSANDS

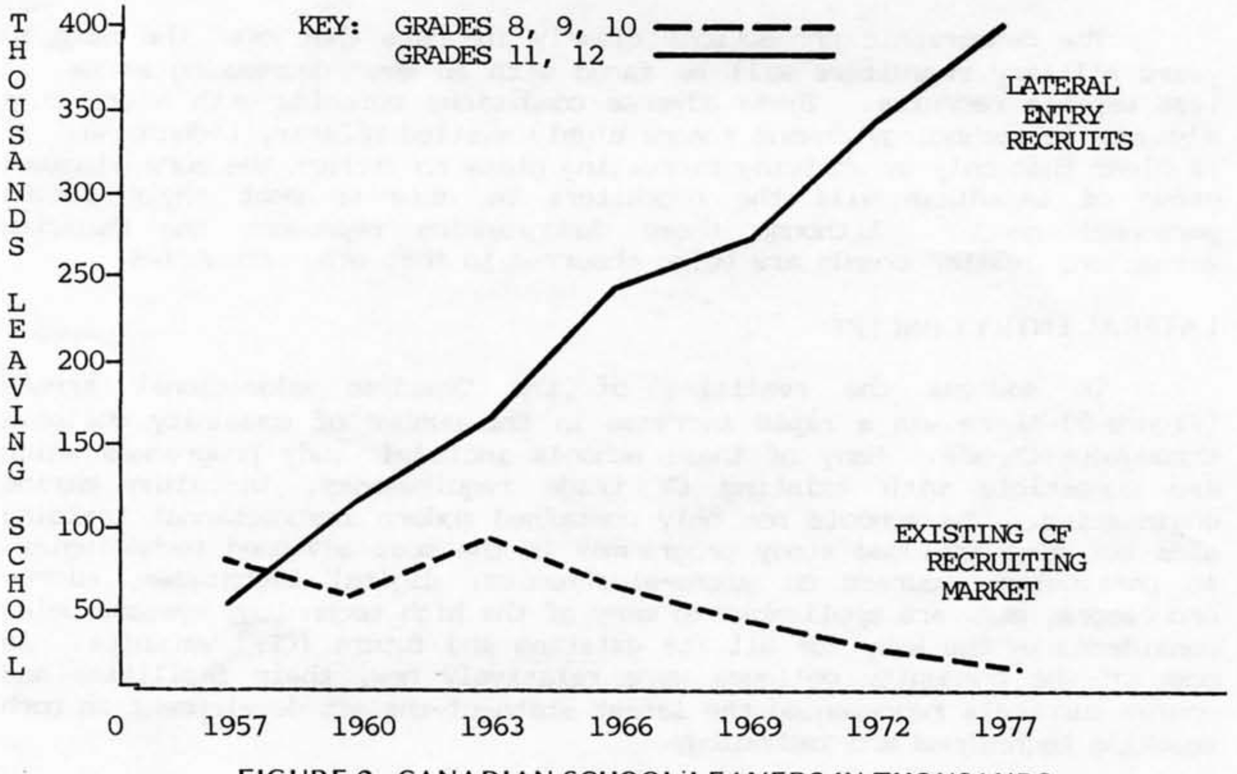


FIGURE 2. CANADIAN SCHOOL LEAVERS IN THOUSANDS

The lateral entry concept involves training of potential CF members at non-military educational institutions. In return for subsidized technical training the graduate is enrolled in the military at a point commensurate with his qualifications. As this normally involves accelerated promotion, the concept is referred to as lateral entry. In many ways the METTP lateral entry concept is a return to the former Naval Apprenticeship programme which served the Navy so well in past years. The personnel branch of the Canadian Forces were aware of the potential of the lateral entry concept and in 1979 a pilot project involving the marine engineering trade was approved to determine if a lateral entry recruiting and training programme could be developed to attract high calibre recruits into the CF. The marine engineering trade with its high historical attrition and demanding technical requirements was the ideal vehicle to test the concept.

PILOT PROJECT DEVELOPMENT

Ideally, the lateral entry concept involves recruiting graduates after they complete their technical studies. Initial studies and extensive interviews with potential lateral entry students confirmed the study team belief that such an approach would not be attractive enough to secure sufficient high quality recruits. The general consensus was that a funded education approach to lateral entry was necessary. In return for subsidized education, selected students would be committed to an obligatory period of naval service. The same approach has been successfully applied to university training plans for officers.

Most community colleges' technologist programmes are based on a three year curriculum. To avoid conflict with officer recruiting policies it was decided to limit the METTP programme to a 2 year curriculum with extensive complementary naval training in the non-academic periods of the programme. This decision limited the number of available training sites as it required the development of a special METTP curriculum to achieve the unique CF marine engineering trade requirements.

SELECTION OF THE METTP TRAINING SCHOOL

Seven potential training facilities throughout Canada were evaluated for the METTP project. Figure 3 depicts the results of the evaluation and clearly points out why St Lawrence College in Cornwall, Ontario was selected as the best site. It should be noted that although the purely Francophone training facility, L'institut Maritime Du Quebec, was not selected, this excellent marine school was assessed as the ideal site to implement the follow-on Francophone option of METTP which will commence in June 1983. Although not a specific selection factor the closeness of St Lawrence College to National Defence Headquarters in Ottawa, Ontario was certainly a point in their favour. Project personnel were able to directly communicate with College personnel and in all instances this close proximity

FIGURE 3.
EVALUATION OF POTENTIAL METTP TRAINING SITES

FACTOR	GEORGIAN	ST. LAWRENCE	DOUGLAS	PACIFIC MARINE	CAMOSUN	INSTITUTE MARITIME DU QUEBEC	COLLEGE OF FISHERIES
Academic Program	A	E	U	U	P	E	A
Facilities and Resources	P	E	P	P	E	E	U
Instructor Qualifications	A	E	P	A	A	E	A
Program Flexibility	E	E	U	E	P	P	P
Student Capacity	E	E	A	P	E	A	P
Accreditation	E	E	P	P	E	E	A
Civilian * Commitments	P	A	E	U	A	P	A
Administration	E	E	P	P	A	E	P
Proposal Interest	E	E	A	P	A	A	A
Military Experience	E	E	A	U	U	A	A

Evaluation Ratings

E – Excellent   P – Poor
A – Acceptable   U – Unacceptable

* Civilian Commitments refers to existing arrangements with commercial interests which could cause conflict with the CF proposal.

NOTE: This evaluation reflects the study team's assessment of how the various facilities could achieve the unique CF METTP requirements in marine engineering only. It is not an overall assessment of the school and in no way reflects the excellent standards all these schools maintain in their individual programmes.

allowed potential problems to be addressed and resolved with relative ease and dispatch.

All the evaluated training facilities were offering the traditional marine engineering curriculum, which, in the project team's assessment, was not acceptable in terms of the technology being considered for the highly complex CF warships. Naval marine engineering appeared to be leading the civilian marine industry by at least 10 years of technological advances. The lack of training on controls, instrumentation, digital techniques, electronics, micro-processors and computer applications was of particular concern to the project team as these technical skills were crucial to the long term requirements of the CF marine engineering trade. Discussions were held with St Lawrence College and a new curriculum reflecting CF requirements was developed. The curriculum included subjects from three established St Lawrence College Technologist programmes - Marine Engineering, Electronics and Instrumentation. Figure 4 illustrates the final METTP curriculum.

The objective of the METTP curriculum was to achieve CF marine engineering requirements while still retaining all the St Lawrence College courses which were required to achieve technologist graduation standard. Those subjects which were deleted to achieve the 2 year training programme were compensated for by the additional CF marine engineering training courses. The compression of the normal 3 year college course resulted in a 15 per cent increase in academic load for METTP students but, to date, academic results have been higher than expected, so the increased workload is not considered a significant factor in overall success or failure of the programme.

METTP TRAINING PROGRAM

The overall METTP programme is accomplished in seven training phases as shown in Figure 5. The purely military phases (1,4 and 7) are the critical phases as the available training time results in compressed military qualification periods which, if unsuccessful, could seriously impact on the military credibility of the graduates. The following comments reflect the study team's approach to the problem and the decisions which were made.

a. Phase One - Recruit Training. Normal new entry recruit and environmental training requires 16 weeks whereas METTP had only 8 weeks to accomplish this training objective. By opening up the METTP programme to qualified members of the CF marine engineering trade it was possible to include 15 fleet candidates in each METTP class. These highly motivated fleet candidates were required to repeat the recruit training with the civilian entry METTP recruits. This class concept of METTP recruit and environmental training was very successful and by using a "buddy" system it was possible to accelerate the training to the

FIGURE 4

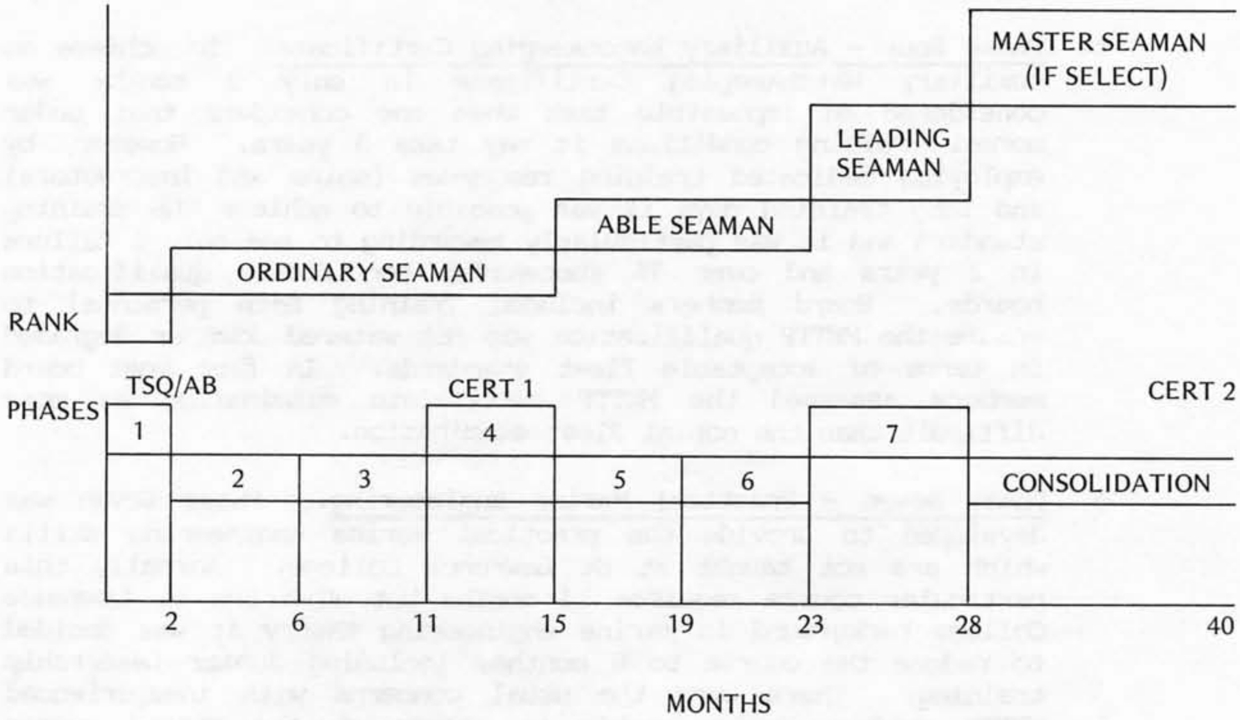
METTP CURRICULUM

PHASE I	PHASE II	PHASE III	PHASE IV	PHASE V	PHASE VI	PHASE VII
NEW ENTRY TRAINING	EN 10/20	EN 20/30	AMOC	ME 34/54	ME 80/81	TQC FLEET SCHOOL HALIFAX
	APPLIED COMMUNICATION I & II	APPLIED COMMUNICATION II & III		BASIC THERMO-DYNAMICS	APPLIED THERMO-DYNAMICS	
	MA 10	MA 20		MA 30	ME 63	
	TECHNICAL MATH	BASIC CALCULUS		APPLICATION OF CALCULUS	NAVAL ARCHITEC-TURE	
	PH 10/50	IN 01/02		ME 88	IN 30/31	
	APPLIED PHYSICS & LAB	BASIC INDUSTRIAL INSTRUMENTATION LAB		ENGINEERING MATERIALS & QUALITY ASSURANCE	BASIC CONTROL THEORY & LAB	
	ME 01	EL 34/35		IN 58	ME 24/57	
	TECHNICAL DRAWING I	DIGITAL CIRCUITS & LAB		COMPUTER INTERFACING	BASIC FLUID POWER & LAB	
	EL 78/79	EL 20/21		IN 34/35	IN 36/37	
	INDUSTRIAL ELECTRONIC FUNDAMENTALS	ELECTRONIC FUNDAMENTALS & LAB		PNEUMATIC PROCESS INSTRUMENT-ATION	ELECTRICAL MACHINES & POWER SYSTEMS THEORY & LAB	
	CH 09	ME 10/50		ME 64	ME 30/59	
	GENERAL CHEMISTRY	MECHANICS & LAB		MARINE POWER SYSTEMS	MACHINE DESIGN	

PHASE IV: AUXILIARY MACHINERY OPERATING CERTIFICATE. (CERT 1)

PHASE VII: PRACTICAL MARINE ENGINEERING TRAINING INCLUDING: – MACHINE SHOP; FITTING; OVERHAUL; MACHINERY OPERATING TECHNIQUES AND JLC.

FIGURE 5
METTP TRAINING CONCEPT



PHASE I - CFB HALIFAX/CORNWALLIS

- New Entry Training
- TSQ/AB
- Sea - 1 Week

PHASES 2 & 3 ST LAWRENCE COLLEGE

- Hand picked Marine Engineering Courses
- Supplementary Military CERT 1 Lectures
  - Auxilliary Machinery Operation
  - Lubrication
  - Safety
  - Seals, Packings, etc.
- Military Training
  - Divisions
  - Rifle Drill

PHASE 4 - HALIFAX-ESQUIMALT

- Certificate 1 at sea

PHASES 5 & 6 ST LAWRENCE COLLEGE

- Marine Engineering Courses
- Supplementary Military Lectures
- Organization
  - NEU, NETE,
  - NDHQ
  - Dockyard
  - SMMIS, etc.
- Technical Topics
  - Hydraulics
  - Gearing
  - Power, Vibration, etc.

PHASE 7 - HALIFAX

- TQC/JLC
- Maintenance Skills
- Technical Reports

CONSOLIDATION PHASE AT SEA ON HMC WARSHIPS

- Consolidate all previous training
- Further practical sea experience
- Achieve Certificate Two

required rate. The benefits of being selected as a fleet METTP candidate far outweighed the short term discomfort of having to repeat recruit training. Recruit graduation was successful with all METTP students completing every performance objective.

b. Phase Four - Auxiliary Watchkeeping Certificate. To achieve an Auxiliary Watchkeeping Certificate in only 3 months was considered an impossible task when one considers that under normal training conditions it may take 3 years. However, by employing dedicated training resources (ships and instructors) and long training days it was possible to achieve the training standard and it was particularly rewarding to see only 1 failure in 2 years and over 75 successful certificate qualification boards. Board members included Training Ship personnel to ensure the METTP qualification was not watered down or degraded in terms of acceptable Fleet standards. In fact most board members assessed the METTP certificate examination as more difficult than the normal Fleet examination.

c. Phase Seven - Practical Marine Engineering. Phase Seven was developed to provide the practical marine engineering skills which are not taught at St Lawrence College. Normally this particular course requires 14 months but with the St Lawrence College background in marine engineering theory it was decided to reduce the course to 6 months, including Junior Leadership training. There were the usual concerns with inexperienced METTP students being unable to accomplish the stated course objectives but as in phases one and four the METTP students achieved every assigned training objective and when combined with other Fleet personnel for leadership training the METTP students represented themselves well and the top graduate of the course was a civilian entry METTP student.

COST AND ATTRITION

In developing the METTP concept it was necessary to conduct a cost analysis of METTP versus existing CF marine engineering training in Fleet facilities. The use of community colleges with non-military instructional staffs has provided METTP a significant 5 to 1 cost benefit over existing training concepts. Part of this cost benefit is derived from the lateral entry principle of injecting the graduates into the military rank structure above the high attrition point. With an average marine engineering attrition rate of approximately 75 per cent in the first five years of service it is easy to calculate that every METTP graduate represents 5 normal entry recruits. METTP has an additional advantage; increasing the number of METTP graduates allows the Fleet training schools to reduce normal training back to a level where quality and not quantity is the major training consideration.

FLEET ACCEPTANCE

Any programme which appears, for whatever reasons, to place any group at a disadvantage will receive some criticism. METTP graduates receive promotion to Master Seamen in only 30 months as compared to a minimum time requirement of 6 years for normal entry recruits. If METTP were allowed to take all the annual promotions to Master Seamen the programme would destroy all career prospects for those less qualified marine engineering personnel who still fulfill a necessary role in the marine engineering trade. Lateral entry programmes such as METTP are required for all high technology trades but intake numbers must be adjusted annually to maintain promotions at no more than 25 per cent of the annual promotions for each trade. With METTP open to Fleet candidates much of the Fleet acceptance problem was eliminated and as every METTP graduate, in addition to academics, is also required to achieve all the normal trade qualifications it is anticipated that no friction will result when the graduates join their respective ships. In reality, it is impossible, after completion of the METTP programme, to differentiate between a student who commenced METTP as a fleet or civilian entrant.

METTP UPDATE (FEB 1983)

METTP Class 1 graduated from the programme on 7 January 1983. Classes 2 and 3 comprising another 75 potential graduates are undergoing various phases of their academic training at St Lawrence College. In July 1983 Class 4 which includes the first total Francophone component will commence recruit training. The initial Francophone option will comprise 16 students who will attend a Francophone marine engineering course in Rimouski, Quebec and who, in addition to gaining an excellent marine engineering education, will receive English language training.

Academic problems with Fleet candidates in Class 1 were of concern and an analysis of the situation pointed out the necessity of maintaining high selection standards and the requirement to conduct pre-academic courses in mathematics and physics to ensure potential METTP Fleet students can adjust to the demanding academic environment. The pre-academic courses provide sufficient stress to act as an excellent screening device for marginal candidates and those students who are successful on the course have also proven themselves academically at St Lawrence College.

COMMISSIONING OF METTP GRADUATES

The CF are currently experiencing serious shortages of Marine Engineering officers and it is natural to look to the highly qualified METTP graduates as potential officers. There is no question that METTP can supply significant numbers of both University Training Plan Men (UTPM) and commissioned-from-the-ranks (CFR) officers. However, all METTP graduates should be allowed to gain practical experience before being recommended for commissioning. The commissioning of too many of the top graduates will degrade the original project aims and turn METTP into just another commissioning scheme. Properly managed, METTP can provide excellent personnel for all marine engineering career streams.

CONCLUSION

The METTP pilot project has come a long way in only 3 years and all indications are that the concept is sound and provides a new source of highly skilled personnel to meet both the recruiting and technology requirements of the Canadian Forces. METTP Classes 1, 2 and 3 have met or exceeded every project milestone set for them. Through their excellence the programme has received Fleet acceptance and although the final project assessment will not be rendered for some time, success is virtually guaranteed. The METTP lateral entry concept is applicable to most CF trades and given the experience of METTP it should be possible to expand the concept with relative ease.

For the Navy, METTP is a return to the former Royal Canadian Navy apprenticeship training which served the CF so well. The reasons for the cancellation of this successful programme are no longer important but hopefully some lessons were learned which can be applied to the long term management of METTP as it terminates its pilot project status. METTP is the key to the future of the CF marine engineering department and it is expected that the concept will soon expand to include the majority of the highly technical CF trades.

An In-Line Speed Change Gear Unit

AUTHOR Mr. L.T. Taylor

Mr. Taylor graduated from RMC in 1965 with a BEng Physics degree. His post graduate training was carried out at RNC Greenwich and RNEC Manadon where he successfully completed the Dagger Course in 1972. His academic studies also included the Canadian Forces Staff College Course, the class of 80/81. He recently retired from the Canadian Forces as a LCdr with 22 years service and is now a civilian engineer on the MSEO staff in NEU(A). During his time in the service he was the Engineer Officer of HMC Ships - Iroquois, Annapolis, Fraser, Bras D'Or and Flight Deck Engineer Officer of HMCS Bonaventure. LCdr Taylor served in NDHQ (DMEE) for three years where he was involved in various projects including writing the NEM and the initial studies into the DDH-280 engine change out. From 1975 to 1977 he instructed Transmissions to the Marine Engineering Application Course and Advanced Marine Engineering Course at RNEC Manadon where he became very interested in the subject of this paper.

ABSTRACT

This paper describes an in-line speed change gear unit proposal for use in a CODAG (COmbined Diesel And Gas) propulsion plant. The advantages and disadvantages of such a proposal are discussed. A sample installation is described. The views expressed in the proposal are solely those of the author. The author knows of no installation of his type previously or presently in service or planned for the future, however, he feels that his proposal meets a possible need and is a lively topic for consideration and discussion.

INTRODUCTION

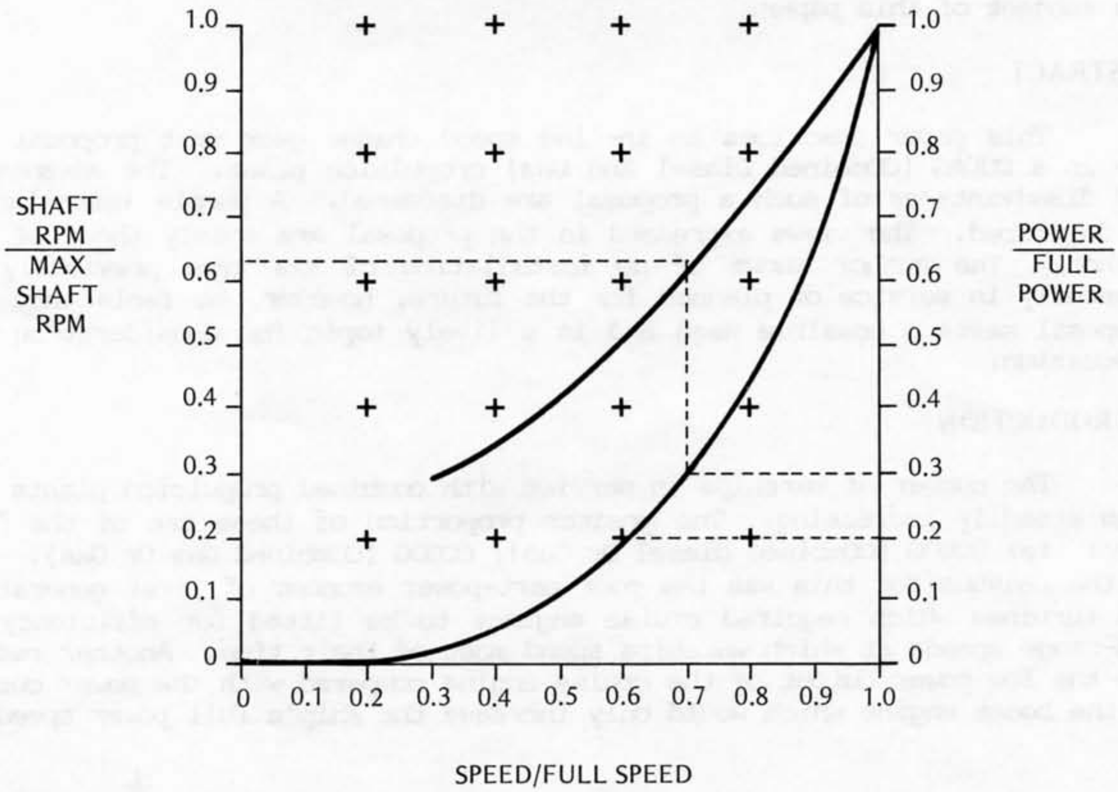
The number of warships in service with combined propulsion plants has been steadily increasing. The greater proportion of these are of the "OR" type: ie; CODOG (COmbined Diesel Or Gas); COGOG (COmbined Gas Or Gas). One of the reasons for this was the poor part-power economy of first generation gas turbines which required cruise engines to be fitted for efficiency at mid-range speeds at which warships spend most of their time. Another reason was the low power output of the cruise engine compared with the power output of the boost engine which would only increase the ship's full power speed by a knot or two. This minor increase was not worth the complication of an "AND" arrangement. Circumstances are changing.

THE REQUIREMENT

The power output from diesels which are suitable for warship cruise engines has been increasing and will increase still with two stage supercharging. Cruise diesels of 6000 to 7500 HP are or soon will be available. Cruise gas turbines with good part-power fuel consumption and power outputs in the same range are also available. At the same time boost gas turbines in the middle power range and with improved part-power fuel consumption are now available. The percentages of the total installed power which the cruise engines represent is becoming more significant. The "AND" configuration is thus of greater interest now.

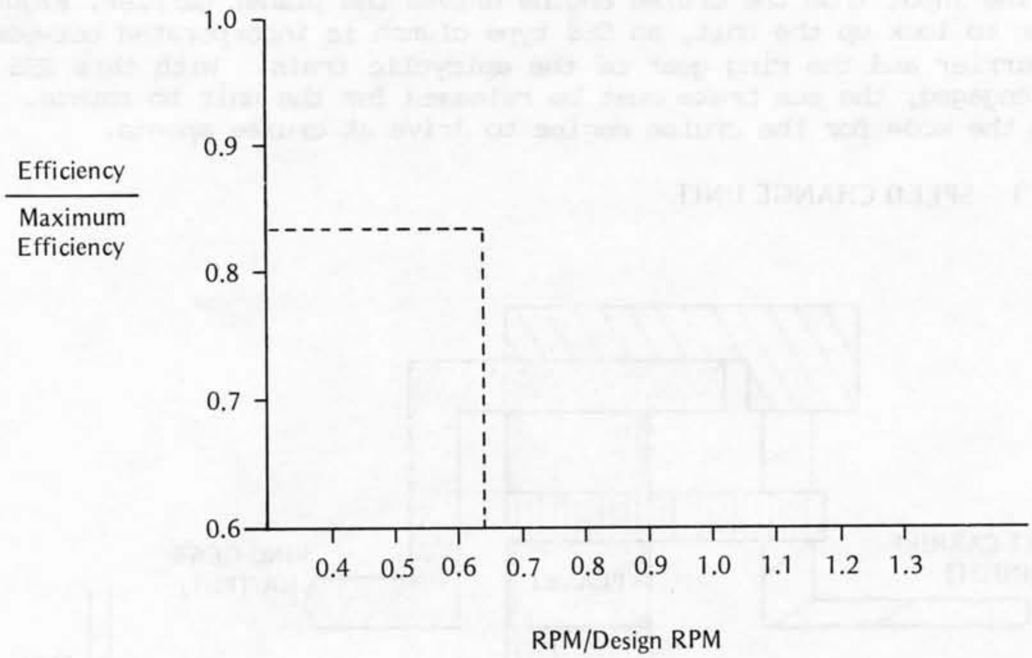
If the installation is designed for the full power case only, the power and efficiency available from the "AND" configuration for cruise is limited. Consider figure 1 and cruise engines which provide 30% of the installed full power. Without considering the engine's capability yet but only looking at the laws a ship follows, 30% of the installed power would drive it at about 70% of its maximum speed and the shaft RPM at full pitch would be about 65% of full RPM.

FIGURE 1 TYPICAL SHIP CHARACTERISTICS



A gas turbine has considerable flexibility in its operation but it is paid for in efficiency. Figure 2 is a typical efficiency envelope for a modern gas turbine. With a 15% loss in efficiency, the gas turbine would not be able to produce its full power and thus the maximum cruise speed of the ship would be reduced.

FIGURE 2 TYPICAL GAS TURBINE EFFICIENCY CHARACTERISTIC



The situation with the diesel is even more difficult since the engine will be restricted in its maximum cylinder pressure and using the basic power formula, PLANS, power will be reduced by 35% with a 35% speed reduction. Taking this first iteration back into figure 1 cruise power is now 20% of full power. The cruise speed would be about 60% of maximum speed or less.

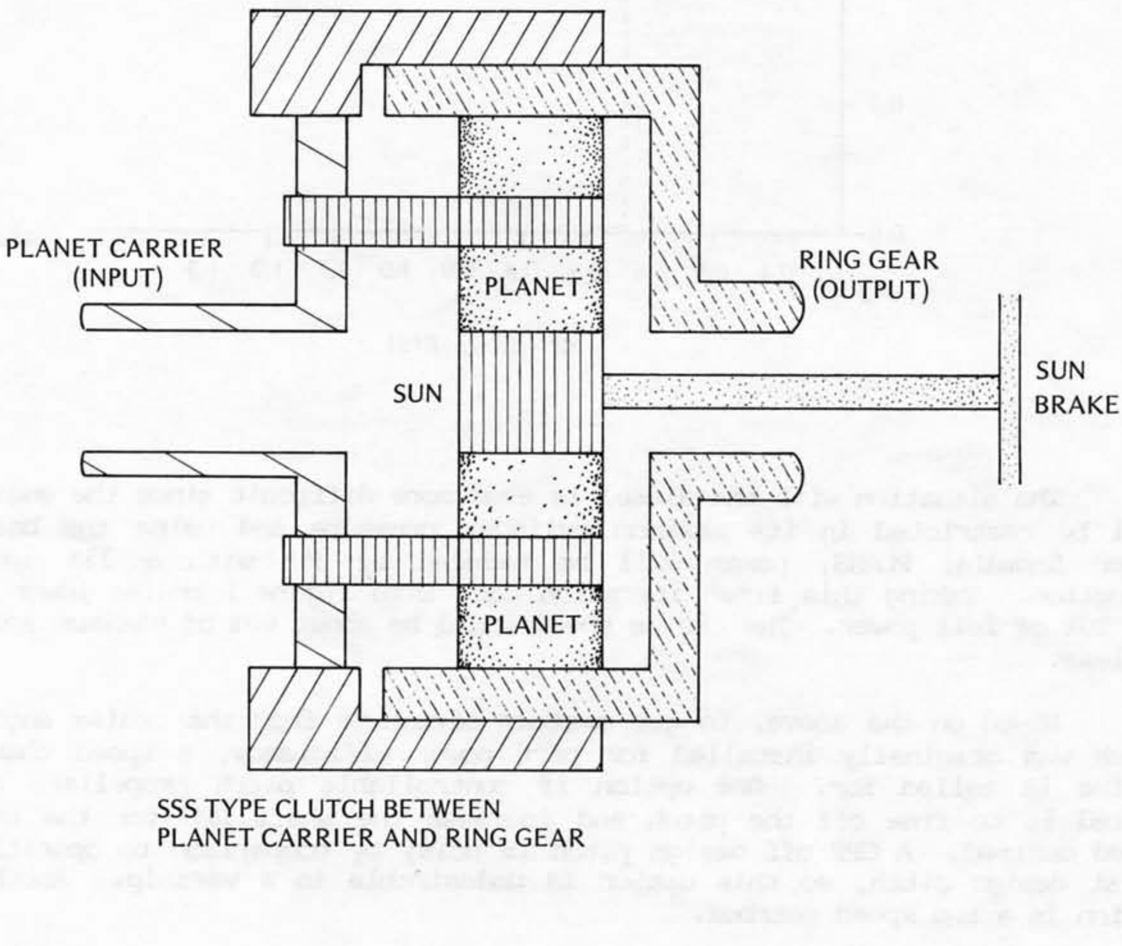
Based on the above, to get maximum advantage from the cruise engine which was originally installed for part power efficiency, a speed change regime is called for. One option if controllable pitch propellers are fitted is to fine off the pitch and increase the shaft RPM for the ship speed desired. A CPP off design pitch is noisy by comparison to operating it at design pitch, so this option is undesirable in a warship. Another option is a two speed gearbox.

THE PROPOSAL

The speed change element proposed to be fitted into the cruise train of a CODAG or COGAG (COmbined Gas And Gas) gearbox is a solar epicyclic step up unit which locks up as a solid coupling for cruise mode operation and increases the input speed for full power mode operation. As an epicyclic, the unit is "in-line" with the input and output co-axial. The solar arrangement has the same rotation of input and output and is well suited to ratios between 1.1 to 1 and 2 to 1.

The input from the cruise engine drives the planet carrier, Figure 3. In order to lock up the unit, an SSS type clutch is incorporated between the plant carrier and the ring gear of the epicyclic train. With this SSS type clutch engaged, the sun brake must be released for the unit to rotate. This then is the mode for the cruise engine to drive at cruise speeds.

FIGURE 3 SPEED CHANGE UNIT



Although the SSS type clutch between the planet carrier and the ring gear could be used as a disconnect for the cruise engine, the speeds of the planet pinions on the stationary planet carrier pins are excessive if this is done. To change from the cruise to full power mode, apply the sun gear brake. The planet carrier now drives the planet pinions around the fixed sun and the ring gear is driven in turn at a higher speed than the planet carrier. The SSS type clutch then finds itself with the output trying to drive the input and it will disengage itself.

To revert back to the cruise mode, releasing the brake will result in the planet pinions having no fixed element to react against and they will cease driving the ring gear; the input speed will catch up with the output speed; the clutch will engage and the cruise engine will again drive through the locked up epicyclic unit.

ADVANTAGES

The cruise engine is now matched to both the cruise and the full power condition. The cruise engine has additional flexibility to also allow better matching for single engine, mixed engine or three engine operation than without a speed change unit. Efficiency, cruise power and maximum cruise speed are improved.

The speed change unit functions as a solid coupling only for the majority of its operation. Typically, for peacetime escort operation, less than 5% of the ship's time is spent in the speed range at which the cruise engine would be connected in the "AND" mode.

The in-line arrangement has installation advantages in some situations and would allow for insertion of a straight coupling in case of damage.

Mode changes using SSS type clutches are well proven at all operating speeds envisioned for the unit in question.

DISADVANTAGES

Added complexity. The addition of another clutch, the unit itself and the brake are all additional complications over the direct input method.

Bearings which cannot be monitored for temperature have been added to the gearing. The planet pin bearing and any bearings on the sun extension to its brake will be rotating and RTDs or thermocouple devices cannot be hardwired to them.

The brake no matter if inside or outside the gearbox, is a friction device and as such is a heat source. There are transients associated with brake application and release which add to the dynamic problem.

COMPARISON

The justification for the complexity was put forward in the opening requirement section when dealing with efficiency and maximum cruise speed capability. When the improved flexibility in single engine, mixed engines and three engine operation is also taken into account the complexity is considered to be more than justified.

Although the bearings for the planets cannot have their temperature monitored, they are used less than 5% of the operating time. There have been a large number of commercial marine epicyclic gears which are always in use when the ship operates and many of these have this same limitation and have operated satisfactorily for many years.

The brake is a problem which is justified by the same argument as the complexity. In addition by including the second disconnect clutch between the speed change unit and secondary gearing, the masses to be accelerated are small and the transients are small as well. This arrangement also allows the brake to be applied or released with the diesel stopped so there are no transients associated with the change over; although, it should not be necessary to change over while the diesel is stopped.

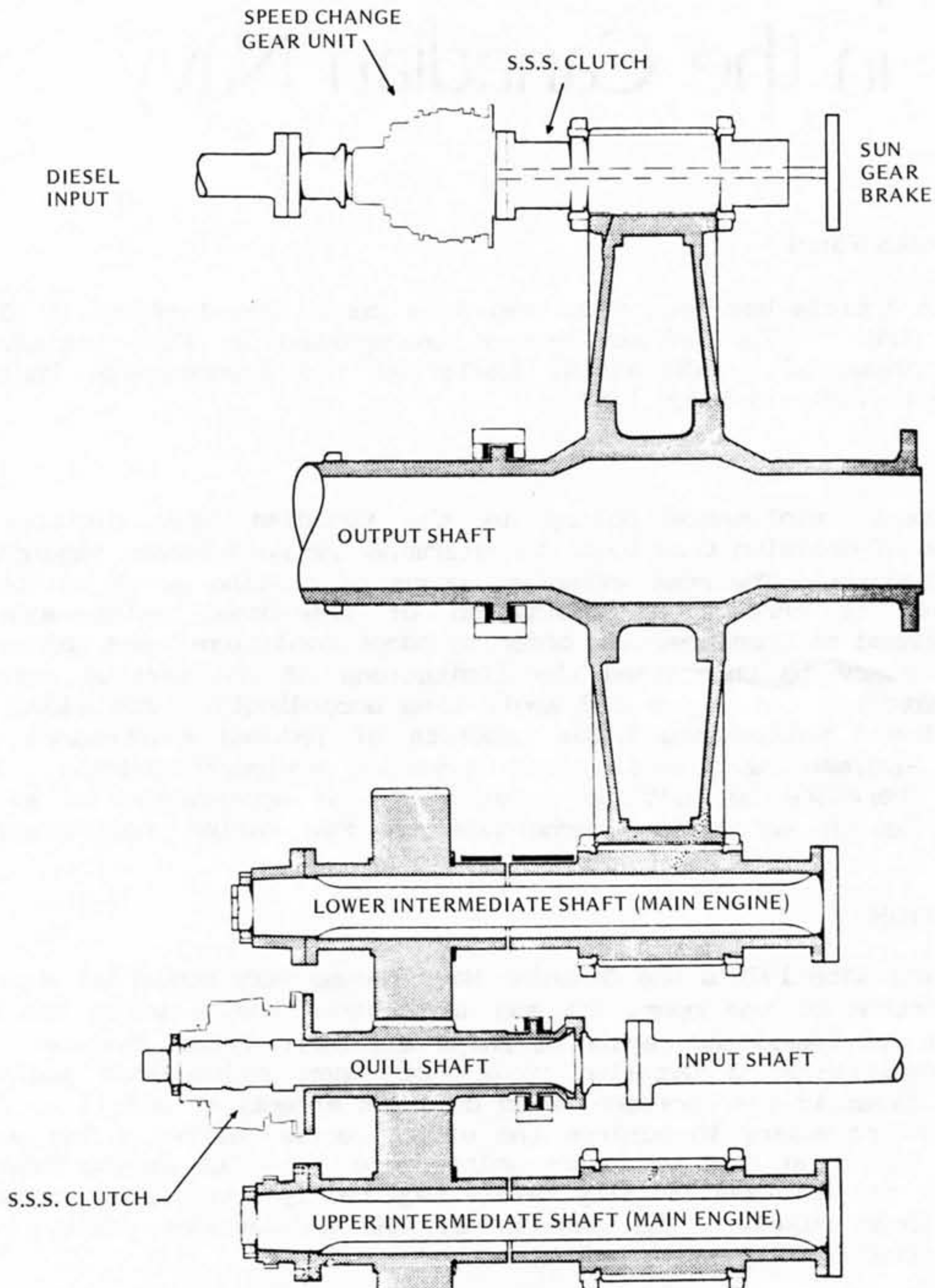
SAMPLE INSTALLATION

Figure 4 shows a possible CODAG gearbox using the in-line speed change gear unit. With the diesel driving in the cruise mode, the speed change gear unit is locked up by its integral SSS type clutch and drives through the second SSS type clutch to the parallel shaft gearing. To increase speed above cruise engine capability, the gas turbine is started, when it has accelerated up to match the diesel speed, the clutch in the gas turbine line engages. With a cut back in fuel to the diesel, its second clutch disengages and the gas turbine then drives.

To increase to full power the brake is applied to the sun gear of the speed change gear unit; the diesel speed is now stepped up by the speed change gear unit; the diesel is accelerated until the speed change gear unit output speed matches the diesel pinion speed when the second SSS type clutch engages. The ship speed is now controlled using the throttles of both the diesel and the gas turbine.

To convert figure 4 to a COGAG arrangement with a small and a large gas turbine, an additional reduction stage is required. This could be easily provided by the inclusion of an epicyclic primary before the speed change gear unit or by converting the existing diesel final drive pinion to the primary pinion in a double reduction parallel shaft gear arrangement.

FIGURE 4


SPEED CHANGE
GEAR UNIT
S.S.S. CLUTCH
DIESEL
INPUT
SUN
GEAR
BRAKE
OUTPUT SHAFT
LOWER INTERMEDIATE SHAFT (MAIN ENGINE)
QUILL SHAFT
INPUT SHAFT
S.S.S. CLUTCH
UPPER INTERMEDIATE SHAFT (MAIN ENGINE)

Equipment Health Monitoring in the Canadian Navy

AUTHOR DMES 6 Staff

This article has been submitted as a consolidated effort by DMES 6 staff in DGMEM. The subject matter encompassed in this article was initially presented by Captain(N) Lawder at the Commonwealth Engineers Conference in India in March 1983.

ABSTRACT

Current maintenance policy in the Canadian Navy dictates the application of decision tree logic to determine the maintenance requirements of naval systems. The most effective means of meeting naval maintenance requirements is through a combination of time-based maintenance and condition-based maintenance. In order to adopt condition-based maintenance it is necessary to understand the limitations of the various equipment health monitoring techniques and apply them accordingly. The adoption of condition-based maintenance holds benefits of reduced maintenance cost, increased equipment availability and increased equipment safety. It is important therefore to continue development and application of as many equipment health monitoring techniques to the marine environment as possible.

INTRODUCTION

In the late 1970's the Canadian Navy became very concerned about the high proportion of the operating and maintenance budget which was being devoted to the upkeep and repair of ships and their fitted systems. This concern precipitated a detailed review of naval maintenance policy to determine, first if the approach being used was effective, and if not, what changes were necessary to achieve the effectiveness desired. The object, therefore, was to attempt to reduce maintenance costs but at the same time ensure that the ship availability levels required by operational commanders were not compromised. The results of the maintenance policy review indicated several interesting points.

First among the findings was that the Canadian Navy was over-maintaining its fleet in a number of areas. The preventive maintenance policy which had been developed over many years had grown to the point where detailed maintenance routines were required to be performed at regular intervals irrespective of how well a system or equipment was performing. In addition, several years previously, ship refit cycles had been extended from two years to four years; the four yearly refit work content was based on a criterion that the ship be brought back to a "baseline" or virtually as-new condition. This means that practically every equipment was given an extensive overhaul during refit. The problem here, as with the preventive maintenance system, was that the performance of each equipment prior to refit was not a factor which was considered in determining the refit content. While particularly good results were achieved in areas such as maintaining the structural integrity of ship hulls and in paint and preservation, improved reliability of operating equipment was not necessarily achieved. In a significant number of instances, equipment reliability did not show an improvement. Generally, this was a result of faults introduced during the overhaul process.

The second point the study revealed was that the defined requirements for both preventive maintenance and periodic overhauls were usually based initially on manufacturers' recommendations (often conservative). While in many instances maintenance requirements were often further amplified by the equipment life cycle materiel manager on the basis of intuition and experience or on the specific recommendation of ships' personnel, only infrequently were attempts made to relate maintenance requirements either to the operational significance of the equipment or to an assessment of its observed performance in service.

The third point that the study revealed was that much data had been accumulated on condition assessment of machinery over some fifteen years. In particular considerable effort had been expended to introduce a comprehensive program for vibration analysis and spectrometric oil analysis of mechanical systems. Too seldom however were the available data used to establish the necessity for comprehensive inspections or overhaul of a particular item of machinery. In the same vein, very little use was made of the results of the exhaustive machinery trials program immediately preceding refit.

The fourth point made in the policy review was that even though reliability centered maintenance theory had proven itself to be effective in the determination and validation of maintenance requirements in a number of navies, very little attempt was being made on the part of life cycle materiel managers in the Canadian Navy to avail themselves of this method.

The final point made by the policy review was that the requirement to carry out running repairs on critical equipment which failed in service had a negative effect on a ships' operational availability. It was considered that achieved availability could be improved by greater reliance on the concepts of repair by replacement for those equipments which fail in operation and on maintenance by exchange for those equipments which require periodic overhaul. The use of condition assessment techniques to determine the time of overhaul has the potential to not only increase ship availability but also reduce maintenance cost.

As a result of the maintenance policy review the Canadian navy has adopted the application of decision tree logic to determine the maintenance requirements of naval systems. Commonly referred to as Reliability Centered Maintenance (RCM), decision tree logic defines naval maintenance requirements on the basis of a maintenance task's ability to reduce the risk of system failure. That is, if a maintenance task can minimize the adverse effects of failure such as reduced availability, reduced safety and increased maintenance cost, the decision is made to incorporate the maintenance task into the scheduled maintenance package for the system. The inverse also holds true. If a maintenance task cannot minimize the risks of a system failure it is not incorporated into the scheduled maintenance package of the system. (See figure 1.)

EQUIPMENT HEALTH MONITORING

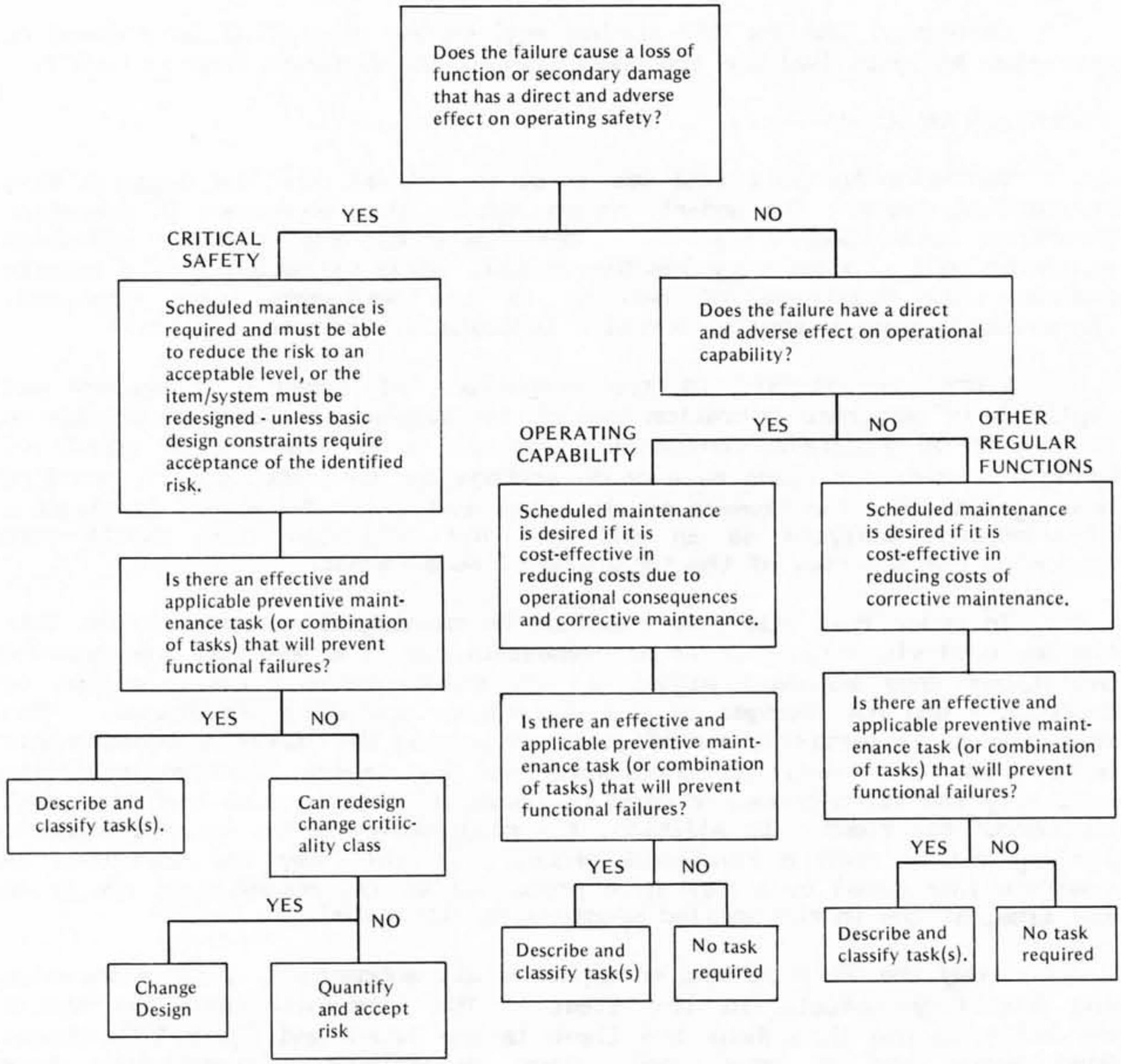
The most critical component in the application of the RCM concept is the continued development and successful application of current equipment health monitoring (EHM) techniques. Successful application of current EHM techniques has the potential to reduce the amount of time-based maintenance the fleet currently performs by replacing it with condition-based maintenance. Condition-based maintenance initiates preventive maintenance only when the performance of an equipment has deteriorated or the equipment shows signs of approaching failure. This means that equipments are left in continuous operation for longer periods of time. Overall maintenance cost is reduced. Equipment availability is increased.

To be effective an EHM technique must be capable of correctly forecasting developing conditions which would cause failure. It must not indicate a defect where no such defect exists. Failure to accurately assess the machinery condition will result in a loss of confidence in the system on the part of the user/ship.

For an EHM programme to be effective it must require less manpower to implement and carry out on a continuing bases than it would to carry out the traditional periodic preventive maintenance. The measuring instruments or meters must be compatible with shipboard installation or be readily portable. Instruments and meters must be reliable and robust to ensure that instrument error does not give false readings. The gathering of data must be performed by a trained technician with a sound background and understanding in equipment construction materials, lubrication and operation. Further, specialized EHM techniques must not require extensive additional training but be simple to use and readily understood by technicians designated for employment as equipment health monitors.

Figure 1

DEFINITION OF PREVENTIVE MAINTENANCE USING DECISION TREE LOGIC



In order to minimize implementation and training costs, EHM techniques should preferably have a wide application to many different types or units of equipment. Only where an equipment unit has singularly high value or operational significance should specific EHM systems be developed to monitor internal conditions.

Currently, EHM for the marine engineering discipline is focused on Vibration Analysis (VA) and the Spectrometric Oil Analysis Program (SOAP).

VIBRATION ANALYSIS

Vibration Analysis (VA) was first introduced into the Canadian Navy in the late 1960s. Its underlying concept is that equipment in operation generates noise and vibration. Well balanced and properly assembled equipment will produce very low vibrations. High vibration levels usually indicate the existence of defects in the equipment being analysed. Increasing vibration levels generally indicate a developing defect.

Vibration analysis is the comparison of measured frequency and amplitude of equipment vibration against established standards to provide an indication of equipment condition. The old naval practice on rounds of using a screwdriver blade as a crude stethoscope to listen to the sound of bearings was once the essence of vibration analysis. The formal development of vibration analysis as an EHM tool has only concerned itself with improving the accuracy of the technique of measurement.

In order that vibration readings be meaningful it is essential that the measured vibration signals are repeatable in time and that the observed deviations from standard signatures do indeed reflect deterioration of components and not changes in the ambient on operating conditions. This prerequisite is partially satisfied by conducting the vibration measurements under identical operating conditions and by taking the readings from specially installed blocks mounted in identical positions on each equipment throughout the fleet. In addition, the readings are taken using a magnetic pick-up rather than a hand-held probe. In this way the variation in readings introduced by a hand-held probe due to the movement of the probe and fluctuations in the applied pressure is eliminated.

Today the VA programme encompasses all submarines, surface warships and auxiliary vessels in the fleet. The vibration measuring system currently in use throughout the fleet is the Bruel and Kjaer 5604 Octave Band Meter and a Bruel and Kjaer piezoelectric compression type accelerometer. Each ship is provided with a meter and one or more technicians trained in its use.

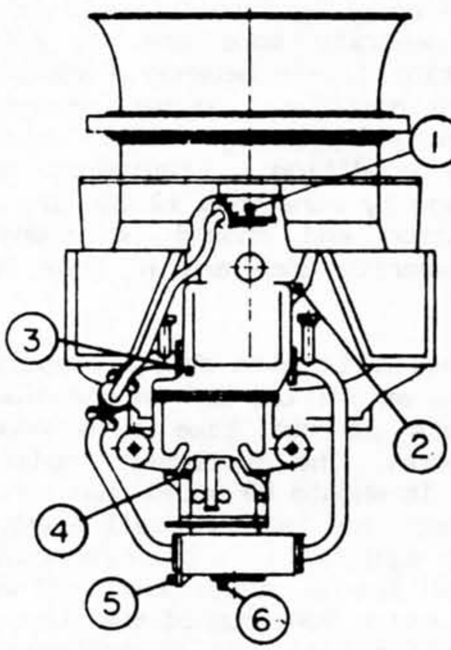
To assist the technician(s) in the analysis of equipment condition each ship has been issued a number of diagnostic aids which have been prepared for each piece of equipment in the VA programme. The first aid is a sketch of the equipment showing the position of all monitoring blocks and their relationship to the position of internal components. The second aid is a table of all discrete frequencies generated by the unit at a set of prescribed operating conditions. This aid also describes the different equipment components responsible for the vibration, the octave band in which the vibration frequency will be included and the monitoring position where the vibration will be dominant. The third diagnostic aid is a summary of the octave band signatures associated with typical defects such as imbalance, misalignment, worn or defective gear teeth, bearings, etc.. The fourth aid is the presentation of historic vibration data of the unit in numerical or graphical form. This data defines qualitatively the relationship between vibration amplitude in Vdb and machinery status. Vibration readings which do not exceed the normal vibration level for a specific type of equipment by 6 VdB are considered to indicate good working order. Units which fall in this severity zone are in satisfactory condition. Equipment exhibiting vibration levels between 6 Vdb and 12 Vdb above a specific type of equipment are considered to have sustained some deterioration and should be monitored more frequently. Units which fall in this severity zone are in moderate condition. Equipment exhibiting vibration levels which exceed the average by more than 12 Vdb are deemed to have sustained significant deterioration and should be operated with caution. Units which fall in this severity zone are in poor condition. (See figures 2, 3, 4, 5)

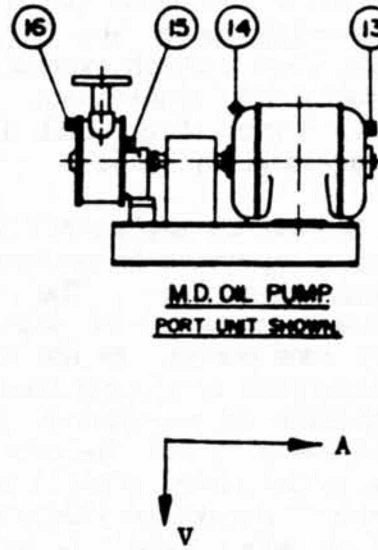
It must be emphasized that the equipment data sheets supplied to the technician are meant to provide him with an initial aid in the diagnosis of equipment condition. The data sheets do not take into account the simultaneous presence of multiple defects. The assessment implied in the severity zone concept is not absolute. It should be noted that VA does have its limitations as an EHM tool. VA cannot for instance tell anything about the condition of non-moving parts in an equipment. Erosion/corrosion could very seriously affect the operating condition of an equipment and would only show up as secondary effects in the vibration spectrum of the equipment such as in the fluid motion characteristics of a pump. In an equipment such as the ship's main gearbox the vibration monitoring points are particularly far from the potential source of vibration, the interpretation of internal condition is at best very chancy. Other limitations on vibration analysis effectiveness may arise where the proximity of machines to one another in the ship can create a masking effect of the true vibration level of an equipment. In an equipment like the multi-cylinder reciprocating diesel engine the equipment motion is very complex as is the vibration signature of the equipment. In such a case, the interpretation of vibration results is a very difficult task and the confidence in any diagnosis rather low.

In instances such as those cited above vibration analysis should be used as a means to corroborate the predication of equipment condition using other EHM techniques. Preventive maintenance inspections for the cases cited above should never be deferred solely on the grounds of a satisfactory VA survey.

Figure 2. Diagnostic Aid #1
POSITION OF MONITORING POINTS

MACHINE:	TURBO-BLOWER	NEI NO:	E-25-352-000/00-000
CLASS:	ISL, IRE, MKE, ANS	SHIP(S):	206, 207, 229, 230, 233, 234, 236, 257, 258, 259, 261, 262, 263, 264, 265, 266.





NOTE: POINT 1 TAKE READINGS IN THE 1L DIRECTION ONLY

EQUIPMENT CODE		UNIT	LOCATION	ORIENTATION*
NEI NO.	LOCATOR			
E-25-352-000/00-000	01	STBD	BOILER ROOM	L ← ↓ V
E-25-352-000/00-000	02	PORT	BOILER ROOM	L ← ↓ V

OPERATING CONDITIONS: AT SEA (104 RPM) OR ALONGSIDE, 2500 BLOWER RPM
ACCEPTABLE RANGE: 2400-2600 BLOWER RPM

*L and A axes point towards the bow and port side respectively for the orientation depicted in the machinery sketch.

Figure 3. Diagnostic Aid #2
EXPECTED VIBRATION FREQUENCIES

MACHINE: TURBO-BLOWER	NEI NO: E-25-352-000/00-000
CLASS: ISL, IRE, MKE, ANS	SHIP(S): 206, 207, 229, 230, 233, 234, 236, 257, 258, 259, 261, 262, 263, 264, 265, 266

OPERATING CONDITIONS: 2500 BLOWER RPM

CALCULATED DISC. FREQ. (Hz)	VIBRATION DESCRIPTION	POINTS AT WHICH DOMINANT	OCTAVE BAND
17.1	Tachometer drive & L.O. Pump shaft	5, 6	16
19.5	Auxiliary lube oil pump rotational	13, 14, 15, 16	16
41.8	Blower shaft rotational	1, 2	31.5
45.2	Auxiliary gear box intermediate shaft	5	63
78.3	Blower shaft fundamental x 2	1, 2	63
120	Turbine shaft fundamental	3, 4	125
170	Lub oil pump gear meshing	6	125
176	Auxiliary lub oil pump gear meshing	15, 16	125, 250
240	Turbine fundamental x 2	3, 4	250
341	Tachometer drive gear meshing	–	250
905	Lub oil gearwheel meshing	6	1K
1008	Blower impeller vanes	1, 2	1K
2016	Blower impeller vanes x 2	1, 2	2K
2400	Auxiliary gear box, turbine pinion	5	2K
3590	Main gear box, turbine pinion	3	4K
11350	Turbine blading	3, 4	16K

NOTE: When the machine rotational speed differs from the recommended condition the calculated discrete frequencies must be adjusted using the following formula:

$$\text{New Disc. Freq.} = \text{Calculated Disc. Freq.} \times \frac{\text{Actual Rotational Speed}}{\text{Recommended Rotational Speed}}$$

Figure 4. Diagnostic Aid #3
DIAGNOSIS OF FAULTS

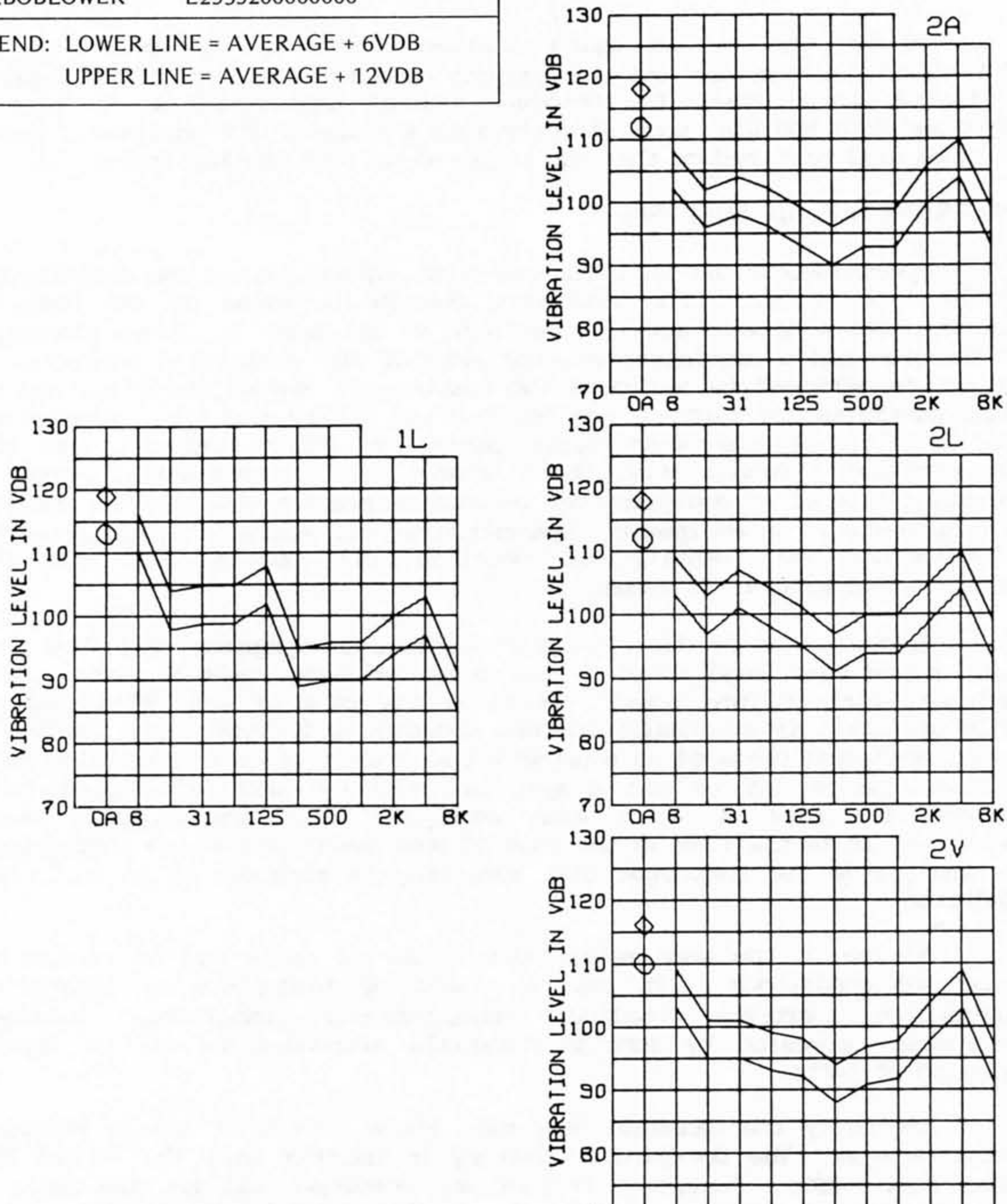
MACHINE: TURBO-BLOWER

DEFECTS PRESENT	ASSOCIATED OCTAVE BAND PATTERNS
Blower Rotor Imbalance	Points 1 & 2 high radial vibration in the 63, 125 & 250 octave bands.
Turbine Imbalance	Points 3 & 4 high radial vibration in the 250 & 500 octave bands.
Worn Gears in the Main Gearbox	Points 4 & 5 high radial vibration in the 2K & 4K octave bands.
Worn Lub Oil Pump Gears	Point 6 high radial vibration in the 250 octave band.
Lub Oil Pump Misalignment	Point 6 high axial vibration in the 250 & 500 octave bands.
Auxiliary Lub Oil Pump, Motor Imbalance	Points 13 & 14 high radial vibration in the 16 & 31 octave bands.
Auxiliary Lub Oil Pump Motor to Pump Misalignment	Points 14 & 15 high axial vibration in the 31 octave bands.
Auxiliary Lub Oil Pump Defective Gears	Points 15 & 16 high radial reading in the 125 & 250 octave bands.
Tachometer Drive Resonance	Points 2, 3 & 4 high readings in the 4K octave band. Remove tachometer drive and use strobe light to check RPM.

Figure 5. Diagnostic Aid #4
OCTAVE BAND SEVERITY ZONES

TURBOBLOWER E2535200000000

LEGEND: LOWER LINE = AVERAGE + 6VDB
UPPER LINE = AVERAGE + 12VDB



It should be mentioned that on the occasion when the shipboard technician requires assistance in the vibration assessment of an equipment, the NEU and NETE are readily available. Both NEU and NETE possess the capability to utilize discrete frequency and real time analyzers.

To date the problems being experienced with the system are the cost of VA block maintenance and the tedious hand recording which is required. In future, it is hoped to introduce digital tape reorders, to tape the digitized data and play back directly into a computer for analysis. The use of tapes will also reduce the time required to take the readings.

SPECTROMETRIC OIL ANALYSIS

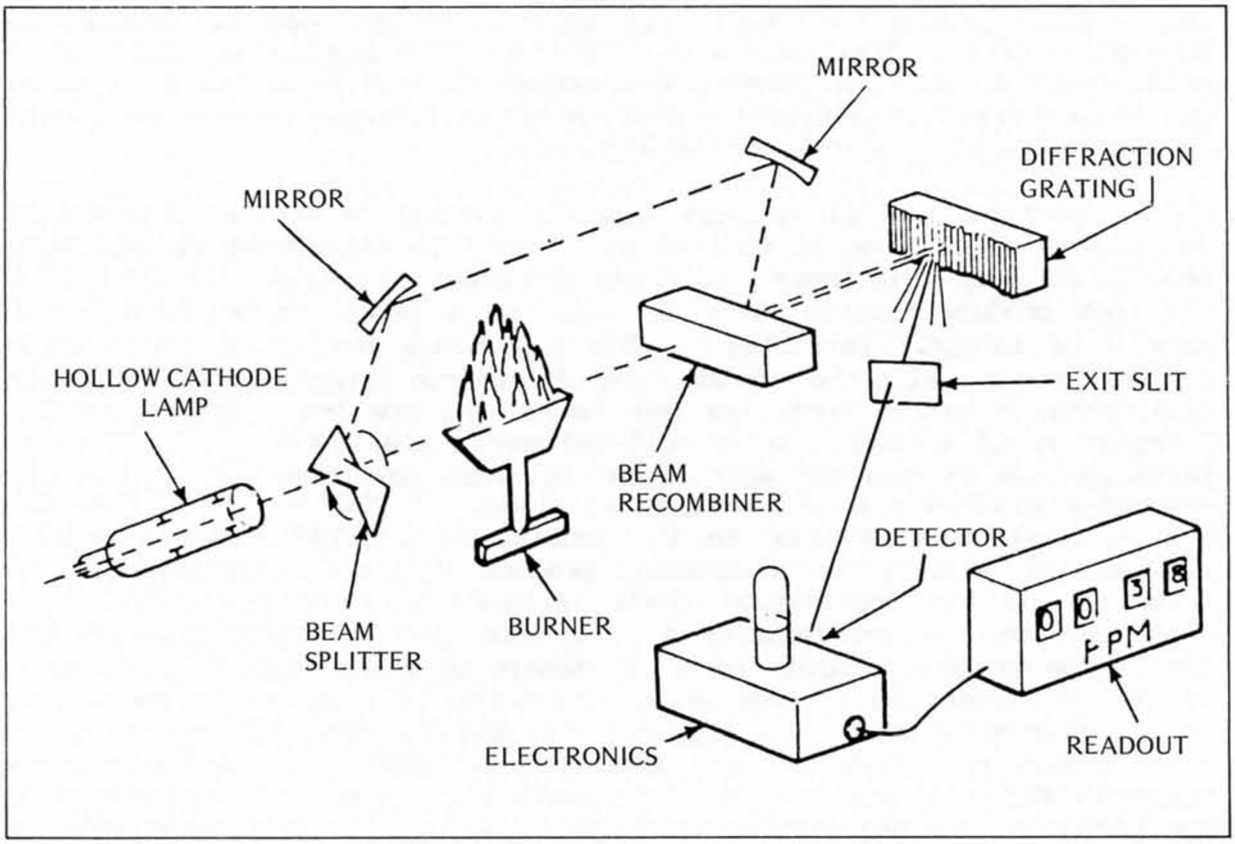
Spectrometric oil analysis was first introduced in the Canadian Navy in the late 1970s. It's underlying concept is based on the fact that relative motion between metallic parts in an equipment is always accompanied by friction and a continuous wearing away of the contacting surfaces. In equipments serviced by a closed lubricating oil system the resulting wear metal particles are flushed away and carried off by the oil. Knowledge of the identity of the wear metal particles within the oil and their concentration, particularly their change in concentration, over the operating life of an equipment can be used to predict the internal condition of components in an equipment. Spectrometric oil analysis is concerned with establishing the identity of metallic oil contaminants and their concentration within oil sumps.

Initially or immediately after overhaul an equipment will show a very high rate of wear metal build up due to initial bedding-in of parts. As the equipment settles into normal operation the rate of wear metal build-up falls off until it eventually becomes constant and quite slow. During the normal operating phase of an equipment the concentration of particles in the oil may change due to oil usage, oil addition and oil replenishment; however, the rate at which wear metal particles are produced remains constant. It is the rise in the rate of wear metal production that triggers the analyst to the suspicion that something is abnormal in an equipment's condition.

A rise in the wear metal rate of moving parts can be caused by a number of conditions. It can be caused by incomplete or intermittent lubrication, extreme loading, misalignment, imbalance, inadequate clearances, abrasion by foreign materials suspended in oil or improper alloying of parts.

Currently the Canadian Navy uses three models of atomic absorption spectrometers. The Dockyard Laboratory in Halifax uses the Perkin Elmer Model 603. DREP, Provider, Protecteur, Preserver and the DDH-280's are using or are scheduled to use the Perkin Elmer Model 370A. NETE is using the Perkin Elmer Model 305B. All of these instruments are capable of

Figure 6.
ATOMIC ABSORPTION SPECTROPHOTOMETER



measuring extremely low concentrations of wear metal down to approximately one part per million (PPM) by weight.

Spectrometric analysis of wear metal content is possible because metals when vaporized or burned, absorb and emit light energy. When an atomic absorption spectrometer is used the analysis of wear metal concentration is accomplished by the oil sample being aspirated into a flame and vaporized. The atoms of each element are brought to a dissociative state where light energy is absorbed. Light energy of a specific element being analyzed is radiated from a hollow cathode lamp into the flame. The exited atoms of the wear metals in the flame which have the same characteristic wavelength as that being produced by the lamp, will absorb some of the energy radiated from the hollow cathode lamp. The amount of absorption is proportional to the concentration of wear metal present in the sample. (See Figure 6)

Since rate of wear metal increase is the primary basis of assessment of equipment condition, it is most important that oil samples collected for analysis are truly representative of the oil circulating in the system. It is equally important that systematic and accurate equipment records are kept detailing hours run since new or since overhauled, hours since last oil change, the quantity and type of oil added since last sample. Without the submission of the above data with individual SOAP samples it would not be possible to distinguish between an increase in wear metal which is normal due to many hours of equipment operation and an increase in wear metal which is abnormal due to an incipient defect.

Spectrometric oil analysis does have limitations as an EHM technique. Its biggest limitation is that it is limited to oil-wetted systems which have an oil sump. In those equipments where the technique is applicable it will not produce results where the wear metal particles or chips are 10 microns or larger. Particles in this size range tend to be deposited on system filters. With the introduction of 5 micron filters in most auxiliary equipments, 5 micron particles and larger are now being eliminated from lubricating oil systems. It is believed that the elimination of the larger particles has reduced the wear caused by these particles but it has also removed a major source of sub-micronic sizes. It is considered that this has resulted in a decrease in the sensitivity of SOAP analysis and has reduced its ability to accurately predict defects. Furthermore, the technique has no application where failures occur very rapidly. For instance, most fatigue failures are characterized by a process which from the beginning of a problem to major damage or total failure there is no significant production of wear metal. Likewise the seizure of a bearing due to oil starvation cannot be predicted by spectrometric oil analysis. As with vibration analysis, the assessment of equipment condition using spectrometric oil analysis is not absolute. However, application of spectrometric oil analysis in conjunction with other EHM techniques can often corroborate test results.

INITIATIVES IN EHM

Both the VA and the spectrometric oil analysis programmes suffer from the lack of comprehensive feedback documentation. Verbal contact with ship and dockyard analysts has confirmed that the predictive capabilities of these techniques can be effectively utilized when the user possesses an understanding of the limitations of the respective techniques. However, there exists no quantitative evaluation of the abilities of EHM techniques to predict and accurately diagnose equipment condition.

In an attempt to establish a confidence factor in EHM techniques NETE has been tasked with the Shipboard Machinery Performance Test (SMaPT) programme. This programme involves the assessment of six types of marine auxiliary equipment on seven ships (the six ISL class ships and the Nipigon) using VA, spectrometric oil analysis, shock pulse measurement and ultrasonic flow measurement.

Performance tests are performed by NETE/NEU personnel prior to each ship entering refit, upon completion of refit and annually for the remainder of the cycle. Test results where and when possible are correlated with strip down inspections at the NETE to verify the EHM techniques ability to accurately diagnose and predict equipment defects.

To date strip down correlation is available for two ships only and only for a total of ten units on those ships. These preliminary results indicate detection of defects with an accuracy of 80% or greater. Only one of these ten units is an oil lubricated equipment and therefore little analysis is available at this time to indicate the accuracy of spectrometric oil analysis. When this project is completed it is hoped that the establishment of a confidence factor for various EHM techniques will provide the users of EHM techniques with a valuable tool in the preparation of repair and overhaul lists for marine equipments.

CONCLUSION

Over the years EHM techniques have demonstrated their capabilities at providing early warning of potential parts failure. They have precluded serious casualties to numerous shipboard equipments; improved equipment operational availability and demonstrated cost savings by preventing major damage to equipment. In recognition of the past achievement of EHM techniques, the Canadian Navy continues the application of and development of these techniques and is gradually changing from a time-based maintenance policy to a combination of time-based and condition-based maintenance.

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The Influence and Effect of Anaerobic Non-Nuclear Submarine Propulsion Systems

AUTHOR COMMANDER S.B. EMBREE

Commander S.B. Embree graduated in 1970 from RMC and CMR with a B. Eng degree in Mechanical Engineering. He attended the MEAC at RNEC Manadon in 1972 between Assistant EO postings in HMCS Saguenay and Saskatchewan. C of C II and submarine qualification were completed in 1974. From October 1974 until August 1976, he was on exchange in Gosport, England as the engineer officer of HMS Ocelot. On return to Canada he became Technical Officer of HMCS Okanagan until February 1979. LCDR Embree then obtained his MSc on the AMEC at RNEC Manadon in July 1980. After a short posting as Submarine Support Officer in SRU(A), he was appointed Squadron Technical Officer to the First Canadian Submarine Squadron from Dec 1980 until July 1982. LCDR Embree has just completed the Canadian Forces Command and Staff College Toronto. He was promoted to Commander on 30 June 1983 and appointed as the Planing Officer of SRU(A). There is lots of opportunity for volunteers to a similar career in submarine engineering and this article presents some of the opportunities which may develop in that career in the future.

ABSTRACT

Numerous non-nuclear submarine propulsion system improvements being researched are indicated in this paper. Air-independent energy conversion systems will soon be available that will enable the diesel-electric military submarine to possess some nuclear submarine advantages. The effects on operations and designs must be considered in any submarine development project. This article complements some of the articles of the past year in the US Naval Institute Proceedings regarding conventional and nuclear submarines.

INTRODUCTION

The choice between diesel-electric and nuclear propelled submarines has been a difficult one for several navies. Diesel-electric (that is, conventional) submarines have advantages of low cost and silence when on battery power. The nuclear propelled submarine has an even greater advantage in submerged endurance. The advantages of these two types of vessels may be usefully amalgamated by anaerobic propulsion systems. An anaerobic or air independent propulsion system is one that does not use free oxygen from the atmosphere but some other form of stored oxidant. A nuclear submarine is anaerobic but does not need to carry stored oxidant to burn the fuel. What are the possibilities for a submarine with non-nuclear, anaerobic propulsion, and is there a role for such a vessel?

ROLE OF CONVENTIONAL MILITARY SUBMARINES

The covert capability of submarines was the basis for their genesis and all their possible roles. This covert, passive nature continues to be to the submarine's advantage. This advantage can be used to maintain a patrol area which may be established as an anti-submarine or anti-shipping barrier, for surveillance or for deterrence reasons. A patrol area could be established in support of international alliances or national commitments in war or periods of rising tension. The other key role of the conventional submarine is special operations, primarily in inshore waters. These operations include surveillance as well as mining, photo reconnaissance and work with special purpose commando teams. The small size and quietness of the conventional submarine gives it an additional covert advantage over the nuclear submarine for these functions.

To fill these roles, the first requirement is a covert platform. This is the most important requirement, and it resulted in the enthusiasm during the past two decades for the nuclear submarine which is capable of 100% submerged operation. The second most important requirement is for action information/fire control systems, sensors and communications (C^3). This requirement is then followed by the weapons system to make a complete warship system. These three requirements (platform, C^3, weapons) are balanced as roles and possible functions are adapted to meet needs.

For this paper it must be assumed that in Canada there will be a continuing role for submarines, and that in replacing the current submarines any design should employ "state of the art" technology. However, it should also be assumed that the cost of nuclear propelled submarines and support facilities precludes their purchase. Nuclear submarines, in any case, emphasize different aspects of submarine roles than do the conventional submarines. A further assumption is that a diesel-electric submarine is quieter than a nuclear submarine. In order to enhance the conventional submarine's capability in its role, it is the power generation technology that needs improvement to more closely relate to the long submerged endurance of nuclear propelled submarines.

CONVENTIONAL SUBMARINE PROPULSION IMPROVEMENT AREAS

Consider the following information, presented in tabular form to orientate the reader and to orientate anaerobic power generation to the submarine propulsion system. There are five broad areas of improvement possible for conventional submarine propulsion with numerous methods available in each area. These five areas are energy sources, rechargeable storage systems, energy conversion systems, drive/transmission systems and propulsors. The table is derived by the author from the references (1), (2), (3) and (4). The methods are noted in a subjective order of probability by the 21st century as a result of study of the same references.

Rechargeable storage systems, drive/transmissions systems and propulsors are not exclusive to the anaerobic generating capability of a propulsion system. Energy source and energy conversion are the primary concerns of the air-independent capability to generate power. Only these propulsion system areas will be considered.

ANAEROBIC ENERGY CONVERSION

Development of anaerobic methods of energy conversion were experimented with during the 1930s, 40s and 50s, but they were not entirely successful due to a lack of technology and development funds. Recent advances and requirements have encouraged development. Prototype modules of the fuel cell for conventional submarine use are functioning in West Germany (1) and have been used on a US Navy submersible. (4) Fuel cells are more commonly in use in power stations and space cart. (3) A module of the Stirling engine is operating at simulated depth at United Stirling in Sweden. The Stirling engine is also trying to compete with the diesel and automotive engine in vehicle use. (5) Development of the closed cycle diesel was at quite an advanced stage in England until development was stopped because of lack of financing. (2) The references indicate anaerobic equipment will be available within 5 to 10 years for inclusion in submarine design.

At present, the fuel necessary for submarine propulsion is stored in tanks. For sources of oxidizer other than atmospheric air, the storage is currently solved by storage in compressed, liquid or cryogenic form in high pressure tanks (bottles) or bladders. These would most probably be fitted externally to the pressure hull in an anaerobic submarine.

Of key concern to this paper is the method of energy conversion because these methods will have the greatest impact on the overall vessel design and operation. Anaerobic energy conversion systems on ocean going submarines when initially used will be limited to a secondary power generation system. This is because the endurance of the anaerobic system is limited by the need to store both oxidizers and fuel on board. As a hybrid submarine (that is a submarine with diesel-electric and secondary anaerobic power generation), the secondary system is foreseen to carry the hotel (domestic) and low propulsive loads. The primary diesel electric system would provide power for the medium and high propulsive loads. In the hybrid design, a short length of hull section will probably carry a fuel-cell, Stirling cycle engine or closed cycle diesel module. The order stated is probably the order of availability of these systems.

TABLE: POTENTIAL ANAEROBIC, NON-NUCLEAR SUBMARINE PROPULSION SYSTEM IMPROVEMENT AREAS

AREA	METHOD	REMARKS
ENERGY SOURCES	FUEL – DIESEL OIL – HYDROGEN – METHANOL	Attractive. Availability and storage methods need improvement.
	OXIDIZER – ATMOS, AIR – (LOX) LIQUID 0_2 – (HPT) HYD PEROXIDE – FREON	Volume carried may limit endurance. Storage methods need improvement.
ENERGY–CONVERSION SYSTEMS	DIESEL – MECH SUPER-CHARGERS – TURBO SUPER-CHARGERS FUEL CELL STIRLING CYCLE ENGINE CLOSED CYCLE DIESEL CLOSED BRAYTON (GAS TURBINE) CYCLE	In use. Prototype modules are in use. Prototype developed and tested. Development stopped. Major development effort required.
RECHARGEABLE STORAGE SYSTEMS	ELECTROCHEMICAL BATTERIES – Pb/h_2SO_4 – ni – Ag/Zn-Cd – $Li/S–C1_2–F$ and others THERMAL – SENSIBLE HEAT – PHASE CHANGE CHEMICAL REACTION	Incremental improvements continue to show promise. Various problems such as cost, life, operating temperature and performance inhibit development/use. High energy density. Requires high heat engine efficiency. Major development still required.
	MECHANICAL – SUPER FLYWHEEL – HYDRAULIC – PNEUMATIC	High strength/weight mat'ls showing promise. Low density - short endurance or low power.
DRIVE TRANSMISSION SYSTEMS	ELECTRICAL – DC, AC, AC/DC – SUPER CONDUCTING – LIQUID COOLED – DISC	In use. Great advantages available. Should be available, beyond prototype, early 21st century. Major development required.
	MECHANICAL – DIRECT DRIVE – GEAR/BELT DRIVE	Available. Fixed geometry.
	HYDRAULIC – FLUID COUPLING	Available.
PROPULSORS	PROPELLERS – LARGE, SLOW, SKEW PULSE JET GLIDER	Only feasible conventional

Fuel cells may be classified by electrolyte, fuel, oxidant and temperature of operation. The fuel cell converts the chemical energy of a fuel directly into DC electricity with minimum moving parts and thus no noise. Hydrogen from the oxidation of fuel oil is the usual fuel cell fuel. The output of the fuel cell is varied by electrical load. Power and potable water are produced. It is a very efficient process with no intermediate conversion to heat energy. (2), (3)

The Stirling engine is a reciprocating, external combustion engine in which heat energy is transferred to the engine's working fluid by a heat exchanger. The combustion chamber can be maintained at a steady state temperature and pressure. Because of steady state combustion and the lack of cylinder explosions, Stirling engines are smooth and efficient. An added bonus for the submarine application is the pressurized exhaust which can be discharged at depth to be cooled and absorbed by the sea water, leaving little trace. The author doubts the absorption possibility, however, because of the unequal density of the gas bubbles and water. A gasless chemical reaction as heat source is desired. The Stirling engine is comparable to the diesel in specific weight and volume. It is better in efficiency but more complex. Most importantly, it is significantly quieter and can be configured to run on a variety of heat sources making hybrid propulsion systems attractive. (2)

The closed cycle diesel aspirates an atmosphere composed of oxygen, metered to match the fuel supply, and exhaust gases to act as diluent for the oxygen in place of atmospheric nitrogen. As with other anaerobic systems, the oxygen comes from decomposed hydrogen peroxide (HPT), compressed oxygen (O_2) or liquid oxygen (LOX). The thermal efficiency is about 80% of the air cycle. The inlet temperature must be regulated by the exhaust gases to ensure compression ignition. Surplus cooled exhaust gas is discharged overboard by compressor. (2) The complexity of the control system is the major drawback as well as the drawback of noise usually associated with diesel engines.

INDIRECT EFFECTS ON MARITIME WARFARE

The most probable anaerobic system is the fuel cell which several West German firms plan to incorporate in the German Navy class 208 submarine of the 1990s. (1) Time and research and development funds are needed to move from the prototype stage. Confidence has been established. The inherent quietness of the fuel cell system with its lack of traceable exhaust are undoubted advantages. In a hybrid system, the ability to maintain battery level while generating power enough for domestic and small propulsive loads is just as significant in improving role effectiveness.

When Canada replaces her submarines in the 1990s, as is assumed, the state of anaerobic systems will be such that they are unlikely to be part of the design. By 2005, however, not just a hybrid propulsion system but an anaerobic, non-nuclear submarine will probably be at sea. (1) Thus the replacement Canadian conventional submarines at that time will be out-of-date when only one-third of their way through life requiring an update in operational and propulsion equipment if room for growth is available.

A nuclear propelled submarine has unbeatable submerged endurance thus being able to select, relatively freely, its moments of indiscretion (mast exposure). It was submerged endurance, rather than the bonus of great speed capability, that was the initial attraction of nuclear submarines. The lack of necessity for resupply of consumable fuel or oxides enhanced this attraction. Operating disadvantages of inherent noise and large size detract marginally from nuclear submarine performance, depending on the designed role. The initial cost and extensive support requirements reduce the number of military forces for which it is a viable option.

The conventional submarine is of relatively low cost for a very effective role. It is smaller and able to carry out many operations in confined and shallow waters which would not be possible for nuclear submarines. As well, the conventional submarine is extremely quiet while running on its battery. On the other hand, its distinct disadvantage of limited submerged endurance was often its demise in World War II. The conventional submarine must use atmospheric air to operate its engines and recharge its batteries. The mast exposure, engine exhaust and noise are controllable indiscretions but are always too frequent and inopportune.

The best of both worlds is the anaerobic submarine or perhaps the hybrid submarine. It retains the quietness and size of the conventional submarine, but it significantly improves the submerged endurance. The cost, until the technology is more firmly established, is between the conventional and nuclear options. A submarine with an anaerobic system suffers from an initial lack of confidence in the system plus the requirement to carry both fuel and oxidizer.

The indirect effect, then, of choosing an anaerobic propulsion system is the smaller indiscretion ratio (exposed time divided by unexposed time) which will make the hybrid or anaerobic submarines significantly more effective than the conventional submarine in the same role. Those nations with a submarine and limited military budget are more likely than before to be in a position to buy submarines with nuclear-like capabilities. Even nations with a nuclear submarine service may consider the trade-off between 100% submerged endurance, cost and quietness, as the United States is apparently doing in discussions with European countries. (1)

INDIRECT EFFECTS ON MARITIME WARFARE

How does the small indiscretion ration gained from an anaerobic submarine propulsion system affect the conventional submarine's role? There is actually no change in role but rather a change in role effectiveness and operational tactics. As stated, the commanding officer would have available a power source that he could use without exposing his position or reducing his battery state. The submarine role has been related to two spheres, patrol area and inshore operations. In the patrol area the improved vessel could remain covert longer, thus increasing the time span in which the commanding officer could choose to charge his batteries using the atmosphere for his engines. This also applies to the unlikely situation in which he may be tracked or the more likely situation in which an hostile environment exists such as inshore operations. Significantly, for the inshore operation scenarios, because of longer submerged endurance, the commanding officer could choose to make a longer approach or retreat than now possible with a purely diesel-electric system. As the CO now has the battery state as a prime consideration for submerged endurance, he would also have the secondary propulsion system to consider in future. Basically, the current quietness advantage held by the conventional submarine would be increased by the use of an anaerobic propulsion system in naval warfare.

A less traditional role for conventional submarines may become available to the hybrid boat. Under-ice capability and confidence would be significantly improved if a second power source could be available. Other systems and capabilities such as navigation, air purification and reliability also need improvement before under-ice operations become realistic for even a hybrid submarine.

INFLUENCE ON CONVENTIONAL SUBMARINE DESIGN

In building submarines the factors of weight, space (volume), power/ cooling requirements, length/diameter ratio, etc and the negligible allowances for growth in each factor severely limit design. Energy source and conversion equipment currently make up about 30% of the weight of a conventional submarine therefore, improvements in energy conversion could directly and profoundly affect submarine design, performance, potential and effectiveness. Vessels in design now cannot use the propulsion system improvement previously mentioned; but, by the early 21st century submarines could be propelled by them. The result, of course, is that growth allowances must be included in appropriate design factors in order that submarines at half-life can be converted to hybrid when anaerobic systems are proven. It follows too, in some cases ,that for the first half-life of the vessel an unused capacity in growth factors is carried which may be expensive yet wise.

Turning to the design of a hybrid submarine then, despite the advantages, there is the distinct disadvantage of carrying passsenger equipment, that is, equipment used only for relatively little time. What portion of the propulsion system, weight and space can be taken up by a system used only part-time? If a large portion of such a secondary system can be shown to be common with the primary system then the passenger equipment syndrome is avoided, but redundancy advantages are decreased.

Commonality would accrue from a duel oxidant (or dual fuel) plant in the discussion of anaerobic systems, that is, a diesel engine and anaerobic energy conversion plant using the same fuel or oxidant. Thus, Stirling engines and closed cycle diesels become attractive in combination with diesel engines. The power/weight ratio is comparable for the three most likely anaerobic sytstems. As a result, internal volumes and overall submarine size can be considered in terms of replacing primary power generating capacity or adding additional hull length to gain volume for increased generating capacity. These space requirements must be part of initial design considerations. As in any design, a trade-off is required between operational requirements and technical feasibility.

In order for the military to gain use of anaerobic energy conversion methods, government agencies may have to lead the way in further development rather than wait for further commercial developments. Government and not commercial enterprise established the gas turbine as a marine propulsion system.

CONCLUSION

Proven systems are the foundation of future conventional submarine propulsion, and no real alternative to diesel-electric propulsion exists at present. The most probable improvement should appear in about ten years with hydrogen/oxygen fuel cells incorporating cryogenic storage and all-liquid exhaust for which prototype modules of the appropriate size are now functioning. (6) This means that conventional submarines, currently in design, need appropriate growth factors so they can be adapted at half-life to hybrid, that is, conventional-anaerobic propulsion systems. As ASW techniques improve, the vessel of the early 21st century must not be allowed to fall behind in submerged endurance. Otherwise, the conventional submarine may suffer the fate of the battleship (which is only now making a comeback with the aid of modern technology).

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3 Arnold P. Fickett, "Fuel-Cell Power Plants", in Scientific American, December 1978, pp. 70-76.

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5 United Stirling (Sweden) AB and Co, brochure.

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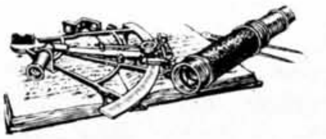

Note Book

A WORD TO THE WISE

On examination of the 1982 Report of OPDP Achievement, I was somewhat surprised to see the low level of achievement by MARE officers. Upon investigation I soon discovered that the MARS and MARE statistics do not reflect the OPDP serials which are conducted concurrently with the NOTC classification training. As a consequence, the statistics are misleading. Yet they still indicate to some degree that there is insufficient preparation time and less than a full rate of participation. The word to the wise is this: Personnel development of this kind requires your own personal initiative. The statistics themselves are informative and will broaden your perspective on the role and function of the Canadian Forces. Finally, successful completion of OPDP is now a prerequisite for selection for Staff College, a step in itself of considerable career importance. I have asked the Director Professional Education and Development to note in future reports that OPDP 2, 3, 4 and 5 are waived for MARE officers. The rest is up to us as individuals. 'Nuff said!'

E.C. Ball
Commodore

MARE PROFESSIONAL DEVELOPMENT SEMINAR – 1984

The Branch Adviser intends to sponsor a MARE Professional Development Seminar in June 1984. The formal request to hold the seminar must still be staffed, however the following can be used for planning purposes:

Dates	- 25 to 27 June inclusive.
Place	- Transport Canada Training Institute (TCTI) Cornwall, Ontario.
Transportation	- Service Air to Ottawa; Ground transportation Ottawa/Cornwall area to be provided.
Accomodation	- In the TCTI, expected cost $22.00 for meals and room.
Registration Fee	- Estimated $25.00 (Mess Dinner extra).

All MAREs will be encouraged to attend. A call for papers will be promulgated concurrent with Departmental approval.

The Journal would like to acknowledge the promotions of the following MAREs to the ranks indicated:

a. Rear Admiral W.B. Hotsenpiller

b. Commodore D.R. Boyle

c. Captain J.E. Ironside

d. Captain B.H. Baxter

e. Commander G.D. Ralph

f. Commander W.R. Starchuck

g. Commander W.B. Embree

h. Commander J.M. Madden

i. Lieutenant Commander W.M. Howes

j. Lieutenant Commander B.O. Coates

k. Lieutenant Commander M.G. Fitzgerald

l. Lieutenant Commander R.K. Miskowicz

m. Lieutenant Commander R.H. Harding

n. Lieutenant Commander M.J. Churcher

o. Lieutenant Commander N.A. Duinker

p. Lieutenant Commander P.J. MacGillivary

q. Lieutenant Commander M. Kling

r. Lieutenant Commander F.E. Harrison

s. Lieutenant Commander D.J.M. Marshall

t. Lieutenant Commander L.P. Mosley

u. Lieutenant Commander J.H. Lavalee

v. Lieutenant Commander J.D. Joyal

w. Lieutenant Commander P.W. Brett

Good luck in your new positions and ranks.

Recommended Reading

REPORT of the Sub-committee on NATIONAL DEFENCE of the Standing Senate Committee on Foreign Affairs - Canada's Maritime Defence - May 1983 was released in early June '83. This comprehensive report covers Canada's Maritime Defence roles, priorities, equipment, manpower, resources, and budget. We recommend all Naval Officers read this report. Copies are available upon request from the Clerk of the sub committee on National Defence, The Senate, Ottawa, K1A 0A4. Cat No. YC 23-321/2-02, ISBN 0-662-52500-0. The following, Summary of Recommendations and Observations, has been extracted from the report for your information:

1. The sub-committee persists in its January 1982 recommendation that work on a white paper on national defence begin immediately. The white paper should clearly state Canada's defence policy and priorities. It should describe the tasks, military or other, which the government expects Canada's armed forces to perform. This process should not, in the meantime, stand in the way of re-equipping the forces.

2. The sub-committee further recommends that the white paper be followed by a firm government commitment to ensure that the required manpower and materiel will be provided according to a stated, definite timetable.

3. Because the first item in the current list of commitments of the Canadian Armed Forces, the protection of Canadian sovereignty, has been narrowly interpreted to include only police functions, the sub-committee recommends that it be recast so as to include specific reference to the defence of Canada.

4. The sub-committee reiterates the recommendation from its first report that the entire question of the CAST (Canadian air-sea transportable brigade group) commitment should be re-examined by Canada in consultation with Norway, the other allied governments and Alliance military commanders.

5. The sub-committee recommends that the Description of Military Tasks, which provides the framework for the daily operations of the Canadian Armed Forces, be reformulated immediately so as to give appropriate emphasis to the defence of Canada; to clarify priorities; to show performance criteria; to indicate dedicated resources; and to identify their geographic distribution.

6. In order to enhance public understanding of defence requirements and to strengthen parliamentary control over defence expenditures, the sub-committee recommends that the Description of Military Tasks in

its new and more comprehensive form be revised at the beginning of each new Parliament and tabled for reference to the relevant committees of both Houses.

7. The sub-committee finds that there is a requirement for Canada's maritime forces to be equipped to perform a sea-denial role in waters over which Canada claims jurisdiction.

8. The sub-committee recommends that the precise nature of the maritime tasks undertaken by Canada within the context of the Atlantic Alliance be subject to continuous review so as to ensure that Canada's maritime forces will reacquire the capacity to make a full contribution to NATO at sea, while maintaining their ability to act in defence of Canadian sovereignty and to continue effectively to the defence of North America.

9. The sub-committee recommends that Canada's anti-submarine warfare tasks be confined to those of a tactical nature - defense against anti-shipping submarines - and only such strategic surveillance missions as can be carried out with the same equipment.

10. The sub-committee recommends that any equipment acquired for Maritime Command should be designed with specific wartime tasks in mind. Peacetime duties could then be assigned as ancillary missions, as is now the case.

11. The sub-committee recommends that the practice be established of regularly seconding some Maritime Command personnel to the Coast Guard for practice and training in Arctic navigation.

12. To arrest the continuing decline in the status and readiness of our maritime forces, the sub-committee recommends that, as an increment to funding required for replacement of current equipment on a one-for-one basis, an extra $550 million per year, in constant 1983 dollars, be dedicated to the acquisition of capital equipment for MARCOM. This would represent a 7 per cent real increase in the defence budget, a 0.64 per cent increase in the national budget, and an increase in defence expenditures as a percentage of GNP from the current just over 2 per cent to about 2.2 per cent.

13. The sub-committee's general recommendations for a balanced fleet are, in order of priority:

- that contracts be let immediately for the CPF program and for the follow-on programs;

- that orders for eighteen more Aurora aircraft be placed immediately, in order significantly to improve MARCOM's capabilities in the shortest possible time, and to provide an ongoing, enhanced capability;

- that a significant mine-countermeasure capability be acquired by MARCOM;
- that more diesel-electric submarines be acquired by MARCOM;
- that missile-equipped fast patrol boats be acquired;
- that the existing Auroras be equipped with air-to-air and air-to-surface missiles, and the Trackers with rockets;
- that the Oberon-class submarines receive a sub-surface-to-surface missile and a more modern torpedo and that the ten newest DELEX destroyers be equipped with a surface-to-surface missile and a close-in defence system.

14. The sub-committee recommends that two studies be undertaken without delay by DND, for tabling in Parliament. The first should analyze the relative merits of providing Tactical Air Group with anti-shipping attack aircraft or equipping Tactical Air Group and Fighter Group CF-18s with Harpoon or other air-to-surface missiles. The second should examine the feasibility in the Canadian context of fitting several merchant vessels to accommodate the helicopters and other weapons necessary for ASW escort duties.

15. The sub-committee recommends that the government seek to lengthen its perspective on military procurement, de-emphasize formula funding and favour series production in order to shorten the procurement process and to effect economies.

16. The sub-committee recommends that, to the extent possible, costs incurred by DND for purposes other than defence be identified as such in the spending estimates.

17. The sub-committee was deeply impressed by the evidence presented in support of the requirement for additional opportunities for shore duty for sea-going personnel and recommends that the Department of National Defence immediately explore means of increasing the number of shore postings available to the naval trades and allocate a larger number of positions in the training and service functions for such personnel.

18. The sub-committee recommends that the projected rate of increase in MARCOM's authorized personnel establishment be accelerated.

19. The sub-committee, on the basis of testimony received, recommends that MARCOM personnel be issued and permitted to wear recognizable trade badges and distinctive rank identificaation.

20. In order to fill the gap between the size of the Regular Force in peacetime and the immediate requirement for trained personnel in the event of war, the sub-committee recommends that:

- the number of identified Naval Reservists from all components of the Naval Reserve be increased to a minimum of 8,000;
- four additional Naval Reserve divisions be established in communities where no division exists at present;
- a Fishermen's Reserve be created;
- as recommended in the sub-committee's first report, the Supplementary Reserve be provided with some minimal training and that arrangements for its mobilization be put in place;
- each component of the Naval Reserve provide personnel in the following numbers:

Primary Reserve	4,500
Supplementary Reserve	2,300
Fishermen's Reserve	1,200
Total	8,000

21. The sub-committee recommends that the government consider adding $75 million to the capital budget of DND for procurement of essential training aids; upgrading of accommodation for some existing Naval Reserve units; and construction of four new Naval Reserve divisions.

22. The sub-committee recommends that the Naval Reserve be provided with suitable training vessels on a priority basis and that, to the maximum extent possible, reservists be trained in peacetime aboard classes of vessels which they would be called upon to operate in wartime.

23. The sub-committee recommends that, in order to encourage all other employers to grant leave for reserve training, the Government of Canada make it mandatory for federal departments and crown corporations to allow reservists up to two weeks special leave a year for purposes training.

24. The sub-committee recommends that a mobilization plan for Canada's armed forces be adopted and promulgated forthwith so that Canadians may be re-assured by more than bland assertions.

25. The sub-committee recommends that planning and organization for the national emergency agencies defined in Order-in-Council 1981-1305 be proceeded with on a priority basis, and that the resources necessary

to complete such arrangements in no more than four years from the commencement of the current fiscal year be allocated to the relevant departments.

26. The sub-committee recommends that new legislation be presented to Parliament for early enactment to permit graduated government responses in crisis situations; to enable the government to draw on civilian capabilities in crisis situations short of war; and to authorize the mobilization of reserve forces and civilian capabilities as required by crisis situations or the outbreak of war.

27. The sub-committee believes that the question of the status, in crisis period of wartime, of Canadian vessels operated under foreign flag requires examination. Because of the important commercial and transportation considerations involved, the sub-committee recommends that this matter, in its civilian and military aspects, be referred to the Senate Committee on Transportation and Communications for study and report.

28. (a) The sub-committee recommends that the feasibility of modification for military use be studied before any new government vessel is constructed, acquired or refitted and that, where possible, the design incorporate the necessary features up to and including the fitting for, but not with, the necessary weapons, communications and sensor systems. Such systems should, however, be acquired and stored in appropriate locations for rapid installation as required.

(b) The sub-committee also recommends that any resulting additional costs be financed by commensurate increases to the capital budget of the Department of National Defence so that the already inadequate re-equipment program for the Canadian Armed Forces will not be further retarded.

29. The sub-committee reiterates the recommendation from its first report that a comprehensive system for the mobilization of Canada's non-military maritime resources be established and that, as a first step towards this end, plans be developed for full integration of all government operations at sea in times of hostilities.

30. Keeping in mind the need to continually assert sovereignty, the sub-committee recommends that the government examine the need for a year-round Arctic base to provide support for air, land and sea operations of all departments with responsibilities in the North.

31. The sub-committee recommends that the Canadian Armed Forces continue to be assigned search and rescue as a major task.

32. The sub-committee recommends that the government immediately undertake a study to determine which strategic materials are vital to Canada and which depend on uninterrupted sea lines of communications. It should also seek to determine the feasibilty and costs of creating stockpiles of strategic materials for which substitutes are not available in Canada.

In the sub-committee's view, the primary aim of Canadian maritime defence policy should be to create a renewed, balanced fleet within twelve years. The policy should take into account both the need for approximately twice as many major weapons-platforms as MARCOM now possesses and the need to compensate rapidly for current lack of capabilities and numbers, while ultimately creating a balanced force.

The sub-committee is fully conscious that the implications of the recommendations contained in this report involve increases in defence expenditures. Pains have been taken to spell out these costs. The report argues that, to rebuild Canada's maritme forces, an additional $550 million a year in constant 1983 dollars must be added to the capital budget of the Department of National Defence over the next twelve years and earmarked for this purpose. The ongoing costs for personnel, operations and maintenance of implementing the recommendations would be approximately $80 million a year (in constant 1983 dollars). In the sub-committee's first study, Manpower in Canada's Armed Forces, the cost implications of the recommendations amounted to $350 million a year (approximately $400 million in 1983 dollars). Taken together, these recommendations of the two reports would see defence expenditures mount, in relation to Canada's GNP, from about 2 percent to about 2.3 per cent. The sub-committee has not completed its studies of Canada's armed forces. As it looks at other commands, such as Mobile Comand and Air Command, the sub-committee fully expects to encounter situations demanding additional expenditures. The sub-committee finds it is being drawn inexorably towards recommendations which would ultimately see Canada's defence expenditures rising to somewhere between 2.5 per cent and 3 per cent of its GNP.

For years, Canada has placed great emphasis upon reducing the risk of nuclear conflict. Canada has been singularly active in pursuing this goal in international forums and through informal consultations. In addition, this country has sought to distance itself. Later, Canadian forces were withdrawn from nuclear roles. Shortly, the last nuclear weapons held by Canada, those deployed with its NORAD forces, will be replaced by conventional systems. It would be utterly inconsistent with Canada's past attitudes and present policies not to continue to act in a manner which has the ultimate effect of reinforcing efforts within the Alliance to minimize the possibility of nuclear war. Canada should, in particular, do everything possible to enable the Alliance to espouse a strategy of "no early use" of nuclear weapons. By running down its forces, as it did in the late 1960s and through the 1970s, Canada contributed not to raising but to lowering the nuclear threshold.

National Defence Défense nationale