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Postgraduate Instruction

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By Lieutenant A. M. Granum, U. S. Navy

THE necessity for specialized training for officers, beyond the fundamental education received at the Naval Academy, probably is not now seriously questioned by anyone. In practically every department on board ship an officer requires a comprehensive understanding of the fundamentals of engineering, and in many cases is faced with complex problems which call for expert treatment. The need for special training is great in the operating field. It is essential if real progress is to be made in improved methods and design. What is said of engineering applies with equal force to other fields. Just as intricate problems present themselves in administration, law, and command. Each is merely a part of the great problem of the conduct of war.

While the need for specialized training has always existed it has not always been so well recognized as it is today. As early as 1871 the rank of cadet engineer was created, showing a recognition of the need for specialized engineering knowledge, and establishing an engineer corps to supply that need. Later, in 1889, when it was seen that a good knowledge of engineering practices was an essential equipment of every line officer, the engineer corps, as such, was abolished, and amalgamated with the line. Perhaps the first step toward postgraduate instruction, as we think of it today, was the application of Cadet Engineer Francis T. Bowles for a course in naval architecture. After some difficulty he obtained for himself and Cadet Engineer Richard Gatewood, appointments as assistant naval constructors and permission to go to the Royal Naval College at Greenwich, England, to take the course in naval architecture there. Naval constructors were first sent to Massachusetts Institute of Technology in 1903.

A school of marine engineering was established at the Naval Academy in 1909. The instruction was largely informal. Students selected specialties and consulted a technical library for information. It was found that they were greatly handicapped by lack of knowledge of mathematics and the fundamental sciences. The need for more instruction and a carefully planned curriculum was soon recognized. Accordingly, in 1912, the title of the school was changed to "Postgraduate Department" of the Naval Academy. The scope was enlarged to include postgraduate instruction for naval constructors, civil, ordnance, electrical, and radio engineers. Its first head was Captain J. P. Morton, U. S. Navy. It occupied rooms in Isherwood Hall, the steam-engineering building at the Naval Academy.

Work of the Postgraduate School was necessarily suspended during the World War. In 1919 the school was reopened, the old marine barracks at the Naval Academy being remodeled for the purpose. Location of the Postgraduate School at the Naval Academy makes available the facilities of the Engineering Experiment Station and of the Naval Academy itself. It places the Postgraduate School in close proximity to the various bureaus of the Navy Department, the Proving Grounds, Naval Gun Factory, Naval Research Laboratory and various scientific institutions in Washington. The Postgraduate School itself has well-equipped laboratories for experiments in general physics, engineering measurements, chemistry, heat physics, optics, hydraulics, thermodynamics, metallography, internal-combustion engines, electrical measurements and tests, radio, and tests of materials. Textbooks are furnished to the student officers and the library contains excellent references, including the current technical and scientific papers.

The requirements for entering the Postgraduate School are given in the Bureau of Navigation Manual. For the class entering in July, 1928, there were applications and selections as follows:
The present size of the school is considered sufficient to meet the needs of the Navy. If expansion is to be made the Bureau of Navigation hopes to make it in the direction of a greater general line course. The appropriation for the Postgraduate School for the past fiscal year was $150,000. Except in law the first year of all postgraduate instruction is spent at the Postgraduate School at the Naval Academy. The general plan provides that the first nine months shall be devoted to a basic course, taken with minor exceptions, by all students. This does not apply, however, to officers taking the general line course, as they pursue a separate line of study throughout.

The fourth term of the first year's work is a specializing term. The different groups then are divided up and take work applying more directly to their respective specialties. There follows one or two years further of specialized work, usually at some civil school, supplemented during the summers by practical work at navy yards or stations and at various industrial plants.

New classes start work at the Postgraduate School about July 1 each year. Officers find themselves faced with a program of classroom exercises, laboratory work, and study which requires an estimated expenditure of time of fifty-eight hours per week. These include fourteen hours of classroom exercises, twelve and a half hours of practical work, one hour lecture, five hours of athletics and twenty-five and a half hours' estimated time for preparation. The lectures are usually given on Saturday mornings during the fall and winter terms. The lectures ordinarily cover subjects of broad professional interest. They are given by officers and civilians who are authorities in their respective fields. The athletic periods are to be devoted to some form of strenuous exercise, outdoor whenever practicable. Baseball, tennis, basketball, soccer, indoor baseball, golf, swimming, and volley ball are accepted forms of exercise.

The basic course to which the first three terms—nine months—are devoted, gives training in and provides for study of the fundamentals common to all engineering subjects. These include mathematics, mechanics, physics, electricity, engineering measurements, hydraulics, engineering materials, thermodynamics, metals, and chemistry. In the third term the communication engineers take courses in alternating current circuits and sound instead of chemistry or thermodynamics. The aero logical engineers do not take metals or engineering materials in the second term, or metals or electricity in the third term. They substitute for these subjects a course in German, since German texts are used in some of their later work. Their thermodynamics in the third term is slightly different from that of other groups. Particular attention is given to the properties of gas mixtures, and of gas and vapor mixtures such as the atmosphere, instead of to the working cycles of the steam plant.

The above outline is taken from a syllabus of the courses prepared by the head of the Postgraduate School. Much of the other material herein submitted is derived from the same source.

In the fourth term the groups are more definitely separated and given work along the lines of their particular specialties. This term prepares the student officers for the specialized work of the following year and gives them an introduction to such study.

The mechanical, electrical, and Diesel engineers all take the same work during this term, as their subsequent courses at Columbia are similar in many respects. The subjects taken are mathematics, mechanics, electricity, thermodynamics, and metals. The mathematics is a continuation of the study of the first three terms, with additional work on integrals in several variables, treatment of empirical data and solutions of systems of differential equations with applications in electricity and mechanics. An introduction to partial differentiation is given. Mathematics is stressed in all courses, as it is the basis of any form of engineering. The text used throughout is Professor R. E. Root's Mathematics of Engineering, prepared especially for the off Postgraduate School, but it has in other engineering schools.

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In this term the Columbia group stresses the mechanics of engines, including engine balancing, forces affecting bearing pressure and friction losses in engines of standard types, and study of free and forced vibrations and resonance of elastic bodies, with particular reference to torsional and transverse vibrations of a rotating shaft under variously assumed loading. The applications of thermodynamics to steam engines and turbines, combustion, boilers and furnaces, internal-combustion engines, air compressors, refrigeration, heat transmission, and air conditioning are studied. The course in electricity pays particular attention to the fundamentals of alternating-current circuits and machinery. In metallurgy a special course is given in preparation for more advanced work in metallurgy and metallography during the second year. Alloys are taken up in a general way, with a more thorough study of the metallography and heat treatment of iron and steel. One group makes a special study of storage batteries.

Mathematics for the communication engineers includes a study of hyperbolic functions, differential equations, vector analysis, and electric oscillations and electric waves, all of which come up during the work of the second year. Their electricity is similar to that of the Columbia group, but with emphasis more particularly on the power systems and circuits required for large radio stations. They make a study of the elements of radio, including vacuum tubes, radio circuits and measurements at high frequency.

In the mathematics for the aeronautical engineers the applications of special topics, such as conformal transformations, potential and stream functions, vortices, line integrals, etc., to the problems of air flow in two and three dimensions and to the determination of the air forces on monoplanes, biplanes, and propellers are studied. Their mechanics is the same as that for the mechanical engineers. They make special studies in internal-combustion engines, engineering materials, metallurgy, and chemistry. The chemistry deals with motor fuels and lubricants.

The naval constructors take the same course in thermodynamics and electricity as the Columbia group. They have advanced work in mathematics and take an introductory course in the speed and power of ships. An inspection trip is made to the model basin in the Washington Navy Yard. One group specializing in airplane design is given a course in engineering materials with particular emphasis on structure and design of airplanes.

Civil engineers are given introductory courses in railroad curves, surveying and structural engineering, and a general course in electrical engineering, such as applies particularly to stationary power plants.

The aerologists continue study of German, and start reading German texts on meteorology and thermodynamics of the air. They take courses in physics of the air, weather-map drawing, oceanography, and collateral reading. They continue with advanced work in mathematics.

Ordnance engineers specializing in explosives, torpedo design, and metallurgy are given work to prepare them for the following year at civil universities. Those interested in explosives take advanced work in mathematics, a course in mechanics with emphasis on elastic strength of guns and exterior ballistics, and qualitative chemical analysis with a view to preparing for courses in quantitative and physical chemistry. They take the same course in electricity as the Columbia group. The metallurgists study mechanics, including elastic strength of guns, and exterior ballistics, electricity, qualitative chemical analysis, and an intensive course in ordnance metallurgy. Much collateral reading of Navy ordnance pamphlets is required. The officers specializing in torpedo design follow the same courses in mathematics and mechanics as the explosives group. They take the same work in thermodynamics as the Columbia group. Special courses are given in electricity with emphasis on the characteristics and phenomena of direct-current machinery, and in kinematics.

For some years it was the practice to divide the ordnance class into six subdivisions, specializing in explosives, metallurgy, torpedo design, ordnance design, fire control and ballistics. In 1926 the Postgraduate School was informed by the Bureau of Ordnance that the best interests of that bureau were not served by such minute specialization. On account of the technical knowl-
edge required for explosives, metallurgy and torpedo design it was decided that the existing practice should be continued for those groups. The remaining groups were amalgamated into a general ordnance class.

No educational institution offers courses that meet the special character of the needs of this general ordnance class. Accordingly there has been designed a course for the second year at the Postgraduate School which embraces all the subjects deemed necessary to qualify an officer for duties in ordnance design, fire control, and ballistics which he may be called on to perform under the Bureau of Ordnance. Further, it is believed that this course will make an officer a far more valuable gunnery man at sea. It has been the aim of the school to give the faculty members specially concerned direct contact with ordnance designers and operating personnel. To this end conferences have been arranged between members of the faculty and officers, designers and engineers in the bureau, the gun factory, Dahlgren, Indian Head and the Army Proving Ground at Aberdeen, Maryland. It is hoped to establish regular contact with forces at sea, preferably on a ship whose gunnery officer has had postgraduate instruction. The opportunity they would thus have to observe ordnance and fire-control material and operation during target practice would be of great value in giving them a practical background. The faculty have cooperated fully in the aims of the Bureau of Ordnance and of the head of the Postgraduate School.

The new course gives instruction in the old standard methods in exterior ballistics as presented by Alger, Cranz, and Herrmann, as well as the more modern methods of numerical integration, and in the stability of projectiles in flight. The Le Duc formulas, the Ingalls methods and the method of numerical integration as applied by Bennett are covered in the work on interior ballistics. All the desirable features of the old course in ordnance design and all of the work in fire control have been retained and amplified. The work in metallurgy compares favorably with that done by those specializing in this subject. All in all a very satisfactory course has been designed. An officer who completes it satisfactorily goes out well equipped to handle any general ordnance problem with which he may be confronted.

For the general ordnance group the work of the specializing term includes mathematics, mechanics, electricity, kinematics and mechanism of machines, optics, and ordnance equipment. The summer course following the first year's work consists of three months' practical instruction in the design section of the gun factory, Navy Yard, Washington, D.C. During the second year at the Postgraduate School this group goes on with advanced work in the subjects taken during the specializing term and in addition takes up a study of metallurgy, structures and materials. The third year is spent in practical instruction at navy yards and industrial plants such as, for example, the proving ground, powder factory, gun factory and optical shop, Ford Instrument Co., Sperry Gyroscope Co., General Electric Co., Navy Yard, New York, Aberdeen, Edgewood, and the Bureau of Ordnance.

For most of the groups the second year's work is taken at civil universities selected by the Department. Tuition for the officers is paid out of funds allotted. Books are furnished by the Postgraduate School. Where universities offer courses which meet the requirements of the several specialties there are many advantages in sending officers to such schools. The courses are given by professors who have made notable contributions in their specialties and are recognized authorities. The laboratory equipment in most cases is of the best, and designed to give the students thorough training in applying the principles expounded in the lecture room. These universities are generally located near industrial plants which may be visited in connection with the work. Methods and practices can be observed which are different from those in use in the Navy, but which may have possible application therein. Contacts are made with prominent civilians from all over the country, and from foreign countries. This gives the officers an opportunity to promote popular knowledge of, and interest in, the Navy. Officers from the Postgraduate School are cordially received by the universities, and it is believed that their work compares very favorably with that of other graduate students.

Columbia, with extensive facilities, and in close proximity to numerous manufacturing plants, has a mechanical, electrical, and I. All three of these groups metallurgy and metallographic control, and in experimental work. The mechanical and Diesel the same courses in heat transfer, design, thermodynamics, high speed engines, and oil engines. Electrical engineers take one course in each, while the Diesel engineers take courses in technical animation, in direct-current plants, and design of electrical machinery. They also have radio. A storage-battery with stress laid on physics and chemistry.

In all of the work at Columbia plays a very important role, and in the majority of this work is given to the officers. It is believed that their work compares favorably with that of other graduate students.

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close proximity to numerous power and manufacturing plants, has most to offer the mechanical, electrical, and Diesel engineers. All three of these groups take courses in metallurgy and metallography, electric-motor control, and in experimental procedure. The mechanical and Diesel engineers have the same courses in heat transfer, machine design, thermodynamics, high-speed gasoline engine, and oil engines. The mechanical engineers take one course in steam turbines, while the Diesel engineers spend more time on oil engines. The electrical engineers take courses in technical alternating current, in direct-current design, electrical plants, and design of electrical propulsion machinery. They also have some work in radio. A storage-battery course is given, with stress laid on physical and electrochemistry.

In all of the work at Columbia the laboratory plays a very important part. A great deal of problem work is given. A degree of master of science in engineering is given if the courses are completed with high credit.

The school longest associated with our postgraduate instruction is the Massachusetts Institute of Technology. There have all our naval constructors received their training since 1903. They have had the particular inspiration of Professor William Hovgaard. Professor Hovgaard was a Danish naval officer. He graduated from the Royal Naval College at Greenwich, England, in the same class with Bowles and Gatewood. This man, of slight figure and unpretentious mien, has had a profound influence on ship design and construction in the Navy of his adopted country. Our men may go to sea with every confidence in their ships.

The naval constructors spend two years at Massachusetts Institute of Technology with a program of intensive study. During the first year the courses include alternating currents and machinery, business law, internal-combustion engines, marine engineering, merchant shipbuilding, model making, naval architecture, political economy, shipyard practice, steam turbines and warship design. A shop-practice course during the summer preceding is followed by three weeks at the General Electric works at Schenectady, New York. Warship design is the major course during the second year.

Other subjects studied are naval architecture, rigid dynamics, structures and structural design, and precision of measurements. A short course in aeronautics is given. A satisfactory thesis is required for a degree of master of science in naval architecture.

One group of naval constructors specializes in airplane design. Their course is altered to include airplane design, airplane structures, propellers and airships, aeronautical laboratory, and airplane-engine design.

A new course in aeronautical engineering at Massachusetts Institute of Technology may require some revision later. At present it includes one year of work in airplane design, automotive fuel, problems, dynamics of engines, aircraft metallurgy and metallography, heat treatment, machine design, airplane-engine design, and aerial propellers. A thesis is required for a degree of master of science in engineering.

With undoubtedly the most complete equipment of any school in this country for instruction in shop-work and engineering practices, Massachusetts Institute of Technology is equipped to give our torpedo designers the best possible preparation for their later duties. They take courses in automatic machinery, dynamics of machines, machine design, mechanism of machines, materials of engineering, heat engineering, heat treatment, metallography, physical chemistry, theory of the gyroscope, thermodynamics, and torpedoes. This covers one year's work. They are given a research of 300 hours to perform between June 15 and December 15 of the following year.

All the above courses at the Massachusetts Institute of Technology are preceded by a summer of practical work in the laboratories and shops of the school.

The ordnance metallurgists take their second year's work at the Carnegie Institute of Technology, which is believed to give the best course obtainable for this specialty. The subjects included are general metallurgy, non-ferrous metallography, physical chemistry, and electrochemistry. There is a special study of aluminum and its alloys, and special metallurgical problems.

At the University of Michigan the explosives engineers study organic chemistry, physical chemistry, unit processes, utilization of fuels, material balances, chemical technology of the organic and inorganic industries, and explosives and pyrotechnics.
The aerologists divide the time during their second year between Massachusetts Institute of Technology and Harvard. This year they are taking at the former institution *Dynamische Meteorologie*, using a German text by Exner, physics of the air, weather forecasting, and research problems as found practicable. At Harvard they are taking a course in climatology under Professor Ward. They are given a program of collateral reading. Last year they were conferred degrees of master of science in engineering by Harvard University.

Communication engineers are divided for their second year's work between Harvard and Yale. At Harvard more attention is paid to the mathematics and theory of radio, while at Yale the practical side is stressed. At the latter school our officers come in contact with officers from the Army who go to Yale for postgraduate work in communications. Professor G. W. Pierce, at Harvard, was prominent among the group of scientists and engineers interested in the problem of submarine detection during the World War. Much of our present-day under-water sound equipment is due to his work. Like most of the professors with whom the postgraduate has to deal, he maintains a sympathetic and helpful interest in the aims and problems of the Navy.

At Harvard courses are given in electric oscillations and electric waves with their applications to radio telegraphy and radio telephony, electron tubes, hydrophone engineering, and special problems in communication engineering. A degree of master of science in communication engineering is conferred if the work is completed with an average grade of B—about 90 per cent.

The courses at Yale include mathematical theory of sound, transient phenomena, electron theory, high-frequency measurement, hydrophone engineering and wave propagation, and filter design. A language qualification, French or German, and a thesis are required for a degree.

The civil engineers spend two years at Rensselaer Polytechnic Institute, Troy, New York. This school was established in 1824 and has been in continuous existence longer than any other purely scientific and engineering school in English-speaking countries. During this first year the civil engineers receive instruction in bridges, electrical engineering and power distribution, material testing, railroad engineering, power plants, machine construction, building construction, waterworks and sewers, concrete highways, paints, oil and varnishes. Upon successful completion of their courses and submission of a satisfactory thesis they are given a degree of civil engineer. The second year includes work in geology, graphics, heating, ventilating and refrigeration, power plants, electro-metallurgy, communication engineering, retaining walls, dams and docks, business administration, and the writing of specifications. They are required to write a satisfatory thesis for degree of master of science in civil engineering.

During their first summer this group makes a surveying trip under supervision of the school. The second summer is spent at some large power plant, such as the Brooklyn Edison Company, Brooklyn, New York.

The summer practical work is an important part of the course for all groups. Officers are required to keep notebooks of their activities during these periods. These notebooks, when carefully kept, become a file of useful information for later reference.

The summer program for some of the groups has already been described. Most of the first summer for the Columbia and Massachusetts Institute of Technology groups is spent in practical instruction at these schools. The second summer is spent at navy yards and the important industrial plants concerned with manufacture of Navy material. The latter include such firms as General Electric Co., Worthington Co., and the Pratt and Whitney Co., (for aviators).

The communication engineers spend the first summer in the Office of Naval Communications and with the Bureau of Engineering. Under the Bureau of Engineering they receive instruction at the Naval Research Laboratory, the radio test shop of the Washington Navy Yard, and at the high-power radio stations at Arlington and Annapolis. The second summer includes visits to the Submarine Base, New London, Connecticut; Fort Wright, General Electric Co., Bell Telephone Co., etc. The last two months are spent in the office of naval communications, studying confidential publications and hearing lectures on all phases of their work.

The aerologists spend some time at Lakehurst during the second summer. During the past summer (1928) petroleum engineering r inspection tour of oil fields.

The general line courses are offered by the Bureau of 1919, when it was first mended. For some time a shortage of officers. A valuable training and education that are important but for has too little time to spare duties. It will qualify officers now held by those who are trained, and should : in operation and admin posed course for 1928-1928 in tactical maneuver electricity, radio, ordnary military law, information mechanics, mechanical engineer diplomatic history and government, communicative coding, naval aviation, sashore, stability, damage xperience. The second ye Naval War College, Ne-
the past summer (1928) two officers taking petroleum engineering made an extended inspection tour of oil fields in the United States.

The general line course has been considered by the Bureau of Navigation since 1919. For some time it was held up by a shortage of officers. The aim is to give valuable training and education along lines that are important but for which an officer has too little time to spare from his regular duties. It will qualify an officer for many billets now held by those with more technical training, and should supply the experts in operation and administration. A proposed course for 1928-1929 includes instruction in practical work in geology, engineering, retaining walls, business administration, specifications. They are a satisfactory thesis for science in civil engineering.

First summer this group of officers again takes a trip under supervision. The second summer is spent in power plant, such as the Company, Brooklyn, New York, and in other important industrial plants, such as the General Electric Co., Allis-Chalmers, Chicago.

Practical work is an important part of a course for all groups. Officers keep notebooks of their experiences. These notes are helpful to them in keeping in mind the details of their work and may be useful for later reference.

Postgraduate work in law is taken in two years at George Washington University, during which time officers are attached to the office of the judge advocate general of the Navy.

The foregoing is a survey of the present-day scope and work of the Postgraduate School. It is recognized that details of the courses require modification from time to time.

Quoting from a recent address delivered at the Postgraduate School by Rear Admiral R. H. Leigh, chief of the Bureau of Navigation, a final point of equal importance to all postgraduates is this: "After leaving the Naval Academy it is my belief that the mind of each officer needs to be sharpened up and refreshed for five or ten years' service, and that he is forty-five or fifty years of age. Aside from his own personal reading and study any well-regulated course serves to stimulate his ambition, refresh his mind and contribute to his ideas and imagination. Without this, and with personal, individual study alone, it is the more modern belief in the system of education and training that the most successful results cannot be obtained—either in naval, military, or in civil life."

Rear Admiral Leigh says further: "Graduates of the Postgraduate School have already made efficient contribution in the design and production of fields of engineering and ordnance which the service might not have had without this school. The subject of personnel and its importance is recognized by all of us. The Navy cannot overlook the part which invention, research, and modern production are directing to naval-officer specialties has played in the increased efficiency of the present Navy today. It is believed that the officer who has had the dual experience of furnishing and handling both material and personnel can better understand the demands and problems of each."

Officers of the line taking up postgraduate work are reminded by the Bureau of Navigation that they will nevertheless be required to assume the responsibilities of command. Many of the best officers in the higher grades in the Navy have been specialists or have spent considerable time in engineering or other technical branches of the service. The need for specialists is great and the Bureau of Navigation appreciates the work and ambition of those who desire to fit themselves as such. It desires them to feel that they may do so without prejudice to their opportunity for higher command. To this end it is the aim of the bureau to arrange details of duty to permit every officer to progressively fit himself for the responsibilities of command. The mental discipline and the experience received through postgraduate work and the application to a specialty are assets which will benefit the officer in later years.