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POSTGRADUATE INSTRUCTION

By Commander Alexander Sharp, U. S. Navy

The object of this paper is to outline the postgraduate course in technical subjects and to show its value to the service.

The time is opportune to present this subject, for nothing has been written for a number of years and in that time the course has progressed.

The training of naval officers has received a great impetus since the war. A training division has been established in the Bureau of Navigation to have complete charge and direction of naval education and considerable has been written on the subject in the service papers and the newspapers.

It has been sometimes erroneously believed that because an officer has taken the postgraduate course he is limited to a specialty thereafter. That is not the case. If on account of special aptitude, however, an officer elects to go in for design work as a career, that is his own concern. Research work and design are important fields for a limited number.

Completion of the postgraduate course in an engineering or other specialty in no way unites an officer for regular line duties, but on the contrary it has been found to be a great asset in the performance of line duties of any kind.

All junior officers of the service would be benefited if they were required to take the course; at present it is elective only.

Technical Engineering Training a Necessity

That technical engineering training is a necessity for all naval officers is certain. "Engineering" is here used in its broadest sense. It does not mean marine engineering alone, but it includes ordnance, mechanical, electrical, radio, aviation engineering. A dictionary definition is, "The art or science by which the mechanical properties of matter are utilized in structures and..."
All engineering principles are basically the same. Physics lies at the bottom of all engineering. A recognized educator has stated that if he were given a class of college graduates well founded in physics he could develop them into many different kinds of engineers in a year. The moral to be drawn from this is that attention to fundamentals lays the foundation for proficiency in not only one specialty but in many specialties. The mastery of one specialty gives a sympathetic understanding of other specialties and clears away much of the mystery that previously surrounded them. On the other hand it probably will always be necessary to have a few officers especially trained in design.

The Naval Academy gives a course in elementary engineering theory and practice sufficient to start the junior officer on his way in the service. The Naval Academy is, however, not essentially an engineering college. The time available is too short and the requirements of the embryo naval officer are too numerous to permit his receiving the equivalent of the standard four-year undergraduate course of a civilian engineering institution.

Subsequent duty afloat cannot afford sufficient educational facilities to replace a sound postgraduate course ashore. Both are necessary to secure the best results.

**History of the Postgraduate School**

The Postgraduate School was established at the Naval Academy in 1909 as a school of "Marine Engineering." Students chose specialties under engineering and consulted a technical library in order to obtain information. It was found that they were hampered in their education in mathematics, mechanics, thermodynamics, etc., and to meet the demand for training in fundamental theory a system of lectures was introduced.

In 1912 the title of the school was changed to "Postgraduate Department" of the U. S. Naval Academy, and its field was enlarged to include postgraduate work of naval constructors, ordnance, electrical, radio and civil engineers.

In the evolution of the school it was found necessary to establish resident professors with a definite schedule of lectures, laboratory work and preparation. The predominant service opinion was that headquarters of the school should be at Annapolis and that after one year’s work there the student officers should be sent to universities not under naval control. This was for the purpose of broadening their viewpoint by contact with civilians and to permit of the utilization of those universities which offered the best facilities in the several specialties. It was deemed essential to maintain the first part of the course under the direct control of naval officers to permit close observation of the students during the important period of indoctrination which is found necessary. Other considerations were the availability of well-equipped laboratories and the proximity of the Naval Engineering Experiment Station.

Advantage has been taken of the counsel of experts in engineering education to develop the postgraduate course. A committee of representative educators appointed by the Secretary in 1916 studied the special problem and their recommendations have been embodied in the course.

By gradual evolution the course has come to consist of one year at the Postgraduate School at Annapolis, followed by a summer’s practical work and eight months at a university and concluded by another summer of practical work.


In 1920 a board was appointed by the Bureau of Navigation to recommend regarding the instruction and training of line officers. The board’s report, which was published in the August, 1920, number of the Naval Institute Proceedings, placed emphasis upon specialization and divided all line officers into five main groups for the purpose of accomplishing this object. The plan of the board was to initiate a "general line course." It also provided for officer instruction in four phases: viz., at the Naval Academy, the general line course, the junior war college course, and the senior war college course. The recommendations of the board were never put into effect.

The effect of this board’s report has been probably to give impetus to the recent movement to establish a junior course at the War College. With equal consistency it should be regarded also as giving emphasis to the necessity for a course of technical instruction, as now standardized at the Postgraduate School. It
is hoped that a combined course suited to the needs of all junior officers may be the outgrowth.

The Postgraduate School does not aim to give a course in "operating" engineering. Operating engineering, it is apparent, can only be satisfactorily learned at sea. The grounding in fundamental principles given at the Postgraduate School, however, forms a valuable contribution toward the making of a competent and intelligent "operator" in any of the activities on board ship, by giving him a grasp of principles involved in any problem in the broad engineering field.

**Outline of Course at Postgraduate School, Annapolis**

The course at the Postgraduate School is divided into four terms of twelve weeks each. Experience has demonstrated that encyclopedic information is not adequate, but on the contrary that the students must be led to a firm grasping of fundamental principles and to think for themselves. The first three terms (nine months) are devoted by all groups to a study of the fundamentals common to all engineering subjects. These are: mathematics, mechanics, physics, electricity, engineering measurements, engineering materials, thermodynamics, metals, chemistry and English exposition.

The fourth term consists of work along the line of the student officer's specialty and forms a connecting link between the fundamental postgraduate course and the specialist course given at the university.

The morning periods at the Postgraduate School are devoted to classroom work while the afternoons are spent in the laboratories. This laboratory work, which takes the form of practical demonstrations of the classroom work, serves to fix firmly the elemental laws in the student's mind. The student is therefore made more practical by this particular method than if he undertook practical work without a knowledge of the theory. It is this very feature of the course that places the student on a plane above the practical mechanic, however good the latter may be. The practical mechanic soon reaches his limit, whereas the man who has practical knowledge plus the understanding of fundamental principles is not thus limited and to him we must look for continued progress.

The laboratory facilities of the Postgraduate School are exceptionally good. They represent a large investment and are believed to be quite on a par for their purposes with any in the country. They consist of laboratories for general physics; electrical measurements; electrical tests, heat physics, optics, chemistry, metals and metallurgy, testing materials, internal combustion engine tests, radio and mechanical engineering measurements.

The Engineering Experiment Station offers facilities for experiments and tests to determine efficiencies and operating characteristics as well as to illustrate the principles of thermodynamics. Examples of the tests under service conditions at the Experiment Station are: steam turbine, condenser, steam air ejector, three effect evaporating plant, feed water heater, steam orifice, dynamic balancing machine, forced draft blower, coal and oil burning boilers and airplane engines.

The facilities of the departments of the Naval Academy are used by the student officers. The proximity to Washington makes it possible to visit the Gun Factory, the Bureau of Standards and other places of professional and scientific interest located there.

The professors of the Postgraduate School are specially selected; they understand the naval officer's point of view and they are very able in their methods of imparting their information. Emphasis is placed on the student officer's learning to think things out for himself. "Quizzes" are given from time to time. Examinations are held at the end of each term. Marks received are not entered on the student officers' fitness reports and officers are given to understand that they are not engaged in a competition for marks. This fact has a great deal to do with the freedom felt by the student officers in approaching their instructors to obtain explanation of difficult points. The whole atmosphere of the place is one of study and the officers leave the Postgraduate School enthusiastic about their work and equipped to uphold their end in the civilian institutions. The results are very satisfactory.

Following is a condensed outline of the first three terms' work at the Postgraduate School.

**First Term Work**

*Mathematics—Functions, graphs, solution of equations, analytic geometry and beginning calculus. Uses of slide rule, etc.*
Mechanics—Fundamentals, force systems, graphic and algebraic representations.

Physics—General physics, particularly the fundamentals in mechanics, sound, heat, light and electricity which are most important in engineering subjects. Laboratory work—Fundamental measurements and tests to illustrate classroom work.

Engineering Measurements—Measurements of time, angular and linear speed, temperature, pressure, flow of liquids, power. Calibration and limits of accuracy. Laboratory work to illustrate.

Hydraulics—Study of fundamental principles and applications. Laboratory work to illustrate.

Chemistry—Principles, chemical reactions and atomic theory—gas laws and kinetic theory. Valency; equations; ionization; chemical equilibrium; electrochemistry; thermo-chemistry; preparation and properties of non-metals and metals, etc. Laboratory work.

Lectures are given each Saturday during three terms on subjects of interest in the engineering field, and those of general interest calculated to stimulate the student’s imagination and to broaden his outlook.

English Exposition—How to study. Logic. English exposition with lectures and practical problems. One hour a week for one or two terms.

SECOND TERM WORK

Mathematics II—Conic sections. Further work in calculus, and analytic geometry.

Mathematical Laboratory—Construction of scales, curves, alignment charts. Exercises in uses of mathematical instruments such as integrators, planimeters, etc.

Mechanics II—Moments, moments of inertia. Kinematics, kinetics, applications such as balancing, governors, gyroscope, etc.

Physics II—A laboratory course in the physics of heat designed as a complement to the course in thermodynamics. Heat values, specific heat, mechanical equivalent, coefficient of expansion and temperature of a gas, coefficient of linear expansion. Vapor—pressure—temperature, relation for water, P. M. F., versus temperature for a thermo couple, etc.

Electricity II—Electric and magnetic circuits. Laboratory experiments go into subject extensively.

Thermodynamics II—Introduction to the specialized study of any of the branches of naval engineering which include in their scope the phenomena of energy transformation involving heat, as in main drive machinery, steam auxiliary machinery, internal combustion engines, refrigerating systems, the torpedo or interior ballistics. First law, second law, general equations. Supplemented by laboratory work.

Engineering Materials—Course in strength or mechanics of materials. Problems of practical engineering situations are given to illustrate the text. Study of specifications. Stress, strain, shear, beams, deflection, columns, struts, torsional stresses in shafts, horsepower of shafts, springs, thin spheres and cylinders, riveted joints, plates, hooks, links, etc. Laboratory work acquaints the student with methods of testing, physical properties of materials, and illustrates the theory.

THIRD TERM WORK


Mechanics III—Work and energy, force systems; efficiency, impulse and momentum, impact. The gyroscope.

Electricity III—Structure of dynamo. Armature winding, magnetization curves and leakage, armature reactions, characteristics, motors, commutation, efficiency, rating, heating, etc. Laboratory work. Experiments to illustrate, and operation of many types of electrical machines.

Optics III—Primarily for ordnance class. Geometrical optics of telescopic instruments and physical optics applicable to naval use. Extensive laboratory work to illustrate.

Thermodynamics III—Continuation of Thermodynamics II. Applications in practical working cycles and processes. Steam engine, turbines, air compressor, refrigeration, combustion, internal combustion engines, processes with gas and vapor mixtures. Laboratory course illustrates.

The laboratories of the Postgraduate School, Engineering Experiment Station and Department of Marine Engineering and Naval Construction, U. S. Naval Academy, are all used.

Metals—Includes metallurgy and manufacture of commoner metals and alloys, followed by general metallography and the metallography and heat treatment of iron and steel in detail. Laboratory work to illustrate.

Chemistry III—Laboratory work in qualitative analysis. Quantitative analysis, common standard tests of engineering materials.

FOURTH TERM WORK

(Special work for each group)

Mechanical and Electrical Engineers


Electricity ME I—Alternating currents, theory. Application in laboratory.

Thermodynamics and Marine Machinery ME I—Special application to naval prime movers and auxiliaries.

Machine Elements ME I—Introduction to specialized study in any branch of mechanical design work. Supplemented by computation periods.

Metals ME I—Special preparation for advanced work in metallurgy and metallography. Alloy diagrams, photo micrographs, microscopic examina-
tion and analysis of relationship between microstructure and alloy diagram to which it belongs. Illustrated lectures, and laboratory.

Communication Engineers (Radio)

Mathematics R4—Vector analysis, differential equations.
Electricity R4—Same as Electricity ME4.
Radio R4—Principles of electric oscillations, waves, and their applications to modern radio apparatus. Radiation, radio compass, vacuum tube and uses. Laboratory work to illustrate. Sending and receiving are practiced daily.

Aeronautical Engineers

Mathematics A4—Same as Mathematics E4.
Mechanics A4—First half term same as ME4. Second half term—dynamics of a rigid body. Moments and products of inertia for solids, ellipsoids, etc. Motion about fixed axis, in two, and then three dimensions.

Aeroplane Engines A4—Preparation for advanced work in power plant unit of aeroplanes. Engine as a heat motor, as a mechanism. Miscellaneous theory. Laboratory work and practical work. Analysis and test of various engines, blower, heat transfer, ignition. Diagrams and layouts and problems in machine elements specially applicable.

Engineering Materials A4—Stress analysis and framed structures, strength of materials specially applicable to aviation. Laboratory work to illustrate.

Chemistry A4—Special course for aeronautical engineers on the chemistry of fuels and lubricants. Laboratory work to illustrate.

Ordnance Engineers

Metals (Torpedo and Ordnance Design Group)—Fundamental principles of general metallography. Heat treating steel.
Machine Elements (Fire Control—Torpedo and Ordnance Design Group)—Principles of kinematics and mechanics applicable to the construction of ordnance.

Marine Machinery (Torpedo Group)—Principles of thermodynamics and application to torpedo power plant.
Electrical Engineering (Fire Control Group)—Alternating currents covering inductance and capacity, and A.C. circuits. Finish D.C. machinery and begin A.C. circuits in laboratory.

(Other groups) Alternating currents covering inductance and capacity, and A.C. circuits as above. Elementary D.C. design.

Engineering Materials (Fire Control, Torpedo and Ordnance Design Groups)—Review of principles involved in mechanics of materials.
Chemistry (Explosives group)—Principles of organic chemistry and physical chemistry relating to explosives.

Ordinance (All groups)—Rules for gunnery exercises, Naval Academy ordnance textbook for general information, fire control installations, torpedoes, mines, spotting and plotting room procedure. Practical work on these subjects in Department of Ordnance and Gunnery, U. S. Naval Academy.

Mechanics (All groups)—Elastic strength of guns and an introduction to the new ballistics.

Optics (Cont'd) (Fire Control, Explosives and Ordnance Design Groups)—Geometrical optics of telescopic instruments used in Navy. Theoretical and practical quantitative laboratory study of the properties of lenses, prisms, and assembled optical systems.

On leaving the Postgraduate School, Annapolis, the student officers are sent to civilian universities for more specialized work. The university work covers a period of eight months.

The following courses are pursued in civilian universities: ordnance engineering (fire control, explosives, ballistics, ordnance design, torpedo design, ordnance metallurgy); engineering design (mechanical, electrical, electric ship propulsion, internal combustion engines); aviation engineering; communication engineering (radio); naval construction; and civil engineering.

Marine Engineering at Columbia University

(Period—one year)

Mechanical—Summer term: Alternating currents, storage batteries. Winter Term: Heat transfer, machine design, engineering thermodynamics, machine analysis, experimental procedure, metallurgy and metallography, electrical laboratory. Spring term: Organization and management, electrical laboratory, experimental procedure, shop processes and machine tool analysis, steam turbines and power plant equipment, optional (one of the group must be selected), steam machinery analysis, drawings, computing and reports, or internal combustion engines, drawings, computing and reports.

Electrical—Summer Term: A.C., storage batteries. Winter Term: Telephony, D.C. design, technical A.C., motors, electrical laboratory, heat transfer, metallurgy and metallography. Spring Term: Electrical plants, motors, electrical laboratory, radio laboratory, steam turbine and power plant equipment, optional (one of the group must be selected) design or auxiliary apparatus, seminar, electricity on ships, or design of electric propulsion machinery, seminar, electric propulsion.

Communication Engineering (Radio) at Harvard University

(Period—one year)

Special problems in communication engineering, hydrophone engineering, telegraphy and telephony, electric oscillations, applications, electric waves and radio frequency measurements, electron tubes.
AERONAUTICAL ENGINEERING AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(Period—one year)
Advanced calculus, theoretical aeronautics, airplane design, airship design, aeronautical laboratory, theory of structures, aeronautical engines, machine design, propeller design.

ORDNANCE AT CARNEGIE INSTITUTE OF TECHNOLOGY

(Period—one year)
Metallurgy: Physical chemistry, metallurgical calculations and laboratory, special metals and laboratory, electro-metallurgy, quantitative analysis, industrial management.

ORDNANCE DESIGN AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mechanics of machines, dynamics of machines, materials of engineering, physical metallurgy, heat engineering, engineering laboratory, special machine design, special turbines, metallography and heat treatment, A.C. and A.C. machinery and design, mathematical laboratory, gyroscope and applications.

BALLISTICS GROUP AT UNIVERSITY OF CHICAGO
Special advanced mathematical course.

FIRE CONTROL AT COLUMBIA UNIVERSITY
Electrical motors, D.C. and A.C. design, A.C. engineering, telephony, A.C. laboratory, standardizing laboratory, theoretical optics and radio.

EXPLOSIVES AT UNIVERSITY OF MICHIGAN
Advanced course in chemistry and explosives.

NAVAL CONSTRUCTORS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

First Year:
A.C. and A.C. machinery, A.C. applied, electrical engineering laboratory, internal combustion engines, marine engine design, marine steam turbines, business law, model making, naval architecture, political economy, shipyard practice, theory of warship design, warship design.

Second Year:
Aeronautics theory and design, merchant shipbuilding, naval architecture, business management, structures (lecture and drawing), mathematics, rigid dynamics, theory of warship design, warship design, thesis.

CIVIL ENGINEERS

Two-year course at Rensselaer Polytechnic Institute in essential civil engineering subjects.

PRACTICAL WORK

The naval constructors receive instruction at navy yards.

The ordnance groups have a ten months' course of practical work at such places as the Naval Gun Factory, the Naval Proving Ground, Bureau of Ordnance, Army Proving Ground and at private plants.

RESULTS
It is hard for many officers to have to go to school again, but this has been found to be the one best way to prepare them, and there is no alternative to a solid fundamental grounding.

Officers upon reporting at the Postgraduate School are found weak in mathematical equipment as well as in physics, thermodynamics and other fundamentals. The first three or four months are proof positive to the officers themselves as well as to the faculty, of their condition of lack of preparation. This is natural as they have been out of touch and have lost the "study habit."

As the student officer progresses in the course he realizes that he is fitting himself to face future problems in any line of work. He becomes schooled to think things out along logical lines and to avoid snap judgments. His outlook is broadened, his mental stamina is increased, he appreciates his own limitations. When the student officer completes his first year at the Postgraduate
School he is then ready to pursue an advanced technical course or to continue general duties of the line with better results.

Valuable as is the technical training received, the greatest benefit of all lies in the increase in mental efficiency. The general standard of the line of the Navy would be very appreciably raised and it is believed the amalgamation problem would be largely solved if all junior officers were required to take the standard course at the Postgraduate School, preliminary to taking the junior war college course.

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MILITARY GENIUS AND THE NAVAL WAR COLLEGE

By Major J. M. Scammell, Infantry O. R. C.

Great captains are made, not born.

It may be laid down as a general rule that the greatest military leaders of modern times have been the product of the systematic and intensive study of their profession. Of antiquity we cannot say the same for two reasons. The first reason is that we lack the records of the early preparation for command of the great captains of ancient times. The second reason is as follows: war being merely an extraordinary means of carrying a national or dynastic policy into effect, it is no more than an aspect of statecraft. In antiquity, diplomacy, one of our modern resources for the carrying out of policies without recourse to violence, was crude and ineffective. Therefore, war was almost the sole means available to a statesman when a policy of one state was opposed by another. War and statecraft were therefore intimately related and the heads of states were commonly instructed in the arts of war and themselves led armies in battle. Even in republics, such as Athens and Rome, those who held the civil power conducted wars likewise. Examples are Themistocles, Pericles, Pompey and Caesar. Moreover, this was more practicable in those days because war was not the complicated and technical business that it is today.

But from the time that gunpowder introduced not only a new technique but also an element of mystery into war—the gunners jealously guarded their trade secrets at first—the breach between soldier and civilian, especially between general and civilian, became wider. This was emphasized by the growth of professional armies.

When this process began, soldiers commenced to study carefully the art of war. Although there was fighting continuously, and men desirous of learning the technique of war went from one army to another to get experience, it would be a great

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