PAPER #101

The Accredited Marine Engineering Systems Curriculum At The United States Merchant Marine Academy

by

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History

The United States Merchant Marine Academy is a public institution operated by the Maritime Administration, United States Department of Transportation. A federal law known as the Merchant Marine Act of 1936 established the federal government's role in the education and training of U. S. Merchant Marine Officers. As a result of this policy, the Academy was constructed at Kings Point, New York and dedicated on September 30, 1943.

The Academy served the nation well during World War II by graduating over six thousand merchant marine officers who joined the growing merchant fleet.

In 1949, the 81st Congress authorized the Academy to grant a Bachelor of Science Degree to graduates. The Degree was soon accredited by the Middle States Association of Colleges and Schools, the regional accrediting organization.

While the Academy has always had an engineering program, resulting in an alumni who serve in thousands of technical and management positions in the maritime industry, it was not until recently that the Academy sought and obtained accreditation of the engineering curriculum from the professional engineering accreditation organization, i.e. Accreditation Board for Engineering and Technology (ABET) formerly the Engineers' Council for Professional Development (ECPD). Five years ago, the Maritime Administration upon recommendation of the Academy Superintendent and the Advisory Board authorized the Academy to seek engineering accreditation. In June 1982, the first students graduated from the accredited curriculum of Marine Engineering Systems.

Marine Engineering Systems

Historically, the marine engineer was a designer, builder and manager of machinery components and systems for ships. As the complexity of ships has continued to grow other engineering specialists working in the maritime support industries have taken over many of the historical activities of the marine engineer. Today, most would agree that the specialization called marine engineering is concerned with the design, construction and management of systems for marine platforms. The evolved discipline of marine engineering with its emphasis on systems requires the practictioner to be skilled in the methods of system engineering, including control theory, electronics, computers, economics, optimization methods, and man-machine problem solving methods as well as the traditional mechanical design and heat power disciplines of marine engineering. For this reason, the Engineering Faculty devised and achieved accreditation recognition of a new curriculum in Marine Engineering Systems. It is a curriculum designed to prepare a graduate for a technical engineering or technical management role in the many segments of the international marine industry.

Academy Mission

The broad mission of the Academy which the new curriculum supports includes:

1. Train graduates as merchant marine engineer officers with the ability to assume shipboard duties as the Third Assistant Engineering Officer without further training;

2. Train graduates as naval reserve officers capable of assuming duty as officers in the U. S. Navy in the event of a national emergency;

3. Provide graduates with a general and engineering education which prepares them for a wide range of activities and future leadership in commercial and naval ship system design, development, construction, maintenance and operations management.

The approach to the development of a curriculum which satisfies all these objectives is the subject of this paper.

An Accreditable Engineering Program

The Accreditation Board for Engineering and Technology (ABET) was founded as the Engineers' Council for Professional Development in 1932, and it began to accredit engineering programs in 1936. From the beginning the objective was to develop a consensus on what constituted a proper engineering program and to evaluate, when requested, the engineering programs of an institution against that consensus. The definition of a proper engineering program has undergone considerable change over the last five decades, but ABET has kept pace. As a result, ABET accreditation is widely recognized as a reliable indicator of quality.

In evaluating a program for accreditation, ABET considers five general areas[1]:

1. The extent to which the program develops an ability to apply pertinent knowledge to the practice of engineering in an effective and professional manner,

2. The size and competence of the faculty, the standards and quality of instruction in the engineering departments and in the scientific and other operating departments in which engineering students receive instruction, and evidence of concern about improving the effectiveness of pedagogical techniques,

3. The admission, retention, and scholastic work of students and the records of graduates both in further academic study and in professional practice,

4. The attitude and policy of the administration of the engineering division towards teaching, research, and scholary production, and the quality of leadership at all levels of administration of the division,

5. The commitment of the institution, both financially and philosophically, to the program in engineering.

Criteria 2 through 5 above are self explanatory, at least in the general sense. Criterion 1, however, deserves amplification, because it is under this criterion that ABET gives specific guidance concerning the curriculum. The requirements are specified in terms of "one half year" or "one year" of a particular type of material. "One half year" is interpreted to mean one eighthof the curriculum, and "one year" is interpreted to mean one fourth of the curriculum. With these definitions in mind, the curriculum requirements are[2]:

1. One half year of mathematics beyond trigonometry,

2. One half year of basic sciences,

3. One year of engineering sciences,

4. One half year of engineering design,

5. One half year of humanities and social science.

Since the sum of the above requirements is three years, an institution has one remaining year in which to satisfy its own special objectives.

The distinction between engineering science and engineering design in the above list is clarified by ABET as follows, "The engineering design component of a curriculum should include some of the following features: development of student creativity, use of open-ended problems, formation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, and detailed system descriptions."3 Courses, or parts of courses, that satisfy the above description count toward the one half year of engineering design. The remainder of the engineering courses count toward the one year of engineering science.

Individual engineering societies that are members of ABET may establish their own program criteria. These criteria are intended to amplify the basic ABET criteria as they apply to specific engineering disciplines. The Society of Naval Architects and Marine Engineers is developing program criteria for several disciplines, including Marine Engineering.

SNAME Program Criteria

The Society of Naval Architects and Marine Engineerins (SNAME) was founded in 1893 to, "...advance the state of the art; to afford facilities for the exchange of information and ideas; to disseminate the results of research, experience and information among the members; to encourage and sponsor such research; to cooperate with educational institutions and to promote the professional integrity and status of the members."[4]

Consistent with the objective of cooperating with educational institutions, SNAME is, as previously noted, developing program criteria for Marine Engineering degree

programs. A draft of these criteria was presented by D'Arcangelo and Skinner[5] at the 1981 annual conference of the American Society for Engineering Education (ASEE). Since that presentation, these criteria have undergone continuous review and revision, and their final form is not yet set. The discussion below will deal with the criteria as proposed by D'Arcangelo and Skinner.

For purposes of this discussion, Marine Engineering is defined as follows: "Marine Engineering encompasses the design, construction, operation, and repair of energy conversion devices for marine applications - principally vehicle propulsion systems." [6]

The proposed criteria define eight engineering course stems and then classify each stem as essential, recommended or optional in a particular degree program. The classification of stems for Marine Engineering is as follows[7]:

Essential
- Marine systems statics and dynamics
- Marine systems resistance and propulsion
- Marine systems energy conversion devices

Recommended
- Marine systems materials, strength and structures
- Marine systems operations and economics

Optional
- Marine systems fabrication and production
- Environmental sciences and related engineering
- Marine systems management.

In addition to the above, the proposed criteria suggest the following complimentary curriculum features[8]:

- Meaningful laboratory experience,
- Training in graphical handling of technical ideas,
- Training in written and oral communication, and
- Training in the use of computers.

The section which follows explains in detail how the curriculum of the United States Merchant Marine Academy fulfills the requirements of ABET and SNAME.

USMMA Compliance with Accreditation Requirements

Previous sections of this paper have set forth the accreditation requirements of ABET and the proposed program criteria of SNAME. Over the past decade the United States Merchant Marine Academy (USMMA) has devoted much effort to achieving compliance with these requirements. This effort paid off in June 1982 when ABET granted accreditation to the Marine Engineering Systems program. The paragraphs below indicate the means of satisfying ABET criteria 1 through 3. A discussion of compliance with criteria 4 and 5 is beyond the scope of this paper.

ABET criterion 1 relates to the curriculum content. Details of the curriculum may be found in Table I. The compliance of the Marine Engineering Systems

curriculum with the five parts of the ABET curriculum requirement is indicated below:

ABET Requirement	Marine Engineering Systems Curriculum
1/2 year math	Calculus & Analytic Geometry -16 credits
1/2 year basic science	General Chemistry-8 credits Physics-14 credits Materials Science-2 credits
1 year engineering science	Computer Engineering-1.5 credits Materials Engineering-1.5 credits Engineering Mechanics-7 credits Thermodynamics-10.5 credits Strength of Materials-4.5 credits Naval Architecture-2 credits Fluid Mechanics-3.5 credits Electrical Circuits-7.5 credits Automatic Controls-2.75 credits Electrical Machinery-3.75 credits Electronics-3.75 credits Mechanical Vibrations or 2-credits Heat Transfer
1/2 year engineering design	Naval Architecture-1 credit Fundamentals of Design-3 credits Machine Design-3 credits Automatic Controls-1 credit Marine Engineering-10 credits Design Electives-6 credits Design Graphics-3 credits Mechanical Vibrations or 1-credits Heat Transfer
1/2 year humanities and social science	Literature-6 credits Economics-6 credits History-9 credits Humanities Electives-9 credits

Note that certain courses appear in two categories above. This is because the subject material of those courses naturally crosses the boundary betweeen two categories.

The term "credit" is used above to mean quarter credit hour. For the information of readers not familiar with the U. S. credit hour system, one quarter

credit hour represents 10 clock hours of lecture or 20 to 30 clock hours of laboratory in a 11 week period known as a quarter.

Comparison of the above curriculum with the proposed SNAME program criteria reveals compliance with all essential and recommended content areas except Marine Systems Resistance and Propulsion. A portion of the course in Naval Architecture is devoted to this topic, but a proposal to insert a required course on this subject is under review by the Academy. In addition the curriculum includes elements of Marine Systems Fabrication and Production from SNAME's optional content area.

The curriculum also includes all of the complimentary curriculum features recommended by SNAME. Of these, the curriculum is particularly rich in laboratory experience as indicated in Table II. A new wing was recently added to the building that houses the Engineering Department. This new wing contains many new engineering laboratories including: materials testing, fluid mechanics, thermodynamics, simulation, electrical circuits, electronics, electrical machinery, and automatic controls.

ABET criterion 2 relates to the size and compentence of the faculty. The USMMA engineering faculty numbers about 25. There are about 600 engineering students enrolled at the Academy with about 450 of these on campus and 150 at sea at any given time. Thus the ratio of engineering students to engineering faculty is about 18 to 1. Most classes at the Academy have 20 to 30 students in them, and there are no large lecture groups of 100 or more. Thus the size of the faculty is appropriate to the size of the student body.

ABET's interest in the competence of the faculty is in their competence as engineering scholars. Because of the multiple missions of the Academy, competence of the faculty is especially challenging. As a whole the faculty must be competent engineering scholars and competent merchant mariners. The ideal professor would hold a doctorate in engineering and a chief engineers license. However, such people are extremely rare, and some relaxation of this constraint is necessary. Standards have been developed which attempt to balance the value of advanced degrees and merchant marine officer licenses.

A summary of these standards is tabulated below:

Academic Rank	Degree/License Requirement
Assistant Professor	Second Assistant Engineer's License and Bachelor's Degree and 12 credits of graduate study
	or
	First Assistant Engineer's License and Bachelor's Degree
	or
	Master's Degree
	or
	Professional Engineer's License and Bachelor's Degree
Associate Professor	Second Assistant Engineer's License and Master's Degree and 12 credits of advanced graduate study
	or
	First Assistant Engineer's License and Master's Degree
	or
	Chief Engineer's License and Bachelor's Degree
	or
	Doctorate
Professor	First Assistant Engineer's License and Master's Degree and 18 credits of advanced graduate study
	or
	Chief Engineer's License and Master's Degree
	or
	Doctorate

ABET criterion 3 relates to the admission and retention of students. Admission to the USMMA is highly competitive with more than 5 applicants for every vacancy in the entering class. As a result, only highly qualified students are admitted. The average student admitted has Scholastic Aptitude Test scores of 520 verbal and 620 math and stands in the top 10% of his or her graduating class. Students must maintain a C average in order to be retained at the Academy and graduate.

As indicated earlier, a discussion of compliance with ABET criteria 4 and 5 is beyond the scope of this paper.

Merchant Marine Officer Training

A requirement for graduation from the U. S. Merchant Marine Academy is the success-

ful completion of the U. S. Coast Guard Examination for Third Assistant Engineer (Steam and Diesel) and the acceptance of the U. S. C. G. Merchant Marine Officer License which is necessary to seek employment in that capacity.

Employers expect newly licensedpersons to have the knowledge and skills necessary to accept responsibility for an engine room watch, to safely operate machinery, to handle shipboard machinery emergency conditions and to undertake adjustment, repair and routine overhaul of shipboard machinery and systems all without further training. This expectation suggests that the new graduate, upon joining his ship, must have many of the skills associated with the electrical, rigging, machinist, boilermaking, welding, plumbing, instrument and control trades. While it takes many years to develop a journeyman in any of these trades, the skilled seaman must have significant skills in most to successfully operate and maintain his ship. The training portion of the Academy education program is designed to provide the introductory skill levels on which the professional seaman can continue to build as he gains experience at sea. This training is accomplished primarily in the freshman year at the Academy and during the eleven months each student is assigned to U. S. Flag vessels for co-operative education.

Table I lists the intensive merchant marine officer training activities during the freshman year when the student takes courses in seamanship, shop practice, welding, machine tool operation, and electrical fundamentals. The student gains skills in drawing interpretation during the academic courses in engineering graphics. The Academy has been able to achieve professional engineering accreditation without sacrifice of the traditional skill training which is necessary for the graduate to meet the initial expectation of the industry.

Perhaps the most valuable segment of the skill training is the two half year assignments each student has on shipboard. During these periods in the sophomore and junior years, the student is assigned to commercial vessels as an engineering department midshipman, ie, apprentice. The student works with the ship's engineering officers learning and performing the work tasks of the merchant marine engineer officer. Such tasks include operation, preventive maintenance, watch standing, record keeping and the ordering of stores and parts. The sea going student is required to allocate much of his non-working time to the study of practical aspects of marine machinery, systems, operations and management.

The vehicle for the shipboard individual study program is the Sea Project which consists of a series of assignments of readings and practical shipboard investigations designed to assure the student achieves a maximum exposure to the procedures required and the problems associated with the engineering systems on his vessel. The comprehensive report prepared by the student concerning his shipboard study program is submitted to the faculty for evaluation upon return from the sea assignments. In addition, the officer evaluations of the student's performance while assigned to a ship become a part of the student's record.

Typical Sea Project assignments for engineering students include the following activities:

a) Preparing engineering sketches of principal shipboard systems
b) Preparing written procedures for operating the machinery
c) Observing and reporting on repair, maintenance, and emergency procedures used aboard ship
d) Collecting and analyzing data on power plant performance
e) Using shipboard machine tools to make parts
f) Using shipboard drawing and technical documentation to accomplish assigned tasks.

Table III lists the subjects covered in the Sea Project program.

The sea year and the Sea Project provide important benefits to the student in his subsequent study of professional engineering subjects. An appreciation of the practical aspects of machinery systems provides a useful supplementary for the study of engineering synthesis and analysis. It is this background which most accredited engineering schools must forego to accomplish professional education in a timely and economic manner. It is a unique attribute of the U. S. Merchant Marine Academy marine engineering systems graduate that he or she is equally comfortable with problems in design, operation, maintenance or management of marine engineering systems.

During the four academic years at the Academy, the student is involved in laboratory programs which augment both the professional engineering study and the development of technician skills. In many cases, these needs have been incorporated into the same laboratory exercises. For example, in senior engineering courses students must select and set-up instrumentation and operate machinery to run ASME performance tests and collect data for analysis. Such exercises give the student many opportunities to practice technician skills and engineering analysis simultaneously. Table II lists all the engineering laboratories and indicates the utilization of the laboratories in engineering education and skill training.

A desirable future modification to the co-operative training program would require the student to work as a machinist apprentice in a ship repair or shipbuilding yard for thirty to sixty days instead of spending all the training assignment periods aboard ship. The extensive disassembly of machinery and hull fittings during repair periods and the alignment and start-up of machinery in shipbuilding yards would be a valuable enhancement of the officer training period.

Training As A Naval Reserve Officer

The United States Navy has a vital interest in the United States Merchant Marine Academy based on the national defense requirement for an adequate merchant marine manned by well trained officers who possess an understanding of naval procedures so that merchant vessels are capable of operating with the Navy in time of war or national emergency. In addition, graduates of the Academy have historically been a source of active duty naval officers in time of mobilization. In view of this interest, the Secretary of the Navy appoints all qualified students of the U. S. Merchant Marine Academy as Midshipman, USNR and upon graduation they are commissioned as Ensign, USNR.

As shown in Table I, the Naval Science program consists of four courses which

include:

Fundamentals of Naval Science
Naval Weapons Systems
Naval Operations I
Naval Operations II

These courses are designed to provide the graduate with the basic knowledge needed by merchant marine officers to operate with the Navy.

The following lists the study areas incorporated in the Naval Science Program to stress Navy-Merchant Marine interfaces in joint operations.

Seapower, past, present and future
US/Soviet relations and maritime developments
Sea control/Power projection
Status of merchant ships in time of war
Naval control of shipping (NCSO)
National Defense Features (NDF) incorporated into merchant ships
Radar and sonar fundamentals
Naval tactics in major warfare areas-SW/AAW/ASW (Surface warfare/anti-air warfare/anti-submarine warfare)
Potential threats for naval merchant shipping
Convoy systems, procedures and defense
Use of publications in time of emergency
Communications
Defense against nuclear, biological and chemical warfare
Defense tactics available to merchant ships
Anti-sabotage/terrorist measures
Arapaho program
Firefighting/Damage control
Military Sealift Command (MSC)
Replenishment at sea

Conclusions

The four year accredited engineering program of the U. S. Merchant Marine Academy is rich in laboratory experience, co-operative shipboard training and training in skills of ship operations and ship maintenance. The combination of an accredited engineering curriculum and these practical training experiences is unique in engineering education.

TABLE I

	ACADEMIC PROGRAM	Credits	MERCHANT MARINE OFFICER TRAINING ACTIVITIES	Credits	NAVAL RESERVE OFFICER TRAINING ACTIVITIES	Credits
Freshman Year	Calculus & Analytic	16	Marine Safety	2	Naval Science	3
	General Chemistry	8	Nautical Science	5		
	Physics	7	Safety of Life at Sea	1½		
	Engineering Graphics	4	Marine Engineering	3½		
	Humanities	9	Electrical Engineering	2½		
	Introduction to Engineering	3	Engineering Shop	3		
	Introduction to Computers	½	Metal Cutting and Joining	2½		
		47.5		19.75		3
Sophomore	Differential Equations	4	Shipboard Training (Students are assigned to ships as apprentice for six months)	6½	Naval Weapons	3
	Physics	7				
	Computer Engineering	3				
	Materials Engineering	3½				
	Mechanics	7				
	Thermodynamics	3				
	Economics	6				
		33.5		6½		3
Junior	Differential Equations	4	Shipboard Training (students assigned to ships as apprentice for six months)	6½	Naval Operations	3
	Strength of Materials	4½				
	Naval Architecture	3				
	Fluid Mechanics	3½				
	Thermodynamics	7½				
	Electric Circuits	7½				
	Managerial Processes	3				
	Humanities	3				
		36		6½		3
Senior	Marine Engineering	24½			Naval Operations	3
	Machine Design	6				
	Control Engineering	3 3/4				
	Electronics	3 3/4				
	A. C. Machinery	3 3/4				
(Note 1)	Heat Transfer	3				
(Note 1	Vibration	3				
(Note 2)	Ship Propulsion	3				
(Note 3)	Design Electives	6				
	Humanities	15				
	Management	3				
		68 3/4		0		3
Totals		187.75		32.75		12

Note 1: Students must elect one of these two courses.
Note 2: A planned addition to the curriculum. Credits not included in total

Note 3: Design electives must be selected from the following list:

Computer Controls
Advanced Machine Design
Ship Structures and Dynamics
Thermal Systems Analysis
Advanced Automatic Controls
Advanced Electronics
Basic Ship Design
Engineering Seminar

TABLE II

USMMA LABORATORIES UTILIZATION

LABORATORIES	INSTRUCTION AT ENGINEERING LEVEL	INSTRUCTION AT TECHNICIAN LEVEL
Heat Power Laboratory	x	x
Materials Joining Laboratory		x
Materials Cutting Laboratory		x
Controls Laboratory	x	
Refrigeration Laboratory	x	x
Electric Circuits Laboratory	x	
Electrical Machinery Laboratory	x	x
I. C. Engine Laboratory	x	x
Thermodynamics Laboratory	x	
Material Science Laboratory	x	
Strength of Materials Laboratory	x	
Non-destructive Test Laboratory		x
Marine Engineering Introduction Laboratory		x
Steering Engine Laboratory		x
Simulation Laboratory, Power Plant	x	x
Engineering Graphics Laboratory	x	x
Naval Architecture Laboratory	x	
Fluid Mechanics Laboratory	x	
Computer Laboratory	x	

TABLE III

SEA PROJECT ASSIGNMENTS

THIRD CLASS YEAR (Sophomore)

Marine Engineering
- Shipboard Systems
- Shipboard Machinery
- Normal Plant Operation
- Casualty Operation

Machine Shop
Shipboard Electrical Engineering
Diesel Engineering
Naval Architecture
Deck Operations

SECOND CLASS YEAR (Junior)

Marine Engineering
- Boiler Construction and Maintenance
- Turbine & Gear Construction and Maintenance
- Auxiliary Systems and Components
- Instruments and Controls

Marine Refrigeration Systems
Electrical Engineering
Diesel Engineering
Machine Shop
Ship Construction
Labor Relations

REFERENCES

1. Accreditation Board for Engineering and Technology, 49th Annual Report, page 42.
2. Ibid., page 43.
3. Ibid., page 43.
4. Society of Naval Architects and Marine Engineers, Biennial Directory and Information Book - 1980, page 7.
5. "Proposed Guidelines for Accreditation of Marine Engineering, Naval Architecture and Ocean Engineering", Amelio M. D'Arcangelo Bruce C. Skinner, 1981 ASEE Annual Conference Proceedings.
6. Ibid.
7. Ibid.
8. Ibid.