CHARACTERISTICS OF EXCELLENCE IN ENGINEERING TECHNOLOGY EDUCATION

Final Report

of

The Evaluation of Technical Institute Education

American Society for Engineering Education

1962

Additional copies of this report may be obtained from professor W. Leighton Collins, Secretary, The American Society for Engineering Education, University of Illinois, Urbana, Illinois.

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FOREWORD

In the past few years much has been written about the technical manpower shortage in the United States. In the mass media and sometimes even in the technical press one can see an unfortunate tendency to equate this shortage with a shortage of scientists and engineers. We tend to lose sight of the fact that a substantial part of the problem can be attributed to a shortage of engineering technicians. There are even those who claim that if technicians were properly utilized, there would be no shortage of engineers. Be that as it may, there is no serious disagreement that as the shortage continues, there will be greater and greater use made of engineering technicians.

The potential impact of the technician shortage upon national defense and the nation’s economic growth has induced national, state, and local legislation to supply funds for the expansion of some levels of technical education. The total effect of this legislation is, as yet, difficult to assess since many states are essentially still in the planning stage. However, it now appears obvious that with government support as a stimulus we may expect to see a continuing growth in the number of technical curricula being offered.

Enrollment pressures on the colleges and universities have already caused the public to face the fact that not all high school graduates are suited for or interested in college programs at the baccalaureate level. Throughout the country the number of junior colleges, community colleges, technical institutes, and other institutions offering two-year programs of higher education has increased greatly. Four-year colleges and universities have increasingly shown interest in offering two-year programs leading to the associate degree or a similar award. A substantial number of these curricula are aimed toward educating technicians. The U. S. Office of Education publication, *Organized Occupational Curriculums*, shows that the number of curricula for technician education increased from 694 in 1956 to 1,127 in 1959. There is every indication that the trend will continue.

This rapid expansion of technical education has brought about a great diversity in both the level and quality of technical curricula. In the minds of educators this has quite naturally led to confusion, misunderstanding, and conflict as to the definition, scope, means, and ends of technical education. The technical education community, of course, does and should insist upon a high degree of variety and diversity within the field, but it also recognizes that within this variety and diversity there must be a core of agreement if chaos is not to result. It is in search of this core of agreement in a segment of the technical education spectrum that this study has been prepared.

The General Council of the American Society for Engineering Education recognized that engineering technician education in the United States was seriously in need of re-evaluation of standards of both level and quality. Consequently, in the spring of 1959 it appointed a steering committee to plan and oversee an evaluation of technical institute education. ASEE was encouraged to undertake this evaluation by its own Technical Institute Division and by the Engineers’ Council for Professional Development. The project was financed by a grant to the Society by the National Science Foundation. A working committee of nine members was appointed, a project director was named, and the project was officially begun September 1, 1961. This study does not duplicate the work of the National Survey of Technical Institute Education (1957-59) or of other studies to determine the current status of technical education. Its task has been to draw conclusions from these other studies, to solicit expert advice, and to formulate a set of educational criteria for engineering technology curricula. It is hoped that these criteria will be useful for strengthening existing engineering technology curricula and for constructing new ones. It is hoped also that these criteria will be of value to the Engineers’ Council for Professional Development in its program of accreditation of engineering technology curricula.

The working committee, in a series of meetings in the fall and winter of 1961-62, prepared a tentative draft of educational standards for review by the steering committee. In the spring of 1962 five conferences were held in selected geographical regions to examine, discuss, criticize, and recommend modifications to the prototype criteria. In addition to those who attended the meetings a number of persons submitted their criticisms by mail. The preliminary draft, therefore, has been reviewed by persons from institutions that offer ECPD-accredited engineering technology programs, junior college administrators involved in technical education, representatives of engineering colleges and professional societies, and employers of engineering technicians in both industry and government (a list of these reviewers is contained in the appendix). The draft has been revised in the light of comments.
obtained, but the working committee and the steering committee have made the final determination of the content of this report.

The Committee wishes to express appreciation to the National Science Foundation, without whose generous assistance this study could not have been undertaken. It is grateful also to the regional offices of the United States Office of Education and the United Engineering Center for providing facilities and making arrangements for regional meetings. We extend our thanks also to the University of Dayton for granting Professor McGraw a leave of absence to direct this project and for providing him with a headquarters office. And finally, we wish to especially thank all those who reviewed the preliminary draft at the regional meetings or through correspondence.

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INTRODUCTION

Purpose and Scope
This report outlines quality standards proposed by the ASEE Technical Institute Evaluation Working Committee as guidelines for constructing, improving, and evaluating engineering technology curricula, as defined below. It seeks to define terms related to engineering technology, to examine weaknesses in the present approach to technician education, to suggest minimum standards for selecting faculty and students, and to explore curriculum requirements in both technical and non-technical areas.

Designation of Curricula
Many technical educators are dissatisfied with the term technical institute curriculum as a designation for programs of the type discussed in this report. Much of this dissatisfaction is traceable to the ambiguity of the word institute, which is more often associated with an institution than with a type of program. Programs of this type have historically been offered by a variety of institutions, not all of which are called technical institutes. The Committee does not wish to take a position regarding the appropriate title for the institution but it does recommend that in view of its imprecision and ambiguity the term technical institute curriculum be dropped and that curricula of the type discussed in this report be called engineering technology curricula. It also recommends that the terms engineering technology and engineering technician be adopted to represent the field of study and the practitioner, respectively. The following definitions of these terms are proposed.

Definitions
Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer at the end of the area closest to the engineer.

(a) Engineering technology is identified as a part of the engineering field to indicate that it does not by any means encompass the entire field and also to differentiate it from other types of technology in areas such as medicine and the biological sciences. The engineering field is viewed as a continuum extending from the craftsman to the engineer. Engineering technology falls, in the continuum, between the craftsman and the engineer and closer to the engineer than to the craftsman.

(b) Engineering technology is concerned primarily with the application of established scientific and engineering knowledge and methods. Normally engineering technology is not concerned with the development of new principles and methods.

(c) Technical skills such as drafting are characteristic of engineering technology. Engineers graduated from scientifically oriented curricula (See ASEE Report on the Evaluation of Engineering Education, 1955) may be expected to have acquired less of these skills than previously and the engineering technician will be expected to supply them.

(d) Engineering technology is concerned with the support of engineering activities whether or not the engineering technician is working under the immediate supervision of an engineer. It may well be that in a complex engineering activity he would work under the supervision of an engineer, a senior engineering technician, or a scientist.

An engineering technician is one whose education and experience qualify him to work in the field of engineering technology. He differs from a craftsman in his knowledge of scientific and engineering theory and methods and from an engineer in his more specialized background and in his use of technical skills in support of engineering activities.

(a) The Committee does not wish to suggest job or position titles for use by employers. Position titles will vary from one company to another and would normally be functional titles. The Committee recommends, however, that the generic term for those in this field be engineering technicians.

(b) If the term engineering technician is restricted in its application to the upper portion of the range between the craftsman and the engineer, considerable future confusion can be avoided.
An engineering technology curriculum is a planned sequence of college-level courses, usually leading to an associate degree, designed to prepare students to work in the field of engineering technology.

(a) The term *college-level* in the definition of an engineering technology curriculum indicates the attitude with which the education is approached, the rigor, and the degree of achievement demanded, and not *solely* or even necessarily that the credits are transferable to baccalaureate programs.

(b) Although throughout this report the generic term engineering technology curriculum is used, there are many specific branches of engineering technology in which curricula are offered. Commonly encountered are such curriculum titles as mechanical engineering technology, electronic engineering technology, architectural engineering technology, chemical engineering technology, and civil engineering technology.

**Distinction Between Quality and Level**

A large number of programs has been inaugurated in recent years under the name of technical curricula. They have had a variety of goals and a corresponding diversity of educational levels. This diversity has been a source of disagreement among educators and of confusion to the public, legislators, employers, parents, and students. The Committee believes that a distinction should be made between the quality of a program and its educational or difficulty level.

The level of a program is determined by its objectives, and the quality by how well it achieves these objectives. If, for example, the objective of a program is to train retarded persons to perform simple household tasks, it may excel at accomplishing this objective. On the other hand, a graduate program in a highly abstract field may well be of poor quality.

Some technical curricula intend to cover their subject matter at a level close to that of the engineering college, or at least that of the engineering college of a few years ago. Others set their objectives at essentially the same level of difficulty as the secondary school. Between these extremes we find a well-distributed range of objectives and levels. The sole point of agreement, and even that is not unanimous, is that technical education is post-high school. Almost all technical curricula are admittedly *after* high school, but misunderstanding arises because the term post-high school is chronological rather than indicative of level of difficulty.

The level at which a technical program is cast depends largely on the type of position for which the graduates are being educated. In the early years of the technical education movement it may have been assumed that the range of positions between the craftsman and the engineer was narrow enough for a single level of curricula to prepare students to occupy positions throughout the entire range. This can no longer be taken for granted.

Recent occupational analyses\(^1\) have indicated that the range between the craftsman and the engineer includes positions which vary considerably in the level of technical education required. The diversity in educational levels mentioned above is undoubtedly a reflection of this occupational diversity.

Confusion has resulted in many instances, however, because institutions have continued to generalize in their statements of objectives and have at least implied that they are trying to cover the entire range. As a consequence differences in level have often been interpreted as differences in quality.

1 The distinction between quality and level is prerequisite to the formulation of educational standards. The Committee believes that quality standards can be stated only for a given level of education.

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Some technical educators have suggested that two levels of technicians be recognized and that one level be called the engineering technician and the other level the industrial technician or the highly-killed technician. It may well be that there is need for even further division of the range. In any case, this report deals only with education for the end of the range close to engineering, defined above as engineering technology. Perhaps similar standards should be formulated for other levels and types of technical education.

Premises

Engineering technology curricula must continue to be sensitive to changes in adjoining sectors of education. There has been in recent years a steady increase in the mathematics and science level of the curricula of both the secondary school and the engineering college. Consequently, if engineering technology curricula of the near future are to provide a challenging program for the high school graduate and produce a technician competent to support the engineer, they cannot remain static. The engineering technician of tomorrow must be educated at a higher technical level than he has been in the past.

The standards proposed in this report are based upon the premise that increasingly engineering technicians will need to acquire greater technical ability and that increasingly high school graduates entering engineering technology curricula will be better prepared.

Many engineering technology programs of the past have educated the student solely for the entrance-level position as it existed at the time he attended school. Since the typical graduate has a working life of approximately 45 years, it is unrealistic to educate him merely for the job he holds for the first several years. Moreover, his job constitutes only one part of his life. He has other needs if he is to be an effective citizen and member of society. Though it is difficult to accomplish in the short span of two years, there are certain areas (e.g., mathematics, physical sciences, humanistic-social studies) in which the student must be given a broader base than has heretofore been the common practice.

Beyond doubt some engineering technology curricula already exceed some of the standards put forth in this report. This is both expected and desirable since these are conceived as minimum standards for curricula at the engineering technology level. There is ample opportunity for reasonable variation above the minimum in keeping with differences in regional needs. The Committee is aware that in many cases it will take several years to fully implement these suggested standards. Yet, it anticipates that in the next five to ten years more stringent technical requirements will demand that engineering technology curricula have the characteristics described in this report.
The ultimate quality of a curriculum depends largely upon the quality of its faculty. The attributes desirable in the faculty of an engineering technology curriculum are identical with those desired of all college teachers: intelligence, a genuine interest in developing students, personal and professional integrity, a capacity for communicating ideas in oral and written form, a thorough knowledge of the subjects taught and of relevant supporting subjects, and skill in the fundamentals of the teaching-learning process.

It is important that all members of the engineering technology faculty be familiar with and sympathetic toward the goals of this type of education. The engineering technology teacher must not only be conscious of a desire to teach his subject, but also to teach it at the engineering technology level. Unless the faculty has this quality an institution can easily find itself overloaded with teachers for whom engineering technology education is at best a secondary interest.

This devotion to the objective is best accomplished if most of the instruction in engineering technology is conducted by full-time teachers whose principal concern is the education of engineering technicians. The use of an unduly large proportion of part-time faculty members or faculty members from vocational or engineering programs is undesirable.

The principles just expressed apply equally to teachers of technical and non-technical subjects. It is in mathematics and the non-technical subjects, in fact, that we are likely to encounter the greatest misunderstanding of objectives. The implied problems are most prevalent in comprehensive institutions that offer engineering technology curricula but that draw indiscriminately on a common staff for teaching vocational, engineering technology, and baccalaureate courses.

Since engineering technology curricula are by definition of college level, it is obvious that a proper proportion of the faculty should have acquired at least a baccalaureate degree. Since these curricula are so closely related to engineering, it is equally obvious that a satisfactory engineering technology faculty must contain a substantial proportion of graduate engineers. It is the Committee's opinion that approximately half the faculty members teaching the technical specialties should be graduate engineers or the equivalent.

If the curriculum is to keep pace with technology, it is not feasible to depend to any great extent upon faculty members whose technical competence is only slightly greater than that of the students. However, engineering technicians with considerable industrial experience are an important asset to the faculty. Experience has shown that engineering technology graduates who have continued their education toward a higher degree in their field often make excellent teachers in this type of program. The development of new curricula at some universities to prepare teachers for technical education programs may provide a significant opportunity for engineering technology graduates to enter the teaching field.

Diversity of faculty background provides the student with the opportunity for breadth of view. The Committee, therefore, feels compelled to reiterate the admonition so frequently heard in academic circles against excessive inbreeding by the hiring of too many graduates of anyone institution. If such faculty members are employed, they should be encouraged to obtain degrees at other institutions. It is also undesirable to hire too many faculty members with the same industrial experience, since the student should be given insight into many companies and many specific jobs.

Since engineering technology curricula educate students primarily for specialized occupational areas, it follows that a significant proportion of the faculty must have had relevant industrial experience and that this experience must be reasonably current. In some fast moving technological fields experience over ten years old can be as much a handicap as an asset.
This, of course, leads to the important requirement that faculty members maintain technical competence in their fields. To foster this, faculty members should be encouraged to participate in technical and professional societies and to engage in work in industry or in research. They should be urged to keep up with the literature of their fields, to continue their education, to attend professional meetings, and to experience first-hand what is taking place in the industries related to their specialties. Encouragement of this sort is most effective when opportunity is provided in the form of time and financial assistance. Such opportunity is more likely to be seized if promotions are based on a balanced judgement of the instructor's capability to bring a broad experience and academic background to bear on his teaching and not solely on acquisition of higher academic degrees.

1 See page 32 for explanation of technical specialties.

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If an effective engineering technology curriculum hinges greatly upon the quality of its faculty, it hinges perhaps even more greatly upon the quality of its incoming students. If the students’ high school backgrounds are inadequate, instructors will tend to adjust their course material to these inadequacies. The inevitable result will be that the courses will lose the depth and scope implied in the catalogue and faculty capabilities will not be fully utilized. Any discussion of academic standards, therefore, must be preceded by a statement on admission requirements and student selection.

Admission Requirements
A modern engineering technology curriculum will be based on the assumption that incoming students have been graduated from an accredited secondary school or have had the equivalent education (substantiated by the method recognized in their state). It goes almost without saying that the student should also exhibit some evidence of sufficient ability and the necessary aptitudes for satisfactory achievement in the curriculum. Mere possession of a high school diploma does not, of itself, guarantee sufficient background.

The Committee believes, therefore, that a satisfactory engineering technology program should be based upon the following minimum secondary school units:

(a) Three units of English. The student should at least have been exposed to the rudiments of communications skills.

(b) Two units of mathematics, one of which is in algebra and the other in plane geometry (or the equivalent of these in integrated modern mathematics). The Committee strongly suggests that, in addition to these minimum units, intermediate algebra and trigonometry are desirable.

(c) One unit of physical science with laboratory. Because of the nature of engineering technology it is desirable that wherever possible this unit be in physics or chemistry. The student should have acquired this minimum background before entering the engineering technology program itself. An institution which admits students with less than these minimum high school units must be prepared to offer a longer program or an acceptable non-credit pre-technical or remedial program.

Transfer of Credits
Credits submitted for transfer from other institutions of higher education should be evaluated realistically on the basis of comparative course content or of validated, reliable proficiency examinations rather than on an inflexible basis of equivalent credit hours.

Testing
Testing of students as part of the admissions procedure has become a common practice in higher education. However, the use of this valuable tool is not as widespread in technical education as it might be. The Committee suggests that institutions offering engineering technology curricula consider using reliable standardized or local tests to aid in student selection, placement, and guidance. Each test should be validated at each institution, whether it is a standard or local test.

Guidance and Counseling
Each institution should develop definite means for providing the student with effective guidance and counseling. The student should be aided in selecting educational and occupational objectives consistent with his interests and aptitudes. He should be advised to revise his educational objectives if he seems more suited to an engineering program, a trade program, or a program in other educational areas. The student who decides to change his field of emphasis after pursuing one curriculum for some time is especially in need of help. For this reason guidance and counseling should be available to the student throughout his education and not just at the time of his enrollment. Besides advising students on educational matters, counselors should provide assistance in dealing with personal and
financial problems. To do the job effectively, guidance personnel must be thoroughly familiar with the curriculum and its objective.

Placement

Since engineering technology curricula are occupationally oriented, the student normally expects that some effort will be made to aid him in contacting prospective employers. The graduate should be given every possible assistance in finding suitable employment. But even beyond this, if those responsible for placement maintain the desirable liaison with industry they will learn of opportunities and will, in fact, be sought out by industrial recruiters. The placement function is, consequently, extremely valuable to the student, the institution, and industry. Placement personnel should know the needs of industry, should be familiar with the curricula offered by their institution, and should be in a position to inform prospective employers of the general types of positions for which the graduates of any particular curriculum are qualified.

Administrative Policy

In closing this discussion of admission requirements and related topics, the Committee considers it appropriate to paraphrase a portion of the ASEE Report on the Evaluation of Engineering Education (1955). It recommends that institutions:

(a) State clearly the requirements for admission to their programs.
(b) Admit students with deficiencies only when there is strong indication of probable success and always state specifically what the deficiencies are and how they may be removed.
(c) Maintain records of criteria used to determine admission.
(d) Use these records to improve the screening process.

THE ENGINEERING TECHNOLOGY CURRICULUM

The term curriculum, as used in this report, connotes several ideas and distinctions which are important to any discussion of engineering technology curricula. First, a curriculum is an integrated sequence of organized courses. This would imply that a loose collection of courses, even though all are in a given occupational area, does not constitute a curriculum. Secondly, a curriculum is planned to fulfill a particular objective within a specified time. From this it follows that courses designed for a four-year program in engineering would not, in most cases, be appropriate components of a two-year program in engineering technology. The selection and organization of subject matter would be different, and the emphasis of the curriculum and of each course in it would be different.

An engineering technology curriculum differs significantly from a pre-engineering curriculum, which is equivalent to the first two years of an engineering program. The one is the preparatory part of a more inclusive program; the other a complete program in its own right. The first two years of an engineering curriculum are devoted primarily to mathematics, science, and general education. They contain relatively few specialized technical courses. An engineering technology curriculum, on the other hand, must initiate specialized technical courses early in the program if it is to cover its material within the short span of two or three academic years.

The more concentrated demands of time impose upon the engineering technology curriculum a greater need to integrate the courses with each other and to aim the subject matter more directly toward the particular demands of the specialized occupational field. This means that individual courses must usually be designed specifically for the engineering technology curriculum. Only if this is done can a balanced program with adequate coverage of the material be achieved within the time permitted. If courses are designed for the engineering technology curriculum, they will be more likely to give appropriate stress to the application of established engineering
principles rather than to theoretical derivations. It is this factor more than any other, incidentally, that underlies the earlier insistence that faculty members understand and be sympathetic toward the goals of the engineering technology curriculum.

Credits

The Committee recommends that institutions offering engineering technology curricula use conventional credit units in describing their curricula. Much confusion that currently exists in comparing these curricula could thus be avoided. The generally accepted system is to grant one credit for three hours of study per week, whether in classroom, laboratory, homework, or any combination thereof. An academic hour is usually defined as a 50-minute class period. Thus, one credit is equivalent to one hour of classroom lecture or recitation per week plus approximately two hours of assigned homework. Alternatively, one credit is normally granted for approximately two hours of laboratory work per week plus one hour of assigned homework, or three hours of laboratory work per week with no assigned homework.

If one credit is granted for a period of from 15 to 18 weeks it is normally called a semester credit. If one credit is granted for an academic quarter of 11 to 13 weeks it is normally called a quarter credit. Usually a quarter credit is considered to be two-thirds of a semester credit.

Length

The proportions described in this report assume a curriculum length of two academic years. An academic year is considered to be approximately nine months in length and comprised of two semesters or three quarters. The Committee recognizes that there are engineering technology curricula which are longer than two years and some which operate for more than nine months per year. Administrators of such programs should interpret this report in the light of their own programs.

Atypical engineering technology curriculum is probably about 72 to 75 semester credit hours in length. However, existing curricula vary in length from 61 semester credit hours to over 100. Expressed in terms of time, curriculum lengths vary from two academic years to three calendar years. This situation made it difficult for the Committee to phrase meaningful curricular recommendations in terms of percentages or proportions since it is not reasonable to assume that the proportions would be the same for all curriculum lengths. It therefore became necessary to state recommendations in terms of minimum semester credit hours suggested for the various curriculum elements.

The Committee believes it is unrealistic for the published catalogue curriculum to require more than 20 credits in any semester of a full-time program. The average number of credits per semester in the program should probably be less than 20. It should be remembered that in terms of the credits defined above a curriculum requiring more than 20 credits per semester or quarter assumes that the average student studies more than 60 hours per week.

Curriculum Breakdown

For purposes of this study the Committee has divided the curriculum into three major sections: Basic science courses, which include mathematics and physical sciences; technical courses, which include technical skills and technical specialties; and non-technical courses, which include communications, humanities, social sciences, and other life-oriented courses. Each of these is discussed more fully in succeeding sections of this report.

The following table summarizes the minimum semester hour recommendations of this report along with an illustration of their possible application to a 72-hour curriculum. It should be emphasized that the 72-hour program shown is an example only and should not be interpreted as a recommendation or as an ideal. Many variations are possible.
BASIC SCIENCE COURSES

In order to promote versatility and future technical growth in engineering technology graduates and to minimize the risk of technological unemployment be-

CURRICULUM SUMMARY
IN SEMESTER CREDITS

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<th>*Minimum</th>
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Basic Science Courses

Mathematics
(e.g. algebra, trigonometry, calculus) 9 12

Physical Sciences
(e.g. physics, chemistry) 6 15 6 18

Non-Technical Courses

Communications
(e.g. English composition, speech, report writing) 6 6

Humanistic-Social Studies
(e.g. economics, literature, history) 6 6

Other
(e.g. management, human relations, or additional humanistic-social studies) 3 15 3 15

Technical Courses

Technical Skills
(e.g. drafting-basic manufacturing processes) 6 6

Technical Specialities
(e.g. semiconductors, strength of materials) 24 30 33 39

Totals 60 72

*Institutions should view with concern any curriculum which meets only the minimum shown above. Variations above the minimum are not only expected but desirable.

cause of obsolescence of their technical knowledge, the Committee recommends a rather substantial program in mathematics and physical sciences. The reasons for this are fairly apparent. First, of course, is the fact that all branches of engineering technology are built upon a foundation of mathematics and physical science. Secondly, the specific applications of mathematics and science change quickly with our evolving technology, but the core of principles that underlies these remains more stable. Finally, a broader knowledge of mathematics and science gives the student a better base upon which to advance occupationally. Conversely, a limited mathematics and physical science background is one of the greatest barriers to comprehension of new technical developments and maintenance of technical competence.
Mathematics

Most technical educators and employers of technicians have long recognized that mathematics is one of the more critical determinants of both the level and the quality of an engineering technology curriculum. This is evident in manpower analyses of the Executive Office of the President, Office of Emergency Planning and in the report of the Technical Institute Curricula Task Force of the President's Committee on Scientists and Engineers. 2

In surveys conducted by the Technical Institute Curricula Task Force, the most common criticism by graduates and employers is directed toward the level of mathematical content of engineering technology programs. Top management as well as first-line supervisors expressed a desire for graduates well educated in mathematics. The working engineering technicians themselves expressed a desire for more mathematics and specifically mentioned analytic geometry and calculus.

There is no doubt that the ultimate depth to which the physical science and technical specialties portions of the curriculum can be pursued will be determined greatly by the mathematical preparation of the student. If the curriculum is to provide the greater technical competence needed by tomorrow's engineering technician the mathematics courses must be expected to increase in level. Such an increase is also consistent with the anticipated improvement in the level of mathematical preparation of entering students.

The proportion of the curriculum devoted to mathematics will necessarily vary with the admission requirements. The Committee believes that an adequate program in mathematics can be offered in nine to twelve semester credit hours if topics are carefully selected and the courses are specifically designed for the engineering technology curriculum. The selection of mathematical topics and the best sequence in which to teach them must be determined by coordinated effort of the mathematics and technical faculty members in the light of the aims of their own institution and its curricula.

With these thoughts in mind, the Committee makes the following recommendations concerning mathematics in the curriculum:

(a) Mathematics taught in the engineering technology curriculum should be of college level. This refers to the pace at which the course proceeds, the difficulty of the problems solved, the attitude with which the material is approached, and the degree of achievement demanded of the students. While of college level, engineering technology mathematics programs are essentially applied in nature; that is, they emphasize problem solving rather than extensive mathematical proofs. The Committee believes such mathematics courses to be of college level whether or not they are transferable to baccalaureate curricula. If secondary school-level mathematics is taught to permit students to overcome deficiencies it should not be an integral part of the engineering technology curriculum.

(b) Mathematics should generally be taught in separate courses from science and technical subjects by qualified mathematics instructors familiar with the engineering technology objective. This will give the student flexibility in applying mathematics to a greater variety of problems rather than restricting him to applications presently used in his technical courses. It will also tend to be more adaptable to any further mathematics education which the student may wish to pursue either formally or informally. This provision,
of course, does not relieve instructors in technical courses of their responsibility for giving supplementary instruction and insight into applications of mathematics.

(c) Mathematics programs should include carefully selected topics from such areas as analytic geometry, differential calculus, integral calculus, differential equations, probability and statistics, vector algebra, and Boolean algebra. The selection of topics will depend on the branch of technology and on the functions the curricula are designed to perform. The Committee feels constrained, however, to make special note of the part that calculus plays in technical literature and in almost every technical field today. It recommends that enough calculus be taught to guarantee that the students are professionally literate and to permit the use of this mathematical tool in the technical specialties.

(d) The curriculum should be so arranged that principles are taught in the mathematics courses prior to the time they are needed in the technical courses. This requirement does not necessarily demand that all mathematics courses be completed before the student undertakes his technical courses. It does demand sufficient integration to assure that if the student is taking mathematics and technical courses concurrently a given mathematics topic will be covered in the mathematics course before its application is required in the technical courses. This may well necessitate rearrangement of topics within the mathematics courses in such a way as to differ from the traditional sequence.

Physical Sciences

If the mathematical sciences underlie all the technical courses of the curriculum, similarly the physical sciences give them unity. Thus it is to the physical sciences that the engineering technician must look for the fundamental concepts which tie together all the technical areas. Because of this integrative function, it is apparent that most of the observations about the role of mathematics in the engineering technology curriculum apply equally to the physical sciences. There are, however, particular aspects of a satisfactory physical science sequence within the curriculum which merit additional clarification. Therefore, the Committee makes the following recommendations:

(a) The physical sciences should be taught in separate courses from the technical specialties. The Committee makes this recommendation in keeping with its previously expressed conviction of the need for a broader foundation of knowledge for engineering technicians. It believes that certain physical science fundamentals may be required by the engineering technician which are not likely to be included in his specialized technical courses. For example, a mechanical engineering technician working in machine design may need some knowledge of the principles of optics and light. Separate courses are preferable since, where physical science is integrated into technical courses, the coverage will tend to be limited.

(b) An engineering technology curriculum should contain at least a one-year sequence (six semester credits) in the physical sciences at the college level. The problem of condensing the desirable theoretical background in the applicable sciences into this few hours is itself considerable. Many curricula may have to exceed this minimum requirement to meet their objectives. The function of the physical science courses is to interrelate the technical subjects and provide the student with a foundation of scientific principles. Toward this end the courses should emphasize the understanding, measurement, and quantitative expression of the phenomena involved. This points up the importance of the student's having had some science in high school. It also is the basis for the previous statement that this high school science training should, if at all possible, be in physics or chemistry.

(c) Physical science courses should be accompanied by appropriate laboratories. Experiments should be chosen to reinforce comprehension of the principles and to aid in developing methods of observation. Careful work, precise observation, and accurate measurement and recording should be emphasized.

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NON-TECHNICAL COURSES

The engineering technician requires more than technical knowledge. He must be able to use his native language both during and after working hours. He must live with other people both on and off the job. He is a citizen as well as an employee.
and must participate with other citizens in the making of democratic decisions. Consequently, the Committee recommends that as part of both his occupational and cultural development an engineering technician's education should include instruction in linguistic communication, the humanistic-social studies, and other appropriate non-technical studies. A minimum of 15 semester hours should be devoted to these non-technical subjects. The Committee recommends that six of these credit hours be devoted to communication, six to humanistic-social studies, and the remaining three either to additional humanistic-social studies or to other non-technical studies such as industrial organization, human relations, or supervision.

Communications

There is no aspect of modern education which has been singled out for criticism more than the area of communications. This is especially true of written communications. Technical education is no exception to this general criticism. Much has been written in the technical press regarding the inability of technical personnel to communicate their ideas cogently and concisely. Schools working in close cooperation with employers have frequently heard criticism of the communications ability of their graduates. In answering the questionnaire of the President's Committee on Scientists and Engineers, technicians expressed the need for better preparation in English and in report writing.

In fact, the occupational futures of the graduates probably depend on their ability to communicate as much as on their technical ability. The first line supervisor is not judged by how well he can do the job from which he was promoted. He is judged on how well he can communicate with others and be communicated with. The importance of this facet of his education should be reflected in the curriculum. The Committee, therefore, recommends a minimum of two semesters of study (six semester credit hours) in

written and oral communication. Basic would be such courses as English composition, technical report writing, and speech. The Committee further recommends strongly that institutions offering engineering technology curricula insure that faculty members in all departments promote the use of good English in all course-related writing and speaking, including classroom recitation. Nothing influences the technical student in his assessment of the importance of good English so much as his instructors' valuation of its proper and effective use.

Humanistic-Social Studies

Engineering technology curricula must accept with other collegiate programs responsibility for educating students not only for immediate employment after graduation but also for subsequent development as citizens and responsible human beings. It is the obligation of engineering technology education to acquaint the student with the resources of humanistic-social studies at least sufficiently to whet his interest in personal development in these areas after graduation.

Here, as in other curriculum areas, courses specifically designed for engineering technology students can prove especially effective. Much has been done recently in some engineering colleges toward the development of integrated courses and sequences in humanistic-social studies and it would seem that engineering technology education could benefit from a similar approach. The "selected topics" approach described under mathematics above is worthy of investigation by engineering technology faculties constructing humanistic-social sequences. The effectiveness of courses in the humanistic-social studies depends to a great extent upon the instructors. They must be genuinely interested in and enthusiastic toward the humanities, but at the same time they must be familiar with and sympathetic toward the goals of the engineering technology curriculum. They must plan their courses with the interests and the needs of the engineering technology student in mind.

The Committee recommends a minimum of six semester hour credits in humanistic-social studies, which might include such subjects as psychology, sociology, economics, political science, history, and literature.

TECHNICAL COURSES

The technical courses consist of all subjects that directly and immediately pertain to the specialized occupational education of the engineering technician. For purposes of this report the Committee has separated these courses into two groups, the technical skills and the technical specialties.

The technical skills group comprises those courses which are intended to familiarize the student with techniques and practices associated with his occupation and to develop some facility in their application. The technical skills include such subjects as drafting, breadboard construction, welding, building construction practices, and manufacturing processes. The technical specialties group is made up of courses in the student's major field and others designed to supply the core of engineering knowledge he needs in his chosen occupation. This group would include such courses as strength of materials, machine design, semiconductors, highway design, and soil mechanics.

The division of technical courses into two groups is not intended as a division between laboratory courses and lecture courses. It is presumed that both the technical skills and the technical specialties would include some classroom and some laboratory instruction.

Technical Skills

The ASEE Report on the Evaluation of Engineering Education (1955) indicated that future engineering curricula would probably show a decrease in the proportion of time devoted to technical skills such as drafting and manufacturing processes. The engineering technician has been expected to move upward to fill this gap. While development of a high degree of manual skill is not the principal objective of the engineering technology curriculum, it is apparent that the engineering technician's education must include at least an introduction to the art and practice of engineering.

It would be impossible to list all the technical skill areas associated with specific branches of engineering technology. However, the Committee would like to emphasize the importance of two technical skill areas common to all branches of engineering technology.

(a) Every engineering technician should know the rudiments of making and reading drawings.

Without this skill he may find that he is partially illiterate in his field, for graphic expression is as much a part of technical language as is mathematics. Every curriculum should include at least one course (three semester hours) in engineering graphics. The emphasis and specific content would, of course, vary with the field of specialization. In many cases additional graphics instruction can be anticipated in design courses which are included in the technical specialties.

(b) Every engineering technician should have a first-hand knowledge of the general capabilities, limitations, and economics of the conventional manufacturing or construction techniques used in the industry in which he works. He does not, of course, need the high degree of skill and proficiency demanded of the craftsman whose primary function is the application of these techniques. Yet, he can scarcely function in his field if he is ignorant of the methods by which things are made. For example, the engineering technician who works as a designer should be able to evaluate the manufacturing feasibility of his designs.

At least one course (three semester hours) should be given in the manufacturing processes, construction techniques, or chemical unit operations associated with the technical specialties portion of the curriculum. Such a course would normally be accompanied by a laboratory. Supervised work experience of a comparable nature can accomplish entirely or in part the objectives of this course.

Technical Specialties

The technical specialties portion of the curriculum includes the area which the student will find most immediately applicable on the job after graduation. For example, if the student is majoring in electronic engineering technology, the technical specialties would consist of his electrical and electronics courses and appropriate supporting technical courses. The technical specialties are always in transition. What today is an innovation in professional engineering design or methodology, tomorrow becomes the established engineering practice.
falling within the province of the engineering technician. For this reason it is impossible to establish permanent course content for the technical specialties in any branch of engineering technology. The subject matter of the technical specialties must be reviewed and revised at regular intervals.

Since an engineering technology curriculum is inherently specialized, a substantial portion of the curriculum should be devoted to the technical specialties. It is the Committee's opinion that 30% to 50% of the total credits (comprising not less than 24 semester credits) should be devoted to courses in the technical specialties. It is obviously impossible in a report of this type to describe in detail the specific courses which would comprise the technical specialties in each of the many branches of engineering technology. There are, however, certain general points concerning the technical specialties courses which deserve particular comment:

(a) Course Emphasis: Since engineering technology curricula are oriented toward mathematics and science, and since technicians will work within the engineering field, technical specialties courses should include considerable attention to problem identification and solution. They should also emphasize the quantitative, analytic approach rather than be limited to the descriptive. Textbooks in the technical specialties courses should also utilize the quantitative approach and should be at a mathematical level compatible with that of the program.

It is undesirable to use texts in the technical specialties which are at a substantially lower mathematical level than the mathematics in the program. In like manner it is undesirable to utilize textbooks which require a mathematical maturity beyond that which the student would normally obtain from the mathematics courses in the curriculum.

(b) Integrative Project: All too often students view their curriculum as a sequence of compartmentalized courses and fail to see how the material covered in the various courses is interrelated. Provision should be made somewhere in the curriculum, preferably near the end, for a design project or course in which the student is required to integrate the knowledge obtained throughout the program.

(c) Laboratories: Laboratory instruction is an essential part of any engineering technology curriculum. Theory courses in the technical specialties should be accompanied by coordinated laboratory experience. An important feature of this experience is the acquisition of familiarity with techniques and instrumentation used in measuring physical phenomena. The student should also be given the opportunity to learn and practice the collection, analysis, interpretation, and presentation of data. The Committee believes that industrial work experience, in itself, is not an adequate substitute for laboratory experience directly coordinated with the curriculum.

One of the major functions of laboratories is to support closely the lecture and recitation portions of the curriculum to which they are related. Thus, in the engineering technology laboratories, students should have opportunities to verify phenomena described in the theory portion of the course, to familiarize themselves with standard technical equipment, and to develop experimental skills. Many engineering technicians are employed in laboratory work and one of their significant responsibilities is the selection and utilization of laboratory instruments. It is thus apparent that administrators must attempt to outfit their laboratories with equipment that is as current as possible in order that their graduates may be reasonably familiar with the types of apparatus that they may encounter in industry. An adequate laboratory for engineering technology curricula must have sufficient equipment so that all students will have an opportunity for extensive participation in the manipulation and use of laboratory equipment.

LIBRARY

A brief mention of the library is appropriate when discussing the curriculum, although it is not, strictly speaking, part of the curriculum. Use of the library, however, is essential in all forms of higher education. The engin-
ering technology student will most certainly require the opportunity to supplement his textbooks. Such use would normally be a requirement in several courses. The student must be urged to discover that a great deal of information exists which is not included in his texts and which cannot be readily obtained by word of mouth. He must be instructed in methods of finding this material in order that he can cope with problems that have not been specifically covered in his courses but which may have been solved elsewhere.

One of the principal ways by which technical persons obtain increased competence and familiarity with new developments in their fields is through the reading of technical periodicals. The library supporting an engineering technology program should be one which will encourage the student to develop the habit of consulting the technical press and professional journals in his field.

The engineering technology student must have ready access to a library which includes modern technical books, current technical periodicals, and journals in his field. The library should also contain sufficient library materials to support adequately the non-technical portion of the curriculum. The library should be adequately staffed and open to the students during school and study hours.

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CONCLUSION

The great diversity of objectives and levels existing among technician curricula presents a particular problem in establishing quality criteria. The Committee has, therefore, limited this report to the education of the engineering technician and has proposed definitions and terminology intended to clarify his position in the spectrum of occupations between the craftsman and the engineer. Failure to distinguish between the level of programs and their quality has created confusion and sensitivity in the past. Distinctions to clarify this area have been made. Within this basic framework the Committee has attempted to present realistic recommendations concerning the three principal variables involved in modern, high-quality engineering technology programs conducted at the college level - faculty, students, and curriculum. It has made specific recommendations on the minimum number of credit hours that might reasonably be devoted to specific curriculum areas. Serious effort has been made to reconcile the demands of general education and the demands of technical education in engineering technology. Underlying these recommendations is a desire to identify the common core of knowledge essential to technical competence and growth potential among engineering technicians.

Within the context of our present and anticipated levels of engineering and secondary education the Committee believes that its recommendations can be pursued as a present goal and it hopes that standards will be constantly improved as our educational system expands and advances. In closing this report, the Committee urges consideration of these recommendations by individual institutions as a step toward meeting the demands of technical education in supplying the needed engineering technicians.

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<td>Southern Technical Institute</td>
<td>ECPD</td>
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