ADVANCED MARINE ENGINEERING COURSE AT R.N.E.C., MANADON

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Introduction

The Royal Navy since 1918 has provided an Advanced Marine Engineering Course (AMEC) for selected naval engineer officers to prepare them for appointments associated with the design and development of marine engineering systems and equipment for the Fleet. A significant landmark in the history of the course was its transfer from the Royal Naval College, Greenwich, to the Royal Naval Engineering College, Manadon, in 1971 in order to take full advantage of the expertise and specialist engineering facilities already established at Manadon. The course was redesigned to reflect advances in technology and the content of the then current Mechanical Engineering first Degree Course at Manadon. In 1976 the AMEC was successfully submitted to the Council for National Academic Awards (CNAA) for recognition of the award of Master of Science in Marine Engineering.

Following an initial revalidation by the CNAA in 1979, the course underwent a major review, as a consequence of the introduction of a single Electro-Mechanical First Degree Course at the College in place of separate Electrical and Mechanical Engineering Degree Courses. The review included an exhaustive analysis of course objectives in consultation with the Ministry of Defence Procurement Executive (Ship Department) as the employers, the Commander-in-Chief Naval Home Command as the Administrative Authority, and the Ministry of Defence (DNMT(E)) responsible for training policy. The most important single decision that emerged from the discussions was to introduce an electrical option in parallel with the existing steam and gas-turbine options, each based on an integrated common core of subjects. The need for the introduction of the electrical option arose from the change in the Engineering Branch delineation of responsibilities requiring some marine engineer officers to possess in-depth knowledge of electrical power systems and electronics applied to ship and submarine propulsion and auxiliary systems.

The revised course with its agreed objectives using the new first degree as a platform was successfully submitted to the CNAA in December 1980 for M.Sc. recognition. Subsequently the first course to include the electrical option was launched in May 1981.

The purpose of this article is to provide an appreciation of the AMEC, in the context of the Course review, identifying its objectives and the underlying philosophy leading to its structure, content, and conduct.

Course objectives

The broad aim of the AMEC in 1981 has altered little in sense since its inception in 1918 and this is to provide selected marine engineer officers with a suitable post-graduate education for subsequent employment in the Ship Department of the Ministry of Defence (Procurement Executive) or equivalent posts in the Ministry of Defence Research Establishments, so that they can complement effectively their civilian counterparts.

During the course review an operational task was stated identifying the role of the AMEC-qualified officer as controlling and leading the design and development of ship systems in selected appointments, matching industrial and technological capabilities with naval operational requirements. The following operational objectives were agreed as those necessary to carry out the task:

(*a*) Development and specification of engineering requirements and standards to meet stated ship or system functions.

(*b*) Analysis of options for meeting future ship requirements in the light of advancing technology, research, and development.

(*c*) Introduction of new systems into satisfactory sea service by leading design, development, and proving teams.

(*d*) Solution of engineering problems arising from in-service systems to promote satisfactory operational sea service.

(*e*) Presentation of arguments logically, both orally and in writing, justifying engineering and economic decisions.

It was quite clear that no single course could meet all of these. However, one of the great strengths of the Navy is that, as the employer/educator/trainer, it is in a position to devise integrated programmes of training over a long time period to achieve its known objectives. The AMEC was thus viewed and designed as part of a whole, building on the first degree and combining known subsequent professional training and experience with the intellectual demands of the AMEC to meet the overall operational objectives.

The AMEC is essentially an educational component of the whole, developing the intellect and providing a body of knowledge and expertise demanded by the work to be undertaken. Three educational objectives emerged and whilst they cannot be ascribed exclusively to any operational objective they contribute to a greater or less extent to all. They are:

(*a*) to extend and develop knowledge and comprehension in subjects of central relevance to marine engineering with particular regard to warship propulsion and auxiliary systems;

(*b*) to apply theory and techniques acquired through the course to typical engineering problems involving critical judgement, analysis and synthesis for their solution, and to establish clarity in their expression and presentation;

(*c*) to develop the ability to conduct research and development studies within accepted standards of scientific discipline, and to organize, carry out, and present such work.

These three educational objectives led to a set of relevant enabling objectives which are listed in the Annex and essentially summarize the course content. From these, the lesson plans, tutorial work, course schemes, and project conduct were derived.

Many will recognize the influence of NAVCOTS in this attempt to identify clearly the course objectives, establishing what we are doing and why we are doing it. To some, this rather cumbersome approach is anathema and difficult to apply at higher levels of learning. There is no doubt that it generates a mountain of documentation. However, the process proved an excellent mind-clearing exercise for all concerned and was of good value. After all, if you do not know where you are going then you are not likely to get there.

SUBJECTS	OPTIONS		
	GAS TURBINE PROPULSION	STEAM PLANT	ELECTRICAL
MAIN SUBJECTS (with number of periods)	← CONTROL (120) →	← CONTROL (120) →	← CONTROL (120) →
	← VIBRATIONS (80) →	← VIBRATIONS (80) →	← VIBRATIONS (80) →
	← HEAT TRANSFER THEORY (43) →	← HEAT TRANSFER THEORY (43) →	ELECTRICAL POWER SYSTEMS (132)
	GT PERFORMANCE (61) AND COMBUSTION (22)	STEAM-PLANT PERFORMANCE (83)	
	BEHAVIOUR OF MATERIALS (67)	BEHAVIOUR OF MATERIALS (67)	ELECTRONIC SYSTEMS (61)
COMPLEMENTARY SUBJECTS (with number of periods)	← COMPUTATION (31) →	← COMPUTATION (31) →	← COMPUTATION (31) →
	← MATHEMATICS (24) →	← MATHEMATICS (24) →	← MATHEMATICS (24) →
	← DIESEL-PLANT PERFORMANCE (22) →	← DIESEL-PLANT PERFORMANCE (22) →	← DIESEL-PLANT PERFORMANCE (22) →
	← PROPULSION TRANSMISSION SYSTEMS (20) →	← PROPULSION TRANSMISSION SYSTEMS (20) →	← PROPULSION TRANSMISSION SYSTEMS (20) →
	← RELIABILITY (13) →	← RELIABILITY (13) →	← RELIABILITY (13) →

FIG. 1—SUBJECTS UNDERTAKEN ON THE ADVANCED MARINE ENGINEERING COURSE

Course Structure

The AMEC is a full-time fifteen month course of four terms duration divided into two halves. The first half of two terms comprises a lecture and tutorial course supported by course schemes, leading to mid-point examinations. The second half is allocated to a major project, set in one or more of the academic disciplines studied. The course is arranged with a common core of subjects together with three specialist options:

(*a*) Gas Turbine Propulsion ('G' Option).

(*b*) Steam Plant Propulsion ('S' Option).

(*c*) Electrical Power Systems ('L' Option).

The subjects included in each option are summarized in FIG. 1. As the course progresses there is a change in emphasis from the acquisition and application of knowledge to analysis, synthesis, and evaluation. Throughout the course, attention is given to the effective communication of technical information. Extension of knowledge and comprehension of modern techniques applied in marine engineering are further achieved by technical visits to industrial firms and Ministry of Defence Research and Development establishments undertaking work on behalf of the Director General Ships.

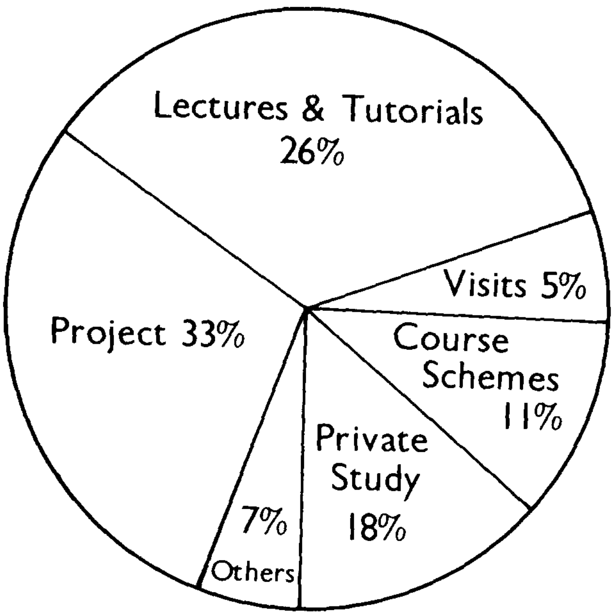

FIG. 2—CONTENT OF THE ADVANCED MARINE ENGINEERING COURSE

Lectures and tutorials	503
Private study	345
Course schemes	205
Project	649
Visits	112
Other, including exams, joining, leaving, ELWEs, public holidays.	146
	1960 periods (56 weeks)

TERM \ OPTION	GAS TURBINE	STEAM PLANT	ELECTRICAL
ONE	← Simulation →		
(Summer)	Combustion Chamber Design	Steam Flow Analysis	Parallel Operation of Generators
	← Diesel Uprating →		
	← Sampled Data →		
TWO	← Stress Analysis →		Induction Motor Starting Transients
(Autumn)	Power Turbine Design	Condenser Design	Microprocessor Controlled Data Acquisition System
	← Gearbox Vibrations →		
THREE (Spring)	Nil		
FOUR	Transmission Design		
(Summer)	Reliability Study		
	Warship Machinery Comparison Study		

FIG. 3—COURSE SCHEME PROGRAMME

FIG. 2 provides a breakdown of the relative time allocation to the various course activities and FIG. 3 shows their position in the overall programme.

Lecture Programme

The programme of lectures and tutorials is associated mainly with the first educational objective of extending and developing knowledge and comprehension of subjects of central relevance to marine engineering with particular regard to warships and propulsion systems. The lecture programme dominates the first two terms of the course and commences with five days devoted to digital and analogue computation, developing competence in elementary FORTRAN 4, and programming the College's Rank Xerox Sigma 6 computer. On completion, the main subjects—thermofluids, electrical power systems, control, vibrations, electronic systems, and behaviour of materials—are taught throughout the first two terms and additionally, during term 1, there are lectures and tutorials in mathematics and diesel plant performance. For most subjects teaching time is divided between lectures and tutorials in approximately a 2:1 ratio.

During the course review, it was noted that a consistent adverse criticism was the intensity of the lecture programme which left too little time for in-depth study during that part of the course. To alleviate the situation, the following changes were introduced:

(*a*) A reduction of formal examinations from five to four, reducing the amount of revision work required for the examinations by assessing certain sections within the appropriate course schemes.

(*b*) Timetable adjustments, including delaying some technical visits to the second half of the course and a re-arrangement of lecture, tutorial, and private study periods aimed at significantly enhancing the effective use of private study.

(*c*) A reduction in the content of examination material.

(*d*) A reduction in the number of course schemes conducted prior to the examinations at the end of the first two terms.

These modifications have improved the situation but there is still room for further development. More time must be found for officers to pursue in depth directed self study, thereby inducing a greater atmosphere of scholarship, normally associated with post-graduate degree courses. This could, of course, be achieved at a stroke by simply reducing course content. However, the objective nature of the course design presents the dichotomy of the breadth of material to be covered, with the in-depth study demanded for 'intellectual stretch'. This incompatibility can effectively be overcome by introducing a spiked profile to the lecture programme where selected topics associated with staff special expertise form the spikes and are used as the vehicle for in-depth studies. Other areas, such as techniques, alternative analysis, and methods, of which the student must be aware, are not dealt with as exhaustively as hitherto. This solution presents problems of its own in assessment and selection of material and these are currently being addressed with the aim of reducing lectures by some 25 per cent.

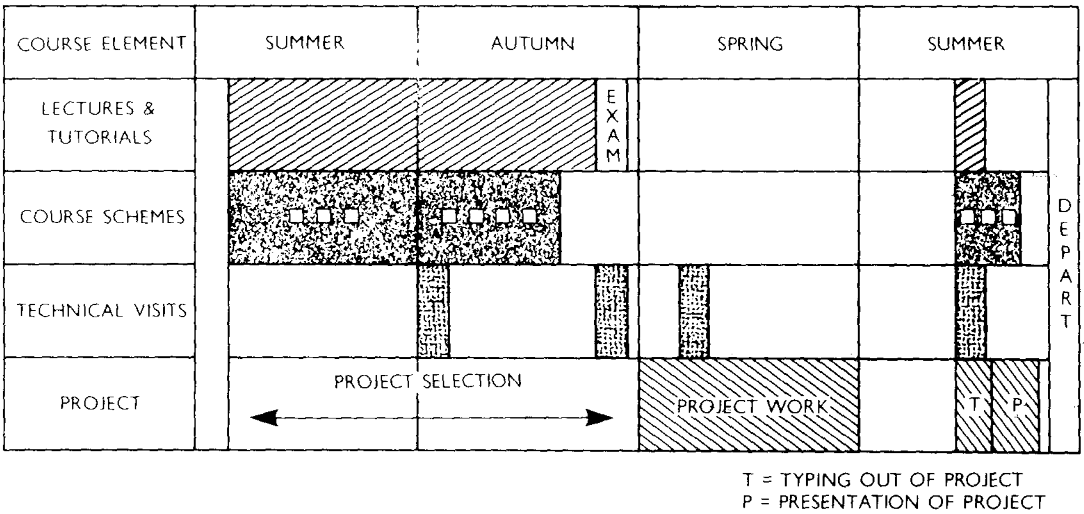

FIG. 4—AMEC OVERALL PROGRAMME

Course Schemes

A major feature of the AMEC is the course schemes associated mainly with the second educational objective of applying the theory and techniques of the lecture programme to typical engineering problems. These involve critical judgement, analysis, and systhesis for their solution and help to establish clarity in their expression and presentation. Altogether twenty-one course schemes are available of which a student on a particular option will do ten. The schemes are typical engineering problems that the students may confront in later employment and they provide a bridge between conventional tutorial work and the open-ended project work of the latter half of the course.

Some of the schemes are carried out individually whilst others are done in syndicates to provide experience of tackling quite large problems on a team basis. Each scheme is allocated from two to four calendar weeks for completion and a typical three-week scheme is designed to be completed by the average student in twenty-one programmed periods and ten hours of unprogrammed time. An example of a typical course scheme programme and its broad location within the course is shown in FIG. 4.

During the course review, the course schemes emerged as a particularly useful and well-received part of the course. The main criticism was that the assessment system did not properly recognize either their importance or the effort demanded of the student. This was rectified by doubling the contribution of the course-scheme mark to the final degree award. There is scope within the course-scheme programme for encouraging the enhanced atmosphere of scholarship that is now being sought. The possibility of excluding subject matter covered in course schemes from formal examinations, viewing that material as part of continuous assessment, is under consideration. Further, the opportunity to reduce formal written presentation in DRIC Spec 2000 report form in favour of a viva voce for some schemes is under investigation.

Project Work

The project relates mainly to the third educational objective of developing the ability to conduct research and development studies within accepted standards of scientific discipline, and to organize, carry out, and present such work. Project selection occurs early in the second term to provide a lead time for a literature survey. Each officer chooses an individual topic from a list provided and studies this during the final two terms of the course under the direction of a suitable member of staff.

Great care is exercised in providing suitable project topics. These normally arise from established college research areas, often in collaboration with the Ship Department or Research Establishments. A major consideration is the selection of supervisors and the considerable effort devoted to developing research work at the College during the past decade has played a vital part in providing staff officers of the calibre required to ensure that the intellectual demands on the student are at an appropriate level.

Completed project work is submitted as a bound volume and a feature of the project arrangements is individual oral presentations to an invited audience comprising representatives from interested sections in the Ship Department or MOD research establishments, universities and polytechnics, MOD civilian contractors, and guests from foreign and Commonwealth navies. The presence of a large, distinguished, and knowledgeable audience does much to stimulate discussion and constructive criticism of the work presented. It also goes a long way towards ensuring that the College does not delude itself as to the quality of the project work. TABLE I lists the projects undertaken by the most recent course.

TABLE I—*List of projects undertaken by the 1980 AMEC*

1 The building-block approach to system dynamics
2 An investigation into the susceptibility of nickel-aluminium-silicon brass to stress-corrosion cracking in sea water
3 Calculation of offset propeller thrust
4 A low-cost onboard engine-health-monitoring system
5 Steering, stabilization, and computer control
6 The modelling and control of ship dynamics using spectral methods
7 Adaptive control of periodic vibration

During the course review, ample evidence from external sources indicated that the standard of project work on the course was very high indeed, comparing favourably with that expected at universities. The key to success was identified as the provision of real naval problems as project topics and an adequate underpinning by active researchers to provide staff of the right supervisory calibre. This policy will continue.

Assessment

Assessment procedures satisfy the CNAA regulations for the Award of a Master of Science Degree and amount to a combination of continuous assessment and written examinations. A major hurdle is the mid-course formal examination in the four main subjects where a maximum of 400 marks are available; failure at this stage results in removal from course. There is a strong emphasis on continuous assessment both in the course schemes and the project. The course schemes carry 200 marks and individual performance is assessed on the basis of active and constructive participation, the written report if applicable, and where appropriate a viva voce on completion of the work. The maximum mark for project work is 400 and progress is monitored and assessed by the Supervisor, the Head of Section involved, and Course Leaders. Each student is required to maintain a project work book for periodical reviewing, in addition to the formal written and oral presentations mentioned earlier. Satisfactory completion of the course and award of the CNAA M.Sc. degree are achieved by obtaining at least 45 per cent. of the available marks in each of the three course activities. Individual written examination failures can be condoned if the student achieves 45 per cent. overall in the examinations and his general performance warrants exceptional treatment. Officers who achieve the total of 70 per cent. on the course as a whole and whose performance has been outstanding may be recommended for the M.Sc. Degree with Distinction. The best performance by an officer on course is rewarded by the award of the Course Prize, currently a cheque for £100. All R.N. officers who pass the course are subtitled ME† or MESM† in the Navy List, the (†) indicating that they are AMEC-qualified officers.

At the course review, several changes were made to the assessment procedures, the major two of which were a doubling of the course scheme contribution to the final mark and modification of the system for the award of project marks. The effects of these and other fine tuning adjustments are currently being assessed.

Student Population

The AMEC is open to Royal Navy, Foreign, and Commonwealth officers and to civilian defence contractors. Conditions for entry to the course are normally an Honours Degree in an appropriate discipline, together with recommendations from a Manadon Application Course, and from sea. These conditions are for R.N. officers in particular, for whom the course is designed, but they also apply to many Foreign and Commonwealth candidates. It is not always possible to apply these criteria directly to, for example, civilian defence contractors and each case is considered carefully on an individual basis by the Course Leader and his Deputy.

The basic philosophy of acceptance is that the student should have a reasonable chance of success. It is not always possible to make such a judgement and quite often the College requires attendance at a pre-AMEC, normally for a term, to assess potential. The pre-AMEC has proved quite valuable in de-rusting officers and making good deficiencies in subject areas not entirely covered by their earlier degree. It has also proved particularly useful for Foreign and Commonwealth officers as a settling-in period.

Since 1918 over 500 officers have attended the AMEC and over 80 per cent. of these have been R.N. officers. This proportion for recent courses has been nearer to 50 per cent. reflecting in part the growing international popularity of the course. TABLE II summarizes the student population figures from 1918. Since CNAA recognition for the M.Sc. award in 1976, five courses have been completed at the College with a total of 43 acceptances for attendance. Of the 43 candidates, 7 were awarded M.Sc. Degrees with Distinction, 31 were awarded M.Sc. Degrees and 5 were failed. The results are considered satisfactory although there is some concern with the failure rate of some 12 per cent. a proportion that is gradually reducing with the judicious use of the pre-AMEC.

The policy of accepting a significant proportion of students other than R.N. officers has been a success and it is considered that their inclusion has added a further dimension to the educational experience. Recent enquiries have been received from Brazil, Nigeria, Canada, Australia, and Holland for the next course and this is welcomed, but it is intended that a balance of 50 per cent. R.N. officers be maintained on any one course.

TABLE II—*Course statistics*

		RN	RCNC	CF	RAN	IN	PN	RNLN	Other	Total
Current Course (1980/81) incorporating 'L' option		5		1	1		1		1	9
Total numbers qualified	Since 1976 M.Sc. award	24		7	1	1	1	2	2	38
	Since 1971 move from Greenwich	39	5	11	2	3	4	3	2	69
	Since 1918 start of the course	418	9	29	16	20	8	5	9	514

Administration

Administration of the course is carried out by a small course staff consisting of the Assistant Dean of the College (a Commander (I) as Course Leader), the Head of Marine Engineering (a Commander ME† as Deputy Course Leader), and a Course Officer Lt.-Cdr. ME†. The course staff arrange for the use of College resources from relevant sections to provide lectures, project and course scheme supervisors, and general support in accordance with the approved course documentation.

Forums for discussion and decisions on the major issues involved in designing, implementing, and controlling the AMEC are provided in the form of a Course Committee and an Examination Board. Both these bodies are accountable to the College Academic Board which will normally discuss all major issues relating to the AMEC before final decisions are taken. The structure of these two committees is shown in FIG. 5.

The Course Committee is responsible for ensuring that the course aims and objectives are achieved effectively and economically. It is responsible for the preparation of course documentation and for the conduct of the course in accordance with the approved curriculum.

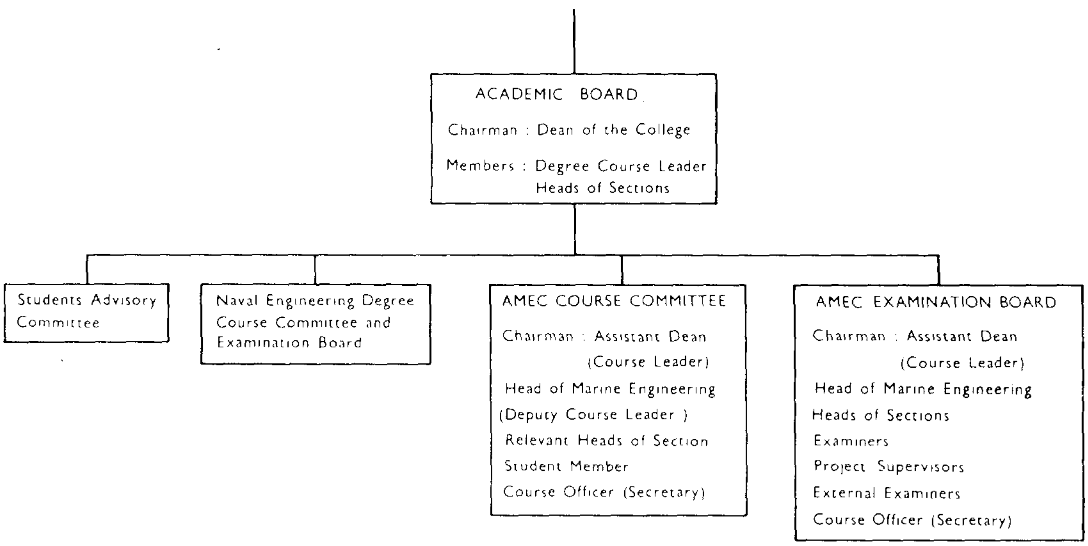

FIG. 5—COURSE ADMINISTRATION AT THE R.N.E.C.

The Examination Board is responsible, in conjunction with the external examiners, for providing a mechanism for the control of academic standards and the proper conduct of the assessment of course schemes and project work. The role of these committees has attained greater importance since, as a result of the course review and of subsequent M.Sc. recognition, the CNAA has authorized the College to administer the Course under their 'Partnership in Validation' system. This provides for much greater flexibility in modification of course content and assessment procedures—in consultation with the external examiners but without prior agreement with the CNAA. More formalized internal validation arrangements than exist at present are called for and proposals to this end will be tabled before the next CNAA visit to the College.

The Future

The College status with the CNAA as an educational establishment is very high and this is due in no small part to the presence of the AMEC which has done much to influence and support the College's growing academic maturity. The moves toward engendering a greater atmosphere of scholarship, referred to in this article, represent a further embellishment of this state which will more easily be achieved within the framework of partnership in validation.

This said, the course is firmly based on user agreed operational objectives and it is emphasized that the 'pursuit of academic maturity' should not be confused with 'academic pursuits'. The course is functionally orientated and is continually changing to provide marine engineer officers of the calibre necessary to respond effectively to advancing technology and changes in the role of the Royal Navy.

ANNEX

Advanced Marine Engineering Course—Educational and Enabling Objectives

Educational Objective	*Enabling Objectives* Options (G—Gas, S—Steam, L—Electrical)
1. To extend and develop knowledge and comprehension in subjects of central relevance to marine engineering with particular regard to warship propulsion and auxiliary systems.	1.1G and S—Develops the analysis of heat transfer phenomena associated with conduction, convection, and radiation, reviewing empirical correlations, numerical methods and current problem solving techniques applied to heat transfer situations. 1.2G—Understands the validity, limitation, and applicability of current theoretical and empirical methods used for marine gas turbine design and performance analysis, and identifies the technological prospects for the future. 1.3G—Examines factors influencing combustion chamber design and evaluates the application of practical and theoretical approaches to the development of future designs.

1.4S—Applies analytical theory to the geometric and thermodynamic design of steam turbines and steam-plant auxiliaries, incorporating manufacturers' empirical design procedures where necessary, with particular reference to the design of machinery for use with nuclear power plant.

1.5L—Develops the general theory of electrical machines, examines design criteria and testing techniques, and obtains machine equivalent circuits so that detailed analyses of their behaviour can be undertaken.

1.6L—Reviews semi-conductor devices and establishes the principles of solid state analogue and digital machine control techniques to enable the dynamic behaviour of variable speed drive systems to be analysed.

1.7L—Develops hardware and software modelling techniques, to enable the stability and performance of finite and infinite bus-bar systems to be evaluated.

1.8—Investigates analysis and design techniques appropriate to the dynamic performance of marine engineering plant represented by linear lumped-parameter models with particular reference to multi-variable systems operating under direct digital control.

1.9—Examines current methods of analysis, synthesis, and associated measurement techniques in the control of vibrating systems.

1.10G and S—Develops the principles of stress analysis and identifies the fundamentals of materials behaviour in marine engineering service, with particular application to components used in gas turbines and steam plant.

1.11L—Evaluates the properties of electronic system elements by analytical determination, and interpretation of their parameters and features.

1.12L—Examines the fundamental concepts of programmable systems, and identifies and illustrates the requirements of a digital processor.

1.13L—Establishes an awareness of information transfer and display methods, with particular regard to machine interfaces and the requirements imposed by human operation.

1.14—Develops ability and familiarity with essential complementary subjects containing subject matter and methods essential for effective understanding and participation in the integrated course, and as a preparation for initial tasks in the operational role:

1.14.1—Establishes ability in FORTRAN programming and the use of a general purpose computer in time sharing and batch modes together with analogue solutions of engineering problems.

1.14.2—Identifies established mathematical methods, together with their assumptions, limitations and applicability, in preparation for their use in the course core subjects.

1.14.3—Develops an understanding of compression ignition engine processes, together with the use of computer modelling techniques for their analysis, and gains an appreciation of factors affecting the design of future naval CI engines.

1.14.4—Reviews warship propulsion transmission systems including gearing and electrical transmission design, and assesses their capabilities and limitations.

1.14.5—Establishes an awareness of reliability criteria applied to survival time of in-service equipments and components.

1.14.6—Reviews warship machinery installation techniques and available systems, and understands the trade-offs involved in the design compromise for a surface warship design.

1.15—Attends technical visits to MOD establishments and civilian firms to extend knowledge and comprehension of design methods and development progress in warship marine engineering.

Educational Objective	*Enabling Objectives* Options (G—Gas, S—Steam, L—Electrical))
2. To apply the theory and techniques acquired through Educational Objective 1 to typical engineering problems involving critical judgement, analysis and/or synthesis for their solution, and to establish clarity in their expression and presentation. (Not all the problems listed are completed by each course).	2.1—Prepares a technical paper on a selected engineering topic, using DRIC-SPEC 2000 for the format and presentation. (Usually combined with another objective.)
	2.2G—Estimates the performance characteristics of a given single-spool gas turbine unit over the operating range, and superimposes the equilibrium running line on the compressor characteristic.
	2.3G—Produces a design for a separate long-life single-stage power turbine for the Tyne RM1A marine gas turbine as an alternative to the existing integral two-stage power turbine.
	2.4G—Produces a sketch design of a gas-turbine combustion chamber, and comments on likely performance at idle and maximum power condition.
	2.5S—Produces two sketch designs of a main condenser associated with a given steam turbine, and discusses their relative merits.
	2.6S—Calculates the specific steam consumption of a steam turbine at various powers, compares the relative advantages of throttle and nozzle steam flow control, and proposes design improvements.
	2.7S—Produces sketch designs for the first and last stage of the steam turbine introduced in 2.6S, and justifies the choice of the number of turbine stages.
	2.8L—Reviews selected papers on naval electrical power and distribution systems and discusses relative merits of split or parallel running of generators.
	2.9L—Calculates the parameters of salient pole synchronous generators, compares the parameters with test values and discusses the validity of the calculation methods.
	2.10L—Formulates generalized machine theory equations for the induction motor and rearranges these in order to predict the transient response of a motor started from a constant voltage supply, comparing the results with the responses of a laboratory machine.
	2.11—Derives a mathematical model of a pressurized water reactor and steam generator, and simulates responses of typical perturbations on an analogue computer.
	2.12—Formulates a mathematical model for a linear control system, and examines stability and possible compensatory improvements.
	2.13—Determines the computer algorithm involved in the control of the yaw of a ship by means of direct computer control, and modifies the plant characteristics to produce a stable system.
	2.14—Implements the algorithm of 2.13 using a PDP 11/34 and a real-time frigate manoeuvring simulator.
	2.15—Analyses the natural frequencies and mode shapes of a modern naval gearbox, and investigates design optimization using synthesis and other appropriate techniques.
	2.16G and S—Determines stress distribution and material behaviour of stages in a marine gas turbine power turbine disc using conical shell analysis, finite element techniques and fracture mechanics, and assesses whether design objectives have been achieved, proposing desirable design modifications where relevant.
	2.17L—Produces a sketch design for a microprocessor controlled data acquisition system to log into memory the data available from a number of analogue transducers, and evaluates the system 'sub-unit' parameters.
	2.18—Evaluates the feasibility of uprating an existing high-speed marine diesel engine, and comments on likely problems to be encountered.

2.19G and S—Produces a sketch design for the reduction gearbox of a gas-turbine-powered warship and evaluates the design for two possible maximum engine speeds (syndicated).

2.20L—Produces a sketch design for an electrical transmission scheme for the propulsion system of a gas-turbine-powered warship, and evaluates the design for various operating conditions (syndicated).

2.21—Analyses given data on in-service equipment or component failures using reliability techniques to establish equipment hazard function, reliability growth or degradation, or other aspects as specified (syndicated).

2.22—Carries out a warship machinery preliminary design exercise to establish the design compromises necessary to meet a particular Naval Staff Target (syndicated).

Educational Objective	*Enabling Objectives* Options (G—Gas, S—Steam, L—Electrical)
3. To develop the ability to conduct research and development studies within accepted standards of scientific discipline, carry out and present such work.	3.1—Selects a suitable research project to be conducted under limited supervision on a topic of current naval research, design, or development interest related to the knowledge gained through Educational Objective 1. 3.2—Gathers information on research area, identifies information sources, obtains information, and assesses its validity and reliability. 3.3—Defines objectives, scope, and extent of the research content within the prescribed time scale; evaluates problem areas, identifies resource requirement and other authorities involved in similar work. 3.4—Selects techniques and resources to be used in the study. 3.5—Produces project plan, together with monitoring arrangements for supervisor and others involved in continuous assessment. 3.6—Initiates and carries out work using knowledge gained from Educational Objective 1 and analysis and synthesis experience gained from Educational Objective 2. 3.7—Monitors, evaluates, and records progress at each stage of the study, initiating changes to the project plan where necessary. 3.8—Conducts and presents written report on work carried out in the format required by DRIC-SPEC-2000 for assessment. 3.9—Presents research paper orally to Examination Board, recognized topic experts, and senior staff for dissemination of information, questioning, and assessment. 3.10—Writes up research paper in conjunction with supervisor to publish results in an appropriate journal. (If relevant.)