R.N.E.C., MANADON, POST-GRADUATE PROJECTS

As a part of the M.Sc. Course in Marine Engineering (AMEC) and the M.Sc. Course in Maritime Defence Technology (AMDTC) at the Royal Naval Engineering College, each student spends 17 weeks working at a particular research project. Those who are successful are awarded M.Sc. degrees by the Council for National Academic Awards. Successful students on the AMDTC are also eligible for the City and Guilds Insignia Award.

A summary of each project is printed below. The full reports are held at R.N.E.C. and further information may be obtained from the Director of Post-Graduate Studies, Royal Naval Engineering College, Manadon, Plymouth PL5 3AQ.

Projects by AMEC 22 (1986–1987)

Further Developments in the Application of Scanning Reference Electrode Techniques in the Study of Pitting Corrosion in Gas Turbine Disc Materials
by Lieutenant J. G. C. HAINSE, B.Eng., M.Sc., Canadian Forces

A Scanning Reference Electrode Technique (SRET) has been developed at the Royal Naval Engineering College to monitor *in situ* local variations in potential adjacent to the pitted surface of a gas turbine disc steel. This technique can distinguish anodic and cathodic sites in a corroding material but detailed analysis is limited by its inability to acquire and display large amounts of data.

This project continued the development of this technique by interfacing a microcomputer for real time data acquisition, greater data storage and improved data handling capabilities. The analysis of local potential changes in the pitted area can be displayed using a line graph or contour map which provide a pictorial representation of the corrosion activity taking place.

A Quantitative Study into Cavitation Corrosion of 'Superston Seventy', a Marine Propeller Material
by Lieutenant T. J. HALEY, M.Sc., C.Eng., M.I.Mar.E., R.N.

The corrosion characteristics of Superston Seventy, a manganese aluminium bronze marine propeller material, have been examined in natural sea water. It has been shown that Superston Seventy is a more active metal than other propeller bronzes.

Selected specimens were subjected to various intensities of cavitation by a 20 kHz ultrasonic vibrator. The test rig was designed and operated in the laboratory. Results from the project show that if a Superston Seventy specimen is subjected to both cavitation and polarization the subsequent weight loss increases between 3 and 15 times that from either corrosion alone or from cavitation alone in a sea water electrolyte.

Acoustic Emission Source Location in Bi-Directionally Reinforced Composites
by Lieutenant-Commander E. O. IBITOLU, B.Eng., M.Sc., Nigerian Navy

Acoustic emission is widely used in isotropic materials to determine the location of defects from the relative arrival times of the elastic wave at individual transducers within the sensor array. In isotropic materials the wavefront is circular, but in fibre-reinforced plastics the anisotropic heterogeneous structure of the material leads to a distorted wavefront. The elastic properties of fibre composities vary with the orientation of the loading axis

relative to the principal axis of the reinforcement. The velocity of propagation of an acoustic wave is a function of the elastic modulus relevant to the mode of propagation.

This project describes a method of source location in bi-directionally reinforced composites. The non-circular wavefront precludes the use of the conventional source location algorithm. The form of the wavefront was established by direct measurement and compared with that obtained by calculation from experimental elastic moduli. The new source location algorithm uses a model for the shape of the wavefront in which a cosine function is superimposed on a circle. This method significantly improves the accuracy with which the defect position is predicted.

Increasing the Submerged Endurance of a Conventional Submarine using a Stirling Generator System
by Lieutenant R. A. SYLVESTRE, B.Eng., M.Sc., P.Eng., Canadian Forces

The results show that the use of a Stirling generator system in a Type 2400 submarine could significantly increase its submerged endurance. An advanced engine simulation code was developed and then validated against test results for a 40 kW United Stirling P40 engine. The simulation was then used to investigate the uprating of the P40 engine design so that two generator sets could supply the power for slow speed submerged patrol. The system, which included a liquid oxygen storage tank, was designed for installation into a 7 m add-on section to the submarine.

Analysis of Ship Roll Stabilization Systems using Purely Passive and Controlled Anti-Roll Tanks, with the Aid of a Digital Simulation
by Lieutenant-Commander T. L. BARBOZA, M.Sc., BRAZILIAN NAVY

At low speeds, active fins have no effect on ship stabilization. Under these conditions the fins are appendages which increase the hull resistance. Although stabilization can be improved by incorporating anti-roll tanks, little is known of the control philosophy and therefore few ship designs have adopted this approach. This report investigates a control strategy and analyses the performance of anti-roll tanks using simulation techniques.

Mathematical models for the dynamics of a system consisting of a ship and anti-roll tank in controlled and uncontrolled forms are proposed. Digital simulations corresponding to these mathematical models have been developed in order that predictions of roll motion and some analysis of the control of this type of system can be made.

Two numerical applications are presented. One is to a landing ship dock type, since this type of ship performs disembarkation operations at zero or very low speed. The other is a typical ship having the same displacement and same metacentric height as H.M.S. *Challenger*. Discussion of the results obtained and the limitations of the simulation methods are presented.

Cascade Testing of Turbine Blades
by Lieutenant-Commander M. N. KHAN, B.E., M.Sc., Pakistan Navy

There is a need to design turbine blades such that the surface velocity distribution does not promote the onset of boundary layer separation causing unacceptable losses. This project attempts to validate a prescribed velocity distribution (PVD) by predicting turbine blade shape from measured velocity data. A test rig was manufactured and velocity and turbulence profiles were measured for a range of air incidence angles between $-5°$ to $+20°$. This information was processed by a PVD analysis programme to generate a blade profile using inverse design techniques. The predicted blade profile was then compared with that used in the test rig and similarities were found.

An Assessment of Modal Analysis Techniques for Force Prediction in Open-Coupled Systems
by Lieutenant S. J. LLOYD, M.Sc., C.Eng., M.I.Mar.E., R.N.

The application of modal analysis techniques to force prediction in an open coupled system were considered. A rigidly clamped mild steel beam was modelled with 3 degrees of freedom. Two types of model were formed for the beam: a modal representation in terms of natural frequencies and mode shapes, and an equivalent spatial representation in terms of mass and stiffness elements. Displacement measurements were taken from the beam in response to a single applied harmonic force. These response measurements and the system models were used to predict the force vector applied to the structure. The procedure was repeated for a 5-element model of the beam, and the tests were extended to include the application of 2 in-phase harmonic forces. The accuracy of force prediction decreased as both the number of elements and applied forces were increased. The natural frequencies and mode shapes of a system show an increased sensitivity to measurement error in certain elements of mass and stiffness. An analytical technique was demonstrated to locate these particular elements and a second technique was used to assess the effect of errors in the modal parameters on the predicted force. A procedure was proposed for an open coupled system to minimize the sensitivity of force prediction to error in displacement measurement.

Digital Control of a Marine Diesel Engine
by Lieutenant K. A. HOWARD, M.Sc., R.N.

The dynamic characteristics of diesel engines can vary greatly with power and speed. Existing marine diesels are fitted with simple hydraulic or electronic speed governors which are tuned for one specific condition and take no account of these variations. A digital controller offers scope for improving the transient performance of the engine and allows for future developments. Other benefits such as data logging facilities and fault diagnosis procedures can easily be incorporated.

In this project, simple linear transfer function models of a turbo-charged 4-stroke diesel engine were identified for different loads and speeds. A digital engine controller was designed and implemented on a micro-computer and tested on the engine. Results have shown that one transfer function model is insufficient to describe the engine transient behaviour other than at its design operating condition.

Multivariable Control of a Marine Diesel Generator System
by Lieutenant R. W. TOOKE, M.Sc., R.N.

Naval warships have traditionally used diesel generators for electrical power systems and, more recently, for cruise propulsion. The requirement to maintain accurate and stable power supplies has led to improvements in diesel governors and automatic voltage regulators. Incorporating these devices in a single loop control system does not take into account the fundamental interaction between rotational speed and generated e.m.f. A more sophisticated control strategy is required. Recent multivariable control techniques allow interactive systems to be decoupled by using integrated controllers. Improved transient and steady-state performance results. Application of these techniques has been shown to produce a significant improvement in the transient response of turbo-alternators operating on infinite bus systems.

This project investigates the application of multivariable techniques to a single marine generator system and shows that decoupling of the speed and voltage loops can be achieved.

Power System Analysis

by Lieutenant J. M. NEWELL, M.Sc., C.Eng., M.I.Mar.E., R.N.

It is common practice to use computer aided design packages during the development of new electrical power systems. Although packages with proven capabilities were available, the MOD (Procurement Executive) requested the Royal Naval Engineering College to develop a package tailored to specific requirements for validating new and existing marine power system designs.

This report describes the methods by which a marine power system analysis package has been developed. The modules include load flow analysis and fault level analysis sections. There is also the facility to store systems on file and alter them as required. Simple models of synchronous machines and induction motors were used to obtain the transient response during short circuits. Further work would be required to validate the techniques used.

A Modern Conventional Submarine Propulsion System Simulation

by Lieutenant-Commander R. E. WORMALD, M.Sc., R.N.

Modern conventional submarine designs offer quiet propulsion using d.c. electric motors powered by lead-acid batteries. In this project a simulation was developed capable of predicting the discharge of a typical submarine battery by a propulsion system which may be configured in a number of ways. Further, it has shown how the simulation could be used to provide advice to the submarine Commanding Officer as to the preferred system configuration for any specified speed in order to conserve battery charge and maximize the boat's true submerged endurance.

Projects by 86 AMDTC (1986–1987)

Maximum Entropy Filtering and its Application to Target Motion Analysis

by Lieutenant C. M. G. BULLARD, M.Sc., C.G.I.A., R.N.

This report examines the application of time domain filtering by the Maximum Entropy Method, to the problem of Target Motion Analysis. A computer program has been developed which models the motion of the target and the noise environment, filters the resultant bearings and frequencies, and estimates target motion. The major constituents of this program are discussed in the report. The results of Maximum Entropy filtering are examined and compared, both in the time domain and the spacial domain, with those of a simple Kalman filter.

Expert System Advisor for Damage Control in Warships

by Lieutenant-Commander R. J. IBBOTSON, M.Sc., C.G.I.A., R.N.

This project investigates the application of expert system technology to computerized decision support for a warship's damage control headquarters. The type of support that would be useful is identified, appropriate response times specified, and the nature of the man-machine interface clarified. An estimate is made of the size of knowledge base required and the capabilities and limitations of currently available expert system shells are reviewed. A simple demonstrator system has been implemented using tools from the Alvey Directorate's Expert System Starter Pack and a commercial expert system shell 'Insight 2+', running on an IBM personal computer.

Coded Radar Signals

by Lieutenant I. G. RANKIN, M.Sc., C.Eng., M.I.E.E., C.G.I.A., R.N.

This project reviews some of the techniques available for the coding and pulse compression of radar signals. An 'ideal' military radar signal is proposed that would have amongst its attributes a high probability of

detection, good range resolution and a low probability of intercept. Each technique is examined against this ideal signal. Both theory and principles of each technique are discussed and their properties are reviewed. Possible military applications of these techniques are summarized. A laboratory teaching system to demonstrate some of the key properties of several of the techniques has been constructed and is described. Coding techniques and applications requiring further research are proposed.

Passive Sonar Target Tracker

by Lieutenant S. G. WALTERS, M.A., M.Sc., C.G.I.A., R.N.

Current passive sonar systems generate a number of channels, each covering a sector in azimuth and producing frequency versus time information on possible targets. The human operator is required to monitor and correlate the data displayed. Future systems will generate hundreds of channels. A target tracker will be required to process this data and reduce the operator's task to manageable proportions. A set of computer programs has been developed at ARE Portland to carry out the functions of a Passive Sonar Target Tracker. This project implemented the program on the R.N.E.C. Cyber, and evaluated them under a wide range of input conditions. Modifications were carried out to improve detection rates and reduce ambiguities.

Optical Correlation Techniques

by Lieutenant J. F. WOMBWELL, M.A., M.Sc., C.G.I.A., R.N.

The use of acousto-optic devices in real-time signal convolution and correlation has grown dramatically in recent years. Depending on the application, correlators may be implemented using spacial or temporal integration. A technique has been postulated that would make use of the ability of optical techniques to produce rapidly the cross-correlation function, the shape of which may then be examined to detect Doppler shifts. This report describes work done at R.N.E.C. to set to work non-heterodyning and heterodyning spatial correlators and to investigate the shape of the correlation, using linear FM and Barker coded waveforms. The most accurate results were obtained from a Double Side Band, Large Carrier spatial correlator, and are analysed in the report.